DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS

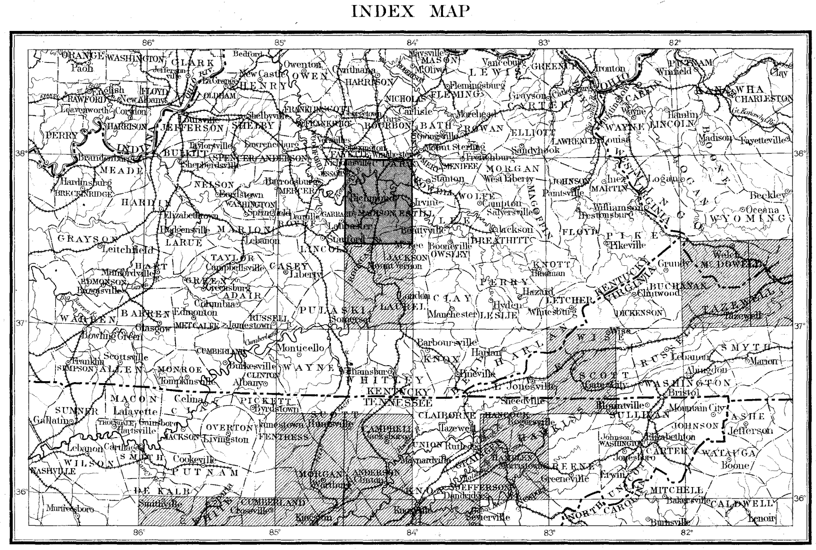
OF THE

UNITED STATES

RICHMOND FOLIO

KENTUCKY

INDEX MAP



SCALE: 40 MILES = 1 INCH

AREA OF THE RICHMOND FOLIO

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FOLIO 46 | LIBRARY EDITION | RICHMOND

WASHINGTON, D. C.

ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY

BAILEY WILLIS, EDITOR OF GEOLOGIC MAPS   S. J. KÜBEL, CHIEF ENGRAVER

1898

EXPLANATION.

The Geological Survey is making a geologic map of the United States, which necessitates the preparation of a topographic base map. The two are being issued together in the form of an atlas, the parts of which are called folios. Each folio consists of a topographic base map and geologic maps of a small area of country, together with explanatory and descriptive texts.

THE TOPOGRAPHIC MAP.

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

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

The manner in which contours express elevation, form, and grade is shown in the following sketch and corresponding contour map:

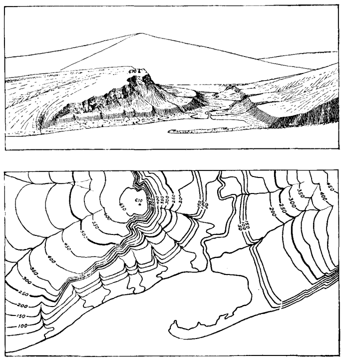


Fig. 1.—Ideal sketch and corresponding contour map.

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

1. A contour indicates approximately a certain height above sea-level. In this illustration the contour interval is 50 feet; therefore the contours are drawn at 50, 100, 150, 200 feet, and so on, above sea-level. Along the contour at 250 feet lie all points of the surface 250 feet above sea; and similarly with any other contour. In the space between any two contours are found all elevations above the lower and below the higher contour. Thus the contour at 150 feet falls just below the edge of the terrace, while that at 200 feet lies above the terrace; therefore all points on the terrace are shown to be more than 150 but less than 200 feet above sea. The summit of the higher hill is stated to be 670 feet above sea; accordingly the contour at 650 feet surrounds it. In this illustration nearly all the contours are numbered. Where this is not possible, certain contours—say every fifth one—are accentuated and numbered; the heights of others may then be ascertained by counting up or down from a numbered contour.

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

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

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

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

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

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

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

Atlas sheets and quadrangles.—The map is being published in atlas sheets of convenient size, which are bounded by parallels and meridians. The corresponding four-cornered portions of territory are called *quadrangles*. Each sheet on the scale of $\frac{1}{250,000}$ contains one square degree, i. e., a degree of latitude by a degree of longitude; each sheet on the scale of $\frac{1}{125,000}$ contains one-quarter of a square degree; each sheet on 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, respectively.

The atlas sheets, being only parts of one map of the United States, are laid out without regard to the boundary lines of the States, counties, or townships. To each sheet, and to the quadrangle it represents, is given the name of some well-known town or natural feature within its limits, and at the sides and corners of each sheet the names of adjacent sheets, if published, are printed.

Uses of the topographic sheet.—Within the limits of scale the topographic sheet is an accurate and characteristic delineation of the relief, drainage, and culture of the district represented. Viewing the landscape, map in hand, every characteristic feature of sufficient magnitude should be recognizable. It should guide the traveler; serve the investor or owner who desires to ascertain the position and surroundings of property to be bought or sold; save the engineer preliminary surveys in locating roads, railways, and irrigation ditches; provide educational material for schools and homes; and serve many of the purposes of a map for local reference.

THE GEOLOGIC MAP.

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

KINDS OF ROCKS.

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

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

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

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

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

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

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

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

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

The surface of the earth is not fixed, as it seems to be; it very slowly rises or sinks over wide expanses, and as it rises or subsides the shore-lines of the ocean are changed: areas of deposition may rise above the water and become land areas, and land areas may sink below the water and become areas of deposition. If North America were gradually to sink a thousand feet the sea would flow over the Atlantic coast and the Mississippi and Ohio valleys from the Gulf of Mexico to the Great Lakes; the Appalachian Mountains would become an archipelago, and the ocean's shore would traverse Wisconsin, Iowa, and Kansas, and extend thence to Texas. More extensive changes than this have repeatedly occurred in the past.

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

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

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

AGES OF ROCKS.

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

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

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

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

Strata often contain the remains of plants and animals which lived in the sea or were washed from the land into lakes or seas or were buried in surficial deposits on the land. Rocks that contain the remains of life are called fossiliferous. By studying these remains, or fossils, it has been found that the species of each period of the earth's history have to a great extent differed from those of other periods. Only the simpler kinds of marine life existed when the oldest fossiliferous rocks were deposited. From time to time more complex kinds developed, and as the simpler ones lived on in modified forms life became more varied. But during each period there lived peculiar forms, which did not exist in earlier times and have not existed since; these are characteristic types, and they define the age of any bed of rock in which they are found. Other types passed on from period to period, and thus linked the systems together, forming a chain of life from the time of the oldest fossiliferous rocks to the present.

When two formations are remote one from the other and it is impossible to observe their relative positions, the characteristic fossil types found in them may determine which was deposited first.

Fossil remains found in the rocks of different areas, provinces, and continents, afford the most important means for combining local histories into a general earth history.

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

To distinguish the sedimentary formations of any one period from those of another the patterns for the formations of each period are printed in the appropriate period-color, with the exception of the first (Pleistocene) and the last (Archean). The formations of any one period, excepting the Pleistocene and the Archean, are distinguished from one another by different patterns, made of parallel straight lines. Two tints of the period-color are used: a pale tint (the underprint) is printed evenly over the whole surface representing the period; a dark tint (the overprint) brings out the different patterns representing formations.

PERIOD.	SYMBOL.	COLOR.
Pleistocene	P	Any colors.
Neocene { Pliocene / Miocene }	N	Buffs.
Eocene (including Oligocene)	E	Olive-browns.
Cretaceous	K	Olive-greens.
Juratrias { Jurassic / Triassic }	J	Blue-greens.
Carboniferous (including Permian)	C	Blues.
Devonian	D	Blue-purples.
Silurian (including Ordovician)	S	Red-purples.
Cambrian	Є	Pinks.
Algonkian	A	Orange-browns.
Archean	AR	Any colors.

Each formation is furthermore given a letter-symbol of the period. In the case of a sedimentary formation of uncertain age the pattern is printed on white ground in the color of the period to which the formation is supposed to belong, the letter-symbol of the period being omitted.

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

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

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

THE VARIOUS GEOLOGIC SHEETS.

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

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

Economic geology sheet.—This sheet represents the distribution of useful minerals, the occurrence of artesian water, or other facts of economic interest, showing their relations to the features of topography and to the geologic formations. All the formations which appear on the historical geology sheet are shown on this sheet by fainter color-patterns. The areal geology, thus printed, affords a subdued background upon which the areas of productive formations may be emphasized by strong colors. A symbol for mines is introduced at each occurrence, accompanied by the name of the principal mineral mined or of the stone quarried.

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

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

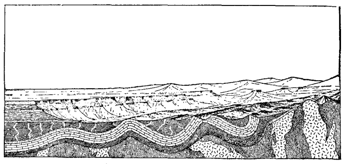


Fig. 2.—Sketch showing a vertical section in the front of the picture, with a landscape beyond.

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

The kinds of rock are indicated in the section by appropriate symbols of lines, dots, and dashes. These symbols admit of much variation, but the following are generally used in sections to represent the commoner kinds of rock:

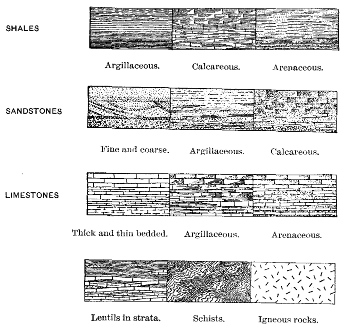


Fig. 3.—Symbols used to represent different kinds of rock.

The plateau in fig. 2 presents toward the lower land an escarpment, or front, which is made up of sandstones, forming the cliffs, and shales, constituting the slopes, as shown at the extreme left of the section.

The broad belt of lower land is traversed by several ridges, which are seen in the section to correspond to beds of sandstone that rise to the surface. The upturned edges of these beds form the ridges, and the intermediate valleys follow the outcrops of limestone and calcareous shales.

