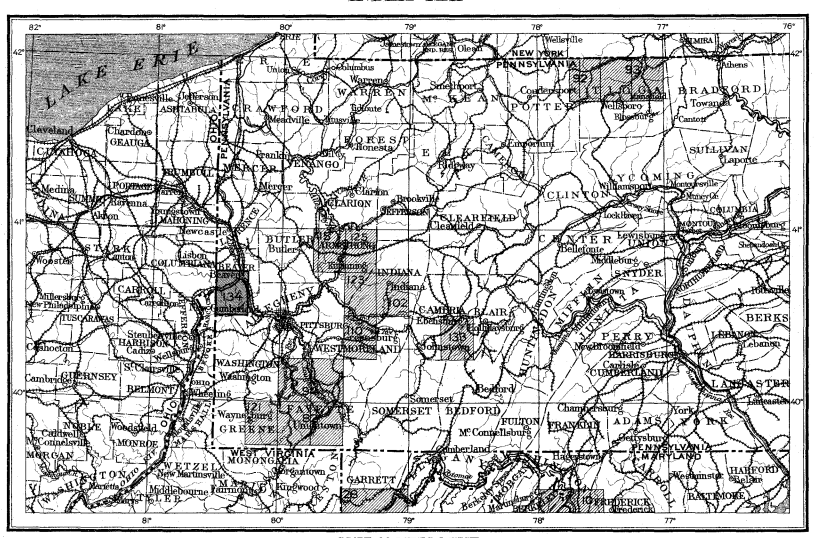
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS
OF THE
UNITED STATES

BEAVER FOLIO
PENNSYLVANIA

INDEX MAP



SCALE: 40 MILES - 1 INCH

BEAVER FOLIO

OTHER PUBLISHED FOLIOS

CONTENTS

WASHINGTON, D. C.
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1905

GEOLOGIC AND TOPOGRAPHIC ATLAS OF UNITED STATES.

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

THE TOPOGRAPHIC MAP.

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

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

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

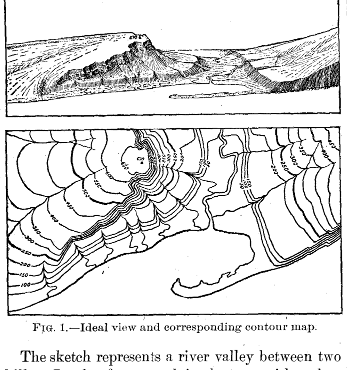

FIG. 1.—Ideal view and corresponding contour map.

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

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

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

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

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

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

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

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

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

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

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

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

THE GEOLOGIC MAPS.

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

KINDS OF ROCKS.

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

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

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

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

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

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

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

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

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

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

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

FORMATIONS.

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

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

AGES OF ROCKS.

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

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

(Continued on third page of cover.)

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

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

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

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

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

Symbols and colors assigned to the rock systems.

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

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

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

SURFACE FORMS.

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

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

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

THE VARIOUS GEOLOGIC SHEETS.

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

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

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

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

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

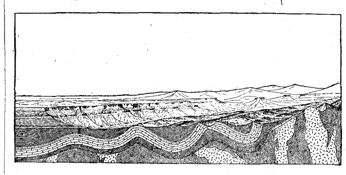

Fig. 2.—Sketch showing a vertical section at the front and a landscape beyond.

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

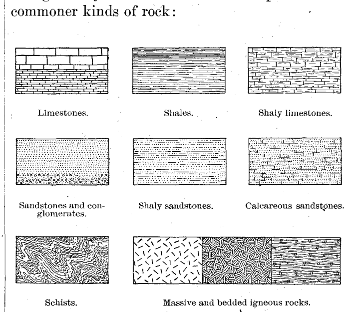

Fig. 3.—Symbols used in sections to represent different kinds of rocks.

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

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

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

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

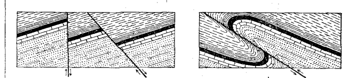

Fig. 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* fault.

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

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

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

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

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

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

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

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

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

CHARLES D. WALCOTT,

Director.

Revised January, 1904.

DESCRIPTION OF THE BEAVER QUADRANGLE.

By Lester H. Woolsey.

INTRODUCTION.

GEOGRAPHIC RELATIONS.

The Beaver quadrangle is located in western Pennsylvania, its western boundary being about 1 mile from the Ohio State line. Its whole area lies in Beaver County, except a triangular portion in the southeast corner, which is in Allegheny County. Ohio River flows through the middle of the quadrangle in a general westerly direction, and near the town of Beaver, which gives its name to the quadrangle, receives from the north its chief tributary, Beaver River. The quadrangle lies between latitude 40° 30′ on the south and 40° 45′ on the north, and between longitude 80° 15′ on the east and 80° 30′ on the west, including one-sixteenth of a square degree of the earth's surface, with an area of about 227 square miles.

PHYSIOGRAPHIC AND GEOLOGIC RELATIONS.

In its physiographic 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 Canada.

PHYSIOGRAPHY OF THE APPALACHIAN PROVINCE.

With respect to the topography and the attitude of the rocks, the Appalachian province may be divided into two nearly equal parts by a line which follows the Allegheny Front throughout Pennsylvania, Maryland, and West Virginia (see fig. 1) and the eastern escarpment of the Cumberland Plateau across Virginia, Tennessee, Georgia, and Alabama. East of this line the rocks are greatly disturbed by faults and folds, while west of it they are less disturbed and lie nearly flat, the few folds which break the regularity of the structure being so broad that they are scarcely appreciable. Immediately east of the dividing line roll the alternating ridges and valleys which have been designated the Greater Appalachian Valley, and still farther east stretches a slightly dissected upland known as the Piedmont Plateau. West of the line extend broad plateaus, unbroken save by a few ridges where minor folds have affected the rocks, but greatly dissected by streams. In contradistinction to the lowlands of the Mississippi Valley on the west and the furrowed highlands of the Appalachian Valley on the east, this part of the province has been called by Powell the Allegheny Plateaus. The Beaver quadrangle lies entirely within this plateau region, which will be described in detail.

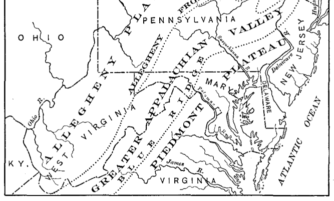

Fig. 1.—Diagram of northern portion of the Appalachian province, showing physiographic divisions.

ALLEGHENY PLATEAUS.

The Allegheny Plateaus are characterized by distinctive types of drainage, surface features, and geologic structure, which are described below.

Drainage. — The Allegheny Plateaus drain almost entirely into Mississippi River, but the northeastern part of the region drains either into the Great Lakes or through the Susquehanna, Delaware, and Hudson into the Atlantic Ocean.

In the northern part of the province the arrangement of the drainage is largely due to former glaciation. Before the Glacial epoch all the streams north of central Kentucky probably flowed northwestward and discharged their waters through the St. Lawrence system (see fig. 2). The encroachment of the great ice sheet closed this northern outlet and new drainage lines were established along the present courses of the streams.

In the southern half of the province not only do the westward-flowing streams drain the Allegheny Plateaus, but many of them rise on the summits of the Blue Ridge and cross the Greater Appalachian Valley as well.

Relief.—The surface of this division of the Appalachian province is composed of a number of plateaus, the highest and most extensive of which lies along the southeastern margin of the division. This feature is very old and consequently is so greatly dissected that its plateau character is not always apparent. It was discovered in northwestern New Jersey by Davis and Wood, who named it the Schooley peneplain, from its good development in the vicinity of Schooley Mountain (Davis, W. M., and Wood, J. W., Proc. Bost. Soc. Nat. Hist., vol. 24, 1889, p. 377). In central Alabama its surface rises from beneath the Cretaceous cover to a height of 500 feet above sea level. From this altitude it gradually ascends to probably 4000 feet at its culminating point in central West Virginia. From this point it descends to 2000 or 2400 feet in northern Pennsylvania and southern New York.

The surface of this topographic feature is best preserved in Alabama and Tennessee, where it constitutes the Cumberland Plateau. North of Tennessee it is difficult to identify, and in northern West Virginia and northern Pennsylvania only a few remnants of high-level land in the hilltops appear to be parts of its original surface.

The surface of this plateau is generally separated from the next lower plateau on the west by a more or less regular westward-facing escarpment. This escarpment is most pronounced in Tennessee, but to the north it diminishes until in the central part of Pennsylvania it merges into a mass of irregular hills and the upper and lower plateaus seem to approach each other.

The lower and younger plateau surface, which is distinctly developed in Tennessee and Kentucky, is known in these States as the Highland Plateau or Lexington Plain. Farther north the relief is less regular and the exact position of the plateau is more difficult to determine. This surface, which has been described by Campbell (Bull. Geol. Soc. America, vol. 14, 1903, pp. 277–296), was named by him the Harrisburg peneplain, because of its excellent development near Harrisburg, Pa., where it is 500 feet above tide. This peneplain appears dome shaped, with an apex in Potter and McKean counties, 2200 feet above sea level, from which its surface slopes in all directions.

The surface features of this plateau are varied, but there is not so much diversity as in the higher plateau. The higher divides and ridges along the Ohio and its tributaries in Pennsylvania, including the surface of the Beaver quadrangle, probably approximate the surface of this peneplain. In the same general region the early stages of a lower, younger, and less extensive plain have been traced. This plain is well developed between Worthington and Allegheny River in Armstrong County and has, therefore, been named by Charles Butts (Geologic Atlas U. S., folio 115) the Worthington peneplain.

Structure.—The structure of the Allegheny Plateau is comparatively simple. The strata lie nearly flat and their regularity is broken only by small faults and low, broad folds which usually have little effect on the general structural features of the region.

The most pronounced fold is a low, broad arch, known as the Cincinnati anticline. The main axis of the fold enters the Allegheny Plateaus from the direction of Chicago, but a minor fold from the western end of Lake Erie joins the major axis near the type locality. From Cincinnati the axis of the anticline passes southward into Kentucky and Tennessee.

This anticline separates the Allegheny Plateaus into two structural basins, which are best known from the coal fields which they contain. The western basin extends far beyond the limit of the province, and contains the Eastern Interior coal field of Illinois, Indiana, and Kentucky. The eastern basin lies entirely within the limits of the Allegheny Plateaus, and is generally known as the Appalachian coal field. The Beaver quadrangle is situated well within the boundaries of the latter field, hence a somewhat detailed description is necessary in order to present a clear idea of the geologic features of the quadrangle.

The Appalachian coal field lies in a broad, flat, canoe-shaped trough. The deepest part of this trough follows a line extending southwestward from Pittsburg across West Virginia to Huntington, on Ohio River. Toward this line the rocks dip from both sides of the trough, and about the canoe-shaped northern end the rocks outcrop in a rudely semicircular line and at all points dip toward the lowest part of the trough.

In Pennsylvania the deepest part of the trough is situated in the southwest corner of the State, and the inclination of the rocks is generally toward that point.

Although the general structure of the region is of this simple character, the eastern limb of the trough is crumpled into a number of parallel wrinkles or folds that make the detailed structure somewhat complicated and break up the regular westward dip of the rocks, so that at first sight it is not apparent. These undulations are similar to the great folds east of the Allegheny Front, except that they are much smaller and have not been broken by faults, as have many of the great folds farther east. These minor folds are a constant feature along the southeastern margin of the basin from central West Virginia to southern New York. Across the northern extremity of the basin the minor folds are developed in large numbers, extending at least halfway across Pennsylvania near its northern boundary. In the southern part of the State there are only six pronounced anticlines, two of these disappearing near the West Virginia line. Farther south the number is less, until on Kanawha River the regular westward dip is interrupted by only one fold of small proportions. In the extreme western part of Pennsylvania, along Ohio River, these folds waste away to faint rolls which can hardly be detected.

ROCKS OF THE APPALACHIAN PROVINCE.

The rocks of the Appalachian province belong to two general classes—crystalline rocks, such as granite and gneiss, and sedimentary rocks, chiefly sandstone, limestone, and shale, and occasionally unconsolidated deposits. The crystalline rocks, which outcrop along the northern and eastern borders of the province, probably underlie the sedimentary rocks and are, therefore, presumably the oldest rocks in the region. The great mass of younger sedimentary rocks which covers the rest of the province is many thousand feet thick and comprises several systems. The lower systems are exposed in the greatly folded and disturbed region east of the Allegheny Front, within the border of crystalline rocks, but toward the interior of the province the most prominent part is the upper portion, which belongs to the Carboniferous system.

CARBONIFEROUS SYSTEM.

The Carboniferous system is divided into two series, the Mississippian below and the Pennsylvanian above. The former is best developed in the Mississippi Valley. In general it is not coal bearing, but in certain parts of the Appalachian region it includes not only limited beds of workable coal, especially in its upper portion, but also strata bearing petroleum and natural gas. The Pennsylvanian series, on the other hand, includes the coal-bearing rocks, or Coal Measures, of the Appalachian coal fields, and is typically developed in Pennsylvania. Both series, therefore, are of eminent importance in western Pennsylvania, and in the Beaver quadrangle both afford valuable economic resources. For purposes of economic as well as scientific study, the geologists of earlier Pennsylvania surveys divided both series into a number of separate formations. Of the Pennsylvanian series the Monongahela, Conemaugh, and Allegheny formations, and a portion of the Pottsville are exposed in the Beaver quadrangle, while the lower part of the Pottsville and beds of the Mississippian series, supposed to represent the Pocono and Mauch Chunk formations, are found in deep wells.

MISSISSIPPIAN SERIES.

Pocono formation.—This name is derived from the Pocono Mountains in eastern Pennsylvania, where the formation is well exposed, resting conformably upon the Catskill red beds (uppermost Devonian). It contains thin coals and fossil plants, and was, therefore, early assigned to the Carboniferous system. In the type region it measures over 1000 feet in thickness and consists largely of gray sandstones. The Catskill at this point is composed chiefly of red and greenish rocks, so that the two formations are easily distinguished by lithologic character. To the west, however, distinction is less certain for the reason that red shales of Catskill character interbed with rocks of Pocono type. The Catskill also seems either to thin to a featheredge or to dovetail with Chemung rocks. While the exact base of the Pocono thus becomes indeterminate to the west, in lithologic character, the top is well marked in most of Pennsylvania by a sandy calcareous member, commonly designated the "siliceous limestone." Where this is absent, the upper limit of the formation also is not well defined. In the Beaver region its limits are indefinite, but it seems to approximate 800 feet in thickness and to lose something of its predominating sandstone character.

Mauch Chunk formation.—This formation overlies the "siliceous limestone" of the Pocono. At Mauch Chunk, from which it is named, it is 2000 feet thick and composed largely of red shale; but west of the type locality both its thickness and character change, for on the Allegheny Front it is composed of 80 feet of heavy sandstones, overlain by 100 feet of red shale. On Chestnut Ridge it resumes its general shaly character. Apparently the thickness of the formation continues to decrease to the west; it is thinly developed in some deep wells of Westmoreland County and north of that area it has been found only sporadically. It has not been identified in the deep wells of the Beaver region and probably is largely or entirely absent beneath the Beaver quadrangle.

PENNSYLVANIAN SERIES.

Pottsville formation.—Since the Mauch Chunk is probably absent in the Beaver quadrangle the Pottsville formation here lies unconformably upon the supposed Pocono. It is named from a town in the anthracite coal field, near which it is 1200 feet thick. In the bituminous coal field its thickness is in places less than 300 feet. In both the anthracite and bituminous fields it generally carries some workable coal, clay, or limestone. In eastern Pennsylvania these beds lie between two heavy conglomeratic members, which there form the top and bottom of the formation; in western Pennsylvania coals occur not only between these members, but between the lower one and a third sandstone bed at the base of the formation. The upper group of coal, clay, and limestone is well developed in Mercer County and has been named the Mercer group; the lower coal is designated Sharon coal because of its good development at Sharon, Mercer County.

The three sandstone members have been named by the Second Geological Survey of Pennsylvania the Homewood, Connoquenessing, and Sharon, respectively. In the Beaver quadrangle the formation, averaging about 250 feet in thickness, seems to include usually two, but sometimes three sandstones, with intermediate coals or shales comparable to the above-mentioned horizons.

Allegheny formation.—The Allegheny overlies the Pottsville conformably. From the fact that most of the workable coal beds in the lower part of the Pennsylvanian series occur within this formation, it was formerly called the Lower Productive measures. More recently it has been referred to as the Allegheny River series, but in this folio it will be spoken of as the Allegheny formation. The name is taken from the river along which it outcrops typically.

In addition to coal seams it contains valuable beds of fire clay and some limestone. It was for the purpose of including the beds of economic importance in one group of rocks, in contradistinction to a barren group above, that the boundary of this formation was early set as the top of the Upper Freeport coal. These economic beds usually occur in groups which are separated by shales and lenticular sandstones of greatly varying character. The Allegheny formation has nearly the same thickness on the Allegheny Front as in the Beaver quadrangle, namely, about 300 feet.

Conemaugh formation.—This formation conformably overlies the Allegheny group, and was named by Rogers from Conemaugh River, along which it is exposed in typical form. This name has been recently revived and applied to this formation in the same sense in which it was used by Rogers. I. C. White called it the Elk River series, from a locality in southern West Virginia; and as it is generally destitute of workable coals it was formerly known as the Lower Barren measures in contradistinction to the Lower Productive measures. In some parts of Pennsylvania, however, it contains coals of a workable thickness. The formation is composed almost wholly of shales and lenticular sandstones, and in order to include only such barren beds, the boundaries of the formation have been arbitrarily set as the top of the Upper Freeport coal and the base of the Pittsburg coal. Between it and the Allegheny formation below or the Monongahela formation above there is no lithologic, fossil, or other stratigraphic break. In the Beaver quadrangle it averages about 520 feet in thickness and is composed chiefly of shale, with two well-marked sandstones, a few worthless coals, and thin limestones.

Monongahela formation.—The Monongahela formation overlies the Conemaugh conformably in the southwestern part of the State. It derives its name from Monongahela River, along which it is well exposed and contains several workable coal beds, the Pittsburg seam being the most valuable and best known. Because of this coal and its other economic beds, this formation is the counterpart of the Lower Productive measures and was therefore formerly called the Upper Productive measures. For this reason only has it been retained as a separate formation, with the Pittsburg coal as the basal member and the top of the Waynesburg coal as the upper limit. Unlike the other Carboniferous formations of this part of the State, it contains a large proportion, over two-thirds, of limestone, while the remainder of the formation is sandy and shaly. The northernmost limit of these rocks near the State line is in the southern portion of Beaver County; consequently only a few outlying patches, including the basal coal and some overlying rocks, are found within the Beaver quadrangle.

QUATERNARY SYSTEM.

The unconsolidated rocks of the Appalachian province belong to two series, the Pleistocene and Recent. The Pleistocene series includes all deposits of the Glacial epoch, whether due to stream or glacial action; the Recent series embraces only those deposits which have been laid down since the end of Glacial time, including present-day flood plains.

These series have not received sufficient general study to make possible the correlation and tracing in detail of formations throughout the province. No general descriptions of formations can therefore be given for the entire province. At many localities, however, the Quaternary deposits have been investigated and local subdivisions of the series made. Those made in the Beaver region are described under the head of "Geology."

PHYSIOGRAPHY.

DRAINAGE.

Present drainage.—The entire quadrangle drains into Ohio River, which cuts it into northern and southern portions. The drainage of the northern portion is mainly through Beaver and Little Beaver rivers. The former, entering the Ohio near Beaver, drains the larger area through Brady and Blockhouse runs. Little Beaver River, lying mostly in Ohio, controls the drainage of the smaller portion through Brush, Bieler, and Island runs. Besides these streams several small runs, such as Upper Dry, Wolf, Sixmile, Fourmile, Twomile, and Crow runs, enter the Ohio and drain a narrow belt along its northern bank.

The drainage of the southern portion is carried by Logtown, Elkhorn, and Moon runs into the Ohio above Monaca. Between Monaca and Georgetown enter the other streams which drain this region—Rag Run, Poorhouse Run, Raccoon Creek and its laterals, Squirrel Run, Haden Run, Peggs Run, and Mill Creek, named in order from east to west. Of these Raccoon Creek is the largest, draining alone two-thirds of that part of the quadrangle south of Ohio River.

Past drainage.—A discussion of this subject can not be limited to the boundaries of a single quadrangle. Beaver River, the main tributary of the Ohio within the Beaver quadrangle, has its source on the northern slope of a region which would naturally drain into Lake Erie. Its headwaters, in fact, are only a score of miles distant from the lake, yet they lead directly away from it and take little part in the drainage of the Erie basin. The same is in general true of Allegheny River. It may be further noticed from a map that the valleys of Beaver River and Ohio River above Beaver form a nearly straight line, and that from this line the Ohio below Beaver takes an almost perpendicular course to the west. This unusual relation of main to lateral stream was recognized many years ago, and more detailed work along the Beaver Valley revealed the fact that the rock floor of the high terraces slopes northward. In view of these facts Carll, Leverett, and others concluded that the Ohio once flowed northward into Lake Erie, through the

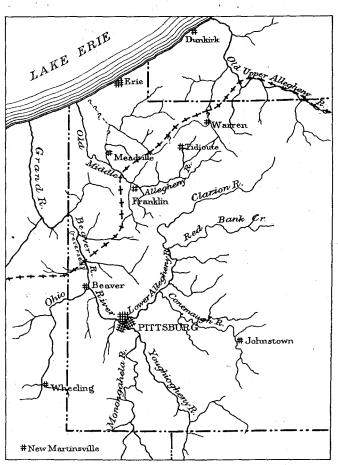

FIG. 2.—Sketch map showing probable pre-Glacial drainage of western Pennsylvania.
The terminal moraine is shown by broken crossed line.
(After Frank Leverett; with addition of terminal moraine.)

Beaver Valley (see fig. 2). For this former stream flowing from the locality of Pittsburg to Lake Erie the name Anabeaver has been suggested, as expressing the idea that it occupied the valley of the Beaver in the reverse direction. Further investigation developed the fact that another stream nearly coincident with the present course of the Ohio between Wheeling and Beaver flowed northeasterly into the Anabeaver. The divide at the head of this stream was then in the vicinity of New Martinsville. These general lines of pre-Glacial drainage of Ohio and Beaver rivers, as well as of the Allegheny, are represented in fig. 2. Recent work in the Beaver quadrangle has disclosed similar changes in the courses of smaller streams. Of these, Raccoon Creek, which is the most interesting, proves to have taken, in pre-Glacial time, an easterly course from the present site of New Sheffield, and to have entered the Ohio 10 miles above its present mouth.

The size and arrangement of the streams which drain a region are prominent factors in both its topographic development and its usefulness to man. The important part which streams have played in shaping the surface features of this quadrangle and the effect which these features have on human affairs will be discussed below.

RELIEF.

The streams of this region have carved the hills and valleys, whose local difference in elevation constitutes the relief of the country. In the following description relief is, for the sake of comparison, reckoned from water level of Ohio River. North of the Ohio the highest land, or main divide, rises about 600 feet above the river, lying in general near the Lisbon road and extending northwestward from Beaver through Fairview and Blackhawk. Spurs from this divide form minor divides between small streams; the most notable of these is the spur lying between North and South branches of Brady Run. The relief of that portion lying between Beaver River and Crow Run is about 550 feet above Ohio River.

The tributaries south of the Ohio inclose an arborescent divide, rising at most 650 feet above the river and extending in general from Kendall northeastward through McCleary, with spurs between laterals of Raccoon Creek and Ohio River. The uncommon length of the branches makes the relief of most of the country west of Raccoon Creek and southwest of the divide about 550 feet, and north of the divide, in the vicinity of Hookstown, 450 feet. The area within the quadrangle east of Raccoon Creek is divided into northern and southern portions by the abandoned valley of Raccoon Creek, in which New Sheffield is situated. The northern section has an extreme relief of 550 feet, but, being deeply dissected, there is very little flat land left. Similar conditions exist south of New Sheffield, at Scottsville, Gringo, and farther south, where the relief is about the same.

HARRISBURG PENEPLAIN.

The high country in this quadrangle, as viewed from the summit of Big Knob, in New Sewickley Township, appears as a nearly featureless plain. Though slight irregularities in detail may be noted, the summits of the hills exhibit a remarkable uniformity of elevation. In such a view the valleys are lost from sight and the surface has the appearance that it had before they were cut. When examined in detail, however, the surface is found to be far from regular, being in almost all parts of the area decidedly hilly. From the topographic map it will be observed that the altitude of these hills ranges, as a rule, from 1200 to 1300 feet above sea level. Along the major streams the summits rise but little over 1200 feet above tide, while throughout the quadrangle they are in general much higher in the western half than in the eastern. The structure also is as a whole possibly more pronounced in the western half than in the eastern. But this seeming relation between relief and structure can not, from the study of so small an area, be stated as a rule. Moreover, in the southern part of the quadrangle the Morgantown sandstone no doubt has a decided effect on the relief. The regularity of the highest upland surface in this quadrangle is not so remarkable as in the Brownsville and Connellsville region. In most of the Beaver area but little land lies above 1200 feet, though in the western part of the quadrangle there are considerable patches whose altitude is higher and regular, cutting across dome and basin alike.

This upland may be regarded as a peneplain, the surface of which at present ranges in altitude from 1180 to 1300 feet and seems to coincide with the Harrisburg peneplain, which has been traced over a large part of the Appalachian region. Its geologic age has not been definitely determined, but observations made in other parts of the province indicate that it was produced in early Tertiary time, probably during the Eocene epoch.

WORTHINGTON PENEPLAIN.

In the Beaver quadrangle a substage of erosion is strongly marked at an altitude of a little over 1100 feet. This is indicated by flat areas in the vicinity of Hookstown and Holt and on many spurs of the upland. These agree so closely in altitude that they seem to mark approximately another base-level of erosion. This is especially evident in the flat spurs along Raccoon Creek and in the areas south of Bellowsville and north of Beaver. The divides between Poorhouse Run and Moon Run and between Twomile Run and Brady Run also stand at altitudes between 1100 and 1120 feet. In the northwest corner of this quadrangle this substage is not marked, because of the Fredericktown anticline, and in the southwest corner its development was prevented by the cap of Morgantown sandstone. This substage has also been recognized in the Kittanning region and has been named in the Kittanning folio the Worthington Peneplain, from the town of that name in Armstrong County.

