DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS

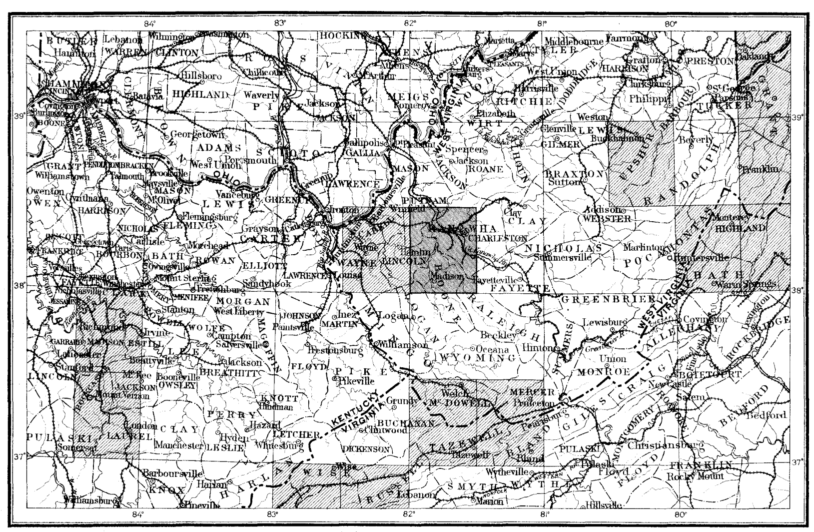
OF THE

UNITED STATES

CHARLESTON FOLIO

WEST VIRGINIA

INDEX MAP



SCALE: 40 MILES = 1 INCH

AREA OF THE CHARLESTON FOLIO

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FOLIO 72 | LIBRARY EDITION | CHARLESTON

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

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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:

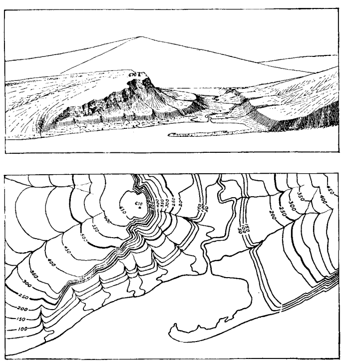


Fig. 1.—Ideal sketch and corresponding contour map.

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	€	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 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:

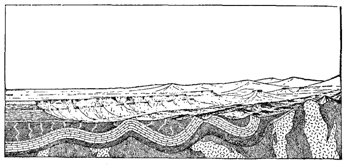


Fig. 2.—Sketch showing a vertical section in the front of the picture, with a landscape beyond.

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:

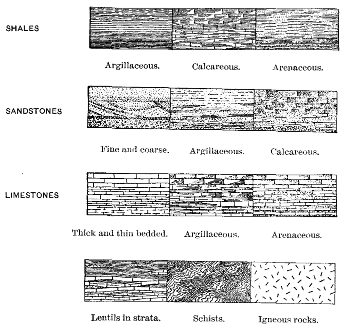


Fig. 3.—Symbols used to represent different kinds of rock.

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 CHARLESTON QUADRANGLE.

By **Marius R. Campbell.**

GEOGRAPHY.

General relations.—The Charleston quadrangle embraces an area of 938 square miles, extending from latitude 38° on the south to 38° 30′ on the north, and from longitude 81° 30′ on the east to 82° on the west. The quadrangle is located in the State of West Virginia, including parts of the counties of Kanawha, Boone, Putnam, and Lincoln, and is named from the city of Charleston, which is situated at the junction of Elk and Kanawha rivers, in the northeastern part of the quadrangle.

Location of quadrangle.

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 central New York.

Subdivisions of the Appalachian province.—Respecting the attitude of the rocks, the Appalachian province may be divided into two nearly equal parts by a line which follows the northwestern side of the Appalachian Valley, along the Allegheny Front and the eastern escarpment of the Cumberland Plateau. East of this line the rocks are greatly disturbed by folds and faults, and in many places they are so metamorphosed that their original character can not be determined. West of the division line the rocks are almost wholly sedimentary and with few exceptions the strata lie nearly flat, in approximately the same attitude in which they were deposited.

The western division of the province is therefore sharply differentiated from the eastern division, but it can not be so easily separated from the remaining portion of the Mississippi Valley. In a geologic sense it is a part of the Mississippi Valley. The character and the stratigraphic succession of the rocks are the same, and the geologic structure that is characteristic of one is also found throughout the other. On account of these facts it would be arbitrary, on geologic grounds, to separate the two, or, in other words, to assign a definite western limit to the Appalachian province.

Relation of the Appalachian province to the Mississippi Valley.

From a physiographic standpoint this western division is clearly a part of the Appalachian province, for its history can not be written apart from that of the whole province, but it has little or no known relation to the region west of Mississippi River in either its physiographic history or its present surface features. This division is, therefore, physiographically limited on the east by the Allegheny Front and the eastern escarpment of the Cumberland Plateau and on the west by the flood plain of Mississippi River and the prairie plains of Illinois and Indiana. In contradistinction from the lowlands on either side, it has been called by J. W. Powell the Allegheny Plateaus.

Limits of the western division of the Appalachian province.

The Allegheny Plateaus are made up of a variety of topographic features, including the greatly dissected Cumberland-Allegheny Plateau on the east, the Highland Rim and the Lexington Plain in the middle of the territory, and the Central Basin of Tennessee and the low plains bordering Mississippi River on the west.

Allegheny Plateaus.

The geologic structure of the Allegheny Plateaus is comparatively simple. The strata lie nearly flat, but in places along the eastern margin their horizontality is disturbed by sharp folds which give rise to long, even-crested ridges, or to equally long, narrow valleys parallel with the margin of the field. In the interior there are a few broad folds, but their height is so small compared with their breadth that the resulting dip of the rocks is scarcely perceptible.

The most prominent structural feature is a low, broad arch, known as the Cincinnati anticline, which enters the Allegheny Plateaus from the direction of Chicago, curves southward through Cincinnati and Lexington, Kentucky, and then trends southwest, parallel with the Appalachian Valley, as far as Nashville, Tennessee. Its maximum development is in the vicinity of Lexington, where the Trenton limestone is exposed at the surface at an altitude of 1000 feet above sea level, but in Tennessee it again swells out into a dome-like structure which, being eroded, is represented topographically by the Central Basin of Tennessee.

Cincinnati anticline.

Geographically this anticline separates the Allegheny Plateaus into two parts, or structural basins, which differ from each other in the character of the rocks which they contain, in their geologic structure, and in the topography developed upon their surfaces. The eastern basin, extending the entire length of the province from northeast to southwest, is well known as the Appalachian coal field. The western basin is more restricted, being the southeastern portion of the coal field of Illinois, Indiana, and Kentucky. The rocks outcropping on the crest of the Cincinnati anticline are prevailingly calcareous, and the two coal fields are therefore not only structurally distinct but are separated by a wide band of rocks which are lithologically very different from the sandy coal-bearing strata on either side.

Appalachian coal field and the coal field of Illinois.

Topography of the Allegheny Plateaus.—The altitude of this division is greatest along the southeastern margin, where the ridges and plateaus attain sufficient elevation to be considered mountains. They are not continuous, and in no sense can they be grouped into a single mountain system. In the northern part of this division of the province the general surface forms a plateau at an altitude of from 2000 to 3000 feet above the sea. Upon this platform stand numerous ridges which have been formed by the partial erosion of small anticlinal folds that traverse the plateau in lines parallel with its eastern margin. To the south the plateau is not so well marked nor so high, and it has been deeply dissected by the streams which drain its surface, leaving a hilly, broken region in the place of the plateau. This region is also free from minor folds; hence there are no ridges rising above the general level. Farther south extensive folds occur within the limits of this division, and parallel ridges or valleys are found which are similar to those in the northern part of the province. In southern Tennessee and northern Alabama, however, the lithologic and structural conditions have been such that the anticlines are eroded, leaving the central parts of the broad synclines as elevated plateaus, which, in various places, have received local names, but which may be grouped under the general name of the Cumberland Plateau.

Ridges on the plateau surface.

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 part of the province. From this extreme altitude on the southeastern margin the surface descends to less than 500 feet on the western border, near Mississippi River. This descent is accomplished by a succession of steps or escarpments, which mark the present extent of particularly hard beds of rock and also the various stages in the reduction 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 on the east. In Tennessee the escarpment is steep and regular and the plateau is perfectly preserved, but in Kentucky the capping rocks were not hard enough to protect the plain after it was uplifted, and it has been greatly dissected by the numerous streams which drain its surface, forming a hilly region in place of the plateau and a broken margin of irregular hill slopes instead of an escarpment. North of Ohio River the distinction between the topographic features is less pronounced than farther south and there is more or less merging of the eastern plateaus into the low plains of the Mississippi Valley.

Altitude of the mountainous belt.

Escarpment at western margin of coal field.

From the foot of the escarpment that marks the western limit of the coal-field plateau there extends a second plain or plateau, which is a prominent feature of the topography of Kentucky and Tennessee. This plain stands at an altitude of about 1000 feet throughout the "Blue grass" region of Kentucky, and it can be traced northward into Ohio and Indiana. In Tennessee it is perfectly developed along the western front of the Cumberland Plateau, where it has approximately the same altitude as in central Kentucky. Doubtless this surface once extended across the Central Basin of Tennessee, for the latter is bounded on the south by high land along the Tennessee-Alabama line, and on the north by the great interior plain of Kentucky.

Plains at altitude of 1000 feet.

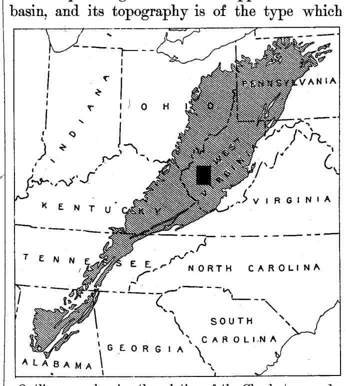
The evidence indicates that this surface was formed by subaerial erosion which operated so extensively that it reduced the soft rocks nearly to the level of the sea, forming a peneplain. Since that time the surface has been elevated to its present position, 1000 feet above sea level, and streams have dissected it extensively. Owing to the softness of the rocks in Tennessee and to the geologic structure which is there developed, a second limited plain of lower altitude was formed, which was subsequently elevated and now forms the floor of the Central Basin. This surface has a general altitude of from 500 to 700 feet, and it is separated from the higher surface by a steep slope or escarpment which is generally called the Highland Rim. Since the formation of the Central Basin the land has been elevated several hundred feet and the principal streams have carved deep and narrow valleys in its once even surface.

The Central Basin of Tennessee and the Highland Rim.

In northern Kentucky the conditions were not so favorable for extensive erosion as in Tennessee, and consequently there is no feature exactly equivalent to the Central Basin, but there are old high-level stream valleys, such as have been described in the Richmond (Kentucky) folio, which indicate that similar although not identical conditions prevailed in the Ohio Valley during the same general period.

TOPOGRAPHY OF THE CHARLESTON QUADRANGLE.

This quadrangle lies in the Appalachian coal basin, and its topography is of the type which



Outline map showing the relation of the Charleston quadrangle to the Appalachian coal field.

characterizes the basin where the rocks are comparatively soft and undisturbed.

Drainage.—The Charleston quadrangle is located in the hydrographic basin of Ohio River, and most of its surplus waters reach that stream through Kanawha River, which joins it at Point Pleasant, West Virginia. Kanawha River is the largest stream in this region; it crosses the quadrangle in a northwesterly direction, flowing in a rather narrow valley which has been incised in the general surface of the plain to a depth of from 500 to 1000 feet. Elk, Coal, and Pocatalico rivers are its principal tributaries within this territory. Elk River is the largest branch, but its extent in this quadrangle is slight and consequently it is not an important factor in carrying off the waters of the district. Coal River drains the largest territory in the quadrangle, whereas Pocatalico River has only an insignificant part of its drainage basin in the area. Along the western side of the quadrangle there are several streams which flow toward the west and join either Mud or Guyandot rivers, which enter the Ohio near Huntington, West Virginia.

Kanawha River has now a complete system of locks and dams by which navigation is possible throughout the year from its mouth to a point far above the limits of this quadrangle. This affords an easy mode of transporting the coal that is extensively mined along the river, from the mouth of Campbell Creek to the head of navigation. Elk River has never been improved by locks and dams, but the channel has been cleared so that considerable traffic can be carried on by push-boats and in time of high water by rafts of lumber and logs which descend from the upper course of the stream. Coal River was once improved by private enterprise as far up as the cannel coal mines at Peytona, but with the abandonment of the mines came neglect of the locks and dams and their consequent destruction by high water, so that to-day the river is in its original unhampered condition. Great quantities of timber are rafted down this stream in time of high water, but during the ordinary stage the water is too low for commerce of any kind to be carried on.

Navigation on the Kanawha.

The history of the drainage of this region is extremely interesting, for, in a geologic sense, it has been only a short time since Kanawha River below St. Albans was deflected to its present course. The details of this history will be given in a subsequent paragraph, and here it will be necessary only to note that at one time this river, instead of turning northward as it does at present, continued westward through Teay Valley, along the line of the Chesapeake and Ohio Railroad, past Scott Depot, Hurricane, Milton, Barboursville, and Huntington. It is probable that Ohio River then had no existence and that the stream formed by the junction of Kanawha and Big Sandy rivers flowed northward through the valley of the present Scioto River and discharged its waters into the system of the Great Lakes. The subsequent ponding of these northward-flowing streams by the advance of the glacial ice caused them to overflow and form a new river along the line of lowest divides. This new stream is Ohio River and its outlet is into the Mississippi instead of the Great Lakes. The details of these great changes have not been worked out, but sufficient data are now available to establish the principal facts of the change as here outlined.

History of the drainage.

Relief.—The surface features of any quadrangle are difficult of interpretation if the student is confined to the facts shown in that quadrangle, for many of the conditions which have modified the action of erosion so as to produce the present topography are general in their character and can be understood only through a knowledge of the surface features and the configuration of the drainage lines over a wide extent of territory. The topography of the Charleston quadrangle is especially difficult of interpretation, for the rocks which compose the surface are so nearly homogeneous that topographic features formed at different times and under different conditions of erosion grade almost imperceptibly one into another.

Topography typically developed in Kentucky.

In attempting to read the physiographic history of this quadrangle, it will be necessary first to consider the history of a portion of the same general region in which the topographic forms are well marked and clearly distinguishable one from another. The nearest place to which we can go for reference is central Kentucky, where there is a clean-cut and sharp distinction between the features of the coal field and those of the "Blue grass" region. This has been described in the Richmond and London (Kentucky) folios, to which the reader is referred for a more detailed account.

In Kentucky the surface of the coal field is a partially dissected plateau which stands at an elevation of about 1500 feet above sea level. At its western edge there is a sharp descent to the surface of the Lexington Plain, which has an altitude of about 1000 feet. Along divides and near the headwaters of the streams the plain is perfectly preserved, but near the lower courses of the principal drainage lines its even surface has been destroyed to some extent by the backward cutting of small branches. Below the Lexington Plain, Kentucky and Licking rivers have cut deep gorges, but the presence of extensive terraces on both streams shows that their down-cutting was interrupted by a pause in the upward movement of the land, which permitted the streams to broaden their valleys at some stage of their development. Since the episode of terrace cutting there is no evidence of variation in the work of the streams, and presumably the conditions under which they accomplished their work have remained fairly constant from that time to the present.

Cycles of erosion.

These features of central Kentucky are probably due to subaerial erosion. They are the results either of complete cycles of erosion, during which the surface of the entire region was reduced to a peneplain, or of partial cycles in which the reduction extended only to such areas as were characterized by the outcrops of soft rocks. In the Lexington region the rocks are so nearly horizontal that, at first sight, they appear to have controlled the operation of erosion by determining level surfaces corresponding with their bedding planes, but careful examination shows that the surface of this plain bevels the formations at a very low angle. These conditions indicate that the work of erosion was limited in its downward progress to some horizon below which it could not operate and which had no relation to the bedding planes of the underlying rocks. Such a limiting horizon is a base-level of erosion, and extensive areas of the surface in Kentucky were reduced approximately to this position in at least two periods of post-Paleozoic time.

Ages of the surface features.

The ages of these surface features have not been definitely determined, but there is sufficient evidence to class provisionally the uppermost peneplain as Cretaceous, the Lexington Plain as late Eocene or Neocene, and the terraces of the river valleys as early Pleistocene.

The Charleston quadrangle doubtless passed through approximately the same cycle of events, but the conditions in West Virginia were not so favorable for the formation and preservation of topographic features with sharp distinctions, and hence any interpretation of these features is inexact on account of the obscurity of the record.

Topographic features not clearly developed in West Virginia.

By reference to the topographic map it will be seen that the surface of the Charleston quadrangle shows little variation. It is a deeply dissected plateau in which there is a fair degree of regularity in the altitude of the tops of the hills along northeast-southwest lines, and a gradual descent from 1800 or 2000 feet on the south to about 1000 feet in the northwestern corner. The depth of dissection varies in a similar manner from 1000 feet on the south to 400 feet on the north. There is a regularity in this hilly surface, which bears no resemblance to the striking topographic features of central Kentucky, and, at first sight, it seems impossible to interpret the features of the Charleston quadrangle in terms of erosion cycles by which we are accustomed to express the physiographic history of land areas. It is apparent that the criteria for the interpretation of physiographic history in the Charleston region must be very different from those which are used in central Kentucky.

