DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS

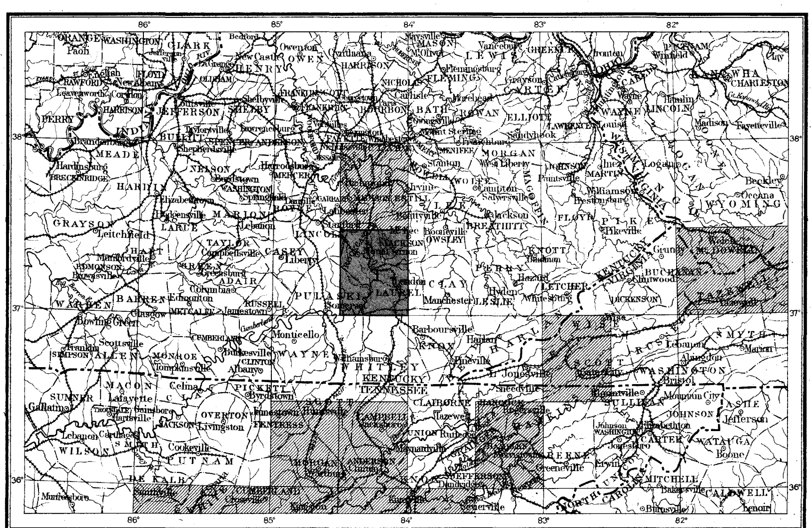
OF THE

UNITED STATES

LONDON FOLIO

KENTUCKY

INDEX MAP



SCALE: 40 MILES-1 INCH

AREA OF THE LONDON FOLIO

AREA OF OTHER PUBLISHED FOLIOS

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FOLIO 47 | LIBRARY EDITION | LONDON

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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:

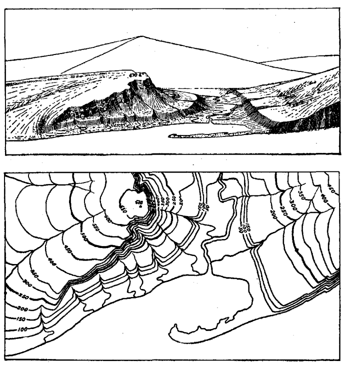


Fig. 1.—Ideal sketch and corresponding contour map.

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 quarzite, 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 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	Æ	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

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:

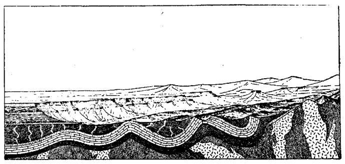


Fig. 2.—Sketch showing a vertical section in the front of the picture, with a landscape beyond.

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:

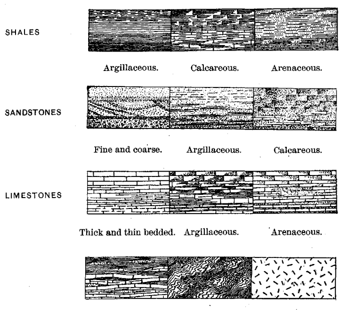


Fig. 3.—Symbols used to represent different kinds of rock.

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

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.

DESCRIPTION OF THE LONDON QUADRANGLE.

GEOGRAPHY.

Extent and counties.

General relations.—The territory represented by the London atlas sheet embraces an area of 950.4 square miles, extending from latitude 37° on the south to 37° 30′ on the north, and from longitude 84° on the east to 84° 30′ on the west. It includes, wholly or in part, the counties of Pulaski, Laurel, Rockcastle, Jackson, Lincoln, and Garrard, and it is named from London, the principal town within its borders. The adjacent quadrangles, so far as surveyed, are Richmond on the north, Beattyville on the northeast, Manchester on the east, Cumberland Gap on the southeast, and Williamsburg 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.

Distinction between eastern and western divisions of the Appalachian province.

Subdivisions 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 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 of the London quadrangle.—The London quadrangle is located upon the western margin of the Appalachian coal field, which at this particular point is destitute of its characteristic features. The hardest rocks do not reach outward to the margin of the field, and consequently the upper plain and the escarpment are lacking.

River systems.

The major portion of the territory is drained by the Rockcastle River, which unites with the Cumberland River a few miles beyond the southern margin of the quadrangle. The Rockcastle River, throughout its entire course, flows in a narrow valley which is generally bordered on either side by perpendicular walls of sandstone or conglomerate. Below Line Creek its valley is extremely rugged and abounds in wild and picturesque scenery.

The southeastern portion of the territory is drained by Laurel River, another tributary of the Cumberland River. Near its headwaters this stream flows in a high, broad valley which is only slightly below the general level, but as it approaches the Cumberland it cuts deeper and deeper into the heavy conglomerate, until it also is confined by rocky walls from 100 to 400 feet in height.

Buck Creek, another tributary of the Cumberland, drains considerable territory in Pulaski County. It has cut through the thin capping of Coal Measure rocks, and flows in a deep gorge cut wholly in the heavy-bedded Carboniferous limestone.

The only drainage not belonging to the Cumberland system is that of Dick River, which heads in Rockcastle County and flows northwestward into the Kentucky River just above Highbridge, Kentucky. In the London quadrangle this stream flows in a broad, flat valley, but its lower course is marked by a canyon like the canyons of the tributaries of the Cumberland River.

Relief of the surface.

The general altitude of the surface of this quadrangle is not far from 1200 feet above sea level; above this altitude many knobs rise to a height of 300 feet, and below it the valleys are cut to depths sometimes as great as 550 feet. The topographic features found in this quadrangle, if considered apart from the general features of the region, can not be interpreted easily. When taken in connection with similar features in the surrounding territory, it is evident that a high-level peneplain once extended across this territory, the surface of which is now shown only in a few isolated hills in the northern portion of the quadrangle and in two or three similar eminences in the neighborhood of London. These stand at an altitude of 1500 feet, and they are presumably the sole representatives of the plateau which once existed here, and was continuous with the Cumberland table-land of Tennessee. Over most of this area the rocks then at the surface were too soft to preserve the peneplain, except in the northern portion, where the heavy conglomerates came to the surface and assisted in its preservation. In this portion of the area the limestone is much higher than it is farther south, and erosion would have had a more appreciable effect had it not been for the protecting cap of conglomerate.

