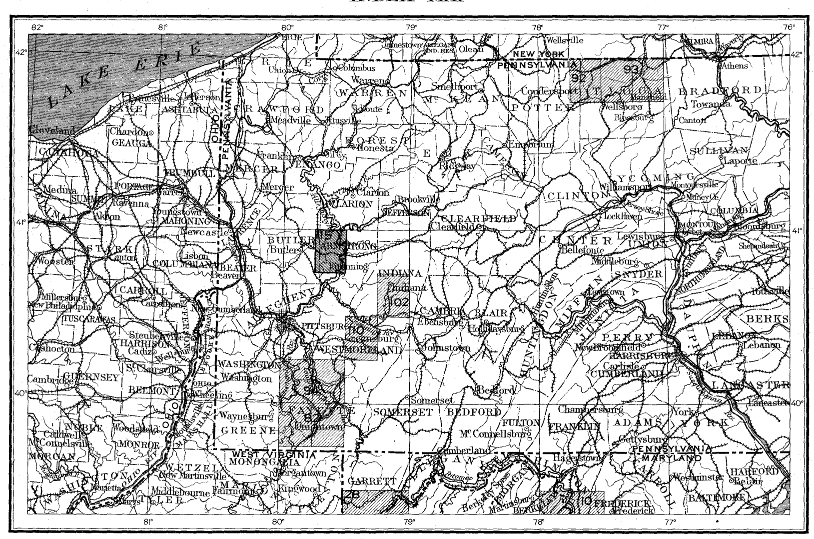
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS
OF THE
UNITED STATES

KITTANNING FOLIO
PENNSYLVANIA

INDEX MAP



SCALE: 40 MILES-1 INCH

KITTANNING FOLIO

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KITTANNING FOLIO
NO. 115

WASHINGTON, D. C.
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GEORGE W. STOSE, EDITOR OF GEOLOGIC MAPS S. J. KUBEL, CHIEF ENGRAVER
1904

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).

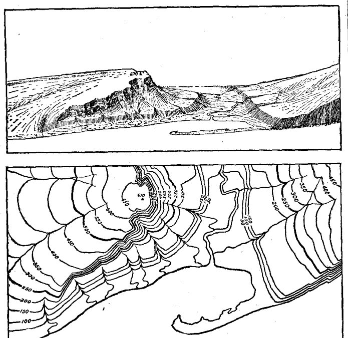


FIG. 1.—Ideal view and corresponding contour map.

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.
Cenozoic	Tertiary	Pliocene; Miocene; Oligocene; Eocene	T	Yellow ocher.
Mesozoic	Cretaceous		K	Olive-green.
Mesozoic	Jurassic		J	Blue-green.
Mesozoic	Triassic		Ꞧ	Peacock-blue.
Paleozoic	Carboniferous	Permian; Pennsylvanian; Mississippian	C	Blue.
Paleozoic	Devonian		D	Blue-gray.
Paleozoic	Silurian		S	Blue-purple.
Paleozoic	Ordovician		O	Red-purple.
Paleozoic	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:

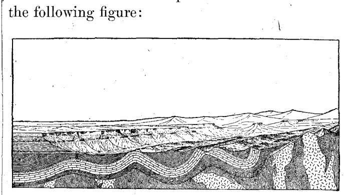


Fig. 2.—Sketch showing a vertical section at the front and a landscape beyond.

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:

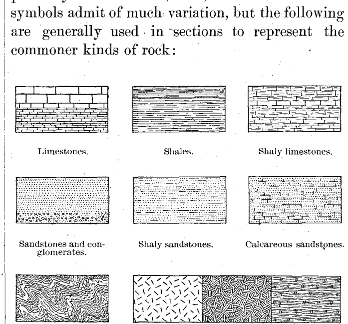


Fig. 3.—Symbols used in sections to represent different kinds of rocks.

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

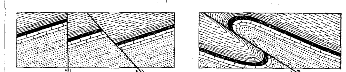


Fig. 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* fault.

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 KITTANNING QUADRANGLE.

By Charles Butts.

GENERAL RELATIONS.

Location.—The Kittanning quadrangle is located in the Allegheny Valley in the west-central part of Pennsylvania. It extends from latitude 40° 45′ to 41° and from longitude 79° 30′ to 79° 45′, and includes one-sixteenth of a square degree of the earth's surface, or about 226 square miles. The larger part of the quadrangle is in Armstrong County, but it includes a small portion of Clarion County on the northeast and a considerable strip of Butler County on the west. It takes its name from Kittanning, the most important town within its boundaries.

Relation to the Appalachian province.—In its physiographic and geologic relations this quadrangle forms a part of the Appalachian province, which extends from the Atlantic Coastal Plain to the Mississippi lowlands, and from central Alabama to Canada.

GEOGRAPHY AND GEOLOGY OF APPALACHIAN PROVINCE.

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, and the eastern escarpment of the Cumberland Plateau across Virginia, Tennessee, Georgia, and Alabama. East of this line the rocks are greatly disturbed by faulting and folding, and in many places are so metamorphosed that their original character can be determined only with difficulty. West of this line the rocks are less disturbed; they lie nearly flat, and the few folds which break the regularity of the structure are so broad that they are scarcely noticeable.

The general topographic features of the northern part of the province are well illustrated by fig. 10 (illustration sheet.) Immediately east of the Allegheny Front are alternating ridges and valleys, designated the Greater Appalachian Valley, and still farther east is a slightly dissected upland like the Piedmont Plain of eastern North Carolina and Virginia. West of the Allegheny Front are more or less elevated plateaus which are broken by a few ridges where minor folds have affected the rocks, and are greatly dissected by streams. In contradistinction to the lowlands of the Mississippi Valley on the west and the regularly alternating ridges and valleys of the Appalachian Valley on the east, this part of the province has been called by Powell the Allegheny Plateaus. (Nat. Geog. Mon. No. 3, pp. 65–100.) The Kittanning quadrangle is entirely within the Allegheny Plateaus.

Allegheny Plateaus.

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

Drainage of the Allegheny Plateaus.—The drainage of the Allegheny Plateaus is almost entirely into Mississippi River, but in the northeastern part it is either into the Great Lakes or into the Atlantic Ocean through Susquehanna, Delaware, or Hudson rivers.

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 northwest and discharged their waters through the St. Lawrence system. 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 the westward-flowing streams not only drain the Allegheny Plateaus, but many of them have their sources upon the summits of the Blue Ridge and cross the Greater Appalachian Valley.

Relief of the Allegheny Plateaus.—This division of the province is composed of a number of plateaus, the highest and most extensive of which lie along the southeastern margin.

These plateaus are believed to be the remnants of a very old land surface which has been reduced nearly to a plain by long-continued erosion, and could therefore properly be called a peneplain. This peneplain was first studied by Davis in northwestern New Jersey, and was named by him the Schooley peneplain because it is well developed in the region of Schooley Mountain (Proc. Boston Soc. Nat. Hist., vol. 24, p. 377). The peneplain has been deformed by differential elevation, and on account of its great age has, in most regions, been so completely dissected that its original character is not apparent. Its surface rises from a height of 500 feet above sea level in central Alabama to 1700 feet at Chattanooga, 2400 feet at Cumberland Gap, 3500 feet at New River, and probably 4000 feet at its culminating point in central West Virginia. From this point it descends to about 2800 feet on the southern line of Pennsylvania and 2200 to 2300 feet in the central part of the State. North of this point the peneplain is widely developed in the northern counties of Pennsylvania and throughout southern New York, and ranges in altitude from 2000 to 2400 feet.

The Schooley peneplain is best preserved over an extensive area in Alabama and Tennessee, where it constitutes the Cumberland Plateau. North of Tennessee it doubtless was once well developed, but now is difficult to identify. In northern West Virginia and northern Pennsylvania are a few areas of high, level land that appear to be remnants of the original surface of the peneplain, which is generally so dissected that only the hilltops mark its former position. Throughout most of the province knobs and ridges rise above the surface of the peneplain, as is attested by the fact that they rise above the general level of the surrounding hill tops.

The Cumberland Plateau slopes to the west, and is generally separated from the next lower plateau, the Highland Plateau, by a more or less regular westward-facing escarpment. This escarpment is most pronounced in Tennessee, where it has a height of 1000 feet. Toward the north it decreases in altitude to 500 feet in central Kentucky, and north of Ohio River it is so indistinctly developed that it has not been recognized. In southern Pennsylvania it becomes more pronounced where the hard rocks of Chestnut Ridge rise abruptly above the plain formed in the soft rocks of the Monongahela Valley, but the surface of the uppermost plateau is so greatly dissected that the escarpment can be recognized only with difficulty. Toward the central part of the State the plateau surfaces usually separated by this escarpment approach each other, and the escarpment is merged into a mass of irregular hills which represents all that remains of the higher plateau.

Bordering the Cumberland Plateau on the west in Tennessee and Kentucky, and extending northward over large portions of Ohio, Pennsylvania, and New York, are remnants of a second peneplain, younger than the Schooley peneplain. This surface has recently been studied by Campbell (Bull. Geol. Soc. America, vol. 14, pp. 277-296), who has called it the Harrisburg peneplain on account of its excellent development near Harrisburg, Pa., where it is about 500 feet above the sea. North of Ohio River this peneplain was developed on harder rocks than in Tennessee and Kentucky and the result is that the surface is less regular and its exact position is more difficult to determine. It appears to rise from an altitude of 700 or 800 feet in Indiana to 1000 feet in Tennessee, Kentucky, and Ohio, 1200 to 1300 feet in southwestern Pennsylvania, and probably 1600 to 2100 feet throughout northern Pennsylvania and southern New York.

The Harrisburg peneplain is best preserved in portions of Tennessee and Kentucky. In Tennessee it is known as the Highland Plateau; in Kentucky it is called the Lexington Plain. The surface of this plateau slopes to the west, but throughout its eastern margin it has an altitude of 1000 feet above sea.

The surface features of the Highland Plateau are variable, but there is not so much diversity as in the Cumberland Plateau. In Kentucky and Tennessee the Highland Plateau is preserved in large areas as a nearly featureless plain, but in other States it was less perfectly developed and has suffered greatly from dissection since it was elevated. West of the Highland Plateau there is a third plain, which is developed in the Central Basin of Tennessee and in the western portions of Kentucky and Indiana.

Geologic structure of the Allegheny Plateaus.—The structure of the Allegheny Plateaus is generally simple. The strata lie nearly flat and their regularity is broken only by small faults and low, broad folds. The most pronounced fold is a low, broad arch known as the Cincinnati anticline. The major axis of this anticline 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 Cincinnati. From Cincinnati the axis of the anticline passes due south to Lexington, Ky., and there curves to the southeast parallel with the Appalachian Valley as far as Nashville, Tenn. The anticline has its maximum development in the vicinity of Lexington, where the Trenton limestone is exposed at an altitude of 1000 feet above sea level. In Tennessee it again swells out into a dome-like structure, which is represented topographically by the Central Basin of Tennessee.

The Cincinnati 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 western Kentucky. The eastern basin lies entirely within the limits of the Allegheny Plateaus, and is generally known as the Appalachian coal field. The Kittanning quadrangle is situated entirely within the latter field (see fig. 11, illustration sheet), the geologic features of which will therefore be described in greater detail.

The geologic structure of the Appalachian coal field is very simple, consisting, in a general way, of a broad, flat, canoe-shaped trough. This is particularly true of the northern extremity, as may be seen in the illustration just referred to. The deepest part of this trough lies along a line extending southwest from Pittsburg across West Virginia to Huntington on Ohio River. To the southeast of this line the rocks dip northwest and to the northwest they dip southeast. About the canoe-shaped northern end the rocks outcrop in a rudely semicircular belt and at all points dip toward the lowest part of the trough. In Pennsylvania the deepest part of the trough is in the southwest corner of the State, and the inclination of the rocks is generally toward that point.

Although in general the structure is simple 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 and conceal the regular westward dip. These undulations are similar to the great folds east of the Allegheny Front, but are on a very much smaller scale and have not been broken by faults. These minor folds are present 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 and extend 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 or two folds of small proportions. Close examination shows that west of the Allegheny Front each trough, as well as each arch, lies lower than the one on the east, so that the rocks which are over 2000 feet above sea at the Allegheny Front extend below sea level in the central part of the basin.

Rocks of the Appalachian Province.

PRE-CARBONIFEROUS ROCKS.

The oldest rocks of the Appalachian province are crystalline rocks, such as granite and gneiss, which outcrop along its eastern and northern margins and presumably underlie all the younger rocks. Overlying the crystalline rocks is a great mass of sandstone, limestone, and shale, mostly of marine origin. These comprise several systems, some of which are of great thickness. These rocks are exposed in the greatly folded and disturbed region east of the Allegheny Front and around the northern and western margin of the province, within the belt of crystalline rocks, but in the interior, as well as in the deep synclines of the Anthracite and Broadtop regions of the Greater Appalachian Valley, they are concealed beneath the younger rocks, which belong to the Carboniferous system.

CARBONIFEROUS SYSTEM.

This system is of especial interest because in it are included the rocks of the Appalachian coal field, in the northern part of which the Kittanning quadrangle is located.

Pocono formation.—At the base of the Carboniferous system lies the Pocono formation, which derives its name from the Pocono Mountains in the eastern part of Pennsylvania. In the Pocono Mountains this consists largely of sandstone, is over 1000 feet thick, and rests conformably upon the red rocks of the Catskill formation, the uppermost member of the Devonian system. Over a large area in Pennsylvania its top is well marked by a calcareous and sandy stratum, known as the "siliceous limestone," but where this is absent the top of the formation is not so well defined. The thickness of the Pocono on the Allegheny Front is about 1030 feet. On the eastern margin of the coal field sandstone predominates, but there are beds of gray sandy shale of considerable thickness, and occasionally beds of red shale, which, though generally thin, may be of considerable thickness locally. In the Kittanning quadrangle only the top of the formation is exposed in the deeper valleys, but it is penetrated in drilling deep wells for oil and gas and possibly includes all the rocks between the top of the Mountain sand and the bottom of the Hundred-foot sand. It contains workable beds of coal of limited extent in the southeastern part of the Appalachian field in Virginia and West Virginia, and thin worthless beds in parts of Pennsylvania. On account of the presence of these coal beds and the occurrence of fossil plants similar to those of the later coal-bearing formations, the Pocono is assigned to the Carboniferous system.

Mauch Chunk formation.—This formation overlies the siliceous limestone on the Allegheny Front, along Conemaugh River east of Blairsville, and along Chestnut Ridge in Fayette County. It takes its name from Mauch Chunk, in the anthracite coal region, where it is over 2000 feet thick in the deep synclines and is composed largely of red shale. On the Allegheny Front it is about 180 feet thick and is composed of about 80 feet of heavy grayish to greenish sandstone overlain by 100 feet of soft red shale. It has this character along the Conemaugh between South Fork and Johnstown, but on Chestnut Ridge the sandstone beds disappear and the formation is composed of red shale overlying and underlying a bed of limestone in which marine fossils are very abundant. The limestone represents the upper part of the great Carboniferous limestone of the Mississippi Valley. The Mauch Chunk red shale occurs as a thin stratum in several wells drilled in the vicinity of Blairsville in Westmoreland County, but north of that place it has been detected in the records of only two or three wells and is not present where its horizon reaches the surface. It is probably entirely absent below the surface of the Kittanning quadrangle.

Pottsville formation.—This formation derived its name from Pottsville, in the Southern Anthracite field. It is there 1200 feet thick and is composed mainly of a coarse heavy conglomerate which in part of the field carries several workable coal seams. In the eastern part of the bituminous coal field of Pennsylvania the formation consists of two sandstone members separated in general by a bed of shale, often carrying several thin coals. In places the shale contains a coal bed of workable thickness and in other places a bed of valuable fire clay. A bed of limestone is also locally developed. These beds are known as the Mercer coal, clay, and limestone, respectively, because they are well developed in Mercer County. Along the western border of Pennsylvania a third sandstone member occurs below the lower of the two just mentioned and is separated from it by another shale bed with a coal seam which is locally of workable thickness. This is the Sharon coal, so called from its good development at Sharon, Mercer County. In most of the bituminous coal fields of the State the thickness of the Pottsville formation will probably run from 125 to 200 feet. Since the Mauch Chunk formation is not present in the Kittanning quadrangle the Pottsville lies unconformably upon the Pocono.

Allegheny formation.—The Allegheny formation overlies the Pottsville conformably. It receives its name from the Allegheny Valley, along which it is typically developed and well exposed. It is rather more variable in character than the lower formations of the Carboniferous system. It is especially distinguished by the fact that in the Northern Bituminous field it contains a greater number of workable coal seams than any of the lower formations of the system in this region, and on that account it was originally called the Lower Productive Measures. Nearly all the coal mined in the State north of Pittsburg and east of Connellsville and Blairsville is taken from it. In addition to its coal seams, it bears valuable beds of fire clay, limestone, and iron ore. These members are separated by beds of sandstone and shale. The clay and shale beds form the basis of important industries in several localities. The formation varies in thickness from about 270 feet on the Allegheny Front in Blair and Cambria counties, Pa., to about 370 feet in parts of the Allegheny Valley.

Conemaugh formation.—The Conemaugh formation lies conformably upon the Allegheny formation and includes all the rocks between the top of the Upper Freeport coal and the bottom of the Pittsburg coal. Its thickness varies from 600 to 700 feet. It derives its name from Conemaugh River, where it is well developed and exposed. The formation was formerly known as the Lower Barren Measures because it is generally destitute of workable coals. In some parts of Pennsylvania, however, it contains workable coals of limited extent, sometimes accompanied by thin limestones. The great mass of the formation is composed of a succession of shale and sandstone, the shale being commonly, perhaps prevailingly, sandy. The sandstone strata are variable in thickness and occurrence. In some regions there are several beds; in others there may be scarcely any sandstone. In the latter cases the formation is composed almost wholly of shale.

Monongahela formation.—The Monongahela formation conformably overlies the Conemaugh formation in the southwestern part of the State and extends from the bottom of the Pittsburg coal to the top of the Waynesburg coal. Its thickness varies from 310 to 400 feet. It is so named because well exposed along Monongahela River. It contains several workable coal beds, of which the Pittsburg is by far the most valuable and the best known. It is much less sandy and shaly than any other Carboniferous formation, but contains far more limestone, more than one-third of its thickness in the State being composed of this rock. The formation extends over an oval-shaped area the longer diameter of which runs from Pittsburg, Pa., to the vicinity of Huntington, W. Va., and which includes considerable portions of Ohio and West Virginia adjacent to Ohio River. It is not present in the Kittanning quadrangle.

Dunkard formation.—Above the Monongahela formation lie the highest rocks of the Carboniferous system, having a thickness in the southwest corner of Pennsylvania of about 800 feet. They are mainly shale and sandstone, but include beds of coal and limestone. Some of the coals are locally workable, but they are generally worthless. This group of rocks was formerly known as the Upper Barren Measures, and later as the Dunkard formation, from Dunkard Creek in Greene County. In the forthcoming Waynesburg folio these rocks will be divided into the Washington and Greene formations. The Washington will include the rocks between the Waynesburg coal and the upper Washington limestone, and the Greene will comprise all higher rocks. It is doubtful whether this division can be carried beyond the boundaries of Pennsylvania, so that in Ohio and West Virginia these uppermost and youngest rocks of the Carboniferous system will be known simply as the Dunkard formation. This group occupies an area in southwestern Pennsylvania and along both sides of Ohio River in West Virginia and Ohio, of a shape similar to that of the Monongahela formation, but of less extent. No rocks of this group occur in the Kittanning quadrangle.

GEOGRAPHY.

Drainage.

Streams exercise an important influence on the topography of an area and on its adaptability to the uses of man. Towns and industries are found upon the banks of the streams, and the railroads follow the principal watercourses in this quadrangle as well as throughout western Pennsylvania. The relation of the streams of this quadrangle to the topographic development will be discussed in a later section.

Allegheny River is the principal stream of the quadrangle. It flows across the northeast and southeast corners and receives all the drainage of the quadrangle, but it is not navigable at ordinary stages. In the northeast corner of the quadrangle the Allegheny is joined by Redbank Creek, its most important tributary. This stream is 75 miles in length and its drainage basin lies almost wholly east of the quadrangle. Second in size, but more important so far as the drainage of this quadrangle is concerned, is Buffalo Creek, which, with its tributaries, drains most of the western half of the quadrangle and crosses its southern border before joining Allegheny River. Beaver Run in the northwest, Sugar Creek and Huling Run on the north, Limestone Run on the east, and Glade Run between Allegheny River and Buffalo Run, drain smaller areas and are of less importance. Allegheny River receives Cowanshannock Creek from the east about 3 miles above Kittanning, and Garrett Run about 1 mile south, but these are of minor importance in the drainage of the quadrangle.

Drainage relations, present and past.—Allegheny River is the main headwater tributary of the Ohio and drains an area of about 11,500 square miles, of which 2000 square miles are in southwestern New York and 9500 square miles in northwestern Pennsylvania. Some of its affluents in Cattaraugus and Chautauqua counties, N. Y., and Erie County, Pa., have their sources on the southern slope of an elevated region which overlooks Lake Erie at points only 7 to 15 miles distant from the lake, yet they take a course directly away from the lake and form no part of the St. Lawrence drainage.

As shown many years ago by Carll (Second Pennsylvania Geol. Surv., Rept. I3, 1880) and later by Chamberlin and Leverett (Am. Jour. Sci., 3d ser., vol. 47, 1894, pp. 247-283), the apparently anomalous course of Allegheny River is due to the fact that it was formed by the union of a number of independent streams, parts of which originally flowed north into the basin of Lake Erie. As shown by the sketch map, fig. 1, the upper part found an outlet to the northwest by Salamanca to Gowanda and thence down Cattaraugus Valley. The middle portion, from as far south as Emlenton, flowed through Venango, Crawford, and Erie counties, Pa., along a channel now utilized in part by French and Conneaut creeks, and entered the Erie basin just east of the Ohio–Pennsylvania State line. The waters of the Clarion and lower Allegheny, with its tributaries, followed the present course of Allegheny River to the mouth of Beaver River, where they apparently turned to the north and followed an old valley, occupied in part by Beaver and Grand rivers, to the Lake Erie basin.

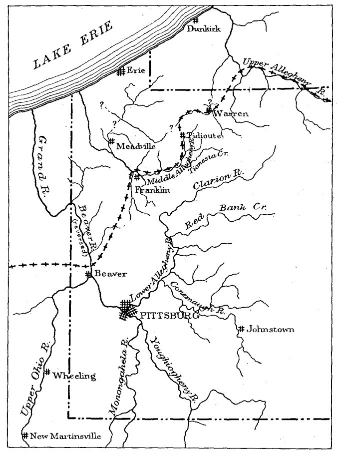


FIG. 1.—Sketch map showing the probable pre-Glacial drainage of western Pennsylvania. The terminal moraine is shown by a broken crossed line.

(After Frank Leverett; with addition of terminal moraine.)

While the streams within the Kittanning quadrangle have not changed their courses, their present relation to the drainage of the continent is very different from what it was before the Glacial epoch. Furthermore, the present drainage basin of Allegheny River down to and including Redbank Creek is about four times the size of the area drained by the lower Allegheny in pre-Glacial time.

Relief.

The surface of the quadrangle is hilly. The valleys are narrow, with precipitous sides and narrows or no flood plains, so that they contain but little land suited to cultivation. This is particularly true of Allegheny Valley throughout most of its course and of the valley of Buffalo Creek from Buffalo Mills southward. Considerable areas of flat or gently sloping land mark the more elevated portions of the quadrangle. Agricultural pursuits are therefore chiefly confined to the uplands.

Harrisburg peneplain.—At first sight this hilly surface appears to be wholly irregular and without any common element, but closer study of the area in connection with other parts of the Allegheny Plateaus shows that this is not true. Viewed from a distance the inequalities of the surface do not appear and the upland presents a fairly even sky line, as the higher hilltops reach an approximately uniform height.

Northwest of a line running from the southwest corner of the quadrangle through West Winfield, Buffalo Mills, Cowansville, and French's Corner are many gentle slopes, flat hilltops, spurs, and divides at altitudes ranging from 1340 feet above sea level on the southwest to 1460 feet on the northeast. In the continuation of this belt of country to the northeast in the Rural Valley quadrangle are extensive tracts of gently undulating uplands, in the vicinity of Kellersburg, at an altitude of 1500 feet. In the vicinity of Fosters Mills are several hills which rise to altitudes of over 1500 feet, but these stand above the general upland surface and must be classed as exceptional topographic features.

If the valleys in the northwestern half of the quadrangle were filled until the surface stood at an altitude of about 1340 feet in the vicinity of West Winfield and of about 1460 feet in the northeast corner of the quadrangle there would result a gently sloping and undulating surface that would resemble a plain and hence could properly be called a peneplain. This peneplain would, of course, extend over the southeastern half of the quadrangle, which now stands in general at a considerably lower altitude. Where the softer rocks outcrop it probably would be nearly flat, but where harder rocks are present isolated knobs would stand above its general surface, as in the vicinity of Fosters Mills.

The flat surfaces and the divides mentioned in the preceding paragraph are believed to be remnants of an ancient land surface which was produced by subaerial erosion operating through a very long period, during which the crust of the earth in this region moved neither up nor down. The result was a nearly horizontal surface, or peneplain, which was much nearer sea level than the present general surface. Above the peneplain a few small unreduced areas rose to a height of 100 to 180 feet, and these still rise above the surface as it is restored in imagination. These unreduced areas may be due in part to the presence of hard sandstones, in part to their distance from the main drainage lines, and in part to their relation to geologic structure. However, had the period during which this portion of the earth's crust remained stationary been long enough, even these comparatively slight eminences would have been reduced to the common level.