The general upland surface of this quadrangle slopes with considerable regularity toward the northwest at an average rate of about 25 feet per mile. The rocks dip in the same direction, but their average rate of descent is considerably greater than the slope of the surface; hence the older rocks, which are exposed in the southeastern corner, dip below the surface in passing to the northwest, and are replaced by younger formations in successive order. Since the Charleston sandstone, which caps the hills in the southern half of the quadrangle, is harder and more resistant than the other formations, the surface, to a certain extent, is modified by this stratum. Its effect, however, is not so pronounced as one would imagine, for in passing off its outcrop, either onto younger strata toward the northwest or onto older strata toward the southeast, the general regularity of the sloping, hilly surface is fairly well preserved. Taken as a whole, the rock series is fairly homogeneous and quite resistant to the action of erosion. It is impossible under ordinary conditions of erosion for escarpments or even a moderate degree of differentiation between features formed at widely separated epochs to be produced upon rocks with the character and attitude above described and with similar relation to the surface. If, then, the cycles and subcycles of erosion have been the same in West Virginia and Kentucky the results should nevertheless be characterized more by differences than by resemblances in their topographic expression.

Remnants of the Cretaceous peneplain.

The oldest topographic feature in the Charleston quadrangle is the fairly even hilltops back from the main drainage lines. From their great regularity these tops are regarded as the last remnants of a plateau surface which once existed in this region and extended to and was continuous with the coal-field plateau of eastern Kentucky. The generally accepted belief is that this surface was once a peneplain, formed probably during Cretaceous time near sea level, subsequently elevated, and dissected by running water until it has reached its present condition.

The surface represented by these high summits has been elevated since its formation, and its altitude in the northwestern corner of the quadrangle is about 1200 feet above sea level. Owing to the tilting and warping which accompanied this upward movement the surface gradually rises toward the southeast to 1400 feet at Charleston, 1800 feet at the forks of Little Coal River, and about 2100 feet at the southeastern corner of the quadrangle.

By a close study of the topographic map it will be seen that the summits of the ridges decrease in height on approaching the principal streams of the region. This change in height is usually noticeable several miles back from the stream, but after a descent of a few hundred feet the ridges extend with nearly level tops to the very brink of the gorge in which the river flows. The projecting spurs on both sides are at about the same altitude, and the conclusion seems almost inevitable that at some time the large streams of this region were flowing in broad, shallow valleys, the bottoms of which corresponded with the level of the tops of the spurs along the rivers and the sides with the gentle slopes at a distance of several miles from the present streams.

This region may be restored in the imagination to approximately the condition just described by supposing the valleys of the principal streams to be filled to the height of the bordering hills. It will be seen that this surface was one of comparatively low relief. Along the major streams the valleys were broadened to a considerable extent, especially in the softer rocks, and the valleys of the lesser rivers were cut somewhat in proportion to the volume of water carried by each.

Terraces corresponding to the Lexington Plain.

These old, broad valleys seem to correspond to the Lexington Plain of Kentucky. They lie distinctly below the high-level plateau surface of the coal field, which is continuous throughout West Virginia and Kentucky, and they represent the oldest period of undisturbed erosion that has been generally recognized in this region. At first it seems almost impossible to correlate these ill-defined and poorly preserved valleys, having a width of only a few miles in their greatest development, with the extensive and unobstructed level surface of the Lexington Plain, but when it is remembered that the latter is carved from soft limestones and the West Virginia valleys from resistant shales and sandstones, the difficulties of correlation are greatly reduced and it is possible to consider the two as representing essentially the same physiographic conditions.

The cycle of erosion just described was incomplete, being interrupted by an extensive elevation of the land. Under the stimulus of increased slope the streams cut deep gorges in their old, broad valleys. At present these gorges show depths ranging from 500 to 800 feet. In many of them it is impossible to detect any variation in slope from top to bottom except that which is due to difference in hardness of the underlying rocks. In certain localities terraces and abandoned stream channels show that there was a slight pause in the movement of the crust of the earth, during which the downward cutting of the streams was practically at a standstill and lateral corrasion widened the valley to an appreciable extent.

Teay Valley.

The most interesting episode in the recent geologic history of this region is the change in the course of Kanawha River from west to north, resulting in the evacuation of its old channel along Teay Valley. Teay Valley has long been recognized as an abandoned river channel, and various suggestions have been made to explain the diversion of the stream which formerly occupied it and to account for the deposits of clay occurring in it. Prominent among the suggestions is one which assumes that Ohio River was dammed by a glacier at Cincinnati during the Glacial epoch, but this fails to account for the facts, as do other assumptions involving the direct effects of glacial ice masses or of warping of the earth's crust.

Nevertheless, these adjustments appear to be intimately though not directly related to the great ice epoch. Teay Valley is but one of several similar features that occur within about 100 miles of the outermost limit of glaciation; and in some of the most noted cases on Monongahela River, clay analogous to that of Teay Valley has yielded fossil plants which, according to Dr. F. H. Knowlton, belong to a Glacial flora. Although these abandoned channels seem to be due to conditions which were general throughout the Ohio Valley, their relation to the surrounding topography, the variation, from place to place, of the character of the sediments deposited in them, and the difference in height to which these deposits extend, indicate that local and special conditions determined each case of diversion separately.

Abandonment of channels due to local ice dams.

The only hypothesis which appears to satisfy existing conditions is that of local ice dams formed by the occasional breaking up of river ice. In order to accomplish the diversion of the river to a new course the dam must have been capable of raising the water from 100 to 150 feet above its former level and the climate must have been severe enough to hold such a dam in place from season to season until the ponded water corraded a new channel around the obstruction and to a depth below the level of the silt which, in the meantime, had accumulated on the rocky floor of the old channel.

Ice dam at Ashland, Kentucky.

In applying this hypothesis to Teay Valley it will be necessary to suppose that a dam of this kind occurred in the vicinity of Ashland, Kentucky, by which the stream was forced to abandon its valley back of Russell and to seek a new channel farther north, by Ironton, Ohio, where the present Ohio River is located. Below such a barrier there would be no deposition of sediments, for since the formation of the dam the valley has not been occupied either by standing water or by a stream of any consequence. Above the barrier the water, although ponded to such an extent as to cause it to drop most of its load of fine material, was still affected by currents, so that the material laid down was rudely stratified, being arranged in much the same manner as the flood-plain deposits of the present large streams.

Ice dam near Milton, West Virginia.

In the course of time another dam appears to have formed in the vicinity of Milton, and this barrier was so high and strong that it backed the water up to the level of the divide on the northern side of the valley, across which the stream found several outlets into the present valley of Kanawha River. The corrading action of a current flowing across a divide from 100 to 150 feet above the general stream level is very strong, and it would require only a short time, comparatively, for the channels to be cut below the level of the silt in the old valley. At least three channels appear to have carried off the overflow from the submerged valley. One of these was located along the present course of Kanawha River; the other two were situated farther west, in the valley of Hurricane Creek. Owing to the favorable location of the easternmost channel and to the large deposit of silt in the upper end of Teay Valley, the stream was turned into its present course and the outlets by way of Hurricane Creek were abandoned. During the reduction of this divide the water in the upper end of Teay Valley was stationary and undisturbed by the current which passed northward through the new outlet. In this quiet water finely laminated clay was deposited, not only in Teay Valley, but wherever the ponded water was free from the current of the river.

Laminated clay deposit.

Changes in the Pocatalico River channel.

Pocatalico River also suffered changes in its alignment about this time, for it has an abandoned valley almost as clearly defined as that of the Kanawha. The stream appears originally to have passed by Rocky Fork post-office, through the "Flatwoods" at Fry, and to have joined the old Kanawha River near Scary. This abandoned valley is at the same altitude as Teay Valley, and it must have been evacuated at about the same time as the latter. The water of the Kanawha undoubtedly overflowed this valley, for it has left deposits of laminated clay on the highest point of the old valley floor now remaining. It seems probable that Pocatalico River also was choked by the ice that was brought from its upper course and that it was forced to seek a new outlet in its present location.

Old channels of Elk River.

Similar features may be seen on Elk River near Charleston. The divide between Coonskin Branch and Elk Twomile Creek is low and rather broad and is deeply covered with river deposits including bowlders as large as 7 inches in diameter. These bowlders could have been deposited only by a stream flowing across this divide, and it seems almost certain that Elk River at one time turned south through the valley of Coonskin Branch and ran west along that of Elk Twomile Creek to the present course of the river. The evacuation of this channel presumably occurred contemporaneously with the abandonment of Teay Valley, for they are at about the same elevation. Presumably a local dam was formed on Elk River similar to the dam in Teay Valley, and it turned the stream from its original course into its present position. A feature similar to the one just described is seen opposite the mouth of Coonskin Branch, where the wagon road up Elk River leaves the stream, crosses a low divide, and descends to Minkshoal Branch. The low saddle through which the road passes contains a deposit of rounded bowlders and sand which evidently marks the position of an old stream channel. The altitude is somewhat greater than at the head of Coonskin Branch, and it seems probable that this small diversion antedated the one previously described.

Scattering deposits of this character occur at a number of points, but their relation to Teay Valley was not determined.

Most of the large stream valleys of this region are marked by terraces cut into the bluffs and projecting spurs at about the same altitude as the rocky floor of Teay Valley. They are particularly prominent on Coal River and its various branches. They are remnants of old, broad valleys within which the streams have cut their present narrow channels. These broad valleys indicate a somewhat advanced cycle of erosion, which was interrupted by elevation of the land and the inauguration of the present, or post-Glacial, cycle.

The physiographic features discussed in the previous paragraphs indicate a sequence of events which may be summarized as follows: First, a long epoch of subaerial erosion, in which the surface of this quadrangle, as well as that of most of the Appalachian province, was reduced nearly to the level of the sea. This was followed by an uplift along an axis located southeast of this quadrangle, which raised the surface and tilted it toward the northwest. On this uplifted surface erosion became active and, in the epoch of quiescence which followed the uplift, it developed a peneplain over the outcrops of soft rocks and in regions adjacent to the principal drainage lines. Peneplanation was again interrupted by an upward movement, during and following which the streams again cut sharp channels into the level floors of their old, broad valleys. From the beginning of this uplift to the present time the active work of the streams has been interrupted only once by cessation of the upward movement, and that epoch was of so short duration that the river valleys were broadened to only a slight extent. The activity of the present streams shows either that upward movement of the land is in progress at present or that the cessation of movement has been so recent that the streams have not had time appreciably to widen their valleys.

Summary of events producing surface features.

GEOLOGY.

GENERAL SEDIMENTARY RECORD.

All the consolidated rocks appearing at the surface within the limits of the Charleston quadrangle are of sedimentary origin—that is, they were deposited by water. They consist of shales, sandstones, and coal beds, having a total average thickness of about 2000 feet. The materials of which they are composed were originally mud, sand, and gravel derived from the waste of the older rocks and from the remains of plants which lived while the strata were being laid down.

The geography of the time when the rocks of this quadrangle were deposited is not well known, but some progress has been made in the determination of the physical conditions which prevailed, especially in ascertaining the configuration of the land during the period of the deposition of the coal-bearing rocks. In the closing stages of the lower Carboniferous or Mississippian epoch, a considerable, although probably variable, thickness of mottled red and green calcareous shale (Mauch Chunk) was deposited over most of the Appalachian province. In all except the northeastern part of the province this followed a long epoch of limestone deposition, and hence the shale is generally regarded as indicative of a shallower sea and also relatively higher adjacent land than existed during the limestone-forming epoch. In the Appalachian Valley it is uncertain what was the next change, but along the western margin of the coal field, across eastern Ohio, Kentucky, and central Tennessee, the red shales were lifted above the level of the sea, forming a land area that corresponded, in a general way, with the Cincinnati anticline. It also seems probable, although at present it can not be demonstrated, that the Appalachian Valley, or at least a large portion of it, also rose above sea level, leaving a narrow trough along the eastern margin of the Appalachian coal field, in which deposition of the coal-bearing rocks first occurred.

Wide distribution of the lower Carboniferous shale.

Land area at the close of the lower Carboniferous.

The scarcity of fossil marine organisms in the coal-bearing rocks of this region leads to the supposition that this basin was generally separated from the sea and consisted, in large measure, of fresh-water lagoons and extensive swamps, in which the vegetable matter that has since been consolidated into coal was accumulated, and over which the sand and mud constituting the larger part of the formations were distributed. It has lately been suggested that rivers may have played an important part in the distribution of the greatly diversified sediments of the coal-bearing rocks. This is certainly possible, for the existence of extensive peat swamps implies a land surface of faint relief, and the close succession of coal and beds of sandstone and shale formed from the waste of the land shows that there were frequent incursions into the swamp of rivers or lakes, and occasionally of the sea. It can not be doubted that the great and presumably rapid accumulation of mechanical sediments was accomplished by large streams, and it seems possible that these streams may have been agents of wide distribution as well, depositing their load on the low plains at or slightly above the level of the sea.

Into the narrow basin on the eastern margin of the present coal field the streams from the continental area on the east swept their burden of waste from the surface of the land. The rock floor of the Appalachian trough gradually sank, allowing the accumulating material to extend farther and farther toward the west, each succeeding bed overlapping that which was laid down before it and resting unconformably upon the eroded surface of what was previously land on the western side of the trough. The continued subsidence allowed the coal-bearing rocks to be deposited as far west as the present limit of the field, and it is possible that originally they extended entirely across the Cincinnati anticline, connecting the Appalachian coal field with that of western Kentucky, Indiana, and Illinois.

Unconformity toward the west of the basin.

After the deposition of beds of sandstone, shale, and coal to a thickness of several thousand feet, the entire Appalachian coal field was raised above the level of the sea and permanently added to the continental area.

Close of sedimentation.

Since the final emergence of this part of the province from the Carboniferous sea the coal field has been continuously dry land, and its history during this period is more or less perfectly preserved in the topographic features found upon its surface to-day. To a certain extent this history has been interpreted, and the leading features have been presented under the heading "Topography of the Charleston quadrangle."

STRATIGRAPHY.

The strata exposed in the Charleston quadrangle have a thickness of about 2000 feet. The thickness of the formations, their order of succession, and their general characters are given on the Columnar Section sheet, but a more detailed description of the individual beds and a statement of their probable equivalents in other fields are given in the following paragraphs.

DEEP-WELL SECTIONS.

A number of deep wells have been drilled in this quadrangle, which reveal the presence of many formations lower in the geologic series than those appearing at the surface. These sections are shown in graphic manner on the Columnar Section sheet. The driller seldom appreciates the value of a carefully kept record, and, since it involves some trouble and cost, the record is generally neglected and frequently is only fragmentary and imperfect. In all cases some allowance must be made for the difficulty which the driller encounters in determining the exact nature of the material passed through and for the possible inaccuracy of his observations. The well sections are given as reported by the driller. For the sake of preserving details that can not be shown in a small-scale drawing the sections are here described.

Well A.—Along the lower portion of Kanawha River no wells have been drilled in this quadrangle, but a short distance to the north, in the vicinity of Winfield, Putnam County, a well has been drilled which began at about the horizon of the so-called Pittsburg coal. The following section was obtained from that boring and is given for reference and comparison.

Log of well at Winfield, on Kanawha River.

	Thickness in feet.	Depth in feet.
Shale	20	
Sandstone	7	27
Limestone	5	32
Slate	87	115
Red shale	10	125
Shale	5	130
Sandstone	25	155
Shale	5	160
Red rock	25	185
Sandstone	15	200
Red rock	15	215
Sandstone	10	225
Slate	85	310
Sandstone	10	320
Slate	37	357
Sandstone	40	397
Slate	43	440
Sandstone	35	475
Slate	25	500
Sandstone	10	510
Slate	25	535
Sandstone	70	605
Coal and slate	20	625
Sandstone	108	733
Slate	52	785
Sandstone	20	805
Slate	37	842
Sandstone	21	863
Slate	15	878
Sandstone	19	897
Shells	13	910
Sandstone	45	955
Slate	10	965
Sandstone	20	985
Slate	15	1000
Coal and slate	25	1025
Sandstone	45	1070
Slate	45	1115
Sandstone	15	1130
Slate	20	1150
Sandstone	255	1405
Dark sandstone	20	1425
Limestone	15	1440
Sandstone	5	1445
Limestone	175	1620
Slate	25	1645
Sandstone	25	1670

Well B.—This is the only well that has been drilled along Kanawha River in this quadrangle below Charleston. It is located on the river bottom, 1 mile below Lock No. 6, and, according to J. W. Penhale, furnished the following section:

Log of well on Kanawha River 1 mile below Lock No. 6.

	Thickness in feet.	Depth in feet.
Conductor	45	
Sandstone	405	450
Coal	5	455
Sandstone	35	490
Slate and shale	220	710
Sandstone	10	720
Slate and shale	40	760
Sandstone	50	810
Shale	10	820
Lime	35	855
Sandstone	45	900
Coal	3	903
Sandstone	7	910
Shale	35	945
Sandstone	480	1425
Lime	213	1638
Slate and shale	25	1663
Sandstone	47	1710
Shale	425	2135
Shells and shale	115	2250
Shale	145	2395
Sandstone	5	2400
Shale	208	2608

This section begins at about the base of the red shales of the Braxton formation and furnishes the best measure of the lower formations in this part of the coal field.

Well C.—The log of this well has frequently been referred to as the type section of the lower coal-bearing rocks in the Kanawha Valley. The well was drilled in 1887 at Charleston Kanawha County.

Log of well at Charleston, Kanawha County.

	Thickness in feet.	Depth in feet.
Conductor	28	
Unknown	12	40
Shale	34	74
Coal		....
Sandstone	76	150
Shale	42	192
Coal		....
Shale and sandstone	68	260
Limestone	20	280
Sandstone	60	340
Shale	60	400
Sandstone	70	470
Coal		....
Unknown	20	490
Shale	20	510
Sandstone	50	560
Shale	30	590
Sandstone	355	945
Unknown	55	1000
Sandstone	170	1170
Shale	10	1780
Limestone	10	1190
Sandstone	60	1250
Limestone	200	1450
Unknown	25	1475
Sandstone, pebbly	40	1515
Sandstone, red	85	1600
Sandstone, shelly and slaty	12	1612
Sandstone	80	1692
Shale to bottom	148	1840

Well D.—The partial record of a well at the mouth of Lick Branch is given by Prof. I. C. White in Bulletin 65 of the United States Geological Survey, as follows:

Log of well on Kanawha River near mouth of Lick Branch.