From the extended development of the peneplain above described it seems highly probable that after the general reduction of the surface of this region to about 1100 feet in early Tertiary time the land was elevated about 150 feet and again remained stationary, allowing the streams to reach a very low grade and to reduce many of the divides at their headwaters nearly to the altitude of the principal valleys. Under favorable conditions the valleys of the principal streams were reduced to comparatively flat surfaces, bordered by gentle slopes leading up by easy stages to the residual uplands farther back. Below the 1100-foot level just described streams have cut steep banks 150 to 200 feet high. Though these banks are steep compared with those above 1100 feet, they are sometimes not so steep as those bordering the modern streams, which are precipitous in many places. In the smaller valleys, near the heads of streams, the bottom of the intermediate slope is not clearly defined, but in the vicinity of the substage development the line is generally apparent.

TERRACES.

The streams of this quadrangle, as will be seen from the topographic map, have in general rather narrow, precipitous valleys, displaying but a small expanse of flood plain. But ancient flood plains, a unique feature of the surface relief, are still preserved as terraces along the larger streams. Among these, Raccoon Creek is the only one which shows both terraces and an abandoned channel.

I. C. White has recognized in the Beaver quadrangle five different terraces, which may be genetically grouped into two classes—cut and built terraces. To the former belong those described below under Parker strath.

Parker strath.—The term strath, adopted from Geikie's Scenery of Scotland, was used in the Kittanning folio to designate the broad floor of an ancient valley. The name is taken from Parker, on Allegheny River, where such a physiographic feature is well preserved at an elevation of 1020 to 1040 feet, or about 200 feet above the present river level. From this point the old valley can be traced by remnants of rock shelves along Allegheny and Ohio rivers to the Beaver quadrangle.

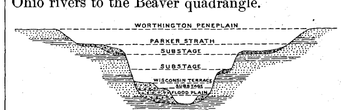

FIG. 3.—Generalized section across Ohio River, showing terraces.

In the Beaver region the Parker strath is represented at several points on both sides of Beaver and Ohio rivers and on Raccoon Creek, by rock shelves covered with silts and gravels (see fig. 3). These are remnants of a former broad valley floor on which the present streams flowed during pre-Glacial time. On the rivers such shelves are best shown at Monaca and Beaver and along the east bank of Beaver River. Between Beaver and Georgetown they are less conspicuous though terrace remnants may be seen at intervals. Just west of Georgetown, however, in the Wellsville quadrangle, there is a rather prominent terrace between Mill and Little Mill creeks. These shelves lie between 900 and 1000 feet above tide. The difference in elevation may be due to short substages of erosion, but it is more probably the result of local inequalities of the old valley bottom. Between Rochester and McDonaldtown a small rock terrace was observed at 840 feet above sea. From this single shelf not much can be deduced; it represents perhaps a valley floor that had been eroded below the level of the Parker strath, and probably indicates a halt or substage in the erosion of the present valley subsequent to the formation of the strath.

On Raccoon Creek similar terrace remnants occur, with a rock floor at an elevation of about 900 feet. The full width of the ancient valley is best shown at New Sheffield, where for a short distance the whole floor is still preserved, free from incisions of modern streams. Remnants of this abandoned valley, which may be traced eastward to the Ohio, mark the former course of Raccoon Creek. This old outlet is fully a mile across at New Sheffield, a width approached at only one other point, north of Independence, where the ancient creek probably flowed alternately on either side of a small rock island, but finally cut down its present course on the east side.

Along the rivers of the quadrangle the width of the Parker strath also varies greatly. From nearly 2 miles at Monaca, 1½ miles at Beaver, and 1 mile on Beaver River, it narrows to a uniform width of one-half mile elsewhere on the Ohio.

Built terraces.—The remaining terraces of this region belong to the class of built terraces. They are distinguished from the cut terraces of the Parker strath by the fact that they lie upon the rock bottom of the present streams, instead of upon a rock shelf whose floor is above water level. The built terraces consist of 90 to 150 feet of unconsolidated, waterworn gravels. Most of them have an elevation approximating 780 feet, and this height no doubt defines the main stage of the river at that time. At two localities, however—Monaca and New Brighton—there are terraces at the 740-foot contour. At the latter place the 780-foot stage, too, is distinctly marked by a corresponding terrace. This leads to the conclusion that the built terraces, perhaps like those of the Parker strath, have undergone a substage of erosion. Small remnants of built terraces also occur in the lower stretch of Raccoon Valley, and still smaller representatives in Brady Run. Along the Ohio the old valley in which these terraces lie included at most places the present river channel, and must have averaged about three-fourths of a mile wide, while along the Beaver it is, within the quadrangle, somewhat narrower.

EFFECT ON HUMAN AFFAIRS.

Topographic features control, in a large measure, man's activities. Level or moderately sloping arable lands invite farming; large streams like the Beaver and Ohio, by cutting strata containing valuable mineral deposits, such as clay and coal, offer facilities for mining operations; broad terraces provide admirable sites for large plants and towns; the even grade of river valleys influences their selection for lines of railway; narrow, swift streams furnish cheap water power for various industries. All these natural advantages are illustrated and utilized in the Beaver quadrangle to a degree so evident from the map that description is unnecessary.

DESCRIPTIVE GEOLOGY.*

STRATIGRAPHY.

All the rocks known in the Beaver quadrangle were deposited by water. The materials of which they are composed were mud, sand, and pebbles, derived from older rocks, or the remains of plants and animals that lived while the strata were being laid down. The oldest of these materials became consolidated into hard and more or less compact masses, usually denoted by the term "rocks;" but the more recent materials, such as river gravels, which are as yet unconsolidated, are also termed "rocks" by geologists. Some limestones were formed, largely from shells of various marine animals, and the beds of coal are the remains of luxuriant vegetation which covered low, swampy shores.

The consolidated rocks exposed at the surface in the quadrangle are entirely of Carboniferous age. There are, however, certain unconsolidated rocks, such as glacial deposits and river gravels, which belong to the Quaternary age. As noted above, the Carboniferous rocks are divided into the Mississippian and Pennsylvanian series. For convenience of economic and scientific study geologists early divided these series into separate formations, based on fossil and lithologic characteristics. In this quadrangle the Mississippian series is represented by rocks supposed to belong to the Pocono formation, and the Pennsylvanian is represented by the Pottsville, Allegheny, Conemaugh, and Monongahela formations. The general characteristics of these formations have already been outlined, and here special attention will be given to various members of local importance. The data concerning Devonian rocks and certain of the Carboniferous not exposed within the quadrangle are derived from records of deep wells and these rocks will be discussed in order from the surface downward.

* A large amount of detailed geologic data collected in the region can not be published in this folio, but will be presented in Bulletin No. 286 of the Survey, now in press, entitled "Economic Geology of the Beaver Quadrangle, Pennsylvania."

Rocks Not Exposed.

POTTSVILLE FORMATION.

In the counties north of Beaver, where the entire section of the Pottsville formation is exposed, I. C. White has found its total thickness to be 250 to 275 feet. In the Beaver quadrangle not much of the formation is exposed, and information regarding its character and thickness as a whole is gathered from logs of deep wells. Complete well records, carefully kept, are exceptional. Mr. F. G. Clapp and the writer have collected about 700 records in Beaver County, of which nearly 300 are of wells within the Beaver quadrangle. Six of this number, together with four complete records from wells outside but near the quadrangle boundaries, have been selected for study and illustration. (See detailed section sheet.) These sections show types of variation in thickness and kinds of rocks encountered at the same horizon. Such apparent variability is due in part to the difficulty of recognizing the kind of rock by the action of the drill while passing through it, and also to the careless manner in which records are kept.

Nevertheless, the Pottsville and its members may be recognized in a more or less general way. With the assumption that its thickness here is nearly the same as farther north—that is, about 250 feet—it seems usually to include two sandstones, between which occur coals and shales. In some places, however, a third lower sandstone appears also to belong to this formation. The shales separating the beds may be overlooked in drilling, and the logs may consequently show different numbers of sandstones. Naming the sandstones Homewood, Connoquenessing, and Sharon, from the top downward, may therefore quite as often be wrong as right. For convenience of description, however, the name Homewood is applied to the topmost bed, Connoquenessing to the one next below, and Sharon to the third, when present.

Well logs from Hanover Township, in the southern part of the quadrangle, show two rather distinct beds of sandstone which may perhaps be correlated with the Homewood and Connoquenessing members of the Pottsville. In the Nelson well, for example, the upper bed has a thickness of 80 feet and the lower one a thickness of 50 feet. Another well shows two beds at this horizon, but they are nearly twice the thickness of those just described, and it is a question whether both belong to the Pottsville. The lower bed, however, seems from stratigraphic relations certainly to belong to the Pottsville, and may indeed represent both Homewood and Connoquenessing, the separating shale being either absent or disregarded in the record. Normal conditions recur in the records of Moon, Independence, and Hopewell townships. For instance, the Vandergrift well indicates two sandstones separated by a black slate or coal member, which perhaps represents the Mercer coal horizon. No coal, however, was noticed in the Johnston well, though the record carefully details three sandstone members.

Records from wells near Georgetown, in the west-central part of the quadrangle—the Poe well, for example—do not distinguish clearly between the members of the Pottsville formation, though this horizon is marked by a sandy member (probably two in the Poe well) 25 to 75 feet thick. Near the mouth of Raccoon Creek, however, the Charles Deens well reveals in this position several distinct sandstone beds separated by dark shale. The upper two, and perhaps three, probably belong to the Pottsville formation, while the dark slates may represent the Pottsville coals. In this well the sandstone members, from the top downward, have a thickness of 50, 75, and 30 feet.

In the northern portion of the quadrangle a line of wells extending from Ohioville through Beaver Falls into New Sewickley Township show the Pottsville formation more or less distinctly. Of these sections, those of wells between Ohioville and Beaver Falls represent the Pottsville, with no additional details, merely as a single or double bed of sandstone about 75 feet thick. But the records from Beaver Falls and farther east show two distinct and well-marked sandstone members. A coal above the upper is probably the Brookville. Between the two sandstones is an interval of about 100 feet, filled in the upper part sometimes with coal or black slate, toward the middle with iron ore or limestone, and elsewhere with shale. The thickness of the sandstone varies from 20 to 50 feet in the case of the Homewood bed, and from 25 to 100 feet in the case of the Connoquenessing.

Nearly all the sections throughout the quadrangle record a shale bed of variable thickness at the base of the formation. Whether this belongs to the Pottsville or to the Pocono can not, without fossil and other stratigraphic evidence, be stated with certainty.

MAUCH CHUNK FORMATION.

Below the Pottsville in some parts of western Pennsylvania occurs the Mauch Chunk formation, containing 150 to 250 feet of red and green shale, with a green, flaggy sandstone and a blue fossiliferous limestone near the base. Where this formation is present it is usually shown in well records, because its red color makes it easily recognized by drillers. But in this quadrangle, as will be seen from the sections here published, no such red beds seem to occur immediately below the Pottsville formation. This seems good evidence, therefore, that the Mauch Chunk is absent. It has also been shown to be absent or patchy farther north, in the Kittanning and Rural Valley quadrangles; and from all the evidence now available it seems to be rather well established that there is an unconformity at the base of the Pottsville formation, at least in this portion of Pennsylvania.

POCONO-CATSKILL ROCKS.

General statement.—The Mauch Chunk being absent, the Pocono and Catskill rocks lie unconformably beneath the Pottsville. In eastern Pennsylvania these rocks are distinguished by lithologic characters, but in the Beaver quadrangle thin red beds are distributed through a considerable thickness of sandstones without a sharp dividing plane between the two. Since the only means of identifying the Catskill formation from well records alone is by the presence of red rocks, it is manifestly impossible to draw a definite boundary between the Catskill and Pocono. For this reason no such line has been attempted and the rocks of both formations are discussed together. In general, however, the Pocono possibly includes all rocks between the top of the Burgoon sandstone and the bottom of the Hundred-foot sand, approximating 800 feet in thickness and containing in all five or six sandstone beds, separated usually by gray or black shales, which at one horizon near the top become red. Certain of the beds—the Burgoon, Berea, and Hundred-foot sandstones, and Red shale—can be easily traced and are important enough both stratigraphically and economically to deserve separate discussion. Besides these economic beds, the Pocono in parts of the Appalachian field contains workable seams of coal, but in Pennsylvania they are not of great value and in the deep wells of the Beaver region are not recognized at all.

The top of the Pocono is well marked throughout much of Pennsylvania by the "siliceous" or Loyalhanna limestone. In no case do the well records of the Beaver region, with the possible exception of the Vandergrift well in Independence Township, show this limestone, but the driller might easily fail to recognize it. If part of the shale member referred to above as possibly belonging to the lower shales of the Pottsville formation is not a part of the Pocono, the latter formation in the Beaver quadrangle, as shown in the well sections, has a heavy sandstone as its topmost member. This sandstone will be called in this folio the Burgoon sandstone, the term being used in the same sense as in the Kittanning folio.

Burgoon sandstone.—This member is named from Burgoon Run in the Kittanning region. North of Kittanning, on Allegheny River, it was found to contain fossils regarded as indicating Pocono age. It is known among drillers of this region as the "Mountain" or "Big Injun" sand, and in a few instances has been called "Glass Rock" or "Murdockville" sand. It is at an average distance of 525 to 600 feet below the Upper Freeport coal. Among drillers it is usually thought to consist of one bed, but a lower accompanying bed may be considered as belonging to it. The thickness of the upper bed, according to the well records is extremely variable, apparently ranging from a knife-edge to 150 feet. Some well logs from the southern part of the quadrangle (for example, that of the Clutter well) give a thickness of even 200 to 300 feet; but other sections and many skeleton records at hand show the usual thickness to be about 75 feet. It is probable, therefore, that in instances of extreme thickness either the records are faulty or this rock is separated from a Pottsville sandstone by an interval too small for the driller to recognize. The lower bed is a thin layer of sandstone accompanying the Burgoon sandstone proper. It is usually about 25 feet thick, rarely increasing to 100 feet, and is separated from the upper bed by 30 to 50 feet of shale. The Burgoon sandstone is characterized by drillers as being gray or white and varying from a fine, close-grained, hard rock to a soft rock of medium grain. It is generally persistent throughout the oil and gas regions of this territory, so far as partial records show, and seems to approach the Pottsville toward the north, perhaps because of the unconformity between the two.

Underlying the Burgoon sandstone and extending about 300 to 350 feet below its top is a series of beds usually composed of shales and shaly sandstones, with here and there a sandstone lens. This series rests upon the Berea sand, and seems to thin somewhat toward the north, bringing the Burgoon and Berea closer together.

Berea sandstone.—The Berea sandstone takes its name from Berea, Ohio. From this locality it has been traced in deep wells across the State into Beaver County, Pa., and the stratum there called Berea is presumably the same as that outcropping at the type locality. The Berea of Ohio has been referred by Newberry and many others to the Carboniferous system, and likewise the supposed equivalent of the Berea in Pennsylvania—the "Corry" sandstone—is pronounced basal Carboniferous by G. H. Girty. The Berea in Beaver County, therefore, is presumably of Carboniferous age and part of the Pocono formation.

It is a white or gray sandstone, varying from a hard, fine-grained rock to one coarse and loose. One section, that of the Economy No. 2 well, records it as a pebbly sandstone. Though somewhat variable in character, it is particularly persistent throughout the drilled portions of the quadrangle, and its position in the formation lies between 825 and 900 feet below the Upper Freeport coal, the most reliable data averaging 880 feet. By a careful study of accurate skeleton records, it appears that the "Smiths Ferry" sand, in Hanover, Greene, and Ohio townships, has been correlated with the Berea sandstone. These records also show a coal at 700 to 750 feet above this sandstone, which is, with little doubt, the Lower or Middle Kittanning.

The Berea sand has a thickness varying from 25 to 50 feet. In some instances, however, the records show 150 feet, though the majority of the best records show the usual thickness. Exceptional thicknesses, as in the Cookson, Beaver Falls, and Calhoun wells, may be due to merging with a lower sandstone. A lower bed indeed occurs, according to good records, at 15 to 30 feet below the Berea proper, and is from 15 to 75 feet thick. It scarcely deserves separate mention and is discussed with the Berea, but its position is relatively that of the Butler gas sand of northern fields.

Below the lower sandstone lentil shales or shaly sandstones, sometimes developing into distinct beds, extend to a well-marked red stratum 100 to 150 feet below the top of the Berea sand. In the McElhaney well this distance seems increased to 200 feet. Conditions are not very clear here, which may be due to wrong identification of the top of the Berea sandstone by drillers. But this interval, as the detailed section sheet shows, certainly increases northward.

Red shale.—The red shale, as shown in well records, occurs in Greene, Hopewell, Hanover, and Moon townships, but the writer has no record of it north of Ohio River, except in the Cookson well, in New Sewickley Township. It has a thickness of 25 to 75 feet and is usually shaly, but in some records it is given as somewhat sandy. It is a transition member of the Pocono-Catskill group, and is probably one of the Waverly shales described by the Ohio Geological Survey, but exactly which one it is difficult to say. On the basis of its red color it might be identified with the Bedford shale above the Cleveland shale, but in view of its distance beneath the Berea it apparently belongs under the Cleveland shale. The Bedford shale in the early Ohio reports was placed in the Carboniferous system, but G. H. Girty, while not certain of its identification, is inclined to believe it Catskill. The red shale, therefore, whether a part of the Bedford shale or below it, may be Catskill. Consequently the division line between the Catskill and Pocono in this region may lie between this red shale and the Berea, but as shown below there is reason for putting it even lower. This member is not the Patton shale of the Kittanning region of northern Butler County, for that bed lies immediately under the Burgoon sandstone, as has been established by carefully correlating a series of well sections extending from the Kittanning region to the Beaver quadrangle. These sections show the red bed absent in northern Butler County, though present in the vicinity of Cove Hollow and Muddy Creek, where wells reported by Carll show the stratum with the same thickness and in the same position as in Beaver County.

A series of shales or shaly sandstones 25 to 70 feet thick separate the bottom of the red shale from the top of the "Hundred-foot sand."

"Hundred-foot sand."—To this member, which is equivalent to the "First Oil sand" of more northern oil regions, the name "Shannopin sand" is locally applied. It is also designated "Hundred-foot," which is a misnomer in this region, since the sand rarely attains a thickness greater than 25 feet. In two cases, however (Johnston well, for example), it is much thicker and begins just under the first red shale. This may also be true in a few other wells whose records give the full thickness of 100 feet. This sandstone, like the others, varies from fine grained to pebbly, and in the southeast corner of the quadrangle seems to be composed of two parts, a hard, siliceous, impervious cap a few inches thick and a lower portion consisting of an open mealy sandstone which contains many white, pink, and yellow pebbles. It is generally present wherever drilling has been carried sufficiently deep.

The Hundred-foot sand is perhaps another transition member, for its base has, by some writers, been considered the top of the Catskill formation. After careful correlation of a measured section on the Allegheny Front with logs of wells extending westward to Allegheny River, Charles Butts has provisionally fixed the base of the Pocono on lithologic grounds, and in the Kittanning region has tentatively considered the top of the first red bed below the Hundred-foot sand as the upper limit of the Catskill formation. This relation is best shown in the Garver and Poe records, but even in these the red bed in question varies 200 feet in its position. An extreme variation of 400 feet is seen in the Cookson well, while other wells show no red beds at all. It is likely that these sections do not represent the same bed, but rather different lenses of the Catskill formation, and this shows the difficulty of drawing adequate boundaries.

So few records at hand show the other Venango sands besides the Hundred-foot that little can be said of them except that they seem generally thin when present, and perhaps some of them are absent. The Deens, Poe, Cookson, Garver, Economy, and other wells show what drillers have recognized as the "Blue Monday," "Gordon," "Boulder," "Third," "Fourth," and "Fifth" sands. The Economy No. 2 well was sunk 700 to 800 feet deeper than the section given, but the record is of no value because poorly kept.

Rocks Exposed.

CARBONIFEROUS SYSTEM.

PENNSYLVANIAN SERIES.

POTTSVILLE FORMATION.

The Pottsville formation lies at the base of the Pennsylvanian series, or true coal-bearing rocks. It is also the lowest formation exposed in the quadrangle, being seen near water level in Beaver and Ohio rivers. Only the topmost bed of the formation, called the Homewood sandstone, comes to the surface in this quadrangle. The exposures, however, are limited, but, though fossil evidence is wanting, it can be distinguished from the succeeding formation by its lithologic character. It is, in general, a gray, hard, massive sandstone, usually coarse to conglomeratic, and often cross-bedded. It is, therefore, evidently a shore deposit. It is visible in the river bed at low water immediately below the lower dam opposite New Brighton. The sandstone here is hard and massive. A short distance below the New Brighton-Beaver Falls toll bridge it rises to 10 feet below the tracks of the Pittsburg and Lake Erie Railroad, and here its contact with the gray sandy shales of the Allegheny formation above is clearly seen. No fossils were observed, but the lithologic break between the two formations is very sharp. At the same level on the opposite river bank, apparently forming the floor of the New Brighton terrace, the same sandstone is traceable to the Pittsburg, Fort Wayne and Chicago Railroad bridge. The rock here has assumed a flaggy, cross-bedded appearance, while retaining its usual hard, coarse character. For some distance below the next dam it is visible at low water in the river bed, as a hard, massive sandstone, containing numerous potholes of various sizes. The unexposed interval between this and the last occurrence may mark the position of the pre-Glacial channel of Beaver River, as previously determined by I. C. White (Second Geol. Survey Pennsylvania, Report Q, p. 15). Above the dam the Homewood sandstone is covered by the pool and is not seen again until it rises above the tracks of the Pennsylvania Railroad near Fetterman. Its contact here with thin shales above is well marked.

On Ohio River the Pottsville is first seen in the bed of the river at low water half a mile above Smiths Ferry. The next occurrence is just outside the quadrangle boundary, in the bed of Little Beaver River at the road bridge near its mouth. From this point it rises rapidly above the creek to the north, but it is not again seen in the quadrangle. At both localities named the rock maintains its massive character and on Little Beaver River huge dislodged blocks of the hard white sandstone lie in the stream bed.

To judge from its customary persistence elsewhere in western Pennsylvania and from records of deep wells within the Beaver quadrangle, there is reason to believe that the Pottsville formation is present beneath the surface throughout this region. Further discussion of its underground extent and character has been given under "Rocks not exposed."

ALLEGHENY FORMATION.

General character and relations.—Resting conformably upon the Pottsville sandstone and reaching to the top of the Upper Freeport coal, the Allegheny formation shows in outcrop as a narrow belt, with its base in most places just below river level, bordering the river hills and extending up the lateral streams until it disappears under cover of the Conemaugh formation. It underlies the whole of the Beaver quadrangle. This is by far the richest group of rocks along upper Ohio River, containing, as it does, most of the workable coals, clays, limestones, and sandstones of central western Pennsylvania. The formation has an average thickness of about 310 feet, but ranges from 280 to 345 feet. The full thickness may be studied in detail along the rivers south of Beaver Falls and east of Smiths Ferry.

The individual beds vary so greatly in character and thickness throughout the quadrangle, as will be seen on the detailed section sheet, that no one section can be regarded as typical of the region. A generalized section, therefore, compiled from various detailed sections which embody many of the variations that occur in the stratigraphy of this formation, is presented on the columnar section sheet in the natural order, from the top downward. This section is of value chiefly as showing the interrelation of the different coals and their underlying clays and as giving the general characteristics of the Allegheny formation. As a whole, it is composed of repeated groups of coal, clay, and limestone, between which occur variable shales and sandstones. The economic members warrant separate descriptions, which are given below.

Brookville coal.—The base of the Allegheny formation is best exposed on Beaver River at the mouth of Brady Run, and above, where section A was measured. This section shows at least 10 feet of gray shale (with 3 feet of fire clay at the top) intervening between the top of the Pottsville and the first coal which is 6 inches thick. Another coal of similar thickness occurs about 5 feet higher up. One or both of these seem to be in the horizon of the Brookville coal, and may represent one seam split by an enlarged parting. At another locality, a short distance above the railroad bridge over Brady Run, the coal is about 5 feet above the Pottsville, which lies near by in the bed of the run. The coal, here about 3 feet thick, dips under Beaver River just below the mouth of Brady Run and rises gently up the Beaver Valley; but in most places, except at section A and on the railroad above New Brighton, it it covered by river deposits.

In general a variable bed of 50 to 60 feet of shale and sandstone separates the Brookville coal from the Clarion coal and clay above (section A). Above New Brighton, however, a stray coal appears, only 20 to 30 feet below the Clarion coal. It is possible that this may represent the Brookville coal, but no decisive evidence on this point was secured. Near the mouth of Island Run, too, a 6-inch coal occurring about 180 feet below the Upper Kittanning coal seems to be in the right position for the Brookville.

Clarion coal.—This bed is exposed within the quadrangle for only a short distance on Beaver River and Brady Run. It dips under the former stream about one-half mile below Bolesville. From this point northward it rises in the same manner as the Brookville coal, being visible east of New Brighton on Blockhouse Run, above the Sherwood pottery; on the railroad above New Brighton; and, according to Hopkins, in Paved Run. It is exposed in the ravine along the railroad south of Beaver Falls (section A), and thence runs under Beaver Falls terrace.

An excellent bed of fire clay in some instances underlies the Clarion coal. On Brady Run, opposite Fallston, the clay has been opened, but the coal above was reported absent. The average thickness of this coal is about 9 inches, when present, but it may be cut out locally by an overlying sandstone, as shown above New Brighton and as is probably the case on Brady Run. Between 15 and 35 feet of clay and dark shales, often bearing iron nodules, intervene between the Clarion coal and the Vanport limestone.

Vanport limestone.—This was formerly called the "Ferriferous limestone," from the fact that in western Pennsylvania and Ohio it is generally overlain by "buhrstone" iron ore, which in the early days was largely used as a source of iron. The name "Ferriferous" has clung to it for over half a century, but in this folio it will be spoken of as the Vanport limestone, the name being taken from a town on Ohio River, on the Cleveland and Pittsburg division of the Pennsylvania Railroad, where it outcrops in typical form. Here it has a face of 19 feet, the extreme thickness known in this quadrangle. It is shown in detail as follows:

Section of Vanport limestone at Vanport.

	Feet.	Inches.
Blue limestone	4	0
Shale	0	4
Blue limestone	8	0
Shale	0	6
Limestone	0	6
Shale	2	2
Hard ferruginous limestone	1	0
Shale	0	6
Fossiliferous limestone	2	0
	19	0

The limestone in general is characterized by its wealth of fossils—including chiefly brachiopods, gasteropods, lamellibranchs, and crinoid stems, with a few cephalopods—and its wavy, shriveled appearance on weathering, called "cone-in-cone" structure. It is very brittle, fractures irregularly, and often has a reddish tinge to its prevailing gray or blue color.