Ancient peneplain.

In the vicinity of London the same peneplain was doubtless formed, but the rocks were not of adequate hardness to prevent its removal. In the epoch of active erosion which followed the formation of this peneplain the soft rocks were removed and a second regular surface was formed, but this surface is a structural plain, formed by a hard bed of conglomerate, which has not permitted the streams to cut lower.

Second peneplain.

Along the western side the presence of a large body of limestone above drainage level afforded opportunity for the streams to remove the surface to a second peneplain. Only a small area of this is seen in the quadrangle, but that is continuous with the great plain of central Kentucky. Below this plain, whose altitude is approximately 1000 feet above sea level, the gorges of the principal streams have been cut; hence they are necessarily a later feature than the plain itself.

Ages of the peneplains.

Little direct evidence can be found concerning the geologic periods in which these various peneplains were formed. The uppermost plain is usually regarded as of Cretaceous and the lower as of post-Cretaceous age. Some evidence has been adduced which seems to limit the lower plain to the Eocene period, but at present its date can be regarded only as one of those unsettled questions which can not be definitely answered until more evidence is available.

GEOLOGY.

GENERAL SEDIMENTARY RECORD.

All of the rocks appearing at the surface within the limits of the London 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 2000 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 that 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 upper 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 history of the continental area from which were derived the sediments now forming the rocks of the London quadrangle may at some future time be determined with considerable certainty, but at present our knowledge of the conditions of deposition will permit only the broadest generalizations.

From the outcrop of the lower Silurian limestones a few miles northwest of the London quadrangle, and from their presence in the Appalachian Valley southeast of this region, it is inferred that they are continuous from one outcrop to the other, and hence that they underlie this territory. The character of these rocks indicates that the territory represented by the London atlas sheet was deep sea during much of the early Paleozoic era.

The first indication of the rise of land areas in this body of water is found at the top of the Silurian sediments, but these formations are so greatly eroded in central Kentucky that it is impossible to locate the exact margin of the sea. In the closing stages of this era there may not have been any large body of land in this region, but there must have been at least islands upon which no deposition was taking place.

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 is 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.

Theories relating to the deposition of black shale.

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 therefore that land probably existed in that locality during the deposition of the black shale, but no evidence, aside from the presence of fossil plants in this shale, could be found. The most satisfactory explanation assumes that the Devonian sea in the southern Appalachians was shallow, and received little or no sediment from the surrounding land areas and from the islands which existed in the area, because the land had previously been reduced to base-level. It was thus too low to afford fall by which streams might carry material to the 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.

Waverly sea followed by erosion interval.

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 London 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."

Rise of land at the close of Carboniferous period.

STRATIGRAPHY.

The strata exposed in the London quadrangle have a thickness of about 2000 feet. The thickness of the formations, the order of succession, and their general character are shown 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.

SILURO-DEVONIAN STRATA.

In searching for oil and gas the drill has revealed the presence of a large body of rocks of Silurian age, but only the uppermost member shows at the surface within the limits of this quadrangle.

Panola formation.—This formation is named from the station of Panola, in Madison County, Kentucky. In its complete development it is a complex formation consisting of three members: coarse yellow sandstone at the base, fine blue shale in the middle, and a brown massive limestone at the top. The sandstone and shale are generally regarded as of Silurian, and the limestone as of Devonian age.

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

Only a small area of this formation outcrops in this quadrangle, and it is formed entirely of the uppermost member of the series. This member is the most constant, but occasionally it thins and disappears, leaving the black Devonian shale in contact with the blue calcareous shale of the Richmond formation. When fresh this limestone is of a bluish cast, but upon weathering it soon becomes brown. In places it is very cherty, but the chert is an irregular feature and frequently disappears in a distance of less than a mile. The outcrop on Dick River is the only exposure of this formation in the London quadrangle.

DEVONIAN STRATA.

Throughout the southern portion of the Appalachian province, and 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. In a well recently drilled at Broadhead it was found to be 150 feet in thickness, a measure which is probably more nearly correct than any that has been obtained at the surface. The line of separation between this shale and the limestone beneath is usually sharp and distinct, but in some localities in central Kentucky it is found interbedded with the limestone through a distance of about 20 feet.

Black shale.

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 — 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.

CARBONIFEROUS STRATA.

Rocks of this age occupy almost the entire area of the London quadrangle. Although belonging to one geologic period, they have been separated into two series, Mississippian and Pennsylvanian.

MISSISSIPPIAN SERIES.

The rocks of this series are mainly of marine origin, and distinctly underlie the lowest coal-bearing stratum.

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.

Blue shale grading into argillaceous sandstone.

Over most of this quadrangle the Waverly is characterized by a great number of siliceous concretions, which ordinarily are only a few inches in diameter, but which occasionally attain a diameter of two feet. So numerous and so large are they in the northern portion of this area that they have given the name to Roundstone Creek, one of the principal tributaries of Rockcastle River. In the vicinity of this creek they occur at the top of the formation, but toward the south they are more abundant at other horizons, having been replaced at the top of the formation by a coarse yellow sandstone which is well shown at the crossing of Buck Creek west of Dallas.

The name Waverly is derived from Ohio, where it was used in designating this formation in the early surveys of that State. It makes a large portion of the hilly district in the northwestern corner of the London quadrangle, and it extends along the bottom of the valleys toward the southeast, far within the limits of the area where the limestone prevails. It has an average thickness of about 350 feet.