	Thickness in feet.	Depth in feet.
Unknown	20 ?	
Shale, blue	27	47
Sandstone	51	98
Shale and sandstone	6	104
Sandstone	73	177
Shale	21	198
Sandstone	94	292
Shale, blue	33	325
Sandstone	50	375
Shale	32	407
Sandstone, white	15	422
Sandy shale, dark blue	195	617
White pebbly sandstone.		

The lowest member in the above section generally has been supposed to be the top of the Pottsville series, but Professor White has expressed the opinion that the top of this series may occur in the bed of sandy shale noted by the driller as immediately overlying the pebbly sandstone, and this supposition seems best to accord with the sections of the adjacent wells.

Well E.—This well was drilled in 1887 by the same persons who drilled well F. It is located at Malden, Kanawha County.

Log of well at Malden, Kanawha County.

	Thickness in feet.	Depth in feet.
Conductor	60	
Sandstone, white	30	90
Shale	10	100
Sandstone, white	240	340
Sandstone, dark	10	350
Coal and shale	6	356
Sandstone, soft	100	456
Unknown	100	556
Limestone	20	576
Broken rock	24	600
Sandstone, white	180	780
Sandstone, dark	94	874
Shale, dark	10	884
Limestone, blue	10	894
Shale, red	2	896
Sandstone, bastard, and lime	20	916
Limestone, blue	50 ?	966
Shale	834	1800

This section as given and platted shows the limestone abnormally thin, but in the record the thickness is noted as doubtful; hence it seems probable that the discrepancy is in the record and that the limestone holds its general thickness of 150 to 250 feet.

Well F.—In 1887 a deep well was drilled on the Cool Spring Fork of Burning Spring Branch, and the section which is given below was preserved with considerable care:

Log of well on Cool Spring Fork of Burning Spring Branch.

	Thickness in feet.	Depth in feet.
Conductor	53	
Sand	100	153
Shale, gray	8	161
Sand, gray	40	201
Shale, dark	25	226
Sand, hard and white	174	400
Coal	6	406
Sand, hard and white	200	606
Shale, white	10	616
Limestone, white (shale ?)	50	666
Shale, white	40	706
Sand, hard and white	255	961
Shale, black	50	1013
Sand, hard and blue	50	1063
Limestone, blue	300	1363
Red rock, shaly	50	1413
Unknown	187	1600
Sand, coarse	2	1602
Shale, blue	250	1852
Shale, black	75	1927
Shale, blue	322	2250
Shale, shelly	100	2350
Shale, blue	50	2400
Sand, shelly	50	2450
Shale, blue and very soft	92	2542

Well G.—On Simmons Creek, $1\frac{1}{4}$ miles from Kanawha River, is another well. Its section, as reported by Mr. Penhale, is as follows:

Log of well on Simmons Creek $1\frac{1}{4}$ miles from mouth.

	Thickness in feet.	Depth in feet.
Sandstone	935	
Lime shales	180	1115
Limestone	165	1280
Red sand at bottom of well.		

Well H.—At a distance of 2 miles from the river another well was drilled. which, on the same authority, gave the following log:

Log of well on Lens Creek 2 miles from mouth.

	Thickness in feet.	Depth in feet.
Drift	10	
Sand	110	120
Shale	80	200
Sand	200	400
Coal	4	404
Sand	296	700
Shales, green, red, and blue	280	980
Limestone, gray and blue	240	1220
Red sand	2	1222

Well I.—On Lens Creek two wells have been drilled in close proximity. The one farthest down the stream, or at a distance of $1\frac{1}{2}$ miles from Kanawha River, affords, according to Mr. Penhale, the following section:

Log of well on Lens Creek $1\frac{1}{2}$ miles from mouth.

	Thickness in feet.	Depth in feet.
Sandstones (?)	840	
Lime shales	200	1040
White lime	160	1200
Red sand at bottom of well.		

All details are lacking regarding the character of the material down to a depth of 840 feet. These are supplied, in a measure, by section H.

Well J.—This well is located on Kanawha River at the mouth of Witchers Creek; the elevation of the head of the well is unknown, but it is presumably about the level of the bottom land along the Kanawha at this point, or 570 feet above sea level. The section is given on the authority of J. W. Penhale of Charleston.

Log of well on Kanawha River near mouth of Witchers Creek.

	Thickness in feet.	Depth in feet.
Unknown	500	
Coal and shale	20	520
Unknown	370	890
Bottom of all sand		890
Lime shale	70	960
Sand	5	965
Lime shale, red and black	135	1100
White limestone	2	1102
Lime shale	106	1208
Red sandstone at bottom of well.		

Well K.—This well was drilled in 1887 near Winifrede, Kanawha County, by the Winifrede Coal Company, which is authority for the following section:

Log of well at Winifrede, Kanawha County.

	Thickness in feet.	Depth in feet.
Conductor	32	
Coal, "Winifrede"	4	36
Unknown	11	47
Sandstone	51	98
Shale	5	103
Coal	2	105
Sandstone	20	125
Shale	25	150
Sandstone	115	265
Shale	10	275
Sandstone	39	314
Coal	2	316
Shale	105	421
Coal	2	423
Sandstone	8	431
Unknown	9	440
Sandstone	120	560
Coal	4	564
Shale	21	585
Sandstone	870	1455
Shale	15	1470
Sandstone	105	1575
Limestone	15	1590
Sandstone	160	1750
Shale	10	1760
Shale, red	15	1775
Shale, black	15	1790
Red rock and shale	70	1860
Limestone	140	2000

Well L.—This well, which has proved to be the largest gas well in this district, is located at Racine, Boone County. The log of the well was very poorly kept and it is valuable only in determining certain well-marked formations. It is given on the authority of C. C. Sharp of Corning, Ohio.

Log of well at Racine, Boone County.

	Thickness in feet.	Depth in feet.
Unknown	400	
Coal (?)	4	404
Unknown	196	600
Coal	11	611
Unknown	314	925
Red sandstone and shale	175	1100
Limestone	165	1265
Sand at		1285
Sand at		1335
Red shale in bottom of well.		

It is unfortunate that this record was not more carefully kept, as the well is the only deep one in that part of the quadrangle, but the finding of a large supply of gas will doubtless lead to the drilling of other wells in the near future. The location of the coal bed at 400 feet is doubtful, since, in a well drilled about 25 feet from this one, a coal bed having a similar thickness is reported at 500 feet. The tools were lost in the latter well and it was never completed.

Well M.—This well is located on Guyandot River near the mouth of Big Hart Creek. It is not in the Charleston quadrangle, but its reported section is given for comparison with the wells along Kanawha River.

Log of well on Guyandot River near mouth of Big Hart Creek.

	Thickness in feet.	Depth in feet.
Conductor	26	
Slate	20	46
Sandstone	80	126
Coal	9	135
Sandstone	175	310
Blue slate	107	417
Sandstone	403	820
Blue slate	20	840
Sandstone	22	862
Blue slate	6	868
Yellow sand and flint	38	906
Slate	45	951
Sandstone	182	1133
Blue slate	18	1151
Red rock	20	1171
Sandstone	42	1213
Limestone	235	1448
Red rock	80	1528
Blue slate	180	1708
Sandstone	105	1813
Blue slate	20	1833
Sandstone	10	1843
Blue slate	168	2011
Black sandstone	15	2026
Blue slate	1150	3176
Gray sandstone	8	3184
Black slate	77	3261

CARBONIFEROUS PERIOD.

By comparing the plotted sections it will be seen that in several cases the drill penetrated far below the Carboniferous limestone, but the similarity of the material occurring below that stratum makes it practically impossible to subdivide it into formations or to correlate it with beds of similar age on either side of the basin. Well M, on Guyandot River, is the deepest of the series, and it penetrated shales and sandstones to a depth of 1800 feet below the limestone horizon. Some of the sandy and especially the red beds of the upper part of this interval without doubt belong to the Carboniferous series, but the greater portion may be more safely classed as Devonian and correlated with the thick sediments of this age in the Appalachian Valley to the east. The Carboniferous limestone, or Newman limestone, as it is termed in these folios, is the reference stratum in all of these wells from which measurements are made and by which the other formations may be classified. It is present in full force in all but two sections, and in these it seems probable that the record is at fault rather than that the limestone is absent or as thin as indicated. It is barely possible that the limestone is variable in this region, but its great regularity in the majority of well sections leads to the supposition that it is present in them all and that its reported variability is due to the failure of the driller to observe it rather than to the absence of the bed itself.

The Carboniferous limestone.

The regularity of the thickness of this limestone is rather surprising when it is considered that this quadrangle is intermediate in position between the region of its great development on the eastern side of the coal field, where it is approximately 900 feet thick, and southern Ohio, where it thins to a feather edge and disappears. The sections given show no trace of thinning toward the northwest, but, on the contrary, the limestone seems to hold a constant thickness throughout the region.

Above this limestone, in several sections, occur thin beds of limestone, red shale, calcareous shale, and red sandstone which evidently also belong to the Mississippian, or lower Carboniferous, series. In the geologic folios treating of this region this formation is called the Pennington shale. On the eastern margin of the coal field it is several thousand feet in thickness, but in this region it is reduced to less than 300 feet at the maximum and in many sections it is entirely absent. This variation in thickness is presumably due to the unconformity between the Mississippian and the Pennsylvanian, or upper Carboniferous, series. At the close of the Mississippian epoch the land on the Cincinnati anticline rose above the level of the water and the red Pennington shales, forming the surface of the land at that time, were eroded irregularly and in some places were entirely removed before the coarse beds of the Pottsville series were deposited.

Wherever deep borings have been made the Pottsville series has been found, but its thickness and composition vary greatly from place to place. This series is complex, being composed of shale, sandstone, and conglomerate, but the driller rarely differentiates these beds in his record book. Since only the upper portion of this series is exposed at the surface in this quadrangle, the remainder need not be described in detail.

The Pottsville series.

Sewell formation.—This is the uppermost member of the Pottsville series. It is named from the town of Sewell, on New River, where some of the earliest mines in this district were established for the purpose of obtaining coal from this formation.

Along New River, on the southeastern margin of the coal field, the Pottsville is a great, complex series having a thickness of not less than 1400 feet. In passing northwest it gradually becomes thinner, being reduced to 925 feet in the section at Racine, which is one of the most accurate measurements in the eastern part of the Charleston quadrangle. From this it decreases to about 550 feet at Charleston, 480 feet at Lock No. 6, and about 290 feet at Winfield. These figures show that the decrease in thickness is greater in this quadrangle than it is eastward, but the exact manner in which the change is accomplished is not well understood. Since this series gradually overlapped farther and farther upon what was previously land to the northwest, the lowest beds of the complex series that occurs on the eastern side of the coal field are probably the first to disappear in passing in a northwesterly direction. In like manner, the overlying beds successively disappear until, on the northwestern side of the field, only the uppermost members are present to represent the Pottsville series. A study of the fossil plants, by David White, shows clearly that the basal members of the Pottsville series have no representatives on the western side of the coal field and that the rocks found there belong to the Sewell formation, at the top of the series.

Overlap of the upper Carboniferous.

This series is particularly conspicuous on New River in the vicinity of Caperton, its prominence being due largely to a massive sandstone or conglomerate which forms high cliffs along the brink of the gorge. This sandstone dips to the northwest, in conformity with the general descent of the rock series in this direction, and it reaches water level in the vicinity of Kanawha Falls. Owing to a change in the direction of the stream at this point, it flows for a few miles up the dip of the strata and forms a fine cascade in plunging over the slightly upturned edge of the massive bed of sandstone.

Local heavy sandstone at top of Pottsville.

The section along New River has been accepted generally as the type for the middle part of the coal field, and the massive sandstone at the top of the Pottsville series has been regarded as a constant and distinguishing feature of this horizon. Careful search, however, for this bed in the territory on both sides of the river clearly proves its lens-like character. It can not be identified beyond 15 or 20 miles from New River, and even down the stream below Kanawha Falls it is soon lost to view, although its horizon continues above water level to the mouth of Armstrong Creek.

In the Oceana quadrangle, lying south of the area under discussion, the horizon of this bed is present, as shown by the fossil plants, but there is no particularly hard or thick bed of sandstone. These facts are of the utmost importance in the interpretation of deep-well sections. Since it has been generally assumed that the top of the Pottsville is marked by a heavy sandstone, the line separating this formation from the one above has been drawn at the topmost bed of a generally sandy series. In a measure this is correct, but the evidence of fossil plants shows that it is not universally so, and it should be accepted merely as a provisional determination.

In tracing the top of the Pottsville along Coal River into this quadrangle, it was found that there is no well-defined stratum of sandstone at this horizon, and consequently the top could be located only approximately from such stratigraphic evidence as was available and by means of fossil plants. The horizon thus determined passes below the level of the stream in the vicinity of Round Bottom Branch and has been generally supposed not to show again at the surface before reaching the western margin of the coal field. In the vicinity of Racine and Peytona, however, there is a coarse, massive sandstone which until recently had been regarded as belonging to the Kanawha formation, but which was identified by Prof. B. S. Lyman (Some Coal Measure sections near Peytona, West Virginia: Proc. Am. Philos. Soc., Vol. XXXIII, pp. 282-309) as the topmost bed of the Pottsville series. This determination was at first not generally accepted, but it has been verified by David White from a collection of fossil plants made from a coal bed immediately overlying the heavy sandstone at Racine. Under the influence of the Brownstown anticline this Pottsville sandstone rises above water level near Joe Branch, attains its maximum altitude at the mouth of Whiteoak Creek, and then sinks below the level of the stream again near Lick Creek.

Discovery of Pottsville strata at Racine.

This series is also above water level on both forks of Little Coal River above Madison. On Spruce Fork the top is marked by a coarse conglomerate, which is quite prominent near Low Gap Creek but which disappears toward Madison and also in the opposite direction. On Pond Fork there is nothing unusual in the character of the beds and their horizon can be told only from the fossils which they contain. The presence of the Pottsville rocks on both Coal and Little Coal rivers is well established by the evidence of fossil plants and should be expected from the rise of the rocks over the Brownstown anticline and the thinning of the various formations toward the northwest.

The section from Racine across the divide to Brownstown seems to show that the sandstone which is so heavy at Racine is also present on Lens Creek from the forks of the creek to Kanawha River. During the past season a few fossil plants were collected from the shale immediately overlying the heavy sandstone on Lens Creek, and while the material is not sufficient for final determination it seems to indicate that the plant-bearing horizon is below that of the Eagle coal. Since the interval between the Eagle coal and the top of the Pottsville thins toward the northwest, as do most of the other formations, it is quite probable that the sandstone in Lens Creek forms the top of the Pottsville series. This assumption is still further strengthened by the comparison of well sections. The section at Racine may be considered as a correct scale for measurement because the well head is within 25 feet of the top of the heavy sandstone that is regarded as Pottsville. The section is lacking in details, but the dividing line between the coarse sands of the Pottsville and the red shales and red sands of the Pennington beneath is probably well determined. On the assumption that this is correct, the Pottsville at Racine has a thickness of about 925 feet. The two wells on Lens Creek, I and H, strike the red or calcareous shales at 840 and 700 feet respectively. On the assumption that these three wells start at approximately the same stratigraphic horizon, it will be seen that the Pottsville is even thinner on Lens Creek than it is at Racine. This is not surprising, for there is a northward as well as northwestward element in the thinning of this formation, and it is only reasonable to suppose that the red shales are nearer the surface on Lens Creek than at Racine; but if the sandstone on Lens Creek is not Pottsville, then the top of the Pottsville must be below the surface and its thickness must be correspondingly reduced. Such a reduction in thickness, however, does not correspond with the section on Burning Spring Branch (well F), which shows a probable measure of 837 feet. The structure, stratigraphy, and fossils seem, therefore, to indicate the Pottsville age of this sandstone on Lens Creek. It has not been heretofore recognized by geologists and its adoption here is only provisional, pending the production of more definite evidence.

Pottsville strata on Lens Creek.

The proof of the existence of Pottsville rocks at Racine necessitates a change in the correlation of all the coal beds of this region. The beds on Coal River have been definitely correlated with those on Kanawha River, but, unfortunately, a coal bed lying directly above the heavy sandstone at Racine has been correlated with the Cedar Grove coal on the Kanawha, a correlation which is manifestly incorrect and which will have to be changed.

Change in correlation of coal beds made necessary.

Kanawha formation.—This is the great coal-bearing formation of southern West Virginia. It occupies the interval between the Sewell formation and the Charleston sandstone. This formation varies in thickness in the same manner as the Pottsville, but, since it is not limited by unconformities, the change in thickness is accomplished by the general decrease toward the west in the amount of sediment supplied during the deposition of each stratum. In the vicinity of Kanawha Falls this formation is about 1100 feet thick. A short distance below this point the base passes below water level, and, until recently, was supposed not to appear again until the northwestern side of the coal field was reached, but, as shown in the description of the previous formation, it probably does appear a few feet above the level of the river at the mouth of Lens Creek, and then disappears as it passes below the center of the basin. The reappearance of the base of the formation at Brownstown and the various well sections in this vicinity afford measurements of the thickness of this formation at several points in this quadrangle. At Brownstown it is approximately 700 feet in thickness, at Charleston 600 feet, below Lock No. 6 500 feet, and at Winfield 425 feet. Thus we can trace the change in the thickness of this formation from 1100 feet on the southeastern margin of the coal field to 425 feet in the center, and, as reported by Prof. I. C. White, to 244 feet at Ironton, Ohio, on the northwestern margin of the field. Along its outcrop in the Charleston quadrangle it varies in thickness from 800 to 650 feet, but under cover it probably decreases to 450 feet.