The limestone in this area is extremely variable in thickness, owing to its occurrences in irregular lenses. It is therefore absent in many places, but in others has been observed to range from a few inches to 19 feet. When thick it is usually composed of two or more layers a few feet thick, separated by thinner beds of calcareous shale.

The "buhrstone" iron ore immediately over the limestone is even more fragmental in occurrence. It is but a few inches thick where present, and so far as observed within the quadrangle does not occur in quantities sufficient for economic purposes.

Kittanning sandstone.—Between the Vanport limestone and the first coal above is an interval of 36 to 80 feet, containing at the bottom dark sandy shale and at the top, underneath the Lower Kittanning clay, shaly to heavy sandstone (see detailed section sheet). In some cases, notably on Fourmile and Sixmile runs (section E), the lower sandstone, which may be called the Kittanning sandstone, fills the entire interval. Elsewhere the sandstone gives way, at least in part, to nodular shale, as south of Phillis Island and at West Bridgewater (sections H and C).

Lower Kittanning coal and clay.—The town of Kittanning on Allegheny River, is the type locality of the Kittanning group of three coals. These were named Lower, Middle, and Upper Kittanning by the Second Geological Survey of Pennsylvania. The Lower Kittanning coal in the type locality is characterized by stratigraphic associations which were recognized by the Second Survey in the Beaver region and which, therefore, led to the identification and naming of this coal in the Beaver quadrangle. It is popularly known as the "Sulphur vein" or "Blacksmith vein," and is usually $1\frac{1}{2}$ to $2\frac{1}{2}$ feet thick and very persistent. The fire clay beneath shows an equal persistence throughout the quadrangle, and varies in thickness from 2 to 11 feet. As a whole the clay is everywhere of a drab-gray color when fresh and creamy white on long exposure. Locally the lower part seems to grade insensibly into a sandy clay below, which may acquire a hard shaly character.

This coal and the accompanying clay are found above and on both sides of Ohio and Beaver rivers. Its elevation varies from about 180 feet above low water at New Brighton to water level at Freedom, just below which town it disappears under the river; and from about 150 feet above the river at the State line it undulates gently eastward, being 60 feet above at Phillis Island, 50 feet at Industry, 100 feet at Vanport, and 80 feet at Beaver. It is not, however, actually exposed throughout this distance, but is covered by broad, flat gravel terraces at Rochester, northeast of New Brighton, at Beaver, at Monaca, west of Bellowsville, east of Industry, at Shippingport, north of Phillis Island, and at Georgetown. Elsewhere it is exposed along the more precipitous banks of the rivers and on some of their tributaries. Of the latter Brady Run, though not the largest tributary, uncovers the greatest extent—about 4 miles along the South Branch. North Branch of Brady Run exposes this coal for an almost equal distance.

Blockhouse Run exposes the Lower Kittanning for only a mile east of New Brighton. On Raccoon Creek, however, this horizon, though covered at several points by stream gravels, remains above water level to the mouth of Fishpot Run, about $2\frac{1}{2}$ miles from the Ohio. For a distance of a mile and a half a broad synclinal trough lies with its axis tangential to the eastern bends of Raccoon

Creek. Owing to this condition, strata which are not exposed in the eastern bends may be exposed on the western bank, and therefore a lower coal, tentatively mapped as Lower Kittanning, is found in outcrop for a greater distance on the west side of the Creek than on the east side. If this coal is truly identified as the Lower Kittanning, then the Darlington coal appears to be absent, possibly being cut out by the Freeport sandstone. The conclusion to refer the exposures under consideration to the Lower Kittanning horizon is based on the fact that there is an unusually large interval between this coal and the Upper Freeport coal, as shown in section G. On the other hand, the sandstone closely overlying the coal suggests from stratigraphic associations that this may be the Darlington coal, and on that supposition the interval between the Lower Kittanning and Upper Freeport is still greater, agreeing with the interval found opposite Phillis Island (section H). Excavations beneath these coals to determine the presence or absence of the characteristic Lower Kittanning clay bed would prove their identity. Near Georgetown the same horizon is exposed for about a mile from the river on both Mill and Little Mill creeks. On the opposite side of the Ohio the Lower Kittanning coal extends several miles up Little Beaver River; on Island Run, a tributary, it disappears just outside the western boundary of the quadrangle. This interpretation of the coal on Island Run differs from that of the Second Geological Survey of Pennsylvania, whose map shows it as disappearing under Island Run at the State line. The map of the Second Survey also shows the Lower Kittanning horizon as disappearing at the Lisbon road on Twomile Run, but to the present writer it seems on this stream to seek the cover of the Beaver terrace, about half a mile above Vanport.

Between the Lower Kittanning and the next higher coal are dark shales carrying iron nodules. The shales range from 20 to 45 feet in thickness, averaging 35 feet, and seem to thin out to the west, for the smallest measurement, 20 feet, was obtained on Mill and Little Mill creeks. They form one of the best defined stratigraphic landmarks in this region, for they always occur, at least to some extent, between these two coals. (See detailed section sheet.) In a few cases, however (section D, opposite Beaver), the upper part of the shales assumes a sandy character, appearing as sandy, gnarly clay or shaly sandstone. The first coal above this characteristic shale bed has been a source of much confusion to geologists, who have described it under the various names, Upper Kittanning, Darlington, and Middle Kittanning.

Middle Kittanning (Darlington?) coal.—This coal was recognized by the First Survey of Pennsylvania, but was considered too insignificant to name. Therefore I. C. White, finding it well developed in Beaver County and the first seam above the Lower Kittanning, naturally termed it Upper Kittanning. He also correlated it with a cannel bed associated with plant remains at Darlington, which name he used in local descriptions. Later, when the Second Survey covered the Kittanning region, Platt recognized the Kittanning group of three coals, Upper, Middle, and Lower, and thereupon White lowered the Darlington seam of Beaver County to the rank of Middle Kittanning (White, I. C., Stratig. of bit. coal fields, etc.: Bull. U. S. Geol. Survey No. 65, 1891, p. 166). The name Middle Kittanning will therefore be retained in this folio. The third coal, however, described by White under the name "local coal," will now naturally become equivalent to the Upper Kittanning of the type region, and will here be treated under that name.

The Middle Kittanning horizon, being but a short distance above the Lower Kittanning, has practically the same geographic distribution in the quadrangle as the latter; and the coal, which is generally known at Smiths Ferry as the "block vein," together with the clay underneath, is very persistent throughout the quadrangle. The fire clay has an average thickness of about 4 feet, but rarely reaches 10 or 15 feet. It is in general impure, becoming clouded on the weathered surface by iron oxides and in places containing more or less sand. The coal varies in thickness from 4 to 26 inches. In two instances, however—at Dam No. 5 and Industry (section G)—the coal bed has been cut out by an overlying sandstone, in a manner similar to the instance cited under Clarion coal. In section G, at the proper position in the sandstone for the Middle Kittanning coal, bituminous layers are interbedded with sand. This condition seems to indicate a contemporaneous deposition of coal and sandstone. At Dam No. 5, however, the coal-making material either was not deposited or was deposited and subsequently eroded by a stream whose channel was later filled with sand.

Back of Freedom, in the run which enters the Ohio just above town, is exposed an unconformity between the Darlington coal and the Freeport sandstone above. The coal here is very thin and interbedded with laminated sandstone; below is the characteristic nodular shale, the whole dipping about 20° SE., while a heavy sandstone in horizontal strata lies above.

On Brush Run the identification of the Middle Kittanning coal is doubtful. The lowest seam there opened was apparently taken by I. C. White for the Lower Freeport and the bed 30 feet above it for the Upper Freeport. That the latter identification was probably incorrect is shown under "Upper Kittanning coal," and it follows for the same reasons that the former is also to be doubted. Though the coal in question can hardly be the Lower Freeport, but is doubtless some lower coal, it can not be definitely stated that it is the Middle Kittanning. It is at least 135 feet and at most 150 feet below the Upper Freeport, as identified by the present survey. It would seem, therefore, to correspond to the Middle Kittanning but for the fact that the Lower Kittanning has not been found in this valley within the quadrangle. It may possibly, therefore, belong to the Lower Kittanning horizon, but if so its distance below the Upper Freeport is less than it is anywhere else in the quadrangle.

Upper Kittanning coal.—The Upper Kittanning coal—the "local coal" described by I. C. White—is the first coal above the Darlington and is separated from it by an interval of 13 to 30 feet. In a few cases, however, the interval may reach 45 feet, but 27 feet may be taken as an average. In general this interval seems to vary inversely as the thickness of the Freeport sandstone, for where the sandstone is well developed its base seems lower than usual, in some instances possibly replacing the coal, in others filling swamps in which coal has been formed. It seems, then, that if the coal occurring at this varying distance above the Darlington belongs to the same horizon, it must have been deposited on a very uneven surface. The interval between this coal and the Darlington in every case where exposed, except in Dry Run, where a sandstone fills the upper part of the interval, is occupied by shales, occasionally nodular. (See detailed section sheet.) The coal as seen from the rest of the sections is in the majority of cases absent; when present it varies from 2 to 18 inches in thickness, and is peculiar in that it seldom carries an underclay.

On Brush Run there is some confusion regarding the position of this coal. A coal 4 feet thick, locally called the "dirt vein," has been opened on several properties and seems to be the one taken by I. C. White for the Upper Freeport (Second Geol. Survey Pennsylvania, Rept. Q, p. 242). White's identification seems incorrect, for adjoining this locality and having all the stratigraphic relations of the Upper Freeport is a coal bed which White himself called Upper Freeport and which corresponds to a coal lying about 110 feet above the "dirt vein." Indeed this coal bed lies not over 160 feet above the true Lower Kittanning on Brush Creek just beyond the margin of the quadrangle, so that it seems, considering the average interval between Upper Freeport and Lower Kittanning to be 177 feet, that this coal could not be lower than the Upper Freeport. Moreover, 50 feet above the "dirt vein" is another coal with all the stratigraphic relations of the Lower Freeport coal. The "dirt vein," therefore, would seem to correspond to the Upper Kittanning coal, or, as has been shown under "Middle Kittanning coal," possibly to the latter.

Freeport sandstone.—At about the horizon of the Upper Kittanning coal the prominent sandy part of the Allegheny formation, as found in this region, first makes its appearance as lenticular bodies of heavy sandstone. The lowest member, which has been named the Freeport sandstone, when massive is usually a moderately coarse, micaceous, gray rock, often exhibiting false bedding. In places, as on and near Elkhorn Run, at Smiths Ferry, and on Island Run, it lies immediately above or near the Darlington coal. It has, indeed, been observed to begin below the Darlington coal in a few places, as at Dam No. 5 and Industry (section G), and even to lie unconformably upon upturned strata at one point back of Freedom. At other localities, however, it rests conformably upon or is separated by shales from the Upper Kittanning coal, notably in the vicinity of Merrill and Cooks Ferry (sections E, I). If the sandstone at all these points of observation is the same bed, which is open to doubt, the evidence indicates local irregularities at the base of the Freeport sandstone, which should not be unexpected, from the manner of its deposition. A study of the sections will, on the other hand, show that the sandstone is often absent altogether, being replaced by shales. The edge of the lenticular bodies thus formed is exposed somewhat as follows: South and east of a line drawn from the forks of Blockhouse Run through New Brighton to Fallston, thence making a loop about Rochester and Monaca through Dam No. 5, and crossing the river opposite Beaver on a westward course through Vanport. From Vanport westward along the river the lens thickens, attaining just below Industry a maximum of 140 feet of unbroken sandstone (section G). Thence it thins westward to the edge of the quadrangle, where it has a thickness of about 50 or 75 feet (section I), while on the north toward Island Run it has thinned still more (section J). South of Vanport it becomes attenuated between Bellowsville and Raccoon Creek. It soon thickens, however, as the creek is followed southward, and disappears beneath water level not far above Gums Run. The spur of another lens coming in from the west exposes its edge 2½ miles above Fallston on Brady Run, and then taking a southeasterly course toward Fallston turns sharply to the south about half a mile west of the village. As seen in the sections, especially those near Vanport, the lower part of the Freeport sandstone is irregularly interbedded with shale, often for as much as 50 feet (section E).

Lower Freeport coal.—This horizon is properly above the Freeport sandstone, when the latter is present. When the sandstone is absent the Lower Freeport is separated from the Darlington coal by a shaly interval averaging 82 feet. This interval varies from 60 to 85 feet, as shown on Brady Run and west of Monaca (sections B and D), and perhaps in two or three cases reaches 105 feet. The shales sometimes become sandy (section E), and infrequently carry iron nodules, as at West Bridgewater (section C). The Lower Freeport coal is not at all persistent throughout the quadrangle, and so far as observed seems to be lacking in about half of the exposures. Where the Freeport sandstone attains its greatest thickness, as at Industry, this coal is reciprocally absent. This causative relation may be explained by the supposition that the thick sandstone formed, in the surrounding Carboniferous swamp where coal-making plants grew, an island whereon very little or no carbonaceous material was deposited. Where the Lower Freeport coal is absent in other cases the cause is not so evident, though in some instances its absence may possibly be due to erosion of the coal-producing vegetation by heavy currents which deposited sand instead. The sand so laid down may correspond to the Butler sandstone described later. For these reasons the horizon was in places difficult to determine closely and in one locality it was still more complicated, as shown in the following section measured on North Branch of Brady Run:

Section of Lower Freeport coal and associated rocks on North Branch of Brady Run.

	Feet.	Inches.
Coal and shale	1	0
Concealed	8	0
Sandstone	8	0
Bituminous shale	0	4

It is a question whether the highest or lowest bed in this section represents the Lower Freeport coal. Indeed, by supposing the intervening rocks to be a lenticular delta in the Carboniferous marsh, such as sometimes occurred in the Upper Freeport period, both beds may be assigned to the same horizon.

Both the Lower Freeport coal and the fire clay beneath are locally of paper thinness; the coal ranges up to nearly 3 feet (averaging 12 inches), and the clay to 5 feet. The latter on weathered exposure is usually light colored and plastic, but in certain localities it contains iron, which gives it a streaked, brownish appearance. In places a limestone underlies the fire clay, as will be seen in the sections. The limestone is very impure, being usually a hard, fine-grained, nonfossiliferous rock of buff color. Locally it is ferruginous. A thickness of 1 to 9 feet was observed, but the average is about 4 feet. Like the coals, its occurrence is lenticular and therefore it can not be regarded as a key rock for purposes of identifying the associated coal. Though in places somewhat stratified, it is practically a solid bed.

The horizon of this coal, being much above the Lower Kittanning, has therefore a somewhat more extended and sinuous line of outcrop, but practically the same distribution. In addition, however should be mentioned the valleys heading in the northwest corner of the quadrangle, such as Brush and Bieler runs, which, though not uncovering the Lower Kittanning coal within this area, do expose the Lower Freeport coal. Here, indeed, this coal and limestone show the best development.

An interval averaging 60 feet separates the Lower Freeport coal from the Upper Freeport coal, which forms the top of the Allegheny formation. This interval, whose extreme variation is from 38 to 85 feet, seems to be usually occupied in the upper part by shale and in the lower part by sandstone.

Butler sandstone.—The basal bed of the interval just mentioned, called the Butler sandstone, is like the Freeport sandstone, lenticular in form, varying in thickness from a knife-edge to about 40 feet. (See detailed section sheet.) In character it is a very compact, coarse, yellowish-white rock, which attains its most typical development along Beaver River and lower Brady Run. On thinning it gives way to shales which take up the whole lower part of the interval.

Above the sandstone, when present, or in any case toward the middle of the interval, usually occur about 20 feet of dark shales bearing iron nodules, and above these lie generally drab caky shales. Either of these two kinds of shales may be absent or replaced by sandy beds (section F).

Upper Freeport coal.—This horizon averages about 177 feet above the Lower Kittanning coal, and has, therefore, a line of outcrop which lies near the top of the irregular river bluffs, and in general follows the undulations of the coal last mentioned. For example, from an elevation of 350 feet above Beaver River at Beaver Falls, it dips southward to 260 feet above the Ohio at Rochester, 190 feet at Crow Run, and thence gradually lower toward Pittsburg. From 240 feet above river level at Beaver it undulates westward, being 270 feet at Vanport, 250 feet at Merrill, 295 feet 1 mile below Merrill, 235 feet at Industry and Phillis Island, rising to 290 feet at the State line. Occurring at a greater elevation than the Lower Kittanning, the Upper Freeport horizon has a correspondingly greater exposure on all the lateral streams. It dips under Raccoon Creek near Independence, under Mill Creek near Hookstown, under Upper Dry and Island runs near Ohioville, and under South Branch of Brady Run about a mile east of Blackhawk. (See structure and economic geology map.)

This coal with its underlying fire clay and limestone is, along Allegheny River, a most valuable horizon, but within this quadrangle the group shows extreme variability (see detailed section sheet), the coal being absent in about one-third of the exposures and the limestone absent in about one-half. The coal, with a maximum thickness of 4 or 5 feet and an average of about 2 feet, reaches its best development, as the geologic map shows, in Greene and Raccoon and portions of Industry, Ohio, and South Beaver townships; elsewhere, so far as observed, it thins in general to proportions at present not profitably minable. This is due to three causes—irregularities in the roof of the coal, unevenness of the floor, and unusually thick partings. The first of these generally occurs wherever the Mahoning sandstone is well developed and rests upon the coal. It seems that the coal-making material was more or less eroded by currents carrying the coarse sand of the Mahoning, and the sand may have been deposited in the erosional hollows. Fragments of bituminous matter and pebbles of clay perhaps derived from the clay beneath the coal are sometimes seen mingled with sand and pebbles at the base of the Mahoning member. Thus the Upper Freeport coal may change in thickness in surprisingly short distances. One instance was observed where it thinned from 5 feet to 8 inches within a distance of 200 feet.

Unevenness of the surface on which coal-making material was deposited may have caused shoals or islands, on which little or no such material gathered. This condition, however, is not so easily demonstrated with this coal as with the Lower Freeport.

Partings are in places unusually well developed and apparently split the benches of coal several feet apart. The following sections are examples:

Sections of Upper Freeport coal and accompanying rocks on Raccoon Creek.

	Feet.	Inches.
SPUR OPPOSITE MOUTH OF FRAMES RUN.		
Coal	0	6
Dark clay	0	3
Dark shale	10	0
Coal	1	0
FISHPOT RUN.		
Coal	3	0
Sandstone	4	0
Coal	0	6
SQUIRREL RUN.		
Shale and coal seams	1	0
Clay	3	0
Shale	8	0
Coal	1	8
Shale	1	8
Coal	1	7

On Island Run also this horizon is marked by a series of interbedded coal and sandstone layers, each only a few inches thick, but the whole aggregating 10 feet.

It seems, therefore, that the formation of the Upper Freeport coal seam was in places interrupted by the deposition of clay, shale, or sandstone. Such occurrences possibly represent delta deposits which were formed in the luxuriant swamps of Carboniferous time and which afterwards became covered with vegetation. Thus a single coal-making period, as that of the Upper Freeport, may now be represented by two separate beds both really belonging to the same horizon.

While the coal is many times absent and often represented by papery layers of bituminous matter, the underlying clay is much more persistent. It is generally present in thicknesses of 3 to 5 feet, and frequently is of pale-bluish color and excellent appearance. In many places, however, it is pregnant with nodules of iron which stain it and render it of little value. The limestone is usually impure, being buff colored and ferruginous, often brecciated, and generally nonfossiliferous. Occasionally, however, the bed occurs as a bluish rock of pure quality. Owing to its lenticular mode of occurrence, which is common with the limestones of this region, it may or may not be present. Wherever found it averages 4 feet in thickness, with extremes of 6 to 7 feet observed on branches of Brush Creek and Upper Dry Run, and, though at times somewhat stratified and rather nodular, it is practically a solid bed.

The stratigraphic succession about the Upper Freeport coal is in most places sufficient for its identification, but in portions of South Beaver and Ohio townships exposures are poor and the associations are abnormal. In South Beaver Township the horizon is difficult to determine, owing to the presence of two limestones, one above and one below a lenticular coal, which is probably the Upper Freeport. In addition the Mahoning sandstone, which forms the basal member of the overlying formation, has a variable development. It is evident, then, that in a section where the Mahoning sandstone is shaly and the coal absent an accompanying limestone does not much aid in identifying the position of the Upper Freeport horizon. This is the case on portions of Brady Run in this township. One ravine in particular exposes 1 foot of limestone, 25 feet above a cannel-like slate which might ordinarily be taken for the Upper Freeport coal, and a few feet above the limestone a coarse sandstone resembling the Mahoning. The Upper Freeport horizon probably belongs above this limestone, for the reason that here the sandstone, probably the Mahoning, cuts out the Upper Freeport coal, which is reported present beneath the same sandstone a few hundred feet distant. In Ohio Township the same difficulty in identifying this horizon is encountered on the Lisbon road, where a blue brecciated limestone a foot or more thick outcrops at several points. The Mahoning sandstone here has a thin development and no coal was seen, hence the horizon in question may, so far as other stratigraphic evidence goes, lie either above or below the limestone described. From the fact, however, that the yellow and red caky shale which persists above the Mahoning sandstone is well represented on the highway 30 or 40 feet above this limestone, there is little doubt that the horizon is at least very near the latter. The presence, moreover, of Ames limestone on the knob at the road forks farther east, together with records of wells on the Turner and Moore farms near this road, confirms this conclusion. But since no coal was observed and other stratigraphic evidence here is wanting, the position of the Upper Freeport horizon can not be definitely determined.

The Second Geological Survey of Pennsylvania mapped the Upper Freeport coal on Island Run as crossing the Ohioville-Blackhawk road, but the present survey shows that it goes under Island Run a considerable distance west of the road. The Second Survey also mapped this coal as outcropping on Bieler Run almost in the town of Blackhawk, but this exposure has been found to lie about 1 mile west of Blackhawk.

CONEMAUGH FORMATION.

General character and relations.—The Conemaugh formation, lying conformably upon the Allegheny, varies somewhat in thickness, but its range is not great and 520 feet may be regarded as the average. It is composed largely of shale, but carries two beds of sandstone, the Mahoning near the base and the Morgantown somewhat above the middle of the formation. These in places are massive and have had some influence in shaping the topography of the region. The shales are somewhat variegated, but the prevailing tint is green or gray. The formation has infrequent limestones, three insignificant beds being known in this territory. The most important of these is the green fossiliferous limestone, known as the Ames limestone, that usually occurs about 30 feet below the Morgantown sandstone. Of coal there is here and there a small seam which attains workable proportions over limited areas.

The base of the formation, which rests upon the Upper Freeport coal, follows the undulations of that bed, as described above. In brief, from 350 feet above Beaver River, at the northern margin of the quadrangle, it dips southward toward Pittsburg, being 190 feet above the Ohio near Hog Island; westward on the Ohio it undulates between 240 feet above water at Beaver and 290 feet at the State line. The river bluffs do not rise much above this line, and therefore catch only the lower portion of the Conemaugh formation; but notwithstanding the fact that the rocks in general rise to the northwest, this formation covers practically all of the high country within this quadrangle, except the few isolated spots of Pittsburg coal in the southeast corner.

Owing to a lack of good exposures but few detailed measured sections of any length were obtained for this formation. By very carefully compiling fragmental sections throughout the formation, and checking by level the whole thickness of the formation, the generalized section on the columnar section sheet has been obtained. This section is believed to show, as nearly as practicable, the interrelation and thicknesses of the most important members, which are described in detail below.

Mahoning sandstone.—This sandstone forms the basal member of the formation and overlies the Upper Freeport coal of the Allegheny. It is usually yellowish to brown in color and coarse grained. In fact, it often assumes a conglomeratic character, generally marked by the presence of white quartz pebbles (section E). This character seems rather persistent on the north side of Ohio River, from Phillis Island westward, in the vicinity of Dam No 6, and east and north of the town of Freedom. At Dam No. 6 and near Freedom the pebbly sandstone contains at its base rounded nodules of clay, and papery bituminous fragments representing the Upper Freeport coal.

The sandstone and coal are usually in direct contact, but occasionally they are separated by a few feet, rarely as much as 15 feet, of shale. These general relations may be more specifically studied on the detailed section sheet.

When the Mahoning sandstone lies immediately over the Upper Freeport coal the contact, as noted above, is often very irregular and in places, as on Island Run, the sandstone and coal are interbedded. In many other cases, as shown in a number of the sections, the Mahoning sandstone rests directly upon the clay beneath the Upper Freeport coal, which then is absent. In such instances fragments of bituminous matter and pebbles of clay, as noted above, are mingled with the coarse sand at the base of the Mahoning. These irregularities at the base of the Mahoning sandstone include cases where not only the coal but the clay also is absent. A notable instance occurs on the north branch of Blockhouse Run, where owing to a 20-foot irregularity in the base of the sandstone, nothing of the Upper Freeport group was observed except perhaps a thin limestone. A similar phenomenon was observed on Raccoon Creek, near Independence, where the Mahoning sandstone first appears above water level. At this point the massive sandstone rises abruptly to 20 feet above water, cutting across green shales and finally grading into shaly sandstone. This is not only underlain by clay and limestone nodules, probably remnants of either the Upper Freeport horizon or a local limestone above (section C), but overlain by the yellow and red clay shale presently to be described.

Within the Mahoning sandstone member, about 30 feet above the Upper Freeport coal, are found not infrequently from 1 to 8 feet of limestone, as shown in section C. This limestone is extremely variable in occurrence, its habit being that of small lenses. It is locally developed east of Rochester, west of Monaca, perhaps on the Lisbon road 2 miles east of Blackhawk, and on the Smiths Ferry road just south of Ohioville. It has also been found, though somewhat thinner, on the north side of Brady Run, in South Beaver Township. The limestone at Monaca and along the Lisbon road is of light-blue color, but at Rochester it has buff, ferruginous phases. In most occurrences it seems to be more or less brecciated.