Where the edges of the strata appear at the surface their thickness can be measured and the angles at which they dip below the surface can be observed. Thus their positions underground can be inferred.

When strata which are thus inclined are traced underground in mining, or by inference, it is frequently observed that they form troughs or arches, such as the section shows. But these sandstones, shales, and limestones were deposited beneath the sea in nearly flat sheets. That they are now bent and folded is regarded as proof that forces exist which have from time to time caused the earth's surface to wrinkle along certain zones.

On the right of the sketch the section is composed of schists which are traversed by masses of igneous rock. The schists are much contorted and their arrangement underground can not be inferred. Hence that portion of the section delineates what is probably true but is not known by observation or well-founded inference.

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

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

The 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 strata thus rest upon an eroded surface of older strata the relation between the two is an *unconformable* one, and their surface of contact is an *unconformity*.

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

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

Columnar-section sheet.—This sheet contains a concise description of the rock formations which occur in the quadrangle. The diagrams and verbal statements form a summary of the facts relating to the character of the rocks, to the thicknesses of the formations, and to the order of accumulation of successive deposits.

The rocks are described under the corresponding heading, and their characters are indicated in the columnar diagrams by appropriate symbols. The thicknesses of formations are given under the heading "Thickness in feet," in figures which state the least and greatest measurements. The average thickness of each formation is shown in the column, which is drawn to a scale—usually 1000 feet to 1 inch. The order of accumulation of the sediments is shown in the columnar arrangement: the oldest formation is placed at the bottom of the column, the youngest at the top, and igneous rocks or other formations, when present, are indicated in their proper relations.

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

The intervals of time which correspond to events of uplift and degradation and constitute interruptions of deposition of sediments may be indicated graphically or by the word "unconformity," printed in the columnar section.

Each formation shown in the columnar section is accompanied by its name, a description of its character, and its letter-symbol as used in the maps and their legends.

CHARLES D. WALCOTT,
Director.

Revised June, 1897.

DESCRIPTION OF THE RICHMOND QUADRANGLE.

GENERAL RELATIONS.

Extent and counties.

The Richmond quadrangle embraces an area of 944.2 square miles, extending from latitude 37° 30′ on the south to 38° on the north, and from longitude 84° on the east to 84° 30′ on the west. It is named from the town of Richmond, the capital of Madison County, Kentucky, and it includes, wholly or in part, the counties of Fayette, Jessamine, Clark, Madison, Estill, Rockcastle, and Garrard. The adjacent quadrangles, so far as surveyed, are Beattyville on the east, Manchester on the southeast, and London on the south.

In its geographic and geologic relations this quadrangle forms a part of the Appalachian province, which extends from the Atlantic coastal plain on the east to the Mississippi lowlands on the west, and from central Alabama to southern New York.

SUBDIVISIONS OF THE APPALACHIAN PROVINCE.

Distinction between eastern and western divisions of the Appalachian province.

Respecting the attitude of the rocks, the Appalachian province may be divided into two nearly equal portions by a line which follows the northwestern side of the Appalachian Valley along the Allegheny front and the eastern escarpment of the Cumberland table-land. East of this line the rocks are greatly disturbed by innumerable folds and faults, and in many places they are so metamorphosed that their original form and composition can not now be determined. West of the division line the rocks are almost wholly sedimentary and the strata lie nearly flat, in the attitude in which they were deposited on the bottom of the sea. Since the western division lies almost wholly within the drainage basin of the Ohio River, it will be referred to in this description as the Ohio Basin.

OHIO BASIN.

This portion of the province embraces the Cumberland Plateau and the Allegheny Mountains and the lowlands of western Tennessee, Kentucky, and Ohio. Its northwestern boundary is indefinite, but it may be regarded as coinciding with the Mississippi River as far up the stream as Cairo, and thence extending northeastward across the States of Illinois, Indiana, and Ohio to the western end of Lake Erie. Contrasted with the intensely folded strata of the Appalachian Valley, the rocks of this region may be classed as horizontal, but, strictly speaking, they are rarely in this position, being gently inclined in various directions in different portions of the field. These slight undulations of the rocks have been produced by gentle uplifts which, though small by comparison, are pronounced geologic features of the region in which they occur.

The Cincinnati arch.

The most prominent structural feature of the Ohio Basin is an arch in the strata, which has been styled the Cincinnati arch or anticline. The main portion of the fold enters the basin, as it is here outlined, from the direction of Chicago; it curves southward through Cincinnati and Lexington, Kentucky, and continues southwestward to Nashville, Tennessee. Originally the principal arch was supposed to extend northeastward from Cincinnati to Toledo, but evidence afforded by numerous oil and gas wells in that region has proved that the Toledo fold is only a small branch of the principal uplift. Stratigraphically the maximum development of this fold occurs in the vicinity of Lexington, where the Trenton limestone is exposed at an altitude of 1000 feet above sea level.

Coal fields adjoining the Cincinnati arch.

Geologically this arch separates the Ohio drainage basin into two parts, or structural basins, each of which contains coal-bearing rocks. The basin on the eastern side of the Cincinnati arch is generally known as the Appalachian coal field, and that on the western side as the coal field of western Kentucky or the central coal field of the United States. Besides these main structural features, the rocks of the Ohio Basin have been disturbed by a few small folds, and in places they have been broken by small faults.

Topography of the Ohio Basin.—The altitude of this division is greatest along the southeastern margin, where some of the ridges attain the dignity of mountains. They are not continuous, and they do not form a system. At the north they constitute the Allegheny ranges, in the center they form a group of ranges limited on the northwest by Pine Mountain and on the southeast by Stone Mountain, and in the south the so-called mountains are only the escarpments of the Cumberland Plateau. The altitude of the mountainous belt varies from 500 feet in central Alabama to 2000 feet at Chattanooga, 3500 feet in the vicinity of Cumberland Gap, and from 2000 to 4000 feet throughout the northern portion of the Allegheny ranges.

General relations of topographic features and their significance.

From its extreme altitude on the southeastern margin, the surface descends to less than 500 feet on the western border along the Mississippi River. This descent is not regular, but it is accomplished by a number of steps or escarpments which mark the present extent of particularly hard beds and also the stages in the erosion of the surface to its present position. The highest and most pronounced escarpment is along the western margin of the Appalachian coal field, separating, in Kentucky, the great interior plain from the higher and more hilly region of the coal field, and, in Tennessee, marking the line between the eastern highlands and the Cumberland Plateau. In the latter State the escarpment is steep and regular and the plateau is very perfectly preserved, but in the former the rocks were not hard enough to protect the plain after it was uplifted, and as a consequence it was completely dissected by the numerous streams which drain its surface, leaving a hilly region in place of the plateau, and an irregular margin instead of an escarpment.

The great interior plain of Kentucky is continuous with both the eastern and the western highlands of Tennessee, and also probably with much of the highest land of Ohio and Indiana. Its general elevation along the western margin of the Appalachian coal field is about 1000 feet above sea level, but toward the west it probably descends to somewhat lower levels. The principal streams draining the Ohio Basin have cut deep channels below the surface of this plain, producing rugged topographic features in place of the gently undulating surface of the plain. In central Tennessee the drainage was especially active, and since the rocks exposed to the action of the streams were soft, the highland surface was entirely removed and a second plain was formed at a lower level. This is particularly well developed in the vicinity of Nashville, and it is known as the central basin of Tennessee.

Since the formation of the central basin, the land has been elevated again and the streams have cut deep gorges in its surface and deepened their old valleys in the region outside of the central basin.

TOPOGRAPHY.

River systems.

The Richmond quadrangle is located upon the margin of the Appalachian coal field, but its northwestern corner extends nearly to the center of the Cincinnati arch. It is almost entirely within the drainage basin of the Kentucky River, the trunk stream of which crosses this territory in a general way from east to west. The principal tributary is Red River, which unites with the main stream near the eastern margin of this quadrangle, and which consequently drains only a small portion of its surface. The other tributaries consist of creeks from 10 to 20 miles in length, which are so disposed that they receive the surplus water from the entire territory, except a small area in Rockcastle County in the drainage basin of Rockcastle River.

Relief of the surface.

The general altitude of the Richmond quadrangle is about 1000 feet above sea level. Its surface is essentially a plain, above which the hills in the southeastern corner of the area rise 500 feet, and below which the main streams have cut deep, narrow channels. As a rule, the minor drainage lines have not kept pace with the major streams in the excavation of their channels, although at present they are actively engaged in the operation of deepening their beds to the level of the controlling stream.

The most striking topographic feature of the Richmond quadrangle is the great plain of central Kentucky, which shows to excellent advantage at Winchester, Richmond, and Berea, the principal towns of the quadrangle, and which is named from the city of Lexington, situated a few miles to the northwest.

When viewed at a single locality the apparent parallelism between the surface of this plain and the bedding of the rocks suggests that it was formed by the erosion of soft beds down to the surface of a more resistant stratum, but when a large area is examined it is found that this plain truncates the Cincinnati arch, causing different beds of rock to form the surface in different portions of the plain. In view of this fact it is not possible to ascribe the formation of this topographic feature to the influence of hard beds of rock, or to the geologic structure. There are two methods by which this plain may have been produced: either by the shore action of the waves of a large body of water, or by sub-aerial erosion of the land to base-level. If this feature was produced by waves, central Kentucky must have been beneath the water of the ocean at some time since the Paleozoic era. If the sea covered this territory, there must have been sediments deposited on its surface; but no such material has ever been discovered; therefore this cause seems not to have operated to produce the plain in question. Sub-aerial erosion on a land surface which is free from movement will produce such a feature if time enough is allowed for the approximate reduction of the surface to base-level. The surface resulting from such conditions will be almost a plain—a peneplain. This hypothesis is in accord with the facts in central Kentucky, so far as known, and consequently this feature will be regarded as of sub-aerial origin, and it will be referred to as the Lexington peneplain.