The great coal-bearing formation of southern West Virginia.

Decrease in thickness of the Kanawha formation to the northwest.

Considered broadly, the Kanawha formation may be distinguished from both the overlying and the underlying formations by the relative fineness and softness of its material, but when it is examined in detail this difference is not so marked as it seems from the general statement. Probably the prevailing element is sandy shale, but mingled with it are numerous beds of sandstone, which are as massive and prominent in the topography as many of those occurring above and below the formation. As a rule it carries more coal beds than any of the other formations, and many of these beds are of workable thickness and of sufficient purity to be extremely valuable. The base of the formation is fairly well differentiated from the next formation below, and since this horizon has been determined with certainty by fossil plants, it will be comparatively easy to carry the plane of subdivision into other parts of the field. In Kanawha County the top of the formation is more clearly marked than the base, for the uppermost limit is defined by the "Black flint," which is well known to every coal prospector and operator and even to most of the citizens of the region in which it is found. Unfortunately its outcrop is limited in geographic range and the bed is somewhat variable in composition in the region in which it occurs. The Black flint is present in full development in the triangle bounded by Elk and Kanawha rivers and the eastern margin of the quadrangle. It crosses Kanawha River and extends to the headwaters of Davis Creek, and it is generally present on the hills near the river, back of Brownstown, Winifrede Junction, and Peerless. It is a regularly bedded deposit which in its greatest development has a thickness of about 10 feet. In some places it consists of heavy beds of dense black flint which is so pure that it has been used extensively for arrow heads and flint implements generally. From this pure condition it grades down to a black siliceous shale which can be distinguished with difficulty from other beds of similar material in the series. In every case it assumes this shaly phase toward the margin of the deposit, and thus fades gradually from sight until finally it becomes unrecognizable. This is well illustrated in the cuts of the Chesapeake and Ohio Railroad, just above the station at Charleston, where it is exposed for some distance. Near Porter Branch the bed is easily identified and can be followed down the track from that point until it degenerates into very sandy shale, and near the station it disappears as a recognizable formation. South of the flint area the top of the Kanawha formation can be determined only approximately. In a general way the sandstone overlying this formation may be found on most of the hilltops, but it is generally impossible to draw a definite line of division between them.

The "Black flint" as a horizon marker.

In the vicinity of Madison the lower part of the Kanawha formation is characterized by a thick bed of fine blue shale which carries a great number of calcareous concretions that are readily recognized wherever they are found. When large they are generally known as "Turtlebacks," and they have suggested the name Turtle Creek which has been given to the stream that enters Little Coal River near the town of Danville.

Charleston sandstone.—The Charleston sandstone consists of a series of coarse sandy or conglomeratic beds which separate the Kanawha formation from the red and green shales and green sandstones of the formation next above. In passing across the outcrop of this formation on any line at right angles to the direction of the outcrop, it is easily seen that this series is, lithologically, clearly separate and distinct from the series which lie above and below it, but when the contacts are traced continuously it is found that the coarse beds are almost universally in the form of lenses, and at the margin of one lens it is necessary to go either up or down in the series to reach the limit of the formation as determined by the next lens. In this way the formation can be traced, but it is very doubtful whether the top as determined at one point is at the same horizon as the top at another point a few miles distant. It is only by means of the fossil plants that the time horizons can be determined in connection with this formation.

Sandstones of the Charleston formation are lenses.

The Charleston sandstone is made up of a variable number of beds of coarse material separated by shale and coal beds. It is particularly prominent in the river bluffs from Malden to Spring Hill. At Charleston it forms picturesque cliffs, especially on the southwestern side of the river, and it is from this place that it has been named.

In variation of thickness this formation seems to follow the same law that governs the lower formations. In the southeastern quarter of the quadrangle it caps the hills without showing any of the red shales of the succeeding formation and has an apparent thickness of about 400 feet. At Charleston it is about 300 feet thick, and in the Little Coal River region it presumably in few places exceeds 250 feet. After passing below water level it seems to be as variable in thickness as it is above. Below Lock No. 6 it is reported 400 feet in thickness, and at Winfield it is apparently 175 feet thick.

Braxton formation.—This includes all the Carboniferous strata of the region above the Charleston sandstone. The formation consists largely of red and green shales and green sandstone, but there are numerous lenses of white, compact sandstone or conglomerate. These lenses are generally of considerable extent, frequently running for 5 or 10 miles, but eventually thinning down and finally disappearing from the section. Owing to the irregularity of the hard and prominent beds, it is almost impossible to determine the exact structure or the thickness of the strata with certainty. The well section at Winfield shows a thickness of 550 feet between the Charleston sandstone and the so-called Pittsburg coal. To this must be added 250 or 300 feet for the height of the hills above this horizon, making a total of 800 or 850 feet for the Braxton formation in this quadrangle.

Red and green shales and sandstones.

The Raymond or so-called Pittsburg coal bed has been taken by Prof. I. C. White as the dividing plane between the Elk River series below and the Monongahela River series above. This division of the strata was first used in Pennsylvania and is doubtless well adapted to that region, but in southern West Virginia this coal bed is too variable to permit of its use as a horizon marker. This division is not a natural one in this district, for the strata above this coal are lithologically identical with those below; consequently the more logical method is to consider all of these rocks as belonging to the Braxton formation, a name derived from Braxton County, West Virginia, where the formation was first studied and mapped in this manner.

Correlation of formations.—The earliest geologic work in the Appalachian coal field was done in Pennsylvania; hence that has been generally regarded as the type locality, and the rock series there exposed has been taken as the standard for the entire basin. When the coal-bearing rocks of the Kanawha Valley were examined they were found to bear a strong resemblance, both in lithologic character and in succession, to the type section of Pennsylvania, and the formation names for the latter locality were carried south to the new field. These names were used in West Virginia entirely on account of the lithologic similarity of the rock series in the Kanawha Valley to the series of the northern field, without reference to the contained fossils. The difficulty in using fossils for correlation purposes was that those of marine origin are too sparingly distributed, both geographically and throughout the geologic column, and the fossil plants had not been adequately studied at the time of the earliest work in this region.

Correlation with the Pennsylvania section.

During the course of the present work extensive collections of fossil plants have been made by David White from the formations in the Kanawha Valley. Upon comparison with fossils from the type localities in Pennsylvania, it has been found by Mr. White that the correlations based on lithologic similarities do not correspond to those made on the evidence of the fossil plants. Hence the application of Pennsylvania names to formations, and even to individual coal beds, in this region is incorrect and the names must give place to a local nomenclature based on the character of the beds, without reference to sections in other parts of the coal field. This space is too limited to express in full Mr. White's conclusions, but they may be found in his paper entitled Relative age of the Kanawha and Allegheny series as indicated by the fossil plants: Bulletin of the Geological Society of America, Vol. II, pp. 145–178.

SURFICIAL ROCKS.

PLEISTOCENE PERIOD.

Teay formation.—In the Charleston quadrangle this formation is found principally in Teay Valley, from which its name is derived, but small areas of it also occur in the "Flatwoods" at Fry and in a few localities north of the main Teay Valley. It consists principally of the flood-plain deposit of the ancient Kanawha River and of the finely laminated clay laid down by this stream before it abandoned Teay Valley for its present course. The rising of the land since this episode and the consequent dissection of the old valley have afforded ample opportunity for the study of the deposits. Wherever the rock floor of the valley is exposed it is found to be covered with a layer of bowlders and gravel, all well rounded and evidently shaped and deposited by a vigorous stream. These bowlders consist largely of vein quartz, which has been transported probably from the mountains of North Carolina, but there is also a notable element of quartzite and Black flint bowlders in the collection. The latter are abundant and of considerable size, one being observed which measured from 12 to 16 inches in its longest diameter and from 10 to 12 inches transversely. The suggestion has been made that some other stream than the Kanawha excavated the Teay Valley, but the presence of flint bowlders in abundance shows clearly that Kanawha River occupied this valley, for only that river traverses the territory in which the Black flint occurs.

Stream gravels at the base of the Teay formation.

Above the pavement of bowlders and gravel there is generally sand, but the arrangement of the different materials is variable, like that in the flood plain of an active stream. Interbedded clay and sand compose a large part of the deposit, and above them is a deposit of finely laminated clay which has a maximum thickness of about 50 feet. This clay is extremely fine and carries the same colors that are found in the shales of the Braxton formation. In all the cuts made by the streams now draining the valley the arrangement of the material corresponds to that already given, showing that the erosion of these small valleys has been accomplished since the deposition of the highest and finest materials in the valley.

Deposit of laminated clay.

The genesis of the coarse deposits has been referred, without question, to the time when the Kanawha occupied this valley as a living stream, but the origin of the laminated clay is not so easily accounted for. Occasional pockets of such clay may occur on the flood plain of a large and sluggish river where the overflow from great freshets collects in back lagoons, allowing the mud carried in suspension to slowly settle, but this explanation will not suffice to explain a deposit 50 feet in thickness which apparently extended originally across the entire valley. At first sight it might seem as though the original suggestion of a glacial ice dam in Ohio River would best explain the phenomena, but if such a dam existed it would cause deposition of fine sediments all along the old channel above the dam, consequently the valley back of Russell, Kentucky, should contain such sediments as well as the Teay Valley proper. Ponding undoubtedly occurred in the upper end of Teay Valley, and it seems probable that it was caused by an ice jam formed by the accumulation of floating river ice borne down by the waters of Kanawha River.

Clay beds formed by the ponded waters of Kanawha River.

On the above supposition the clay deposited in Teay Valley belongs to the early part of the Pleistocene period, and the sand and gravel, which practically can not be separated from the clay in mapping, are considered of the same geologic age.

Alluvium.—The latest formation in this quadrangle is the flood-plain deposit of the present streams. Each stream has its flood plain, which is in process of construction and reconstruction at every period of high water, but on all of the streams except Kanawha River these deposits are so small that they have been omitted in mapping. The alluvial plain of the Kanawha varies in width from one-half mile to one mile, and in a region so hilly and broken as that of West Virginia level land of this extent is of the greatest economic importance.

STRUCTURE.

The structure of the Appalachian coal field is that of a broad, flat trough, in which, in a general way, the oldest strata line the bottom and extend to the margins on either side, while the succeeding formations occupy similar positions, except that their outcrops are always within and concentric with those of the next older formations. This succession continues until the latest or youngest rocks are reached, in the center of the basin. This result may be produced in one of two ways: either the rocks were deposited in horizontal and parallel formations and subsequently folded into a trough or syncline, or they were deposited in a syncline of deposition, the form of which was determined mainly by the floor on which the sediments were deposited. In the latter case the basin would be gradually filled by the successive deposits, restricting its area more and more, until, finally, the last sediments carried into the basin would fill it completely and remove it from the area of active deposition.

Doubtless the geologic phenomena shown in the Appalachian coal field are the combined results of the processes here outlined, for it is evident that much of the material now constituting the coal-bearing rocks was originally laid down in a syncline of deposition, and that this same material, since its consolidation into indurated rock, has been thrown into great folds along the eastern margin of the field.

The coal basin a folded syncline of deposition.

Thus in the Appalachian basin the sedimentation of the coal-bearing rocks undoubtedly began in a trough-shaped depression, but that depression was not located on the axis of the basin; the earliest deposition began along the eastern margin, and since the supply of material came from the east, that part of the basin received by far the larger part of the material and consequently the lower formations are very much thicker there than on the western side. Since the close of deposition, movements have occurred, which, in many places, produced large folds within the limits of the coal field; and in all cases, except in the southern end of the field, they have raised the eastern margin far above the western side.

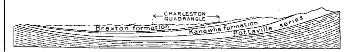


Fig. 2.—Sketch section across the Appalachian coal basin in the latitude of Charleston, West Virginia.

These points are illustrated in the sketch section across the basin as it now exists, shown in fig. 2. The lowest formation represented—the Pottsville—thins from 1400 feet on the eastern outcrop to about 250 feet on the western. A similar change is observed in the Kanawha from 1100 feet on the east to 270 feet on the west; and some change in the same direction is noticeable in the overlying Charleston sandstone. The position of the Charleston quadrangle, as shown by the section, is near the center of the main trough, but its position relative to the Braxton formation is well over toward the eastern side.

Thinning of formations toward the west.

Although the coal-bearing rocks of Virginia, Tennessee, and Alabama may be many times thicker than those of northern West Virginia, Pennsylvania, and Ohio, the northern part of the basin contains more formations and younger rocks than the southern; that is, the northern part represents a longer period of time, but a slower rate of accumulation of material. The Charleston quadrangle is at the southern extremity of this northern part of the basin, and hence its rocks are more influenced by the pitch of the syncline toward the north than by the dips toward the center. Across the end of the basin the limiting outcrop of the Braxton formation is approximately east and west, but when this line is followed to the east and the west it is found to bend to the north and within a score of miles to run parallel with the axis of the basin and on opposite sides thereof.

Structure section.—The section on the Structure Section sheet represents the strata as they would appear in the side of a deep trench cut across the quadrangle along the line A–A. The vertical and horizontal scales are the same, hence the actual form and slope of the land and the dips of the strata are shown.

The only variation from the regular northwestern dips of the strata which prevail on the west side of the Appalachian trough is a low arch that crosses Kanawha River at the mouth of Lens Creek, and consequently has been called the Brownstown arch. On the Historical Geology sheet this arch is well shown where it crosses the principal streams, for it

The Brownstown arch.

brings the Sewell formation of the Pottsville series to view in the stream beds, and on the ridges between these streams it raises the Charleston sandstone so high that it has been eroded, leaving the hilltops composed of the softer material of the Kanawha formation. The direction of the axis of this fold is approximately N. 45° E., and it extends beyond the limits of this quadrangle in both directions. Its maximum development is at Coal River, and it declines in magnitude in both directions from this point. It decreases so rapidly toward the northeast that the Pottsville rocks are barely uncovered at Kanawha River, and beyond the limits of this territory the arch soon flattens out and disappears.

MINERAL RESOURCES.

SALT.

The "Great Buffalo Lick."

Kanawha Valley has long been noted for its production of salt, which dates back even to the advent of the earliest white settlers. The "Great Buffalo Lick," from which salt was first made, was situated at the edge of the river a few hundred yards above the mouth of Campbell Creek. At this spring was erected in 1797 the first salt furnace of the Kanawha Valley, and in 1808 was completed the first rock-bored salt well west of the Alleghenies. During the next thirty years the industry expanded greatly, many wells were drilled, and at one time as many as forty furnaces were in operation in this valley. The salt produced at these works achieved a wide reputation for its preservative quality, and for some years the output was equal to that of the great Onondaga district of New York. The maximum production of the field occurred in the decade from 1844 to 1854, when the yearly output ranged from 400,000 to 600,000 barrels. Later new fields were opened in this and other States where conditions were more favorable and the salt industry on the Kanawha began to decline. This decline has continued down to the present time, when salt making is restricted to a single plant located at Malden, the product being only a small part of what it was at the time of maximum production.

Pottsville series is the reservoir of the salt water.

The difficulties of deep-well drilling were so great in the early days that no effort was made to record the different strata through which the drill passed, except to note the general fact that the brine was found in sandstone at depths ranging from 600 to 1000 feet, and that wells drilled to greater depths were unproductive. From wells recently drilled it is known that the heavy sandstones and conglomerates of the Pottsville series are the salt-water reservoirs and that their depths depend entirely upon location. From the extensive drilling that has recently been done it is also learned that salt water can be obtained at a great many places, but the time seems to have passed for the profitable development of this industry in the Kanawha region.

PETROLEUM AND NATURAL GAS.

The "Burning Spring."

Natural gas has also been known from the earliest settlement of this country, for a gas spring on a small branch about three miles above the "Great Buffalo Lick" was a matter of great curiosity in the early days, and General Washington, who visited this region in 1775, located some land upon this very spot, including the famous "Burning Spring." Gas was encountered in numerous salt wells, but it was not until 1841 that there is any record of its having been used commercially. In drilling for brine in that year near the "Burning Spring" a strong flow of gas was struck, which was utilized in the furnace for evaporating the salt. Two years later gas was struck near the same locality at a depth of 1000 feet, and the pressure was so great that the tools were blown from the well. Dr. Hale of Charleston, in describing this well, says: "For many years this natural flow of gas lifted the salt water 1000 feet from the bottom of the well, forced it a mile or more through pipes to a salt furnace, raised it into a reservoir, boiled it in the furnace, and lighted the premises all around at night." This was so successful that drilling was done in many places for gas with which to run salt furnaces, but, like modern efforts in the same direction, while some were successful, many were disappointing.

Continuation of the Pennsylvania oil field.

In late years systematic search has been inaugurated to find the supposed southwestward extension of the great oil and gas field of Pennsylvania and northern West Virginia. It is impossible here to discuss the geologic relations of oil and gas, but it is generally accepted that low arches or anticlines in the strata offer the most favorable conditions for the accumulation of these valuable mineral products. The "Burning Spring" on the Kanawha is situated upon the western flank of the Brownstown anticline, and here was found in the early days the greatest supply of gas; consequently it seemed probable that there still remained stores of gas upon the crest of this fold. The most extensive drilling in modern times has been in the vicinity of this arch, as is shown by the location of wells on the map. Considerable gas was found in some of these wells and for several years it has been used to supply the city of Charleston, but the amount has gradually diminished and it has been necessary to search for new fields. Wells have been drilled at so many points along Kanawha River that the continuous southwestward extension of the productive oil territory of Pennsylvania is clearly disproved. The most recent development in this field is the striking of a heavy flow of gas in a well at Racine. The capacity of this well is reported to be about 2,000,000 cubic feet per day. It is located nearly upon the crest of the Brownstown anticline and at about its point of maximum development, hence it is entirely in accord with the anticlinal theory of gas and oil accumulation.