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 London 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 250 feet thick. It is a compact blue limestone with cherty beds at the base, and it varies in thickness from 100 to 250 feet. This great range in thickness is due to the fact that at the beginning of Pennsylvanian time a part of the area now occupied by the Newman limestone was land, and that much of the underlying rock was removed by erosion. The deep channels cut in this formation were, upon the return of the sea, filled with sand and gravel, so that at present they are apparent only when numerous measures of the limestone are compared.

Compact blue limestone.

The limestone outcrops in a wide band across the quadrangle from northeast to southwest. Where this rock forms the entire surface it makes a gently rolling country, but where it forms the slopes of the valleys it frequently produces perpendicular cliffs. Its solubility leads to the formation of many caves, sinks, and underground channels. Even Roundstone Creek finds its way to the river, during ordinary stages of water, through such a channel.

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. In many places in this quadrangle it was entirely removed by erosion before the sediments of the Lee formation were laid down. Its greatest exposed thickness is about 90 feet.

Calcareous shale.

This formation does not cover, in its outcrop, any appreciable amount of territory, for it is exposed usually on the steep slopes of the stream valleys, and it is eroded from all of the uplands which were originally covered by it.

PENNSYLVANIAN SERIES.

From an economic standpoint these are the most important rocks which come to the surface within the limits of this quadrangle, for coal is the principal mineral resource of this section. The strata consist entirely of sandstone and shale, which rest unconformably upon the rocks beneath, and are limited in their upward extent only by the amount of erosion which has occurred since they were deposited. They show great variation in character and thickness, and are evidently the result of shore or shallow-water deposition.

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 200 to 600 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. The erosion interval undoubtedly represents a period of time in which the limestone area was dry land and the Pennsylvanian sea was located some distance to the eastward. Later, subsidence of the land allowed this sea to transgress upon the land, forming successive overlaps toward the west; each position of the shore was marked by sand and gravel, which were sorted by the waves and finally laid down as sandstone and conglomerate, while sandy mud was being deposited in the waters off shore. The result of these conditions is the local development of heavy beds in narrow belts along the margin of that ancient sea, which grade off in either direction into materials of entirely different composition. 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.

Sandy shale and sandstone, with two extensive conglomerate lentils.

Rockcastle-conglomerate lentil.—This is a heavy bed of sandstone or conglomerate extending from central Tennessee to the middle of this quadrangle, and is named from Rockcastle River, along which it is particularly prominent. It is the most conspicuous member of the Pennsylvanian series in the southern portion of this quadrangle. It forms high cliffs along Rockcastle River and its numerous tributaries from Line Creek to Cumberland River and up that stream as far as the falls, where it passes beneath water level. This conglomerate is terminated abruptly toward the north along a line which crosses Wood Creek a mile above its junction with Hazel Patch Creek, Hawk Creek in the middle of its course, and the mouth of Line Creek. Toward the west it does not extend as far as Buck Creek, although rocks of this same general horizon are found in the hills west of that stream. Along the margin of the field in the southwestern corner of the quadrangle there are local developments of conglomerate which lie apparently at lower horizons. They are generally thin and discontinuous, and therefore are not worthy of representation on the map.

Conglomerate beds of lenticular form.

In the northern portion of the quadrangle there are heavy deposits of conglomerate at various points which have been provisionally correlated with the Rockcastle. The greatest development occurs in a belt about 4 miles in width which extends northward from Livingston nearly along the main course of Roundstone Creek. It continues northward for a distance of 6 miles beyond the margin of this territory, where it is terminated by the northern escarpment of the coal field.

This conglomerate is one of the most interesting features of the region, for it occupies a channel which was eroded through the Pennington shale and at least 100 feet into the Newman limestone. The channel was filled with well-rounded pebbles, which now form a mass of conglomerate, the top of which is frequently lower than the top of the limestone. The conglomerate varies in thickness from 150 feet in the center of the channel to zero on the edges of the mass. The channel in which this occurs was certainly eroded in the limestone before the deposition of the Pennsylvanian series and when this area was dry land; upon submergence, the channel was filled with gravel, which has since been slightly cemented into the conglomerate of to-day. It descends southward with the general dip of the rocks in this region, and passes beneath drainage level in Rockcastle River a little above the mouth of Roundstone Creek. This isolated outcrop of conglomerate is here provisionally correlated with the Rockcastle of the southern portion of the quadrangle, but the connection is merely assumed from the fact that the Livingston mass lies where the known Rockcastle would be found if continued. The stratigraphic relations of the two beds are different, but it seems probable that the Livingston area is merely an outlier of the main body and that it overlaps upon the eroded surface of the limestone beneath.

There are one or two masses of conglomerate in the valley of Horse Creek which occupy similar positions with reference to the surrounding rocks. No connection could be found between these isolated exposures and the main mass, but they have been regarded as the probable extension of the Rockcastle conglomerate.

Corbin-conglomerate lentil.—This is named from Corbin, Whitley County, Kentucky, and, like the Rockcastle, it occupies a marginal position with reference to the coal basin. It extends 40 or 50 miles into Tennessee, where it is thin and irregular, but it develops into a massive bed from 100 to 200 feet in thickness in this portion of Kentucky. In the southeastern corner of the quadrangle the Corbin conglomerate has an extensive areal development, but farther north it is limited to a narrow belt, the western margin of which is formed either by the limit to which erosion has removed the conglomerate or by the margin of the original deposit; the eastern margin is formed by the line along which this formation goes under cover, or where it changes in character from a coarse conglomerate to a sandstone and then to a sandy shale. South of London the formation passes below drainage level before its character changes, but north of that place it fades gradually into shale before its horizon takes cover.