Such a flat surface, or peneplain, may be produced by marine erosion along a sea coast, and doubtless has been so produced in some parts of the world. There is, however, no evidence that the sea has covered this part of the United States since Paleozoic time, so that this peneplain can not be attributed to such an agency. Plains of considerable extent may, it is true, be formed by a stratum of horizontal sandstone or other resistant rock, and in this quadrangle the peneplain surface on the ridges on both sides of the river above Rimer may have been controlled slightly by the presence of the Freeport sandstone, which is well developed in those localities. The high tract of flat land on the arch of the Kellersburg anticline between Cowansville and Fosters Mills is also developed on the surface of the Freeport sandstone. This tract stands considerably above the peneplain surface and is doubtless due to a combination of conditions. The sandstone is particularly well developed here and is brought to the surface by the anticline. In the Bradys Bend syncline, west of the area just described, the Freeport sandstone, dipping westward from the crest of the anticline, is 200 feet below the tops of the hills, the overlying rocks being soft shales of the Conemaugh formation. Notwithstanding the presence of these soft rocks, the general surface of the hills is less than 100 feet lower than that of the sandstone area on the axis of the anticline, yet, with reference to main drainage lines, they are just as favorably or even more favorably located for erosion.

The 200 feet of soft rocks above the Freeport sandstone in the Bradys Bend syncline have been eroded from the crest of the Kellersburg anticline in the region described, and, in passing from the syncline to the anticline, one crosses their beveled edges. The accompanying ideal section, fig. 2, may serve to make the foregoing discussion clear.

FIG. 2.—Ideal section illustrating planation of folded rocks. Vertical scale and dips greatly exaggerated.

Along the axis of the Kellersburg anticline southwest of Fosters Mills the Freeport sandstone dips beneath the surface, which remains at approximately the same altitude and is formed by successively higher and softer rocks, until, in the extreme southwest corner of the quadrangle, it coincides with the top of the Saltsburg sandstone, which lies at least 250 feet above the Freeport sandstone.

It is apparent that the old peneplain surface of this quadrangle did not coincide with any particularly resistant stratum, but was developed on all kinds of rock, irrespective of structure or hardness. This leads to the conclusion that the peneplain was the result of long-continued erosion.

This peneplain has been called the Harrisburg peneplain by Campbell, who has traced it over a large part of western and central Pennsylvania and into southern New York, and by comparing its altitude at various places he has shown that in the course of its elevation the once nearly horizontal surface of the peneplain has undergone deformation, so that it now has the shape of an ellipsoidal dome whose surface on the southwestern side rises from an altitude of 1300 feet at Pittsburg to 2200 feet at its culminating point in McKean and Potter counties in northern Pennsylvania. The northeastward rise of the surface from 1340 feet at West Winfield to 1500 feet at Kellersburg, about 7 miles east of Redbank Junction, is in harmony with the general deformation of the surface as determined by Campbell.

Worthington peneplain.—The part of the quadrangle southeast of the Kellersburg anticline, an area north of Fenelton, and the region about Bradys Bend and along Redbank Creek were reduced to a peneplain which was about 100 feet below the Harrisburg and is now represented by a considerable number of divides, hills, and gentle slopes, ranging in altitude from approximately 1220 feet in the southern part of the quadrangle to 1360 feet in the northern part.

The reduction of these areas was due to two conditions. The rocks are much more yielding than those underlying most of the unreduced areas and are much nearer the main drainage lines, where erosion was more active at the beginning of the new cycle. In the northwest corner of the quadrangle the rocks are also yielding, but they are farther from the main drainage lines. Toward the northeast corner, where Allegheny River crosses the Kellersburg anticline, the rocks are near the main drainage, but are generally resistant. Erosion was therefore retarded in these localities.

This lower peneplain represents a secondary stage in the Tertiary erosion, and may probably be correlated with the 1100-foot level described in the Masontown-Uniontown folio. It has been called the Worthington peneplain, from the town of that name on its western margin.

Parker strath.—At a number of points on both sides of the river are deposits of silts and gravels the tops of which form well-marked terraces about 250 feet above the river and about 1050 feet above the sea. These deposits lie upon rock shelves that are about 200 to 250 feet above the river and from 980 to 1000 feet above the sea (see fig. 3). They are remnants of a former broad valley floor bounded by

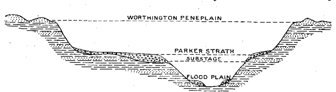


FIG. 3.—Ideal section across Allegheny Valley illustrating the formation of terrace floors.

high steep walls. This broad floor was eroded by the river in consequence of its former low gradient when it was flowing on rocks that are now about 250 feet above the bed. Such rock shelves occur along the river from Parker in northern Armstrong County to the mouth of Beaver River. At Parker their elevation is 1020 to 1040 feet, at Pittsburg 890 feet, and at Beaver 865 feet (Leverett, Mon. U. S. Geol. Survey, vol. 41), while at intermediate points they have intermediate elevations which show a uniform but low grade between Parker and Beaver for the old valley floor.

It has been customary to call such a broad valley floor a gradation plain, but the propriety of using the word plain for so limited a feature is questionable, and on that account, as well as for the sake of brevity, the term strath is here introduced. This is a name used in Scotland for precisely such a feature as that under discussion (Geikie, Scenery of Scotland, p. 165). The name Parker is adopted because the strath is well preserved at Parker, on the Allegheny several miles above East Brady, where it is associated with an abandoned oxbow channel known as the Parker oxbow.

In the Kittanning quadrangle remnants of the Parker strath, though much obscured by the gravel deposits, are found along Allegheny River near the northern border of the quadrangle, on the upland just east of East Brady, on both sides of Allegheny River south of the mouth of Redbank Creek, on both sides of the mouth of Limestone Run, at Kittanning, Weskit, Manorville, and Ford City, and on the point between Allegheny River and Glade Run.

The distance between the inner margins of the rock floors of the rock shelves on opposite sides of the river just south of the mouth of Redbank Creek is barely one-half mile, and the old valley floor would scarcely have been wider, for the rock shelves are narrow. The extreme width south of Ford City probably did not exceed 1½ miles. The width of the present valley at the 1000-foot contours on opposite sides of the river one-half mile south of Rimer is hardly one-quarter of a mile, and of course the old valley floor could not have been so wide, because the valley must have been somewhat widened while the river was cutting from the 1000-foot contour to its present level. It is probable that in this part of its course the valley was only a few times wider than the old river itself. The narrowness here was due to the hardness of the rocks through which the river had to cut its way, while the greater width at Ford City is due to the fact that the rocks are softer and more erodible in that locality.

The rock floor of the gravel-covered terrace extending from east of Ford City to Manorville stands at an altitude of about 940 feet above sea level and about 60 feet below the level of the more elevated remnants of the Parker strath. On the west side of the river opposite Ford City is another terrace with rock floor at about 940 feet. At Applewold and at the mouth of the Cowanshannock are small and narrow gravel-covered rock shelves at the same elevation. These shelves appear to be remnants of a valley floor of considerable breadth that had been eroded 40 to 60 feet below the level of the Parker strath, and probably represent a substage in the erosion of the valley subsequent to the formation of that feature. The location of the deepest part of this inner valley is not certainly known, but there are evidences that the rock floor is somewhat lower one-half mile east of Ford City than in the brow of the bluff. This indicates a rise of the lower valley floor toward the present river and leads to the conclusion that the old channel lay to the east at Ford City. The rock floors of the upper and lower terraces at the localities mentioned do not seem to be separated by any well-marked escarpment; there appears to be a gradual slope from the higher to the lower.

MAN'S RELATIONS TO THE TOPOGRAPHY.

Man's activities in a given region are largely controlled by its topographic features. Farms are on level or moderately sloping land; railroads, cities, and manufacturing industries are generally in the valleys, which are easily accessible to the surrounding region. Where valleys are cut in strata containing valuable mineral deposits—as coal—mines will be located on account of ease of mining and transportation. In the Kittanning quadrangle farming is mostly confined to the uplands and manufacturing and mining to the valleys. The chief towns, Kittanning, Ford City, and East Brady, are located on the river. The Allegheny Valley Railroad has long been the main artery of commerce and of communication with other parts of the country. More recently the Winfield Railroad has been built along Buffalo Creek to the limestone and sandstone quarries at West Winfield. The Buffalo, Rochester and Pittsburg railroad crosses the quadrangle from east to west by way of Limestone and Buffalo runs. Another form of activity less dependent on topography has been the production of oil and gas, one or the other of which has been the basis of an important industry and the source of great wealth in nearly every township of the quadrangle.

GEOLOGY.

STRUCTURE.

Method of representing structure.—In this folio the method of representing structure by means of structure contours has been used. These contour lines are determined as follows: The upper or lower surface of a particular stratum is selected as a reference surface, the form of which is ascertained, first, from the altitude of its outcrop, and second, from its depth beneath some higher exposed bed. In the first case the reference stratum outcrops; in the second case it is underground, but, the thickness of rocks between the observed stratum and the reference surface being known, the depth of that surface can be calculated. In many cases the depth is measured directly in a deep well boring.

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 form of the reference surface at that elevation. Many such lines are drawn at regular vertical intervals. They are contour lines, and as printed on the geologic structure 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 of the reference horizon may be determined by subtracting the elevation of the reference horizon from that of the surface of the ground.

As a rule these structure contours are generalized and are only approximately correct. It is assumed that over small areas the rocks maintain a uniform thickness, hence the position of a contour will be inaccurate by the amount by which the actual varies from the assumed thickness. Being measured from the altitude of observed outcrops, the position of the contour is uncertain to the degree that that altitude is approximate, and while in many instances altitudes are determined by spirit level, in most cases the elevation of a bed is found by means of aneroid barometers. The aneroids are constantly checked against precise bench marks, and the instrumental error is probably slight, but it may be appreciable. 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 the total error is probably less than the contour interval; that is to say, the altitude of the reference surface will not vary more than 50 feet from that indicated by the contours; and the relative altitudes for successive contours may be taken as very nearly correct.

Reference surface.—In the determination of the structure of the Kittanning quadrangle the Vanport ("Ferriferous") limestone has been used as a key rock, and the structure is delineated on the map and in fig. 4 by contours drawn upon the top of that stratum at vertical intervals of 50 feet.

Former views of the structure.—Before taking up the detailed description of the structure there will be given the description of the structure as made out by previous surveys, especially by the Second Geological Survey of Pennsylvania. These results will be found fully stated in Platt's report on Armstrong County (Rept. H5, pp. xliv–xlvi, with map, p. xxxvi) and in the report by Chance on northern Butler County (Rept. V, p. 10). In these reports the structure of the quadrangle was described as follows:

The northwest corner was thought to be crossed by the Millerstown anticline, whose axis followed a straight northeast-southwest course. The Bradys Bend syncline was considered to lie to the southeast, its axis following a straight course parallel to that of the Millerstown anticline and passing near Nichola and Phillipston and beyond the quadrangle in either direction. Still farther southeast was the Bradys Bend anticline. Its axis was mapped as passing in a straight line through West Winfield, Craigsville, the mouth of Redbank Creek, and off the quadrangle to the northeast. Southeast of the Bradys Bend anticline the Lawsonham syncline was believed to extend from the head of Cornplanter Run to Lawsonham, on Redbank Creek, and its axis was mapped as following a straight course through Worthington and Cowansville. Next, to the southeast, the axis of the Kellersburg anticline was mapped and described as passing through Kellersburg and the mouth of Mahoning Creek, points a short distance east of the quadrangle, to French's Corner and dying out near Limestone Run. Next, on the southeast, was believed to lie the Fairmount syncline, its axis following the river to the mouth of Garretts Run and thence pursuing a straight northeast course through Fairmount, on Redbank Creek, and several miles east of the quadrangle.

The results of the present survey as regards structure differ materially from those described above, as will be shown below. The structure will be described in detail, beginning at the northwest and proceeding to the southeast corner of the quadrangle.

Structure of the northwest corner.—The structure here is not pronounced, and its determination is based almost wholly on the position of the Vanport (Ferriferous) limestone as given in many well records. A low syncline apparently passes through Chicora to Karns and connects with the Bradys Bend syncline in the northwest corner of Sugarcreek Township, by a broad, shallow depression around the northeastern end of the Millerstown anticline. From the syncline passing through Chicora and Karns the strata rise gently to the Martinsburg anticline on the northwest. The point of an anticline enters the northern part of Bradys Bend Township and extends southwestward into the southeast corner of Fairview Township. No name has been applied to either syncline or anticline, since it seems better first to learn something more of them outside of the quadrangle, where they may be better developed.

Millerstown anticline.—The determination of the position and extent of this anticline by the present survey agrees fully with the description given by Chance (loc. cit.). Its axis crosses Buffalo Run about 2 miles southeast of Chicora and runs about N. 40° W. As shown in a number of wells, the Vanport (Ferriferous) limestone on the axis is about 1050 feet above sea level near the margin of the quadrangle. That the rocks dip slightly from the axis of this anticline northwest toward Chicora is proved by the fact that the Upper Freeport coal at Chicora is 1260 feet above sea, and as the limestone lies about 260 feet below the coal in the

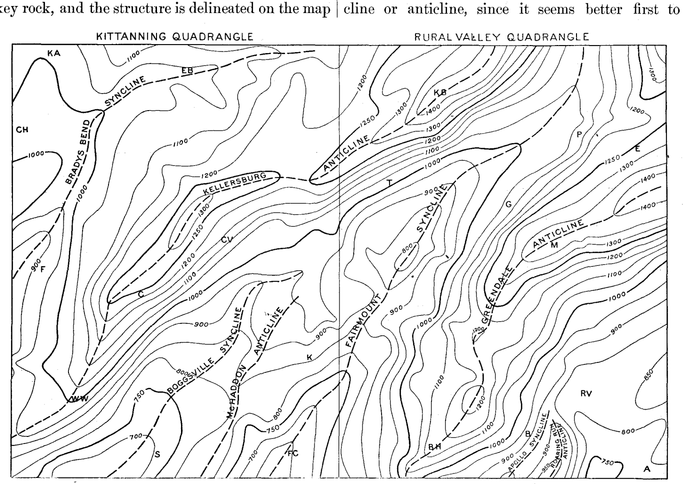


FIG. 4.—Map of Kittanning and Rural Valley quadrangles showing the geologic structure by means of contour lines drawn on the top of the Vanport ("Ferriferous") limestone. Contour interval, 50 feet.

KA, Karns; CH, Chicora; F, Fenelton; C, Craigsville; WW, West Winfield; EB, East Brady; CV, Cowansville; S, Slate Lick; K, Kittanning; FC, Ford City; KB, Kellersburg; T, Templeton; P, Putneyville; E, Eddyville; G, Goheenville; M, Muff; BH, Blanket Hill; RV, Rural Valley; B, Bianco; A, Atwood.

northwest corner of the Kittanning quadrangle, its elevation at that point is about 1000 feet. The regular dip of the rock to the southeast toward the Bradys Bend syncline is shown by the position of the limestone in many wells along the axis of the syncline. The Millerstown anticline is separated from the anticline in Bradys Bend Township to the north by the shallow depression between the Bradys Bend syncline and the shallow syncline at Chicora, as shown in many wells by elevations on the limestone of 1000 feet or a little less.

Bradys Bend syncline.—Platt described the axis of this syncline as crossing the boundary between Butler and Armstrong counties on Buffalo Creek and extending in a straight line northeast through Bradys Bend. Evidence now in hand, however, shows that this axis lies farther to the west. Many oil wells on the Riley and Hickey farms northwest of Fenelton show the Vanport limestone at an elevation of about 900 feet above the sea. From these localities the limestone rises regularly to the axis of the Millerstown anticline on the northwest, as shown by many wells. In the southeast corner of Donegal Township, on the Goldlinger and Malery farms, about 1½ miles west of the Hickey wells, three wells show that the elevation of the limestone is 1050 feet. The axis of the syncline then lies west of the latter locality, probably in the vicinity of the Hickey farm. Another line of evidence also leads to the conclusion that the axis lies considerably west of Platt's location. The Upper Freeport coal is near water level on the western margin of the quadrangle. Along Buffalo Creek it rises constantly to the southeast, and one-half mile east of Fenelton is more than 100 feet above the stream. About a mile southeast of Fenelton the Lower Kittanning coal is opened 40 to 50 feet above the creek, and at Nichola the limestone is about 50 feet above the creek. These facts show conclusively that the rocks rise eastward along Buffalo Creek from the western margin of the quadrangle and that the axis of the Brayds Bend syncline enters the quadrangle about 1 mile southwest of Fenelton and passes thence in a nearly straight line one-half mile west of Rattigan and enters Armstrong County in the northwestern corner of Sugarcreek Township, in the neighborhood of the Pontius and Reep farms, where the elevation of the limestone is 1000 feet above sea. In the vicinity of Adams well records show the elevation of the limestone to be about 1100 feet, and the stratigraphic evidence points to a regular rise of the rocks in that direction from the northwest corner of Sugarcreek Township. At the latter locality the axis bends sharply to the east and passes through East Bradys, as is shown by the fact that the limestone at a number of points near the mouth of Holder and Sanders runs has an altitude of from 1020 to 1030 feet. From this locality it rises on the north to 1050 feet at the mouth of Pine Run, 1110 feet one-half mile up Pine Run, and 1100 feet one-half mile north of the village of Bradys Bend, just beyond the quadrangle; on the south it rises to 1050 feet in the apex of the river bend 1 mile below East Brady. Farther down the river, one-half mile west of Phillipston, two points on the limestone were noted at 1025 and 1020 feet, which indicate a transverse wrinkle in the syncline running from East Brady toward Phillipston, and this may have influenced Platt in locating the axis near Phillipston. From this locality southeastward numerous observations on the limestone and other beds show a constant rise toward the Kellersburg anticline. About one-half mile northeast of Phillipston the elevation of the limestone, determined from an observation on the Lower Kittanning coal, is 1075 feet; almost due north of this point, on the bluff of the Allegheny, it is 1055 feet; still west and north nearly one-half mile it is 1075 feet. On the north side of the river north of East Brady and just beyond the quadrangle the elevation is 1095 feet, and in the bluff on the eastern side of the river just south of the margin of the quadrangle the limestone is 1100 feet above sea. These observations locate the axis definitely along the neck between the two limbs of the river east of Bradys Bend. From this point eastward the position of the axis is more obscure. Near the head of a ravine entering Redbank Creek about a mile above its mouth are old ore pits, and presumably the limestone, at an elevation of 1100 feet. This point is about a mile north of the mouth of Redbank Creek. From this point the rocks were observed rising to the north and south. North of the point the limestone was not seen, but the Lower Kittanning coal could be traced for some distance, rising perceptibly. Southward the strata rise also, and the limestone was observed north of the mouth of Redbank Creek at 1160 feet, while 1 mile up the creek it has an elevation of 1200 feet. Still farther west, three-quarters of a mile southwest of Lawsonham and just east of the quadrangle, the limestone was observed at 1150 feet. From this point the strata rise to the southeast, but the exact position of the axis is unknown, as the country to the north has not been investigated. It seems probable, however, that it passes a short distance north of Lawsonham.

Kellersburg anticline.—This is the principal structural feature of the quadrangle. It corresponds in part with Platt's Bradys Bend anticline and in part with his Kellersburg anticline. Its axis very nearly coincides with that of the Bradys Bend anticline as mapped by Platt from the southwest corner of the quadrangle to the southeastern part of Sugarcreek Township, but from this locality onward the location of the anticline by the present survey differs greatly from that given by Platt. It is desirable, therefore, to give the evidence upon which the determination here made is based.

The limestone on the axis of the Kellersburg anticline rises very regularly from an elevation of 950 feet in the southwestern part of the quadrangle to a point about 1 mile southeast of Fosters Mills, where two wells reveal the limestone at altitudes of 1310 and 1330 feet. Midway between Cowansville and Browns Crossroads the Freeport sandstone is exposed on the road at an elevation of 1500 feet above sea, and since this stratum is about 200 feet above the limestone the latter has an altitude of 1300 feet. From this place the strata dip to the north, west, and south, as shown by observations on the limestone and coal beds. One-half mile southeast of Browns Crossroads the altitude of the limestone is 1240 feet, as shown in a well; at Sherrett it is 1244 feet, and abundant observations show a constant dip from this point to Phillipston and a dip of nearly 100 feet to the mouth of Redbank Creek. From the southeastern part of Sugarcreek Township to a point about midway between Rimer and Morrows Corner, however, the limestone dips very gradually eastward until it has an altitude of less than 1250 feet. This determination is based mainly on the evidence of coal beds. The Upper Freeport coal, whose horizon on the axis of the anticline in Sugarcreek Township must be at least 1550 feet above the sea, since it is at least 50 feet above the Freeport sandstone, is present on the knobs at an altitude of 1500 feet in the vicinity of Peach Hill, thus showing a descent of 50 feet. Allowing an interval of 250 feet between the Upper Freeport coal and the limestone, the latter would have an altitude of 1250 feet near Peach Hill. North of this locality, at a point about 1 mile north of Rimer, the Lower Kittanning coal was struck in a test well at an elevation of 1230 feet, so that the elevation of the limestone at that point is about 1200 feet. Numerous observations on coal beds and on the limestone show that its elevation in the northern parts of Washington and Madison townships is 1200 feet or less. Southward, in the vicinity of Morrows Corner, the Lower Kittanning coal is about 1170 feet above sea level, and this would make the altitude of the limestone at that point 1130 feet. One-half mile north of Adrian its elevation is about 1050 feet. The evidence presented above clearly shows, it is believed, that the rocks dip both north and south from a line passing nearly east and west through the above-mentioned point between Rimer and Morrows Corner, and that that line is therefore to be taken as the anticlinal axis which connects the Bradys Bend and Kellersburg anticlines. About a half mile west of the river the axis turns northward and can, by means of abundant exposures of the limestones and openings on the Lower Kittanning coal, be traced without difficulty to and beyond Kellersburg in the Rural Valley quadrangle to the east. Instead, therefore, of two anticlines with parallel straight axes as mapped by Platt, there is but one anticline with a strongly curving axis between Fosters Mills and the river. This anticline is very appropriately named the Kellersburg anticline, since its axis passes through that place.

Boggsville syncline.—Platt mapped the Lawsonham syncline as extending from the head of Cornplanter Run in a straight line through Worthington and Cowansville to Lawsonham. Evidence presented in describing the Kellersburg anticline shows that, while there is a sag in the anticline north of Morrows Corner, the anticlinal structure so predominates in the region that a syncline could not properly be regarded as crossing there. To the northeast in Madison Township there is, however, a transverse buckle of a synclinal nature which passes in the direction of Lawsonham, and to the southwest there is a distinct syncline which originates on the southeastern limb of the Kellersburg anticline near Limestone Run south of Adrian and becomes a well-developed structural feature near the southern margin of the quadrangle. This syncline occupies in a general way the position of the southern end of the Lawsonham syncline, but Platt located its axis too far west. The Vanport limestone outcrops at West Winfield at an altitude of 1000 feet; near Boggsville it was noted in two wells at altitudes of 680 and 733 feet, showing a dip of 300 feet between the two places. This dip is confirmed by the records of many wells between the two places and also by the fact that the Upper Freeport coal, which has an altitude of 1240 feet at West Winfield, dips southeastward to an altitude of 920 feet near Boggsville. In the vicinity of Boggsville the strata probably begin to rise to the southeast, for wells just beyond the quadrangle south of Slate Lick show the limestone at an altitude of 750 feet above the sea. These facts indicate that the axis of this syncline is near Boggsville, and it is therefore named the Boggsville syncline.

This syncline in the southern part of the quadrangle is broad and flat bottomed and the position of its axis is rather indefinite. Its location as mapped is based upon an occasional well record and upon careful and thorough stratigraphic tracing in the region. In the vicinity of Walkchalk the syncline narrows suddenly and its axis is well determined by the opposing dips of the rocks to be observed there. Its course north of Walkchalk was determined by observations on the Upper and Lower Freeport coals, by well records, and by observations upon the limestone in outcrop along Limestone Run.

McHaddon anticline.—This is a low anticline whose axis enters the quadrangle 2 miles southwest of North Buffalo village, runs in general nearly parallel to the axis of the Boggsville syncline, and dies out near the mouth of Limestone Run. In this vicinity the McHaddon anticline merges with the Kellersburg anticline and ceases to be a separate feature. The name was applied because the axis runs near McHaddon.

Fairmount syncline.—Southeast of the McHaddon anticline the Kittanning quadrangle includes a small portion of the Fairmount syncline, whose axis follows Allegheny River from the southern margin of the quadrangle to Garrett Run, where it turns eastward, soon leaves the quadrangle, and continues northeastward through the Rural Valley quadrangle, in which it is an important feature. From this axis the strata rise regularly eastward to the axis of the Greendale anticline in the Rural Valley quadrangle.

Dip of the rocks.—The dips throughout these quadrangles are generally low. The highest are found on the southeastern flank of the Kellersburg anticline and probably do not exceed 3 to 4 degrees.

Pitching axes.—A noticeable feature of the anticlines and synclines of the region is the general southwestern pitch of the axes. The axis of the Bradys Bend syncline pitches from 1150 to 900 feet, that of the Kellersburg anticline from 1400 to 950 feet, that of the Fairmount syncline from 1070 feet at Fairmount on Redbank Creek to 650 feet on the southern margin of the quadrangle. The pitch, however, is not always uniform. The crests of the anticlines often are nearly level for long distances, as along the Kellersburg anticline in the vicinity of Craigsville and of West Winfield. In other cases they exhibit elevations like the Kellersburg anticline east of Fosters Mills.

Course of structure lines.—Another noticeable feature of the structure of the quadrangle is the deviation of the anticlinal and synclinal axes from straight lines (see fig. 4). In general each axis is composed of reversed curves. The failure to recognize these facts and the assumption that the folds follow definite northeast-southwest courses have led to serious errors in previous attempts to determine and map the structure and to no little confusion to those engaged in drilling for gas and oil.

STRATIGRAPHY.

The rocks in this quadrangle comprise those not exposed at the surface and those that outcrop. The former are revealed in deep wells sunk for gas or oil (see well-section sheet); the latter can be studied directly.

ROCKS NOT EXPOSED.