The search for petroleum in this quadrangle has not been so successful. Small quantities have been encountered in numerous wells, but there is no record of any considerable amount and the territory must be regarded as unproductive as far as the present developments have extended.

Geologic horizon of the gas-bearing strata.

The strata which carry the gas of this region belong to various geologic horizons. All of the early supplies were derived from some member of the Pottsville series, and doubtless much of the gas of the present day comes from the same horizon. That there are gas-bearing sands at other horizons is shown by the Racine well, which finds its supply at the bottom of the well in a sandstone below the Carboniferous limestone. This sand presumably corresponds with the Pocono sandstone of Pennsylvania and the "Big Injun" sand of the oil driller.

COAL.

Exploitation of coal beds in the quadrangle.

Coal is by far the most important mineral product of this quadrangle. It is distributed throughout all of the geologic formations showing at the surface within the quadrangle, but the beds are of much more frequent occurrence in the lower than in the upper members of the series. Along Kanawha River and in the small valleys immediately adjacent, the coal beds have been thoroughly exploited for the purpose of establishing mines on lines of easy transportation, and in that region their number, position, and character are well understood. On Coal River work of this character has also been done which has furnished considerable information about the coal beds, but not to the same extent as along the Kanawha. In other parts of the quadrangle little has been done except to open coal beds for local supplies and for the purpose of showing the value of the property. Since this work is usually done in an irregular manner, the evidence furnished by it, although at times extensive, is difficult to systematize and arrange for correlation purposes.

Mining has been carried on along Kanawha River since the days of the early salt works, but many of the beds then mined are too small and the coal is too impure to compete in the open market with the standard coals, and consequently they have passed into oblivion along with the salt furnaces which they supplied. About the middle of the last century great activity was manifested in the development of the cannel coal beds along Coal River. Locks and dams were constructed along the river as far as Peytona and considerable coal was shipped from this point and from mines near the mouth of Little Coal River. The mines have long been abandoned and the improvements along the river have fallen to decay.

From the great difficulty which is encountered in trying to correlate the various coal outcrops in this quadrangle it will be impossible to describe them according to horizons, hence they will be considered geographically. For this purpose the quadrangle is divided into nine parts by the ten-minute projection lines, and these are designated by the first nine letters of the alphabet, as shown in the diagram on the Coal Section sheet, beginning with A at the northwestern corner and passing eastward across the sheet, ending in the southeast corner with I.

Division A.—This division occupies the northwestern corner of the quadrangle. The surface is formed mainly of the red shales of the Braxton formation, but the top of the Charleston sandstone is exposed in the valleys of Coal River and some of the smaller streams in the southern part of the division.

The Raymond bed.

The most important coal horizon in this division is the so-called Pittsburg bed, or, as it will be called here, the Raymond bed. This is mined along Kanawha River from Raymond northward at several points, but the bed is irregular in its occurrence and can not be found at every point at which its horizon is due. At Plymouth, on the eastern side of the river, it is reported to run from 2 to 7 feet in thickness in the mine, with an average of from 5 to 6 feet. On the western side of the river little is known concerning this coal. An opening on Bill Creek shows a total thickness of 40 inches (section 1 of Coal Section sheet), with some shale partings which could not be measured. West of this point it is presumably too thin to attract attention.

Within a distance of 50 feet from the top of the Charleston sandstone there is a coal horizon of some prominence in the western part of this quadrangle, but in Division A it appears to be too thin to mine. At an opening on Browns Creek, 3 miles above Tornado, it shows a thickness of only 25 inches, which indicates that it is valueless in this division. Other thin beds occur, but nothing was seen which gives promise of becoming commercially valuable.

Type section of the Raymond bed.

Division B.—In this area occur several openings on the Raymond bed. It varies greatly in thickness from place to place and at some points is presumably wanting altogether. It reaches its maximum development at the mine 3 miles east of Raymond, where section 2 was measured by Prof. I. C. White. Although showing such a large aggregate section, only the main bench, 6 feet in thickness, is mined at this place. One mile above Brillian a prospect pit reveals a coal which is represented in section 3 and which is supposed to be the Raymond coal. This same bed was probably found on Hammond Creek (section 4), but the exact thickness could not be determined.

In Division B there appears to be a coal horizon about 350 to 400 feet above the Charleston sandstone. Section 5 shows the thickness of the bed on the Left Fork of Twomile Creek. South of the Kanawha a coal at about this horizon has been opened on the dividing ridge between Smith Creek and the river. It shows 46 inches of clear coal (section 6), but the outcrop is so near the summit of the ridge that only a small area of the coal remains to be mined.

Eastward extension of the Raymond bed.

Division C.—The Raymond coal is present in full thickness on the dividing ridge which separates the basin of the Pocatalico from that of the Elk and Kanawha, but, unfortunately, it is so near the top of the ridge that only a small area of it remains. On the divide between Twomile and Tupper creeks this bed is extensively mined and the coal is hauled to Charleston in wagons to supply the local demand. Section 7 shows this bed at a new opening at the head of Tupper Creek, where it shows 5 feet 11 inches of clear coal. There are numerous openings along this ridge farther northeast, but it was difficult to find one in which the coal was fully exposed. On the ridge between Sigman and Legg forks of Tupper Creek this coal has been opened and its reported thickness is shown in section 8.

Graham mines coal bed.

Near the middle of the Charleston sandstone is a coal horizon that carries at least two beds of moderate size along the valley of Elk River. The upper bed, shown in section 9, has been worked for a long time at Graham Mines. This coal occurs about 120 feet above the base of the formation which, in this region, is generally marked by the ledge of the Black flint. Twelve feet below the main coal is another, which is shown in section 10. The upper bed has been opened three-quarters of a mile east of the mine, where it shows the thickness given in section 11. It is not always easy to distinguish these beds, for where a single opening occurs it is frequently impossible to say whether it belongs to the upper or the lower of these two coal beds. On Cooper Creek, one mile from Elk River, there is an opening on one of these beds which shows a total thickness of over 3 feet, but the coal is slaty and broken by two partings (section 12), so that its available thickness is reduced to 2 feet.

Several openings were observed on a coal bed which occurs just beneath the flint ledge. This bed is irregular in thickness and also variable in quality, so that it is generally of little commercial importance. Its best observed showing is in the bluffs of the Kanawha above Charleston, where it has the thickness shown in section 13. It has been opened on the various branches of Elk Twomile Creek, but at no point does it seem to promise much for future development.

Coal at Griffithsville.

Division D.—In this territory the hills are not high enough to reach the horizon of the Raymond coal. The highest horizon at which a workable bed occurs is in the base of the Braxton formation, within 50 feet of the Charleston sandstone. Apparently this horizon is productive only on the western margin of this quadrangle. The most important developments are in the neighborhood of Griffithsville, where the coal is mined at a number of points to supply the local demand. Section 14 represents it at a small mine just northeast of the village. The bed is thin at this point, but it seems probable that the bony coal noted in the next section is not taken up here but is left to form the floor of the mine. A short distance southeast of Griffithsville the same bed is mined and its thickness and character at this point are shown in section 15. On Sugartree Fork, about 2 miles south of Griffithsville, a coal at about this horizon is opened, but, judging from section 16, it is hard to believe that this opening is on the same bed of coal as that mined at Griffithsville.

The Charleston sandstone, which carries the heaviest beds of coal on Guyandot River, is apparently almost barren in this region. On Laurel Fork of Horse Creek a thin coal was observed (section 17) which apparently belongs about the middle of this formation, but since no other opening was seen at this horizon it is impossible to say whether it is a valuable coal or not. Another poor coal which apparently belongs in this formation was observed on Ely Fork of Cobb Creek and is represented in section 18.

Thick coal bed on Horse Creek.

The Kanawha is the most productive formation in this division as well as in the whole quadrangle. In the uppermost 70 feet of this formation there seems to be a coal horizon of considerable value and extent. In a general way it corresponds to the group of coals on Kanawha River which occurs within about 60 feet of the Black flint, but it is impossible to attempt the correlation of individual beds. The greatest known development is on Horse Creek within a mile of Little Coal River. From section 19 it will be seen that the bed is divided into two benches, the upper being splint and the lower block coal. Each bench presents a fine body of coal, and it is unfortunate that they should be separated by such a thickness of shale. It seems probable that the bed does not hold this great thickness far toward the north, for an opening on Ivy Creek, about 3 miles north of Horse Creek, shows either a very large bed which is mostly shale or else two beds separated by an interval of 6 feet of shale. Section 20 represents the coal at the last-mentioned opening. On Cobb Creek openings have been made at this horizon which reveal coal of workable thickness, but thin in comparison with the bed on Horse Creek. It is possible, however, that the bed is here so split up that the openings are only on one bench.

The exact condition is unimportant, for the main consideration is a bench of good coal of workable thickness, without regard to whether it is the entire bed or only one of its benches. Near the mouth of Ely Fork of Cobb Creek an opening has been made on a coal which is represented in section 21.

Sixty feet below the thick coal on Horse Creek there is a bed which at some localities has a thickness of 6 feet. At the opening previously referred to on Horse Creek it is 40 inches in thickness, and the bed is represented in section 22. On Trace Branch, ½ mile east of the above-mentioned locality, this bed has been opened, but at the time of examination the coal was not accessible. It is reported, however, to be 6 feet in thickness (section 23).

On the whole the Horse Creek locality is very promising. There appear to be at least two coal beds which are of workable thickness in most parts of this district, and the quality of the coal is good enough to warrant development in case transportation can be secured for the output of the field.

Division E.—So far as known, there are no beds of any great thickness exposed in this area; nevertheless, there has been considerable activity manifested here since the earliest development of the property near the forks of Coal River. The works have long since fallen to decay, but the ancient reports of this property contain some sections, made at the time of the first development, that are of considerable interest, for they are the best and most complete sections of the coal beds in the Charleston sandstone in this district at present available. The coal which was most extensively worked in the early days lies presumably at about the horizon of the Black flint, or at the base of the Charleston sandstone. The coal occurs 60 feet above low water at the mouth of Manning Branch on Little Coal River, and its thickness and character are shown in section 24. It is much broken by partings, but it is reported that these partings varied considerably in the mine, so that at some points the coal is much better than the section indicates. A mine was also established on this bed 2½ miles below this place and on the other side of Little Coal River. At this mine the bed is not so large, nor does it carry so many partings of shale and clay, but, as shown in section 25, it is not a promising coal for commercial mining.

Coals on Manning Branch.

A very good general section of the coal beds in the lower part of this formarion was obtained at the mouth of Manning Branch, where a number of beds were opened on the hillside, one above another. Twenty feet above the mine previously described, or 80 feet above water level, occurs a 30-inch coal, which is shown in section 26. One hundred and twenty feet higher on the hillside, or at an elevation of 200 feet above water level, occurs the most promising coal of the series. As shown in section 28, this is largely cannel coal. If this character holds over any extent of territory, with the thickness shown at this point, the bed will certainly be of considerable value. Reports are current of a bed of cannel somewhere on the headwaters of Manning Branch, but, so far as could be learned, it is not opened and the rumor could not be verified; presumably, however, it is the same as the bed just described. At Chilton, on Davis Creek, a coal has been mined for a number of years which has generally been regarded as occurring at the horizon of the Coalburg bed of the upper Kanawha. The mine, however, is only a short distance from the outcrop of the flint layer, and from the tracing of the beds which has lately been done it seems probable that this bed is at the horizon of the flint and is not the Coalburg bed. The mine in question does not occur in this division, but an opening has been made on the same coal near the head of the creek which gives the thickness shown in section 29.

Supposed Coalburg bed at Chilton.

The coal bed illustrated in section 26 is exposed at the mouth of Brier Creek (section 30), where it shows a somewhat thicker section than on Manning Branch. This coal is not definitely known farther east, but it may be represented by some of the numerous thin coals about the head of Brier Creek. At Ruth, on Trace Fork of Davis Creek, a bed 3 feet in thickness has been opened (section 31) which probably agrees in stratigraphic position with the coal shown in section 28. What appears to be the same bed has been opened at the head of Middle Fork of Davis Creek (section 32), where it has the same thickness that it has at Ruth. On Middle Fork near its junction with the main creek there is an outcrop of coal which shows the same thickness as the bed just described, but it seems to be stratigraphically somewhat lower. Its thickness and character are shown in section 33.

The coal beds of the Kanawha formation are not well represented in Division E. The only one known is presumably the same as the bed shown in sections 22 and 23, and it lies about 100 feet below the horizon of the Black flint—the top of the Kanawha formation. Section 34 represents this bed as it shows near the mouth of Wilderness Fork of Fork Creek. On the Left Fork of Bull Creek a coal having the thickness shown in section 35 occurs about 120 feet above the top of the Sewell formation. The lower bench of coal at this opening is not well exposed, so that it is impossible to state its exact thickness, but the figures given are presumably not far from correct. On Coal River near the mouth of Bull Creek a lower coal is visible, which is represented in section 36 and which probably occurs within 50 feet of the base of the formation. The opening had so fallen in that only 30 inches of the lower bench was visible; the full thickness is not known, but presumably it is not much greater than the observed thickness. Many other coal openings were observed in this section, but the beds were either too small to note or the openings were so closed by fallen débris that it was impossible to determine their thickness and quality. In every case the number of described beds will not equal the actual number that are of workable thickness, for the reason that many of them are inaccessible.

Division F.—The coal beds of this area are better known than those of any other portion of the quadrangle. Mining operations have been carried on since the first development of the salt industry in the Kanawha Valley and as a result prospecting has been more thoroughly done than in other localities.

The Charleston sandstone carries only a few beds of coal in this area, but to the east they become more abundant and the individual beds are thicker and of more importance.

North Coalburg bed.

Less than a mile beyond the eastern margin of the quadrangle the North Coalburg bed attains its maximum development. It is here 175 feet above the Black flint, and its thickness, as given by W. S. Edwards in "Coals and Cokes of West Virginia," is represented by section 37. This bed contains a large amount of coal, but it is so broken up by shale partings, and the several members vary so much from place to place, that its value is greatly impaired. This bed is doubtless present in Division F of the Charleston quadrangle, but its thickness is probably greatly reduced. On Stitt Branch of Davis Creek a coal was observed which appears to be at this horizon, but its thickness is only about 30 inches.

Cannelton block coal or coal No. 5.

In the Kanawha region above Lock 4 there is another important coal horizon from 50 to 60 feet above the Black flint. This was first known as the Cannelton block coal, from a mine which was formerly operated opposite Montgomery, but now it is generally spoken of as coal No. 5. This bed is not known in the Charleston quadrangle, but it may be present there, since it occurs along Kanawha River only a short distance beyond the eastern border. The nearest point at which this bed is opened is at Monarch, a short distance above North Coalburg, where it has the thickness shown in section 38.

Over much of Division F the horizon of the Black flint is characterized by a bed of coal, but it is generally thin and bony and of little value. The coal which has been mined for a number of years on Davis Creek presumably belongs to this horizon, although it has been classed as Coalburg by a number of geologists. Section 39 is compiled from measurements made at the mine during the present survey; section 40 is from the same bed, as reported by W. S. Edwards; and section 41 is from a report by N. S. Shaler in "The Virginias," made in 1881, in which he gives this section as that of the principal coal bed of the region. These sections are supposed to be upon the same bed of coal, but it is apparent that if such is the case one bench only has been developed.

In the Kanawha formation there are a number of coal horizons which can be traced along the river bluffs with considerable certainty, but which, owing to inadequate exposures and to irregularities in the strata, can not be identified in the interior. The physical and chemical characters of the coals are variable and hence these qualities can not be depended upon for definite correlations.

Lewiston or Stockton coal.

Above Lock No. 4 on Kanawha River there is a well-known coal bed which occurs about 40 feet below the Black flint. It is locally known as the Lewiston or Stockton coal, and it reaches about its maximum development (section 42) at Crown Hill, 6 miles above the eastern margin of this quadrangle. Below Lock No. 4 this bed is doubtless present, but it is too thin to have attracted much attention. On the northern tributaries of Campbell Creek a coal bed which appears to be at this horizon has been opened in a number of places. Section 43 represents the best opening, which is situated on Dry Branch a short distance from Kanawha River, and section 44 is from an opening near the head of Younger Hollow. At the latter opening the bed is of fair thickness, but the coal is too impure to mine under present conditions. On Kanawha Fork of Davis Creek there is a coal which appears to belong to this horizon. As shown by section 45, it is somewhat thinner than the Lewiston coal in the type locality, but this change agrees with the general reduction in thickness toward the west. Section 46 is reported by Prof. B. S. Lyman from an opening on the hills above Brownstown. He regards this coal as the equivalent of the Pittsburg bed, but that is manifestly incorrect, since the Black flint occurs in the same hill at a slightly greater altitude. Its position corresponds to the Lewiston coal.

Coalburg bed.

The next important coal horizon which can be identified in this division or the adjacent territory is that of the Coalburg bed. It is named from the village of Coalburg, a few miles east of this quadrangle, where it has been mined for a number of years. It is variable in the total thickness of the bed and also in the arrangement and thickness of the shale partings which occur within it. The average thickness in this mine, as reported by Prof. I. C. White, is shown in section 47. Toward the south this coal holds its normal thickness as far up Cabin Creek as Ronda, as shown by section 48, which represents this coal in the mine at that place. On the north side of Kanawha River this coal is somewhat reduced in thickness, as shown in section 49, which is from an opening on the Left Fork of Witchers Creek, within a mile of the eastern edge of the quadrangle.