This conglomerate can be recognized generally by its peculiar pink or flesh color and by the softness of the cement with which the individual grains are bound together. Owing to this characteristic, it seldom forms cliffs, but weathers into rounded bosses and domes, which sometimes surprise the observer, who finds himself upon one of these outcrops without being aware that he has crossed an exposure of conglomerate. It is not always conglomeratic, but it preserves the same general character whether the component grains are sand or gravel. In the southern portion of the quadrangle this bed is not favorably disposed for erosion, and consequently it forms the foundation for an extensive area of nearly level land; in the northern portion the distance between it and the limestone is less, allowing the streams to cut deep channels in the limestone and leaving the remnants of the conglomerate as mere caps to the hills.

Equivalent of the Pottsville series of Pennsylvania.

The Lee formation is nearly equivalent to the Pottsville series of Pennsylvania, but it does not contain either the superior or the inferior limits of the type. Probably as much as one-quarter of the lower portion of the series is wanting in this section, being represented by the erosion interval at the base of the Pennsylvanian series. According to the evidence afforded by fossil plants the top of the Pottsville series occurs in a thick bed of shale which overlies the Corbin conglomerate.

Breathitt formation.—This formation includes all of the Carboniferous rocks lying above the Corbin conglomerate, or the top of the Lee formation. It is composed of shale and sandstone with occasional coal seams, but no individual bed is of sufficient importance to be shown as an independent formation. In the highest hills in the vicinity of London this formation shows about 550 feet in thickness. It is named from Breathitt County, Kentucky, where the formation is present in great force.

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 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.

Structure of the London quadrangle.—From the nearly horizontal position of the rocks in this territory it is apparent that the structure is very simple. Since the quadrangle lies on the northwestern margin of the Appalachian coal basin, the dips of its strata are generally toward the southeast throughout the quadrangle.

The monoclinal southeast dip.

There are variations from this regular southeastward descent of the rocks, but such exceptions are local, and have no effect on the structure as a whole. There are also such irregularities as the channels in which the conglomerate is deposited north of Livingston, but these are due to erosion and unconformity between the beds and not to disturbance. The rate at which the rocks dip varies with the position in the field. The northwestern half of the area lies upon the flank of the Cincinnati arch, and consequently the dip is much more pronounced in that locality than in the southeastern half, which lies farther within the coal basin.

Overlap at base of the Pennsylvanian series.

In drilling some deep wells in this district it was found that the limestone dips more steeply in the southeastern portion of the quadrangle than do the coal-bearing rocks of the Pennsylvania series. This is explained by the overlap at the base of the latter series, which permitted sedimentation to go on in the center of the basin while the margin was land and received no deposits. It has long been known that the Pottsville series increases in thickness from a few hundred feet on the western side of the field to 1500 or 2000 feet on the eastern side, but no one could say positively how this change was accomplished. It has lately been demonstrated, by study of the fossil plants of this series, that a large portion of the base of the series is entirely absent from the western margin of the Appalachian coal basin. Hence, in passing from the western edge of the field toward the center, older beds appear below those which form the margin of the field. The limestone passes beneath the lowest Pottsville beds as they develop toward the center of the basin, and consequently dips more steeply.

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 A and B B. 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.

MINERAL RESOURCES.

Rocks and minerals of economic importance are not very plentiful in this quadrangle. Coal, building stone, limestone, road metal, clay, and iron ore have been found within its limits, but only the first two have been developed beyond the local needs of a farming community.

Coal.—This is by far the most important mineral resource of the quadrangle; it has been mined for a number of years at Pine Hill and Livingston, but these deposits are now practically exhausted, and the production of coal is limited to the neighborhood of Pittsburg, where eight or ten companies are actively engaged in mining steam and domestic fuel.

Origin of coal.

It is a popular belief that coal seams are coextensive with the strata of which they form a part, and consequently that the existence of a workable bed in any locality is evidence that it can be found of the same thickness and quality in all adjacent regions. In order to search intelligently for coal it is essential that the prospector and operator should understand the mode of deposition of coal, its limitation in distribution, and its variability in composition and thickness. Coal is the result of great vegetable accumulations in swamps, and since swamps are usually of limited extent, the coal deposits resulting therefrom will necessarily be also limited in their range, and will not be coextensive with the overlying and underlying strata. Again, swamp vegetation accumulates usually on a somewhat uneven floor, and the seam will show the effect of the inequalities upon which it rests, being thickest in the center of the area, or in the deeper portions of the swamp, and thinning toward the margin. All of the conditions which affect the quality of the coal are not known, but, from the mode of origin, it is probable that physical conditions varied in different portions of a coal swamp, and hence it is hardly likely that the quality of the coal will be constant throughout any very extensive field. On the whole, variations in coal seams appear to be the rule, and continuity and regularity the exception.

In the London quadrangle the deposits of coal are apparently very irregular; they occur at many horizons in the coal-bearing rocks, but they are generally local, and it seldom happens that more than one seam of workable thickness is found in any locality.

Owing to the unconformity at the base of this series and to the irregularity of the various strata composing the productive beds, it is almost impossible to correlate the coal outcrops found in this quadrangle, for the reason that there is no datum from which to measure. Since this is the case, no effort will be made to determine equivalency over broad areas, but the outcrops will be described individually.

Coal in the Lee formation.

In a belt a few miles in width lying along the southern margin of this quadrangle there is a prominent coal seam immediately beneath the Rockcastle conglomerate of the Lee formation, which has been worked at intervals for twenty-five or thirty years along the Cumberland River. It was found in a number of ravines south of Mount Sterling knob, showing 3 or 4 feet of splinty coal, but its full thickness could not be determined. It was also observed near the mouth of Cane Creek, but it was only partially exposed to view. Several outcrops are reported on Rockcastle River, but they were not visited, and the extent of the seam is problematical.