Sources of knowledge.—Information concerning these rocks is derived entirely from the records of deep wells bored for gas or oil and is more or less imperfect. In many cases records have been carelessly kept, important beds from a geologic standpoint, such as bands of red rock or a bed of limestone, have been overlooked or not recorded, and frequently only the oil or gas sands have been noted, thus leaving great blanks in the logs. The methods of measurement introduce some errors. While measurements to the oil and gas sands are mostly made by steel line and are accurate, the depth and thickness of other beds are generally determined by counting the turns of the cable on the bull wheel shaft, and errors may easily occur. In very deep wells the stretching of the cable might be the cause of an error of considerable magnitude. The difficulty of identifying rocks by the relative ease with which the drill penetrates them or by the drillings brought up in the sand pump is also probably a source of error, this being especially true of observers without scientific training. To this fact may be, and probably often are, due in part the lithologic variations recorded in wells in contiguous territory. It may thus happen that important beds that are not recorded are not really absent from the section, but have been overlooked. In other cases a heavy sandstone in one well might change to a highly arenaceous shale or shaly sandstone in an adjacent well and thus be recorded as slate or shale. At best, observations on rocks in deep-well sections must be confined almost wholly to their lithologic character; only in very rare instances can anything be learned of their fossils, a knowledge of which is almost indispensable to the correct determination of the age and stratigraphic position of the rocks.

Thickness.—The thickness of the rocks revealed by the drill below the lowest horizon of exposed rocks in the quadrangle is about 3100 feet. The deepest wells in this region, of which we possess a record (see sec. No. 7, well-section sheet), are the Robert Smith well in Winfield Township and a well which was drilled by Joseph Simpson just beyond the northern margin of the quadrangle, north of Bradys Bend village. The latter well starts just above the Vanport limestone and is over 3500 feet deep, and, as the lowest horizon of exposed rocks is about 400 feet below this limestone, this well extends about 3100 feet below any rocks exposed in the quadrangle. The Smith well is also over 3500 feet deep, but does not penetrate so deeply into the rocks, since it starts at a higher horizon. The Kepple well (No. 12 of the well-section sheet) extends 2800 feet below the Vanport limestone and 2400 feet below the lowest exposed rocks. There are a number of other wells in the quadrangle that are nearly as deep.

General character.—These unexposed rocks fall naturally into three well-differentiated groups. In general the following strata are encountered from the top downward; (1) 700 to 800 feet of gray shale and sandstones; (2) 300 to 700 feet of strata characterized by the presence of more or less red rocks, presumably red shale; and (3) prevailingly dark shale with thin sandstone layers and occasional thicker beds of sandstone to the bottom of the wells.

GRAY SHALE AND SANDSTONES.

The gray shale and sandstones contain several members of sufficient importance to warrant separate description. With the exception of these members the group is composed mainly of gray sandy shale with occasional heavy sandstones.

Burgoon (Mountain) sandstone.—At the top of this group lies about 100 to 175 feet of heavy sandstone, which is the lower part of the Mountain or Big Injun sand of the driller, the upper 225 feet of which is exposed in the Allegheny Valley on the arch of the Kellersburg anticline. For reasons given below, it is proposed to use the geographic name Burgoon sandstone for this stratum.

Patton shale.—In many wells a thin band of red shale occurs just below the base of the Burgoon sandstone. This is a widely distributed stratum and merits attention on account of its importance as a horizon marker. This bed was first described by Richardson (Indiana folio) and was named by him the Patton shale on the assumption that it is the same as the red shale that outcrops at Patton station on Redbank Creek in Jefferson County.

Lower sands (Gas sands).—In some of the well sections shown on the well-section sheet a sandstone is noted about 150 feet below the Mountain sandstone that is called the First sand, but it is by no means certain that the first sand of one well is the same as the first sand of another. This sandstone is sometimes regarded as the equivalent of the Pithole grit of Venango County and the Berea grit of Ohio, but there is no conclusive evidence that these strata are represented in this region. The bottom of this group of gray shales and sandstones is prevailingly sandy and several beds are distinguished. These are the Murrysville gas sand, about 300 feet below the Mountain sand, the Second or Hundred-foot sand, about 450 feet below the Mountain sand, and the Thirty-foot sand, just below the Hundred-foot sand. The Second or Hundred-foot and the Thirty-foot sands occur at the top of the Venango oil sands of the oil regions.

RED BEDS.

Below these gray rocks occur several hundred feet of strata characterized by more or less of what the drillers call red rock, presumably red shale. The proportion of red rocks as well as the extent of the interval in which they occur differs much, as can be seen on the well-section sheet. In some records no red rocks are noted; in most, the part of the section through which they are noted is from about 200 to 350 feet in thickness. In the Kepple well (No. 12) they are noted at intervals through an exceptional distance of 700 feet. The total thickness and the distribution of these red beds vary greatly. In some wells (as in Nos. 7 and 10) they occur as scattered beds of greater or less thickness separated by beds of dark shale and sandstones; in others (as in No. 9) they occur as an unbroken mass 300 feet thick; in still others (as Nos. 6 and 13) no red beds at all are noted. It seems hardly credible that they are absent in such wells; it is far more probable that they occur as thin beds which were either not observed or not recorded.

Oil sands.—In the midst of the red beds in this quadrangle lie the coarse oil-bearing sandstones known as the Stray, Third, and Fourth oil sands, with the overlying thin sandstones known as the Blue Monday and Boulder sands.

DARK SHALES AND THIN SANDSTONES.

The remaining 1500 to 2000 feet of strata comprising the third group and extending to the bottom of the deepest well are composed mainly of gray shales interbedded with thin sandstone layers, to which the drillers apply the name "slate and shells," the sandstone layers being the shells. Occasionally throughout this group thicker strata of sandstone occur, but these are rarely noted as reaching 50 feet in thickness.

Speechley and Tiona sands.—In the midst of the third group and from 500 to 700 feet below the red beds occurs a group of these sands, the upper members of which are known as the Speechley and the lower as the Tiona sands. The latter sands have not, however, been noted in this quadrangle.

GENERAL CORRELATION.

As will be shown in the discussion of exposed rocks, the Burgoon (Mountain) sandstone certainly belongs to the Pocono formation, but the lower limit of the Pocono can not be determined with certainty. By comparison of the well sections on the well-section sheet with those of fig. 5, light may be thrown on the matter. Section A of fig. 5 is a carefully measured section of the Pocono, Mauch Chunk, and Pottsville formations along the Pennsylvania Railroad on the Allegheny Front east of Bennington, in Blair County; B is of a deep well at Johnstown, 25 miles west of the Allegheny Front; C is of the Waddle well near Blairsville; D is of the Peter Heilman No. 2 well, near the southern margin of the Rural Valley quadrangle; and E is of the Montgomery No. 3 well, near Ford City, in the Kittanning quadrangle.

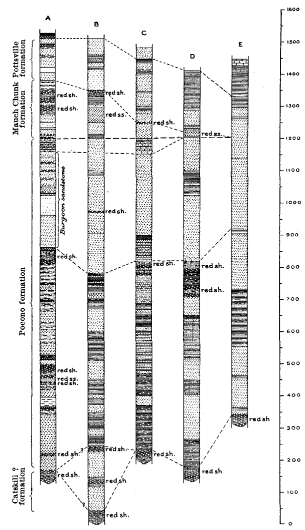


FIG. 5.—Columnar sections of the Mississippian and Pottsville rocks in western Pennsylvania.

A, Allegheny Front along the Pennsylvania Railroad east of Bennington (measured by the author); B, deep well at Johnstown; C, Waddle well, Conemaugh Township, Indiana County; D, Peter Heilman No. 2 well, Kittanning Township, Armstrong County; E, Montgomery No. 3 well, Manor Township, Armstrong County.

SECTION ON THE ALLEGHENY FRONT.

Section A was measured by the writer and W. C. Phalen in the summer of 1903. This is an important section for the correlation of the rocks under discussion, for it was obtained at the nearest point at which they outcrop. On that account a brief description of it will be given here.

The section begins at the curve where the railroad turns into the gorge of Sugar Run from its course along the Allegheny Front south of Kittanning Point and extends to Bennington station, near the highest point on the railroad. The rocks are exposed nearly the whole distance, more than 2 miles. The breaks that occur are noted below.

Red shale and gray shale and sandstone.—At the base of the section at the curve above mentioned are 50 feet of bright-red soft shale. Above this shale are 180 feet of coarse sandstone, separated into two parts by a thin band of red shale 50 feet from the bottom. Above this sandstone are about 530 feet of alternating shale and sandstone, prevailingly gray, but containing bands of red shale and sandstone and occasional beds of clay. At the top of this group of shales and sandstones and included in it is a bed of red shale about 40 feet thick which, as will be shown later, is of considerable importance. The top of this red shale is at track level 3000 feet east of Allegrippus station.

Burgoon sandstone.—Immediately overlying the red shale are apparently 300 feet of coarse and very thick-bedded gray sandstone, which, with the exception of a concealed interval of about 60 feet in a ravine east of Allegrippus, is continuously exposed along the track for the 3000 feet between the top of the red shale at its base and Allegrippus. The concealed interval just mentioned may contain some shale, though it is probably filled with sandstone. The top of this sandstone is about 10 feet above the track at the east side of the ravine at Allegrippus station, and it is very definitely limited by the bottom of a calcareous stratum of highly characteristic appearance. This sandstone is a well-defined lithologic unit in this section, to which the name Burgoon is here applied because it is cut through by the valley of Burgoon Run above Kittanning point. No considerable exposures of the sandstone were seen on the valley walls, but on the southern side abundant bowlders of coarse siliceous sandstone and a soil that is almost pure sand indicate the presence of the stratum close beneath the surface.

Loyalhanna limestone.—Immediately overlying the Burgoon sandstone on the western side of the ravine at Allegrippus is a stratum of coarse calcareous sandstone. This stratum is marked by strong cross-bedding and a surface pitted by differential erosion, and these features give it a very distinctive appearance by which it is recognized at widely separated points in western Pennsylvania. These characters serve to distinguish the stratum sharply from the Burgoon sandstone below, and, as before stated, the boundary between the two is plainly apparent 10 feet above the track at the western end of the cut at Allegrippus station. At the bottom of the cut on the west side of the ravine at Allegrippus a few feet of this stratum appear, but its top descends below the roadbed about 100 feet west of the end of the cut. It is rather more calcareous at this point than on the east side of the ravine, and this may indicate that it is more calcareous toward the top than lower down. It is closely overlain here by a few feet of rock composed of thin bands of red shale alternating with layers of gray sandstone, and these beds are in turn overlain by a considerable thickness of coarse, thick-bedded, gray sandstone of the Mauch Chunk formation.

At the top of the cut immediately east of Allegrippus the thickness of the Loyalhanna limestone exposed was measured and found to be 40 feet. It is uncertain, however, whether this is the full thickness of the stratum, since it could not be determined whether its top is exposed at that point. Its thickness is probably not much over 40 feet. This stratum is universally known in the region of its occurrence as the "Siliceous limestone," though generally it is a rather calcareous sandstone. In deference to general usage it is here called a limestone, and the name Loyalhanna is proposed for it because it is well developed along the gorge in which that stream flows across Chestnut Ridge, in Westmoreland County, and because it is extensively exposed on that stream in the quarries at Long Bridge, between Latrobe and Ligonier.

The part of section No. 1 above the Loyalhanna limestone has no bearing on the present discussion and will not be described here. In the western Pennsylvania folios already published, the top of the Loyalhanna limestone has been taken as the top of the Pocono formation, and that usage is accepted here.

Base of Pocono.—There is uncertainty as to the bottom of the Pocono. A few fossil plants, mainly *Lepidodendra*, were found in places down to a point about midway between the top of the Loyalhanna limestone and the top of the red shale at the bottom of the section described above. These are regarded by David White as of Pocono age. About 100 feet lower some fragments of a lamellibranch were found, and still lower, at semaphore tower No. 237, several specimens of a *Lingula* were found in a green clayey layer. These were examined by George H. Girty, with indefinite results. He expresses the opinion, however, that they exhibit Devonian rather than Carboniferous affinities. Associated with the *Lingula* found at the semaphore tower were a number of species of ferns which David White thinks may be either Carboniferous or Devonian. From this point to the bottom of the section at the top of the red shale no fossils were found and it does not seem possible at present to fix, on paleontologic grounds, the bottom of the Pocono with any degree of definiteness. On lithologic grounds, however, there seems to be but one place to draw the boundary between that formation and the underlying Catskill formation, and that is at the top of the red shale shown at the bottom of section A. The top of this shale lies about 380 feet below the clay bed in which the fossils occur, and descends below the level of the railroad track at a point about 2000 feet east of the above-mentioned semaphore tower. From the top of this shale downward for 1600 to 2000 feet, probably 80 per cent of the rocks are of a bright red color, which sharply distinguishes them from the overlying and underlying rocks. For that reason the lower limit of the Pocono and the boundary between the Carboniferous and the Devonian is placed at the top of the main body of red rocks.

By comparing well sections B to E of fig. 5 with section A described in the foregoing pages, it is seen at once that the Burgoon sandstone can be recognized in them all. In the Heilman and Montgomery wells this sandstone is known as the Mountain or Big Injun sand. It is interesting to note that the red shale immediately underlying the base of the Burgoon sandstone in the wells C and D also occurs in the same position on the Allegheny Front, as shown in section A This has been described on a former page as the Patton shale.

In all these sections there is a uniform sequence of rocks from the top of the Burgoon sandstone to the main red beds, as follows: (1) Burgoon sandstone, 300 to 400 feet; (2) shale and sandstone, 600 to 700 feet; (3) main thickness of red rocks. On the Allegheny Front the red rocks proper are about 2000 feet thick and belong to the Catskill formation; in the four wells the red rocks are from 300 to 400 feet thick. Only the top of the red rocks is shown in the sections. In all these sections the Burgoon (Mountain) sandstone is universally assigned to the Pocono formation. In section A the shale and sandstone between the Burgoon sandstone and the red rocks are also classed as Pocono, and on the grounds of sequence, lithologic identity, thickness, and apparent stratigraphic continuity it seems reasonable to conclude that the shale and sandstone in the same position in the well sections are likewise to be classed as Pocono and that the underlying red rocks are to be regarded as Catskill. From this it follows that the base of the Pocono, and therefore the boundary between the Carboniferous and Devonian systems in the Heilman and Montgomery wells, lies at the top of the red beds not far below the bottom of the Hundred-foot sand; and, since the section of these wells may be regarded as typical, this determination holds for the entire region. If, as suggested above, the red beds are to be accepted as belonging to the Catskill formation, the 1500 to 2000 feet of gray sandstones and shales underlying them would naturally fall into the Chemung formation.

Another view of the question is, however, possible. During the present survey of Pennsylvania, fossils were collected on the National Pike, in Fayette County, about 50 feet below the base of the Burgoon sandstone, which is there 300 feet thick. These fossils were identified by George H. Girty, who regards them as of Chemung age.

Professor Stevenson states (Am. Jour. Sci., 3d ser., vol. 15, 1878, pp. 423–430) that he found, within 18 inches of the base of the Burgoon sandstone, a number of species which were pronounced by James Hall to be typical Chemung forms, and on this ground Campbell (Masontown and Uniontown folio) limited the Pocono of the region to the Burgoon sandstone and classed the underlying rocks as Devonian. These facts seem to show that in the southwestern part of the State the Pocono is limited to the Burgoon sandstone and that the underlying beds belong to the Chemung formation. It is possible, however, that these fossils, which are long-lived Devonian forms, survived in the open sea to the west until a considerable thickness of fresh-water Pocono rocks had been deposited and then migrated eastward during a temporary incursion of salt water into the region where the fossils now occur; or it is possible that the fresh-water conditions under which the earlier Pocono rocks of the Allegheny Front were deposited did not extend at first so far west as later, when the Burgoon sandstone was deposited, and that the Chemung species lived continuously in the Chestnut Ridge region, and that their fossils occur in all the underlying rocks. No Mississippian fossils mingling with the Chemung have been found in the region, but in southern New York the writer (Rept. New York State Pal., 1902, pp. 990–995) found such a mingling of Chemung species with a few that are of distinctly Carboniferous aspect, and it seems not unlikely that, by careful search, a similar merging of faunas will ultimately be found in southwestern Pennsylvania.

As matters stand at present, then, the exact position of the plane of division between the Carboniferous and Devonian systems in this region must be regarded as uncertain.

Carboniferous System.

General statement.—Most of the rocks exposed in this quadrangle belong to the Carboniferous system. There are, however, certain old gravels of possible Tertiary age and certain deposits belonging to the Quaternary. The Carboniferous rocks are divided into two series, the Mississippian series below and the Pennsylvanian series above. The Mississippian series is best developed in the Mississippi Valley. As a general thing it is not coal bearing, but in certain parts of the Appalachian region it includes workable coal beds of limited extent. The Pennsylvanian series includes the coal-bearing rocks or Coal Measures of the Appalachian coal fields, and is typically developed in Pennsylvania. Both series include a number of separate formations, which in turn include various members of local importance. In this quadrangle the Mississippian series is represented by the Pocono formation, while the Pennsylvanian is represented by the Pottsville, Allegheny, and Conemaugh formations.

POCONO FORMATION.

General discussion.—Considerable difference of opinion has been expressed regarding the existence of Pocono rocks at the surface along the Allegheny Valley south of Clarion River. In the final report of the First Geological Survey of Pennsylvania the lowest rocks exposed in the valley were included by Rogers (Geol. of Pennsylvania, vol. 2, p. 585) in the Pottsville (Seral formation), but in Report H5 of the Second Geological Survey, W. G. Platt recognized not only the Pocono sandstone but the Mauch Chunk shale as being exposed beneath the Pottsville. This determination was based largely upon the occurrence at McCrea Furnace, on Mahoning Creek, of a bed of siliceous limestone which Platt correlated with the well-known bed of a similar character marking the top of the Pocono formation in the Chestnut Ridge region. Lesley, however, was not willing to accept this determination of Platt's, and in a preface to the same volume states that it is much more probable that this limestone occurs at the Mercer horizon than at that of the "siliceous limestone," and consequently that all of the rocks below this horizon exposed along Allegheny River are parts of the Pottsville formation, which, according to him, consists of three sandy members separated by two shale intervals, as it does in the type locality of the Beaver Valley. The following section (fig. 6) shows the character of the rocks under consideration as they are exposed at the Riverview mine, 2 miles south of Redbank Junction.

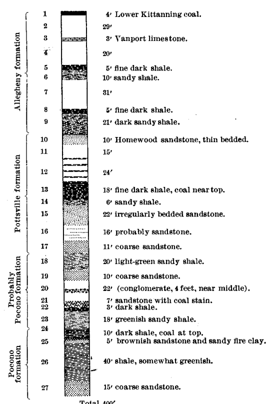


FIG. 6.—Section at Riverview mine, 2 miles below Redbank Junction.

On purely lithologic grounds it is extremely difficult, if not impossible, to subdivide these rocks into formations and correlate them with divisions recognized in other parts of the field, and the different interpretations that have been put upon them doubtless must be attributed to the absence of well-marked beds.

The section at Riverview mine shown is fairly representative of the rocks of this debatable interval and may be considered as typical of this region except that the Pocono part shows more shale than occurs in some other sections.

The section includes the Lower Kittanning coal and the Vanport limestone, two of the best horizon markers in the region. The top of the Pottsville formation is clearly marked at a distance of 94 feet below the top of the limestone by the Homewood sandstone, which generally is massive in this region, but in this section is thin bedded and inconspicuous. This bed is underlain by about 65 feet of shale, which contains several small coal seams and carries a good Mercer flora. The strata underlying the Mercer beds are more difficult to classify, but the first sandstone (Nos. 15, 16, and 17), about 49 feet in thickness, carries impressions of Pennsylvanian plant stems which show that it is to be included in the Pottsville formation, while its position shows that it is doubtless equivalent to a part or the whole of the Connoquenessing sandstone.

Below the bed just described fossils are not abundant, and those which occur are generally poorly preserved, but, so far as observed, there are no indications of Pottsville plants below the Connoquenessing sandstone. Good Pocono plants were found from the railroad up for a distance of 80 feet, but, on account of the scarcity of fossils, it is impossible to say with certainty to which series the rocks between that horizon and the base of the Connoquenessing sandstone belong. The few fossils found in the intermediate zone are too poorly preserved to afford definite evidence, but they seem to partake of the characteristics of a Pocono rather than a Pottsville flora. Provisionally, then, the base of the Connoquenessing sandstone will be regarded as the base of the Pottsville formation, and the rocks lying below will be assigned to the Pocono formation.

In the eastern part of Pennsylvania, where sedimentation apparently was uninterrupted from Devonian to late Carboniferous time, the Pocono formation consists of a great sandy series more than 1000 feet in thickness. It is overlain by a great thickness of Mauch Chunk red shale, and this in turn is overlain by the heavy conglomerates of the Pottsville formation. In the Allegheny Valley the Pocono becomes somewhat thinner; the Mauch Chunk, separating the Pocono and Pottsville in the east, is probably absent; and from evidence presented in the discussion of the Pottsville formation it is shown that the interval occupied by the Mauch Chunk in the east is, in this region, represented by an unconformity, and that the general absence of the Mauch Chunk formation, and probably of the upper part of the Pocono also, is due to their erosion before the deposition of the Pottsville rocks.

Character and distribution of Pocono.—The Pocono rocks exposed in this quadrangle are confined to the valleys of Allegheny River and Redbank Creek. Since the Connoquenessing sandstone rests unconformably upon the Pocono formation, it follows that the beds in actual contact are different in different sections. The unconformity is so slight, the exposures in general are so poor, and the adjacent beds are so often sandstones of nearly identical character, that it is impossible to trace the contact between the two formations. As assumed in sec. E, fig. 5, the plane of division between the two formations lies about 230 feet below the Vanport limestone, and it will be assumed that it holds approximately this position throughout the quadrangle, and the Pocono formation has been mapped and will be described on that basis. The top of the Pocono at the point where Allegheny River crosses the axis of the Kellersburg anticline would accordingly lie at an elevation of about 1060 feet, making a maximum thickness of 260 feet of Pocono rocks exposed in the quadrangle.

So far as exposed in this quadrangle the Pocono formation is composed mainly of a heavy gray to greenish sandstone, the Mountain or Big Injun sand of the driller, which for reasons already stated is here called the Burgoon sandstone. While the sandstone is prevailingly a heavy and nearly continuous mass, in places it is broken by beds of shale of greater or less extent and thickness.

The preceding section (fig. 6) presents the latter phase of the formation, while the section at the mouth of Redbank Creek, where the formation consists of about 150 feet of coarse, thick-bedded to massive sandstone, passing without a break into the Connoquenessing sandstone above, presents the former and probably more common phase. On the bluff of the Allegheny above Mahoning two or three thin coal seams occur.

In the Allegheny Valley the top of the formation, rising toward the axis of the Kellersburg anticline, emerges from below water between Templeton and Mahoning, a short distance east of the quadrangle, reaches an elevation of 260 feet above the river on the arch of the anticline, and then descends gradually to near water level near Phillipston, whence it continues, probably just above the river, to the northern margin of the quadrangle. The Pocono is above water along almost the whole length of Redbank Creek within the quadrangle. The top of the formation is about 150 feet above water at the mouth of the creek, and descends nearly to water level at Lawsonham, just off the eastern edge of the quadrangle.

MAUCH CHUNK FORMATION.

In Rept. H5 of the Second Geological Survey of Pennsylvania, Platt refers certain dark shales exposed in the midst of heavy sandstone in the bluff above Templeton, in the Rural Valley quadrangle on the east, to the Mauch Chunk formation. These shales, however, present no resemblance to the Mauch Chunk shales elsewhere, and to all appearances they are lenticular beds of merely local extent included in the Burgoon sandstone.

Unconformity at base of Pottsville.—The Mauch Chunk formation, which separates the Pocono and Pottsville formations in other parts of the State, is absent from the Allegheny Valley. In southern Indiana and northern Westmoreland counties it has been found in many well sections, and ranges in thickness from a few to more than a hundred feet. It has a thickness of 150 feet in Packsaddle Gap near Bolivar, of 250 feet in northern and eastern Fayette County, where it includes the Greenbrier limestone, of 180 feet along the Allegheny Front, of 1100 feet at Broadtop, and of 2200 feet at Mauch Chunk. Not only is the Mauch Chunk absent in this quadrangle, but the absence of the Loyalhanna limestone shows that some of the upper part of the Pocono also is lacking. According to Platt (Second Geol. Surv. Pennsylvania, Rept. H5, p. 144), a fragment of this limestone is preserved at McCrea Furnace, on Mahoning Creek above Eddyville, in the eastern part of Armstrong County. As shown in a preceding paragraph, Platt's conclusion was strongly opposed by Lesley (Second Geol. Surv. Pennsylvania, Rept. H5, p. xv), who regarded the limestone in question as more probably representing the Mercer limestone, and more recently the writer has reached the same conclusion, not only on stratigraphic grounds, but also on the evidence of fossil plants collected from the sandstone which closely underlies the limestone and which was determined by David White to be of Pottsville age. Neither is the siliceous limestone known west of Allegheny River, though two or three doubtful references to a limestone of similar character occur in some drill records of Butler County.

These facts show that there is an unconformity between the Pocono and Pottsville formations in this region, and this conclusion is further strengthened by the fact that the Pottsville is here only about 140 feet in thickness, and, like the Mauch Chunk, thickens to the east and in the Southern Anthracite basin of eastern Pennsylvania is 1200 feet thick. The thin bed of Pottsville in the western part of the State was formerly believed to represent the whole thickness of the formation in the anthracite region, the difference being due to the difference in the rate of sedimentation, but it is now believed to represent only the upper part of the Pottsville of the anthracite region. This variation will be explained under the heading "Geologic and geographic history."

POTTSVILLE FORMATION.

General character.—The Pottsville formation overlies the Pocono sandstone unconformably and ranges from 120 to 140 feet in thickness. It varies in character, but as a rule it is composed of two sandy members, the Connoquenessing and Homewood sandstones, separated near the middle by a stratum of shale 20 feet or more in thickness, bearing one or more thin seams of coal (the Mercer coal and shale.)

Connoquenessing sandstone.—The lowest member of the formation is the Connoquenessing sandstone, which immediately overlies the Pocono and occurs in a large area throughout western Pennsylvania. It is generally a coarse, gray, thick-bedded sandstone, sometimes massive and conglomeratic, and often flaggy or shaly in places. It averages about 40 feet in thickness and generally fills most of the interval between the Pocono and the lowest of the Mercer coals.