The hills which rise above the Lexington peneplain have a fairly constant altitude of about 1500 feet above sea level. They have generally round or sharp tops which give no suggestion of a higher plain; but the regularity of altitude, despite the variation of the underlying rocks, is strong evidence of the former existence of a peneplain at this level which has been so completely dissected by later erosion that no trace of its surface remains to mark its exact position.

One valley within another.

The valleys which are cut below the surface of the Lexington peneplain are complex in character and show that they are the result of two episodes of erosion. When viewed upon the ground it is apparent that there is a long, gentle slope from the surface of the Lexington peneplain leading down to the brink of steep walls which bound the inner valley of the river. The gentle slopes constitute the sides of an older valley, which was broad. The narrow modern gorge has been cut within it.

Upon the floor of the older valley occur deposits of sand and clay which were laid down by the river when it occupied this valley, before the inner gorge was cut. In order that such widespread deposition should have taken place, the streams must have had moderate fall and have been unable to carry farther the load of sand and mud which they carried with ease in the narrow, upper valley in the Coal Measure plateau. The sediments were laid down in a sort of delta deposit across the entire width of the old valley; they are now found only on the tops of the river hills which mark the surface of the intermediate valley.

Dates of the physiographic features.

No direct evidence has been found in the Richmond quadrangle of the dates of the peneplains or of their allied surface features. The Lexington peneplain and the one 500 feet above it are continuous with similar features throughout the southern portion of the Ohio Basin and the Gulf slope, and it is to these distant portions of the province that we must look for evidence regarding their dates. The higher peneplain can be traced continuously southward to the margin of the Cretaceous sediments of the Gulf coast; it is also a part of the great peneplain which shows over most of the Appalachian province, and which is generally referred to the Cretaceous period. It is obviously very old, and since all of the evidence available agrees with the foregoing statement, it will be accepted as provisionally correct.

The Lexington peneplain is commonly regarded as of post-Cretaceous age, but the period has not yet been satisfactorily determined. The only definite theory yet advanced regarding its age makes it contemporaneous with the Eocene limestone of the Gulf slope. This has been advocated only as a working hypothesis, but so far as known it is in harmony with the facts found in this region, and will be accepted provisionally. On the assumption that the Lexington plain is of Eocene age, the intermediate valley and the deposits connected with it would presumably be referred to the next succeeding period, the Neocene, and the inner gorge to the remaining portion of the Neocene and the Pleistocene. This determination must be accepted as merely provisional, and subject to change when more direct evidence becomes available.

GEOLOGY.

GENERAL SEDIMENTARY RECORD.

All of the rocks appearing at the surface within the limits of the Richmond quadrangle are of sedimentary origin—that is, they were deposited by water. They consist of sandstones, shales, and limestones, having a total average thickness of 2200 feet. The materials of which they are composed were originally gravel, sand, and mud, derived from the waste of the older rocks and from the remains of plants and animals which lived while the strata were being laid down.

Interpretation of the record in the rocks.

These rocks afford a more or less complete record of sedimentation from the lower part of the Silurian period to near the close of Carboniferous time. They also contain a record of the conditions of the land area which furnished the material for their formation. By knowing the conditions under which certain classes of rocks are formed, we can gain a fairly accurate idea of the distribution of land and water and of the physical aspects of the land during the deposition of the rocks of this quadrangle.

Ancient interior sea; migrations of the shore.

The sea in which the Paleozoic sediments were laid down covered most of the Appalachian province and the Mississippi Basin. In the early stages of this era the eastern shore line of this ocean was probably along the Blue Ridge and the Smoky Mountains, but it migrated westward at intervals as the movements occurred which folded the rocks of the Appalachian Valley. Geologists do not agree concerning the westward migration of this shore line; many believe that the Coal Measure rocks were deposited entirely across the Appalachian Valley, and that they were uplifted as a whole at the close of the Carboniferous period. The original westward extent of these rocks is also an unsettled problem. Some believe that they were connected with the rocks of the same age in western Kentucky, while others are of the opinion that the Cincinnati arch formed an island in the Carboniferous sea over which the Coal Measures were never laid down.

The exact physical conditions which characterized the area now known as the Richmond quadrangle, and the conditions which prevailed on the land area that furnished the material for its rocks, may sometime be determined with considerable certainty, but at present our knowledge of the conditions of deposition will admit only of the broadest generalizations.

In this quadrangle the lowest rocks outcropping at the surface are limestones, and hence it is probable that oceanic conditions prevailed throughout central Kentucky near the beginning of the latter half of Lower Silurian time. This condition characterized the Trenton and Hudson epochs, but the sea probably grew shallower, and the sediments greater in amount, until, near the close of the period, clayey mud was the prevailing material settling to the bottom of the sea. This muddy material represents the waste of some land area, but its position and extent have not been determined. If the Cincinnati arch was raised above sea level during or before this time, the land so formed may have supplied the mud, but such an uplift at that early date is hypothetical.

At the close of the Lower Silurian a decided change occurred in the physical aspect of this region; land areas evidently appeared in certain localities, and some of these were of sufficient altitude to furnish sand to the adjacent waters. Whether there was, at any time, land over this entire area is uncertain, for the rocks of this age are rather destitute of fossils, and it is impossible to say whether or not there are any breaks in the life record. During the Upper Silurian and the lowermost Devonian this district experienced many fluctuations of level and conditions, and the formations laid down during that time show corresponding irregularity.

The conditions which prevailed during the deposition of the Devonian black shale have not yet been determined satisfactorily. In Pennsylvania and New York this epoch is characterized by immense deposits which have no representatives in the southern and western portions of the Appalachian province, except possibly in the fine-grained, black, carbonaceous shale of the Chattanooga formation. In this district the shale ranges from 110 to 150 feet in thickness, but over much of the territory farther south it has a thickness of only a fractional part of the Kentucky measure.

Several theories have been advanced regarding the conditions which would permit of the deposition of only a few feet of carbonaceous shale in one locality while thousands of feet of sand and mud accumulated in another portion of the same province, but none has been accepted as entirely adequate. It has been argued that there are traces of shore formations in this shale on the flanks of the Cincinnati arch, and that therefore land probably existed in that locality during the Devonian, but no evidence of such deposits could be found in this quadrangle, except possibly the presence of fossil plants in the black shale on Lulbegrud Creek. It is probable that the Devonian sea, in the southern Appalachians, though extensive, was shallow and surrounded by low land. Neither waves nor streams could then deliver any considerable volume of sediment, and the strata representing the epoch would be thin, as compared with those derived from higher lands east and north of the sea, the present Pennsylvania and New York region.

Theories relating to the Devonian land and sea.

The Waverly sea, which succeeded that of the Devonian period, also probably extended over much of the same district, but the conditions of the land were such that a liberal supply of waste was furnished for the formation of the Waverly shales. This sea deepened until almost the entire Appalachian province west of the Smoky Mountains and south of Pennsylvania was beneath its surface, and limestone deposition was taking place over the entire area. This was followed by an interval in which muddy sediments were laid down, but the extent of the interval and the original thickness of the deposits are unknown. In the uplift which followed, the material just deposited was largely eroded; deep channels were cut in the land, extending in some cases through the shale and into the limestone to a depth of 100 feet.

Eroded surfaces of the early Carboniferous strata. Unconformity with later strata.

This erosion interval represents, without doubt, the earlier portion of Coal Measure time, when the Cincinnati arch was dry land separating the two coal basins of Kentucky. At the beginning of the interval the sea occupied a basin much farther to the east than this region, and coal swamps flourished along its marshy borders, while the Richmond quadrangle was dry land. Gradually the land subsided and the sea encroached toward the northwest, until finally it engulfed the land of this region. The advancing shore line was marked by accumulations of sand and gravel which filled the inequalities of the land and which have since been consolidated into sandstone and conglomerate. Whether this sea transgressed sufficiently to submerge the island of central Kentucky and connect with the western basin can not now be determined, but it is possible that it did, and that the sediments then laid down have been removed by erosion since the land was finally raised above the ocean level.

At the close of the Carboniferous period the strata were raised above the water and exposed to the action of the atmosphere. During the long periods which have since elapsed no marine sediments have been deposited on the surface, but the events of the passing ages are recorded in the forms sculptured from the land and in the river deposits. They have been suggested under the heading "Topography."

STRATIGRAPHY.

The strata exposed in the Richmond quadrangle have a thickness of about 2200 feet. The thickness of the formations, the order of succession, and their general character are given in the columnar sections, but a more detailed description of the individual beds and an indication of their probable equivalents in other fields are given in the following paragraphs.

SILURIAN STRATA.

Highbridge limestone.—The Highbridge limestone, having an exposed thickness of nearly 200 feet, constitutes the lowest formation within this quadrangle. It forms bold cliffs along the valley of the Kentucky River north of the fault which nearly parallels the course of the stream, and also in the valleys of Lower Howard and Boon creeks, and on many of the smaller tributaries which drain the territory north of the line of this fault. Although the cliffs of this formation are prominent features of the river scenery in this quadrangle, they are still more prominent farther down the river, especially at Highbridge, where the Cincinnati Southern Railway crosses the river, south of Lexington. The gorge of the river is here upon the axis of the anticline, and consequently is most deeply cut into this formation. It is the type locality of exposure, and its name is given to the formation.

Fine-grained limestone, light blue or gray colored, with calcareous shale.