There is a lower seam in this district, but it is not known to be of workable thickness in this quadrangle. On the bluffs fronting Cumberland River it was worked years ago, and its thickness at this point is reported to be 30 inches. The probable equivalent of one of these seams has been worked along the western border of this quadrangle, near the main road from Somerset to Dykes, but its thickness at this point is not known.

Northward from Dykes there is a poor showing of coal in this formation. Several small seams show in outcrop, but they are generally too thin to be of commercial importance. At Livingston there were formerly extensive works on two small seams only a few feet above the limestone, but they are now abandoned, as the deposits of workable coal are exhausted. The mines at Pine Hill, on presumably the same seam, are also abandoned, owing to the exhaustion of the pocket of coal upon which they were opened. Isolated outliers of what appears to be the same seam occur in the vicinity of Mount Vernon, but they are probably too limited in extent to be of much value.

In the territory north of the main Rockcastle River there are a number of small coals in the Lee formation. They have been described in detail in the State report on Jackson and Rockcastle counties. Five seams have been recognized, some of which may possibly have a workable thickness over a portion of this area, but none of them are of great promise. Their general thickness is less than 3 feet, and since they outcrop in an exceedingly rough section of the country, it will presumably be a long time before they are developed. The one of most promise seems to be the cannel seam of Horselick Creek. It was not seen by the writer, but if it has the thickness given in the State reports it will be a valuable deposit when transportation can be secured.

Coal in the Breathitt formation.

Decidedly the most important seam of coal in this quadrangle occurs within a few feet of the base of the Breathitt formation. It is known as the Pittsburg or Altamont coal. It is of workable thickness only over a small area which extends along the railroad from London to Altamont, and from near the line of the railroad to Raccoon Creek. It was formerly opened and worked to some extent at Lily, but the seam was too thin for profitable mining and has been abandoned. This locality is evidently on the southern edge of the coal swamp, for in a cut south of town it shows only 12 inches in thickness. In its best development, near Pittsburg, it ranges in thickness from 36 to 41 inches. It is mined by eight or ten companies in and about Pittsburg, and finds a ready sale as a steam and domestic fuel.

A few small seams occur in the country east of Pittsburg, but it is probable that they are of no present commercial value.

Building stone.—Along the valley of Roundstone Creek the Waverly formation carries a bed of fine building stone, which has been quarried at Langford for a number of years. It consists of a fine-grained bluish sandstone, which is soft when freshly quarried but which soon hardens by the action of the elements into a very durable stone. Its principal defect is the thinness of the bed of workable stone, which renders quarrying unprofitable as soon as the cover becomes of moderate thickness.

Stone for rough work could be found at a number of places, both in the limestones of the Mississippian and in the sandstones of the Pennsylvanian series, but it has never been used except for local purposes.

Limestone.—This kind of rock is abundant in the western portion of the quadrangle. Much of it is of good quality for the manufacture of lime, and also for use as road metal, but it has been utilized only in a small way.

Miscellaneous.—Residual clay of good quality for the manufacture of brick could be obtained at many points on the limestone outcrop, but it has never been used. Fire or under clay accompanies many of the coal seams, but it has never received attention, and its value is not accurately known. Surface indications of iron ore are common, but no deposits of value are known in the territory. From time to time interest has been manifested in exploration for oil and gas, and several deep wells have been drilled in this region, but so far as known the results are unsatisfactory and the wells have been abandoned.

SOILS.

The surface of this quadrangle is too deeply cut by streams to make good farming lands. There are, however, two areas of low relief which, so far as the surface is concerned, are tolerably well adapted to agricultural pursuits, but which are very different in value on account of the difference in the soil which is found upon them. One of these areas is composed of the outcrop of the Newman limestone in the western portion of the area. The soil derived from this formation is fairly good, and the region has the appearance of a prosperous agricultural section, but this limestone appears to be almost if not quite destitute of phosphate, and consequently the soils can not compare with those of the "Bluegrass" region, which are derived from the Silurian limestones. The soil characterizing the Newman limestone is easily exhausted, and when once worn out will not renew itself, but requires artificial fertilizers.

The second area of moderately low relief is in the southeastern corner of the quadrangle, and its soils are formed from the decay of the sandstones and shales of the coal-bearing rocks. The soils derived from such rocks are poor and thin, and ill adapted to any sort of agricultural pursuit.

Along the Rockcastle River the valleys are generally floored by the Newman limestone or the Pennington shale, but the extreme narrowness of the valleys and the steepness of the slopes render them of little value to the farmer.

The Waverly formation produces hilly lands and a soil so poor that it is almost valueless for farming purposes.

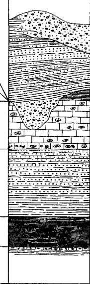
M. R. CAMPBELL,
Geologist.

February, 1898.

COLUMNAR SECTIONS

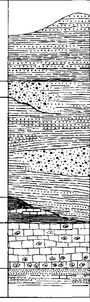
GENERALIZED SECTION FOR THE NORTHERN HALF OF THE LONDON QUADRANGLE.

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)		0-150	Conglomerate or coarse pink sandstone.	Rounded ridges. Sandy soil.
	Lee formation.	Cle		300-600	Sandy shale and sandstone with a few seams of coal.	Hills and ridges. Generally poor soil.
	(Rockcastle conglomerate-lentil.)	Cler		0-150	Coarse conglomerate.	Cliffs. Sandy soil.
	Pennington shale.	Cpn		0-60	Red and green shales and thin limestone.	Clay soil.
	Newman limestone.	Cn		100-250	Blue limestone with a few nodules of chert. Cherty limestone.	Cliff and hill lands. Generally fertile soil where slopes are not too steep.
	Waverly formation.	Cwv		350	Greenish, calcareous and argillaceous sandstones. Light-blue clay shale with iron concretions.	Hilly lands. Very poor soil.
DEV.	Chattanooga shale.	Dc		150	Black carbonaceous shale.	Valleys. Poor soil.
SIL.	Panola formation.	SDp		20+	Brown limestone, generally cherty, at the top; light-blue clay shale below.	Valleys. The shale forms poor soil and bad roads.