Mercer shale and coals.—The Mercer coals are thin; they generally have a thickness of a few inches, rarely reaching a foot. One or more, most often three, beds may occur in an interval of 20 feet, the rest of the interval being occupied by shale and fire clay. The lowest bed is generally about 60 feet above the bottom of the Connoquenessing sandstone. The shale bed accompanying the coals is very irregular in thickness. It may extend 20 feet below the lowest coal and also fill nearly the entire interval between the uppermost coal and the top of the formation. It is usually dark gray and somewhat sandy. In several wells in the southeast corner of the quadrangle a limestone is recorded 150 to 170 feet below the Vanport limestone. This is probably the Mercer limestone, which is not known to outcrop in the quadrangle.

Homewood sandstone.—The uppermost member of the Pottsville is the Homewood sandstone. While it is locally a good, heavy or even massive sandstone 40 feet thick, filling the interval between the Mercer coals and the top of the Pottsville, it as often thins greatly or disappears entirely, its place being occupied by the shale mentioned above.

Distribution of Pottsville.—The top of the Pottsville, rising toward the McHaddon anticline, appears above the river in the vicinity of Wickboro, above Kittanning, reaches a height of about 100 feet three-quarters of a mile below the mouth of Cowanshannock Creek, and then, dipping northeastward, descends below water a short distance beyond the quadrangle boundary. The topmost layers of the Homewood sandstone are of a rather laminated character where they rise above the river opposite Wickboro and in the bed of Cowanshannock Creek a short distance above its mouth. It also outcrops at the mouth of Limestone Creek, where it is coarse and thick bedded. The full thickness of the Pottsville in the quadrangle is shown along both sides of the gorge of Allegheny River in the northeast corner of the quadrangle and along Redbank Creek. The bottom of the formation is 260 feet above the river on the axis of the Kellersburg anticline and at water level at Phillipston. At the mouth of Sugar Creek, opposite East Brady, the Homewood sandstone has changed to shale, below which is the Mercer shale with two thin coal seams, and still lower the coarse and heavy Connoquenessing sandstone, extending down to the creek. In a ravine on the north side of the river a half mile above the mouth of Sugar Creek the formation outcrops and shows the same character as at the latter place. In the vicinity of Craigsville the three members of the formation are exposed. The Homewood sandstone, rather flaggy, occurs in a ledge by the creek back of the Buffalo, Rochester and Pittsburg railroad station; the Connoquenessing sandstone shows at Craigsville and in a railroad cut just above, near creek level, where it is white and thick bedded; the Mercer shale and the blossom of the Mercer coal show between the two sandstones in the road west of Craigsville. The same beds are exhibited on both sides of Patterson Creek on the road from Craigsville to Fosters Mills, but the Homewood sandstone seems to have passed into shale at that locality.

ALLEGHENY FORMATION.

General character and thickness.—This formation, immediately overlying the Pottsville, consists of sandstone, shale, coal beds, and thin limestones, and varies from 340 to 360 feet in thickness. It contains nearly all the valuable mineral deposits, save oil and gas, that are found in the quadrangle. The Upper Freeport coal forms the top of the formation, and since this coal, as well as the top of the Pottsville formation below, can be traced with but little difficulty, the limits of the formation have been very definitely determined. It is the purpose to discuss at this place only the general stratigraphy of the formation. A fuller description of the coal and other economic beds will be found in a subsequent section.

Distribution.—The Allegheny formation is exposed to a greater or less depth along the principal streams of the quadrangle and their tributaries. Allegheny River cuts below the formation from a point a short distance above Kittanning to the eastern margin of the quadrangle and also along its course across the northeast corner. Redbank Creek has cut through the formation the full distance of its course within the quadrangle, and Buffalo Creek and Patterson Creek have cut below it in the vicinity of Craigsville where they cross the axis of the Kellersburg anticline. Rough Run cuts nearly through the formation at West Winfield. Glade Run, Garrett Run, Limestone Run, Huling Run, and Sugar Creek with its tributaries cut well into the formation, and the last three cut below it at their mouths.

In addition to these valley exposures a large area of Allegheny rocks is exposed on the uplands along the Kellersburg anticline. This area begins near Rough Run and Buffalo Creek on the south and widens out northeastward to embrace most of the northeast corner of the quadrangle.

Brookville coal.—Near the base of the formation lies the Brookville coal, separated from the underlying Pottsville by 10 to 20 feet of shale and fire clay. This coal is not known to be of minable thickness within the quadrangle, though, like many other coal seams, it may become so locally.

Craigsville coal.—On Buffalo Creek about 2 miles northwest of Craigsville a coal 3 feet thick, 50 feet below the Vanport limestone and about 40 feet above the Brookville coal, has been recently opened and worked. The Clarion coal at this place is 15 feet below the limestone. What appears to be the same coal has been opened on the hill one-half mile north by west of Craigsville and is reported 3½ feet thick. About 1 mile north of Craigsville, along the road from Craigsville to Fosters Mills, the blossom of a coal shows 50 feet below the limestone, and the Brookville coal has been opened about 50 feet lower. At West Winfield streaks and pockets of coal in a heavy sandstone 40 feet below the limestone and 25 feet below the Clarion coal may represent the same horizon as the coal in the vicinity of Craigsville. It seems certain, therefore, that there is a coal at these places between the Brookville and Clarion coals. So far as the writer is aware the three coals in this relation have not been observed elsewhere in the quadrangle. At present it seems best to regard the intermediate coal as a local development, without attempting to identify it with any previously described coal, and the name Craigsville is here applied to it on account of its good development near that place.

Clarion sandstone.—At the old mill on Cowanshannock Creek 1 mile above its mouth and near the margin of the quadrangle, the following section is exposed.

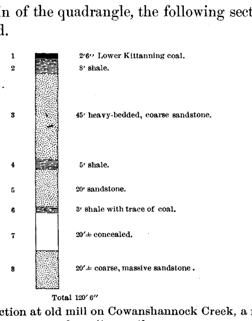


FIG. 7.—Section at old mill on Cowanshannock Creek, a mile above its mouth.

In this section the thicknesses of the concealed interval, No. 7, and the sandstone No. 8 were estimated and may be considerably in error. The sandstone No. 8 shows in the bed of the creek and in a ledge washed by the water, whence have come the great bowlders of coarse white sandstone that fill the channel at the old mill. Near the mouth of the creek the Vanport limestone is about 50 feet below the Lower Kittanning coal. In the section above no trace of the limestone was detected, and its place is apparently occupied by the shale No. 4. The shale with traces of coal, No. 6, probably represents the Clarion coal, and the sandstone No. 8, which may occupy most of the concealed interval also, is probably the Clarion sandstone described in the report on Armstrong County. Its bottom would lie at least 60 feet below the Vanport limestone, and its thickness may reach 40 feet. An interesting feature of this section is the fact that the entire interval of over 100 feet below the Lower Kittanning coal is nearly filled with coarse, heavy sandstone, and this is a good illustration of the variable nature of Coal Measure stratigraphy. At West Winfield a heavy sandstone extends from close below the Clarion coal to water level. Its bottom is not exposed, but it is at least 50 feet thick. At both the above localities the Clarion sandstone was identified by the geologists of the Second Geological Survey of Pennsylvania as Pottsville (Rept. H5, p. 101; Rept. Q, p. 93). There appears to be nothing upon which to base this identification except the coarse, massive character of the sandstone, and, on account of its relations to the Clarion coal and Vanport limestone, the writer prefers to regard it as Clarion. The facts are best explained by assuming that sandy instead of clayey sediments prevailed for a time in these localities.

Clarion fire clay.—Under the Clarion coal near Kittanning there is a good bed of fire clay, which supplies the clay for the brick works at Ewing and Cowanshannock, and beneath the same coal at West Winfield fire clay also occurs, 8 feet thick.

Clarion coal.—The horizon of this coal seam varies from 15 to 25 feet below the Vanport limestone. It is generally poorly developed and worthless and may be entirely wanting in places. It reaches minable thickness only at West Winfield.

With the exception of these coals and the Clarion sandstone the interval between the Pottsville formation and the Vanport limestone is nearly everywhere filled with shale.

Vanport limestone.—From 90 to 100 feet above the top of the Pottsville lies the Vanport ("Ferriferous") limestone. It is a very persistent bed and is invaluable as a reference stratum in working out the structure of the region, as well as a key rock for the identification of the other members of the Allegheny formation.

This limestone is universally known throughout western Pennsylvania as the Ferriferous limestone, because of the iron ore contained in it. The present name was first used by I. C. White (Second Geol. Surv. Pennsylvania, Rept. Q, pp. 60–63), because of the fine development of the limestone at Vanport, on Ohio River in Beaver County.

The Vanport limestone is generally a grayish rock. It is of marine origin, as in places it contains abundant brachiopods and joints of crinoid stems and occasionally cyathophylloid corals, as well as pelecypods and gasteropods. It is nearly pure, running generally 95 per cent of carbonate of lime. It contains very little magnesia. In thickness it varies from 0 to 20 feet, the latter thickness being reached at West Winfield, where it is extensively quarried. The average thickness for the quadrangle is probably about 8 to 10 feet, though in most well records it is noted as about 20 feet thick. It is generally massive or thick bedded.

The limestone is notable from the fact that it bears upon its upper surface an iron ore that is generally a hard, often siliceous layer of impure hematite or limonite, ranging from a few inches to a foot or more in thickness. This is known in Pennsylvania as the "buhrstone ore" because it is often underlain by cherty material (I. C. White, Bull. U. S. Geol. Survey No. 65, p. 173). Sometimes the ore occurs as carbonate nodules in the first few feet of shales overlying the limestone. At Kittanning the ore is fossiliferous, containing abundant impressions of shells, mainly brachiopods. The same might be found elsewhere if careful search were made.

The limestone rises above the river just below Kittanning and remains above water level up the Allegheny to the northern margin of the quadrangle and along Redbank Creek from the mouth of the stream to the eastern margin of the quadrangle. It outcrops along the valley of Limestone Creek to above Adrian, on Sugar Creek nearly to Kaylor, and up Huling Run to the vicinity of Sherrett. On Buffalo Creek the limestone is above water level for a mile north of the junction of Rough Run. Along Rough Run it rises about 50 feet above the stream at West Winfield, on the axis of the Kellersburg anticline, then dips westward, and goes under water about three-quarters of a mile farther up the creek. It rises above Buffalo Creek again about 2 miles below Buffalo Mills and is about 250 feet above water on the axis of the Kellersburg anticline in the vicinity of Craigsville. It then drops to water level on Little Buffalo Run about three-quarters of a mile west of Nichola and on Patterson Creek near Fosters Mills.

Although the limestone is generally persistent, there are areas where it can not be found and is probably wanting. It has not been found over a considerable area east of Rimer, nor in the hills along the south side of Allegheny River for 3 or 4 miles above the eastern margin of the quadrangle. It is absent also on the north side of the river just west of Phillipston, north of the mouth of the Cowanshannock, and on the west side of the river nearly opposite Ewing. At other places the limestone seems to be present, though very much thinner than usual. This is the case on the south side of the river opposite Phillipston and at other places outside the quadrangle. Furthermore, the ore may be present though the limestone is wanting, as along the highway northwest of Phillipston, where hematite ore occurs at the base of a heavy sandstone. Similar conditions prevail opposite Ewing, where the limestone is reported wanting, but, from the number of old pits which occur at this point just beneath a heavy sandstone, it is evident that the ore is present and was mined extensively.

The absence of the limestone may be attributed to either of two causes—original nondeposition of the calcareous sediment or its erosion after deposition. This erosion may have been either subaerial or subaqueous.

The evidence in favor of the assumption that the limestone was not originally uniformly deposited is the generally varied character of the Carboniferous strata of western Pennsylvania. Sandstone and shale alternate in the most surprising fashion along the same stratigraphic plane. This variation is hardly to be attributed to the erosion of previously deposited sediment of one kind and its subsequent replacement by that of another, but rather to the contemporaneous deposition of sediments of different kinds in different places. The local replacement of the limestone by shale or sandstone is only in harmony with the general character of the stratigraphy of the region. It seems not improbable that conditions were locally unfavorable to the growth of the marine organisms from whose shells the calcareous sediment of the limestone was derived, or unfavorable to the transportation of such sediments from some source removed a greater or less distance and their accumulation in the places where the limestone is now absent.

On the other hand, the limestone has a wide extent in western Pennsylvania and eastern Ohio and the areas where it is known to be absent are small and comparatively few. The extent and persistence as well as the apparent purity of this bed over so large an area seem to indicate practically uniform conditions during its deposition, and point also to the fact that noncalcareous sediment was not at the same time being deposited over that area. It therefore seems difficult to conceive of conditions which prevented the deposition of calcareous sediment in the apparently limited, irregular, and patchy areas in which the limestone is now absent. Still, it is possible that the areas in which limestone does not occur were elevations of the old sea bottom which stood near enough to the surface to be affected by the waves, and thus the accumulation of the limy sediment was prevented.

If the supposition that the limestone was removed by subaerial erosion be accepted it must be assumed that after the epoch of general limestone deposition the small areas free from limestone were elevated somewhat above water level, where they probably remained for a considerable time. In that case some of the ordinary evidence of shore accumulation should be found on the margin of such areas. Such evidence, so far as the writer is aware, has never been found. Furthermore, the limestone is not always absent, but often remains as a thin bed, up to a foot or more in thickness (see Rept. V, pp. 142–144). It seems hardly probable that erosion would have proceeded in such cases just far enough to have removed all but the thin layer of limestone remaining. Besides, the ore often occurs and has been mined in places where no limestone is known to exist.

The continuity and bedded character of the ore throughout most of its extent, and the presence of fossils in places, suggest that the ore was deposited as a calcareous layer immediately on top of the limestone or in the same stratigraphic position where the limestone is wanting. If this took place, then of course the limestone could not have been removed without the previous removal of the ore, and any erosion theory becomes untenable. If, however, the ore is always the product of segregation from the overlying shales and sandstones, a theory which is commonly held, then the latter objection would lose its force.

The theory of subaqueous erosion by solution caused by marine currents bearing water differing in character from that in which the limestone was deposited has been advanced. The irregular shape and apparent lack of any sort of linear arrangement of the areas affected seem to be against this theory.

It must be admitted that the problem is a difficult one and that there are not yet sufficient data at hand for a satisfactory solution. The writer is rather inclined to the view that the variations of thickness are due to the accidents of original deposition.

Kittanning sandstone.—The interval between the Lower Kittanning coal and the Vanport limestone is usually occupied by shale and a bed of fire clay of varying thickness which underlies the coal and which at Kittanning affords a valuable clay for brick making. But at West Winfield, near the mouth of Cowanshannock Creek, and south of Allegheny River opposite Rimer this interval is occupied by a coarse, heavy sandstone, known as the Kittanning sandstone. One-half mile west of West Winfield this sandstone is 40 or more feet thick and occupies all or nearly all the interval between the coal and the limestone. The same is true on the south side of the river opposite Rimer. On the Cowanshannock 1 mile above its mouth, in Rayburn Township, the sandstone is nearly as thick and is continuous with the Clarion sandstone below. Along the west bank of the river from opposite Ewing to beyond the margin of the quadrangle it is scarcely so thick, but forms in places a bold ledge 15 to 20 feet thick and immediately overlies the limestone or the horizon of the latter where the limestone is absent.

Lower Kittanning coal.—The Lower Kittanning coal is from 30 to 40 feet above the Vanport limestone in the greater portion of the quadrangle, but may be as little as 15 to 20 feet in the northeast corner. This coal is from 3 to 4 feet thick wherever exposed to view, and probably underlies the entire quadrangle except in the limited areas where it has been eroded by the streams.

Middle Kittanning coal.—Forty to 50 feet above the Lower Kittanning occurs the Middle Kittanning coal. The interval is usually occupied by shale, but at Adrian a heavy bed of sandstone occurs above the Lower Kittanning coal.

The blossom of the Middle Kittanning coal shows at a number of places on Buffalo Creek and its tributaries in the general vicinity of West Winfield, on the hills bordering Buffalo Creek west of Craigsville, on Patterson Creek to above Fosters Mills, and on Long Run west of Cowansville. Near the highway 1 mile west of Cowansville post-office it is 2 feet thick where exposed by stripping. There are abundant indications of its presence in the region between Allegheny River and Sherrett, Morrows Corner, and Adrian. It is known in the ridge between Huling Run and Allegheny River. It is well exposed as a thin bed in the bluff just north of Applewold, and is present as a shaly bed in the ravines on the east side of Allegheny River just south of Kittanning. Its blossom was observed north of Redbank Creek in the northeast corner of the quadrangle, about three-quarters of a mile northwest of Phillipston on the road to East Brady, on the roads leading down to Cowanshannock Creek in Rayburn Township near the eastern margin of the quadrangle, and at North Buffalo near the mouth of Glade Run.

Upper Kittanning coal.—Above the Middle Kittanning coal is an interval of from 40 to 50 feet mostly filled with shale, at the top of which lies the Upper Kittanning coal. This coal is usually a mere streak, but becomes of minable thickness locally in the northern part of the quadrangle in the vicinity of Sherrett and Peach Hill, at Somerville, at Kaylor, and possibly also on Cove Run, where a thick bed is reported at what seems to be that horizon. It is present in the vicinity of Morrows Corner, Adrian, French's Corner, Cowansville, and on Long Run. Its blossom shows along the valley of Buffalo Creek west of Craigsville, along the tributary valley from Nichola to Rattigan, on Buffalo Creek 1½ miles southwest of Buffalo Mills, near the head of Long Run, in the southeast corner of Clearfield Township, near the southeast corner of West Franklin, and near the forks of Rough Run in Winfield. It is known by its blossom along Glade Run from a point 1 mile south of Walkchalk to the mouth of the run, and shows as a thin streak or as small pockets associated with sandstone in the bluffs on both sides of Allegheny River in the vicinity of Kittanning. Along the Cowanshannock in eastern Rayburn Township it gives a good blossom.

The Upper Kittanning coal is known as the "pot vein," from its habit of thickening suddenly into a pot-like deposit of bituminous coal and cannel shale. These deposits are rare and of small extent. The deposit at Somerville is a good example. At this place the coal and cannel shale reach a thickness of 13 feet, but no trace of these was observed in a bluff less than half a mile distant, where the bed should outcrop.

Freeport sandstone.—Between the Upper Kittanning and Lower Freeport coals there is generally present the Freeport sandstone. This is laminated or flaggy and rather fine grained, as at Weskit, or coarse, massive, and conglomeratic, as in the vicinity of Worthington, where it seems to attain its maximum development. It is at least 50 feet thick in this locality, and probably replaces the Lower Freeport and Upper Kittanning coals. It is best developed along Buffalo Creek from below the mouth of Marrowbone Run, where it shows in the creek bed, northward along the axis of the Kellersburg anticline to Buffalo Mills, Worthington, and Craigsville, where it yields large blocks that cover the surface of the hillsides, and still farther northward to Fosters Mills and Browns Crossroads. West of Fosters Mills it outcrops in conspicuous ledges along the hillsides, and east and northeast forms the surface of the flat land in the southern part of Sugarcreek Township. It shows in good strength at Somerville and in the southern part of Donegal Township. It also is well developed on the high knobs east of Allegheny River and south of Redbank Creek, forms the ledges near the mouth of Garrett Run, and is well exposed and extensively quarried as a coarse conglomeratic sandstone along Allegheny River between the southern margin of the quadrangle and Kellys station.

Lower Freeport limestone.—This bed is generally inconspicuous or absent throughout the quadrangle. It is described by I. C. White (Second Geol. Surv. Pennsylvania, Rept. Q, p. 94) as an impure ferruginous bed 5 feet thick on Rough Run, and it shows in the cut along the highway just north of Garrett Run, where it is about 2 feet thick and is apparently of the same character as on Rough Run.

Lower Freeport iron ore.—According to White (Second Geol. Surv. Pennsylvania, Rept. Q, p. 94), this occurs as a bed of limonite and carbonate mixed, lying just above the Lower Freeport limestone. It is developed, so far as known, only on Rough Run and in the western part of West Franklin Township just north of the Butler Pike.

Lower Freeport coal.—The horizon of this coal is from 40 to 50 feet above the Upper Kittanning coal. It is a variable bed, and over the larger part of the quadrangle is probably too thin to be of value. At Kittanning it is reported to vary within a short distance from nothing to 13 feet in thickness: In the latter case the bed is double, several feet of shale dividing it. At Cowansville and southward along Glade Run and Limestone Run it is 4 feet thick. In southern Donegal Township it is thick enough to warrant opening in several places. In the vicinity of Peach Hill it has a thickness of 4 feet. It makes a good showing at the head of Rough Run in southern Clearfield Township and along the ridge southwest of Buffalo Mills. On Buffalo Creek opposite the mouth of Sipes Run it is a mere thread in the sandstone. Its blossom was seen on the hills west of the Cowanshannock in Rayburn Township. It gives a good blossom in the vicinity of Weskit, and about 1½ miles northwest of that place on the road to Cowansville is 3 to 4 feet thick. Little is known of it elsewhere in the quadrangle.

Butler sandstone.—At places a coarse, heavy, conglomeratic sandstone occurs in the interval between the Upper and Lower Freeport coals. This is the Butler sandstone of I. C. White (Second Geol. Surv. Pennsylvania, Rept. Q, p. 47). At Walkchalk this sandstone lies on the Lower Freeport coal and nearly or quite fills the interval between the two coals, which probably does not exceed 30 feet and may be less. It overlies the Lower Freeport coal on both branches of Buffalo Creek in the southeastern part of Donegal Township, occurs on Buffalo Creek north of Boggsville, and is well developed at Bradys Bend, though thin bedded, as described below.

The interval between the Upper and Lower Freeport coals, however, is usually occupied mainly by shale. The Freeport fire clay immediately underlies the Upper Freeport coal. This clay is interbedded with shale and contains iron nodules. Below the fire clay the Freeport limestone occurs over considerable tracts, and below the limestone a bed of iron ore is known to exist over small areas. The following section (taken from Rept. H5, Second Geol. Surv. Pennsylvania, p. 215) shows the relation of these beds.

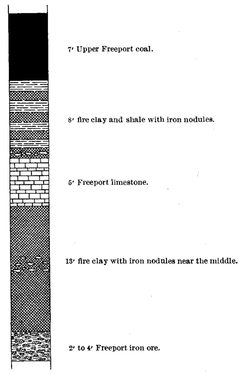


Fig. 8.—Section of Upper Freeport coal and associated clay and iron ore at Bradys Bend.

This section shows a considerable deposit of fire clay below the Freeport limestone, containing iron nodules and underlain by the Freeport iron ore. Below this ore bed about 2 feet more of fire clay with iron nodules occurs, followed by 30 feet of thin-bedded sandstone, below which is the Lower Freeport coal, from 1 foot 6 inches to 4 feet thick.

Freeport iron ore.—The Freeport iron ore is known only in the vicinity of Bradys Bend. It is described as a solid, compact, very argillaceous layer, running about 2 feet thick, but occasionally reaching a thickness of 4 feet and having a layer of nodules below.

Freeport limestone.—The Freeport limestone is best developed in the southeast corner of the quadrangle, in Manor and North Buffalo townships. It is well exhibited along the bluff back of Manorville and Ford City where cut by the highways, along Garrett Run and its tributaries, along the run east of Ford City to the eastern margin of the quadrangle, and in the ravines running down to the west side of Allegheny River opposite Ford City. In the ravine of Fort Run near Manorville it is reported to be 28 feet thick and to contain several beds of rather distinctive character (Second Geol. Surv. Pennsylvania, Rept. H5, p. 256). West of Allegheny River at Ford City it is 18 to 20 feet thick. These thicknesses are exceptional and attained only in this locality. On Garrett Run and east of Ford City it runs from 8 to 10 feet; westward from the river it becomes thinner and on Marrowbone Run and at Beatty's mill is about 5 feet thick. On Buffalo Creek one-half mile above Boggsville it is 2 feet thick. It could not be found on Sipes Run nor westward in the townships of Butler County included in the quadrangle, except that it was noted as a probably thin layer in the road about 1 mile southeast of Chicora. It occurs at the top of the knob one-half mile northwest of Fosters Mills and is well developed in the hills in the neighborhood of Bradys Bend.

As a general thing this limestone is bluish and rather thick bedded. It is generally nonfossiliferous. A few minute gasteropods have been reported from various places. It seems to be entirely destitute of marine fossils and is possibly of fresh-water origin. The extreme paucity of organic remains may indicate that it is not of organic origin. Possibly it was precipitated from waters charged with carbonate of lime in solution.

Freeport fire clay.—The fire clay is generally a plastic clay from 3 to 5 feet thick, but south of Chicora there is a considerable area of flint clay at this horizon, ranging from 8 to 10 feet in thickness. At Bradys Bend a thick layer of clay with iron nodules occurs beneath as well as above the limestone.

Upper Freeport coal.—From 30 to 40 feet above the Lower Freeport occurs the Upper Freeport coal. Next to the Lower Kittanning coal this is the most valuable deposit in the quadrangle. It underlies large areas, and over most of them yields from 3 to 3½ feet of good coal. Locally it becomes thin, shaly, and worthless. The latter character is reported in the vicinity of French's Corner and in the eastern part of Donegal Township. Along Sipes Run it could not be found. It is probably wanting there and seems to be thin in the vicinity of Boggsville. Along Cornplanter Run it is occasionally of good thickness, but is liable to be cut out by the heavy Mahoning sandstone. Along the river bluff west of Ford City it is only a thin layer where exposed. The poor development of the Upper Freeport coal at these places forms probably only local exceptions to its generally valuable character. Its blossom shows on some of the hills, and the coal is probably present in some thickness on all the hilltops along the axis of the Kellersburg anticline from the southwest corner of West Franklin Township to the vicinity of Browns Crossroads, where these hilltops have not been eroded below its horizon.

CONEMAUGH FORMATION.

General character.—In this quadrangle this is essentially a shaly formation. In the southern part of the quadrangle one or two thin coal seams occur locally from 40 to 70 feet above the bottom. In the southwest corner a heavy sandstone 160 to 230 feet above the bottom comes in under the plateaus south of Rough Run and west of Buffalo Creek. A thin coal seam occurs 150 feet above the bottom, and near the tops of some of the higher hills in the southern part of the quadrangle a thin limestone occurs about 300 feet above the bottom of the formation. The more important members of this formation are individually described below.