In character this formation is complex, consisting for the most part of heavy beds of fine-grained limestone of a light-blue or gray color, but frequently carrying bands of blue calcareous shale between the limestone layers. Since the formation which overlies this is also a limestone, the separation of the two on physical grounds may not always be possible. In the Richmond quadrangle the line is drawn at the top of a bed of impure lithographic stone which was found to be a constant feature in this territory. This has been referred to frequently as Kentucky marble, but it is not marble. It shows less of the crystalline structure than many of the beds which occur above or below it. An excellent guide to the horizon of this boundary is a band of cherty limestone which immediately overlies the lithographic stone. The cherts are nodular, and occur scattered through the rock for 30 or 40 feet.

In the State reports on this region the major portion of the Highbridge limestone has been correlated with the Chazy of New York, but the identification is not exact enough to be of service in this region, except in a general way. The top of the Chazy was placed at the base of the "Kentucky marble," which is about 10 feet in thickness. In the field the top of this bed is by far the most conspicuous horizon, and has been adopted here as the only horizon which is clearly recognizable on physical grounds. As a result of the different division line, the Highbridge is equivalent to the "Chazy" of the Kentucky State reports plus 10 feet of the "Birdseye" limestone.

Lexington limestone.—This limestone has a thickness of 150 feet and immediately overlies the lithographic stone which forms the top of the Highbridge limestone. It is in turn covered by another limestone, so that it is in the center of a large limestone series which can be separated into distinct formations only by observing the slightest differences in lithologic character. The only horizons which afford distinctive characteristics and which are constant over this quadrangle are the lithographic stone already described and a band of chert which occurs at the top of the Lexington limestone. This formation has little variation throughout its section. It is composed of bluish, semi-crystalline limestone, the beds of which are thin and irregular and are frequently separated by intervals of calcareous shale.

Semi-crystalline limestone, bluish, with calcareous shale.

This formation underlies much of the rolling lands in the northwestern portion of this quadrangle and in the vicinity of Lexington, from which it receives its name. It also shows in outcrop in the valley of the Kentucky River below Cleveland and south of the fault, and in the valleys of Paint and Silver creeks for a distance of several miles south of the river.

This formation is equivalent, presumably, to the Trenton and the upper portion of the Birdseye as described in the reports on Clark and Garrard counties. The top of the Trenton, as described by Linney, could not be identified in the field, and consequently it is uncertain whether or not the top of the Lexington agrees exactly with it. In the vicinity of Winchester they coincide, as well as could be determined from the map, but west of this point the limestone next above the Lexington in the series was found capping the hills, even in the suburbs of the city of Lexington, although in the reports it is not shown more than 3 miles west of Winchester.

Flanagan chert.—Where not dissolved the Flanagan formation is a zone of cherty limestone, but since the fresh rock is seldom seen in the field, and the observer is guided mainly by the residual products which he finds on the surface, it generally appears to be composed of chert only. It is named from Flanagan, a station on the Louisville and Nashville Railroad, where it was first observed. It varies in thickness usually from 20 to 40 feet, but south of the Kentucky River it is absent from the series. The weathered chert from this formation presents a variety of aspects, but when once observed it can be traced over the entire northern portion of the quadrangle with certainty. In the region south of Winchester the chert is nodular and very dense, in the vicinity of Becknerville it is bedded and very heavy, and toward Lexington it is porous and sandy in appearance.

Cherty limestone, massive, nodular, and sandy.

The Flanagan chert has no particular effect upon the surface, in the region in which it outcrops, different from that of the limestones with which it is associated both above and below. Like the Lexington limestone, it produces a gently rolling surface, and the quality of the soil derived from it compares favorably with that from the limestones on either side of it.

Winchester limestone.—The Winchester formation receives its name from the city of Winchester, in Clark County. North of the fault line this limestone occupies the highest lands in the country, but south of the break it shows only in the bottoms of the valleys.

Semi-crystalline limestone, bluish, with beds of calcareous shale.

The Winchester limestone is about 225 feet in thickness, and it is usually made up of thin semi-crystalline layers of bluish limestone separated by thin beds of calcareous shale or marly, impure limestone. Near the base the limestone layers are thicker than those of the shale, but in the upper portion the order is reversed and the shale predominates. This formation rests upon the Flanagan chert, into which it grades without an abrupt break. The limestone is similar, the only difference being the presence of the chert nodules. At the top of the Winchester limestone there is even a more complete gradation into the mudstones of the formation next above than there is downward into the chert.

In the State reports this limestone is called the Lower Hudson, and its fossil content shows that it is equivalent to the lower portion of the formation of that name in New York.

Garrard sandstone.—The Garrard sandstone is named from Garrard County, where it shows its typical form and composition. It has a thickness ranging from 70 to 130 feet, and it is composed of calcareous sandstone and shale, or mudstone. It can not be distinctly separated from the superior and inferior formations, as it grades into them by almost imperceptible changes in composition.

Calcareous sandstone.

This sandstone is slightly more resistant to the action of erosion than the adjacent formations, and therefore it tends to preserve the Lexington peneplain where it forms the surface. Its principal outcrop is in the territory south of the Kentucky River fault, but beyond the eastern extremity of this fault it covers a considerable area of the highest lands in the corner of the quadrangle. In the State reports this formation is designated the Middle Hudson.

Richmond shale.—The Richmond shale covers a greater expanse of territory in this quadrangle than any other formation. It was formerly called the Upper Hudson, but recently the name Richmond has been applied by Mr. E. O. Ulrich to rocks of the same age in Indiana, and the latter name is therefore adopted for the Kentucky equivalent. This formation outcrops in a wide band across the quadrangle, from northeast to southwest. On its northwestern margin it forms the tops of the hills and ridges, but as it extends eastward it dips gently and passes beneath the higher formations, which likewise cap the hills on the outer margin of their outcrops.

Impure limestone and calcareous shale.

The Richmond shale is nearly 300 feet in thickness. It is composed of bluish, semi-crystalline and impure limestone near its base, which grades upward into blue calcareous shale. At the base there is a gradual transition into the mudstones of the Garrard formation, and toward the top the shales are replaced by calcareous sandstone which is with difficulty distinguishable from that of the formation next above.

SILURO-DEVONIAN STRATA.

Panola formation.—In its full development the Panola formation consists of three members which lithologically are very dissimilar, but which it was found inadvisable to attempt to separate in the field. The lowermost member is a coarse yellow sandstone, generally slightly calcareous, in places as much as 30 feet in thickness. It is present only in the northeastern portion of the quadrangle. In the other portions it is not present as a coarse sandstone, but it may possibly be represented by some other stratum.

Three thin irregular strata associated: calcareous sandstone, shale, and brown limestone.

The second member is a fine blue shale, which usually carries thin beds of impure limestone that weather to a rusty brown. These thin beds abound with fossils which have been identified as Niagara species. Where the sandstone member is wanting, this shale is brought in contact with the blue shale at the top of the Richmond formation, and on lithologic grounds it is almost impossible to separate them. The top of this shale presumably constitutes the top of the Silurian rocks of this quadrangle. Originally there may have been other rocks of this age above the shale, but if they were ever deposited here, they have been completely removed since that time.

The third member consists of a heavy-bedded brown limestone which forms the lowest stratum of the Devonian series. On fresh exposures it is of a bluish cast, but it soon changes to a rusty brown. In places it carries an abundance of nodular chert, but the deposits are local, and can not be used as a guide in searching for this formation. Usually the line of separation between this limestone and the black shale above is sharp and distinct, but in a few places it is wanting and the change from limestone to shale is accomplished gradually by interbedding.

The marked character of the different members of this formation would permit of their separate mapping were it not for the fact that they are too thin to be represented on a map of this scale, and their occurrence is so irregular that grave uncertainty would attend their representation in many portions of the quadrangle. In the northern portion of their outcrop the three members are generally present and separable, but in the southern portion the lowest one probably is not represented at all and the intermediate member is present only in places. Along the railroad south of Whites the sole representative of this entire formation is a bed of dark limestone scarcely a foot in thickness, which is overlain by black shale and which rests directly upon the shaly limestone of the Richmond formation. In other places it is probable that the entire formation is absent, but positive evidence, either of its presence or of its absence, could not be obtained.

DEVONIAN STRATA.

Throughout the southern portion of the Appalachian province, and extending as far north as central Kentucky, the upper portion of the Devonian rocks is of unvarying lithologic character; it consists of black carbonaceous shale, which grows thinner and thinner toward the south, and which in places lies unconformably upon the rocks underneath. Northward from central Kentucky the Devonian increases rapidly in thickness, and many beds of coarse material appear in the mass of shale.

Chattanooga shale.—The Chattanooga formation is named from the city of the same name in eastern Tennessee, where it shows in typical form. It immediately overlies the Panola formation in a belt which crosses this territory from northeast to southwest. It outcrops on gentle slopes, and consequently its thickness is difficult of determination, but it probably ranges from 110 to 150 feet. The water carried by this shale becomes highly charged with mineral matter in solution, so that sulphur, chalybeate, and alum springs abound near it. It weathers rapidly into a white soil which is extremely poor, being almost unfit for agricultural purposes. The excessive blackness of the fresh shale, its well-known bituminous character, and the presence of occasional thin seams of coaly matter have led many persons to search in this formation for coal, but no seams of consequence have ever been found.

Black shale.

CARBONIFEROUS STRATA.

The rocks belonging to this great geologic period occupy only a small portion of the area of this quadrangle; they merely cap the hills in the southeastern portion.

Waverly shale.—This formation overlies the Chattanooga shale, and is easily separated from the latter on account of its color. At its base the Waverly is a light-blue clay shale, which passes upward into sandy shale and argillaceous sandstone. The shale at the base abounds with light-blue or drab ironstone concretions, which on weathering change to a dark reddish brown. In many cases they have been mistaken for volcanic rocks on account of their dark color and their extreme toughness. The

Blue shale grading into argillaceous sandstone.

upper portion of this formation is characterized by siliceous concretions, which are very abundant in some portions of the quadrangle. Upon disintegration the Waverly forms an extremely poor soil, which shows in the barren hills in the southeastern corner of the quadrangle.