In general the Mahoning sandstone caps the river bluffs and walls many of the lateral streams; thus it follows up the course of Raccoon Creek, disappearing at Independence in the manner described above, and forms the bluffs of Mill Creek, underlying the village of Hookstown as a heavy sandstone. The sandstone is not, however, everywhere persistent, being frequently replaced wholly or in part by softer material, as south of Phillis Island, on Brady Run, at Bellowsville, below Independence, and at West Bridgewater (section C). On the north side of the river, however, it changes from a massive rock near Smiths Ferry to a shaly sandstone, becoming heavy toward the base, south of Ohioville; but it becomes thicker and more massive north of Ohioville, on Island and Bieler runs. On Brady Run it is not typically exposed, but where observed it varies from a thin, shaly, insignificant member to a coarse massive sandstone. On Blockhouse Run and the east bank of Beaver River it is a thin but coarse, heavy bed. Not only the character but the thickness also shows extreme variability, ranging from a feather-edge to 50 feet. The Mahoning sandstone grades at the top into shales which continue upward about 55 feet to the Brush Creek coal.

Brush Creek coal.—The Brush Creek horizon varies in its distance above the Upper Freeport from 75 feet on Brady Run to 110 feet at Hookstown, averaging 95 feet (section G). The lower part of this interval—indeed, often the whole of it—is occupied by yellow and red caky shale, which is a very strong stratigraphic key rock in this quadrangle, for it seems to be almost everywhere present at 50 to 60 feet above the Upper Freeport coal. The Brush Creek coal, usually observed merely as a small blossom, is of little importance. At only one place, on Brady Run, does it attain any considerable thickness. Here it reaches a maximum of 20 inches of coal, separated into two benches by a seam of slate.

The horizon of the Brush Creek coal is most conspicuously marked by 20 feet of dark shale, which is almost always present and very often carries at the top a black-blue limestone about a foot thick. This has been called the Brush Creek limestone, and, according to the Second Survey reports, is usually fossiliferous, but in this region it carries few if any distinct species. This limestone is well exposed on the Beaver road just north of Twomile Run and in Ohio and Greene townships.

Between the Brush Creek limestone and the Bakerstown coal an interval averaging 75 feet is occupied by sandy shales and laminated sandstones. This sandy member is the attenuated southern edge of a heavy conglomeratic sandstone of Butler County which bears the name Buffalo sandstone. In the reports of the First Survey this stratum was included in the Mahoning sandstone, but since the two strata are usually distinct and seldom merge into the same mass, the term Mahoning, as applied to the upper member, was properly considered by the Second Survey to be a misnomer.

Bakerstown coal.—This horizon lies about 190 to 200 feet above the Upper Freeport coal, and derives its name from Bakerstown, Allegheny County, Pa., where it has been considerably mined. In the Beaver quadrangle, however, its occurrence is very irregular. It is best developed in a 2- to 7-foot bed of cannel and bituminous coal on the river bank one mile east of Georgetown, where it was mined about 1875. Here "the upper half is an impure cannel, while the lower half approaches more nearly to semicannel" (Second Geol. Survey Pennsylvania, Rept. K, p. 348), and it is reported that oil was distilled from this coal before the discovery of petroleum. When visited by the writer the opening was caved in and no observations could be made. There are other openings near this horizon on coals which may be confused with the Bakerstown seam. On the lower part of Little Service Run, for example, an old opening was observed on a coal about 60 feet below the Ames limestone, but no idea of its thickness could be obtained. This coal apparently is not in the proper position for the Bakerstown seam. Near the head of Frames Run a similar cannel-like coal has been opened about 40 feet below the Ames limestone and 20 feet below a ferruginous, nonfossiliferous limestone. This, too, not being low enough in the series, is very probably not an occurrence of the Bakerstown coal. Aside from these localities the writer does not know that any coal which might be taken for the Bakerstown seam has been opened in the Beaver quadrangle, and the only other evidences of its presence are infrequent coal blossoms at this horizon on the country roads.

Variegated red and green shales of an argillaceous and occasionally nodular character extend for about 70 feet above the Bakerstown coal. The red band of outcrop is a conspicuous feature on farms and along roads where it occurs, and for long distances in the southern part of the quadrangle may be seen just below the outcrop of the Ames limestone.

Above the shales and close below the Ames limestone a thin coal bed is infrequently seen. It has been observed at only two or three places in the quadrangle, being best exposed along the hill road a mile and a half north of Hookstown. When present it seems generally to be quite pure, but unfortunately has a thickness of about 1 foot and can not be worked. It seems, moreover, to be frequently absent, and on the whole is never of any importance. I. C. White has tentatively correlated this coal with the Platt coal of Somerset County and has, therefore, provisionally called it by that name in Beaver County. The name was taken by the Second Survey from a mine operated by a Mr. Platt, near Berlin, Somerset County, where the bed was 7 feet thick and was locally known as the "Platt vein."

Ames limestone.—This limestone was named from Ames Township, Athens County, Ohio, by Andrews, who first described it at this locality in 1873 (Ohio Geol. Survey, vol. 1, pt. 1, p. 235). In previous reports of Pennsylvania it has been called the "Green Crinoidal" or "Berlin" limestone. This stratum may be taken as the approximate middle of the Conemaugh formation, for in this district it averages 290 feet above the Upper Freeport coal and 230 feet below the Pittsburg seam. These intervals in reality vary from 20 to 25 feet in either direction. It is the most persistent member of the formation and is present not only throughout the southern half of the quadrangle, but throughout several counties in Pennsylvania and Ohio. In not more than six localities where it has been diligently sought has it proved to be absent. It seems to retain its peculiar lithologic character wherever known, and can therefore always be readily recognized. Stevenson, in his report on the Greene and Washington district (Second Geol. Survey Pennsylvania, Rept. K, p. 80), describes it as "dark bluish or greenish gray, tough," and breaking with a "granular surface, much resembling that of a coarse sandstone." The weathered rock has a peculiarly rough aspect, due to small protuberances of crinoid stems, with which it is crowded. The general effect, in fact, is very far from the usual appearance of a limestone. Besides the multitude of crinoidal fragments, the other fossils are chiefly brachiopods and gasteropods.

North of Ohio River in the Beaver quadrangle this limestone is scarcely seen, occurring only as the cap of a small knob on the Lisbon road 3½ miles east of Blackhawk, and as eight small patches on the summits of the river hills west of Industry. South of the Ohio the patches become larger and more numerous, as at McCleary, Green Garden, and Bunker Hill, until finally as it dips lower, it makes one continuous though irregular blanket over the southern third of the quadrangle. Its ordinary occurrence is that of a single bed, but in a few instances there seem to be two separate beds of this limestone. This is notably so on the western edge of the quadrangle, opposite Hookstown, where the interval between the two beds is 31 to 35 feet.

The persistent bed has a thickness varying from 1½ to 6 feet, but averaging about 3 feet. Typical exposures may be seen at Harshaville, south of Green Garden, on Bunker Hill, and north of Hookstown.

Because of its easily recognized character and its marked persistence it has been chosen, like the Upper Freeport coal, as a key rock on which to base observations in determining the structure of the southern part of this quadrangle.

Variegated shale or shaly limestone, overlain by a thin coal seam, occupies a 40-foot interval between the Ames limestone and the base of the Morgantown sandstone above. The coal is probably the Elk Lick coal, definitely located by Franklin Platt at 30 or 40 feet above the Ames limestone. The name Elk Lick was first used by Lesley in 1840, for a coal in this stratigraphic position which was then opened on Elk Lick Creek, Somerset County, Pa. (Second Geol. Survey Pennsylvania, Rept. H3, pp. xxxiii, 60). This coal, like others of the Conemaugh formation, is not persistent and generally is of no importance. It is reported, however, to have been mined years ago at two localities in the Beaver quadrangle, namely, in the northwestern part of Independence Township, about half a mile south of Service Creek, and in Greene Township on the Georgetown-Shippingport road. At the former place it is said to have been 1 to 3 feet thick and of excellent quality for smiths' use, but of such varied dimensions that mining was unprofitable. At the latter locality the coal, being only 2 feet thick, was not long exploited. Along this same road, however, due north of Hookstown, it may now be seen as a 1-foot coal 20 feet above the Ames limestone. This interval expands to 32 feet on Trampmill Run, where the bed is a cannel, a foot or more thick. Elsewhere in the quadrangle it has occasionally been observed as a mere blossom under the Morgantown sandstone. In some instances the Morgantown sandstone seems to lie very close to the Ames sandstone, if not in direct contact with it. In that case the coal and shale just described are absent, but in the far southern part of the quadrangle sandstone débris slumps down and covers everything, so that the exact succession of beds is difficult to ascertain.

Morgantown sandstone.—This member was named by Stevenson some years since from Morgantown, W. Va., where it has a marked development and is extensively exploited for building purposes. It is probably the most persistent sandstone in the region, being generally found throughout the southwestern part of the State wherever its horizon is exposed. In this quadrangle the Morgantown sandstone is practically unknown in the northern half and is best developed in the southern third. It varies in character from a coarse, massive sandstone, which is, however, rather soft, to a thin-bedded rock, and sometimes appears to be replaced by sandy shale; but it is generally represented by a heavy sandstone which has a decided effect on the topography of the region. It is responsible especially for many of the high, flat-topped hills at Green Garden, Scottsville, and within or near the boundaries of Hanover Township. The bed is perhaps of sufficient importance here to deserve mapping, but because of its proximity to the outcrop of the Ames limestone, it has not been shown on the geologic map. It has an average thickness of 65 feet within the quadrangle, and its top is about 125 feet below the Pittsburg coal. Southeast of Mechanicsburg, in the vicinity of Harshaville, and toward the western edge of the quadrangle it often attains a thickness of 100 feet. Whether this is all Morgantown sandstone, or whether a sandy member exists above it in this locality and covers by its débris an interval of shale between the two, can not be determined. Though farther north it thins to 65 feet or less, on the east side of Raccoon Creek it maintains a thickness of about 80 feet. To the south across the line in Allegheny County it again thins so considerably that in some cases it is nearly replaced by a shaly or very thin-bedded sandstone.

The rocks for 90 feet above the Morgantown sandstone can not be definitely described because of their variability and poor exposures. In general, however, red shales overlie the sandstone, and are followed by shaly sandstones and shales. White and Stevenson, who covered a much larger area than the Beaver quadrangle, were able to give this series in greater detail. For instance, the limestone reported by White as occurring 87 feet beneath the Pittsburg coal (Second Geol. Survey Pennsylvania, Rept. Q, p. 26) was not observed within the quadrangle. The lowest limestone found outcrops 40 feet below the coal, and the best exposures, which are on the highways between Gringo and the southern edge of the quadrangle, do not show a greater thickness than 2 feet. Above this bed, and separated from it by 15 feet of shale, is a more persistent limestone. It was observed 25 feet beneath the Pittsburg coal wherever the latter occurs within the quadrangle. Good measurements of it were not obtainable, but a thickness of 6 inches was seen, and it is said to attain 2 feet. White has given the name Pittsburg limestone to these beds. Above them a shale interval of 25 feet forms the top of the Conemaugh formation.

MONONGAHELA FORMATION.

The Monongahela formation rests conformably upon the Conemaugh beds. It contains most of the coal seams of the upper part of the Pennsylvanian series, and certainly a large proportion of the limestone. Only a few hilltops in the southeast corner of the quadrangle are high enough to include the Pittsburg coal and some of the overlying sediments at the base of this formation.

Pittsburg coal.—Though this coal has but small extent in this quadrangle, it has been opened in all the knobs that contain it from Gringo south to the quadrangle line. At the time of visit, however, none of the openings were available for coal measurements. Reports show the coal to be between 5 and 6 feet thick, including shale partings, but its quality is said to be inferior because of the leaching action of surface waters.

The overlying rocks have an area still more restricted than the coal itself, and a thickness of not more than 50 feet. In this distance outcrops disclose merely remnants of the Pittsburg sandstone. This member is a yellowish-brown, heavy, or thin-bedded sandstone, grading downward perhaps into a shaly base. The best exposures may be found along roadsides in the far southeast corner of the quadrangle.

QUATERNARY SYSTEM.

Introduction.—After the deposition of the highest rocks of Carboniferous age this region was elevated above sea level, and since that time it has been continuously a land area. Throughout this long period rock material has been removed from the surface, and, except during the Glacial epoch, no deposition but the present flood plains has taken place. The Glacial epoch marks the formation of the high and low terraces of this region, and the material then deposited is found to-day either occupying the rock shelves, which represent parts of the old floors of former valleys, or lying in broad gravel terraces in present valleys. These deposits may be divided, according to age, into three general classes: (1) Kansan or possibly pre-Kansan, including the Carmichaels formation and the earlier glacial gravel; (2) Wisconsin, comprising lower terrace gravels and later glacial gravel, and (3) Recent, embracing the present-day flood plains. The first two are each composed genetically of two kinds of material—that of local derivation and that of glacial origin, all belonging to the Pleistocene series; the third is composed of both and falls within the Recent series.

PLEISTOCENE SERIES.

CARMICHAELS FORMATION.

The deposits composing the Carmichaels formation are differentiated both by the absence of material of glacial derivation and by their age. As should be expected, therefore, they occur on remnants of ancient valley bottoms not likely to carry glacial wash. Such ancient valleys occur along streams heading south of Ohio River and flowing northward into it. Of the many streams in the quadrangle which fill these conditions Raccoon Creek is the only one exhibiting remnants of an ancient valley. The filling of this valley is, with the exception noted below, entirely of local derivation and therefore bears the criterion of origin which distinguishes the Carmichaels formation. Deposits having a similar origin have been found on terraces along Monongahela River, where they have a typical exposure near Carmichaels (Geologic Atlas U. S., folios 82 and 94). The Carmichaels terraces have in addition been found to merge into similar ones on Ohio River, and were so traced to Raccoon Creek, thus establishing their contemporaneity. Being, therefore, of the same origin and age, the ancient filling of the old Raccoon Valley has been assigned to the Carmichaels formation. No vertical section of the material was open for study, and the following description is mostly gathered from surface appearances.

The deposits are composed at the top chiefly of sand, in which are distributed waterworn pebbles of local rocks, generally sandstones. On some of the shelves a light-yellowish silt replaces part of the sand. On the New Sheffield plain sand is particularly abundant and apparently deep, and here were observed the largest native pebbles, a few inches in diameter. It is reported that clay underlies the sand in this locality, and it would, therefore, seem that the deposit is stratified, as it should naturally be. The thickness of the material is at this point estimated to average 20 or 30 feet, and probably the same depth of deposit covers another spur 2 miles southwest of Bocktown. Elsewhere no good exposures showing the depth of the filling were seen.

Upon deposits having this general character an occasional pebble of crystalline rock was found. This would at first appear to throw doubt on the characteristic local origin of the deposits, but these pebbles, as shown later, are very fresh in appearance, and are believed to have been laid down subsequent to the deposition of the main filling. Their presence, therefore, may not impair the local character of the main filling and so with the reservation which their presence naturally requires, the main deposit is still considered as belonging to the Carmichaels formation. This deposit, though possibly not exactly synchronous, belongs no doubt in the same period with the terraces of similar elevation along the rivers, which will be discussed next.

EARLIER GLACIAL GRAVEL (KANSAN OR PRE-KANSAN).

The earlier glacial gravel is characterized by rocks of distant origin, such as granite, gneiss, etc., having deeply weathered surfaces. The extent of this deposit on the uplands in Beaver County is not well known because a covering of later drift obliterates it. But it is believed that no old glacial gravels exist in the Beaver quadrangle save in the Parker strath. Concerning such deposits along Beaver and Ohio rivers, Leverett, in his chapter on "The Oldest Drift (Kansan or Pre-Kansan)" (Mon. U. S. Geol. Survey, vol. 41, 1902, pp. 250–252) says:

> The gravel [in the lower Beaver Valley] is capped by a silt of pale color, 4 or 5 feet in depth, which may prove to be the equivalent of the Iowan loess. Its color is strikingly in contrast with that of the gravel below it. The gravel is weather stained at top and seems to be much older than the silt.
>
> As a rule the gravel is poorly assorted and contains much sand, and in places has a clayey matrix. The largest Canadian rocks noted are nearly a foot in diameter. They are deeply weathered, the red granites being usually very rotten. A few striated stones were found in the north part of Beaver Falls, and these have been weathered deeply since the striation occurred. The proportion of Canadian rocks here, as on the Allegheny, is much smaller in this gravel than in the gravel of Wisconsin age that lies in the valley below the level of this rock shelf.
>
> Below Beaver Falls . . . a clayey deposit appears on the rock shelf, in which stones of various sizes are embedded.
>
> It being uncertain whether the old drift is exposed on the uplands bordering the Beaver Valley outside the limits of the Wisconsin, the relations of the terrace to the drift can not be clearly shown. As yet it is not known whether the border of the old drift lies some distance back beneath the Wisconsin or is practically identical with it in position. There is, however, no question that this gravel, like the similar gravel on the lower Allegheny and Ohio, has been derived from the old drift, and was deposited long before the Wisconsin stage of glaciation . . .
>
> Near the mouth of the Beaver extensive terrace remnants appear. One back of Phillipsburg [now Monaca], south of the Ohio River, carries gravel at an altitude about 310 feet above the river, or 975 feet [aneroid measurement] above tide, and one back of Beaver, on the north side, has a gravel deposit at equally high altitude. This was well exposed by trenches for waterworks at the time the writer last visited that locality (in 1898) and several granite blocks, ranging in size from nearly a foot in diameter down to small pebbles, were found in the material thrown from the trenches. The depth of the gravel is about 15 feet, and it is capped by a reddish sandy clay 8 or 10 feet in depth. These terrace remnants at Phillipsburg and Beaver apparently stand at about the original level of the gravel fillings. There is another terrace in that vicinity [whose top is] 75 to 100 feet lower, which carries an old glacial gravel, but it was probably cut down from the level of the high terrace. This is described by White as the "Fourth terrace," and is well displayed at Rochester and New Brighton.
>
> Just above Industry, on the north side of the Ohio, is a terrace or rock shelf, standing about 275 feet above the river, on which a few waterworn pebbles were found, including a quartzite 9 to 10 inches in diameter, and a gneiss about 3 inches.
>
> From Industry, Pa., down to East Liverpool, Ohio, there are only occasional small remnants of the highest terrace [and these have similar pebbles of distant origin].

The old valley of the Parker strath was no doubt at this time occupied by an active stream. That this stream bore strong currents is evidenced by the general pebbly character of the lower portions of the deposits. At times the water appears to have been free from currents and in it was laid down exceedingly fine yellow or red clay, especially near the top. Some of the large bowlders may indicate the presence of floating ice, which scattered them in the finer deposits. The pale-colored silt at the top is sprinkled with very small pebbles of quartz and flinty materials. The best exposures are at present seen east of New Brighton, where the clay has been utilized in the manufacture of brick and plant pots. On the other remnants of this river terrace the filling appears to have much the same surface character, but it is generally so soft that exposed sections are difficult to find.

LOWER TERRACE GRAVEL.

The deposits of lower terrace gravel are, like those of the Carmichaels formation, characterized as material of purely local derivation. In this they differ from glacial gravel of Wisconsin time described below, though they are assigned to the same age. They are generally limited within the quadrangle to streams least likely to have afforded avenues of discharge for glacial wash. Of such streams Raccoon Creek and perhaps Brady Run are the most prominent examples. The former has the best marked terraces. The composition of these deposits is gathered from surface indications only, since no good vertical sections are available. They differ from the Carmichaels formation in being made up chiefly of fine waterworn gravel and sand, with little or no silt. When the Wisconsin gravel of Ohio and Beaver rivers was laid down the mouths of lateral streams were so choked by it, that they could not discharge their own débris. Thus they built up flood plains of the lower terrace gravel, filling in their valley bottoms; but they have since more or less completely incised this unconsolidated material by headward cutting. There may be small streams, however, such as Mill Creek, Logtown Run, and others, a portion of whose present flood plains, especially in their upper courses, may still contain uncut gravel filling of Wisconsin age.

LATER GLACIAL GRAVEL (WISCONSIN).

This gravel covers the northern portion of Beaver County, valleys and uplands alike. The southern border of the upland deposits extends southwestward across the county, crossing Beaver River 10 miles above its mouth and leaving the State near the northwest corner of the Beaver quadrangle. At two or three points along the boundary small arms of this deposit extend for short distances into the quadrangle. In addition to these there are a few isolated but very small patches of glacial material in the northward-facing valleys. All the material has the appearance of till, but water may have aided in its deposition and the isolated deposits were probably scattered from floating ice in ponds between the glacial front and the divide to the south. None of the deposits, however, seem sufficiently large to represent on the map.

There is some doubt as to the age of the deposits which thus fringe the northwest margin of the quadrangle. They probably belong to the Wisconsin epoch, but may be of Illinoian age.

The other evidences of Wisconsin material within the quadrangle are almost entirely limited to Beaver and Ohio valleys. The form and distribution of the deposits along these streams have already been described. They present the greatest thickness of unconsolidated material in the quadrangle. At Beaver, Shippingport, and Georgetown several wells have been sunk through these terraces to the level of Ohio River, but solid rock was found only near river level. If the same is true of the other terraces, the thickness of these deposits ranges from 70 to 150 feet on the river front, but seems to decrease back from the river as the rock floor rises. Having been built upon the rock floor of the modern streams in a manner similar to the building of the present flood plain, the terraces must mark a time when the rivers were flowing near the level of their surface and depositing a burden of sand, gravel, and small bowlders. This condition was caused primarily by surplus débris from the ice sheet farther north. That there was also surplus water from the same source and a strong current is evidenced by the coarseness of the deposit.

The material, according to reports from well diggings, is composed at the bottom of a very coarse mixture of sand and large bowlders, becoming finer and more sandy toward the top. On the Beaver terrace the sandy deposit is very even and thick. At other localities the terraces appear to be of much the same character, but in general coarse material seems to grow more prominent to the east and north. The pebbles and bowlders, well rounded and polished, are of granite, gneiss, diabase, sandstone, and limestone, varying in size up to 10 inches in diameter.

Frank Leverett, who has described these deposits, as well as those of the higher terraces, states that the former have the fresh, unweathered character of Wisconsin material and are, therefore, younger than those of the Parker strath.

The scattered pebbles of crystalline rocks mentioned in describing the Carmichaels formation in the ancient valley of Raccoon Creek should here be described more in detail. They consist of quartzite, diabase, granite, and gneiss, well rounded and varying in size up to 4 or 5 inches in diameter. Many smaller pebbles of like character were found in the flood plain at Bocktown. These have probably been worked over from the higher terraces. Similar specimens were found on Raccoon Creek as far south as 2 miles above Burgettstown, on the Panhandle Railroad, and other foreign pebbles have been found sporadically as high as 1100 feet above sea level, especially on the knobs northwest of Holt and south of Bocktown. Along the country roads at about the same elevation singular patches of a sandy and silty, yellowish deposit, much like loess, were observed. The collection of erratic pebbles from Raccoon Creek was examined by Leverett, who pronounced them as very probably of Wisconsin age. The occurrence of such rocks on terraces correlative with others on the river that are considered of Kansan age is in itself, not to mention the sporadic foreign material on the uplands, difficult to explain. Their scarcity, not more than two or three being found on a single terrace, adds to the perplexity of the problem, which will be discussed under the heading "Wisconsin history."

It is interesting in this connection to note some confirmatory evidence that Ohio River was flowing westward when these terraces were formed. This evidence consists in the fact that such streams as Sixmile, Twomile, and Haden runs, have their mouths turned downsteam. Raccoon Creek also probably once entered the river in this manner. This seems to be the usual mode of junction when the main stream carries a greater load than its laterals. Though the terraces in question vary in elevation about 70 feet, they all belong to stages of the same terrace-building age.

These broad, flat terraces, offering a level but easily excavated surface and plenty of sand and bowlders for building purposes, present admirable sites for towns and large plants. Owing to the porous character of the material, the terraces have the advantage, too, of affording good drainage, while, on the other hand, the sandy, stony, loose nature of the deposits renders them of little value for agricultural purposes.

RECENT SERIES.

ALLUVIUM.

The large streams of this region are bordered in many places by narrow flood plains, which are the work of the present streams. Evidently, since the sources of the material are both glacial and native deposits, the alluvium is a mixture of foreign and local débris. Much of it, especially near the top, is fine silt-like sand. Some of the flood plains are above high-water level and represent the condition of the streams at a slightly earlier period of their history, but many of the plains are inundated at every flood stage of the river and consequently are in process of construction to-day. In fact, at times Ohio River rises to track level of the Cleveland and Pittsburg division of the Pennsylvania Railroad at Industry, Rochester, and elsewhere, which is a rise of 40 feet above low-water mark. The narrowness of the present gorges, however, allows little room for flood plains, and consequently they are not so extensive as is usual on streams of this size. The largest are seen between Industry and Merrill, at West Bridgewater, and at the mouths of Crow and Blockhouse runs. In addition Georgetown, Phillis, and Montgomery islands are remnants of flood plains. Many of the small streams of the region have developed flood plains larger in proportion to their size than the rivers. This is most notable along Raccoon Creek. Being frequently inundated, the flood plains not only weather severe droughts, but furnish very productive farming land, if not the most productive in this region.

STRUCTURE.

INTRODUCTION.

The general structure of the Appalachian coal field, of which this quadrangle is a part, has been outlined on a previous page. There it was shown that the structure consists of a series of parallel folds and that from the Allegheny Front westward each succeeding trough becomes shallower than the last and the successive arches lower, until near the Ohio-Pennsylvania line the folds are scarcely recognizable.

In describing these folds the upward-bending arch is called an anticline and the downward-bending trough is called a syncline. The axis of a fold is that line which at every point occupies the highest part of the anticline or the lowest part of the syncline; the strata dip from this line in an anticline and to it in a syncline.

METHOD OF REPRESENTING STRUCTURE.

The underground relations, or structure, of the rocks in this area are illustrated in the maps of this folio as follows: The upper or lower surface of a particular stratum of rock is selected as a reference surface. The form of the reference surface is ascertained, first, from the outcrop of the chosen stratum; second, from the depth of that stratum beneath beds above it; and third, from the height of that stratum above beds beneath it. In the first case the stratum outcrops and is observed. In the second case it is underground and the outcrop of some higher bed is observed. The thickness of rocks between the two being known, the depth of the reference surface can be estimated. In some instances the depth is measured directly in a deep-well boring. In the third case the reference surface is in the air—that is, the chosen stratum has been eroded—and the outcrop of an underlying bed is observed. The thickness of the intervening rocks being known, the height of the reference surface can be determined.