General distribution and thickness.—Fully one-half or more of the Conemaugh formation has been eroded from most of the southern part of the quadrangle; nearly all of it has been removed along the axis of the Kellersburg anticline from west of Buffalo Mills to the eastern boundary of the quadrangle, and only about 150 to 200 feet remain in the deepest part of the Bradys Bend syncline. In the northeastern part of the quadrangle only a few thin patches remain on the highest hills. The greatest thickness of the formation remaining in the Kittanning quadrangle is about 400 feet. This is found in the high knob about one-half mile north of Sistersville.

Mahoning sandstone.—Near the base of the formation is a heavy sandstone usually called the Mahoning sandstone. Much confusion exists as to what beds should be included under this name. So far as the writer can discover, the name was first used by Lesley (Manual of Coal and its Topography, 1856, p. 97) for a sandstone composed of two beds 35 feet thick, separated by 25 feet of shale. I. C. White (Bull. U. S. Geol. Survey No. 65, p. 95) describes it in almost identical terms, but makes the sandstone members 40 to 50 feet in thickness, with a bed of shale between, the whole varying in thickness from 100 to 150 feet. In an earlier work (Second Geol. Surv. Pennsylvania, Rept. Q., p. 36) the same writer restricted the name to the lowest member of the triple group.

One difficulty in determining the usage to be adopted arises from the fact that the type locality of the sandstone is not known. In a cut on the Pennsylvania Railroad at Bens Creek, Cambria County, and also in a mine shaft at Cresson in the same county, the section immediately above the Upper Freeport coal agrees almost exactly with the description of the Mahoning sandstone given by Lesley. The section in the mine shaft is given in fig. 9.

The section in the railroad cut at Bens Creek between the Gallitzin and Upper Freeport coals is the same as the above except that the upper bed of sandstone at Bens Creek is thicker and fills the whole of the interval here occupied by the beds Nos. 13 to 16, inclusive. In this section the Mahoning lies in the interval between the Upper Freeport and Gallitzin coals, and it would seem to be judicious to limit the application of the name to sandstone falling within these limits. The sandstone may occur as a double bed nearly filling that interval or as a single bed almost anywhere in the interval; it may be thin and inconspicuous or

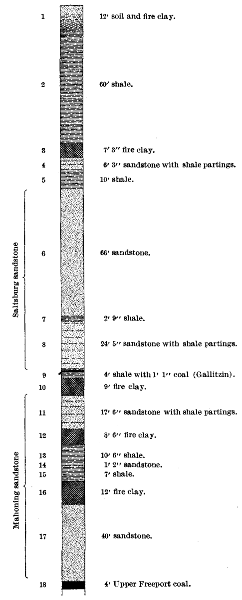


Fig. 9.—Section of Cresson mine shaft, Cresson, Pa.

absent altogether. In this quadrangle about 70 feet above the Upper Freeport coal occurs the Brush Creek coal, which corresponds closely in position and character with the Gallitzin coal, and which, therefore, may be fairly correlated with that seam. For this reason it is proposed to confine the use of the name Mahoning in this quadrangle to sandstones lying between the Upper Freeport and Brush Creek coals.

The Mahoning usually lies at the base of the Conemaugh formation and closely overlies the Upper Freeport coal. It may, however, occupy a higher position and be separated from the coal by a greater or less thickness of shale. It is generally well developed in the southern part of the Kittanning quadrangle. It varies from a medium-grained, flaggy, or even shaly, to a coarse and heavy-bedded sandstone, and runs from 10 to 40 feet thick. On the hills immediately southeast of Kittanning it is flaggy to shaly and 30 feet thick, and at Ford City and eastward it is flaggy and rather coarse. At the quarry west of Allegheny River nearly opposite Ford City it is 40 feet thick, coarse, heavy bedded, and sometimes conglomeratic. It exhibits this heavy-bedded character at numerous exposures in the southeastern part of North Buffalo Township and along Glade Run nearly to Walkchalk, where it yields bowlders of coarse white sandstone that probably mingle on the slopes with those of similar character from the Butler sandstone, which is also heavy at this locality. North and east of Walkchalk it becomes more flaggy and to the west seems to disappear entirely. Along the little run entering Glade Run from the north at North Buffalo post-office it is coarse and heavy. It shows again near the mouth of Marrowbone Run and along Buffalo Creek a short distance to the north as a rather coarse, flaggy rock. It exhibits the same character on Sipes Run about a mile above its mouth, and becomes rather coarse and heavier on Cornplanter Run west of Boggsville, where it immediately overlies the Upper Freeport coal and often cuts out that seam. On the east fork of Buffalo Creek about 2 miles north of Rattigan it is coarse and conglomeratic. Along the western margin of the Kittanning quadrangle, from west of Fenelton northward to Karns, the Upper Freeport coal seems to be immediately overlain by about 20 feet of shale, above which there is a greater or less thickness, though scarcely exceeding 20 feet, of sandstone, generally thin bedded and flaggy, but sometimes coarse, which probably represents the Mahoning. In the northeast quarter of the Kittanning quadrangle it seems to be only locally present.

Thin coal.—At the intersection of the roads one-eighth of a mile east of Beatty's mill, which is on Buffalo Creek about one-half mile north of the mouth of Marrowbone Run, there is a good coal bloom about 40 feet above the Upper Freeport coal and just above the Mahoning sandstone. This coal was noted in several places northward for 1½ miles along the road toward Worthington. It is accompanied in a number of places by a thin limestone. South of the intersection above mentioned the coal was not seen, but its limestone was traced for a mile along the road to Slate Lick. This coal was not observed elsewhere and is probably a local bed.

Brush Creek coal.—Throughout the southern third of the quadrangle there is a persistent bed of black shale running about 70 feet above the Upper Freeport coal and often containing a thin seam of coal. The shale is generally about 5 feet thick, but in a few places thickens to 20 feet. The latter thickness is well shown at the crossroads by the church about 1¼ miles southeast of Worthington. The coal varies from a few inches to 2 feet in thickness. It can be seen along the road between Weskit and Walkchalk, in the road on the hilltop west of Weskit, on the ridge road 1½ miles north of North Buffalo, about one-half mile east of Beatty's mill on the road between Beatty's mill and Weskit, along the road from Beatty's mill to Worthington, along the road over the hill between the head of Sipes Run and Buffalo Creek, in the road westward over the hill from Sipes Run, and in a ravine near the road one-quarter of a mile northeast of Boggsville. This coal occurs at the same horizon and is undoubtedly the same as the Brush Creek coal described by I. C. White in southern Butler County.

Bakerstown coal.—About 75 feet above the Brush Creek coal and 150 feet above the Upper Freeport coal another small and probably worthless coal occurs. Its blossom has been observed at a few points in western North Buffalo Township, South Buffalo Township, Winfield Township, and about 1½ miles southwest of Coyleville in Clearfield Township. This coal seems to be undoubtedly the same as the Bakerstown coal described by White in southern Butler County (Second Geol. Surv. Pennsylvania, Rept. Q). It is not of sufficient importance to warrant further description.

Saltsburg sandstone.—Associated with this coal both above and below is a massive coarse-grained sandstone whose limits are somewhat indefinite, but which is so prominent a feature in the southwestern part of the quadrangle that it has been mapped as the Saltsburg member of the Conemaugh formation. The thickness of this member is variable. There are from 40 to 50 feet of sandstone below the coal and from 60 to 80 feet above. The flat-lying land in the southwestern part of Winfield Township is formed by the upper sandstone. These two sandstones are separated in places by a thin bed of shale containing the Bakerstown coal and fire clay. It is possible that this separation could be made throughout the part of the quadrangle in which the sandstones occur if exposures were good, but under present conditions it is impossible to trace such a separating bed. The sandstone below the coal is clearly the same as the Buffalo sandstone of White (Second Geol. Surv. Pennsylvania, Rept. Q, p. 33), and the upper occupies the position of the Saltsburg sandstone of Lesley (Stevenson, Second Geol. Surv. Pennsylvania, Rept. K3, p. 22). It is believed, however, that the sandstone mass as a whole corresponds best with the Saltsburg sandstone in its type locality, and that name has been adopted.

In this quadrangle the upper sandstone is the thicker and more conspicuous of the two. It occurs over all the area south of Rough Run and caps the high hill between Buffalo Creek and Sipes Run. The quarries on the hilltops at West Winfield are in this sandstone, which is here rather coarse and thick bedded. Besides its occurrence south of Rough Run the lower or Buffalo sandstone of White occurs over the area mapped along the West Winfield–Fenelton road. Along this road, 1½ miles north of the latter area, the Bakerstown coal occurs in the midst of shale, but the sandstone both above and below the coal has practically disappeared from the section.

Red shale.—In the vicinity of Sistersville, close beneath the Ames limestone and about 300 feet above the Upper Freeport coal lies a thin bed of red shale which was not noted elsewhere in the quadrangle. The interval between the red shale and the horizon of the Saltsburg sandstone is largely filled with sandy shale and interbedded thin sandstone.

Ames limestone.—On a few high knobs in North Buffalo Township, north of Slate Lick and Sistersville, a thin limestone occurs. It has a grayish or greenish color and is often full of fossils, among which fragments of crinoid stems are most plentiful. Its exact thickness is not known, but probably does not exceed 2 feet. It has been noted by the present survey at two points. One of these is the top of the knob east of the road one-half mile south of the head of Marrowbone Run and 1⅓ miles slightly northeast of Slate Lick. The other is the knob one-half mile northeast of Sistersville. It is known only by fragments on the surface, and these would indicate a thickness of about 1 foot. In the former locality the distribution of the fragments would indicate that the limestone occurs in two beds separated by almost 20 feet of shale, the lower being about 315 and the upper about 335 feet above the Upper Freeport coal; the horizon of this limestone passes through several other knobs in the southwest corner of the quadrangle, and it may occur on them. Platt (Second Geol. Surv. Pennsylvania, Rept. H5, p. 287) reports it on a high knob about 1 mile northwest of Slate Lick.

The Ames limestone has been traced pretty continuously across southern Butler County by I. C. White (Second Geol. Surv. Pennsylvania, Rept. Q), and found to be the same as the Crinoidal limestone of Beaver County, with which it agrees in its fossiliferous character and in its stratigraphic position, which ranges from about 290 feet above the Upper Freeport coal in the Beaver quadrangle to about 330 feet above the coal in the Kittanning quadrangle. This limestone is generally known as the "Crinoidal limestone" throughout western Pennsylvania, but the geographic name Ames has been substituted for the descriptive name Crinoidal. This name was first used by Andrews (Ohio Geol. Surv., vol. 1, pt. 1, pp. 235, 296).

On the high knob north of Sistersville are about 70 feet of rocks above the Ames limestone, and a less thickness occurs on a few other knobs that extend above the horizon of the limestone near the axis of the Boggsville syncline in the southern part of the quadrangle. The rocks forming the top of the knob at Sistersville, 1432 feet above the sea, occupy the highest stratigraphic horizon of the quadrangle. They are mostly shale and not of sufficient interest to warrant further description.

Quaternary Deposits.

PRE-GLACIAL DEPOSITS.

OLDER ALLUVIUM.

Above the upper limits of the well-defined glacial deposits there has been noted at a few points gravel of apparently earlier age composed of country rock, in some cases associated with soil resembling alluvium. Such deposits occur on the high point in the angle between Redbank Creek and Allegheny River and on both sides of the river at East Brady at altitudes above 1100 feet and over 100 feet above the Parker strath. It seems possible that these deposits are the remnants of old river gravels and silts laid down when the river flowed over beds which are 350 to 400 feet higher in the geologic series than the rocks over which it now flows. They may therefore be of late Tertiary age. So much doubt and obscurity hang over these deposits, however, that but little importance should be attached to this suggestion as to age.

CARMICHAELS FORMATION.

Two small terrace areas, each with rock floor at the 1000-foot contour—the level of the Parker strath—and covered with alluvium of local origin and probably of both pre-Kansan and Kansan age, have been mapped. These areas are small and their mapping would hardly be warranted were it not for the fact that deposits of the same kind and origin are widely distributed over a large part of southwestern Pennsylvania. They are differentiated from the terrace deposits along Allegheny River by the absence of material of glacial derivation. In the last respect they agree with the Carmichaels clay along Monongahela River described by Campbell (Geologic Atlas, folios 82 and 94). They are also contemporaneous in accumulation with the Carmichaels clay. On these grounds the name Carmichaels can be appropriately applied to the deposits under consideration as well as to deposits of like nature in other parts of the State, but since Carmichaels clay would not be appropriate in this connection, Carmichaels formation will be used instead. It must not, however, be inferred from the name that the character, thickness, and mode of accumulation of the formation in the Kittanning quadrangle are the same as in the type locality.

GLACIAL GRAVELS.

By Frank Leverett.

THE DRIFT BORDER.

On the uplands bordering Allegheny River the glacial drift ceases to be a well-defined or easily traced deposit about 25 miles above the point where the river enters the Kittanning quadrangle. Occasional bowlders and pebbles of glacial derivation are found several miles outside the well-defined sheets of drift, and perhaps they may be found within the limits of this quadrangle. E. H. Williams, jr., has expressed the opinion that the ice sheet extended down the Allegheny to the mouth of Redbank Creek, but the writer has not found satisfactory evidence of glaciation so far down the valley. Whether the scattered erratics on the uplands were deposited by the ice or have been carried by human agencies beyond the glacial boundary remains to be determined.

The Allegheny Valley was the main line of discharge for the water from a large part of the ice border in western New York and northwestern Pennsylvania not only while the ice was at its extreme limits but also before and after it had reached its maximum development, and not only in the first but also in the last stage of glaciation, and possibly in intermediate stages. As a consequence, glacial material has filled it to a marked degree throughout its entire length and extends a long distance down Ohio River.

The tributaries of the Allegheny within this quadrangle have not been found to carry glacial material, though the search, perhaps, has not been exhaustive.

OLDEST GLACIAL GRAVEL (KANSAN OR PRE-KANSAN).

Probable age.—The high-level gravel deposits which are so conspicuous along the lower Allegheny Valley are known to be of Glacial age because they contain erratics of various kinds which were brought into the drainage of the Allegheny by the ice sheet. The deposit of glacial drift from which the gravel was derived is among the oldest yet recognized on this continent. Its weathered surface and the great amount of erosion which it has undergone indicate that it is at least as old as the Kansan drift of the interior, and it may prove to be of pre-Kansan age. In weathering and erosion these gravel deposits as well as the drift sheets from which they are derived bear evidence of great age.

Distribution.—The gravel is best displayed on the broad rock shelves of the outer valley of the Allegheny, such as appear in the southeastern part of the Kittanning quadrangle, but it is found in small remnants along the narrower parts of the valley, and is present in greater or less degree along nearly every mile of the entire length of the valley, from the border of the well-defined drift near Kennerdell down to Pittsburg and also to a considerable distance down Ohio River. In the northern part of the quadrangle the glacial gravel occurs up to about 1100 feet above tide, at the mouth of Redbank Creek at 1080 feet, and at the south edge of the quadrangle at 1040 feet, thus showing a marked descent, in harmony with the grade of the present stream, in passing through the quadrangle.

The flat-top gravel terraces so well displayed in the southeast part of the quadrangle are below the upper limit of the gravel and seem to mark two or more levels occupied by the stream in the process of excavating the gravel. The highest one stands near the 1020-foot contour and is preserved in several broad remnants and also in narrow strips along the valley from where the river enters the east edge of the quadrangle down to Kittanning. A lower one, well displayed back of Ford City, barely rises above the 960-foot contour, thus falling short of the upper limit of glacial gravel on its borders by about 80 feet. The terrace back of Manorville stands just below the 1000-foot contour and apparently has a continuation in a narrow terrace on the east edge of the valley farther south. It will be observed that the highest of these terraces lacks 20 feet of reaching the level of the gravel deposits found on the border of the valley at the south edge of the quadrangle, and also at points several miles up the valley. Were the deposits on the slopes above the terraces only sand or silt they might perhaps be considered the flood deposits of a stream which had the highest terrace as its bed; but being composed of coarse material such as would only be carried along the river bed, they seem to indicate an original filling to their upper limit.

Thickness.—Originally this deposit must have extended from the lowest level of the rock floor of the Parker strath, say 150 feet above the river, to the level of the upper limit of pebbles—260 to 280 feet—thus giving a thickness of 110 to 130 feet. There are few if any places where it is preserved in its full thickness. Opposite Templeton, in the part of the valley that is east of this quadrangle, there appear to be 90 feet of gravel, the base of the deposit being 160 feet and the top 250 feet by aneroid above river level. Back of Manorville a well dug by William Piper passed through 50 feet of gravel, and as the well mouth is about 15 feet lower than the top of the terrace the thickness may reach 70 feet. In the terrace cut by the Buffalo, Rochester and Pittsburg Railroad east of the mouth of Limestone Run the deposit has a thickness of about 75 feet, as shown by gullies on the border of the terrace. The railroad cuts into it nearly 50 feet. There is probably fully as thick a deposit on the terrace west of the mouth of Limestone Run, and there may be a similar thickness back of Ewing. Aside from the places mentioned the deposit has been reduced apparently to a thickness of 15 to 35 feet or less. In the part of the valley traversing the northeast corner of the quadrangle no places were noted where it exceeds 25 feet, and its thickness there is usually only 10 to 15 feet.

Constitution and characteristics.—This deposit is often called the high-level gravel. The greater part of it is medium to fine gravel with which there is more or less sand. An occasional glacial bowlder or large local rock appears in it, and stones 6 inches in diameter are not rare. In places where the current was weak the deposit is clayey with only occasional stones scattered through it. Such is the case in the terrace opposite Kittanning, where the gullies and wells show little else than clay to a depth of 30 feet. The stones, whether of local or of glacial derivation, are generally well rounded, as if they had been rolled for some distance along the stream bed. The abrasion by stream action has been so great that striated faces of the glacial pebbles are very rarely found.

The proportion of glacial pebbles in the gravel varies greatly from place to place. In some pits they are so common as to attract attention while in others prolonged search is necessary to discover a single one. They probably constitute, on the average, only a fraction of 1 per cent of the deposit. The most conspicuous and widely prevalent pebbles of glacial derivation are of Medina sandstone from western New York and the neighboring part of Canada. The various kinds of granite, greenstone, and quartzite are present, and also flagstones and sandstones which have their outcrops farther north than the drainage basin of the Allegheny.

The state of decay of the pebbles is on the whole very advanced, many pebbles being so rotten that they can be crumbled or crushed by the hand. The Medina sandstone and some of the quartzites are, however, usually in a good state of preservation. The granites and greenstones are so altered at the surface that one can seldom make a certain identification without breaking them open. In many of the granite pebbles the decay extends to the center. In the fine-textured greenstones the whitening usually extends only one-fourth to one-half inch from the surface, but there is more or less alteration to the center. The local sandstones are usually in a very advanced state of decay. If any limestone pebbles were brought in by the glacial waters with the Medina sandstone and other Paleozoic rocks, they have been dissolved so completely that none were found after prolonged search at several points.

LATER GLACIAL DEPOSITS.

The Illinoian and Iowan drift sheets are not exposed in the region drained by the Allegheny and may not reach the northern limits of its watershed. Nothing has been noted in the Allegheny Valley, either within or above the Kittanning quadrangle, that indicates an outwash into it from an ice sheet between the early one that furnished the high-level gravel and the Wisconsin which contributed material found in the bottom of the trench.

Wisconsin drift border.—As shown by the sketch map, fig. 1, the Wisconsin drift border lies along or very near Allegheny River from its source down to Warren County, Pa., and crosses its main western tributaries a few miles back from the river as far down as Sandy Creek, which enters the river 40 miles above the northern limits of the Kittanning quadrangle. Farther down, the terminal moraine passes west of the border of the Allegheny watershed. The position of the Wisconsin drift border is such that the Allegheny received a large amount of outwash at frequent intervals along more than half its length, and this material was gradually transported down the valley through the Kittanning quadrangle and on into Ohio River.

Character of the outwash.—The outwash is a coarse gravel or cobble in the vicinity of the Wisconsin drift border, with a comparatively small admixture of sand and silt. Upon passing down the valleys the fine material gradually increases until it forms the bulk of the deposit. This is especially true of the surface portion. There are places as far down as the mouth of Allegheny River where the river bed is gravelly. In the Kittanning quadrangle there is a deposit of sand and silt which seems to have been built up to a level about 50 feet above the river but which is now preserved at that level only in a few places on the inner curve of the river bends. The material is so fine within the limits of this quadrangle that the river has cut it away rapidly and remnants at the original level of filling are far less extensive than at points up the valley where coarse deposits occur. It is probable that the river has cut away and redeposited much of this fine material several times since the Wisconsin stage of glaciation. It has become, therefore, a part of the Recent or post-Glacial alluvium and is so mapped.

ALLUVIUM.

The present streams of the quadrangle are bordered in places by deposits of alluvium which has been laid down by the streams at times of overflow and thus constitutes true flood plains. These most recent deposits of the quadrangle are generally narrow along Allegheny River and the lower courses of the tributaries. Nearer the headwaters of the tributaries they are broader, a fact that has been explained elsewhere.

GEOLOGIC AND GEOGRAPHIC HISTORY.

The geologic and geographic development of the Appalachian province in its earlier stages, as generally understood by geologists, will first be outlined, and then the history of the northern end of the bituminous basin in which the Kittanning quadrangle is situated will be given in greater detail.

PRE-CHEMUNG DEPOSITION.

The oldest rocks known in the province are the crystalline rocks of the Blue Ridge and of the Piedmont Plateau on the east. These are believed to have formed the oldest land of which there is any record on this continent. The western shore of this land area lay in the present position of the western flank of the Blue Ridge, and the land extended to an unknown distance eastward, possibly far beyond the present shore of the Atlantic. To the northeast, in the Adirondack Mountain region, lay another area of crystalline rocks. Extending westward from the latter region to the vicinity of Lake Superior was the southern shore of a vast land area, now occupied by the crystalline rocks of Canada. The rocks of the two regions last mentioned are of the same age as those of the Blue Ridge. Thus in earliest geologic time the eastern United States had a rudely V-shaped form, inclosing within its arms a body of water known to geologists as the Interior Paleozoic sea. Into this sea discharged rivers bearing the sediments of which the sedimentary rocks of the Appalachian province are composed. The earliest of these sediments were laid down along the ancient shore line and constitute the oldest sedimentary rocks of the province. In the rocks of this early age remains of living beings become, for the first time in the history of the earth, fairly abundant and varied. From this time forward the filling up of the interior sea progressed steadily from the shores of the ancient land toward the center. At times the surrounding land from which sediments were derived stood higher, the rivers were swifter and the sediments coarser, and thus the materials of great strata of sandstone were brought in and spread out along the shores and over the adjacent sea floor; at other times the lands apparently were worn down or sank lower, the rivers became sluggish, and the finer sediments, of which widely extended strata of shale are composed, were deposited; and at other times, or at great distances from the shores, clear waters prevailed or but small quantities of sediments were laid down and strata of limestone, often hundreds of feet in thickness, accumulated. While these rocks to the thickness of many thousand feet were being deposited, living beings became more and more abundant, new forms made their appearance from time to time, and the earlier forms became extinct. The earlier organisms were chiefly animals or the lower forms of plants, such as sea weeds. Later, land plants made their appearance and the conditions began which eventually resulted in the formation of the coal beds of the province. After a great thickness of sediments had been accumulated an uplift occurred, the axis of which extended from the Great Lakes to western Tennessee. This is known as the Cincinnati uplift. The movement may have been great enough to raise the sea bottom along the axis in whole or in part into dry land. Whether the uplift reached this extent or not, it was sufficient to form a barrier still more completely inclosing the interior sea, which now had the form of a narrow embayment extending from Alabama to eastern New York, and which may appropriately be called the Appalachian Gulf. This uplift, however, is not the only movement recorded by the rocks during their formation. Many beds show unmistakable evidence that they were deposited in shallow water and near the shore. As it is manifestly impossible for thousands of feet of rocks to accumulate in shallow water without constant subsidence, by which the strata are carried downward, while other strata are deposited above them, it is evident that such downward movement was in progress during the deposition of the rocks in the interior sea. The axis of this subsidence lay along the center of the Appalachian trough from eastern New York to Alabama. After the subsidence mentioned above had been going on for a very great time, after thousands of feet of strata had accumulated, and probably after the Cincinnati uplift, the earliest rocks known in the quadrangle were deposited.

CHEMUNG DEPOSITION.

As shown in the discussion of the rocks revealed in drilling oil and gas wells, the lowest strata penetrated by the drill are probably to be assigned to the Chemung formation. In regions where rocks of this formation come to the surface they are composed largely of rapidly alternating beds of shale, sandstone, and impure shell limestone, the shale predominating. There are many evidences also of shallow-water accumulations, and the abundance of fossils indicates that the conditions were favorable to life and that the sea floor swarmed with living beings. The observed facts indicate a broad expanse of comparatively shallow water which was receiving sediments from the adjacent lands, sometimes finer, sometimes coarser, now in abundance, now more sparsely, the kind and rate of sedimentation varying rapidly and producing the rapidly alternating strata and layers of the formation. From time to time or at different localities a quantity of coarser material would be brought in and assorted by waves and currents, forming a coarse sandstone lens or a bed of conglomerate of greater or less extent. At times the accumulation of clays or sands was rapid enough to extinguish locally the organisms of the sea floor; at other times the conditions of life continued favorable for a long time and they lived on, generation after generation, their shells accumulating and, mixed with sand, forming extensive beds of impure limestone.

CATSKILL DEPOSITION.

Before the beginning of Chemung deposition, indeed soon after the close of Hamilton time, the Catskill phase of sedimentation was begun in the northeastern extremity of the Appalachian Gulf in eastern New York with the deposition of the Oneonta beds. From this time onward the deposition of these rocks continued, being contemporaneous at first with the marine Portage, later with the Chemung, and at the top probably with the bottom of the Mississippian deposits. In the beginning the accumulation of these sediments was restricted to a more or less landlocked bay in eastern New York and northern Pennsylvania (Clarke, New York State Museum, Mem. 6, p. 205 et seq.) in which fresh water prevailed, as shown by the presence of fossils of what were probably fresh-water shells and fish. As time went on the Catskill sediments spread farther and farther westward and southwestward, and toward the end the finer sediments extended into western New York and Pennsylvania, where they at present constitute beds of soft red shale of irregular thickness and extent, interbedded with green and gray shales and sandstones bearing Chemung fossils mingled with a few of Carboniferous type (Rept. New York State Pal., 1902, pp. 990–995).