The name Waverly is derived from Ohio, where it was used in designating this formation in the early surveys of the State.

Compact blue limestone.

Newman limestone.—This formation is named from Newman Ridge, Hancock County, Tennessee, a type locality on the eastern side of the Appalachian coal field. The limestone in the Richmond quadrangle is the representative, though possibly not the equivalent, of the Newman limestone in the type locality. In the type locality it is nearly 1500 feet thick, while in this quadrangle it is only about 200 feet thick. The meaning of this change in volume has not yet been determined; it can not be understood until the fossil contents of the rocks of both localities have been thoroughly studied and compared with a standard section. It is possible that as much time was consumed in the deposition of the bed 200 feet in thickness in this locality as was necessary for the formation of 1500 feet of limestone in eastern Tennessee, but it is also possible that there are unconformities in central Kentucky which represent periods of no deposition and possible erosion, and that the limestone of this locality is the equivalent of only a small portion of that in the type locality.

In the Richmond quadrangle this formation is a compact blue limestone with cherty beds at the base, the whole ranging in thickness from 100 to 200 feet. Originally the thickness of the formation was probably fairly constant over this quadrangle, but, owing to the elevation of the land above sea level in early Coal Measure time and the erosion consequent upon this uplift, the thickness has been reduced much below the normal at several points in this area. The outcrop of the limestone covers only a limited territory in this quadrangle. It usually forms steep slopes and perpendicular cliffs. Its solubility leads to the formation of caves, sinks, and underground channels, but its outcrop is so high on the hills that this feature does not interfere to any considerable extent with the drainage of the region.

Calcareous shale.

Pennington shale.—This shale was so named from a water gap through Stone Mountain in Lee County, Virginia. The formation consists principally of calcareous shale, but it also includes many thin beds of impure limestone. It is variously colored, but greens and reds predominate. It succeeds the Newman limestone by gradual transition, and it is unconformably overlain by the Lee formation. The occurrence of this formation is very irregular, and clearly indicates that it was subject to erosion on a land surface, which resulted in its being wholly or in part removed before the succeeding formation was laid down. The Pennington shale has a very limited outcrop in this territory, and has no appreciable effect upon the topography.

Sandy shale and sandstone, with two extensive conglomerate lentils.

Lee formation.—This formation is named from Lee County, Virginia. It includes the basal portion of the coal-bearing rocks which appear on the western side of the Appalachian Basin, and is equivalent to the middle portion of the Pottsville series of Pennsylvania. The formation consists of sandy shale and sandstone, in which occur lentils of coarse material—massive sandstone and conglomerate—the whole ranging from 100 to 300 feet in thickness. Two of these lentils are especially heavy, constituting, topographically, the most important members of the formation. The Lee formation rests upon the eroded surface of the Newman limestone and the Pennington shale. The extent of the interval which separates these formations, and which is represented only by the unconformity, has never been determined with much exactness, but the evidence of fossil plants indicates that probably one-quarter of the Pottsville series is wanting on the western side of the Appalachian Basin in central Kentucky. During the erosion interval this portion of the region was land, and the margin of the Coal Measure sea was probably located some distance toward the southeast. During the subsidence of the land which followed, the sea transgressed upon the land, and each pause of this encroaching sea was marked by deposits of sand and gravel, which have since been consolidated into sandstone and conglomerate. Since shore deposits necessarily occupy areas of limited breadth, unless the shore line migrates during the time of deposition the resulting coarse rocks will be present only along similarly narrow belts, terminating on the land side abruptly, and on the seaward side gradually changing to finer and finer material. There are also apparent unconformities in the Lee formation itself which are indicative of oscillations during the influx of water by which some formations were eroded and others were deposited in their stead. The generally arenaceous character of the Lee formation and the irregularities of the beds which compose it render extremely difficult the separation of individual beds which can be traced over any considerable distance and represented on the map.

Rockcastle conglomerate lentil.—This is a heavy bed of sandstone or conglomerate which extends along the western edge of the Cumberland Plateau from near Bon Air, White County, Tennessee, to the middle of the London quadrangle. It is particularly heavy on the lower portion of Rockcastle River, from which it derives its name, but near the mouth of Line Creek it is terminated abruptly, and it is not known with certainty north of this point. A narrow outcrop of heavy conglomerate reappears, however, from beneath the river at Livingston, which is supposed to have an underground connection with the Rockcastle. It occupies a deep channel in the limestone northward from Livingston into the southern portion of this territory. It shows in very conspicuous cliffs west of Big Hill, which extend as far northward as the margin of the high land. Originally it may have extended much farther in this direction, but if so it has been eroded back to the limit of its present outcrop. It was certainly deposited in a waterworn valley, and accordingly it varies greatly in thickness, from nothing on the margins of the valley to 150 feet in the center.

In the northern portion of Tennessee there are sandstones and shales of the coal-bearing series below this conglomerate which have a thickness of not less than 250 feet. In passing northward these beds grow thinner and thinner, until in the Richmond quadrangle the conglomerate rests directly upon the calcareous shale of the Pennington formation or the limestone of the Newman. In the southern part of the London quadrangle there is a shale interval between this conglomerate and the next lentil above, which has a thickness of about 280 feet. This also thins slightly northward, until in the Richmond quadrangle it amounts to about 200 feet.

Corbin conglomerate lentil.—This is named from Corbin, Whitley County, Kentucky. It occupies a narrow belt along the margin of the coal field from near the northern line of Tennessee far beyond the limits of this quadrangle. This conglomerate can be recognized generally by its peculiar pink or flesh color, and by the softness of the cement which binds the individual grains together. Owing to the latter characteristic, it seldom forms cliffs, but weathers into rounded bosses and domes, which sometimes surprise the observer who finds himself upon one of these masses without being aware that he has crossed an outcrop of conglomerate. This rock is not always pebbly, but it preserves the same general characteristics whether the component grains are sand or gravel. Only one or two areas of this formation are known in this quadrangle, and they occur in the southeastern corner.

NEOCENE(?) STRATA.

Unconsolidated sand, gravel, and clay.

Irvine formation.—The Irvine formation consists of unconsolidated sand, gravel, and clay, which originally covered the intermediate valley of the Kentucky River near the eastern edge of this quadrangle, but which are now found capping the river hills—the few remnants of what was once an extensive and continuous surface. It is named from the town of Irvine, which is located on the Kentucky River a few miles above the eastern margin of this quadrangle. No fossils have been found in these sands by which to ascertain their position in the geologic time scale, so that we are forced to fix their age by their relation to the topography of the region. Unfortunately the dates of the principal topographic features have not been accurately determined, and that of the Irvine formation can be stated only provisionally.

This formation has been considered by some geologists to be of Glacial age, but its close connection with the Lexington peneplain certainly indicates that it is much older than the Pleistocene period. Since the sand occurs on the floor of the intermediate valley of the Kentucky River, and is dissected by the erosion which produced the gorge of that stream, it must have been deposited in the period that intervened between the cutting of the intermediate valley and the cutting of the gorge. The geologic period in which the intermediate valley was eroded has not been determined with certainty, but since it is cut only a slight distance below the surface of the Lexington peneplain, and to only a moderate breadth, it must have been formed soon after the peneplain was raised above base-level. The age of this peneplain has been provisionally accepted as Eocene, and that of the intermediate valley as Neocene; hence the deposits lying upon the floor of the intermediate valley must have been laid down after the valley was cut, or presumably in the closing stages of the Neocene period. They are therefore assigned to the Neocene, but the classification is held subject to revision in case of the discovery of more definite information.

STRUCTURE.

To the eye of the observer the rocks of this quadrangle appear to lie horizontal, but when they are examined in detail and the altitude of one outcrop is compared with that of another, it is evident that the strata are seldom, if ever, in that position. The rocks were formed at the bottom of the sea, and since the sea bottom has generally less diversity of altitude than the present rock strata, it is evident that their present position is due to movement in the crust of the earth.

Definition of terms.—The strata when compared with a horizontal plane are found to be inclined. The inclination is known as the *dip* of the rocks. In the process of deformation the rocks have been thrown into arches and troughs. In describing these folds the term *syncline* is applied to the downward-bending trough, and the term *anticline* to the upward-bending arch. A synclinal axis is a line running lengthwise in the synclinal trough and at every point occupying its lowest part, toward which the rocks dip from either side. An anticlinal axis is a line which occupies at every point the highest portion of the anticlinal arch, and from which the rocks dip to either side. The axis may be horizontal or inclined. Its departure from the horizontal is called the *pitch*, and it is usually only a few degrees in amount.

As a result of the strains and stresses which have affected the crust of the earth, the strata in many places have broken along certain lines, and the rocks on one side of the break have been lifted or depressed with reference to those on the other side. Where the rocks have been intensely folded, as in the Appalachian Valley, the breaks have developed from the compressed and overturned folds; but in the Ohio Basin the faults are due to tension, or the stretching of the strata. Faults of the former type are sometimes of great linear extent and of enormous displacement, and those of the latter are in this district generally short and of very slight displacement.

In addition to the crustal movements which have perceptibly deformed the rocks of this region, the province has been affected by vertical movements which have repeatedly elevated and depressed the surface of the land, but by amounts which are insignificant compared with the magnitude of the folds. These slight movements were not continuous, but occurred now and then, the periods of greatest activity being separated by intervals of quiet in which the agents of erosion had time to record their action on the face of the land.

The monoclinal dip.