By reference to the topographic map the altitude of any outcrop can be ascertained and thus the height above sea for a corresponding point of the reference surface can be determined. This is done for hundreds of points along a very large number of sections taken in various directions. Points which have the same altitude are then connected by a line, which gives the horizontal form of the reference surface at that elevation. Many such lines are drawn at regular vertical intervals. They are structure-contour lines, and as printed on the structure and economic geology sheet they show, first, the horizontal contour of the troughs and arches, second, the relative and also the actual dip of the beds, and third, the height of the reference surface above the sea at any point. The depth to the reference horizon may be determined by subtracting the elevation of the reference horizon, as shown by the structure contours, from that of the surface of the ground, as shown by the topographic contours.

As a rule, these structure contours are generalized and are only approximately correct. Where mines have been opened on the chosen stratum, as on the Upper Freeport coal, which in the Beaver quadrangle, however, has unfortunately no large mines, precise and detailed contours may be drawn, but in other cases they are liable to error from several conditions. Being estimated on the assumption that over small areas the rocks maintain a uniform thickness, the position of a contour will be out to the extent that the actual thickness varies from the calculated thickness. Being measured from the altitude of observed outcrops, the position of the contour is uncertain to the degree that that altitude is approximate. While in many instances topographic altitudes are determined by spirit level, geologic observations are located by hand level or aneroid barometers. In this work the aneroids are constantly checked against precise bench marks, and the instrumental error, though it may be appreciable, is probably slight. Most observations, however, on coal beds in the Beaver quadrangle were located by hand leveling to precise or temporary bench marks. But in the Ames limestone area, where bench marks are less numerous, leveling was in many cases confined to road intersections. Finally, the observations of structure at the surface can be extended to buried or eroded strata only in a general way. The details probably escape determination. These sources of error may combine or may compensate one another, but in any case it is believed that their sum is probably less than the amount of one contour interval; that is to say, the absolute altitude of the reference surface will not vary from the altitude indicated on the map more than 20 feet anywhere in the quadrangle; and the relative altitudes for successive contours may be taken as very closely approximating the facts. That a bed many hundred feet below the reference strata—for example, an oil- or gas-bearing sandstone—has exactly the same structure as the reference surface is doubtful. Stratigraphic irregularities, as already pointed out, may conspire to produce nonconformity between the structures of the two beds. A syncline for example or an anticline in either the Upper Freeport coal or Ames limestone may not exactly overlie similar folds in the Berea grit. It is believed, however, that such discrepancies are not great, and that the axes of corresponding folds are in general not far removed from coincidence. Nevertheless, wherever the structure of a certain bed is desired, as in oil or gas regions, the better method is to contour that bed from accurate well logs, but where deep wells are inadequately distributed over an area, as in this quadrangle, it is inadvisable if not impossible to do so.

REFERENCE STRATA.

In the Beaver quadrangle the reference stratum in the northern half is the Upper Freeport coal and in the southern half the Ames limestone. The purpose of using different reference strata in different parts of the quadrangle is to prevent the possible error referred to above, due to nonuniformity of thickness between two such strata. That is to say, the contours thus drawn on the Ames limestone probably give a more accurate representation of the structure than if these contours were made to represent the roof of the Upper Freeport coal by subtracting from each elevation on the limestone an arbitrary, and, through nonuniformity, perhaps inaccurate interval. Where these two strata overlap near the middle of the quadrangle, parts of some of the contours, however, have been calculated on the assumption that the interval between the two beds is uniformly 290 feet. But it is believed, nevertheless, that the error introduced here is small for the reason that five or six measurements of the interval were made by level along this overlap and used in the calculation of the contours in the central part of the quadrangle.

The contours most likely to be in error lie in regions, such as parts of Ohio, Brighton, and Moon townships, where exposures of the reference strata are scanty. In the first two recourse for structural indications is limited to blossoms of the variable Brush Creek coal, changeable sandstone beds, and a few deep wells, so that exact evidence is meager and the contouring necessarily generalized. Moon Township also, though containing more reliable upper coals, is poor in sandstones and deficient in deep wells.

DETAILED STRUCTURE.

The structural geologic map shows that there are no definitely marked anticlines or synclines of great extent in this quadrangle, but that the reference surfaces have rather smooth, fluted slopes, breaking into small domes and basins. Perhaps these have favored the accumulation of oil and gas in certain parts of the quadrangle, such as the Shannopin, Hookstown, and Smiths Ferry oil fields and the New Sheffield gas pool.

The domes and basins are most numerous near a line drawn from the northeast corner of the quadrangle southwestward, near Ohio River, to the vicinity of Hookstown. In this district the extreme relief from the pits of the basins to the peaks of the domes is rarely more than 60 feet, and generally much less. Their interrelation is so complex as to defy intelligent description without the aid of the structural map. Reference to this map shows a small ellipsoidal basin east of New Brighton having a northeasterly trend. Southeast of this basin, at the edge of the quadrangle, are traces of a dome which is not complete within the boundaries. To the south there is a gentle dip to McDonaldtown, where a small dome (too small to be represented on the map) rises at Dam No. 5 in sympathy with a more extended arch crossing Moon and Poorhouse runs, with a basin on the north in the vicinity of Beaver. Near the mouth of Raccoon Creek this anticline splits into two small domes, one on either side of the river. The one on the north side rises in a gentle northward slope, while the one on the south heads a series of three small domes extending in a line toward Hookstown. The last of this series breaks off into a side dome near McCleary, but the strength of the southwest axis is maintained in a small hook on the 920-foot contour. At Industry begins another basin which, after following the river a short distance, splits, one fork extending toward Georgetown, the other toward Hookstown, and both inclosing a final dome on Mill Creek. This arch has a slight northwest-southeast trend, parallel to Mill Creek.

From this diagonal area of mingled domes and basins the strata, corrugated with small anticlines and synclines having a general northwest-southeast trend, dip away to the south in gentle slopes. The anticlines are usually spurs shot off from the domes, while the synclines lie between these spurs and sometimes coincide with the depressions between the domes. One of these spurs brings up the Upper Freeport coal on Service Creek. A marked syncline of the latter type develops near Gringo and extends to Raccoon Creek, where it forks. One branch extends westward south of Green Garden and fades into the McCleary dome; the other branch extends northwestward to Gums Run and there splits, one trough extending through Holt and across the domal ridge into the Industry basin, the other following along Raccoon Creek and around the west flank of the Moon-Poorhouse anticline into the Beaver basin. In the extreme southeast corner of the quadrangle, the general southeastward dip gives way to another dome, lying in Allegheny County. This dome, so far as can be made out on the map, has an east-west trend, while the syncline inclosing it is semicircular.

North of the domal region along Ohio River the rocks rise in fluted slopes northwestward to a rather well-marked anticline in the northwest corner of the quadrangle. This anticline, which has a northeast-southwest trend, seems to be the extension of the Fredericktown arch recognized by I. C. White. The arch sends out a spur to the south which culminates in a small dome near Fairview.

Since the printing of the structure and economic geology sheet, the structure contours along the northern boundary have been adjusted to those of the Newcastle sheet. The main structural features, however, remain unchanged, and the only change in detail worthy of note occurs in South Beaver Township near Brush Run. At this point the 1120-foot contour of the Fredericktown arch describes a loop about the lower half of Brush Run and leaves the map on its old course. In sympathy with this loop the 1060, 1080, and 1100 foot contours take a more northerly course and leave the map west of Brush Run.

USE OF STRUCTURE CONTOURS.

Structure contours are of value in determining, at any point in the area, the depth to any of the well-known oil or gas sands or other strata whose distance below the surface has once been accurately measured. For instance, given the elevation of a certain well mouth, the elevation of the Upper Freeport coal or Ames limestone at the same point, taken from the structure contours, and the depth to the Berea as measured in the well, the interval between the Berea and coal or limestone is easily determined. With this known interval, the elevation of a prospective well mouth, and the elevation at this well of the key stratum last used, the distance from the surface to the Berea can be ascertained by subtracting from the elevation of the key stratum the interval to the Berea (previously found) and subtracting the result from the elevation of the well. Similar calculations can be made for any other stratum beneath the reference surface. The use of structure contours as further aids in the development of oil or gas territory is discussed under "Petroleum and natural gas."

Structure contours are also convenient in operating mines of coal, clay, etc., which follow the lay of the rocks; for the contours show the rise and dip of economic beds, on which underground drainage and haulage depend.

GEOLOGIC AND PHYSIOGRAPHIC HISTORY.

Time is measured by the succession of events. Events in the history of the earth are recorded in both rocks and surface features. Since the rocks of Pennsylvania were for the most part laid down in seas, and since the surface features have been chiefly carved by streams, the geologic history of this region resolves itself, in general terms, into two great cycles—one of construction and one of destruction—corresponding to times of prevailing deposition and of prevailing erosion of strata. The time in which we are now living belongs to the latter, still unclosed cycle. Neither has, of course, been continuous, for each has often, for short intervals, been interrupted by reversions to the other; nor have both been of equal duration, for it is undoubted that the cycle of construction continued during a period very many times as long as that consumed by the present cycle of destruction. The events of the former are recorded in the consolidated rocks of the region, while the history of the latter may be read in surficial rocks and physiographic forms.

RECORD OF CONSOLIDATED ROCKS.

INTRODUCTION.

The strata forming the consolidated rocks of western Pennsylvania are composed chiefly of sandstones, shales, and limestones, with occasional beds of coal and clay. The sea in which these sediments were laid down covered most of the Appalachian province and Mississippi basin. The shores of this ancient sea were the crystalline rocks of the Blue Ridge on the east and of the Adirondacks and southern Canada as far as Lake Superior on the north. Near the eastern arm of this rudely V-shaped continent, which was all of eastern United States then above water, lay the Beaver quadrangle. Into the inclosed sea discharged streams carrying sediments of which the rocks, not only of the Beaver quadrangle, but of the Appalachian province, are composed. Under these general conditions, often modified in detail, sedimentation continued for ages; but time even then was not uneventful, for in the early part living beings for the first time in the history of the province both made their appearance and left a record. These early organisms were water animals chiefly and primitive forms of plants, probably seaweeds. After deposits had accumulated to a great thickness the sea bottom to the west slowly rose until the sea was still more completely inclosed by a western barrier. This event is known as the Cincinnati uplift, and resulted in the formation of an extended gulf from Alabama to New York. It is probable that this gulf had no great depth; still, with increased deposition from the new land area on the west thousands of feet of sediments accumulated. To accomodate such conditions a downward movement of the sea bottom, following the middle of the Appalachian trough, is presumed. When it is remembered that the vertical movement of the land, the cutting action of streams, and the filling in of the sea were going on then as slowly as to-day—a rate hardly discernible within the time covered by the history of the human race—some idea may be gained of the long ages consumed in depositing the thousands of feet of strata between the crystalline rocks and the earliest rocks known in the Beaver quadrangle.

CATSKILL AND POCONO HISTORY.

As shown on the detailed section sheet, the lowest rocks penetrated by the drill are assigned to the Catskill formation. This is composed of sandstones alternating with colored shales. If the material of these very different beds was carried and laid down by water, it is manifest that the conditions of deposition must have been correspondingly different. Coarse sandstones, being composed of large grains of sand, transportable only by strong currents of water, such as violent streams or shore action of waves, may be taken as evidence of steep land surfaces and shore deposition. Shales, on the other hand, being made up of fine particles easily held in a state of suspension by slight currents and therefore requiring for their deposition very quiet water, indicate offshore deposition and perhaps low land surfaces. Red shales may also originate from a land surface long exposed to rock disintegration and oxidation.

The mere indication, then, on the detailed section sheet, of alternating sandstones, sometimes pebbly, and shales occasionally red, proves that Catskill (late Devonian) and Pocono (early Carboniferous) time was marked by many slow oscillations of the Appalachian sea floor and probably of the land surfaces to the east. Such movements were so strong that, though parts of the sea floor never rose above water and portions of the old land area never were submerged, the shore line migrated backward and forward within wide limits. Along such a shore line land plants probably flourished and at times were buried. These remains are still preserved in the Pocono coals farther south, but no record of such remains is known in the Pocono of the Beaver area. Between shore migrations there were, no doubt, as shown by the preponderance of shale deposition during Catskill and early Pocono time, long periods when conditions were nearly stationary. Then the land surfaces were low and exposed to deep disintegration and oxidation. The resulting red shales may, therefore, indicate in a relative way when some of the longest of such periods occurred.

In late Pocono time general conditions, as shown by the kind of deposition, had changed. Instead of a preponderance of shales, as before, there are in this region about equal amounts of sandstone and shale. Many beds of sand were deposited, becoming thicker and heavier toward the top. It is to be concluded, therefore, that during that time the land areas, though oscillating perhaps as often, reached and maintained for longer periods higher elevations than before. Streams which in the intervals of low elevation were sluggish then renewed their youthful activity on steep slopes and transported to the sea coarse sand and pebbles. The resulting beds of coarse white or gray sandstones form the reservoirs for oil and gas in this part of western Pennsylvania. All through the time of deposition of the rocks of this region the sea teemed with varied living forms, whose remains became entombed in the settling deposits and were thus preserved from destruction. Possibly from these organic remains, both animal and plant, natural gas and oil were derived. The process is unknown, but it may have been a kind of distillation, and in this case the resulting substances, at first remaining in the parent rock, finally exuded and found a convenient storehouse in the open-grained, porous sands. The materials were retained in these sands by an impervious cap of overlying rocks until the drill punctured the cap and oil and gas began to flow out.

MAUCH CHUNK HISTORY.

After many gradual oscillations during Catskill and Pocono time, during which the sea probably never receded from this locality, came the period of Mauch Chunk deposition. This deposition is characterized, where it is known, by red and green shales, but as such it has not been recognized in any wells of the Beaver quadrangle. It may be said, therefore, to be probably absent in this locality. Its absence may be accounted for in two ways—by nondeposition, and by deposition and subsequent erosion. If by nondeposition, then this area must have been raised above water and consequently subjected to more or less erosion. We should then expect the Pocono to be thinner here than where the Mauch Chunk now lies above it; and this, indeed, is the case, if the boundaries in the well sections are rightly drawn; for it will be seen that within the Beaver area the Pocono presents a thickness of about 600 feet, while on the Allegheny Front it is 1000 feet. If, on the other hand, the absence of Mauch Chunk is to be explained by its deposition and subsequent erosion, the same results may be obtained; for if the period of erosion which removed the Mauch Chunk were continued it would also remove part of the Pocono. But whichever hypothesis is adopted, one conclusion remains—that an unconformity probably exists between the Pocono and Pottsville.

POTTSVILLE HISTORY.

The events which attended the deposition of the Pottsville formation constitute one of the most interesting episodes in the geologic history of this region. It was formerly supposed that the variation in thickness of this formation was due to different conditions of sedimentation, and that the rocks in thin sections on the west side of the basin correspond in age with those of the thick sections on the east. Through the study of fossil plants David White (Twentieth Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, pp. 755–918) has demonstrated that this is not the case, that the thin sections are due to lack of sedimentation, and that they are separated from the underlying rocks by a long time interval that is represented by the deposition of at least the lower half of the formation, as it appears fully developed in the type locality in the Southern Anthracite region.

Thus White infers that about the beginning of the Pottsville epoch an uplift occurred which affected much of the Ohio Valley. A large land area was formed that extended as far east as the Broadtop and Northern Anthracite fields. This land area persisted until at least 600 feet of Pottsville sediments were deposited in the Southern Anthracite basin, and it may have been during this time that the Mauch Chunk was eroded. A subsidence then occurred, continuing until unbroken sedimentation was resumed from the anthracite basins to the western edge of the bituminous field. Thenceforth, as shown for the first time by the evidence in this region, oscillations of the sea floor exposed it to long periods of at least partial emergence. Such periods are marked by coal deposits. Thus the Pottsville coals represent times when the surface was of a low, marshy character. Over such country grew luxuriant vegetation in extensive shore swamps and lagoons. The underlying fire clays are supposed to have been the old leached soils on which the coal-making plants flourished. There were, however, two or three intervals of submergence during which heavy cross-bedded sandstones or conglomerates were deposited.

ALLEGHENY HISTORY.

Periods of emergence when plant life thrived became more frequent during Allegheny time, but it is a fact worthy of emphasis that with one exception no emergence during the sedimentation of the rocks known in the Beaver quadrangle attained conditions of extensive erosion. Water action, however, has left its mark in the Carboniferous swamps. In this region the Allegheny formation, containing the largest number of coal seams, offers the best opportunity to study coal-swamp phenomena. Attention has already been called to the abrupt thinning of the Upper Freeport coal, its alternation with sandstone, shale, or clay layers, and its entire absence in places. The other coal seams of the formation exhibit similar phenomena, though in few cases so well marked. The abrupt thinning of coal from the roof downward denotes erosion of the coal-making material by streams; thinning from the floor upward suggests absence of deposition, as on islands or bars elevated above the surrounding marshes; interbedding indicates stream deltas, or even general but ephemeral inundation of the Carboniferous marshes. From the large number of coal seams in the Allegheny formation it is evident that in general swampy conditions were very prevalent during this period. But times of entire submergence were not past. Indeed, the lenticular bodies of sandstone and shale denote different currents of water or sources of material, even within narrower boundaries, and the different limestones denote times when the waters were clear and free from ordinary sediment. The Vanport limestone, for example, is made up largely of shells of marine animals, with little extraneous material. Such conditions of life, with purity of water, probably existed far from washing shore lines, though not necessarily in very deep water. The patchy occurrence of the limestones in the Allegheny formation may perhaps be most reasonably explained by accidents in original deposition, such as the presence of local elevations in the sea bottom so near the surface that deposition upon them was prevented by the waves. The theory of deposition and subsequent erosion, however, which has been advanced to account for this occurrence of the limestone, is not, so far as evidence in the Beaver quadrangle goes, entirely untenable as an alternative explanation. The appearance of the other limestones of this formation does not so clearly define their origin. They are nonfossiliferous except for a rare minute univalve reported in the Upper Freeport limestone. They are therefore probably not of organic origin, but are possibly fresh-water deposits. They may have been precipitated from impure waters charged with carbonate of lime in solution.

Thus the geologic history recorded in the sediments of the Allegheny formation tells of a series of rapidly alternating conditions, repeating themselves wholly or in part at least seven times. Each group of events began by the deposition of many feet of shale and sandstone, probably in a shallow sea near the shore. Then, for some reason, either an arid climate or migration of the shore line, sedimentation of mud and sand ceased, and in the resulting clear waters thrived living forms, whose remains, dropping to the bottom, accumulated beds of limestone; or life may have been practically absent in inland waters heavily saturated with carbonate of lime. Finally, soon after this period of quiescence, an elevation of the water bottoms, probably not far above sea level, followed by another period of quiescence, during which luxuriant plant life thrived and bituminous material was deposited, ended each series of events.

CONEMAUGH HISTORY.

A similar series of events, culminating in the Brush Creek coal seam, is recorded in the beginning of Conemaugh time. But conditions later changed, and as a consequence this epoch is marked by only a few short periods suitable for the accumulation of vegetation as coal beds. Limited areas, however, supported plant life, for plant remains are preserved to us in lentils of impure coal. Marine conditions, too, as shown by the salt-water fossils of the Brush Creek and Ames limestones, recurred at least twice. The Ames limestone, however, is said to mark the last return to marine conditions in the Appalachian basin. The remainder of the strata are shales and sandstones. Submergence, therefore, prevailed throughout this region, but land areas somewhere stood long exposed to subaerial deterioration; for several beds of red shale are distributed throughout the formation.

MONONGAHELA HISTORY.

With the advent of Monongahela time begins a succession of events similar to those recorded in Allegheny time. The initiation of these events is marked by a great period of coal formation, whose widespread and long-continued conditions are shown by the extent and thickness of the Pittsburg seam.

Only a few remnants of this coal still exist in the southeastern section of this quadrangle, but no doubt it once covered this whole area and has been removed from it in geologically recent time. Its position, if it were restored, would average 520 feet above the Upper Freeport coal.

Submergence accompanied by the deposition of heavy sand, followed, and this is the end of the Monongahela record within the Beaver quadrangle.

Other regions, however, show that deposition in a manner generally similar to that described continued through several hundred feet of strata, until the Appalachian sea was finally filled and the shore in eastern Pennsylvania migrated westward. It happened thus that this region was left dry land, which it has remained ever since. So the great constructive cycle closed.

Geologists believe that during this long accumulation of sediments, which are now indurated rocks, folding of the strata took place. As laid down in the sea, the rocks were nearly horizontal, but later became, by the oscillations of the earth's crust (perhaps during Devonian, early Carboniferous, and more particularly late Carboniferous time), crumpled and folded in the manner represented on the structure and economic geology sheet.

RECORD OF SURFICIAL ROCKS AND PHYSIOGRAPHIC FORMS.

INTRODUCTION.

Throughout the constructive cycle represented by the accumulation of tens of thousands of feet of rocks, subsidence was the prevailing movement of the Appalachian province, but since then the reverse action—elevation—has taken place, alternating with intervals of quiescence. This movement has caused a general erosion of land surfaces into those physiographic forms now marking the cycle of destruction. The period of elevation was initiated by the folding referred to above at the close of Carboniferous time. Then the broad parallel series of folds, graduating from the tall anticlines and corresponding synclines of eastern Pennsylvania to the shallow plications of the western border, were presumably made.

SCHOOLEY PENEPLANATION.

The general elevation of the province was finally arrested and a long period of quiescence ensued, during which streams cut away inequalities and, it is believed, reduced the land surface to an approximately horizontal plain close to sea level. This was the making of the Schooley peneplain, already described. Remains of this plain do not exist in the Beaver quadrangle, but it is well known in Tennessee, Alabama, and New Jersey. In the last two States it is found overlapped by Cretaceous deposits and is believed, therefore, to have been completed at least before the end of Cretaceous time.

HARRISBURG PENEPLANATION.

Eventually another uplift occurred and vigorous erosion was again inaugurated. The whole of the Schooley plain was removed from this part of Pennsylvania, and the surface was again reduced to a wasted hilly plain. This is believed to have occurred during early Tertiary time, and remnants of the old surface are still extant in the uplands of the quadrangle. This is the Harrisburg peneplain described in a previous section. The perfect development of this plain was arrested by uplift and doming of the surface, the center of this movement being in McKean and Potter counties (Campbell, M. R., Bull. Geol. Soc. America, vol. 14, 1903, p. 295). The renewed activity thus created in the streams incised the old surface for a depth of nearly 100 feet. The uplift ceased after this much elevation; valleys were widened and in some places divides reduced until the development of a third peneplain was well inaugurated. This was the reduction of the Worthington plain and probably occupied late Tertiary time.

PARKER STRATH.

The Worthington plain was not allowed to develop even so completely as the Harrisburg plain; for soon another uplift occurred during which the widening action of streams was replaced by that of down cutting. The amount of incision and something of the relative time consumed are marked by the depth of the Parker strath below the Worthington substage, averaging about 225 feet. When this depth was attained the uplift had for some time ceased and streams again had opportunity to widen their channels. On account of the conditions necessary for this process the stream bottom could hardly have been far above sea level. At this time, too, drainage of the Beaver area, as shown in fig. 2, was radically different from its present system. There was no Beaver nor Ohio River then, such as we know them to-day, but Anabeaver River took a natural course from Pittsburg along what is now the Ohio Valley to Beaver, and thence through the present Beaver Valley northward to the Great Lakes. The present westward course of the Ohio to Wheeling was occupied by an eastward-flowing tributary with its mouth near Beaver, and Raccoon Creek entered the Anabeaver through its old channel at New Sheffield. The Parker strath, as we know it to-day, was thus in the process of formation, and this probably occupied the close of the Tertiary period, for its further development was arrested during Glacial time.

KANSAN (PRE-KANSAN?) HISTORY

Extended development of the Parker strath was interrupted by the change in climatic conditions which inaugurated the Glacial epoch. Excessive precipitation of snow resulted in the formation of an ice sheet over a great part of North America. The edge of this sheet lay just north of the Beaver quadrangle and extended toward New York (fig. 2). Slowly moving southward, the ice gathered up immense quantities of rock débris. When warmer climatic conditions prevailed the ice front melted back, leaving its load of gravel, sand, and silt over the glaciated area. These deposits are known as the Kansan (possibly pre-Kansan) drift sheet. Some of it was washed farther south and forms much of the present covering of the Parker strath along the rivers. When the ice stood to the north it blocked the northward drainage of the Anabeaver system. This drainage basin was probably ponded until the water level reached a low divide near Wheeling, over which it poured and began to wear out something like its present channel. How much cutting it had done before the ice receded under warmer conditions no man knows, but it is certain that the outlet was lower than the drift deposit which then filled the Anabeaver Valley to the north, and hence the drainage then established has continued intrenching itself to the present day.

It was perhaps during this stage of ponding that Raccoon Creek undertook its present course, but it may have done so at some later date. Possibly local ice dams, such as Campbell suggests (Geologic Atlas U. S., folios 82, 94) for the cut-offs along Monongahela River, standing somewhere in the abandoned channel, furnished the means of diversion. But whatever the cause, the diversion is a fact, and the elevation to which the water must have risen to pour over the preexisting divide between Bunker Hill and Green Garden may be seen by examining similar divides in this vicinity. The lowest ones are not under 1100 feet above tide, and as there has been little erosion at these points since the event under consideration, it seems likely that Raccoon Creek must have risen at least to the level of these divides at the time of its diversion, and it must have remained ponded high and long enough to cut a channel at least to the level of its abandoned course. Moreover, terraces of Wisconsin age exhibited on its lower course seem to prove its diversion prior to that time. But the mere presence of terraces is not enough in itself to prove this point, for similar terraces may have accumulated along the stream which probably occupied this channel before the diversion of Raccoon Creek. The extent of the terraces—continuing several miles upstream, beyond the divide itself—must, in addition to their presence, be brought forward as proof that they were deposited along the present stream. Similarly the southern slope of the present rock bottom of Beaver River, upon which are built the Wisconsin terraces, proves in the absence of tilting that the present direction of the river drainage was established in pre-Wisconsin time.

INTERGLACIAL HISTORY.