GENERALIZED SECTION FOR THE SOUTHERN HALF OF THE LONDON QUADRANGLE.

SCALE: 500 FEET = 1 INCH.

Period.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography and Soil.
CARBONIFEROUS	Breathitt formation.	Cbt		500	Sandy shale and coarse ferruginous sandstone. Pittsburg, Ky., coal seam at the base.	Hilly country, with gentle slopes and rounded summits. Soil fair on shale outcrop; poor on sandstone.
	(Corbin conglomerate-lentil.)	Clec		0-150	Conglomerate or coarse pink sandstone.	Cliffs. Sandy soil.
	Lee formation. (Rockcastle conglomerate-lentil.)	Cle (Cler)		500-1000 (0-150)	Sandy shale and sandstone with a few seams of coal. (Coarse conglomerate.)	Gently rolling uplands in the vicinity of London, and ridges near Rockcastle River. Generally poor soil. (Cliffs. Sandy soil.)
	Pennington shale.	Cpn		0-150	Red and green shales and thin beds of limestone.	Valleys or slopes. Clay soil, sometimes fertile.
	Newman limestone.	Cn		225	Blue limestone with a few nodules of chert. Cherty limestone.	Valleys. Generally fertile soil.
	Waverly formation.	Cwv		100+	Calcareous sandstone.	Rocky valleys.

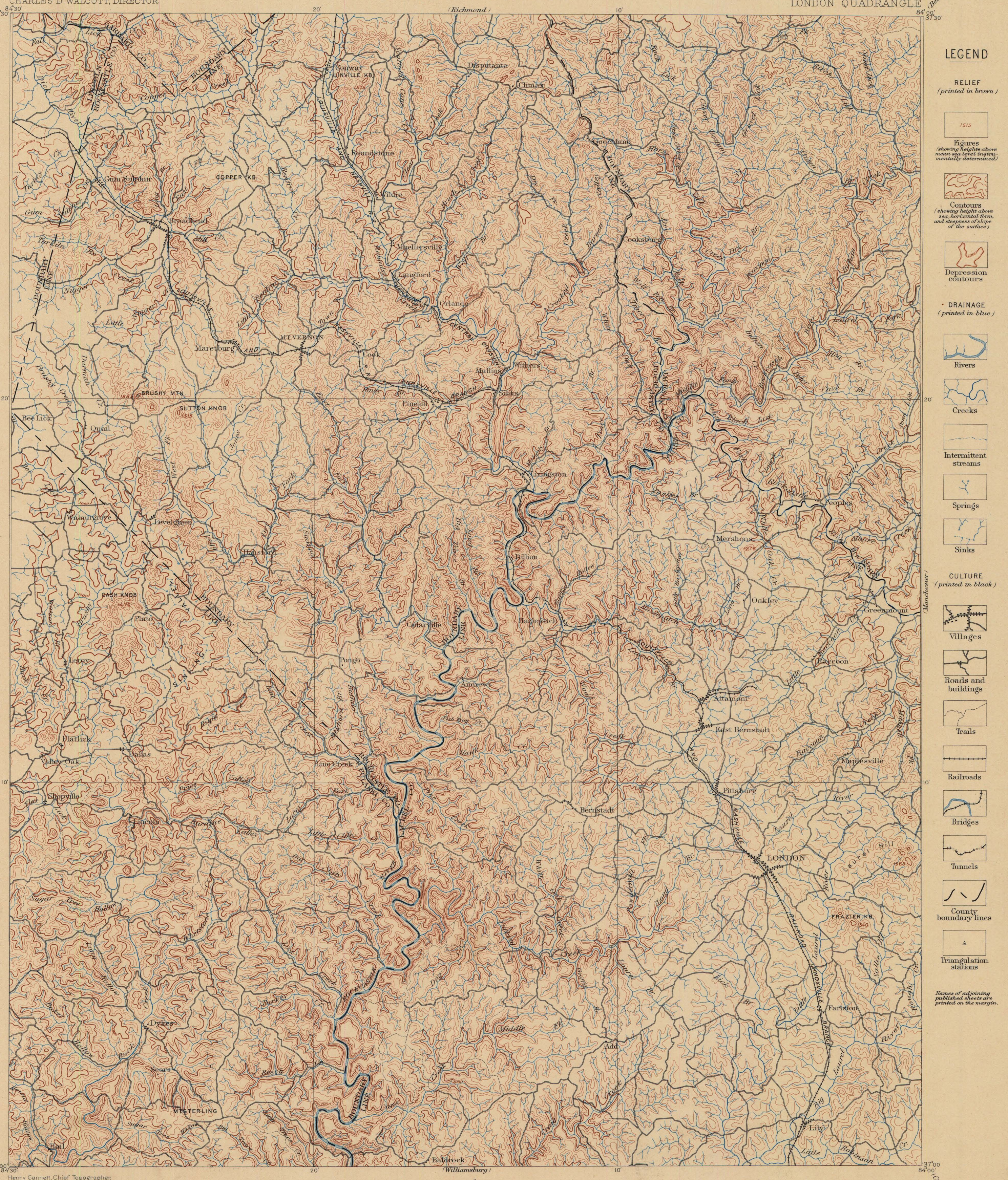
NAMES OF FORMATIONS.