Structure of the Richmond quadrangle.—As a part of the southeastern flank of the Cincinnati arch, the strata of this quadrangle dip gently toward the southeast over the entire area. There are some variations from this regular descent, but the exceptions are local and have no effect on the structure as a whole. The rate at which the rocks dip varies according to their position with reference to the Cincinnati arch. The northwestern corner of the quadrangle is nearly upon the center of the arch, and consequently the rocks there are more nearly horizontal than in the southeastern portion.

The Kentucky River fault and others.

The most pronounced structural features in this quadrangle are the numerous faults which are found within its borders. The largest of these is commonly known as the Kentucky River fault, from the fact that in a general way it runs parallel with the river from the western margin of the territory to Boonsboro, where it leaves the valley and extends across the country toward the northeast. At the point of maximum development in this territory, the displacement of the rocks is about 400 feet; the displacement diminishes toward the northeast, until, on the turnpike northwest of Ruckerville, the fault is represented only by a slight fold in the rocks. Along the river the displacement is such as to bring the Highbridge limestone, on the northern side of the fault, to about the level of the old intermediate valley, whereas on the southern side the Garrard sandstones come to about the same level. The Highbridge limestone is harder than the formations which abut against it on the south, and consequently that portion of the stream which is located north of the fault is characterized by a narrow gorge, and that which lies south of the fault is marked by a relatively broad valley and gentle slopes. The line of separation between these topographic features is sharp and distinct, and serves to locate the fault at every point where it crosses the river.

Near Ruckerville the Kentucky River fault is replaced by a parallel break, which crosses the eastern margin of this quadrangle near the northeastern corner. The secondary break begins, so far as could be determined, in the Kentucky River below the mouth of Indian Creek and passes northeastward near Allensville and Ruckerville, disappearing near Levee, in Montgomery County. The displacement along this fault, at its greatest point, is about 300 feet, and the rocks on the northwestern side are lifted with reference to those on the opposite side of the break.

A line of faulting and general disturbance enters this quadrangle near its southwestern corner and extends nearly to Whites. Near the margin of this area the rocks are broken, and the displacement is sufficient to cut out the Chattanooga shale, or about 150 feet. Toward the northeast it is uncertain whether faulting took place or not; the rocks are greatly disturbed as far as Wallaceton, at which point the disturbance ceases and is apparently replaced by a parallel line of steep dips and possible faulting a little farther toward the northwest. It could not be determined whether faulting had occurred along the latter line, and consequently it is represented on the map by a broken line. Along both these lines the upthrow is along the northwestern side, the same as in the Kentucky River fault.

South of Joe Lick Knob there is a very small fault with the upthrow on the southern side and a linear extent of less than 3 miles. In all of these faults it is very difficult to determine the exact points at which faulting begins and terminates. It is usually easy to trace them so far as the displacement is sufficient to bring different formations in contact, but where the fault is limited to a single formation it is generally impossible to say with certainty where folding leaves off and faulting begins, or vice versa. Very small faults were also observed on Locust Branch and on Crooked Creek, but the displacement along these breaks is small and their linear extent is so limited as to have no appreciable effect upon the general structure.

The faults so far described are in a general way parallel with the strike of the rocks around the southern end of the dome which caps the Cincinnati arch in central Kentucky. Only one exception to this order was found in the fault lines of the Richmond quadrangle, and that is a fault which extends in a northwest-southeast direction through Moberly, east of Richmond. The upthrow is on the southwestern side, and the displacement is sufficient to cut out the Chattanooga shale and the Panola formation, and possibly portions of the formations which are in contact.

It is possible that more faults exist in this territory than are shown on the map, but if so they are slight. In all cases where the break could be observed it was found that the plane of the fault was nearly vertical, generally with a steep dip toward the downthrown side.

Structure sections.—The sections upon the structure sheet represent the strata as they would appear in the sides of a deep trench cut across the country. The sections are located at the upper edges of the blank spaces, along the lines A B and C D. The vertical and horizontal scales are the same, so that the actual form and slope of the land and the dips of the strata are shown. Minute details of structure can not be shown on a map of so small scale; therefore the sections are somewhat generalized from the dips observed in a belt of country a few miles in width along the line of the section. Many of the formations of this quadrangle are too thin to be represented on the sections; hence they are divided into groups which are of sufficient size to be shown.

MINERAL RESOURCES.

The "bluegrass" region of Kentucky is almost destitute of mineral deposits upon which mining or quarrying in a commercial way may be carried on with profit. The coal field which borders it on the southeast is somewhat more promising in its mineral resources, but even here the coal deposits are irregular in occurrence and of uncertain value. Consequently the Richmond quadrangle, which includes a portion of each of these larger areas, can not lay claim to mineral resources of any great value.

Coal.—A few seams of coal are found in the Lee formation in the tops of the hills in the southeastern corner of the quadrangle, but they are generally thin and irregular, and give little promise of successful production. A seam which is reported to be 4 feet in thickness was worked at Morrill for a number of years, but all of the openings have been abandoned, and it seems probable that the area of workable coal is of very limited extent.

Road metal.—All of the rocks occurring below the Waverly shale have been used for the purpose of road-making, but some of these formations have a much greater value for this purpose than others. The rocks which have been used most generally for this class of work are the thin-bedded limestones of the Lexington, Winchester, and Richmond formations. The first two are generally better adapted for this use than the last one, for they have less argillaceous matter associated with them, and consequently do not grind to so fine a dust under the wheels. On turnpikes which run near areas of Devonian rocks, the Chattanooga shale is used as a top dressing with good effect, as is also fine gravel that is found in the beds of some of the streams.

Clay.—The town of Waco has long been noted locally for the excellence of its pottery ware, which is manufactured from the residual clay of the shale member of the Panola formation. Residual limestone clay has been used on almost every farm for brick-making, but the manufacture of brick on a commercial scale is not carried on in any portion of this quadrangle.

Building stone.—There are stones which have been utilized for local purposes, and which have some reputation throughout the central portion of the State, but quarrying operations have been discontinued, except to supply the needs of the farming community. The so-called Kentucky marble has the best reputation as a building stone, having been used in Winchester, Lexington, and Frankfort.

Phosphate.—Most of the Silurian limestones outcropping in the "bluegrass" region abound in phosphate of lime, which has given this section its preeminence as an agricultural region. The phosphate is generally distributed so evenly throughout the mass that it is of no commercial importance, but on weathering it seems to segregate into more or less compact layers of nearly pure phosphate of lime. In Fayette County these have been found 8 or 10 inches in thickness, and future search may reveal deposits of economic importance. The phosphate occurs in the same form and is derived from the same rock as the Tennessee phosphate which is found in the central basin of that State.

Fluorite.—Veins of this mineral 4 feet in thickness have been reported by Professor Miller, of Lexington, as occurring in the valley of Boone Creek, but the discovery is recent and no use has been made of the deposit.

SOILS.

The soils of this quadrangle are almost entirely the result of the decay and disintegration of the rocks outcropping at the surface. Since such a close relationship exists between the rocks and the soils, the geologic map of the region may become, with proper interpretation, a valuable soil map.

The Highbridge limestone almost invariably forms steep slopes and cliffs, and consequently it has no opportunity to become a producer of soils.

Above the Highbridge limestone occur the formations which produce the soils of the "bluegrass" region, noted for its great fertility and for its power to rapidly replenish the elements taken up by growing crops. The readiness with which these limestones dissolve and the amount of phosphate of lime which they carry appear to be the principal factors in the production of the "bluegrass" soil.

The Lexington limestone ranks first as a producer of rich soils. Its outcrop covers most of the better portion of the "bluegrass" region. The soil from different portions of this formation varies considerably, as does also the proportion of surface formed by the different parts of the formation. The upper portion forms most of the upland level in Fayette County, and the soil characterizing it is much richer than that from the lower portion. As reported by the State Geologist of Kentucky, an average of six analyses of the soil derived from the lower portion of this formation (Birdseye) is as follows:

Analysis of soil derived from lower portion of Lexington limestone.

	PER CENT.
Organic and volatile matters	4.453
Alumina, iron, and manganese oxides	6.513
Lime carbonate	.453
Magnesia	.383
Phosphoric acid (P_2O_5)	.207
Potash extracted by acids	.178
Sand and insoluble silicates	84.632

On the same authority an average of thirty-two analyses of soils from the upper portion of the Lexington limestone, or the Trenton proper, gave the following:

Analysis of soil derived from upper portion of Lexington limestone.

	PER CENT.
Organic and volatile matters	6.211
Alumina, iron, and manganese oxides	11.200
Lime carbonate	.749
Magnesia	.644
Phosphoric acid (P_2O_5)	.328
Potash extracted by acids	.404
Sand and insoluble silicates	73.380

Recent examination of the Flanagan chert has demonstrated that it also carries phosphate, not only in the limestone, but in the chert itself.

The Winchester limestone is generally not marked by soils as productive as those of the Lexington limestone. Occasionally, however, it yields equally well and furnishes as good an analysis, as is shown by the following result of a single analysis.

Analysis of soil derived from Winchester limestone.

	PER CENT.
Organic and volatile matters	10.365
Alumina, iron, and manganese oxides	13.126
Lime carbonate	1.995
Magnesia	1.234
Phosphoric acid (P_2O_5)	.333
Potash extracted by acids	.762
Sand and insoluble silicates	72.035

The Garrard sandstone generally forms steep slopes or the tops of narrow ridges, and consequently is not well disposed for farming, although it contains a notable percentage of phosphoric acid and potash, as is shown by the following table, which is the average of eleven analyses made by the Kentucky Survey:

Analysis of soil derived from Garrard sandstone.

	PER CENT.
Organic and volatile matters	4.778
Alumina, iron, and manganese oxides	7.064
Lime carbonate	.101
Magnesia	.605
Phosphoric acid (P_2O_5)	.165
Potash extracted by acids	.155
Sand and insoluble silicates	86.551

The Richmond shale in its lower portion resembles the underlying limestones, and, like them, furnishes an excellent quality of soil, but the upper portion is too shaly to make good farming lands. The soil is stiff and clayey, and is generally wet and cold, except in time of drought, when it bakes extremely hard. It forms most of the surface of Madison County and extends southwestward in a broad belt into Garrard County.