In the Charleston quadrangle no coal was seen that exactly corresponds with the Coalburg bed. A coal was observed in Chappel Branch and on the Right Fork of Rush Creek which occurs about 150 feet below the Black flint; it may be the equivalent of either the Coalburg or Winifrede beds. Section 50 represents the coal in Chappel Branch, and section 51 the one on Rush Creek.

About 200 feet below the Black flint occurs the Winifrede coal, which is named from the locality on Fields Creek at which it is most extensively developed. The interval between this bed and the flint is variable, ranging from 150 to 200 feet. On Fields Creek it appears to be generally at the latter figure, although the interval can not be definitely measured, since the flint is not present, except near the mouth of the creek.

"Black Diamond" coal.

The Winifrede mines are not located in this division, hence they will be more fully described under Division I, but there are a number of openings on this important coal bed in this territory. On Witchers Creek there is an opening on the Winifrede coal immediately beneath the prospect pit on the Coalburg bed, previously described. It is 170 feet below the outcrop of the Black flint, and its character and thickness are shown in section 52. In the hills bordering Kanawha River opposite Winifrede Junction a coal, represented by section 53, is mined under the local name of the "Black Diamond." This is 220 feet below the Black flint. This interval does not correspond with that of any of the well-known coal beds of this region, but it is not far from the interval which characterizes the Winifrede coal on Fields Creek, hence it has been generally regarded as that bed. Section 54 is from an opening at the Winifrede horizon on Cane Fork of Davis Creek. The Winifrede coal has been opened and mined at a number of localities about Winifrede Junction and in the lower part of the drainage basin of Fields Creek, but the mines have been abandoned and the coal is now inaccessible at most of these points. In a prospect pit one mile east of the village of Winifrede the coal is still visible, and its thickness at this point is shown in section 55. This coal bed is generally of moderate thickness, and its regularity and good quality render it more valuable than many thicker beds which have only local development.

Below the Winifrede horizon for a distance of about 200 feet the strata are generally barren of workable coal beds. At the base of this unproductive series occurs one of the most prominent coal horizons of the Kanawha Valley. In different parts of the coal field this horizon is marked by such beds as the "Gas" or Coal Valley of the upper Kanawha, the Powellton of Armstrong Creek, Keystone of Cabin Creek, Cedar Grove near the eastern margin of the Charleston quadrangle, and the Campbell Creek bed in the vicinity of Malden. The beds mentioned belong to one general horizon, but it is probable that they are not exactly equivalent, each one being a local development of an otherwise thin and valueless bed of coal. In Division F these beds range from 425 to 475 feet below the Black flint and from about 200 to 250 feet above the base of the Kanawha formation.

Cedar Grove coal.

Section 56 represents the Cedar Grove coal at the type locality 3½ miles above Lock No. 4. On Campbell Creek occurs the greatest development of coal in this zone to be found in the Charleston quadrangle. In the exploitation of this field it was found that the workable coal lay in a basin that was small in extent but that contained exceptionally fine coal of considerable thickness. The thickest coal is now worked out, but its section, according to W. S. Edwards, is shown in section 57. In places the upper bench contained thin bands of shale which detracted greatly from its value. Where the coal was large the shale was small, so that the total thickness as given in the section was never reached. The old workings are reported to have averaged 6 feet, and the new 4 feet 6 inches, in thickness. In passing up the river this bed changes rapidly by the introduction of shale partings, as shown in section 58, which represents its condition at the salt works mine just above Malden. In this mine the shale partings vary in number and thickness and in all cases they thicken in passing away from the Campbell Creek basin.

The mines recently opened on the western branches of Lens Creek appear to be at this horizon. Section 59 is from the mine in Ring Hollow and section 60 from the mine on Fourmile Creek. From the report of Prof. B. S. Lyman on the territory between the forks of Lens Creek, several sections of this coal bed have been taken which were not visited at the time of the present survey. This bed is locally known as Wood's Upper Coal, and it occurs about 250 feet above the base of the formation. Sections 61, 62, and 63 represent three openings on this bed between Left Fork and the main Lens Creek.

The Factory Cannel bed.

In the Lens Creek field there is a prominent coal bed 50 feet below the one last described, or 200 feet above the base of the formation. This is known as the Factory Cannel bed, for the reason that it was used in early days, before the discovery of petroleum, for the manufacture of oil. This coal is also the equivalent of the main cannel coal which was worked so extensively at Peytona before the civil war.

At the site of the old oil factory on Left Fork of Lens Creek the coal is about 30 inches in thickness, as is shown by sections 64 and 65, which are from openings in that neighborhood. At another prospect pit in this vicinity the total thickness (section 66) appears to be greater than that just given, but it is not known how much of this is cannel and how much ordinary bituminous coal. On the main creek nearly opposite the mouth of Ring Hollow there is an old opening on this bed which is reported to have shown 4 feet of coal (section 67), but the coal is not visible at present and the amount of cannel is problematical.

Brownstown coal.

This bed appears to correspond to the Brownstown coal, which has been extensively prospected along the river hills. Section 68 is from an opening at the old mine near Carkin. So far as known, it does not show any cannel along the Kanawha, but even when the cannel is absent the quality is such that it can be profitably mined when the thickness is reduced to 30 inches. Such was the case at Peerless (section 69) until a few years ago, when all the coal of that thickness was removed and the mine was abandoned. On Lens Creek Professor Lyman reports a lower coal horizon, which is locally known as Wood's Lower Coal. It occurs about 130 feet above the base of the formation and it can be identified over about the same territory as the cannel bed above. Section 70 represents it at the site of the oil factory, and sections 71 and 72 are from farther up the same fork of the creek. On the main creek two openings have been made, which furnish sections 73 and 74.

The lowest recognizable coal bed in the Kanawha formation in this region appears to lie within 40 feet of the base of the formation. It is reported by Professor Lyman at a number of points on both forks of the creek. Sections 75 and 76 show its general condition in this territory.

Division G.—In this part of the quadrangle formations are more difficult to separate than in the parts already considered. Erosion has not proceeded far enough in the valleys of the minor streams to expose the Pottsville series, consequently it is difficult to refer the coal beds to that datum. The Charleston sandstone caps the hills in the northwestern part of the division, and it can be used for reference, but elsewhere there is no recognizable stratum from which to determine the position of the coals.

The highest known workable coal bed in this division occurs on Sycamore Fork, near the northern limit of the area. Its stratigraphic position appears to be about 70 feet below the top of the Charleston sandstone, and its thickness is shown in section 77. Section 78 represents the same bed on Flat Creek. Only a few outcrops of coal are seen within the Charleston sandstone. Sections 79 and 80 represent two small coal beds near the head of Left Fork of Mud River, which occur 130 and 160 feet, respectively, below the top of this formation.

The coal horizon at the base of the Charleston sandstone is represented by several openings in this division. Section 81 is from an opening at this horizon on Mud River at Stonecoal Branch; section 82 is from the same bed near the head of Wash Hill Fork of Horse Creek; section 83 is from an opening on Peter Cave Fork of the same creek; and section 84 is from an opening at Hill, which has provisionally been referred to the same horizon. There is so little resemblance in these sections that it seems possible that they are not all from the same bed, although occurring at the same general horizon.

The classification of the coal beds below the horizon just described is very difficult, and the following correlations must be accepted as merely provisional. A coal 6 feet in thickness is reported as occurring on Little Horse Creek 100 feet below the top of the Kanawha formation. This locality was visited, but the coal was not visible and hence the report could not be verified. Another bed, 5 feet in thickness and 150 feet below the one just described, is reported from the same locality, but owing to the condition of the prospect pit this was likewise unverified.

Coals on Big Creek.

On Big Creek, beyond the western limit of this quadrangle, a coal occurs which was described in the Huntington folio. It lies about 150 feet below the top of the Kanawha formation and its thickness is shown in section 85. Two other beds of coal have been prospected on Big Creek in the same hillside as the one just described. They are represented by sections 86 and 87, and they occur 110 feet and 190 feet, respectively, below the coal bed shown in section 85. The coal represented by section 85 has been opened in Division G of the Charleston quadrangle, at the mouth of Ballard Fork of Mud River, where it has the thickness shown in section 88. The coal bed represented by section 87 is presumably the equivalent of a bed (section 89) opened on the North Fork of Big Creek about one mile from the western edge of the quadrangle. In the vicinity of Danville the last-mentioned horizon appears to be represented by a small bed which, at an opening about one mile southwest of the village, has the thickness shown in section 90. This coal horizon probably occurs about 300 feet above the base of the Kanawha formation.

About 250 feet above the base of the formation there is another coal horizon, which has been prospected on the headwaters of Big Ugly and Turtle creeks. Section 91 is from an opening on Big Ugly Creek, about one mile below the head of the stream, and section 92 shows its thickness on the divide between this stream and Right Fork of Turtle Creek. Section 93 is from an opening on the same horizon on the head branch of Turtle Creek.

About 150 feet above the base of the formation a coal occurs which has been opened at the head of Big Creek, where it has the thickness shown in section 94.

On Little Coal River near the mouth of Camp Creek there are two openings on a coal bed which appears to lie within 50 feet of the top of the Sewell formation. Section 95 represents the opening on this bed above Camp Creek, and section 96 the one just below the creek. The bed is not large, but it appears to be the equivalent of a coal bed on Lens Creek, already described, and hence is important as a guide to other horizons.

Division H.—The known coals of this area occur in all of the formations which outcrop, from the middle of the Charleston sandstone to 40 or 50 feet below the top of the Sewell formation. The highest known coal occurs about 100 feet above the base of the Charleston sandstone; an entry on Cold Fork of Laurel Creek driven on this bed is now fallen shut, but the coal is reported to have shown 6 feet in thickness (section 97). The prominent coal beds occurring just below the base of this formation along Kanawha River apparently have no representatives in this region—at least none of them were seen.

Lower in the series the first important coal horizon occurs from 350 to 370 feet above the base of the Kanawha formation. A bed occurring at this horizon was opened many years ago above the cannel coal mine at Peytona, and its character, as reported by Professor Lyman, is shown in section 98. This bed has been prospected in a number of places high up on the hills about Madison, but the pits have in many cases fallen shut and it is frequently impossible to verify the reported thickness of the coal. Section 99 shows the reported thickness of this coal at an opening on the point between the two forks of Little Coal River. On Rucker Branch east of Madison there is a bed of cannel coal which appears to come at this horizon, although it may not be the equivalent of the one just described. The coal at this opening was not all visible, but that which could be seen is given in section 100. This indicates that the seam is valuable if it holds its character over any considerable extent of territory. Sections 101 and 102 are from a coal bed which has been opened at two places on the headwaters of Laurel Creek and which is supposed to be at this same general horizon. In passing southward the coal horizons become indistinct and hard to follow, but an opening at the head of Whites Branch, shown in section 103, seems to be at the same horizon. The details of this section are not known, but the bed shows many shale partings, which render it of less value than would appear from the total thickness.

Cannel coal east of Madison.

In the old workings at Peytona a small bed of cannel was discovered 20 feet above the main bed, or at a distance of 220 feet above the base of the Kanawha formation. At this point the bench of cannel is reported to have varied from 21 to 31 inches in thickness. Professor Lyman reports this bed on Indian Creek to have the thickness given in section 104, and on Drawdy Creek, within 2 miles of Peytona, to be represented by section 105.

Cannel beds at Peytona.

The upper and main cannel beds at Peytona are so closely associated that they will be considered together as one coal horizon. At the original mine on Old House Branch near Peytona the thickness of the bed is shown in section 106, which is the average of seven measurements in the mine by Professor Lyman. In a report on this region made in 1854 two sections of this bed are given from openings on Drawdy Creek, which are shown in sections 107 and 108. In this same locality an opening which was accessible at the time of the present survey furnished section 109. These beds vary greatly from place to place, not only in the quality of their coal, but in their thickness and relation to each other. Morgan Branch is at present the most noted locality for coal on Drawdy Creek. Two large beds have been opened on this branch and they appear to be at the same horizon as the Peytona cannel coals. One bed is opened almost directly above the other, showing an interval between them of only 15 feet. Section 110 represents the upper bed and section 111 the lower bed at this point. Three openings were observed on these beds on the headwaters of Rock Creek, but it is not possible to say whether both are on the same bed or not. Section 112 represents an opening at Foster, and from the fact that it carries cannel it is provisionally correlated with the main cannel bed of Peytona. Section 113 shows the thickness of a bed on the Right Fork of Rock Creek, which presumably corresponds with the upper bed, 200 feet above the base of the formation.

Shoot bed at Peytona.

At the Peytona mine a bed of coal locally known as the Shoot bed was opened 90 feet below the main cannel bed, or about 125 feet above the base of the formation. Section 114 shows the reported character of this bed at the mines, and section 115 is from an opening on Indian Creek, as reported by Professor Lyman. The coal openings of Whiteoak Branch appear to be on this bed, but the interval down to the base of the formation appears to vary in this part of the field from 125 to 150 feet. Sections 116 and 117 represent these two openings, and from their character and position they seem to be on the same bed. An outcrop of coal at the head of Hubbard Fork of Rock Creek also belongs to this horizon, about 150 feet above the base of the Kanawha formation. Section 118 shows the thickness of the bed at this point. Section 119 represents a coal at the head of Camp Creek, which also occurs at the same horizon.

In descending order the next important coal horizon appears to be about 70 or 80 feet above the base of the formation. Sections 120 and 121 represent two openings on this bed on Brush Creek, and section 122 was measured at an opening across the divide on a branch of Camp Creek. On Pond Fork near the mouth of Robinson Creek there is an opening on a bed of cannel coal, which is represented by section 123 and which appears to belong to this horizon.

Below the last-mentioned horizon there seems to be no well-defined and extensive coal beds, but occasional outcrops are encountered that are worthy of note. Section 124 represents one of these which occurs on Camp Creek within 20 feet of the base of the Kanawha formation. Just back of Racine there is an opening on a small coal which, according to the fossil plants found in the roof shales and also according to the stratigraphy, occurs at the top of the Sewell formation of the Pottsville series. Section 125 shows the part of the bed which is visible, the lower bench being covered so as to conceal its full thickness. On Pond Fork above the mouth of Robinson Creek a coal of workable thickness (section 126) was observed which belongs about 40 or 50 feet below the top of the Sewell formation. This has been mined to some extent, but work has been abandoned and it is difficult to obtain an idea of the general character of the coal.

Division I.—The highest known productive coal horizon in this area occurs near the top of the Kanawha formation, or at the horizon of the Black flint. In the dividing ridge between Coal River and Cabin Creek this bed has a great development, but farther east it even rivals this field in great thickness and continuity over an extensive territory. Many years ago this bed was mined extensively at the head of Left Fork of Long Bottom Creek, which is a tributary of Cabin Creek. The bed at this point is reported to have varied in thickness from 4 to 5 feet (section 127). Most of the openings in this region are now fallen shut, so that it is impossible to see the coal and obtain a definite idea regarding its thickness and character. In passing westward the bed thickens rapidly, as shown by section 128, which represents its condition at the head of Righthand Fork of Joe Creek. It is unfortunate that so large a bed of coal as is represented by this outcrop lies so high in the hills, for erosion has removed so much material from this region that only a small area of the bed remains. This unusual thickness does not appear to hold far toward the northwest, for an opening on Caro Fork of the same creek reveals only a slight thickness, as shown in section 149.

The Winifrede coal.

The next important coal-bearing horizon in this area occurs about 200 feet below the top of the Kanawha formation, and it is generally known as the horizon of the Winifrede coal. The mines at Winifrede, the type locality for this bed, occur in this area. The coal varies somewhat in section, but on the whole is remarkably regular. Section 130 was measured at the time of the present survey, and section 131, which gives more details regarding the quality of the coal, is taken from the report of Prof. I. C. White. This bed has been opened in many places on the head branches of Fields, Slaughter, and Joe creeks, but the openings are generally fallen shut and it is extremely difficult to determine the value of the bed in this territory. An opening directly west of the Winifrede mines, at a distance of about $1\frac{1}{2}$ miles, is reported to have shown a thickness of 45 inches. An outcrop on Bucklick Fork of Slaughter Creek is reported to have shown 4 feet of coal, and one at the head of Slaughter Creek is said to expose a bed 6 feet in thickness. On the head of Spicelick Fork of Joe Creek the coal is still visible, having the thickness shown in section 132. At the head of Coal Fork of Cabin Creek a bed of fine-looking coal has been opened in several places and it is locally considered to be the Winifrede bed. This correlation can not be verified, but the available evidence seems to be in favor of the local determination. Section 133 shows the condition of this bed near the head of the stream.

Peytona cannel coals above Racine.

The next lower prominent coal horizon is that of the Peytona cannel coals, which range from 200 to 220 feet above the base of the Kanawha formation. At the type locality, as already described, there are two beds in this interval, but outside of this locality the two can not be differentiated, if indeed they exist as separate beds. The Peytona cannel coal shows at the head of Short Creek, above Racine, where, although its total thickness is small, it still carries a notable amount of cannel coal (section 134). Southeast of this opening the bed is not known to carry cannel at any point. An opening which is supposed to be on this horizon occurs on Righthand Fork of Joe Creek and is represented in section 135. It shows no cannel coal, but the total thickness of the bed is very much greater than in the region about Peytona. On Little Whiteoak Creek several beds of coal have been opened which are evidently near the base of the formation. One opening, which occurs 150 feet above the river at Orange, seems to be on the Peytona cannel horizon. The exposure shows no cannel, but the lower bench is splint coal, as shown by section 136. On Hopkins Fork of Laurel Creek it is difficult to determine the horizons of the coals, but a bed 30 inches in thickness, showing at the mouth of Lavinia Fork, seems to belong to the Peytona cannel horizon, as well as one which shows one mile below this point and which is represented by section 137.