After the institution of the present drainage system and the recession of the ice, streams were flowing on the glacial filling of the Parker strath, which, for the reasons stated above, was probably not so high as its present elevation above sea level. If this is true, then there must have been an uplift to bring the strath to its present position. This rise would have set the streams to active down cutting and caused the deep gorges now occupied by the present rivers and their tributaries. If, however, the trenching is due, as Leverett believes, chiefly to the increased volume of water gathered from the enlarged drainage basin, then no uplift was necessary. This, it seems, offers the most natural explanation if the strath could have been formed at its present altitude. Since the widening of a valley takes place at elevations depending, among other things, on the volume of the stream, and since the streams here were small before the institution of the present drainage, the Parker strath may have been excavated at an elevation somewhat above the present rivers. The down cutting, however, whatever the cause, was intermittent, for at two intervals of about 50 and 110 feet below the strath substages of widening are evident. Trenching, nevertheless, continued for some time. Finally, after gaining a depth of 200 to 300 feet below the Parker strath, but probably not yet reaching a gradient compatible with valley widening, erosion was interrupted by a second ice invasion, known as the Wisconsin stage. Between this invasion and the former one the deposits of the Western States record two intermediate ice incursions—the Illinoian and Iowan. There are no deposits in the Beaver region which can be assigned with certainty to these periods. Some of the super-Kansan silt, however, and possibly the erratics on Raccoon Creek may belong to the latter stage.

WISCONSIN HISTORY.

During Wisconsin time the ice front paralleled that of the Kansan epoch, but in places did not extend so far south. The outwash from it, however, was enough to clog the border streams with sand and bowlders to such a degree that they could not keep their channels clear. Consequently the Ohio and Beaver valleys became filled with glacial materials to a depth of 70 to 150 feet. The filling might have been much deeper had not warmer climatic conditions returned and the ice receded once for all from this region. Other deposits of similar material, as already described, have been found on the Carmichaels terraces of Raccoon Creek. As this material is considered of Wisconsin age, a definite problem arises which may be stated thus: How came pebbles of Wisconsin age to be distributed on terraces of Kansan or pre-Kansan age? Their scarcity, as before noted, suggests that they were dropped by floating ice. But floating ice dropping Wisconsin material on these terraces requires at once water higher than the terraces and an upstream current. The latter condition suggests, in turn, a southern outlet. A reconnaissance of the divide from Burgettstown to Hickory, in the spring of 1903, failed to show any evidence of such an overflow; in fact, a map of this area which has since been made shows no gap anywhere on the divide which incloses the portion of Raccoon Creek south of New Sheffield lower than 1160 feet above sea. This circumstance would seem at first to preclude a southern overflow, but in view of the high glacial material (elevation 1150 feet) near the knobs between Squirrel and Haden runs, such an overflow might not be impossible; for that material, if of Wisconsin age, must have been deposited there in water at least to that elevation. The flooding of Raccoon Creek basin, even to a lower level, might account for the deposition of the Raccoon pebbles; for the drainage into such a deep pond would not cause a northward current strong enough to prevent wind-blown ice blocks from drifting upstream and scattering glacial material. There may have been, therefore, more than one period of ponding. On the shores of such ponds the silty material before noted may have been laid down as embryo deltas. On the other hand, the pebbles in question may prove to be of earlier age than supposed. Perhaps they belong to the Iowan stage and were deposited at a date earlier than Wisconsin time. In any case these erratics on the Parker strath of Raccoon Creek are evidence of high water over this region during the Glacial epoch, and very likely during Wisconsin or Iowan time.

POST-GLACIAL HISTORY.

When the Wisconsin ice sheet receded the rivers, thus relieved of their excessive load of glacial débris, renewed their task of degradation. Since then they have been engaged in cutting down the Wisconsin filling, so that now the old pre-Wisconsin rock floor is exposed at some points in the river beds.

On the rivers the Wisconsin material, with additions from other sources, is being worked over into present-day flood plains. The size of these alluvial flood plains, however, curiously bears no relation to the size of the streams. The map shows that the flood plain bordering Raccoon Creek not only is the most prominent in the region, but is in some way related to the abandoned channel at New Sheffield. It is a significant fact that the flood plain practically ends opposite this abandoned channel, and that thence northward the valley of Raccoon Creek, though tortuous, is remarkably V-shaped. The relation of these opposing features offers an interesting problem, which may be stated thus: Why has Raccoon Creek, in its upper course, a broad flood plain which ends nearly coincident with its abandoned valley?

The explanation might be easy had there been doming in the vicinity of Bunker Hill, so that for a time the upper part of the creek was practically at base-level. But there are no evidences of such an event; the valley is not deeply filled, for opposite New Sheffield and elsewhere the present stream flows over rock bottom. Nor can the explanation be wholly in a difference in the strata of the upper and lower portions of the valley, for though Freeport and Butler sandstones do not extend beyond the abandoned channel, the Mahoning and higher beds continue to Independence.

It will be noticed that the present flood plain is nearly as wide as the former channel, since the remnants of the latter are very small. Such a wide flood plain is usually made by a meandering stream which is nearly at base level. Thus the problem may be reduced to the question: Why did the meanders not proceed the entire length of the stream?

As already stated, a progression of meanders probably opened the broad valley represented by the Parker strath. This quiet maturity of the creek continued until the time of its diversion. After that event its condition was similar to that which it presents to-day, that is, a broad open valley in its upper course and a narrow gorge in its lower portion. At that time, however, though its upper portion no doubt meandered over the full width of the Parker strath, in a manner much resembling the upper creek of to-day, its lower part probably occupied a rather straight, narrow gorge, unlike its present meandering course. Since then the region has suffered an uplift, as already outlined, during which the creek cut down to something like its present level. The meanders of its upper portion were incised in the Parker strath, while its lower gorge deepened. This was probably its condition before the Wisconsin stage. During Wisconsin time the valley of Ohio River was filled to a height of at least 150 feet above its rock floor. This blocked the mouth of Raccoon Creek and caused it finally to fill up, at least as far as Frames Run. The effect was temporarily the same as if the stream had suddenly become base-leveled. Its action was no longer down cutting, but side cutting. It was probably during this time that the creek, in its lower portion, wandered about on the rather broad top of its filling, cut reentrants into its valley walls by following the lines of least resistance at the mouths of its tributaries, and thus established the present meanders. Owing to the great thickness of rocks to be removed, 300 to 400 feet, these have not yet progressed far downstream, and hence the valley is still gorgelike. Meanwhile the upper portion of the creek was also active. The meanders incised in the Parker strath progressed downstream and, having at most only a thickness of 100 feet of rocks to remove, were able to clear out the whole upper portion to nearly the same width as the strath. This width was continued slightly beyond the old channel, probably for the reason that it could follow the valleys of former tributaries at this point.

Thus the nonprogression of meanders throughout the entire length of the creek seems due chiefly to the greater thickness of rocks to be removed from its lower than from its upper portion.

ECONOMIC GEOLOGY.

In undertaking the geological survey of a region so well known as western Pennsylvania, it was considered needful to surpass former surveys in the detailed character of the work. Under this general plan the detailed distribution of various kinds of rock, including coal, clay, and limestone, the geologic structure, and the occurrence of oil and gas have been carefully studied in the field with the aid of topographic maps. In the Beaver region a greater amount of detail was collected than it is practicable to publish in folio form. This is published in Bulletin 286 of the United States Geological Survey (Economic Geology of the Beaver quadrangle, Pennsylvania), to which readers are referred for detailed information.

COAL.

Bituminous coal is an important resource of the Beaver quadrangle. All the rocks occurring above the base of the Pottsville are coal bearing, but the beds are much thicker and more abundant in certain parts of the series than in others. In this territory the Allegheny formation contains the most important coals, which are the Lower Kittanning and Upper Freeport beds, separated by an interval averaging 177 feet. The parts of the quadrangle that are underlain by these two beds are shown on the geologic map. At present no other coals are mined on a commercial scale, but the Lower Freeport, Darlington, and Brookville coals have some prospective value. The other coal beds of the Allegheny formation are thin and generally worthless under present commercial conditions and the same is true of the Conemaugh coals, such as the Brush Creek, Bakerstown, Platt, and Elk Lick beds. The Pittsburg bed, which elsewhere furnishes most excellent coal, is of small extent and poor quality within the quadrangle and of no great commercial importance. The common mode of occurrence of the coals in this region, except possibly the Lower Kittanning and Pittsburg, is that of irregular lenses. This character varies somewhat at different horizons, but it is generally the same and is detailed below for the various coals.

COALS OF ALLEGHENY FORMATION.

Brookville coal.—The Brookville coal bed is of little importance in the Beaver quadrangle. Generally its horizon is below water level, but in conformity with the northward rise of the strata, it appears slightly above water level in the upper course of Beaver River, north of Bolesville. From here to the edge of the quadrangle, however, it is frequently covered by terrace deposits, and for this reason does not outcrop on the east bank of the river. On the west bank two exposures show a variation in thickness from 6 inches at a mile above Fallston to 39 inches at the mouth of Brady Run.

Section of Brookville coal at mouth of Brady Run.

	Inches.
Coal	6
Coal, slaty	33

In this distance its position also varies from 5 feet above the Homewood sandstone on Brady Run to 10 feet above beyond Fallston.

Clarion coal.—This seam is of no commercial importance within this area, being in places shaly and not reaching more than 12 inches in thickness. Its line of outcrop averages 65 feet above the Brookville coal and is therefore somewhat greater than the latter, but the exposures are limited to Beaver River above Rochester and to Brady Run below the forks. Its position is above the Clarion clay bed, but it is often absent and replaced by a thin sandstone.

Lower Kittanning coal.—The Lower Kittanning is commercially the most important horizon of the region, not alone because of the coal it affords, but chiefly because of the excellent bed of clay that accompanies the coal. For this reason its line of outcrop has been indicated on the economic geology map; its extent is briefly outlined on a previous page. Where the outcrop is hidden by terraces, as at Monaca, Beaver, and elsewhere along the rivers, it may be found by sinking shafts through loose gravels to a depth of 30 to 60 feet along the rear edge of these terraces. At present the coal is rarely worth removing by itself, except for limited local use, but when taken out in conjunction with the underlying clay it often becomes a valuable resource for fuel. This depends, however, on its quality and thickness, which vary considerably; in some localities it is a good steam coal, but in others it is dirty and sulphurous and can not be used. It was not observed less than 14 nor more than 30 inches thick except where separated by partings.

Lower Kittanning coal sections.

	Inches.
NORTH BRANCH BRADY RUN.	
Coal	30
BLOCKHOUSE RUN.	
Coal, sulphurous	18
SOUTH OF PHILLIS ISLAND.	
Coal	23
Parting	2
Coal	6
MONACA.	
Coal, slaty	14
Coal	14

The average thickness is about 24 inches, and this measurement is most uniform in the valleys of Beaver River, Brady and Blockhouse runs, and in the north side of Ohio Valley from Freedom to Vanport. In these localities also the coal is singularly free from partings, though often rendered poor in quality by the presence of sulphur and other impurities. This is particularly true in certain areas east of Beaver River, where it is known as the "sulphur vein;" while in Brady Run this coal was once so much sought by smiths as to receive the appellation of "blacksmith vein."

Elsewhere in the quadrangle the greatest variations both in thickness and partings occur. The partings consist of clay and slaty lenses and seem confined to the upper portion. They are most prevalent on the north side of Ohio River west of Vanport, on the south side, and along Raccoon Creek, so that at places in this general region the Lower Kittanning seam has been abandoned for the Darlington coal above.

Middle Kittanning (Darlington) coal.—This coal is above the Lower Kittanning, from which it is separated by an interval averaging 35 feet. Consequently it has nearly the same geographic distribution, but is not so deeply covered by terrace deposits as the Lower Kittanning. The Darlington coal, though persistent throughout the quadrangle, is on the whole of less importance than the Lower Kittanning, because it is more variable in thickness—the limits being 4 and 36 inches—and because it is underlain by a less valuable clay bed.

There are, however, restricted areas in which the coal itself equals or surpasses in quality the Lower Kittanning of the same area. One area includes the Ohio Valley west of Dam No. 6. In this general region the coal is usually between 14 and 30 inches thick, free from partings, and apparently improving in quality and increasing in thickness toward the west. On both sides of the river in the vicinity of Georgetown it is 24 to 30 inches thick and is an excellent block coal (the "block vein"), which has in the past been largely opened for local consumption.

Middle Kittanning (Darlington) coal sections.

	Inches.
NEAR VANPORT.	
Coal	4
MOUTH OF MILL CREEK.	
Coal	30–36
NORTH BRANCH BRADY RUN.	
Coal	7
Shale	6
Coal	3
SOUTH OF ST. CLAIR.	
Coal	14–20

Another area in which the coal is somewhat uniform in thickness, of fair quality, and free from partings lies east of Beaver and Ohio rivers. In this locality it ranges generally from 14 to 20 inches, but it is likely to be cut out by the Freeport sandstone and is not at present of commercial importance.

The exposures in the remainder of the quadrangle seldom reveal a thickness greater than 6 to 9 inches.

Upper Kittanning coal.—This coal is of no importance within the quadrangle. Except possibly in one locality, it was never observed over 18 inches thick and seldom over 6 or 8 inches. Moreover, it is present in only 50 per cent of the exposures, and then usually as an impure or slaty coal. On Brush Run, however, a coal, possibly belonging to this horizon, has been mined locally and is uniformly reported 4 feet thick, with 6 to 12 inches of parting.

Lower Freeport coal.—This seam is of little value within the quadrangle, probably ranking below the Darlington coal. It averages 60 feet beneath the Upper Freeport coal, whose line of outcrop is shown on the economic geology map. The Lower Freeport horizon, therefore, lies rather high on either side of the river valleys and extends considerable distances up lateral streams. Along Ohio River it ranges in elevation from about 860 feet at Georgetown to about 900 feet at Montgomery Island and 860 feet at Monaca. From this general line the horizon rises to the north and descends to the south.

So far as observed the coal in 50 per cent of the exposures is inclined to be slaty, even becoming merely bituminous shale with thin coal seams. Locally, however, it clears up to good coal, ranging from 12 to 30 inches in thickness, but averaging 15 inches.

Lower Freeport coal sections.

	Inches.
BRUSH RUN.	
Coal	30
PHILLIS ISLAND.	
Bituminous shale with coal seams	36
FREEDOM.	
Coal, slaty	6
Shale	4
Coal	14
SOUTH BRANCH BRADY RUN.	
Coal	12

Such areas are restricted to Blockhouse, McKinley, Brady, and Twomile runs, Raccoon Creek, Island Run, and Brush Run. Even where good, the coal is often separated by clay or shale partings into two main benches, which destroys its value. Moreover, as stated above, it is likely to thin out or be absent over considerable areas. From one or two exposures, therefore, no conclusions can be drawn as to its quality, regularity, or character.

Upper Freeport coal.—Of the seams valuable for their coal alone, the Upper Freeport is the most important of the quadrangle. The horizon of this coal and the localities where the exposures show a workable thickness are indicated on the economic geology map. The extent of this horizon is also briefly outlined on another page. As a rule, wherever this coal supports a shale roof it is more likely to maintain a uniform thickness than where the roof is a coarse sandstone. In the latter case coal several feet thick may thin out to a few inches or to a knife-edge in a few hundred feet. For this reason calculations on the amount of coal in a given area are valueless except as a maximum, unless the area is thoroughly prospected by test holes.

For purposes of description four natural subdivisions of the quadrangle will be used, the northeast corner being first taken. In the area lying east of Beaver River and north of the Ohio this coal is of no commercial importance at present; for here the observed outcrops vary in thickness from 9 to 22 inches, averaging 17 inches. In some instances it is entirely absent beneath the Mahoning sandstone. It may also be slaty or separated by partings. Consequently it has scarcely been opened in this section of the quadrangle.

Section of Upper Freeport coal on Blockhouse Run.

	Inches.
Coal	8
Parting	1
Coal	5

In the area south of Ohio River and east of Raccoon Creek this seam is in places considerably thicker than in the region last described, but is less uniform. In this area it ranges from 1 or 2 inches of bituminous shale to 35 inches of coal and partings together. Obviously this variation greatly lessens the value of the coal. In general, however, the thin and irregular coal is restricted in this area to the river front and to the lower courses of Logtown, Elkhorn, and Moon runs. In these localities the Mahoning sandstone is well developed and often lies upon the coal, thus affording an example of the irregularity of coals having a sandstone roof. But near the heads of these streams and along Raccoon Creek it averages about 26 inches and has been worked by country banks for years.

In general the quality of the coal is good, but it may at times run shaly at the top or bottom or disappear altogether.

Section of Upper Freeport coal on Moon Run.

	Inches.
Coal, slaty	2
Coal	2
Shale	2
Coal, slaty	3
Coal	26

On Raccoon Creek, at the spur opposite the mouth of Frames Run, the following section seems to represent the Upper Freeport horizon:

Section of Upper Freeport coal on Raccoon Creek.

	Feet.	Inches.
Coal	0	0–6
Dark clay	0	3
Dark shale	10	0
Coal	0	12

These coals may both belong to the Upper Freeport horizon; for the lens of dark shale possibly represents a greatly enlarged parting separating two benches of the coal seam.

The area north of Ohio River and west of the Beaver carries westward some of the characteristics of the area first described. In the whole eastern portion of this section, including Brady Run basin and the river front as far as Sixmile Run, the Upper Freeport coal ranges from a knife-edge to 27 inches, averaging about 17 inches. In addition the seam is more or less slaty and parted. The western portion of the area, however, including the valleys of Brush and Sixmile runs and all runs west of the latter, contains more or less restricted patches of excellent coal. Here also the patchy occurrence of the coal is due to irregularities in the Mahoning sandstone roof, and for this reason conclusions as to the extent of minable coal in this area are of little value; but it may be said that the area includes irregular lenses of coal ranging between 30 and 56 inches in their thicker parts and thinning marginally to a few inches and in places to a knife-edge.

Upper Freeport coal sections.

	Inches.
BRUSH RUN.	
Coal, reported	56
BIELER RUN.	
Coal	53
ISLAND RUN.	
Coal	42
WOLF RUN.	
Coal	36
SIXMILE RUN.	
Coal	38–50

The coal in these localities is usually pure and free from partings, and is an excellent fuel.

The coal in the area south of Ohio River and west of Raccoon Creek also exhibits a lenticular habit. The lenses in this area, however, seem more extensive than in the one last described, but the coal, on the other hand, is not so clear as north of the river. In general, in all of the area west of Raccoon Creek where this coal is exposed—that is, in only the northward-facing valleys—this seam is much broken by partings and slaty coal. The benches of coal, however, are generally sufficiently thick to overcome this disadvantage. In this district the observed exposures range from 16 to 70 inches including partings.

Upper Freeport coal sections.

	Inches.
Mill Creek.	
Coal	17–41
Parting	3
Coal	4
Peggs Run.	
Coal, bony	5
Slate	5
Coal	39–50
Clay	¾
Coal	10
Haden Run.	
Coal	15
Parting	4
Coal	23–25
Squirrel Run.	
Shale and coal seams	12
Clay	36
Shale	96
Coal	20
Shale	20
Coal	19
Fishpot Run.	
Coal	36
Sandstone	48
Coal, impure	6
Raccoon Creek.	
Coal	33
Service Creek.	
Coal	12–26

As shown in the sections from Squirrel and Fishpot runs the partings in some instances become thick enough to produce a "split vein." The same phenomenon occurs in this seam near the mouth of Service Creek, on Island Run, and elsewhere. It leads at least to the belief that deposition of the coal-making material of this period was locally interrupted for considerable time, during which sandstone, shale, or clay was deposited. Thus a single coal seam may split, the benches becoming widely separated, but both still belonging to the same geologic horizon.

In the remainder of the area, including Raccoon Creek and its western tributaries, the coal is thinner and free from partings. In this basin the thicker portion averages 24 inches, but where observed it varies from 6 to 33 inches.

In this section of the quadrangle as a whole the Upper Freeport coal, when of minable dimensions, is of excellent quality and rarely inclined to be slaty. It has, therefore, been worked for many years for local consumption. Mill Creek is the only locality, however, where a regular mine is operated throughout the year.

The example of the Beaver Coal Company, in whose tunnel the coal pinched from 5 feet at the outcrop to 8 inches 200 feet in, can not too strongly impress future buyers with the necessity of thoroughly prospecting this area with test holes before purchasing.

COALS OF CONEMAUGH FORMATION.

The coal beds of the Conemaugh formation, except perhaps the Brush Creek coal, have already been given as much space as their importance deserves. They are thin, impure, and extremely variable in structure.

Brush Creek coal.—This coal is of no general importance, but it has been opened in one or two localities. Local pockets of it may be found in which it is thick enough to serve a very limited demand. Its position is, on the average, 95 feet above the Upper Freeport coal. In thickness the coal varies from a knife-edge to 20 inches, 6 to 12 inches being the usual exposure. Its horizon is frequently marked by a black shale which attends it.

Brush Creek coal sections.

	Inches.
South Branch Brady Run.	
Coal	6
Parting	(?)
Coal	11
Blackhawk.	
Coal	18

COALS OF MONONGAHELA FORMATION.

Pittsburg coal.—This is the only coal of the Monongahela formation which occurs in the quadrangle. About a dozen hilltops in the southeastern part show this coal, and it has been opened in all of them; but at the time of visit none of the pits were open for measurement. The coal is reported, however, to be 5 to 6 feet thick, including shale partings. Still, its character is not the best, owing to the fact that the thin rock covering exposes it to the deteriorating action of surface waters; consequently it is deeply weathered and generally considered of poor quality. A measured section taken just outside of the quadrangle, a mile west of Frankfort Springs, may be offered to show the relation of the two benches so characteristic of this coal:

Section of Pittsburg coal near Frankfort Springs.

	Inches.
Coal	8
Shale	12
Coal	54

CLAY.

Clay at present ranks first among the economic resources of the Beaver quadrangle. Coal, while of much less importance, was placed first in order that advantage might be taken of the descriptions.

Origin.—Clay as commonly understood originates from rocks containing minerals made up largely of alumina and silica. Of these minerals the feldspars, augite, hornblende, micas, etc., are most abundant. On the disintegration of such rocks the minerals decompose and the resulting products, together with fragments of the minerals themselves, form the basis of most clays. These materials are often washed away and deposited in favorable places, by water, much after the manner of river silts, and such deposits, whether fluviatile, lacustrine, or marine, are called sedimentary clay. This name may be applied to nearly all of the clay mined in the Ohio Valley in this State, and the manner of deposition explains the banding and the presence of grains of sand and other minerals in the clay. The regularly bedded deposits, such as usually occur in association with beds of coal, have received the general designation of fire clays, though they vary greatly in their refractoriness, that is, in their ability to withstand intense heat. The less pure and uniformly graded deposits in the present and abandoned channels of the streams, especially Ohio and Beaver rivers, are also sedimentary clay, which locally bears the name of "terrace clay." Similar deposits were also formed in temporary lakes of the Glacial epoch, and are sometimes designated "basin clay."

Clay of disintegration, which, instead of being washed away by water and deposited in distant places, remains near the parent rock, is called residual clay. Clay of this kind is found in the uplands, back from the rivers, but is not common in this region. It is, nevertheless, locally present in small quantities on the outcrop of limestone and certain shale beds, but since the upland rocks are of a generally sandy character, such clay is of little commercial importance and has never been utilized.

The fire clays of the quadrangle have experienced in their present situation a vastly longer and more eventful history than either the terrace or the basin clays. They have been exposed for ages to the leaching action of waters, and often to the absorbent action of a dense vegetation which grew upon them and now remains as coal seams. As a result of these conditions fire clay is poorer in alkalies and iron than most terrace or basin clays. In addition fire clay has been subjected to various other influences. Frequent periods of long-continued submergence finally covered it with hundreds of feet of water-laid deposits, and the dynamic forces which consolidated these into hard sandstones and shales must have effected a similar change in the clay. This clay, therefore, in point of structure and hardness is likely to differ from the terrace and basin clays, which are yet in their primitive state.

All these clays within the quadrangle are of either Carboniferous or Quaternary age. To the former belong the fire clays and to the latter the terrace, basin, and other clays.

CARBONIFEROUS CLAYS.

The workable bedded clays, or fire clays, are largely confined to the Allegheny formation. They occur at several horizons which are usually the same as those of the coals. The relative position of the beds is represented on the columnar section sheet, and the same order will be followed in this discussion.

Brookville clay.—This bed of clay, underlying the Brookville coal, is the lowest clay horizon exposed in the quadrangle and has the same extent as the coal. So far as known, nothing has been done toward exploiting the clay in this territory, and of its quality little is known, nor are analyses available from this vicinity. In other places, however, as in Indiana, Fayette, and Jefferson counties, it is a thick clay of good quality and has been extensively used.

Clarion clay.—The horizon of this bed is immediately under the Clarion coal, and it has therefore the same distribution as the coal. It is reported superior in many respects to the Lower Kittanning clay, not only because it contains a smaller percentage of iron and probably of alkalies, but because it will stand more firing and burn to a much whiter color. On the other hand, it resists weathering much more than the Lower Kittanning clay, which, clay workers believe, renders it less fitted for the manufacture of stoneware. On account of the unfavorable position of the outcrop except in small areas along Beaver River and Brady Run, it is not so easily available nor can it be so cheaply mined as higher clays. It has been opened only on Brady Run, where a common thickness of 4 to 5 feet is shown. No analysis of this clay is available, but it has been used with good results at Bolivar, Pa., in the manufacture of refractory materials.

Lower Kittanning clay.—This bed furnishes the best clay of this region. It is the source of practically all the clay mined along Ohio River in Pennsylvania and Ohio, as well as in West Virginia, where I. C. White says it attains its maximum thickness. It lies just under the Lower Kittanning coal and accordingly its horizon is not only above river level throughout the quadrangle, but is exposed for several miles on both Brady and Blockhouse runs. For all practical purposes the outcrop of the Lower Kittanning coal indicated on the economic geology map shows the entire crop line of this bed. Though for considerable distances along the outcrop this clay is covered by terrace deposits, it may, nevertheless, be reached at any point by excavations through loose gravels to depths varying from 30 to 60 feet. It is especially uniform, and, so far as known, is everywhere present at this horizon.

The quality of the clay in this seam varies in different parts of the bed; in general it is purer and more plastic in the upper portion, grading insensibly downward into a more siliceous, ferruginous, or sandy portion at the base. The various clay plants therefore remove different portions, according to the purpose for which the material is to be used. On the whole, the upper plastic portion, which ranges from 2 to 7 feet but is usually 7 feet in thickness, is removed for refractory materials of high grade, as fire brick, flue linings, etc., while the lower portion is mixed with the purer clay in varying amounts for crude products where colors and strength are needed, as in building brick, paving brick, sewer pipe, etc. As a result some mines remove 10 to 11 and sometimes 12 feet, which represents the extreme thickness of the clay.