The soils which are produced from the Panola formation are, as a rule, of not much value for agricultural purposes. This is especially true of the sandstone and shale members, which, fortunately, cover only a small area in outcrop. The limestone member produces better soil, but it is not equal to that from the Silurian limestones.

The outcrop of the Chattanooga shale is marked by a light-colored soil which is extremely poor and ill adapted to agricultural purposes.

The poorest soil of this territory is derived from the Waverly shale. The outcrop is generally marked by sharp conical hills and steep slopes which are almost devoid of vegetation. The timber that is found upon these lands is generally scrubby and of little value, and the lands are an almost uninhabited wilderness.

The Newman limestone, overlying the Waverly, produces a fair soil where it outcrops on moderately level land, but it can not compare with the Silurian limestones as a soil producer. It appears to lack the phosphate which the lower limestones possess to such a remarkable degree, and which renders them capable of renewing the fertility of the soil in a few years, when it has been completely exhausted by tillage. In this area the Newman limestone generally outcrops on steep slopes, and consequently is unimportant in the production of soil.

The coal-bearing rocks produce a thin and sandy soil, but their area in this quadrangle is small.

MARIUS R. CAMPBELL,
Geologist.

March, 1898.

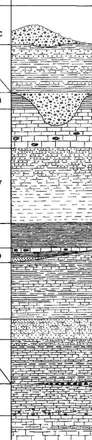
NAMES OF FORMATIONS.

Period.	Names and Symbols used in this Folio.		Marius R. Campbell: London Folio, U. S. Geological Survey, 1898.	Geological Survey of Kentucky; Reports on Garrard and Clark Counties, 1882 and 1884, by W. M. Linney; Report on Jackson and Rockcastle Counties, 1891, by Geo. M. Sullivan.
NEO. ?	Irvine formation.	Ni		
CARBONIFEROUS	Corbin conglomerate-lentil. Lee formation. Rockcastle conglomerate-lentil.	Clec Cle Cler	Corbin conglomerate-lentil. Lee formation. Rockcastle conglomerate-lentil.	Conglomerate formation.
	Pennington shale.	Cpn	Pennington shale.	Chester shale.
	Newman limestone.	Cn	Newman limestone.	St. Louis limestone.
	Waverly formation.	Cwv	Waverly formation.	Waverly shales and sandstones.
DEV.	Chattanooga shale.	Dc	Chattanooga shale.	Black slate.
	Panola formation.	SDp	Panola formation.	Corniferous limestone. Oriskany sandstone. Niagara group. Clinton group.
SILURIAN	Richmond formation.	Src		Upper Hudson beds.
	Garrard sandstone.	Sg		Middle Hudson beds.
	Winchester limestone.	Sw		Lower Hudson beds.
	Flanagan chert.	Sf		
	Lexington limestone.	Slx		Trenton limestone.
	Highbridge limestone.	Shb		Birdseye limestone. Chazy limestone.

COLUMNAR SECTION

GENERALIZED SECTION FOR THE RICHMOND QUADRANGLE.

SCALE: 500 FEET = 1 INCH.

Period.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography and Soil.
CARBONIFEROUS	(Corbin conglomerate-lentil.)	Clec		90	Coarse pink sandstone or conglomerate.	Forms the summit of a hill in the southeastern portion of the quadrangle. Sandy soil.
	Lee formation.	Cle		250-300	Shale and sandstone, with some coal seams. The outcrop of the coal is of limited extent.	Rounded ridges. Soil generally poor.
	(Rockcastle conglomerate-lentil.)	Cler		0-175	Coarse conglomerate.	Cliffs. Sandy or gravelly soil.
	Pennington shale.	Cpn		0-90	Red and green shale and thin beds of limestone.	Steep slopes.
	Newman limestone.	Cn		100-200	Blue limestone slightly cherty near the base.	Cliffs and steep slopes. Good soil where slopes are not too steep.
	Waverly formation.	Cwv		350-420	Green, calcareous and argillaceous sandstone. Fine, green, clay-shale with iron concretions.	Hilly lands and steep slopes. Soil extremely poor.
DEV.	Chattanooga shale.	Dc		110-150	Black carbonaceous shale.	Valleys and level lands. Poor soil.
	Panola formation.	SDp		1-70	Brown limestone frequently cherty, at the top, light-blue clay-shale below, and coarse yellow sandstone or brown siliceous limestone at the base.	No marked effect on topography. The shale produces very poor soil and bad roads.
SILURIAN	Richmond formation.	Src		300	Blue calcareous shale with thin beds of limestone.	Generally level surface. Good farming land, except the extreme upper portion which in places gives a poor, white, clay-soil.
	Garrard sandstone.	Sg		70-100	Brown calcareous sandstone.	Generally caps ridges. Brown sandy loam.
	Winchester limestone.	Sw		200-230	Thin-bedded blue crystalline limestone with bands of calcareous shale.	Gently undulating except near the rivers or large creeks. Rich soil. Blue-grass lands.
	Flanagan chert.	Sf		0-40	Thin-bedded gray limestone and calcareous shale, containing nodules and bands of chert.	No effect on topography.
	Lexington limestone.	Slx		140-160	Thin-bedded gray limestone containing nodules of chert at the base.	Gently undulating except near the rivers and large streams. Rich soil. Blue-grass lands.
	Highbridge limestone.	Shb		190+	White limestone grading downward into gray limestone and calcareous shale.	Forms the walls of the Kentucky River gorge.

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

TOPOGRAPHIC SHEET

KENTUCKY
RICHMOND QUADRANGLE

Henry Gannett, Chief Topographer.
Gilbert Thompson, Chief Geographer.
Triangulation by C.M. Yeates.
Topography by E.C. Barnard.
Surveyed in 1890.

Scale 1/125000
Miles
Kilometers

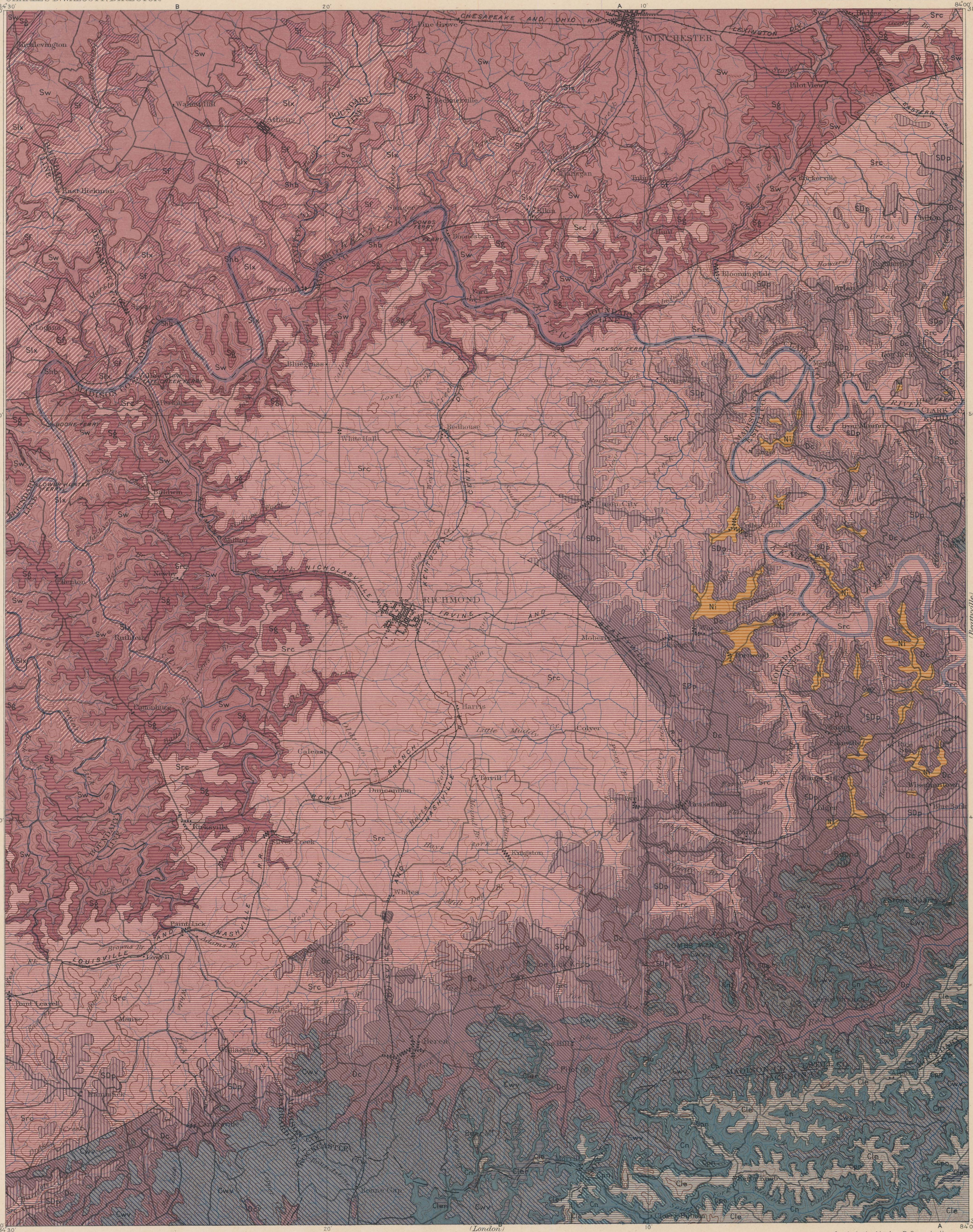
Contour interval 100 feet.
Datum is mean sea level.