The Shoot bed near Orange.

The next lower coal horizon is that of the Shoot bed of Peytona, 125 to 150 feet above the base of the formation. Section 138 represents this bed on Indian Creek, about 2 miles southeast of Peytona. A bed of coal which appears to be at this horizon has been opened below Orange at a height of about 100 feet above water level. It also shows on Whiteoak Creek, about $1\frac{1}{2}$ miles from the river, where it has the same thickness as below Orange. Section 139 is from the opening below Orange, and section 140 is from Whiteoak Creek. On Logan Fork opposite the mouth of Seng Fork there is an opening on a coal bed which furnished section 141 and which appears to belong to the horizon under consideration.

On Coal River at the mouth Mile Branch a coal bed has been opened at an elevation of about 130 feet above the level of the river. The sandstone which shows above the level of the wagon road is regarded as belonging to the Sewell formation; hence the bed on Coal River is about 100 feet above the base of the Kanawha formation. This bed is of considerable thickness, as shown by section 142, and probably corresponds in a general way with a coal horizon which has been described on Lens Creek and in the adjacent region.

Coal beds are of common occurrence at the top of the Sewell formation. On Short Creek two beds have been opened at this horizon, and they are separated by an interval of 20 feet. The lower bed has a thickness of 2 feet 8 inches and the upper a total thickness of about 4 feet, but the coal is cut by several shale partings. Section 143 shows this bed near the mouth of Toney Creek, and section 144 at an opening on Toney Creek about half a mile from the river. This bed has been opened at the mouth of Joe Branch, but the full section is not visible; it does not, however, give promise of being any better than on Toney Creek. It occurs on Whiteoak Creek about 3½ miles above Orange, but with a thickness of only 30 inches. In other localities, wherever this bed has been observed, it is too thin to be mined under present conditions.

IRON.

Black-band ore.

In the early days of the development of the mineral wealth of this section considerable attention was given to iron, and later a small furnace was erected on Kanawha River at the mouth of Davis Creek to smelt the black-band ore which occurs in that vicinity, but the enterprise was not long lived and the old furnace is now gradually falling into decay. The black-band ore of Davis Creek has been known for a long time. Its quality is excellent, but the quantity is not sufficient to enable it to compete with the high-grade ores of the Lake region. In 1881 Prof. N. S. Shaler examined this property and reported the accompanying section of the ore bed.

This ore is reported to contain 31.46 per cent of metallic iron, and when roasted to run about 64 per cent metallic iron.

There are occasional traces of iron ore at other points in this quadrangle, but the quantity is small and the ore is lean, so that the prospect for the establishment of iron industries in this region in the near future is not promising. The almost total absence of limestone in these rocks is another drawback to the profitable smelting of iron in this region.

Section on Davis Creek.

	Feet.	Inches.
Sandstone	..	..
Ferruginous shales with streaks of coal	..	..
Lean iron ore	2	..
Slate	..	8
Black-band ore	4	..

SOILS.

The soils of the Charleston quadrangle are largely derived from the decay and disintegration of the rocks immediately underlying them; consequently the geologic map, which shows the areal distribution of the various formations, may with certain modifications be regarded as a soil map also. In the interpretation of the geologic map, however, it must be distinctly understood that in the process of soil production many of the important elements of the rocks are removed by solution and that consequently the soil consists, in large measure, of the insoluble residue, the sand and clay of the original rocks. Since sand is the prevailing constituent of most of the coal-bearing rocks, and since also it is the least soluble element, the soils are prevailingly sandy and thin.

The least sandy soil is that produced by the weathering of the rocks of the Braxton formation. The deep-red soils produced from these shales are frequently very productive and are especially well adapted to grazing. The surface of that part of the quadrangle which is underlain by this formation is less rugged than that covering the outcrop of the other formations, and it is, therefore, better adapted to agricultural pursuits.

The soils of the Charleston sandstone and the Kanawha formation are generally poor, and the hillsides are so steep that farming is extremely difficult and the crops are light.

The flood plains of the larger streams constitute some of the best farming lands in this region. The flood plain of Kanawha River is particularly valuable on account of its extent and the quality of its soil.

May, 1901.

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

TOPOGRAPHIC SHEET

WEST VIRGINIA
CHARLESTON QUADRANGLE

LEGEND

RELIEF
(printed in brown)

1463
Figures
(showing heights above mean sea level instrumentally determined)

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

DRAINAGE
(printed in blue)

Streams

CULTURE
(printed in black)

Roads and buildings

Private and secondary roads

Trails

Railroads

Bridges

Locks

County boundary lines

B.M.
×
Bench marks

△
Triangulation stations

H. M. Wilson, Geographer in charge.
Control by U.S. Coast and Geodetic Survey and L.C. Fletcher.
Topography by Hersey Munroe.
Surveyed in 1889-90 and 1896-97.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

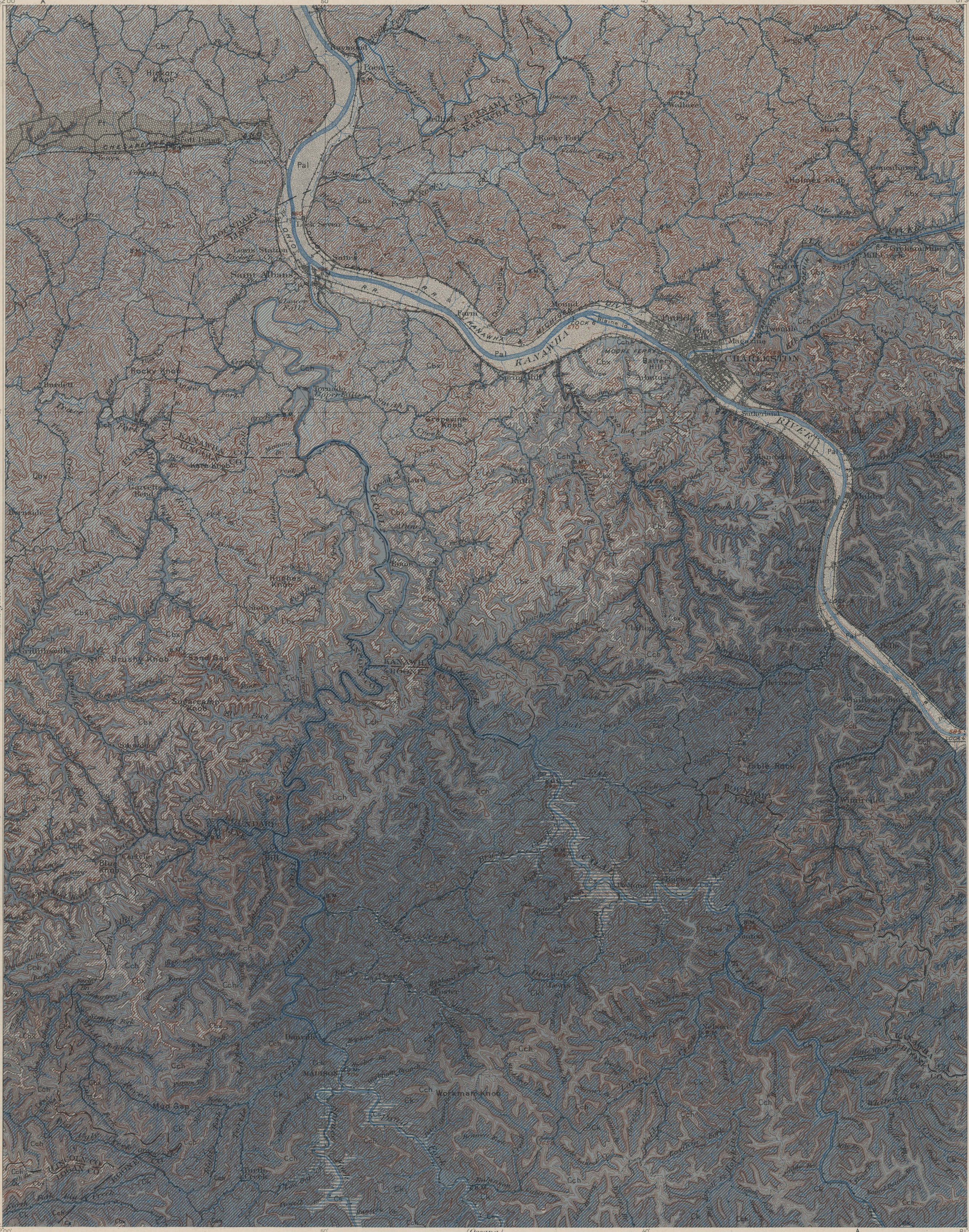
Contour interval 100 feet.
Datum is mean sea level.

Edition of July 1900.

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

HISTORICAL GEOLOGY SHEET

WEST VIRGINIA
CHARLESTON QUADRANGLE



LEGEND

SURFICIAL ROCKS

(Areas of Surficial rocks are shown by patterns of dots and circles.)

PLEISTOCENE

Pal — Alluvium *(flood plain of the Kanawha River)*

Pt — Teay formation *(gravel, sand, and laminated clay deposited by the ancient Kanawha River)*

SEDIMENTARY ROCKS

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

CARBONIFEROUS

XV, XIV — Cbx — Braxton formation *(red and green shales, with local developments of sandstone, conglomerate, and seams of coal)*

Cch — Charleston sandstone *(coarse sandstone or conglomerate frequently interbedded with shale and coal seams)*

XIII — Ck — Kanawha formation *(shales and sandstones with many seams of coal)*

XII — Cs — Sewell formation *(shales and sandstones with coal seams, generally coarser than Kanawha formation)*

Section
A
A

H. M. Wilson, Geographer in charge.
Control by U.S. Coast and Geodetic Survey and L.C. Fletcher.
Topography by Hersey Munroe.
Surveyed in 1889-90 and 1896-97.

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 Nov. 1900.

Geology by M.R. Campbell.
Assisted by W.C. Mendenhall, L.C. Glenn, and C.H. White.
Surveyed in 1895, 97, and 98.

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

ECONOMIC GEOLOGY SHEET

WEST VIRGINIA
CHARLESTON QUADRANGLE

LEGEND

SURFICIAL ROCKS

(Areas of Surficial rocks are shown by patterns of dots and circles.)

PLEISTOCENE

- **Pal** — Alluvium *(flood plain of the Kanawha River)*
- **Pt** — Teay formation *(gravel, sand, and laminated clay deposited by the ancient Kanawha River)*

SEDIMENTARY ROCKS

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

CARBONIFEROUS

- XV XIV — **Cbx** — Braxton formation *(red and green shales, with local developments of sandstone, conglomerate, and seams of coal)*
- **Cch** — Charleston sandstone *(coarse sandstone or conglomerate frequently interbedded with shale and coal seams)*
- XIII — **Ck** — Kanawha formation *(shales and sandstones with many seams of coal)*
- XII — **Cs** — Sewell formation *(shales and sandstones with coal seams; generally coarser than Kanawha formation)*

Section

COAL *Coal Mines*
WELL *Wells drilled for oil or gas*
SALT *Salt wells*
STONE *Sandstone quarry*
X *Coal prospects; numbers refer to detailed sections on coal-section sheet*

Known productive formations

- **Cbx** — Coal *(Braxton formation contains coal seams)*
- **Cch** — Coal *(Charleston sandstone contains coal seams)*
- **Ck** — Coal *(Kanawha formation contains many seams of coal)*
- **Cs** — Coal *(Sewell formation contains minor coal seams)*

(Warfield) (Raleigh)

H. M. Wilson, Geographer in charge.
Control by U.S. Coast and Geodetic Survey and L.C. Fletcher.
Topography by Hersey Munroe.
Surveyed in 1889-90 and 1896-97.

Scale $\frac{1}{125000}$

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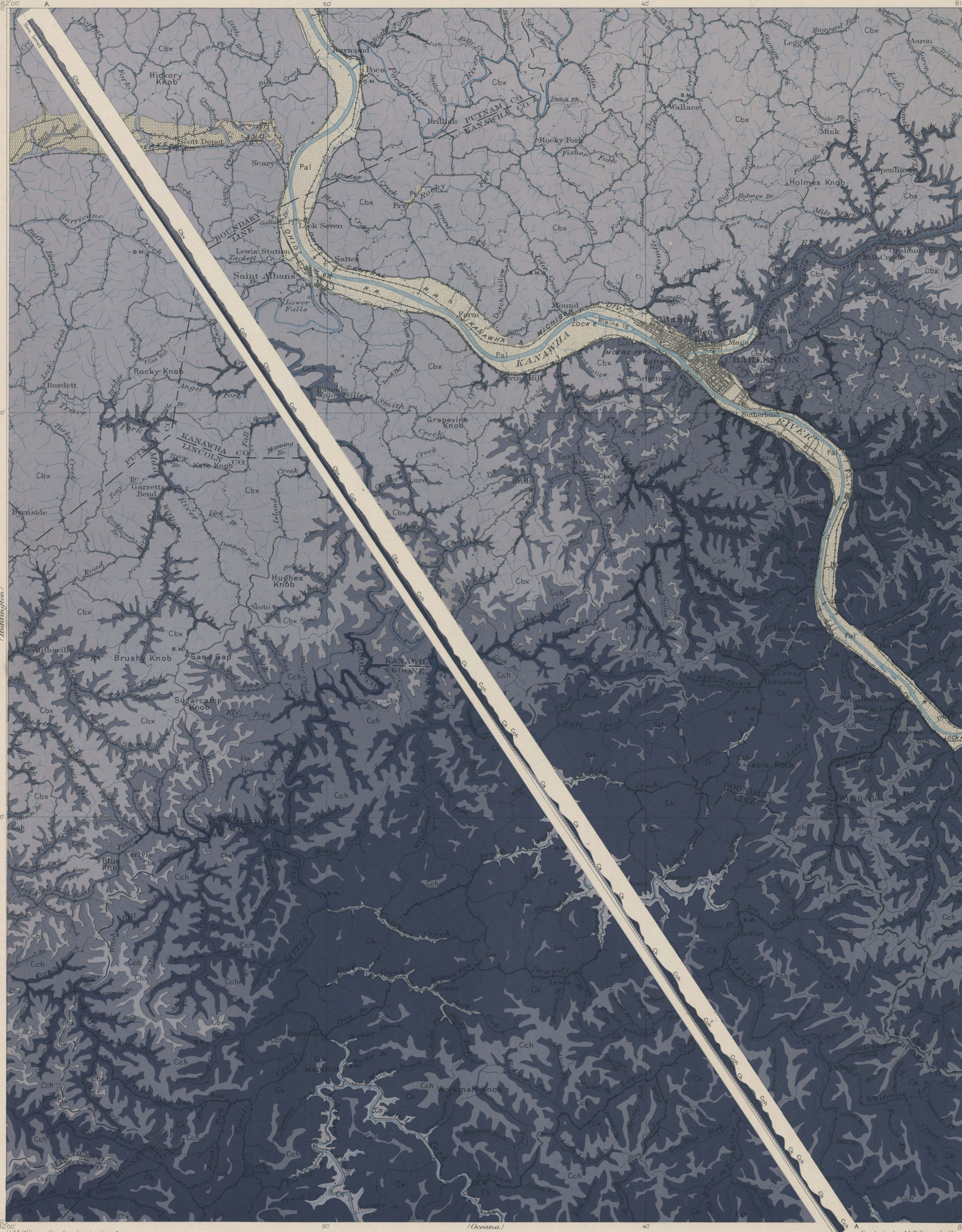
U.S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

STRUCTURE-SECTION SHEET

WEST VIRGINIA
CHARLESTON QUADRANGLE



LEGEND

SURFICIAL ROCKS

SHEET SYMBOL

Pal — Alluvium (flood plain of the Kanawha River)

Pt — Teay formation (gravel, sand, and laminated clay deposited by the ancient Kanawha River)

PLEISTOCENE

SEDIMENTARY ROCKS

SHEET SYMBOL / SECTION SYMBOL

XV, XIV — **Cbx** — Braxton formation (red and green shales, with local developments of sandstone, conglomerate, and seams of coal)

Cch — Charleston sandstone (coarse sandstone or conglomerate frequently interbedded with shale and coal seams)

XIII — **Ck** — Kanawha formation (shales and sandstones with many seams of coal)

XII — **Cs** — Sewell formation (shales and sandstones with coal seams; generally coarser than Kanawha formation)

CARBONIFEROUS

Known productive formations

Cbx — Coal (Braxton formation contains coal seams)

Cch — Coal (Charleston sandstone contains coal seams)

Ck — Coal (Kanawha formation contains many seams of coal)

Cs — Coal (Sewell formation contains minor coal seams)

H. M. Wilson, Geographer in charge.
Control by U.S. Coast and Geodetic Survey and L.C. Fletcher.
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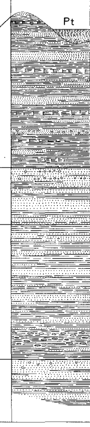
Geology by M. R. Campbell.
Assisted by W. C. Mendenhall, L. C. Glenn, and C. H. White,
Surveyed in 1895, 97, and 98.

COLUMNAR SECTION SHEET

GENERALIZED SECTION FOR THE CHARLESTON QUADRANGLE.

SCALE: 1 INCH = 500 FEET.