It happened, thus, that the Catskill rocks, reaching a probable thickness of several thousand feet in the Catskill Mountain region where sedimentation was continuous from the beginning, thin from the bottom upward until they are represented in western Pennsylvania and New York by only the few hundred feet of rocks characterized by beds of red shale.

The red rocks of the Catskill formation in the Kittanning quadrangle occur near the top of the formation, and, judging from their character at their western margin in western New York, they are probably soft, fine shale resulting from the consolidation of the finer material that was borne by the water farthest from the eastern shores of the Appalachian Gulf where it was discharged by the rivers of the bordering lands. The red rocks of the western margin of the formation appear to lie in detached beds or lenses of greater or less extent and thickness in the midst of gray shales and sandstones that possibly had a different source. This mode of occurrence indicates that the extreme western marginal deposits of red rocks were transported intermittently at times of flood, when the supply of sediment was greater, or at times of great storms, when stronger currents bore the sediments farther westward. At times toward the close of the deposition of the red rocks great beds of coarse gray sandstones that form the reservoirs for oil and gas in this part of western Pennsylvania accumulated. The coarseness of these sandstones may indicate that the neighboring land from which they were derived was uplifted, or that they were carried by stronger coastal currents from a more distant source and assorted in the transportation.

ACCUMULATION OF GAS AND OIL.

Gas and oil are probably the result of the distillation of animal and plant remains which were entombed in rocks in which decomposition of the organic matter was prevented by the presence of water. All through the time of deposition of the marine sedimentary rocks of the Appalachian province the sea swarmed with living beings whose remains were buried at the bottom of the sea and thus preserved from decay. From these organic remains, both plant and animal, the gas and oil were derived. These substances were probably at first disseminated throughout the rocks containing the organic remains, but in the coarse of time they were gradually concentrated into the reservoirs of coarse, porous rocks in which they have been found and were held there by the more or less impervious covering of overlying rocks. This accumulation took place between the deposition of the containing strata and the time when the drill tapped those reservoirs and the oil and gas began to flow out, but when the process began and ended, and whether it has yet ceased, are questions that no man can answer.

POCONO DEPOSITION.

Following the deposition of the Catskill red rocks, fresh-water conditions probably prevailed generally throughout the northern end of the Appalachian Gulf, but there was a decided change in the character of the material brought in. It is prevailingly gray instead of red. In the part of Pennsylvania in which the Kittanning quadrangle is situated the heavy sandstones known as the Hundred-foot and Butler gas sands were among the first strata deposited. These were followed by gray shales with occasional beds of red shale of local extent and sporadic sandstone lenses. During the latter part of Pocono time vast quantities of coarse sand were brought into the Appalachian Gulf and spread widely over the sea bottom, forming the coarse Burgoon (Mountain or Big Injun) sandstone. As the deposition of this coarse sandy material was drawing to a close a large quantity of carbonate of lime was deposited with the sand, making the Loyalhanna siliceous limestone, which is a widely extended and highly characteristic stratum at the top of the Pocono throughout southwestern Pennsylvania. There seems to be but one source from which this limestone could have been derived—the great limestone deposits of the Mississippi Valley, the deposition of which was probably contemporaneous in part with that of the Pocono formation in the Appalachian trough. One of the most striking and persistent features of the Loyalhanna limestone is its cross-bedding, which shows that the limestone is of clastic origin and was distributed by powerful currents. The carbonate of lime in suspension may reasonably be assumed to have been carried from its source by oceanic currents sweeping up from the southwest into the probably very shallow waters of the Appalachian Gulf. It may afterwards have been worked over by wave action or by tidal currents and the cross-bedding developed. One of the most interesting and significant phases of Pocono history was the accumulation of coal seams of considerable extent and thickness in Virginia and West Virginia. These coal seams herald the approach of the biologic and physiographic conditions under which the great deposits of coal in the later formations were accumulated.

MAUCH CHUNK DEPOSITION.

The deposition of the prevailingly gray Pocono was succeeded by a second deposition of a great mass of red beds composing the Mauch Chunk formation. The change in the kind of sediments was probably gradual, for in the region of the Allegheny Front the bottom beds of the Mauch Chunk are sandstone very much like the top sandstone of the Pocono. The great mass of the formation, however, is red shale, which in eastern Pennsylvania reaches a thickness of over 2000 feet, a fact which indicates continued subsidence along the axis of the Appalachian Gulf. During the deposition of the Mauch Chunk conditions seem to have been unfavorable for life, as the formation contains no coal beds and shows little evidence of the presence of either plants or animals. Soon after the beginning of the Mauch Chunk deposition there was an extension of salt-water conditions into southwestern Pennsylvania, where along Chestnut Ridge the Greenbrier limestone, of marine origin and very full of marine fossils, was deposited after the deposition of about 50 feet of Mauch Chunk sediments.

PRE-POTTSVILLE EROSION INTERVAL.

The thickness of the Mauch Chunk formation is over 2000 feet in northeastern Pennsylvania, and diminishes in thickness westward. On the Allegheny Front west of Altoona it is 180 feet. At Blairsville, as recorded in deep wells, it is about 50 feet. On Allegheny River in Armstrong County and farther west the Mauch Chunk is absent.

These facts indicate an uplift that raised above water a large land area extending from southern New York at least to the region of the Kittanning quadrangle and as far east probably as the Allegheny Front. From this land area in the Kittanning region and westward the Mauch Chunk and possibly the upper part of the Pocono were eroded before the deposition of the overlying Pottsville. Just when this uplift occurred can not be definitely determined, but it presumably took place during the latter part or at the close of Mauch Chunk time.

POTTSVILLE DEPOSITION.

The Pottsville is one of the most important and interesting epochs in the history of the province, since in it the accumulation of coal began on a large scale. Assuming that the movements of the earth's crust indicated in the preceding paragraph took place, there would exist at the beginning of Pottsville deposition a deep trough in eastern Pennsylvania and southward, bordered by land on both sides around the northern end and on the southeast. From these border lands, which were probably high on the southeast, the rapid streams brought in immense quantities of coarse material, including a large proportion of quartz pebbles, which form the thick and extensive beds of coarse conglomerate of the Pottsville formation. It is believed that the Pottsville sediments were largely derived from the southeastern side of the trough, because there is no nearby source of quartz pebbles on the other side. This deposition of coarse material went on until 1000 feet of strata were accumulated in the Southern Anthracite field. At times conditions were favorable to a luxuriant growth of plants, and thick, extensive, and valuable beds of coal were accumulated, parts of which are now preserved in the Southern Anthracite field.

Still farther south, along Kanawha River and in other parts of West Virginia, a still greater thickness of Pottsville rocks was deposited. These rocks include the coal beds of the Pocahontas, New River, and Kanawha coal fields, which rank among the most valuable deposits of coal in the United States.

While 800 or 900 feet of sediments accumulated in the Southern Anthracite field, the land surface on the west had probably been worn down nearly to sea level and then submerged by a subsidence, so that toward the close of Pottsville time sedimentation was resumed over the former land area. The submergence of the old land surface west of the Kittanning region preceded by considerable time that of the Kittanning quadrangle, for there accumulated along the western boundary of Pennsylvania a bed of sandstone and a bed of coal—the Sharon conglomerate and coal that underlie the lowest Pottsville rocks of the Allegheny Valley. Thus it happened that the Connoquenessing sandstone, the lowest Pottsville stratum of the Kittanning quadrangle, was deposited upon the surface of the Burgoon (Mountain) sandstone at the top of the Pocono formation. After the deposition of the Connoquenessing there was a change to more quiet conditions and the Mercer shale, limestone, clay, and coal were deposited. This period was followed by one of more active sedimentation and the Homewood sandstone was laid down, this marking the last episode in Pottsville history in western Pennsylvania.

ALLEGHENY DEPOSITION.

The Allegheny epoch was marked by very rapidly alternating conditions, the most important of which was the formation of the coal seams. The origin of the coal and the method of its accumulation in seams of great areal extent are subjects that have provoked much discussion. That coal is of vegetal origin hardly any one at the present day would venture to question. As to the method of accumulation of the vegetal matter there is greater difference of opinion. It seems safe to say that in the main the coal seams of the Appalachian province were formed in marshes near sea level and often extended over thousands of square miles.

The sequence of events during the deposition of the Allegheny formation in the Kittanning and surrounding regions was somewhat as follows: The deposition of the Homewood sandstone was followed by a slight subsidence and the accumulation of 10 to 30 feet of clayey sediments. The sea bottom was raised approximately to water level and marshy conditions resulted over a large area. Upon this marshy land the remains of many generations of plants formed an extensive peat bog. From time to time different parts of this marsh were flooded and thin layers of sediments deposited, which form the partings or binders of the resulting coal bed. In the case under consideration there was so little vegetal matter that the resulting coal bed is generally thin. In places there was more vegetal matter and a coal bed of workable thickness was formed. After a long period of comparative quiescence the region was depressed, sedimentation was resumed, the vegetal matter was buried and, under the pressure of the rocks subsequently deposited, was compressed and hardened into the coal seam now known as the Brookville coal. The subsidence which led to the formation of the Brookville coal was accompanied by a deposition of shale and in places of the Clarion sandstone. By this filling or by reelevation the bottom was again raised to water level, coal-forming conditions were restored, and the material of the Clarion coal bed was laid down. The deposition of this coal bed was followed by another subsidence, apparently of considerable extent, which admitted sea water to a large area, over which the Vanport limestone was deposited. This limestone is known to have been laid down in salt water, as it contains fossil shells or the solid parts of other animals that live only in salt water, and it is probably composed almost entirely of carbonate of lime derived from such sources. This subsidence was apparently of considerable extent, for the limestone seems to have been deposited in water of considerable depth and at some distance from shore, as its purity indicates that it received no admixture of sediments from the surrounding land. Whatever may have been the case, the bottom was raised to water level again, partly at least by sedimentation and probably also by elevation, another period of coal-making began, and the Lower Kittanning coal accumulated. By a repetition of such periods of oscillation and repose the Middle Kittanning, Upper Kittanning, Lower Freeport, and Upper Freeport coal beds with their under clays and the intervening beds of sandstone, shale, and limestone were formed.

While the strata may have been elevated at times during the deposition of the Allegheny formation, the prevailing movement was evidently one of subsidence, for each coal seam was formed at the surface and then buried.

Certain practical deductions are derivable from an understanding of the formation of the coal seams. It is rather current belief in western Pennsylvania that the thickness of a coal seam is proportionate to the size of the hill containing it. Another belief widely held is that a bad streak or area in a coal seam is in some way related to an adjacent valley and that better conditions would be encountered on the opposite side. The fallacy of such ideas is at once apparent when it is understood that the thickness, quality, and condition of a coal seam were determined ages before the hills and valleys were formed.

CONEMAUGH DEPOSITION.

At the close of the Allegheny deposition a marked change in the conditions of vegetation and deposition continued during the laying down of the 600 feet or more of the sediments of the Conemaugh formation. Marine conditions seem to have prevailed locally after the formation of the Upper Freeport coal seam, for salt-water fossils are occasionally found in the roof shales of that bed. In the Kittanning region coal-forming conditions were reestablished for a brief time after about 70 feet of sands and clays had been deposited. At this time the Brush Creek coal was formed. In other parts of the bituminous coal field, particularly in Somerset County, coal-forming conditions were repeated at several horizons in the Conemaugh formation, and several beds of coal of considerable extent and value accumulated. In the Kittanning region thin beds of black limestone with an abundance of marine fossils from 100 to 150 feet above the Upper Freeport coal indicate another incursion of sea water for a short period. Over a large part of western Pennsylvania and eastern Ohio the presence of the Ames (Crinoidal) limestone, 250 to 300 feet above the Upper Freeport coal and full of marine fossils, shows that the sea once more spread over a large area. This limestone is said to mark the last recurrence of marine conditions in the Appalachian basin. Throughout much of the area over which the Conemaugh formation extends the conditions were favorable to the accumulation of thick deposits of coarse sand, from which the Mahoning, Saltsburg, Morgantown, and Connellsville sandstones were formed. In the Kittanning quadrangle most of the Conemaugh deposits were materials that subsequently hardened into shale.

MONONGAHELA DEPOSITION.

The beginning of the Monongahela deposition was marked by another great period of coal formation—that of the Pittsburg coal. With the accumulation of this coal bed the vegetation which was the characteristic feature of the Carboniferous period reached its culmination. The peculiar conditions requisite for the growth and accumulation of the vegetal matter of this great coal bed were long continued and widespread, as is indicated by its thickness and great extent. While the Pittsburg coal is not found in the Kittanning quadrangle, it is present a few miles to the southeast in the Elders Ridge quadrangle, and in a geologic sense has probably but recently been removed from the Kittanning quadrangle. Its position, if it were restored, would be about 200 feet above the highest hills along the southern margin of the quadrangle. The formation of the Pittsburg coal was followed by a series of events similar to those outlined in the history of the Allegheny formation and the minor coal beds of the Monongahela formation and the Redstone, Sewickley, Uniontown, and Waynesburg coal beds were accumulated. Between the formation of the Sewickley and Waynesburg coals the great Benwood limestone of the Monongahela formation was deposited. This limestone shows little or no evidence of organic origin and its origin is hard to account for. It seems certainly to be a fresh-water deposit, and may have accumulated through the agency of rhizopods or microscopic plants, of which no evidence has been as yet discovered.

DUNKARD DEPOSITION.

After the deposition of the Monongahela the shales, sandstones, limestones, and thin coals of the Dunkard group were laid down. The luxuriant vegetation, so characteristic of the Carboniferous period, gradually diminished and finally became extinct, and this great period, so important in the history of the earth, came to an end.

THE APPALACHIAN UPLIFT.

With the close of the Dunkard epoch, sedimentation in the northern end of the Appalachian trough came to a close and a long-continued series of events of a totally different kind began. From the beginning of sedimentation in the interior sea intermittent subsidence had been going on and water had covered the surface in which the sediments from the surrounding land were deposited until tens of thousands of feet of rocks had accumulated. From the close of the Carboniferous deposition until the present the reverse movement, elevation, has prevailed and dry land has existed.

The period of elevation was inaugurated by an epoch of mountain making and the sedimentary rocks of the Appalachian province were, in the Greater Appalachian Valley, folded into a series of high anticlines and deep synclines, and, west of the Allegheny Front, folded into the low anticlines and shallow synclines of the bituminous coal fields.

Schooley peneplain.—With the emergence of dry land degradation began. In the meantime the orogenic forces gradually died out, the elevation of the province was arrested, a long period of quiescence ensued, and it is believed that the surface of the Appalachian province was eroded approximately to a horizontal plain near to sea level. This is called the Schooley peneplain because remnants of the same are well preserved in the Schooley Mountains of New Jersey. The Cumberland Plateau preserves a part of this old peneplain. No portion of it is preserved in the Kittanning quadrangle. The level crests of many of the ridges of the Greater Appalachian Valley, of which those just east of the Allegheny Front in Blair County are good examples, may approximately represent the surface of the Schooley peneplain. This peneplain was completed before the end of Cretaceous time at least, for in New Jersey and Alabama it is found extending beneath deposits of Cretaceous age.

Harrisburg peneplain.—After the reduction of the Appalachian province to form the Schooley peneplain an uplift occurred and erosion once more became active. Later the uplift ceased and extensive areas were again reduced to an approximately flat surface, which has already been described as the Harrisburg peneplain. It is believed that the formation of this peneplain occurred in early Tertiary time. During this period of erosion the softer rocks of the Greater Appalachian Valley were worn away, leaving the harder rocks to form the ridges. All of the Schooley peneplain surface was removed from the Kittanning region, but the surface of the quadrangle was not perfectly reduced to a plain.

The meandering courses of Redbank and Mahoning creeks seem to have been established toward the close of this stage of erosion. These streams are of considerable magnitude and they had probably eroded a broad valley with a floor of low gradient, over which they flowed in meandering courses, as is the habit of streams under such conditions. With subsequent uplift of the region these streams intrenched themselves in their meandering courses and have persisted in them ever since. The more direct courses of the smaller streams, such as the Cowanshannock, may be due to the fact that, on account of their smaller size, they had not, before the beginning of the reelevation of the region, reduced their beds to a sufficiently low gradient to cause the establishment of meanders. The meandering courses of the above-mentioned streams are additional proof of the existence of the Harrisburg peneplain.

The development of the Harrisburg peneplain was arrested by an uplift that was probably slight in southwestern Pennsylvania, but progressively greater from the Kittanning region northward, so that the once nearly horizontal plain underwent a deformation, which is indicated by the fact that its present elevation is 1250 feet in the southern part of the State, over 1400 feet in the Kittanning region, and 2100 feet in southern New York (Campbell, Bull. Geol. Soc. America, vol. 14, pp. 277-296).

Worthington peneplain.—As the elevation mentioned in the preceding paragraph proceeded the streams renewed their activity and the former flat surface was soon furrowed by valleys. When the land had risen about 100 feet above its former position the upward movement seems to have halted for a period of time, during which the Worthington peneplain was developed. This probably occurred in the latter part of Tertiary time.

Parker strath.—Another uplift soon occurred and the streams of the region cut deep valleys below the Worthington peneplain. The upward movement then ceased and the larger streams, especially Mahoning Creek and the Allegheny, which then consisted only of Clarion River and that part of the present Allegheny below its mouth, excavated valleys of considerable width. This period of repose was probably of considerable duration, for the Clarion-Allegheny, though a small stream, succeeded in eroding a valley in places $1\frac{1}{4}$ miles wide with a floor of very low gradient. For a stream of such size to attain such a condition requires a very long time. The altitude above sea at which the Clarion-Allegheny reached this stage is a debatable question. Leverett, for reasons which will appear later, believes that this altitude was but little if any below the present level of the preserved portions of the Parker strath, or in other words, not much if any below 1000 feet above sea level in this quadrangle. The writer, on the other hand, is inclined to believe that at an altitude of 1000 feet the Clarion-Allegheny could not have formed such a valley as it occupied. At that altitude, lightly loaded as it must have been, it probably would have been eroding its bed deeper instead of cutting so wide a valley. For this reason it is believed that the elevation of the Parker strath, at the time of its completion and for some time later, was considerably less than 1000 feet above sea. Late in the development of this strath an uplift of small extent appears to have occurred, which is marked by the substage previously described, during which the lower valley floor preserved at Ford City and Manorville was eroded. The formation of this strath probably marked the close of Tertiary time, for its further development was arrested by the events of the Glacial epoch, which are described in the succeeding paragraphs.

KANSAN OR PRE-KANSAN DEPOSITION.

The further development of the Parker strath was arrested probably at the beginning of the Glacial epoch by the invasion of the ice sheet of the earliest stage of glaciation known to have affected this region. This ice sheet, moving from the north, transported great quantities of rock débris from the region over which it passed and deposited much of the same as gravel, sand, and silt over the glaciated area. This constitutes the Kansan or pre-Kansan drift sheet. This drift sheet covered an area in northwestern Pennsylvania extending to a line roughly drawn from the point where Beaver River intersects the northern boundary of Beaver County through Kennerdell, Oil City, Tionesta, and Warren, following thus the north side of the Allegheny from Oil City northeastward. (See fig. 1.) From this drift sheet great quantities of material were washed down the Allegheny and deposited by the overloaded waters upon the Parker strath. The deposition of this material continued until 100 to 130 feet had accumulated in the valleys, as is indicated by the fact that stream-borne pebbles are now in some cases found on the hillsides 130 feet above the strath.

Drainage modifications.—With the advent of warmer climatic conditions the ice sheet receded, leaving the surface covered with drift and all the old valleys filled to great depths. This valley filling was so great in many cases that the streams were deflected from their pre-Glacial courses and the new drainage relations, described on a former page, were established.

INTER-GLACIAL VALLEY EROSION.

After the drainage changes at the close of this earliest stage of glaciation the Allegheny, now the lower Allegheny, enlarged to four times its original volume, was flowing upon its bed of glacial débris. This material was attacked by the river and mostly removed, leaving only those portions which have been described as covering the remnants of the Parker strath. The work of the river did not end, however, with the removal of these deposits; it continued until a trench over 200 feet deep had been excavated in the rock below the level of the strath.

Causes of down cutting.—Leverett holds that the increased volume of the river resulting from the enlargement of its drainage basin, combined with the accession of waters from the melting ice, which had dropped their load of sediments, was mainly responsible for the trenching of the strath described above. His views are expressed in the following paragraphs.

The deepening of the Allegheny in inter-Glacial times has probably been caused in part by the enlargement of its drainage area and by the accession of glacial waters which have dropped their burden of detritus near the continental divide. In addition to this the upper Allegheny region has been raised in recent times to a higher altitude compared to the country to the west, and possibly this uplift also covers the middle and lower Allegheny regions. In that case the streams have been given a better gradient for eroding their channels than prevailed before these trenches were cut. The precise influence of each of these factors has not been determined. The enlargement of the watershed to four times its former area would quadruple the erosive power. An increase in gradient sufficient to double the fall of the stream would multiply the erosive power about eight times, it being a fair working rule that the power of a stream to erode varies as the cube of its slope or the sixth power of its velocity. From this it will be readily understood how the trenching of the Allegheny has been brought about.

The similar trenching of the lower courses of the Monongahela, Youghiogheny, and Conemaugh rivers (see Campbell, Masontown-Uniontown, Brownsville-Connellsville, and Latrobe folios) and Mahoning Creek is due to the adjustment of these tributaries to the bed of the master stream, the Allegheny-Ohio, for there is no evidence that there has been any increase in the volume of these streams since early Glacial times.

It is of interest to note in this connection that the headwaters of tributaries of the Allegheny are still flowing on the old straths, because more time is needed to effect complete adjustments to the Allegheny trench. For the same reason the Allegheny trench is still narrow, the time having been insufficient for the breaking down of the bluffs by weathering.

It is admitted that this increased volume was a factor in producing the result, but, for reasons presented in part on a former page, the writer thinks that elevation was the greater factor. Leverett admits the possibility of some differential elevation, but he believes it better to hold to certain causes rather than to introduce the more hypothetical one of uplift. The writer believes that at the time of the completion of the Parker strath the old Clarion-Allegheny had reduced its bed to a gradient so low that down-cutting was practically at a standstill, and erosion was confined mainly to a widening of the valley. It is believed that such a condition would have been reached only when the stream beds stood at a level much lower than 1000 feet above the sea—the present altitude of the Parker strath. If this contention is correct, the region must have been elevated to bring the gradation plain to its present elevation and thus give the Allegheny, after removing the glacial deposits, an opportunity to intrench itself in the underlying rock. The second argument is that an uplift at this time would have been in harmony with the history of the region since the close of Paleozoic time. The successive uplifts preceding the formation of the Schooley, Harrisburg, and Kittanning peneplains, and that preceding the formation of the Parker strath, are generally admitted. Why, then, should the assumption of an uplift preceding the inter-Glacial down-cutting of the Allegheny Valley meet with strenuous objection? The third argument for uplift in this region is the well-known fact that uplift throughout northeastern United States in Glacial time is a well-established fact, and is admitted by Leverett to have affected southwestern New York. It does not seem improbable that it extended to the lower Allegheny also.

WISCONSIN DEPOSITION.

Between the earliest stage of glaciation already described and the latest or Wisconsin stage were two intermediate stages—the Illinoian and the Iowan. No drift belonging to either of these stages is certainly recognized in western Pennsylvania, and it is presumed that the ice did not reach the region. During the Wisconsin stage the ice again invaded northwestern Pennsylvania and deposited its load of drift over approximately the area covered by the earlier drift. Its margin lay nearly parallel to the margin of the older drift, but not quite so far to the southwest. The outwash from this drift consisted of coarse pebbles and bowlders near the margin, but farther south, within the limits of the Kittanning quadrangle, it was composed mainly of fine silt, which covered the bottom of the Allegheny Valley to a depth of about 50 feet. Since that time the river has been eroding its present channel in these deposits and probably reworking them to a greater or less extent.

COMPARATIVE LENGTH OF GLACIAL AND POST-GLACIAL TIME.

This can be estimated by comparing the amount of work accomplished by the Allegheny during the two epochs. During Glacial time over 100 feet of glacial detritus was deposited in the valley; this material was then removed and a trench cut 200 feet into the solid rock, after which the 50 feet of Wisconsin silts were deposited. Since the end of Glacial time the river has merely trenched the soft Wisconsin material to a depth of 40 to 50 feet. These facts indicate that the Glacial epoch was many times longer than post-Glacial time.

RECENT DEPOSITION.

During post-Glacial time the alluvium forming the modern flood plains was deposited by the streams as they overflowed their banks from time to time, just as they may be observed to do at the present day.

MINERAL RESOURCES.

In the preparation of this chapter the reports of the Second Geological Survey of Pennsylvania, particularly Report H5, by W. G. Platt, have been freely drawn upon.

Coal.

Coal is to-day the most important mineral resource of the Kittanning quadrangle. There are but few areas within the quadrangle where there does not exist one or more workable seams of coal, and these barren areas are small and belong without exception to the Allegheny formation.

Detailed sections of the various coal seams are given on the coal-section sheet, and a number of analyses of the coals are given in the table at the end of the text.

Brookville coal.—This coal lies near the base of the Allegheny formation. It is at present nowhere worked, nor is it known to be worth working anywhere in the quadrangle. It is reported by Platt to have been opened at one time on the Nickels farm nearly opposite the mouth of Long Run, in West Franklin Township, where the seam is 3 feet 2 inches thick, but so much broken by shale as to be worthless (see sec. 1 of coal-section sheet).

What appears to be this coal was observed partially exposed in the bed of Limestone Run near its mouth and may be there 2 feet thick.

Craigsville coal.—On a former page this name is adopted for a coal apparently of small extent in the vicinity of Craigsville. It was observed north of Buffalo Creek, where it lies about 50 feet below the Vanport (Ferriferous) limestone. There is an opening in this coal about 2 miles northwest of Craigsville and just north of Buffalo Creek, where the coal is 3 feet thick (see sec. 2). It was opened on the hill three-quarters of a mile northwest of Craigsville, where it is reported $2\frac{1}{2}$ feet thick. The blossom of this coal was observed in the road $1\frac{1}{2}$ miles north of Craigsville, and small pockets were seen in a heavy sandstone at West Winfield, where the coal is 40 feet below the Vanport limestone and 25 feet below the Clarion coal. Nothing is known of a coal in this position elsewhere in the quadrangle, and the coal at Craigsville is probably a local development of possible value only in that vicinity.