Period.	Names and Symbols used in this Folio.		Marius R. Campbell: Richmond Folio, U. S. Geological Survey, 1898.	Geological Survey of Kentucky: Reports on Lincoln and Garrard Counties, 1882, by W. M. Linney; Report on Rockcastle County, 1891, by Geo. M. Sullivan.
CARBONIFEROUS	Breathitt formation.	Cbt		
	Corbin conglomerate-lentil. Lee formation. Rockcastle conglomerate-lentil.	Clec Cle Cler	Corbin conglomerate-lentil. Lee formation. Rockcastle conglomerate-lentil.	Conglomerate.
	Pennington shale.	Cpn	Pennington shale.	Upper Sub-Carboniferous.
	Newman limestone.	Cn	Newman limestone.	
	Waverly formation.	Cwv	Waverly formation.	Lower Sub-Carboniferous.
DEV.	Chattanooga shale.	Dc	Chattanooga shale.	Black shale.
SIL.	Panola formation.	SDp	Panola formation.	Corniferous limestone. Crab Orchard shale.

MARIUS R. CAMPBELL,
Geologist.

TOPOGRAPHIC SHEET

KENTUCKY
LONDON QUADRANGLE



Henry Gannett, Chief Topographer.
Gilbert Thompson, Chief Geographer.
Triangulation by C.M. Yeates.
Topography by E.C. Barnard.
Surveyed in 1891.

Scale 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 Mar. 1897.

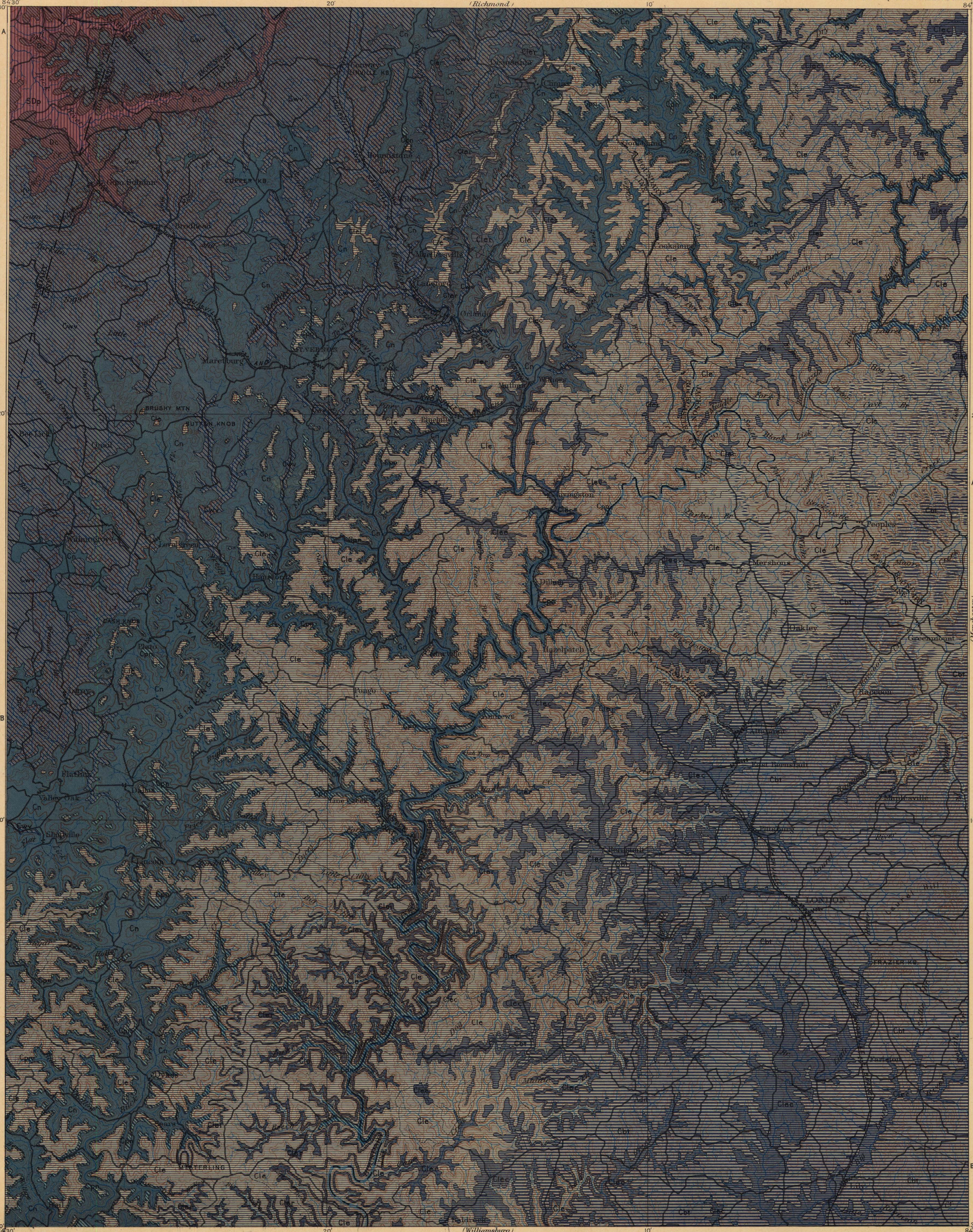
U.S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

HISTORICAL GEOLOGY SHEET

KENTUCKY
LONDON QUADRANGLE

(Richmond)

(Beattyville)



(Manchester)

(Williamsburg)

(Cumberland Gap)

LEGEND

SEDIMENTARY ROCKS

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

CARBONIFEROUS

Cbt — Breathitt formation *(sandy shale and ferruginous sandstone. Pittsburg Ky. coal seam near the base)*

Cle — Lee formation *(sandy shale and sandstone with coal seams)*

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 with thin beds of limestone)*