As already indicated, this clay bed is extensively exploited, but chiefly near the railroads in the northeastern portion of the quadrangle. The first plant to use this clay was established forty-five years ago in the Beaver Valley, and from this beginning the clay industry has grown to include at present about 18 separate plants. The large development on this particular clay seam in preference to other beds is due to its superior quality and natural position. It never lies high up in the steep river bluffs, but on the contrary is low and easily accessible from the broad, flat river terraces and from the open, graded valleys of Brady and Blockhouse runs. The terraces offer admirable sites for manufacturing plants and are located conveniently near means of transportation, while the valleys also contain facilities for many large plants.

A comparison of the analyses of Beaver County clays with those of clays from the same beds in Ohio shows their similarity. The Lower Kittanning bed in Ohio is used by the finer pottery manufactories for saggers, also in part for the manufacture of yellow and Rockingham ware, and even for stoneware, besides sewer pipe, and fire, building, and paving brick. In a similar manner the Lower Kittanning clay of Beaver County supplies all the factories of pottery, hollow ware, and fire, building, and paving brick at New Brighton and the brick yards south of that place on Beaver and Ohio rivers.

Analyses of Lower Kittanning clays.

	1	2	3	4
SiO_2	60.190	61.980	56.37	61.86
Al_2O_3	24.230	23.880	29.62	26.02
Fe_2O_3	2.097	1.395	1.14	.63
TiO_2	2.345	1.830	....	....
CaO	.850	.040	.45	.19
MgO	.036	.281	.14	1.26
Alkalies	1.669	2.677	1.08	.31
H_2O (hygroscopic)	9.015	7.820	1.92	} 9.98
H_2O (combined)	....	....	8.71	
	100.432	99.903	99.43	100.25

1. Near Vanport, on Ohio River, New Brighton Township, Beaver County. Analysis by D. McCreath, Second Geol. Survey Pennsylvania, Rept. MM, p. 262.
2. S. Barnes & Co.'s clay, Bolesville, 1 mile north of Rochester, Beaver County. Analysis by D. McCreath, ibid.
3. Flint clays from Mineral Point, Ohio. Analysis by N. W. Lord, Geol. Survey Ohio, vol. 7, p. 221.
4. Haydenville, Ohio. Analysis by E. M. Reed, Geol. Survey Ohio, vol. 7, p. 139.

Middle Kittanning (Darlington) clay.—This bed occurs immediately under the Darlington coal, and is persistent throughout the region. It therefore has the same extent and lies covered or uncovered in the same manner as the coal, which has been described on a previous page. The clay, however, is rarely worked, as it is said to contain too many iron nodules for most wares. It is in fact distinctly ferruginous at Merrill, opposite Beaver, and on North Branch of Brady Run. The iron on weathering clouds the clay a rusty brown, and seems more evenly distributed through it than is the case with the Lower Kittanning, which carries most iron in its lower part. The usual thickness is 5 feet, sometimes 7 feet, and rarely 10 or 15 feet. In general extreme dimensions are accompanied by more than the usual amount of impurities. No analyses are available, nor does the clay seem to be in general use; its adaptability to practical purposes can therefore only be inferred. Still it is easily accessible and possibly may be used in conjunction with the Lower Kittanning clay for certain crude wares.

Lower Freeport clay.—The clay of this horizon, underlying the Lower Freeport coal, has the same line of outcrop and is equally variable in occurrence. It is entirely wanting in many places, but wherever observed the weathered surface shows a light-colored plastic clay of good character. This bed has not, however, except at one place, been exploited within the quadrangle, perhaps because it contains, as it is said, too much iron. It was once opened for the manufacture of sewer pipe on Blockhouse Run, where it is reported 12 to 14 feet thick. Such dimensions seem either to indicate an uncommon local development or to include some of the underlying shale, for the usual thickness is 3 to 5 feet. The best exposures were observed in the valleys of Beaver River and its tributaries and in the area south of Ohio River and east of Raccoon Creek. In these localities, however, the clay is not enough superior to the Lower Kittanning seam to overcome its disadvantageous position high above river level.

Upper Freeport clay.—This clay bed, averaging 177 feet above the Lower Kittanning coal, underlies the Upper Freeport coal and has, therefore, the same irregular and extended line of outcrop near the top of the river bluffs and along lateral streams. Since the horizon of the Upper Freeport coal is, for all practical purposes, that of the clay, the economic geology map will show in detail its extent. It will be seen, for example, to pass under Raccoon Creek near Independence, under Mill Creek at Hookstown, under Dry Run and Island Run near Ohioville, and under Brady Run near Blackhawk. Its extent on smaller streams can be similarly traced.

The Upper Freeport clay is more persistent than the coal above it and very often is overlain merely by thin papery layers of bituminous matter. Frequently the clay is pale blue and of excellent appearance, but in many places it holds nodules of iron which stain it and which must be removed before the clay can be used. As a rule the clay shows in outcrop 3 to 5 feet thick, but it varies somewhat from place to place, and occurrences of exceptional thickness should be noted. The usual dimensions are common north and south of Ohio River, but exposures are more numerous and better distributed in the northern portion. This area is also marked by having the only opening on the Upper Freeport clay bed known in the quadrangle. This is the mine of the Fallston Fire Clay Company on Brady Run, opposite Fallston. The mouth of the tunnel reveals about 10 feet of clay, but at places in the mine it is reported 22 feet thick. This unusual thickness is confirmed in a near-by ravine by an exposure of 20 feet of variegated and evidently impure clay shale. Other localities where this clay bed shows exceptional development are near Georgetown. Near the mouth of Mill Creek and also 2 miles above, at Stewart's mine, the clay becomes 14 feet thick, while along the river 2 miles east of Georgetown and on the lower course of Little Beaver Creek it is 7 feet. Still, even where exceptionally developed, the Upper Freeport clay can not be exploited to advantage so long as the Lower Kittanning seam, a clay commonly of greater thickness and superior quality, is much more accessible.

Bolivar clay.—The Upper Freeport clay in Beaver County, lying, as it does, immediately under the Upper Freeport coal, is not at the horizon of the famous Bolivar clay. The Bolivar horizon is in fact beneath the limestone which usually occurs just under the Upper Freeport clay, but in general this horizon is marked along Ohio and Beaver rivers by a less refractory shale. Logtown, Blockhouse, and Brady runs, however, furnish a few exceptions, and south of Phillis Island a clay occurs at the Bolivar horizon. It ranges from 2 to 5 feet in thickness, and in some places would make, as practical men believe, a fairly good fire brick, perhaps superior to that made from the Lower Kittanning clay. When the Upper Freeport limestone is absent both clays may lie together, as at Salina, Westmoreland County, without a distinct line of demarcation.

The infrequent clay beds of the Conemaugh formation will be discussed below under "Shales."

QUATERNARY CLAYS.

Terrace clay.—Within the quadrangle these clays are limited to the stream terraces, which have already been described as belonging genetically to two groups. Of these the higher and lower terraces bear generally impure, highly ferruginous, and frequently sandy clay which is chiefly adapted to the manufacture of common brick, though, when the clay is fine and homogeneous, pressed brick and even crude pottery are made. Often the clay is mixed with shale, producing excellent results. None of the lower terraces or flood plains, outside of the river valleys, are known to bear clay, though it is possible that others may be found on the tributary streams. But the higher terraces, belonging to the Parker strath, carry clay on both rivers and also on the lateral streams. For instance, the abandoned channel of Raccoon Creek, in which New Sheffield is situated, contains, it is said, considerable clay, but its character on burning is unknown.

For many years an important deposit has been worked on the higher terrace near New Brighton and Rochester. At the former place it was used for terra cotta and, by mixing with Lower Kittanning clay, for flower pots. It has the following composition:

Analyses of terrace clays.

	1	2
Sio_2	46.160	67.780
Al_2O_3	26.976	16.290
Fe_2O_3	7.214	4.570
TiO_2	.740	.780
CaO	2.210	.600
MgO	1.520	.727
Alkalies	3.246	2.001
Water	11.220	6.340
	99.286	99.088

1. Mendenhall & Chamberlin works, now abandoned.
2. Elverson & Sherwood works. Both analyses from Second Geol. Survey Pennsylvania, Rept. MM, p. 257. A. S. McCreath, analyst.

At present clays from the Parker strath are used only by the Elverson Pottery near New Brighton; while those from the flood plains were, until recently, utilized near Rochester in the manufacture of red building brick. A similar deposit, it is said, was also once used near Vanport.

Basin clay.—In other counties valuable "basin deposits" of glacial clays are worked. Being formed in local lakes, along the glacial margin, they are to be looked for near the terminal moraine, but so far as known, they have not been discovered in Beaver County. Such deposits must, from their origin, necessarily be impure and sandy, but screening and washing often produce a good quality of red clay for bricks, flower pots, and, if mixed with other clays, even for terra cotta.

SHALES.

Allegheny formation.—Clay, through different degrees of induration, passes insensibly into clay shale and shale. It has been found that a mixture of shale and clay gives a better brick, when great strength and lasting qualities are desired, as in paving brick, than fire clay alone. Accordingly, the shale overlying and underlying the clay beds in the Allegheny formation is used in the brick industry of this region. Generally the shale most extensively employed is that nearest the Lower Kittanning clay. For example, the Fallston Fire Clay Company uses the shale between the Lower Kittanning clay and the Clarion coal; the Vanport Brick Company uses the same shale and also that between the Darlington and Lower Freeport coals. Analyses of samples from near-by localities show that still higher shales might probably also be utilized if necessary. The drab shale sometimes present under the Upper Freeport clay, for instance, appears to be worth prospecting. But it is a recognized fact that from shale alone of the Allegheny formation no good colored brick have been made.

Analyses of clay and shale.

	1	2	3
SiO_2 (total)	58.20	57.45	57.15
Al_2O_3	22.47	21.06	20.26
Fe_2O_3 (?)	5.63	7.54	7.54
CaO	.62	.29	.90
MgO	.98	1.22	1.62
K_2O	3.08	3.27	3.05
Na_2O	.42	.39	.58
H_2O (uncombined)	1.65	1.90	2.70
H_2O (combined)	6.15	5.90	5.50
	99.20	99.02	99.30

1. Shale and fire clay mixed, from the T. B. Townsend Brick Company, Zanesville, Ohio. Freeport shale and Kittanning fire clay. N. W. Lord, analyst.
2. Shale from the Ohio Paving Company's mine at Darlington, Ohio. Lower Kittanning horizon. Average samples. N. W. Lord, analyst.
3. Shale used by Bucyrus Brick and Terra Cotta Company, mined at Glouster, Ohio. Horizon of Cambridge limestone (near Ames limestone). Average sample. N. W. Lord, analyst.

Conemaugh formation.—This formation caps all the high country back from the rivers and accordingly forms the heads of most ravines, where slopes are gentle and débris accumulates, so that clean exposures are rare. Few if any beds of fire clay, therefore, such as occur in the Allegheny formation, were observed. Many of the conspicuous residual clays and variegated shales, however, may be found valuable for brickmaking. The most common varieties are yellowish, drab, or bluish gray, and all show evidence of more or less iron, ferrous in fresh shale and ferric in weathered. Red shales are not very abundant and where they occur have generally disintegrated on the outcrop to red residual clay. Analyses of many such shales compare favorably with those of high-grade clays, and some of them have been used for paving brick and terra-cotta ware at Glouster and elsewhere in Ohio. Building brick, too, have recently been manufactured from shales at Pittsburg. In fact, nearly all the shales except the very sandy types may be adapted to the manufacture of colored brick. Of the fifty-seven clay yards mentioned in Hopkin's report, over two-thirds use shale, wholly or in part, making chiefly red brick, but also paving and pressed brick.

PETROLEUM AND NATURAL GAS.

PETROLEUM.

Oil has been produced in this territory for about forty-five years. During that period several pools have been opened and practically drained. These are in the Smiths Ferry, Shannopin, and Hookstown fields. Few large wells, however, have been secured in the Beaver quadrangle in recent years, and the production is now waning.

Smiths Ferry field.—This was the first pool discovered in this area. Long before 1860, it is understood, oil oozed out on Ohio River and was subsequently found in the Pottsville sandstone. This led to deeper drilling and the famous Berea sandstone, locally known as the Smiths Ferry sand, was reached (Poe well, detailed section sheet) and produced large quantities of oil in the eighties. Indeed, some of these wells are still pumped, but most of them have been abandoned. In recent years the field has been extended eastward to the head of Wolf Run, and many profitable though not large wells have been found.

Shannopin field.—This field lies near Shannopin, on Ohio River, and extends westward across the southeast corner of the quadrangle. The first wells which tapped that part of the pool lying within this area were drilled about 1883, but large wells did not come in before the fall of 1886. Thereafter the field became prolific, some wells producing from 400 to 2000 barrels per day; but in 1889 it began to wane and at present, though some wells are still pumped, no new wells are being drilled. The oil-bearing stratum in this field is the Hundred-foot sand (wells Nos. 30, 31, detailed section sheet), locally named Shannopin sand, which occurs 200 to 300 feet below the Berea and also produced the New Sheffield gas pool. It is interesting to note that the upper portion of this bed is hard, siliceous, and perhaps impervious, while the lower part, or "pay," is an open, mealy or pebbly sand.

Hookstown field.—When the Shannopin field began to wane, in 1889, the Hookstown pool was first opened, though unsuccessful drilling had been previously done on its borders. The wells in this pool have never been large producers, probably none yielding over 200 barrels per day. The old field is gradually weakening, but in 1901 some excitement was aroused by the advent of a few 50-barrel wells about a mile north of Hookstown. The producing sand of the field is the Berea (Smiths Ferry sand), and the "pay," which is usually found 5 to 10 feet below the top of the sand, is an open, mealy rock. When the entire stratum is close and compact, it is barren.

NATURAL GAS.

Gas has been produced in the Beaver quadrangle in considerable quantities for about twenty years, and the wells have included several of exceptional volume and pressure. The most productive field lies in the vicinity of New Sheffield and extends southwestward through Independence and Hanover townships.

New Sheffield pool.—This was the largest and most important gas field in the quadrangle. Profitless testing had been carried on previous to 1884, but this field was first opened in the summer of that year, and during the following three years most of the wells in this field were driven. Many wells gave an initial rock pressure ranging from 500 to 600 pounds and a minute pressure of 250 to 480 pounds. After two years these pressures still remained between 350 and 450 pounds and 215 and 375 pounds respectively. At this time, however, the Shannopin oil pool was opened and the escaping oil rapidly reduced the pressure of the gas. At present this field is practically abandoned and few if any wells are being put down. The gas in this district comes from the Venango oil sands, particularly from the Hundred-foot sand, which is also the productive stratum of the Shannopin oil field.

Scattered wells.—Many scattered wells have been drilled for gas or oil at several localities in the quadrangle. Those put down to the Berea at Georgetown and 2 miles to the east along the river have been uniformly of little value or dry. At Industry much salt water was encountered at 310 feet and a show of oil and gas in the Berea, and at the mouth of Raccoon Creek a few barrels of oil were taken from the Hundred-foot. Wells at Monaca and Rochester once provided gas for the tumbler works, together with small amounts of oil, while those near the mouth of Brady Run furnished a little gas with a trace of oil, but the chief product was salt water. Still other wells at Beaver Falls formerly gave sufficient gas for forging and tempering cutlery. A few wells 2 miles east of New Brighton, others north of Big Traverse Creek in the Hundred-foot, and some near Brush Run in the Berea were, so far as known, at least unprofitable and probably dry.

CONCLUSIONS.

The above facts in regard to oil and gas pools in this area, studied both by themselves and in relation to geographic distribution, are confirmatory of well-known geologic principles. They show that pools of oil or gas when tapped begin to wane after a few years of constant production and finally become unproductive except for a few pumping wells. This is apparently due both to the exhaustion of supply and to the resulting loss of pressure. In regard to the producing sands, it is seen that the same stratum is not the producer in all fields. Several causes may be brought forward to explain this: The sands are no doubt more or less lenticular and may therefore be present in some localities while absent in others; or when present they may be too fine and compact to contain oil and gas in paying quantities; or though coarse and open, these products may never have reached them or remained in them, as will be noted below. This brings us to the discussion of a third conclusion, a marked relation between the distribution of oil and gas and the structure of the rocks.

A study of the structure map with regard to the position of the oil and gas fields of this quadrangle shows that the Hookstown field lies on the sides of an arch near Mill Creek, the Smiths Ferry pool on the flanks of the Fairview dome, and the Shannopin field for the most part on the limb and bottom of a shallow syncline, with the New Sheffield gas pool above it on the steep side of a flat anticline. Relations like those at Smiths Ferry and Hookstown were early recognized by operators and geologists and have been formulated in what has become known as the anticlinal theory regarding the occurrence of oil and gas. Salt water is often associated with oil and gas in the same area, and these three products are known to have among themselves a definite relation of occurrence. That relation seems to depend on their respective densities, according to which they apparently arrange themselves in the containing stratum. On the flank of a syncline or anticline, therefore, salt water should occur lowest of the three, then oil, then gas at the top. Oil probably rests upon the surface of a denser liquid, salt water, when present, and gas upon oil. Gas being very much lighter than oil, may occupy the entire inclosing stratum except where the closeness of the sand or a bend in the rocks forbids further expansion. The height of the salt water and the consequent position of the oil on the flank of an anticline are said to depend on the amount of water present. If the sand holds much water, oil should occur high on the flank; if little water, low on the flank; if none, near the bottom of the syncline. The last condition would explain the relations in the Shannopin field.

It therefore follows that if a well is driven for oil and salt water is struck, the well should have been drilled structurally higher up. Also, if gas is found, oil may be struck by drilling structurally lower down. Finally all things being equal, gas seems likely to occur in the summits of domes and anticlines. That oil follows the water line in this region has not been definitely proved. In some sands it is believed that it does, but in others this fact is not clear from the information at hand. In the case of the Berea, oil probably follows the water line, but in the Hundred-foot little or no water seems to be present in this area. By bearing in mind these general relations between structure and product and between the different products themselves, which have been worked out by I. C. White, Orton, Griswold, and others, not only may new fields be found out, but intelligent prospecting for gas or oil may also be carried on.

POSSIBLE NEW FIELDS.

The notes under this heading are merely suggestions based on the above facts considered in their relation to the structure worked out in this quadrangle. The localities here given are therefore only those which the writer believes to be the most promising places for testing, if tests are to be made anywhere.

With regard to oil in the Berea, the area north of Ohio River between the 940- and 1040-foot structure contours and between the eastern extension of the Smiths Ferry field and Brady Run seems a promising one. In this area the southward-pointing structural spur just east of Sixmile Run may be the most favorable spot. The territory lying southeast of Hookstown, near or below the 1180-foot contour, and extending from half a mile from the western edge of the quadrangle eastward along Service Creek, should also be tested. The westward extension of the Shannopin field in the Hundred-foot between the 980- and 1020-foot contours, may possibly be found in the synclines at the mouths of Little Service and Little Traverse runs. Some dry holes, however, have been put down on the intermediate anticline. Possibly some of the other synclines of the area contain oil in the Hundred-foot.

As to gas, prospect wells on the summits of the domes of the central dome-basin region from McCleary to Monaca might bring good results, though no great yield should be expected. The structural spurs radiating from these domes may also contain gas, especially those from the McCleary dome toward the New Sheffield gas pool. If gas be found in the domes and spurs, judicious drilling to the Berea on the sides of the domes might tap small oil pools. The dome at the head of North Branch of Brady Run should also be tested for gas. In general, if salt water is found in any well, oil may perhaps be found structurally higher—that is at the salt-water level—and gas still higher up, above the oil line. When the salt-water limit has been established it should in general be followed at nearly the same structural elevation in the same basin unless disturbed by the condition of the sand.

The above suggestions, however, are of no value if the sand supposed to contain oil or gas is barren or of such a character as to preclude their presence. These facts, unfortunately, can be ascertained only by sinking the drill.

drifts. Scarcity and unavailability, therefore, make limestone of little value throughout this area.

Vanport limestone.—This is the thickest and most largely exploited bed of limestone in the quadrangle, but because of its lenticular occurrence, which is common to all the limestones of this region, it is not everywhere sufficiently thick for working. It is characterized by its wealth of fossils, and, when thin, by cone-in-cone structure. As shown on the detailed section sheet, its position averages 65 feet below the Lower Kittanning coal. Hence, as compared with the coal it has a less extended outcrop, which is restricted to the deeper valleys (Ohio and Beaver rivers and Brady Run), and is covered more deeply and more often by gravel terraces.

At Vanport the type section is 19 feet thick, and is given below:

Section of Vanport limestone at Vanport.

	Feet.	Inches.
Blue limestone	4	0
Shale	0	4
Blue limestone	8	0
Shale	0	6
Limestone	0	6
Shale	2	2
Hard ferruginous limestone	1	0
Shale	0	6
Fossiliferous limestone	2	0

The limestone beds differ very much both in color and quality. The first 9 inches are too impure to burn and are therefore stripped off and thrown away. The next 3 feet, together with the 8-foot layer below the shale parting, are burned for lime. The 3-foot portion is a bluish-gray rock in all of the quarries here and is extremely brittle, while the 8-foot layer, which is light gray or blue in color, is the purest and most compact limestone in the section. This portion burns to a very good white lime. The thin beds of the section are not used for lime.

West of Vanport the limestone seems extremely variable, ranging from zero to 16 feet. A good thickness of 5 to 8 feet, however, is exposed between Vanport and Fourmile Run. Though the horizon remains above river level to the edge of the quadrangle, it is not seen again to the west, except south of Montgomery Island, where it is 16 feet thick. The terraces at Shippingport, north of Phillis Island, and at Georgetown cover the horizon with unconsolidated river gravels.

East of Vanport the limestone attains considerable thickness only at Fallston, where it is 10 feet thick, but on the opposite side of Brady Run it thins to 18 inches. It maintains about this thickness throughout Brady Run, where exposed, and on upper Beaver River, but east of New Brighton and to the south on both sides of the river it is 3 to 4 feet thick. At Monaca, however, though the rocks between the Lower Kittanning coal and river level, a distance of 60 feet, are uncovered, the Vanport limestone is not revealed. It may be below water level.

The localities where this limestone is most accessible for mining are along its outcrop on the north bank of Ohio River and in Beaver Valley. The occurrence south of Montgomery Island is practically inaccessible. On the whole the Vanport is the only bed in the quadrangle which is in places pure enough to produce good lime or to be used in fluxing.

Lower Freeport limestone.—This is the next higher limestone which is of any value within the quadrangle and its horizon is a few feet below the coal from which it is named. Because of the southward dip of the rocks, this horizon is exposed chiefly in valleys of the northern half of the quadrangle, those in the southern portion incising it little. Compared with the Vanport limestone it is very impure, being usually a hard, fine-grained, nonfossiliferous rock of buff color, and it is of little value in the greater part of the quadrangle. Its common mode of occurrence is that of isolated lenses and it is therefore absent in many localities. Indeed, within this area only three lenses of workable dimensions were found. Of these the most extensive lies along the northern edge of the quadrangle, including Beaver Valley in the vicinity of Beaver Falls, Brady Run, and the northward-facing valleys in the northwest corner of the quadrangle. In this general area the limestone ranges in thickness from 3 to 9 feet, averaging 6 feet. The outcrops of two smaller lenses were discovered—one northwest of Smiths Ferry in the lower course of Island Run and the other south of Monaca in the run west of Hog Island. In both runs the limestone occurs from 4 to 5 feet thick.

This limestone is in places pure enough to produce lime for fertilizer, and for such limited purposes it may be quarried in almost any locality where it occurs, especially in the northwest portion of the quadrangle.

Upper Freeport limestone.—This limestone lies a few feet below the Upper Freeport coal and, like the Lower Freeport limestone, occurs chiefly in the northern portion of the quadrangle. It is usually impure, being buff colored or ferruginous, but occasionally it is a bluish rock of pure quality. In many cases it is brecciated and generally it is nonfossiliferous.

This limestone, following the usual habit, occurs in lenses, but unlike the other limestones these lenses seem smaller and more numerous or are connected by very thin beds. Thus on the line of outcrop stretches of limestone thick enough to be of economic importance alternate in short distances with thin beds or with horizons in which it is absent.

In general, localities likely to reveal thicknesses worth exploiting are Blockhouse and Brady runs, 2 to 3 feet; the northward-facing valleys along the northwest margin of the quadrangle, 4 to 6 feet; head of Dry Run, 2 to 7 feet; west of Hog Island, 3 feet; Monaca, 5 feet; and mouth of Raccoon Creek, 4 feet. Though the limestone may be as thick as this at other localities where it is concealed, all other observations recorded its absence or thinness.

This bed, like the Lower Freeport limestone, occurs high in the rocks and hence is not conveniently accessible along the steep sides of deep valleys like those of Ohio and Beaver rivers. Near the heads of small streams, however, it may be easily approached.

Wherever the purer blue rock is found it may burn to a fair strong lime, but elsewhere it is good only for common fertilizer, if for that.

Local limestone.—This bed occurs as small lenses in the Mahoning sandstone about 30 feet above the Upper Freeport coal, and evidences of it have been seen at several places in the quadrangle. A valuable thickness, however, was observed only east of Rochester, where it is 5 to 8 feet. Here it has the bluish-gray color of a remarkably pure limestone and has been quarried to some extent. In other instances it is often impure and ferruginous, outcroping as a thin bed or a few fragments.

Ames limestone.—The position of this bed is nearly midway between the Upper Freeport and Pittsburg coal seams, averaging 290 feet above the former. It therefore occurs chiefly in the southern portion of the quadrangle, and, being a very persistent and characteristic stratum, it is outlined on the economic geology map as a key rock to the structure. It is characterized by a dark-blue or greenish-gray color and a granular surface which resembles sandstone and is rough with protruding pipestem-like fossils or crinoid stems.

It occurs as a very persistent bed ranging from 2 to 6 feet in thickness, but averaging 3 feet. It is accessible over large areas in the southern part of the quadrangle by stripping off the cover at the heads of runs with gentle grade. It is in itself of little economic importance except for fertilizer, because, being impure it does not burn well. Picked fragments, however, containing large numbers of crinoid stems make a good quality of cement for limited household purposes.

Oil and gas wells in Beaver quadrangle.