Clarion coal.—This coal is workable only at West Winfield, where there is a bank from which coal is obtained for use by the company engaged in quarrying at that place. It is there 3 feet 8 inches thick (see sec. 4). The Clarion coal is reported 2 feet thick about 2 miles northwest of Craigsville, in the same section in which the Craigsville coal is shown. It is 15 feet below the Vanport limestone at this place. At Buffalo Mills it is a worthless shaly bed 25 feet below the limestone, and at the base of the bluff just north of Applewold it is a variable bed of no value 25 feet below the limestone (see secs. 3 to 7 of coal-section sheet).

Platt reports the Clarion coal 1 foot thick on Whiskey Run in Bradys Bend (Second Geol. Surv. Pennsylvania, Rept. H5, p. 224), and a mere streak on Limestone Run (Rept. H5, p. 275).

Lower Kittanning coal.—This is the most persistent and probably the most valuable deposit in the quadrangle. Wherever found it is of minable thickness. Owing to its low position in the Allegheny formation, it underlies nearly the whole quadrangle, being absent only where it has been eroded in the deeper valleys. Such areas are small, however, and mostly confined to the northeastern part of the quadrangle. Buffalo Creek and its tributaries, Long Run and Patterson Creek, have cut below and removed considerable areas of the Lower Kittanning coal on the axis of the Kellersburg anticline from Fosters Mills southward to 2 miles below Buffalo Mills and from the head of Long Run westward to Nichola. Buffalo Creek and Rough Run both cut below the coal for a distance of about 2 miles above their junction.

The Lower Kittanning coal is rarely less than $2\frac{1}{2}$ feet thick; it generally runs nearer $3\frac{1}{2}$ feet, and even reaches 4 feet occasionally. It is often much broken by shale partings, which impair its purity, while iron pyrites in many places detracts from its value as a fuel. Secs. 8 to 23 of the coal-section sheet exhibit fairly well the thickness and character of the seam as developed in the various parts of the quadrangle.

The Lower Kittanning coal is at present mined on a commercial scale within the quadrangle only at the Riverview mine at Riverview or Cosmus, at the Monarch mine north of Allegheny River, about 1 mile above the mouth of Redbank Creek, and at the Keystone mine on the south side of Allegheny River above Phillipston. The Great Lakes Coal Company has taken up a large tract of land in the northern part of the quadrangle, and is making preparations to mine the coal on a large scale. Its mines are located near Kaylor. The coal is also largely mined for use at the Kittanning Clay Manufacturing Company's brick works at Kittanning. In addition to these larger operations there are many country banks distributed over the quadrangle from which considerable quantities of coal are taken, or were formerly taken, for local use.

Middle Kittanning coal.—A number of abandoned openings were observed in what is apparently this seam in the region between Allegheny River and Sherrett, Morrows Corner, and Adrian, but as these are now all closed nothing could be learned concerning the coal. On the ridge between Huling Run and the river, about 1 mile south of Wattersonville, a bank in the Middle Kittanning is now open and shows the relations illustrated by sec. 24 of the coal-section sheet.

In the bluff of the river north of Applewold this coal has a thickness of 15 inches. So far as the writer's knowledge goes, this coal is nowhere else open for observation and measurement, and its value is entirely conjectural, though probably it is slight.

Upper Kittanning coal.—This coal is usually a mere streak, only a few inches thick, but swells locally to minable thickness. At Somerville, where it probably is best known and most extensively worked, it is described as a bituminous coal of fair quality, occurring as a seam 2 feet thick at the outcrop and thickening rapidly to 5 feet within the mine, where the bottom of the seam remains about horizontal. The coal is underlain by a bed of cannel shale of no value, which thickens downward from the outcrop even more rapidly than the coal until it attains a thickness of 7 feet, thus making the total thickness of coal and cannel shale 12 feet (Second Geol. Surv. Pennsylvania, Rept. H5, p. 222.) The coal and shale thus occupy a depression in the underlying shale. This mode of occurrence of the seam where it becomes minable seems to be typical of the Upper Kittanning coal in this region and has earned for it the name "pot vein." There is a working bank on this coal at Kaylor and another in Washington Township near the top of the north side of a hill about $1\frac{1}{2}$ miles due northeast of Morrows Corner. There are a number of abandoned openings in the vicinity of Sherrett and Adrian and in the region between those places and Allegheny River. It was formerly mined in the vicinity of Cowansville and on Long Run in West Franklin Township, and sections of the seam at those places, taken from Platt's Report H5, together with sections from other localities, are given on the coal-section sheet (secs. 25 to 31.) The sections should probably be regarded as good only for the immediate locality from which each one was obtained. They seem to indicate, however, the probability of deposits of considerable value in parts of Washington and Sugarcreek townships and in the northern parts of East Franklin and West Franklin townships. The only other locality known to the writer where this coal has been opened is just west of the county line in Donegal Township, near the road eastward from Rattigan. There is an old opening here that appears to be in the Upper Kittanning coal.

Lower Freeport coal.—So far as known this coal is workable only in comparatively small areas. The largest of these extends along Glade Run from the southern border of East Franklin to Cowansville, and thence possibly through the hilltops to Peach Hill, where it is of good thickness over a small area near the top of the hill. It makes a good showing in the road near the top of a narrow ridge in the western part of Sugarcreek Township, $1\frac{1}{2}$ miles slightly northwest of Sherrett. It is about 5 feet thick in the tunnel 1 mile southwest of Cowansville and about 4 feet in the cut midway between Cowansville and Adrian. It was formerly mined in the vicinity of Kittanning, but its thickness there is too uncertain to justify attempts at mining on a large scale. There is a considerable area in southern Donegal and northern Clearfield townships, where the Lower Freeport is probably workable.

The Lower Freeport coal is mined on a commercial scale only at Cowansville, where the Cowansville Mining Company is operating. There is a bank at Walkchalk, another 1 mile south of Walkchalk on Glade Run, and two more on a western branch of Glade Run in the southwest corner of East Franklin Township. In addition to these working banks there are a number along Glade Run that are now abandoned. There is a bank on Buffalo Creek at Fenelton, and a number of abandoned banks on a western branch of Buffalo Run in southern Donegal Township, about 1 to 2 miles northwest of Rattigan. Secs. 32 to 39 of the coal-section sheet show the thickness and character of the seam in those parts of the quadrangle in which it is known.

Upper Freeport coal.—While this seam is, except the Lower Kittanning, the best developed and most valuable coal of the quadrangle, it is worked on a commercial scale only at Karns. It was, however, formerly extensively mined in the vicinity of East Brady, by the Bradys Bend Iron Company, and has been worked out over a considerable area southeast of Kittanning. Aside from the operation at Karns, it is at present mined only at country banks for local use. There are two banks working about 1½ miles south of Chicora and two near Fenelton. There are several banks either working or abandoned south and southeast of Rattigan, toward Nichola. From Rattigan to the western margin of the quadrangle, and also along Buffalo Creek north of Rattigan, surface indications as well as reports indicate that the coal is poor. Near the top of the hill south of Rough Run and 2 miles due west of West Winfield the coal is worked and is of good thickness and quality. There are banks and abandoned workings between this locality and West Winfield, as well as in hills 1 to 2 miles northwest of that place. Near Boggsville and on Cornplanter Run it has been opened in a number of places and found poor, and it is not at present worked in those localities. On Cornplanter Run it is immediately overlain by heavy sandstones, by which it is locally cut out, so that mining is too uncertain to be profitable. About three-quarters of a mile above the mouth of Marrowbone Run there is a working bank. At Beatty's mill, 1 mile north of the bank just mentioned, the coal shows in the bluff of the creek. It is about 3 feet thick, but slaty and worthless. At Worthington, judging from indications and reports, it is thin and of little value. In the vicinity of Adams the same seems to be true. Along the axis of the Kellersburg anticline from West Winfield to Browns Crossroads the horizon of the coal passes beneath many of the hilltops. Its blossom shows in some, but it has never been opened up and nothing is known of its value. In the extreme southwest corner of Sugarcreek Township there are several old workings and the coal is probably good. It has been worked near the top of a number of hills in northeastern Sugarcreek and northern Washington townships and is probably of good thickness, though the areas of it are small and in some places the cover is thin. It has been opened near the top of the hill in Madison Township, Armstrong County, near the eastern boundary of the quadrangle, and also has been worked in Madison Township, Clarion County, near the northern margin of the quadrangle. It has been opened in the ravine near the eastern margin of the quadrangle three-quarters of a mile due south of French's Corner, but the opening is now closed. At Cowansville and Cowansville station it is too thin to be of value, but southward along Glade Run to its mouth it has been opened in a number of places and is of good thickness. There are no workings at present along Glade Run except at one point about 1 mile north of North Buffalo. At the tunnel 1 mile southwest of Cowansville the coal is worked, and there are several openings in the ravines within a mile and a half south of this point, indicating that the coal is of good thickness. On Nicholson Run and along the little stream running into Allegheny River between that run and Glade Run the coal is now open at a number of places and is of good thickness. The fact that the Upper Freeport coal is good around so much of the margin of the Boggsville syncline, and the fact that it is noted in numbers of wells in that area, indicate that it is probably of minable thickness over most of the area of that syncline. This coal has been opened in several of the ravines along the western side of Allegheny River from Limestone Run to a point west of Manorville, but it is not worked to any extent. There is a working bank in Rayburn Township 1½ miles northwest of Kittanning, and the coal is stripped in a ravine at the eastern margin of the quadrangle 1½ miles east of Ford City. Between these two points along the eastern margin of the quadrangle the coal has been opened at several places and is probably of good thickness all along. In a ravine in the west side of the river opposite Ford City the coal is only 6 inches thick and is probably cut out locally, though to what extent is not known.

On the whole the Upper Freeport coal must be ranked as one of the most valuable resources of the quadrangle. The thickness and character of the seam are indicated in secs. 40 to 55 of the coal-section sheet, while some knowledge of its composition and fuel value is given by the appended analyses (p. 15.) The value of the Upper Freeport coal is enhanced by the fact that it makes coke of fairly good quality. It was once largely used for that purpose at Bradys Bend and Kittanning.

Analyses of coals.—In the table (p. 15) below are a number of analyses of samples from the various coal seams of the quadrangle. With two exceptions these samples were collected in the quadrangle. Several of the analyses were made by A. S. McCreath, of the Second Geological Survey of Pennsylvania, and published in Report H5, on Armstrong County. The remainder of the analyses were made by various chemists of the United States Geological Survey. These latter analyses present considerable differences from those made by McCreath. They are higher in fixed carbon and much higher in ash and sulphur. On the other hand they run much lower in volatile hydrocarbons. The fuel ratio is also much higher. These differences may be accounted for in part on the assumption that the two sets of samples were selected differently. The United States Geological Survey samples were taken by stripping a section from the face of the seam about 1 inch deep and 2 inches wide, then thoroughly pulverizing and dividing the samples into quarters and rejecting opposite quarters. This process was repeated until the sample was reduced to a convenient quantity. In taking the section such partings were rejected as are rejected in mining, so that the samples fairly represent the character of the seam.

Petroleum and Natural Gas.

HISTORICAL STATEMENT.

Development of the petroleum industry.—For the last thirty years petroleum has been a most important source of wealth in the western and northwestern part of the quadrangle, while natural gas has been scarcely less important in other parts during the last twenty years. The first oil wells in the quadrangle were drilled in 1873 at Karns. Development proceeded rapidly and by 1875 the most productive parts of the quadrangle had been discovered and drilled over. Over much of the territory the production of individual wells ranged from 100 to 2000 barrels per day. One well near Chicora, though possibly not in the quadrangle, is reported to have produced 150,000 barrels of oil in nineteen months. The wells flowed at first; as the flow decreased, they were pumped; and as production diminished still further, torpedoing was resorted to in order to keep up the production. Since these early days the production has steadily diminished, until now it is but a small part of what it originally was. Many of the wells drilled in those early days, however, are still pumping small quantities of oil. In the meantime, additional small pools have been developed, and between the main pools many wells have been recently drilled which would not have been profitable in the early days, but which, with cheaper methods of drilling and production and careful management, yield fair returns. Possibly there is more such territory in the quadrangle still awaiting development, and, while the palmy days of the oil industry have passed, oil will long continue to be an important though constantly diminishing source of wealth. The relation of the Kittanning quadrangle to the oil and gas producing areas of the northern Appalachians is shown in fig. 12 on the illustration sheet.

Development of the natural-gas industry.—Since the eighties the production of natural gas has been an important industry in the quadrangle. Gas was first encountered in drilling for oil, and allowed to go to waste, but as soon as its value for fuel and power and its suitability for use in various lines of manufacturing came to be appreciated, and methods of handling it were developed, active operations began in search of gas itself. These operations were highly successful in many localities heretofore described; larger reservoirs of gas were tapped by the drill and much wealth has been derived from this source. The limits of these large reservoirs have been fairly well ascertained, and, in spite of the fact that many wells have been drilled in other parts of the gas-bearing portions of the quadrangle, no new reservoirs of equal extent and productiveness have been discovered. A number of wells have been drilled to the Speechley sand within the last two years and some notable strikes have been made, especially at Slate Lick and Worthington. The Kerr well at Worthington, drilled in October, 1902, is a good example of the possibilities of the Speechley sand. This well started off at an estimated flow of from 22,000,000 to 30,000,000 cubic feet in twenty-four hours. As late as June, 1903, however, no other well larger than 1,000,000 to 2,000,000 cubic feet in twenty-four hours had been struck in the Speechley sand, and wells have been drilled into it in many parts of the quadrangle. While, therefore, a big well like the Kerr well may be found occasionally in the deeper sands and smaller ones in the upper sands in territory that has not been thoroughly drilled, it seems improbable that any more large and highly productive reservoirs will be discovered; so the production of natural gas is bound to become a much less important source of wealth than in the past.

DESCRIPTION OF THE OIL- AND GAS-BEARING ROCKS.

The oil-producing territory of the quadrangle lies north and west of a curving line roughly drawn through East Brady, the northwestern part of Sugarcreek Township, southward to 1 mile southeast of Coyleville, and thence to the margin of the quadrangle where it is crossed by Rough Run. The remainder of the territory may be regarded as gas bearing to a greater or less extent.

The oil of the quadrangle is mostly obtained from the Third and Fourth oil sands included in the Venango oil group, and the gas from the Murrysville sand, the Hundred-foot sand, and the latter's lower bench, the Thirty-foot sand. In a number of wells, however, more or less gas is obtained from the Third sand and from the Fifth sand below the oil sands. Recently a few good gas wells have been struck in the Speechley sand, several hundred feet below the Fifth sand.

In the discussion of this subject the Vanport (Ferriferous) limestone, which has always been a guide to the drillers of the region, is used as a reference stratum.

MURRYSVILLE GAS SAND.

At a varying interval below the Pocono, and separated from it in most of the wells generally by shale, lies the Murrysville gas sand. This sand is generally known in this region as the Butler gas sand, but to avoid confusion with the Butler sandstone, described as a member of the Allegheny formation, the name Murrysville gas sand will be used here, since this is probably the same sand as that from which gas is obtained at Murrysville, in Westmoreland County, and which is widely known as the Murrysville sand. In many wells this sand is an important source of gas; in others it is of much less importance than some of the underlying sands of the oil group, especially the Hundred-foot sand at the top of that group.

Depth below limestone.—So far as available records show, the Murrysville sand was first noted as gas bearing in some of the oil wells near the border of the gas-bearing territory. It is probably represented in wells about Petrolia and Karns by what the drillers call the "1000-foot shells." Northward it probably has no representative. In these wells the top of the sand varies from 760 to 825 feet below the Vanport limestone and from 125 to 160 feet above the top of the Venango oil sands. In the southern part of the quadrangle the former interval may reach 930 feet and the latter as little as 60 feet. Assuming that the sands noted as the Murrysville sand in the different parts of the quadrangle are really the same—a doubtful assumption—there seems to be a gradual increase in its depth below the limestone from north to south and southeast and a gradual approach to the top of the Venango oil sands. In the Allegheny Furnace No. 3 and in the Montgomery No. 3 wells, both near the eastern margin of the quadrangle, the Murrysville sand seems to be almost immediately on the top of the Hundred-foot sand at the top of the Venango "group" or to be separated from the latter by only a few feet of shale, a condition that is noted in many wells farther east in the adjoining quadrangle. In 52 wells selected from the various parts of the quadrangle the average interval between the Vanport limestone and the Murrysville sand is 862 feet, in 47 wells the average interval between the top of the Murrysville sand and the top of the Hundred-foot sand, or top of the Venango group, is 147 feet.

Thickness.—The Murrysville sand varies as greatly in thickness as the intervals above described. In some wells it is a thin layer, in others it may reach a thickness of 100 feet, in others it was not found at all, and in still others it seems to be broken into two benches by a bed of shale of varying thickness.

Extent.—So far as records at hand show, the Murrysville sand can not be identified even as a gas-bearing horizon in the oil regions north of the quadrangle, though gas is occasionally noted in the rocks above the Venango sands. South and east it persists as an important gas-producing rock as far as Murrysville, in Westmoreland County.

Variations.—It is much to be doubted whether the Murrysville sand as noted in the various wells at such varying depths below the Vanport limestone is really one and the same continuous stratum. It seems very certain that the sands occur as discontinuous lenses. It may even be doubted whether these lenses occupy the same geologic plane and are even approximately contemporaneous deposits and that the varying depth below the limestone is due to greater thickness of the intervening strata in some places than in others. The actual condition seems to be that in the 200 feet of strata immediately overlying the "Venango oil group," beds of gas-bearing sandstone occur at various levels, the higher generally lying to the north and the lower to the south, and that the first of these gas-bearing sands encountered in drilling a well has been called the Murrysville sand.

VENANGO OIL SANDS.

The oil produced in the quadrangle comes from a group of coarse sandstones, frequently interbedded with red shale and sandstone, which are believed to lie near the top of the Catskill formation. In descending order these sands are known as the Stray, Third, and Fourth sands, and with several overlying non-oil-bearing sands constitute the "Venango oil sand group" (Carll, Second Geol. Surv. Pennsylvania, Rept. I 3, p. 130).

Thickness and depth below limestone.—The distance from the top of the Venango oil sands to the Vanport limestone varies from 920 feet in the northwestern part of the quadrangle to 1090 feet in the southern part. The former interval is shown in the Hazelwood and Evans wells near Karns, just north of the quadrangle, and the latter, which is very extreme, in the Rayburn well near Slate Lick. The average of 61 wells gives the interval at 985 feet. The bottom of the Fourth sand, which seems to be the lowest oil-producing rock, is here taken as the bottom of the "group." It varies from 1250 feet below the limestone in the northwest corner of the quadrangle, as shown in the Hazelwood and Evans wells, to the extreme of 1490 feet in the Lewis Baker well near Slate Lick. Owing to the difficulty of identifying this sand outside the oil-producing territory, there may be a mistake in the latter case and a lower sand taken as the Fourth. However that may be, the depth of the bottom of the Fourth sand, and therefore the depth of the bottom of the "group," increases from north to south just as the depths to the Murrysville sand and the top of the Venango sands increase. Thirty-four wells give an average interval of 1347 feet between the limestone and the bottom of the Fourth sand, and an average thickness for the group of 363 feet.

Character of the sand.—The Venango oil sands form a very well-defined group which has large extent in western Pennsylvania. It is composed predominantly of a series of sandstone beds of varying shape and extent, rarely exceeding 50 feet in thickness, separated by thicker or thinner beds of shale. The occurrence of bands of red shale and red sandstone is very characteristic of the group. These are nearly always thin and may occur in any position.

Second or Hundred-foot sand.—At the top of the group lies a sandstone which is called the Second sand in the oil region of northern Butler County, and the Hundred-foot sand throughout the gas-bearing territory of Armstrong County. It is regarded by Mr. Carll as the equivalent of the First sand of Venango County, the change being due to a mistake in the identification of sands when drilling began in northern Butler County. It may be an unbroken bed 100 feet thick or it may be broken by thin bands of shale into three members, which in descending order are called the Second or Hundred-foot sand, Fifty-foot sand, and Thirty-foot sand. So far as the writer is aware this bed never produces oil in this quadrangle, but it is one of the most important gas-producing rocks of Armstrong County.

Blue Monday and Boulder sands.—Near the center of the group two thin sands are noted in many wells, known as the Blue Monday and Boulder sands, the former above the latter.

Stray, Third, and Fourth sands.—The oil-bearing beds are found near the bottom of the group. When drilling began in that part of Butler County in and adjacent to this quadrangle, the first oil-bearing sand was called the Third sand and was supposed to be the equivalent of the Venango Third sand. Later a lower oil-bearing sand was discovered, which was called the Fourth sand. Mr. Carll (Report I3) believes, with good reason, that the correlation of the Butler County and Venango Third sands is a mistake, that the Butler Third is the equivalent of the Venango Second sand, and that the Butler Fourth sand really represents the Venango Third sand. However that may be, the names originally adopted for the sands in this region will be used here. These names have been applied to the various oil-producing sands of the region according as the drillers believed that they could identify them as the one or the other, so the oil-producing territory has been divided into Third-sand pools, Fourth-sand pools, etc., and where the sand could not be referred to either of these two sands the name Stray sand was adopted, making here and there a Stray sand pool. The Stray sand is regarded as occupying a higher position than the Third sand. Outside of the type region, near the northwest corner of the quadrangle, where both the Third and the Fourth sands occur, one above the other, it is doubtful whether these sands can be identified with any degree of certainty or that the Third sand of one locality is the same as the Third sand of another locality, and so forth. The Third sand yields a little gas in a few wells in the southern part of the quadrangle.

Variations.—The remarks concerning the variations in the Murrysville sand apply equally well to the various Venango sands. The Venango sands are not persistent but fugitive beds. They appear, thicken, thin out, disappear, and their places are taken by other beds of the same character at a little higher or a little lower horizon, or farther on at the same horizon. Thin bands of sandstone may be separated by thin bands of shale. The shale bands disappear and thick beds of sandstone take their places, or vice versa. Thus there are endless variations, such as may be seen to occur under similar conditions where the beds can be traced at the surface. About the most that can be safely said is that in some localities one or more of the sandstone beds occurring toward the bottom of the group bear oil in paying quantities.

The Fifth sand is recorded in various wells from 50 to 100 feet below the oil sands. It is generally thin. It is an important source of gas in a number of wells in the southwestern part of the quadrangle.

SPEECHLEY SAND.

In nine wells at an average depth of 830 feet below the Venango group occurs a sand 20 to 40 feet thick which recently has been found to bear gas in paying quantities at a number of places within the quadrangle. This is regarded by the drillers and gas producers as representing the Speechley sand of Venango and Forest counties. That name will be provisionally adopted here.

Depth below limestone.—The Speechley sand varies in depth below the Vanport limestone from 2080 feet in the Amos Steele well in Bradys Bend Township to 2320 feet in the Rayburn well near Slate Lick. In ten wells the average interval is 2200 feet. Within the quadrangle this sand has yielded gas in important quantities in only a few wells near Slate Lick and Worthington. It has been pierced in a number of other places, both in this quadrangle and in the Rural Valley quadrangle to the east, without very satisfactory results. In some cases, as in the Amos Steele well, where the interval below the limestone is smaller than usual, it seems possible that the true Speechley was not reached, but that the sand identified as such is a higher one. In other cases, however, as in well No. 21, on the Bradys Bend tract, and No. 13 of the well-section sheet, just north of the quadrangle, and in the Robert Smith well in Winfield Township, the drill penetrated more than a thousand feet below what was regarded as the Speechley sand, but neither oil nor gas was reported in these deeper beds.

STRATIGRAPHIC RELATIONS OF THE OIL AND GAS SANDS.

Under the heading "Rocks not exposed" it has been shown that the Murrysville and Hundred-foot sands probably occur in the lower part of the Pocono formation, the bottom of which is probably close below the bottom of the Hundred-foot sand. The oil-bearing sands proper which occur in the midst of the red beds are assigned to the Catskill formation.

DISTRIBUTION OF OIL AND GAS.

Oil pools.—By examining the structure map it can be seen that the oil and gas are not distributed uniformly throughout the beds in which they occur. In the first place, the portions of the quadrangle yielding the two substances are rather sharply separated, the oil-producing territory being confined to the western side, to the northwest corner, and to the northern margin west of Allegheny River. Throughout the remainder of the quadrangle only gas occurs.

Within the oil-producing portion of the quadrangle the drill has revealed the fact that in certain rather well-defined areas the oil has accumulated in much greater quantities than in the surrounding territory. These very productive areas are generally elongated and comparatively narrow and are called belts or pools. What is true of the accumulation of oil is also true of the accumulation of gas. The mapping of the oil pools is based upon the grouping of producing wells at the present day and probably does not fully represent the pools as they existed previous to the drilling of the territory. Many more large wells were probably drilled in the region between Chicora and Karns than now remain, and that region probably constituted one of the most important belts of the quadrangle.

Relation to structure.—It will be seen by the map that in the western part of the quadrangle the longer axes of the oil pools run in a northeast-southwest direction and that the Fourth-sand pool along the northern margin and the Kaylor pool near Kaylor have a general east-west direction. In both regions the pools, as a general thing, lie low on the flanks of the anticlines and are arranged with their long axes approximately parallel to the structure lines and to the axes of the anticlines and synclines, in accordance with the anticlinal theory of the accumulation of oil and gas. The east-west extension of the Fourth-sand pool along the northern margin of the quadrangle was once believed to be at variance with the anticlinal theory, but at that time the Bradys Bend anticline was believed to follow a straight northeast-southwest course. With the determination of the true structure of the region the facts and the theory are found to be in perfect accord.