Period.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography and Soil.
PLEISTOCENE	Teay formation.	Pt		0-60	Gravel, sand, and finely laminated clay deposited by the ancient Kanawha River. The gravel consists largely of vein quartz and quartzite from the Blue Ridge and of black flint from the eastern side of the coal field.	Forms the floor of Teay Valley and the "Flatwoods" north of Saint Albans. Soil generally good where the clay is preserved.
CARBONIFEROUS	Braxton formation.	Cbx		800+	Chiefly red and green shales and green sandstone, with beds of coarse sandstone and conglomerate at intervals. Thin layers of limestone and calcareous concretions frequently occur in the shales.	Forms the surface of the northwestern third of the quadrangle. The shales produce somewhat rounded contours, but the slopes are frequently terraced by the harder beds of sandstone. Soil moderately productive.
	Charleston sandstone.	Cch		250-400	Coarse sandstone or conglomerate, with occasional bands of shale and seams of coal. Black flint occurs at the base of the formation east of Charleston.	Rugged topography and poor soil.
	Kanawha formation.	Ck		650-1000	Shale and sandstone, with many seams of coal.	Steep slopes along Kanawha and Coal rivers. Shale areas are generally sandy and the soil is thin and poor.
	Sewell formation.	Cs		100+	Sandstone, conglomerate, and shale, the latter containing several seams of workable coal.	Steep slopes and poor soil.

SECTIONS OF WELLS IN THE CHARLESTON QUADRANGLE AND VICINITY.

SCALE: 1 INCH = 500 FEET.

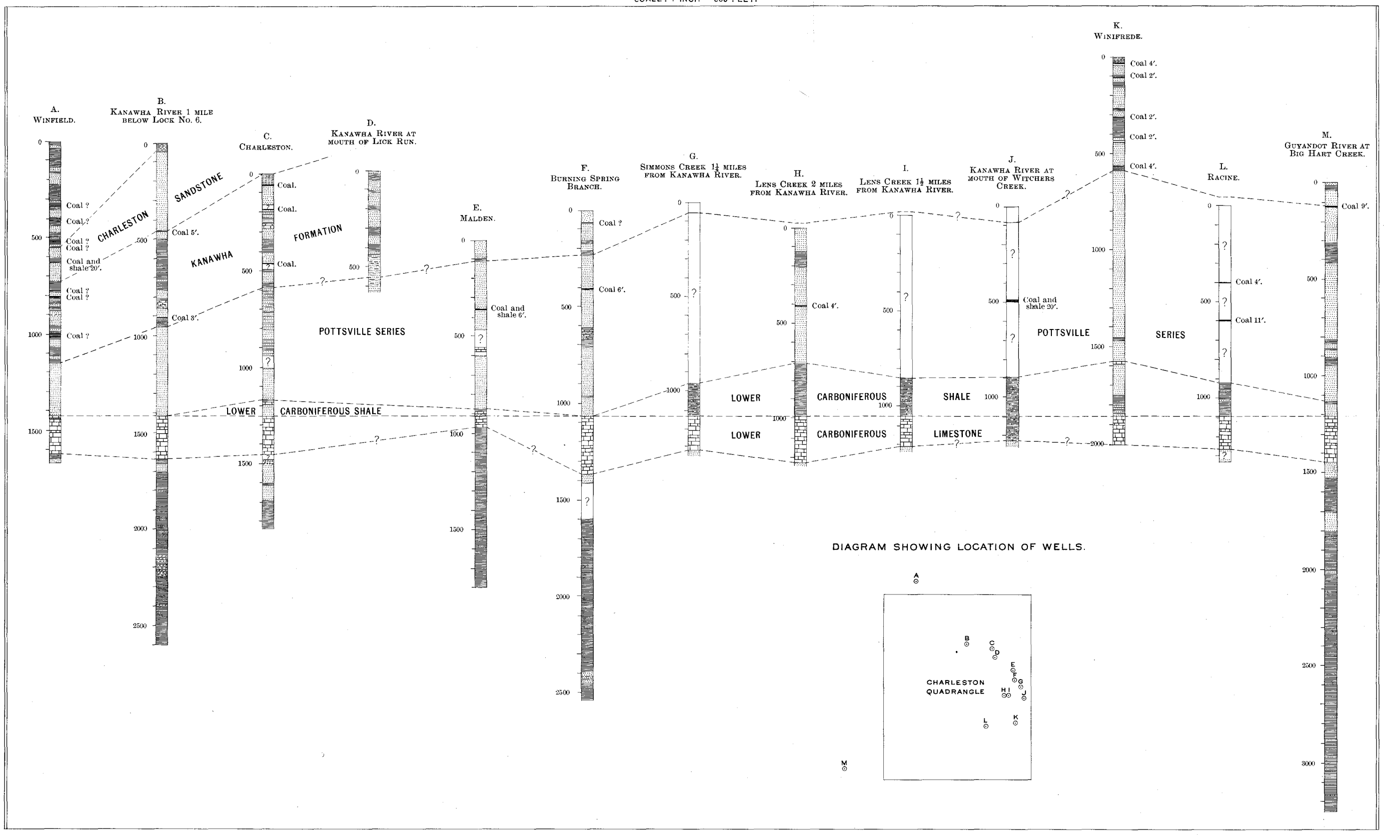


TABLE OF FORMATION NAMES.

Period.	Names and symbols used in this folio.		M. R. Campbell: Huntington Folio, U. S. Geological Survey, 1901.	I. C. White: West Virginia Geological Survey, Vol. I, 1899; and Bulletin 65, U. S. Geological Survey, 1891.	Rogers: The Geology of the Virginias, 1884.
Pleistocene	Teay formation.	Pt	Teay formation.		
Carboniferous	Braxton formation.	Cbx	Braxton formation.	Monongahela River Coal Series.	XV.
	Charleston sandstone.	Cch	Charleston sandstone.	Elk River Series.	XIV.
	Kanawha formation.	Ck	Kanawha formation.	Allegheny River Coal Series.	XIII.
	Sewell formation.	Cs		Pottsville conglomerate.	XII.

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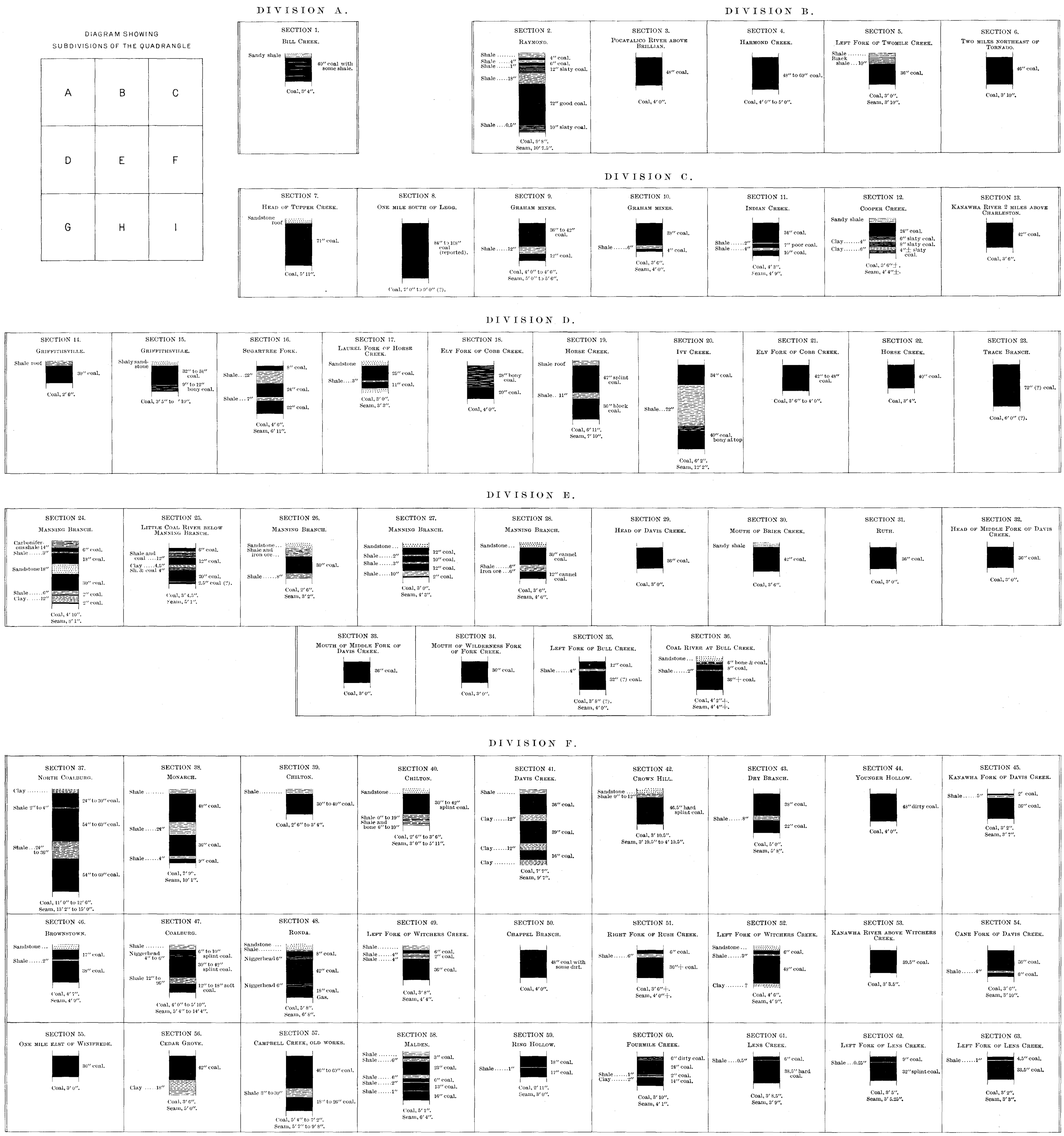
COAL-SECTION SHEET 1

SECTIONS OF COAL SEAMS IN CHARLESTON QUADRANGLE AND VICINITY

(LOCATIONS OF SECTIONS ARE SHOWN ON THE ECONOMIC GEOLOGY SHEET BY NUMBERS)

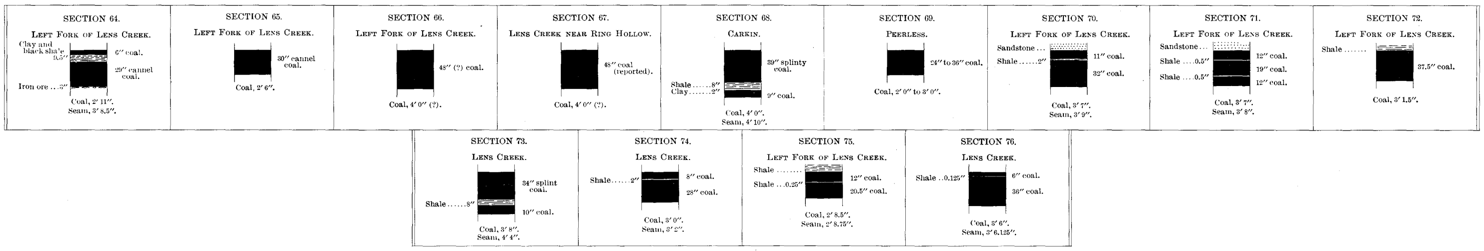
SCALE: 1 INCH = 10 FEET



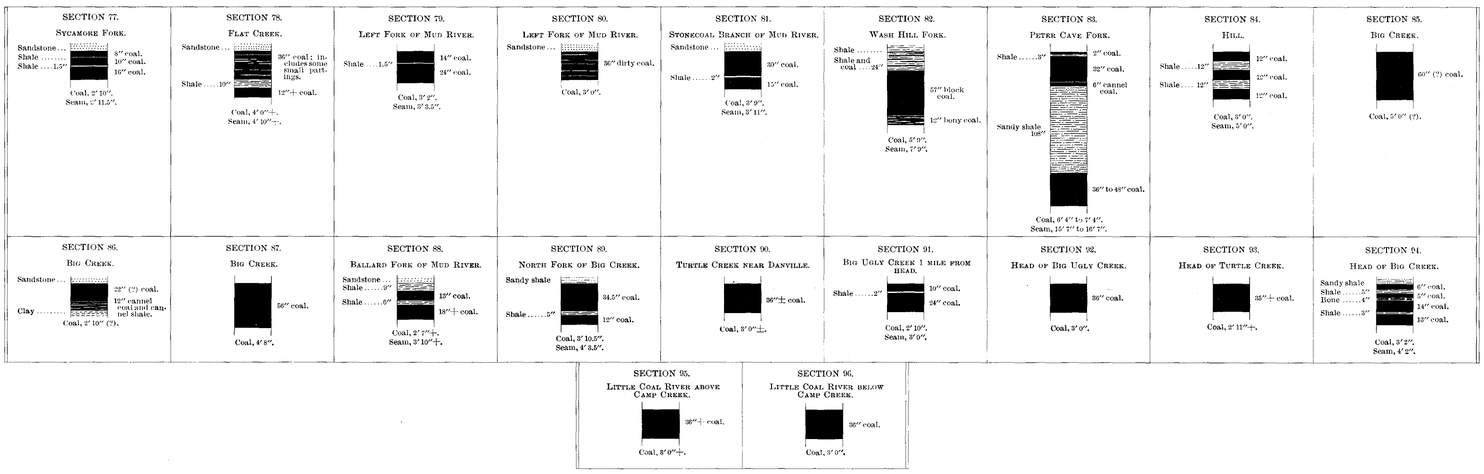
COAL-SECTION SHEET 2

SCALE: 1 INCH = 10 FEET.

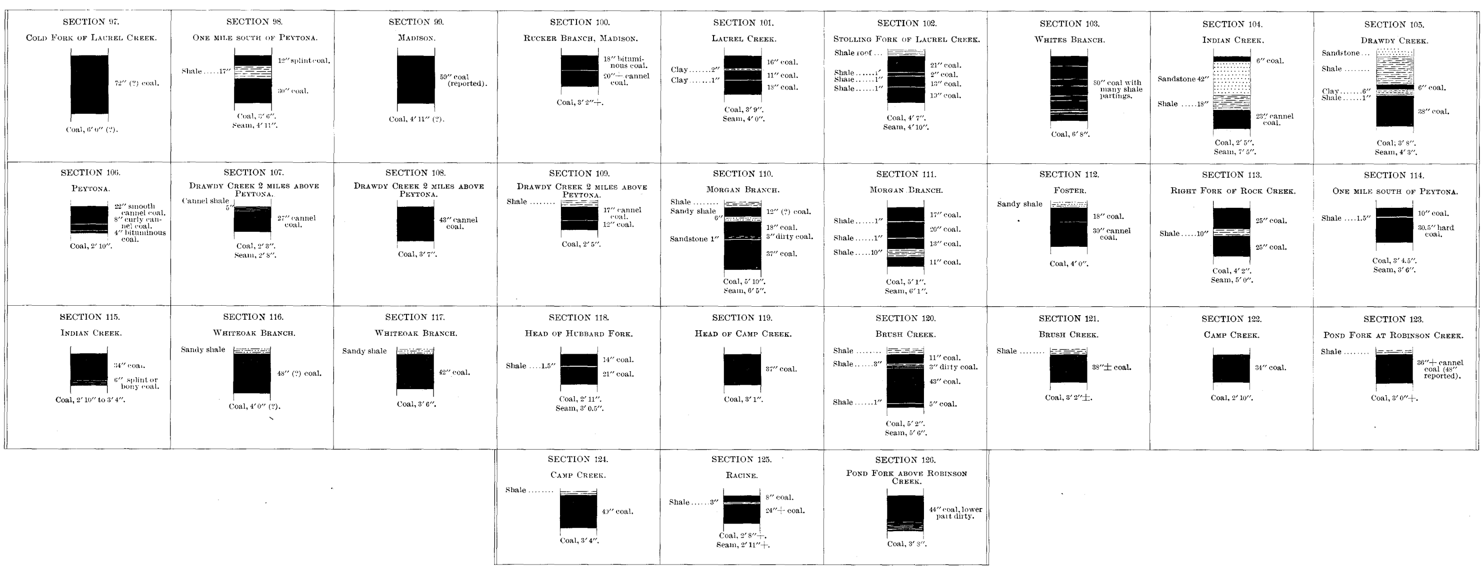
DIVISION F (Continued).



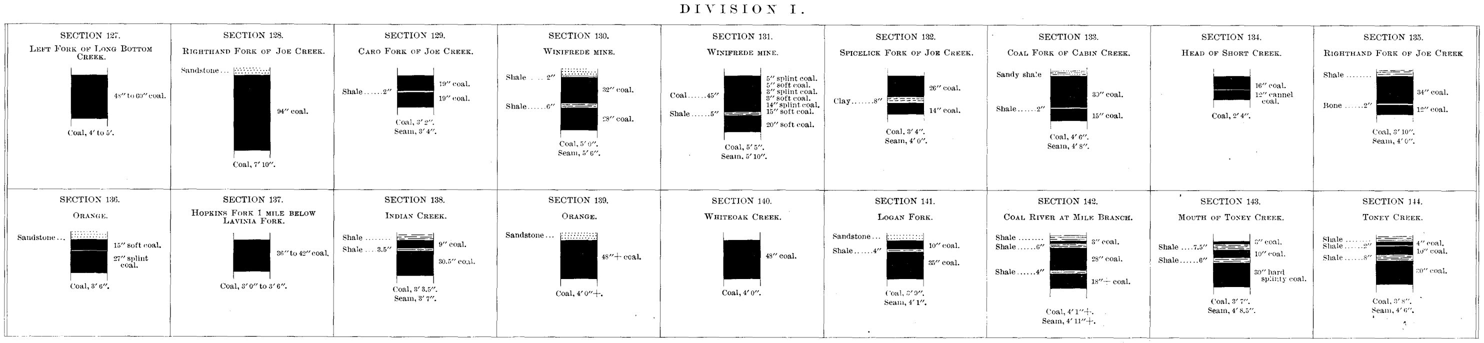
DIVISION G.



DIVISION H.



DIVISION I.



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Washington, D. C.