Number on map.	Approximate elevation.	Name.	Owner.	Authority.	Producing sand.	Depth to pay.	Depth to Burgoon.	Depth to Berea.	Depth to Hundred-foot.	Total depth.
	Feet.					Feet.	Feet.	Feet.	Feet.	Feet.
1	1027	Irons No. 1	Citizens' Gas Co	Wm. Ritchie	Hundred foot		750		1458	2659
2	800?	Bridgewater No. 1	Bridgewater Gas Co	J. F. Carll	do	1257			1250	1257
3	907	W. M. Calvert No. 2		Wm. Long	do		400	1340?		1365
4	1150	James Johnston No. 1	Bridgewater Gas Co	J. F. Carll	do		850	1240	1406	1490
5	1123	Chas. Eacher No. 1	Forest Oil Co	Forest Oil Co	do				1690	1720
6	1138	Hood No. 1	do	do	do				1695	1725
7	1252	A. P. Morrow No. 11	do	do	do				1795	1860
8	1129	Rachel Stone No. 8	do	do	do				1678	1711
9	1150	Solor 26	do	do	do	1711			1694	1721
10	1100	R. M. Cartney No. 2	do	do	do				1688	1746
11	1240	Wm. Purdy No. 2	do	do	do (?)				1727 (1827?)	1772
12	990	Wm. Morrow No. 2	do	do	do	1578			1574	1596
13	1170	Cynthia Wallace No. 1	do	do	do				1762	1795
14	980	Jas. Miller No. 1	do	do	do				1589	1600
15	1190	R. A. and F. G. Reed	Ohio Valley Gas Co	Ohio Valley Gas Co	do			1664		1725
16	1120	Blackledge No. 1	Forest Oil Co	H. H. Mills	Berea			1098		
17	1144	Josephine Glenn	do	Forest Oil Co	do	1110		1100		1126
18	1015	J. H. and M. J. Brown No. 1	do	do	do	980		967		1000
19	777	Capt. Calhoun		J. M. Critchlow	do	704		704		
20	1176	Heineman No. 1		do	do			1030		
21	1226	John Ferguson No. 5	Ferguson Bros	H. Ferguson	Burgoon		800			1145
22	1070	L. R. Davidson No. 1		F. Neely	Berea	946		940		959
23	1139	Wm. Graham		Wm. Hayes	do	982	587	975?		995
24	1162	Geo. Anderson			do			969		
25	1141	T. B. Hunter		R. R. Hice	do (dry)		800	950		1015
26	760	Chas. Deens	Oak Oil Co. (?)	S. E. Duff	Hundred foot (?)			715	964?	1410
27	710	Rochester Brewing Co	Rochester Brewing Co	Rochester Brewing Co.	(Dry ?)		325	695	927	1319

LIMESTONE.

Limestone is not very abundant in this region, nor is much of it favorably located for working. The Allegheny formation carries the thickest beds, and since this formation is generally overlain by the Conemaugh rocks, the most abundant limestones occur in the valleys of streams which incise the Allegheny, and are least accessible by methods of stripping. Except for short distances on the outcrop mining must generally be carried on by drifts.

SANDSTONE.

Sandstone is the only rock suitable for building in this territory, and while it is abundant not all of the beds can be used for this purpose. As a rule, Coal Measure sandstones are suitable only for rough masonry and very few are regular enough in their bedding to supply dimension stone. The only beds which have been quarried in a commercial way are those of the Allegheny and Conemaugh formations. These two formations contain the well-marked sandstones of the Morgantown, Mahoning, Butler, and Freeport beds. The position, extent, character, and variability of these beds are discussed in a previous section.

The Freeport sandstone, which is the lowest and most accessible of these beds, is best developed below Industry, where it has been largely quarried for railroad purposes. This is the only place within the quadrangle where this bed has been worked; owing to its hard and micaceous character, which makes dressing in some directions difficult,it is seldom used for dimension stone.

The Butler sandstone is a very compact, coarse, yellowish-white rock and makes a fine building stone. It has been somewhat extensively exploited along the rivers in the eastern part of the quadrangle, but in the western part it is shaly or replaced by or merged into the Freeport sandstone. Many old quarries, opened years ago, still remain as scars on the hillsides east of New Brighton, on Blockhouse Run, and on the west bank of Beaver River.

The Mahoning sandstone is the bed which has been most extensively worked within the quadrangle. It resembles very closely the Butler sandstone, being coarse grained and yellowish to brown in color, but, unlike the Butler, it frequently contains small pebbles of quartz. Being once highly prized as a building stone, it was for that purpose largely quarried in the eastern part of the quadrangle. But unfortunately for this industry, the greater cheapness and convenience of concrete, combined with an equal durability, has supplanted sandstone for many purposes. In the western part of the quadrangle, along Ohio River, the Mahoning sandstone is conglomeratic and perhaps for this reason, together with its unfavorable position, has never been much worked in that locality. Many remains of old quarries on this bed, however, may be seen on the river bluffs east and west of Monaca, north of Rochester, and on Blockhouse Run. North of Rochester one or two quarries were still active at the time of visit, but most of them were idle.

The Morgantown sandstone is present only in the southern part of the quadrangle, where in places it has a large development. In some localities in Pennsylvania it is a very durable stone, but in this field its friability increases on exposure and it is not exploited. It is possible, however, that on prospecting compact portions of this stratum might be discovered; in this case it would make a good building stone, for it has the requisite color, grain, and quarrying qualities.

SAND.

No sand suitable for the manufacture of glass is obtained in the Beaver quadrangle. A systematic search, however, on the Kansan and Wisconsin terraces of the Beaver quadrangle might reveal pockets of sand of considerable value similar to those at Bellevernon, on Monongahela River.

SOIL.

The lack in this quadrangle of the broad-valley type of stream, affording much bottom land for agriculture necessarily limits farming districts mainly to the uplands. These, as we have seen, are capped by the Conemaugh formation, containing chiefly shale and sandstone. Limestone beds are particularly scarce in this formation, and, except the Ames and the "local" limestones, practically no bed of thickness and extent sufficient for fertilizer is known. The soils of the uplands, being either clayey or sandy, are essentially without a natural fertilizer. It seems, therefore, that under the present agricultural practice the land receives the least of that which it most lacks; for very little lime is either burned or applied as a fertilizer. Under another section is given a description of limestone beds which might be used to some extent for this purpose.

Soil of this character does not naturally lend itself to heavy crops and clearly seems most suitable for stock raising.

TRANSPORTATION.

Only one stream in the quadrangle—Ohio River—is navigable, and even this usually during only the spring and fall months. It is hoped that the dams now being built by the Government across the river will furnish a boating stage, whose permanency will be most advantageous to the industries of the Ohio and Beaver valleys, for then steamboats and coal barges can make the passage from Pittsburg to places on lower Ohio and Mississippi rivers throughout the year, except when prevented by ice. The entire system of dams will not be completed for many years, but the construction of dams from Pittsburg to the State line will render that portion of the river at once available. Beaver River, not itself navigable, is paralleled by the Pittsburg and Erie Canal, which formerly furnished transportation facilities to this valley; but owing to the introduction of railways the canal has been allowed to fall into disuse. Along the rivers the quadrangle is well supplied with railroads, but not in such a manner as to allow the advantages of competitive rates. The Pittsburg and Lake Erie Railroad occupies the west bank of both Beaver and Ohio rivers; the east bank is followed by the main line of the Pennsylvania Railroad, whose branch also runs along the right bank of the Ohio, but the south bank, though rich in latent resources, is as yet untouched by railways.

WATER POWER.

The streams of this region have steep grades and rather narrow valleys which are easily spanned by dams, so that considerable water power can be economically developed. A practical example of such transformation of stream energy into available water power is that of Beaver River. Other streams which have a flow of water the year round, such as Brady Run and Raccoon Creek, may also be made to furnish considerable power for mills, electric lighting, and other purposes.

March, 1905.

U. S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR
STATE OF PENNSYLVANIA
REPRESENTED BY
TOPOGRAPHIC AND GEOLOGIC
SURVEY COMMISSION

TOPOGRAPHY

PENNSYLVANIA
BEAVER QUADRANGLE

LEGEND

RELIEF (printed in brown)

- Figures (showing heights above mean sea level instrumentally determined)
- Contours (showing height above sea, horizontal form, and steepness of slope of the surface)

DRAINAGE (printed in blue)

- Streams
- Lakes and ponds
- Reservoirs

CULTURE (printed in black)

- Roads and buildings
- Churches and school houses
- Private and secondary roads
- Railroads
- Street railroads
- Bridges
- Ferries
- Dam and lock
- County lines
- Township boundary lines
- City, village and borough lines
- Triangulation stations
- Bench marks

H. M. Wilson, Geographer in charge.
Triangulation by S. S. Gannett and D. H. Baldwin.
Topography by Frank Sutton, E. B. Clark, and J. D. Forster.
Surveyed in 1901.
SURVEYED IN COOPERATION WITH THE STATE OF PENNSYLVANIA.

APPROXIMATE MEAN DECLINATION 1902.

Scale 1/62500

Contour interval 20 feet.
Datum is mean sea level.

Edition of Mar. 1894, reprinted Sept. 1905.

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

STATE OF PENNSYLVANIA
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AREAL GEOLOGY

PENNSYLVANIA
BEAVER QUADRANGLE

LEGEND

SEDIMENTARY ROCKS

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

QUATERNARY

Recent

Qal — Alluvium
(in flood plains of present streams)

Pleistocene

Qlg — Later glacial gravel
(outwash sand and gravel of distant origin on lower terraces; probably of Wisconsin age)

Qlt — Lower terrace gravel
(silt, sand, and bowlders of local derivation; probably of Wisconsin age)

Qeg — Earlier glacial gravel
(outwash sand and gravel of distant origin on higher rock terraces; probably of Kansan or pre-Kansan age)

Qcm — Carmichaels formation
(clay, sand, and bowlders of local derivation on higher terraces and in abandoned channels; probably of Kansan or pre-Kansan age)

CARBONIFEROUS

Pennsylvanian

Cm — Monongahela formation
(coarse sandstone and shale with the Pittsburg coal at the base)

Cam / Ccm — Conemaugh formation and Ames limestone lentil
(sandstone, shale, and limestone, with a few small coal beds)

Ca — Allegheny formation
(shale and massive sandstone with beds of limestone and valuable seams of coal and fire clay; Upper Freeport coal at the top)

Cpv — Pottsville sandstone
(coarse massive white sandstone and fine conglomerate)

H. M. Wilson, Geographer in charge.
Triangulation by S. S. Gannett and D. H. Baldwin.
Topography by Frank Sutton, E. B. Clark, and J. D. Forster.
Surveyed in 1901.

SURVEYED IN COOPERATION WITH THE STATE OF PENNSYLVANIA.

TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1902.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 20 feet.

Datum is mean sea level.

Edition of Nov. 1905.

Geology by L. H. Woolsey,
assisted by F. G. Clapp and M. I. Goldman,
under the direction of M. R. Campbell.
Surveyed in 1902-03.

SURVEYED IN COOPERATION WITH THE STATE OF PENNSYLVANIA.

U. S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR.
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STRUCTURE AND ECONOMIC GEOLOGY

PENNSYLVANIA
BEAVER QUADRANGLE

LEGEND

SEDIMENTARY ROCKS

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

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Ca — Allegheny formation *(shale and massive sandstone with beds of limestone and valuable seams of coal and fire clay; Upper Freeport coal at the top)*

Cpv — Pottsville sandstone *(coarse massive white sandstone and fine conglomerate)*

Known productive formations

Coal outcrops *(Upper Freeport, uf, of probably workable thickness; Lower Kittanning, lk, overlying important fire clay; Pittsburg, pb)*

1000 — *Structure contours drawn on top of Ames limestone* *(contour interval is 20 feet; datum is mean sea level)*

900 — *Structure contours drawn on roof of Upper Freeport coal* *(290 feet below top of Ames limestone; contour interval is 20 feet; datum is mean sea level)*

⚒ *Mines and quarries*
C, clay; B, building stone; L, limestone

x *Coal prospects and local banks*
● *Wells drilled for oil*
● *Wells drilled for gas*
⊙ *Wells drilled for oil or gas*

Numbered wells are referred to in text.

H. M. Wilson, Geographer in charge.
Triangulation by S. S. Gannett and D. H. Baldwin.
Topography by Frank Sutton, E. B. Clark, and J. D. Forster.
Surveyed in 1901.
SURVEYED IN COOPERATION WITH THE STATE OF PENNSYLVANIA.

TRUE NORTH
MAGNETIC NORTH
2½°
APPROXIMATE MEAN DECLINATION 1902.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 20 feet.
Datum is mean sea level.
Edition of Nov. 1905.

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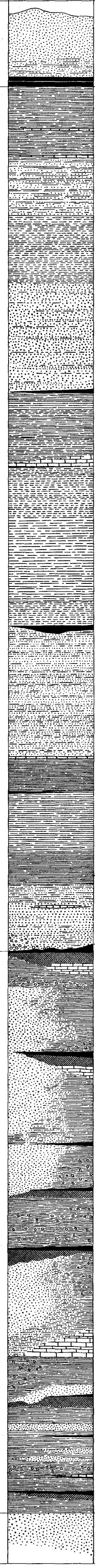
COLUMNAR SECTION

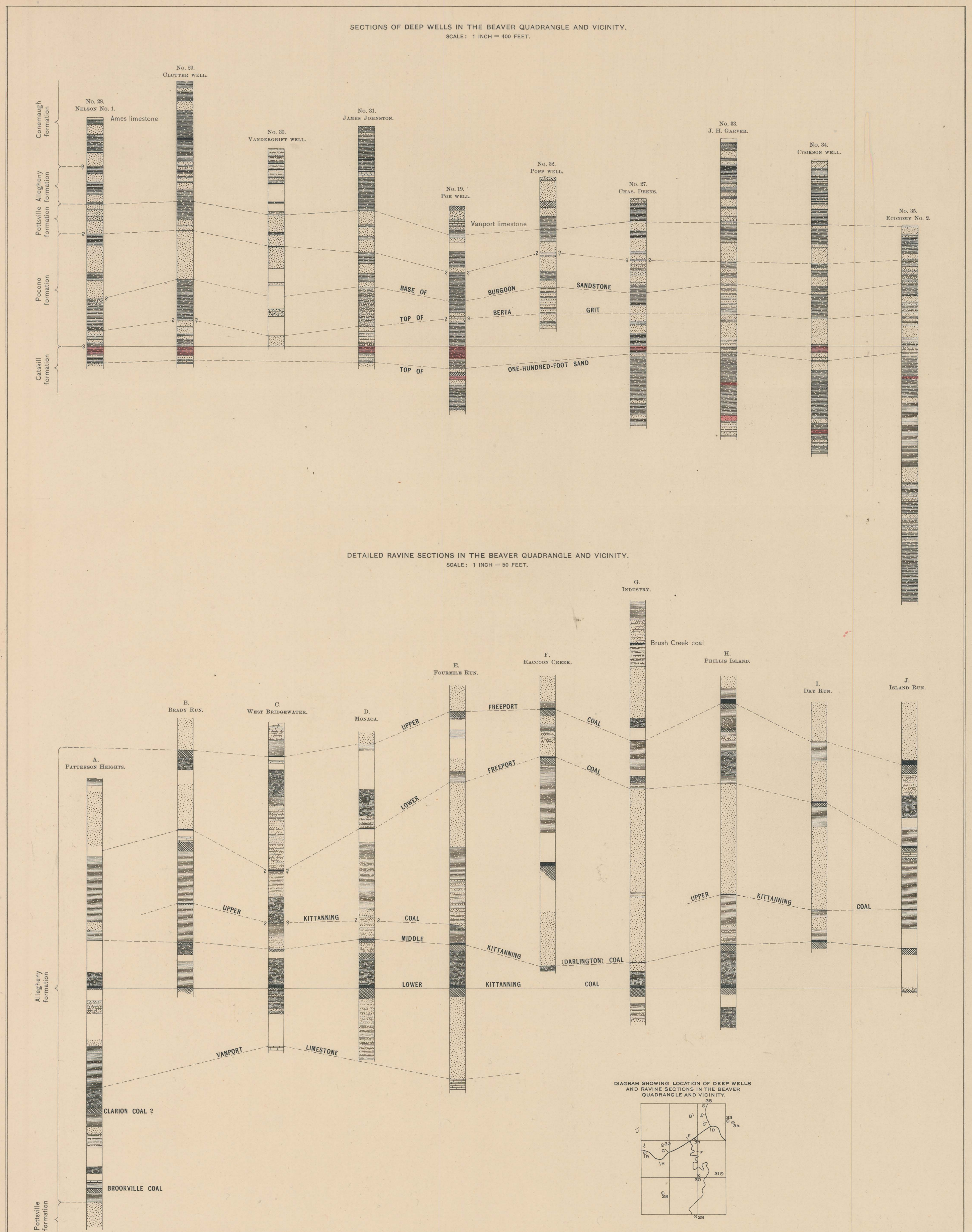
GENERALIZED SECTION FOR THE BEAVER QUADRANGLE.

SCALE: 1 INCH = 50 FEET.

System.	Series.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Names of Members.	Character and Distribution of Members.	General Character of Formations.
CARBONIFEROUS	PENNSYLVANIAN	Monongahela formation.	Cm		35+	Pittsburg coal.	About 6 feet thick, with medial parting. Of little importance because it caps only a few hills in the southeast corner of the quadrangle.	Sandstone and shale overlying a coal seam of excellent quality where thickly covered.
		Conemaugh formation.	(Cam) Ccm		520±	Pittsburg limestones.	Thin beds separated by shale. Unimportant in quadrangle.	Shale and coarse sandstone with occasional thin beds of limestone and coal. The upper portion is prevailingly sandy, while the lower part contains mostly shale. Some prominent beds of green and red shale give a distinct color to the soil on their outcrop.
						Morgantown sandstone.	Coarse and thick bedded, but in places becomes flaggy sandstone and shale. Averages 65 feet thick.	
						Elk Lick coal.	A coal of good quality, but very irregular in occurrence. Varies from 0 to 3 feet thick.	
						Ames ("Crinoidal") limestone.	Greenish-gray, impure limestone, 2 to 6 feet thick, with many crinoid plates.	
						Platt (?) coal.	Unimportant.	
						Bakerstown coal.	Lenticular, in places cannel coal. Varies from 0 to 7 feet thick.	
						Brush Creek limestone.	A dense bluish-black limestone of no importance.	
						Brush Creek coal.	Thin and unimportant, probably made up of lenses not always at the same horizon.	
						Mahoning sandstone.	Shaly to coarse flaggy sandstone, locally heavy and conglomeratic and containing near top lenses of limestone 1 to 8 feet thick.	
		Allegheny formation.	Ca		280-345	Upper Freeport coal, clay, and limestone.	Coal of good quality, but irregular, from 0 to 53 inches thick, and often absent. Pale-drab clay; contains some iron. Usually 4 to 5 feet thick, but locally much thicker. Limestone buff to blue, of variable purity, often brecciated and generally nonfossiliferous. Ordinarily 3 to 5 feet thick. Can be burned for fertilizer. A clay of variable thickness rarely occupies the Bolivar horizon beneath the limestone.	Shale, sandstone, fire clay, coal, and limestone. Sandstone predominates, but in places becomes thin bedded and shaly. Coal beds are promising in small areas, but at present are not much exploited. Limestones, usually thin, locally develop important thicknesses. Fire clay is generally present and of great value, particularly beneath the several coal seams.
						Butler sandstone.		
						Lower Freeport coal, clay, and limestone.	Coal generally unimportant and frequently absent, but well developed in northern part of quadrangle. Usually 1 to 2 feet thick. Refractory clay, valuable in places for crude purposes, commonly 4 to 5 feet thick, but locally 10± feet. Limestone usually impure, hard, nonfossiliferous, of buff color; can be burned for fertilizer.	
						Freeport sandstone.		
						Upper Kittanning coal.	Generally thin and unimportant.	
						Middle Kittanning (Darlington) coal and clay.	Persistent coal, fair to excellent quality, usually 1 to 2 feet thick, underlain by 4± feet of impure ferruginous clay.	
						Lower Kittanning coal and clay.	Coal uniformly 1½ to 2 feet thick and persistent, but varies from an excellent to a slaty or sulphurous grade. Refractory clay, persistent, 6 to 9 feet thick, and valuable; upper part usually pure and plastic, while lower portion is sandy and ferruginous.	
						Vanport ("Ferriferous") limestone.	Rather pure limestone, sometimes overlain by a few inches of iron ore. Usually under 8 feet thick. Certain portions produce good lime.	
						Clarion coal and clay.	Coal is thin and unimportant. Clay is refractory and of good quality.	
						Brookville coal.	Little exposed, 1½ to 3 feet thick.	
		Pottsville sandstone.	Cpv		200±	Homewood sandstone.	Coarse, white, hard, siliceous sandstone about 30 feet thick. Generally massive and sometimes conglomeratic.	Coarse siliceous sandstone and fine conglomerate. Sometimes massive and cross-bedded, with intermediate shale carrying iron ore and coal.

L. H. WOOLSEY,
Geologist.

DETAILED SECTIONS



L. H. WOOLSEY,
Geologist.

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8	Sewanee	Tennessee	25
‡9	Anthracite-Crested Butte	Colorado	50
‡10	Harpers Ferry	Va.-Md.-W.Va.	25
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13	Fredericksburg	Virginia-Maryland	25
14	Staunton	Virginia-West Virginia	25
15	Lassen Peak	California	25
16	Knoxville	Tennessee-North Carolina	25
17	Marysville	California	25
18	Smartsville	California	25
19	Stevenson	Ala.-Ga.-Tenn.	25
20	Cleveland	Tennessee	25
21	Pikeville	Tennessee	25
22	McMinnville	Tennessee	25
23	Nomini	Maryland-Virginia	25
24	Three Forks	Montana	25
25	Loudon	Tennessee	25
26	Pocahontas	Virginia-West Virginia	25
27	Morristown	Tennessee	25
28	Piedmont	West Virginia-Maryland	25
29	Nevada City Special	California	50
30	Yellowstone National Park	Wyoming	50
31	Pyramid Peak	California	25
32	Franklin	West Virginia-Virginia	25
33	Briceville	Tennessee	25
34	Buckhannon	West Virginia	25
35	Gadsden	Alabama	25
36	Pueblo	Colorado	25
37	Downieville	California	25
38	Butte Special	Montana	25
39	Truckee	California	25
40	Wartburg	Tennessee	25
41	Sonora	California	25
42	Nueces	Texas	25
43	Bidwell Bar	California	25
44	Tazewell	Virginia-West Virginia	25
45	Boise	Idaho	25
46	Richmond	Kentucky	25
47	London	Kentucky	25
48	Tenmile District Special	Colorado	25
49	Roseburg	Oregon	25
50	Holyoke	Massachusetts-Connecticut	25
51	Big Trees	California	25
52	Absaroka	Wyoming	25
53	Standingstone	Tennessee	25
54	Tacoma	Washington	25
55	Fort Benton	Montana	25
56	Little Belt Mountains	Montana	25
57	Telluride	Colorado	25
58	Elmoro	Colorado	25
59	Bristol	Virginia-Tennessee	25
60	La Plata	Colorado	25
61	Monterey	Virginia-West Virginia	25
62	Menominee Special	Michigan	25
63	Mother Lode District	California	50
64	Uvalde	Texas	25
65	Tintic Special	Utah	25
66	Colfax	California	25
67	Danville	Illinois-Indiana	25

No.*	Name of folio.	State.	Price.†
			Cents.
68	Walsenburg	Colorado	25
69	Huntington	West Virginia-Ohio	25
70	Washington	D. C.-Va.-Md.	50
71	Spanish Peaks	Colorado	25
72	Charleston	West Virginia	25
73	Coos Bay	Oregon	25
74	Coalgate	Indian Territory	25
75	Maynardville	Tennessee	25
76	Austin	Texas	25
77	Raleigh	West Virginia	25
78	Rome	Georgia-Alabama	25
79	Atoka	Indian Territory	25
80	Norfolk	Virginia-North Carolina	25
81	Chicago	Illinois-Indiana	50
82	Masontown-Uniontown	Pennsylvania	25
83	New York City	New York-New Jersey	50
84	Ditney	Indiana	25
85	Oelrichs	South Dakota-Nebraska	25
86	Ellensburg	Washington	25
87	Camp Clarke	Nebraska	25
88	Scotts Bluff	Nebraska	25
89	Port Orford	Oregon	25
90	Cranberry	North Carolina-Tennessee	25
91	Hartville	Wyoming	25
92	Gaines	Pennsylvania-New York	25
93	Elkland-Tioga	Pennsylvania	25
94	Brownsville-Connellsville	Pennsylvania	25
95	Columbia	Tennessee	25
96	Olivet	South Dakota	25
97	Parker	South Dakota	25
98	Tishomingo	Indian Territory	25
99	Mitchell	South Dakota	25
100	Alexandria	South Dakota	25
101	San Luis	California	25
102	Indiana	Pennsylvania	25
103	Nampa	Idaho-Oregon	25
104	Silver City	Idaho	25
105	Patoka	Indiana-Illinois	25
106	Mount Stuart	Washington	25
107	Newcastle	Wyoming-South-Dakota	25
108	Edgemont	South Dakota-Nebraska	25
109	Cottonwood Falls	Kansas	25
110	Latrobe	Pennsylvania	25
111	Globe	Arizona	25
112	Bisbee	Arizona	25
113	Huron	South Dakota	25
114	De Smet	South Dakota	25
115	Kittanning	Pennsylvania	25
116	Asheville	North Carolina-Tennessee	25
117	Casselton-Fargo	North Dakota-Minnesota	25
118	Greeneville	Tennessee-North Carolina	25
119	Fayetteville	Arkansas-Missouri	25
120	Silverton	Colorado	25
121	Waynesburg	Pennsylvania	25
122	Tahlequah	Indian Territory-Arkansas	25
123	Elders Ridge	Pennsylvania	25
124	Mount Mitchell	North Carolina-Tennessee	25
125	Rural Valley	Pennsylvania	25
126	Bradshaw Mountains	Arizona	25
127	Sundance	Wyoming-South Dakota	25
128	Aladdin	Wyo.-S. Dak.-Mont.	25
129	Clifton	Arizona	25
130	Rico	Colorado	25
131	Needle Mountains	Colorado	25
132	Muscogee	Indian Territory	25
133	Ebensburg	Pennsylvania	25
134	Beaver	Pennsylvania	25

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

Circulars showing the location of the area covered by any of the above folios, as well as information concerning topographic maps and other publications of the Geological Survey, may be had on application to the Director, United States Geological Survey, Washington, D. C.