Edition of Mar. 1897.

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

HISTORICAL GEOLOGY SHEET

KENTUCKY
RICHMOND QUADRANGLE



LEGEND

SEDIMENTARY ROCKS

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

NEOCENE?

- Ni — Irvine formation (unconsolidated sand and clay)

CARBONIFEROUS

- Cle — Lee formation (shale and sandstone including a few seams of coal)
- Clec — Corbin conglomerate-lentil (coarse pink sandstone or conglomerate at the top of the Lee formation)
- Cler — Rockcastle conglomerate-lentil (coarse conglomerate in the Lee formation)
- Cpn — Pennington shale (red and green shale and impure limestone)
- Cn — Newman limestone (blue limestone)
- Cwv — Waverly formation (green shale and sandstone)

DEVONIAN

- Dc — Chattanooga shale (black carbonaceous shale)

SILURIAN

- SDp — Panola formation (brown limestone, green shale, and yellow sandstone)
- Src — Richmond formation (blue calcareous shale and thin beds of limestone)
- Sg — Garrard sandstone (calcareous sandstone)
- Sw — Winchester limestone (thin-bedded, blue, crystalline limestone)
- Sf — Flanagan chert (thin-bedded limestone carrying nodules and bands of chert)
- Slx — Lexington limestone (thin-bedded gray limestone)
- Shb — Highbridge limestone (white limestone, blue limestone, and calcareous shale)

Faults

Sections

Henry Gannett, Chief Topographer.
Gilbert Thompson, Chief Geographer.
Triangulation by C. M. Yeates.
Topography by E. C. Barnard.
Surveyed in 1890.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 100 feet.

Datum is mean sea level.

Edition of Aug. 1898.

Geology by Marius R. Campbell,
Joseph A. Taff, and Walter C. Mendenhall.
Surveyed in 1896.

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

ECONOMIC GEOLOGY SHEET

KENTUCKY
RICHMOND QUADRANGLE

Henry Gannett, Chief Topographer.
Gilbert Thompson, Chief Geographer.
Triangulation by C. M. Yeates.
Topography by E. C. Barnard.
Surveyed in 1890.

Scale $\frac{1}{125\,000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 100 feet.

Datum is mean sea level.

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LEGEND

SEDIMENTARY ROCKS

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

NEOCENE ?

- **Ni** — Irvine formation *(unconsolidated sand and clay)*

CARBONIFEROUS

- **Cle** — Lee formation *(shale and sandstone including a few seams of coal)*
- **Clec** — Corbin conglomerate-lentil *(coarse pink sandstone or conglomerate at the top of the Lee formation)*
- **Cler** — Rockcastle conglomerate-lentil *(coarse conglomerate in the Lee formation)*
- **Cpn** — Pennington shale *(red and green shale and impure limestone)*
- **Cn** — Newman limestone *(blue limestone)*
- **Cwv** — Waverly formation *(green shale and sandstone)*

DEVONIAN

- **Dc** — Chattanooga shale *(black carbonaceous shale)*

SILURIAN

- **SDp** — Panola formation *(brown limestone, green shale, and yellow sandstone)*
- **Src** — Richmond formation *(blue calcareous shale and thin beds of limestone)*
- **Sg** — Garrard sandstone *(calcareous sandstone)*
- **Sw** — Winchester limestone *(thin-bedded, blue, crystalline limestone)*
- **Sf** — Flanagan chert *(thin-bedded limestone carrying nodules and bands of chert)*
- **Slx** — Lexington limestone *(thin-bedded gray limestone)*
- **Shb** — Highbridge limestone *(white limestone, blue limestone, and calcareous shale)*

Faults

Sections

× Coal prospects

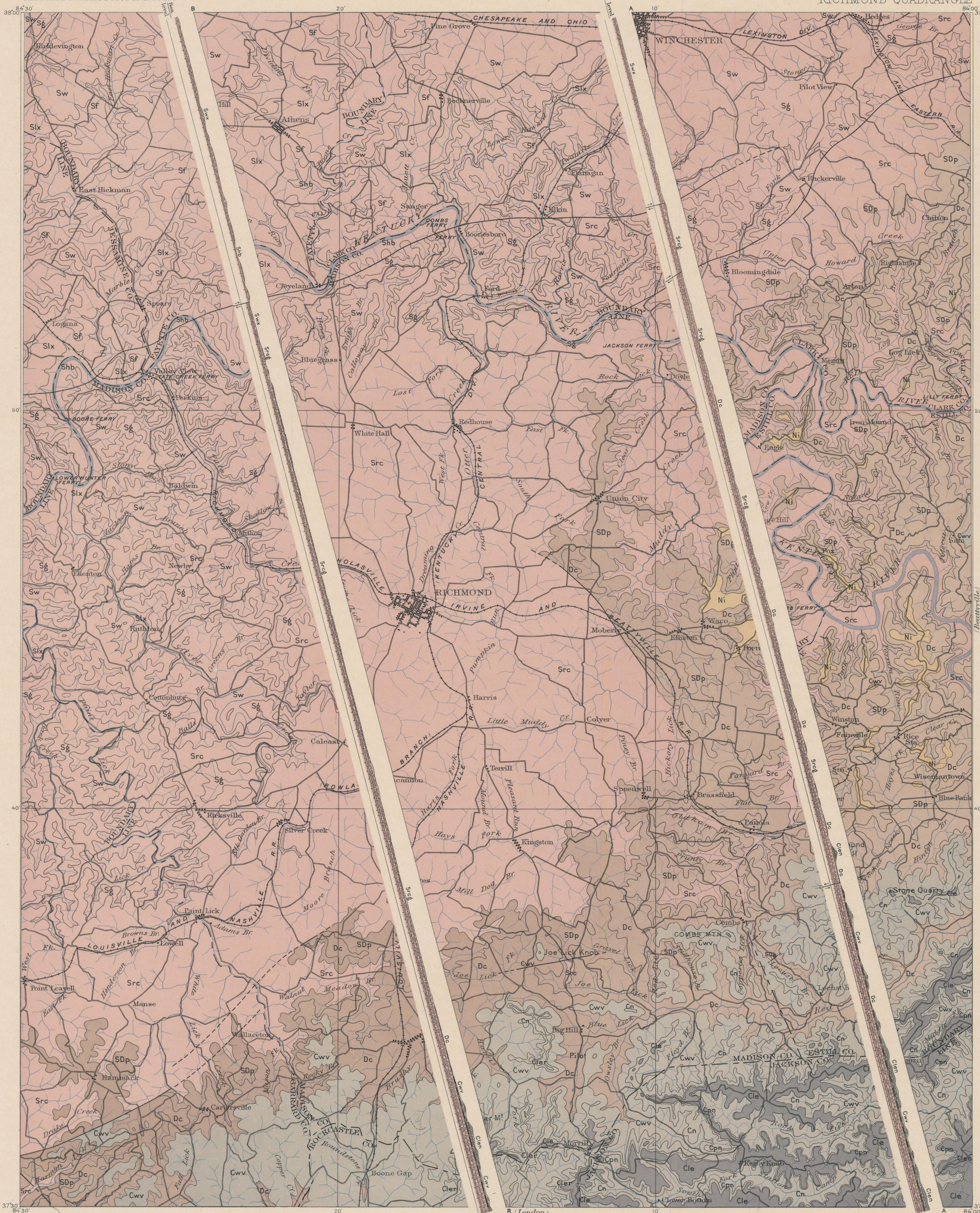
Known productive formations

Coal *(Lee formation contains coal seams)*

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

STRUCTURE-SECTION SHEET

KENTUCKY
RICHMOND QUADRANGLE



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Surveyed in 1896.

LEGEND

SEDIMENTARY ROCKS

Sheet symbol	Section symbol			
Ni		Irvine formation (unconsolidated sand and clay)		NEOCENE
Cle	Clen	Lee formation (shale and sandstone including a few seams of coal)	Grouped on the sections as Clen	CARBONIFEROUS
Clec		Corbin conglomerate-lentil (coarse pink sandstone or conglomerate at the top of the Lee formation)	Grouped on the sections as Clen	CARBONIFEROUS
Cler		Rockcastle conglomerate-lentil (coarse conglomerate in the Lee formation)	Grouped on the sections as Clen	CARBONIFEROUS
Cpn		Pennington shale (red and green shale and impure limestone)	Grouped on the sections as Clen	CARBONIFEROUS
Cn		Newman limestone (blue limestone)	Grouped on the sections as Clen	CARBONIFEROUS
Cwv	Cwv	Waverly formation (green shale and sandstone)		CARBONIFEROUS
Dc	Dc	Chattanooga shale (black carbonaceous shale)		DEVONIAN
SDp		Panola formation (brown limestone, green shale, and yellow sandstone)	Grouped on the sections as Srcĝ	SILURIAN
Src	Srcĝ	Richmond formation (blue calcareous shale and thin beds of limestone)	Grouped on the sections as Srcĝ	SILURIAN
Sĝ		Garrard sandstone (calcareous sandstone)	Grouped on the sections as Srcĝ	SILURIAN
Sw	Swx	Winchester limestone (thin-bedded, blue, crystalline limestone)	Grouped on the sections as Swx	SILURIAN
Sf		Flanagan chert (thin-bedded limestone carrying nodules and bands of chert)	Grouped on the sections as Swx	SILURIAN
Slx		Lexington limestone (thin-bedded gray limestone)	Grouped on the sections as Swx	SILURIAN
Shb	Shb	Highbridge limestone (white limestone, blue limestone, and calcareous shale)		SILURIAN

Faults

Known productive formations

Coal
(Lee formation contains coal seams)