Cn — Newman limestone *(blue limestone, cherty at the base)*

Cwv — Waverly formation *(light-blue shale and argillaceous sandstone)*

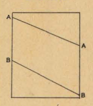
DEVONIAN

Dc — Chattanooga shale *(black carbonaceous shale)*

SILURIAN

SDp — Panola formation *(brown limestone and blue shale)*

Sections



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ECONOMIC GEOLOGY SHEET

KENTUCKY
LONDON QUADRANGLE

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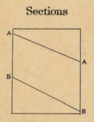

⚒ Coal mines
× Coal prospects

Known productive formations

Coal *(Lee and Breathitt formations; contain Pittsburg Ky. and other coal seams)*

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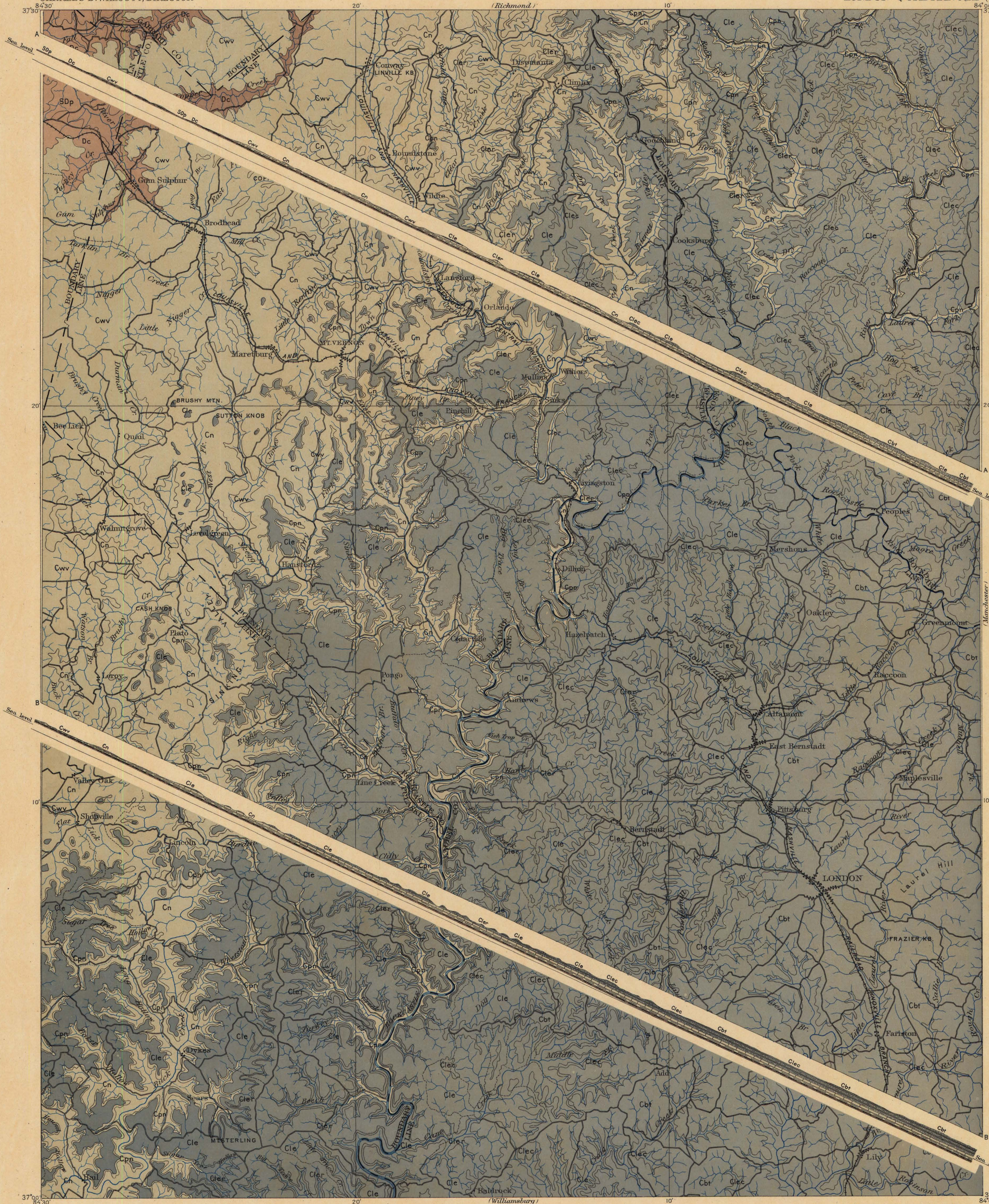
STRUCTURE-SECTION SHEET

KENTUCKY
LONDON QUADRANGLE



LEGEND

SEDIMENTARY ROCKS

SHEET SYMBOL	SECTION SYMBOL		
Cbt	Cbt	Breathitt formation (sandy shale and ferruginous sandstone. Pittsburg Ky. coal seam near the base)	CARBONIFEROUS
Cle	Cle	Lee formation (sandy shale and sandstone with coal seams)	CARBONIFEROUS
Clec	Clec	Corbin conglomerate-lentil (coarse pink sandstone or conglomerate at the top of the Lee formation)	CARBONIFEROUS
Cler	Cler	Rockcastle conglomerate-lentil (coarse conglomerate in the Lee formation)	CARBONIFEROUS
Cpn		Pennington shale red and green shale with thin beds of limestone, grouped with the Lee formation on the sections	CARBONIFEROUS
Cn	Cn	Newman limestone (blue limestone, cherty at the base)	CARBONIFEROUS
Cwv	Cwv	Waverly formation (light-blue shale and argillaceous sandstone)	CARBONIFEROUS
Dc	Dc	Chattanooga shale (black carbonaceous shale)	DEVONIAN
SDp	SDp	Panola formation (brown limestone and blue shale)	SILURIAN

Known productive formations

Coal (Lee and Breathitt formations contain Pittsburg Ky. and other coal seams)

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