The accumulation of gas in the quadrangle seems to be also largely controlled by structure. The main reservoirs of gas have been found across the southern end of the Kellersburg anticline and along the axis of the McHaddon anticline. Many good wells have been struck on both flanks of the Kellersburg anticline, and such wells on the western flank are located east of the oil-bearing territory and higher on the anticline. The gas wells extend lower on the eastern flank of the Kellersburg anticline, where oil does not occur, than on the west, and in the vicinity of Slate Lick a few paying wells have been drilled to the Speechley sand in the bottom of the Boggsville syncline. A number of good wells were obtained in the Murrysville sand at Ford City near the axis of the Fairmount syncline. The general rule, however, is that the most extensive and most productive gas territory occurs well up on the flanks or along the crests of the anticlines.

Conclusions.—So far as this quadrangle is concerned, a study of the relation of the distribution of oil and gas to structure seems to warrant the following conclusions:

(1) Where both oil and gas occur in the same basin, as in the region west and north of the crest of the Kellersburg anticline, they are distributed according to their densities, the oil occurring in the lower and the gas in the higher portions of the dipping strata.

(2) Oil and gas both occur in the synclines, along the pitching axes, where the rocks are descending toward the deeper parts of the synclines.

(3) Where gas alone occurs, as south and east of the Kellersburg anticline, it may be found in the lower parts of the folds as well as in the parts usually occupied by gas in areas where both oil and gas occur.

(4) Structure is not the only condition determining the occurrence of gas or oil. The structure may be favorable, yet neither oil nor gas occur. The chief condition other than structure is the existence of rock of such character as to act as a reservoir.

(5) It is manifestly futile to attempt to follow a gas or oil pool along a 30° or 45° line or along a straight line at any other angle, since the structure lines are curves and not straight lines for any considerable distance.

Clay and shale.

At Kittanning fire clay and shale associated with the Lower Kittanning coal are utilized largely in the manufacture of brick and tile, especially the former. The relationship and thickness of the different beds as they are developed at the quarry of the Kittanning Clay Manufacturing Company are shown in the following section:

Section at Kittanning.

		Feet.
1.	Dark clay shale	25
2.	Lower Kittanning coal	3+
3.	Kittanning fire clay	12
4.	Sandy shale	10
5.	Buhrstone ore	1
6.	Vanport (Ferriferous) limestone	9
7.	Dark sandy shale or shaly sandstone	10
8.	Shale or slate	20
9.	Little or no coal	..
10.	Clarion fire clay	8 to 10

Shale.—From No. 1 is made a fine vitrified brick for building fronts; from No. 4 are made a vitrified brick and building brick; from No. 7 is made a building brick. No. 8 will be utilized for buff fire brick and for sewer pipe.

Kittanning fire clay.—This is a plastic clay. It is extensively used by the Kittanning Clay Manufacturing Company for buff brick. In places in the clay at this quarry occur thin streaks of coal containing much sulphur, which seriously impairs the quality of the clay.

At Daugherty Brothers' Brick Works, also at Kittanning, the Kittanning fire clay is 7 feet thick and the underlying shale 12 feet thick. Both are used for brick. At West Winfield the Kittanning fire clay has been opened by the Duquesne Fire-Proofing Company, which has established a large plant for the manufacture of clay products. The clay is $11\frac{1}{2}$ feet thick, but more suitable for tile than for brick, since it does not make an article of uniform color.

Clarion fire clay.—At Kittanning the Clarion fire clay is beneath the surface, but it rises rapidly northward, and at Ewing, as well as at the mouth of Cowanshannock, it is about 140 feet above Allegheny River. This is also a plastic clay and from it is obtained the material used in the brick works at Neale and Cowanshannock. At the former place a buff and gray building brick is made and at the latter the ordinary fire brick. At West Winfield, according to the report of the superintendent, the Duquesne Fire-Proofing Company is using this clay for sewer-pipe.

Freeport fire clay.—The Freeport fire clay becomes thick in places and may be profitably used in the future. Immediately south of Chicora this seam becomes a flint clay, 10 feet or more thick, which apparently has an extent of several square miles. While nothing is known of its qualities, the thickness and extent of the bed and its proximity to the railroad would seem to warrant an investigation on the part of investors. It might become the basis of a profitable industry at Chicora.

It is hardly to be doubted that these beds of fire clay and shale will be found available in other parts of the quadrangle as facilities for shipment are developed.

Iron Ore.

Buhrstone ore.—This ore lies at the top of the Vanport (Ferriferous) limestone and was formerly extensively mined along both sides of Allegheny River north of Kittanning and in the northeast corner of the quadrangle, in both Clarion and Armstrong counties, in Bradys Bend Township, and along Buffalo Creek and Rough Run. The ore occurs either as a compact layer averaging 8 inches thick at the top of the limestone or as nodules in the immediately overlying shales. In the former case it may be carbonate, limonite, or impure hematite, according to locality; in the latter case it is carbonate. In its unaltered condition, where it has not been changed by weathering, it is probably always a carbonate. The ore was mined along the outcrop by stripping off the overlying disintegrated material, and in some cases, as along Redbank Creek, where the ore could no longer be obtained by this method, it was obtained by drifting beneath the surface. Miles of these old strippings can be followed around the hillsides in the northeast corner of the quadrangle, in Madison Township, in both Armstrong and Clarion counties. This ore was mined also on Buffalo Creek at Buffalo Mills and Craigsville. It seems likely that about all the ore that could be obtained in close proximity to the various furnaces by this comparatively inexpensive method had been exhausted about the time that the higher grade and less expensively mined ores of the Lake Superior region came into use. These two circumstances, combined with the superior quality of the iron from the lake ores, put an end to the production of iron from the ores of this region.

The carbonate ores unroasted contained 33 to 38 per cent of metallic iron, the other ores often as much as 50 per cent. The most damaging impurities in the iron from these ores was phosphorus and silica, and their presence was due, it is believed, to imperfect methods of smelting and to the use of the Ferriferous limestone as flux, which communicated so much phosphorus to the metal that it was unsuited for making Bessemer steel but not for the ordinary uses of mill iron (Second Geol. Surv. Pennsylvania, Rept. H5, pp. lvii-lxiii).

Lower Freeport ore.—This occurs in the southwestern part of the quadrangle, in Winfield and West Franklin townships. It was mined for use at the Buffalo furnace near the top of a hill one-half mile north of the Butler pike, just east of the county line. The ore at this place was regarded by Platt (Second Geol. Surv. Pennsylvania, Rept. H5) as the Upper Freeport, and apparently by I. C. White (Second Geol. Surv. Pennsylvania, Rept. A, p. 94) as the Lower Freeport ore. The writer's observations seem to bear out White's opinion, for the ore in question probably lies from 50 to 60 feet below the Upper Freeport coal, and about 180 to 200 feet above the Vanport limestone, which is opened on the hillside below the old ore strippings. The ore at this point could not be observed, but it is associated with an impure limestone and coal, for débris of both were noted at the diggings. On Rough Run the ore is described by White, in the report referred to above, as occurring about 70 feet below the Upper Freeport coal and 130 feet above the Lower Kittanning coal. It is a mixture of blue carbonate and limonite, running from $1\frac{1}{2}$ to 6 feet in thickness. White expressed the opinion that the ore would probably yield 35 to 50 per cent of iron. This ore largely supplied the old Winfield furnace.

Upper Freeport ore.—This ore was most extensively mined at Bradys Bend. Like the Buhrstone ore, it was mined mainly by stripping, but to some extent by drifting. The old strippings may be seen at the present day in both sides of Holders Run and on the ridge between Harts Run and

Allegheny River. The workings in West Franklin and Winfield were of very small extent. Outside of these localities it is not known.

The Freeport ore is described as a solid, compact, very argillaceous layer 2 to 4 feet thick, 26 feet below the Upper Freeport coal. It is a carbonate ore yielding a little over 30 per cent of metallic iron. The iron is disposed to be red short and would be improved by a mixture of one-quarter magnetic or red hematite ores (Second Geol. Surv. Pennsylvania, Rept. H5, p. 220).

While the Freeport ore probably can not be regarded as an important source of future supply of iron, it is evident that in the Buhrstone ore there exists an almost unlimited store of medium-grade ore which may become an important source of supply when the more productive and profitable deposits are exhausted.

Limestone.

Vanport ("Ferriferous") limestone.—At West Winfield this limestone is extensively quarried and crushed for road metal and railroad ballast and to some extent also for lime. At this place the limestone is 21 feet thick. It is not quarried, but mined in the same way that coal is mined. This limestone is also quarried incidentally by the Kittanning Clay Manufacturing Company for lime and for flux in the furnace located near by. It was formerly much used for flux in the blast furnaces of the region, but it has been superseded for that purpose by purer limestone from other parts of the country. In many parts of the quadrangle the limestone is quarried and burned into lime for fertilizer. It is generally hauled by the farmers to their farms and burned in the fields where it is to be applied. This practice is facilitated by the abundant supply of coal which many farmers have at hand. There are ample supplies of limestone easily accessible for this purpose, and it would seem that such use might be greatly extended with profit.

Freeport limestone.—There are abundant supplies of this limestone in the southeast corner of the quadrangle, and these are drawn upon to some extent for use as a fertilizer. It was once quarried at Manor and vicinity and shipped to Pittsburg for use as flux (Second Geol. Surv. Pennsylvania, Rept. H5, p. 255), but the industry has been discontinued, probably because the use of the Freeport limestone for flux, like that of the Vanport, has been supplanted by the use of limestone from other regions better adapted for the purpose.

Building Stone.

On the hills southwest of West Winfield the Saltsburg sandstone is extensively quarried. This sandstone practically forms the surface of the flat hilltops here and can be reached by a minimum amount of stripping. The quarry already extends over a large space to a depth of from 10 to 15 feet. The rock is a coarse-grained sandstone in layers of such thickness that it is easily worked. It is suitable for coarse masonry only. The quarried blocks are let down by an incline to the West Winfield Railroad for shipment. On the east bank of the river about three-fourths of a mile south of the Cowanshannock a sandstone, probably the Clarion, has been quarried to a considerable extent for the same kind of stone, and the same is true of the Freeport sandstone in the west bluff of the river just south of Applewold.

Sand.

At West Winfield the Saltsburg and Clarion sandstones are being ground into sand. In the vicinity of Kittanning large quantities of sand are dredged from the river and used for grinding plate glass at the Kittanning Plate Glass Works. It is also used to a less extent for mortar. The Mahoning sandstone is extensively quarried on the west side of the river opposite Ford City by the Pittsburg Plate Glass Company. It is reduced to sand, which is use for grinding glass at Ford City.

November, 1903.

Analyses of coals of Kittanning quadrangle.

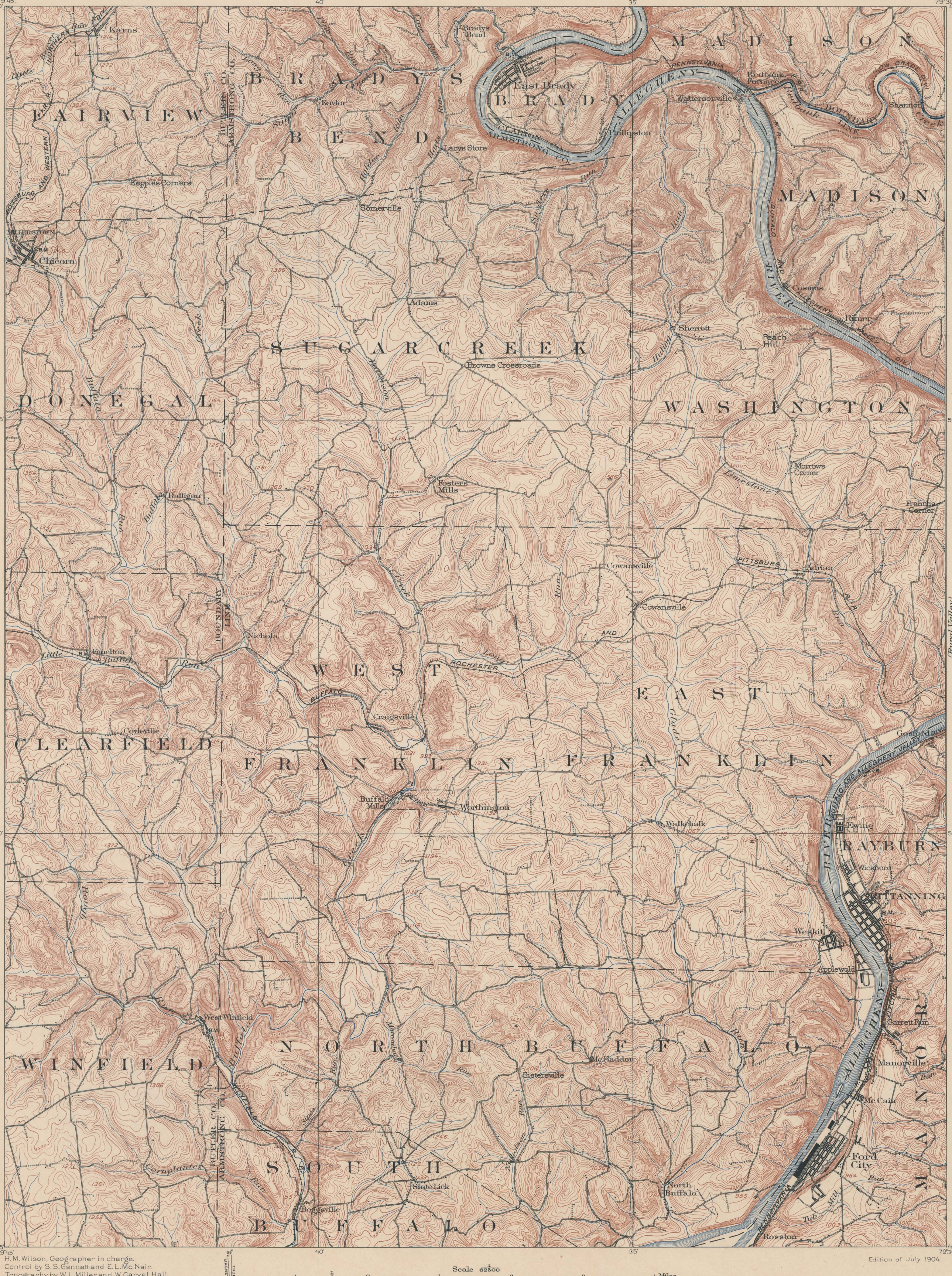
Name of seam.	Locality.	Owner.	Analyst.	Collector.	Fixed carbon.	Volatile hydro-carbons.	Moisture.	Ash.	Sulphur.	Phosphorus.	Total.	Color of ash.	Coke—per cent.	Character of coke.	Fuel ratio.
1. Clarion	West Winfield	A. G. Morris	E. C. Sullivan, U. S. G. S.	J. S. Burrows	50.83	36.19	2.20	10.78	*3.35	....	100.00	Slightly red.	....	Swollen porous.	1:1.44
2. Lower Kittanning	Mahoning	Mahoning Coal Co.	A. S. McCreath (H5, p. 232)	....	49.686	42.55	1.18	4.585	1.999	.0061	100.00	Pinkish gray.	56.27	....	1:1.17
3. Do.	Rogers farm west of Buffalo Mills, near county line.	....	A. S. McCreath (H5, p. 282)	....	48.742	42.72	1.16	5.065	2.313	....	100.00	Reddish gray.	56.12	....	1:1.14
4. Do.	Kittanning	Kittanning Clay Man'f'g. Co.	Geo. Steiger, U. S. G. S.	J. S. Burrows	53.59	35.09	1.61	9.71	*4.62	....	100.00	....	....	....	1:1.52
5. Do.	Mouth of Cowanshannock Creek	....	do.	do.	49.19	32.93	3.19	14.69	*7.32	....	100.00	....	....	....	1:1.49
6. Do.	Craigsville	Mr. Bowser	do	do	52.97	37.06	1.89	8.08	*4.41	....	100.00	....	....	....	1:1.42
7. Lower Freeport	Cowansville	Cowansville Mining Co.	W. F. Schaller, U. S. G. S.	do	53.34	31.73	2.97	11.96	*3.51	....	100.00	....	....	Good.	1:1.67
8. Upper Freeport	Stewartson Furnace, off quadrangle	....	A. S. McCreath, (H5, p. 171)	....	55.545	35.52	1.47	6.63	.835	.0684	100.00	Yellowish gray.	63.01	....	1:1.56
9. Do.	Near Freeport, off quadrangle	....	A. S. McCreath, (H5, p. 262)	....	50.206	39.835	1.43	5.71	2.819	....	100.00	Cream.	58.735	....	1:1.26
10. Do.	One mile east of Ewing	Galbreath bank	Geo. Steiger, U. S. G. S.	J. S. Burrows	49.78	31.65	2.72	15.85	*4.06	....	100.00	....	....	....	1:1.57
11. Do.	One and one-quarter miles SW. of N. Buffalo p.-o.	Bruner bank	do.	do.	51.37	29.00	2.17	17.46	*2.58	....	100.00	....	....	....	1:1.77

*Sulphur determined separately.

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

TOPOGRAPHY

PENNSYLVANIA
KITTANNING 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

CULTURE
(printed in black)

Roads and buildings

Churches and school houses

Private and secondary roads

Railroads

Tunnels

Bridges

Ferries

Dams

County lines

Township lines

City, village and borough lines

Triangulation stations

Bench marks

H. M. Wilson, Geographer in charge.
Control by S. S. Gannett and E. L. Mc Nair.
Topography by W. L. Miller and W. Carvel Hall.
Surveyed in 1900.

SURVEYED IN COOPERATION WITH THE STATE OF PENNSYLVANIA.

APPROXIMATE MEAN DECLINATION 1902.

Scale $\frac{1}{62500}$

Contour interval 20 feet.
Datum is mean sea level.

Edition of July 1904.

(Elders Ridge)

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

AREAL GEOLOGY

PENNSYLVANIA
KITTANNING 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

Qg — Glacial gravel *(outwash gravels and sands of probable Kansan age; contain pebbles of Medina sandstone and crystalline rock)*

Qcm — Carmichaels formation *(sand, silt, clay, and water-worn particles of underlying rocks)*

Qoa — Older alluvium *(gravel and silt of local derivation)*

CARBONIFEROUS

Pennsylvanian

Ccm (Cam, Csb) — Conemaugh formation with Ames limestone and Saltsburg sandstone lentils *(sandy shale and coarse sandstones, with thin coal seams and impure limestones)*

Ca (Cv) — Allegheny formation and Vanport limestone lentil *(shale and massive sandstones with beds of limestone and several valuable beds of coal and fire clay)*

Cpv — Pottsville formation *(massive sandstone, often shaly at the top and at horizon of Mercer coals)*

Mississippian

Cpo — Pocono formation *(massive sandstone, with small coal seams and associated shale)*

Section

H. M. Wilson, Geographer in charge.
Control by S. S. Gannett and E. L. Mc Nair.
Topography by W. L. Miller and W. Carvel Hall.

SURVEYED IN 1900, IN COOPERATION WITH THE STATE OF PENNSYLVANIA.

APPROXIMATE MEAN DECLINATION 1902.

Scale $\frac{1}{62500}$

Contour interval 20 feet.
Datum is mean sea level.

Edition of Sept. 1904

Geology by Charles Butts, L. H. Woolsey, and Frank Leverett, under the direction of Marius R. Campbell.

SURVEYED IN 1901-02, IN COOPERATION WITH THE STATE OF PENNSYLVANIA.

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

STRUCTURE AND ECONOMIC GEOLOGY

PENNSYLVANIA
KITTANNING QUADRANGLE

LEGEND

SEDIMENTARY ROCKS

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

QUATERNARY

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Pennsylvanian

Cam, Ccm, Csb — Conemaugh formation with Ames limestone and Saltsburg sandstone lentils *(sandy shale and coarse sandstones, with thin coal seams and impure limestones)*

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Cpv — Pottsville formation *(massive sandstone, often shaly at the top and at horizon of Mercer coals)*

Mississippian

Cpo — Pocono formation *(massive sandstone, with small coal seams and associated shale)*

Known productive areas

Coal outcrops *(continuous lines represent coal beds of workable or probably workable thickness; dashed lines, coal beds not known to be workable)*

Upper Freeport, uf
Lower Freeport, lf
Upper Kittanning, uk
Middle Kittanning, mk
Lower Kittanning, lk
Clarion, cl
Craigsville, cg

Contour lines drawn on the upper surface of the Vanport limestone lentil in the Allegheny formation *(contour interval is 50 feet; datum is mean sea level)*

Oil pools *(projected to the surface; individual wells not shown)*

Mines and quarries — *Coal mines, unless otherwise marked*
Scattered oil wells
Gas wells
Sections of numbered wells are shown on well-section sheet.

Section

H. M. Wilson, Geographer in charge.
Control by S. S. Gannett and E. L. Mc Nair.
Topography by W. L. Miller and W. Carvel Hall.

SURVEYED IN 1900, IN COOPERATION WITH THE STATE OF PENNSYLVANIA.

APPROXIMATE MEAN DECLINATION 1902.

Scale $\frac{1}{62500}$

Contour interval 20 feet.
Datum is mean sea level.
Edition of Sept. 1904

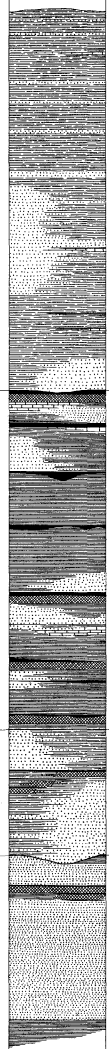
Geology by Charles Butts, L. H. Woolsey, and Frank Leverett, under the direction of Marius R. Campbell.

SURVEYED IN 1901-02, IN COOPERATION WITH THE STATE OF PENNSYLVANIA.

COLUMNAR SECTION

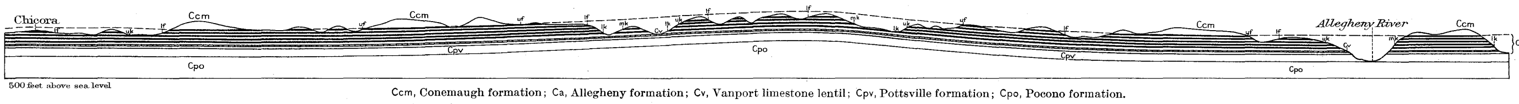
GENERALIZED SECTION FOR THE KITTANNING QUADRANGLE.

SCALE: 1 INCH = 100 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	Conemaugh formation.	(Cam)			Ames ("Crinoidal") limestone.	Grayish-green, fossiliferous limestone, 2 feet thick. Hills north of Slate Lick.	Chiefly shale of clayey or sandy composition, with thick coarse sandstones and thin coal seams and limestone.
							Red shale. Hills northeast of Slate Lick.	
			Ccm		400+			
			(Csb)			Saltsburg sandstone.	Coarse, thick-bedded sandstone. Excellent quarry rock. Hills in southwest corner of quadrangle.	
						Bakerstown coal.	Thin and worthless. Southwest corner of quadrangle.	
							Red shale.	
						Brush Creek coals.	Generally thin and worthless, associated with bed of black shale. Underlying limestone rarely found. Occurs in south half of quadrangle.	
					(0-50)	Mahoning sandstone.	Often coarse and thick-bedded or massive; sometimes a thin bed of fine-grained flags. Generally present in some form.	
		Allegheny formation.				Upper Freeport coal.	Generally present and of minable thickness. Thin and poor occasionally.	Shale with heavy beds of sandstone, beds of limestone with associated iron ores, and several valuable coal seams and beds of fire clay. Source of all the valuable mineral products of the quadrangle except oil and gas.
						Fire clay.	Usually plaster, rarely flint; probably always present under coal.	
					(0-20)	Upper Freeport limestone.	Hard blue limestone.	
						Upper Freeport sandstone.	Coarse, heavy-bedded sandstone, rarely present.	
						Lower Freeport coal.	Generally thin. Valuable seam along Glade Run.	
						Lower Freeport limestone.	Thin and rarely present.	
					(30-50)	Lower Freeport sandstone.	Generally flaggy and coarse, and heavy-bedded near Fosters Mills.	
						Upper Kittanning coal.	Generally thin and worthless; locally thick and valuable.	
					(0-2)	Middle Kittanning coal.	Not known to be of minable thickness in the quadrangle.	
			Ca		340-360			
					(3-4)	Lower Kittanning coal.	Present throughout quadrangle so far as known. The most valuable coal in the area. Underlain by thick, valuable fire-clay.	
					(0-40)	Kittanning sandstone.	Coarse and heavy bedded.	
			(Cv)		(0-20)	Vanport limestone.	Gray fossiliferous limestone, often cut by Kittanning sandstone. Thin seam of iron ore at top.	
						Clarion coal.	Generally thin and of little value. Underlain by valuable fire clay.	
						Clarion sandstone.	Coarse, massive sandstone, rarely present.	
						Craigsville coal.	Local, 3 feet thick or less.	
						Brookville coal. Brookville fire clay.	Thin and worthless.	
		Pottsville formation.				Homewood sandstone.	Variable. Often partly replaced by shale; rarely coarse and massive.	Generally heavy-bedded sandstone, often shaly at top and at horizon of Mercer coal.
			Cpv		120-140	Mercer coals?	Thin and worthless.	
						Connoquenessing sandstone.	Coarse, heavy-bedded sandstone with beds of shale. Exposed along Allegheny River and in vicinity of Craigsville.	
		UNCONFORMITY						
	MISSISSIPPIAN	Pocono formation.	Cpo		200+		Heavy-bedded gray sandstone, found along the gorge of the Allegheny River and along Red Bank Creek.	Mostly a heavy-bedded sandstone to depth exposed in quadrangle, with small coals, accompanied by shale near top. Underlain by an unknown thickness of shale.

STRUCTURE SECTION ALONG THE LINE A-A ON THE GEOLOGIC MAPS.

HORIZONTAL SCALE: 1 INCH = 1 MILE. VERTICAL SCALE: 1 INCH = 1500 FEET.



Ccm, Conemaugh formation; Ca, Allegheny formation; Cv, Vanport limestone lentil; Cpv, Pottsville formation; Cpo, Pocono formation.
uf, Upper Freeport coal; lf, Lower Freeport coal; uk, Upper Kittanning coal; mk, Middle Kittanning coal; lk, Lower Kittanning coal.

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Geologist.

WELL SECTIONS

SECTIONS OF DEEP WELLS IN THE KITTANNING QUADRANGLE AND VICINITY.

SCALE: 1 INCH=400 FEET.

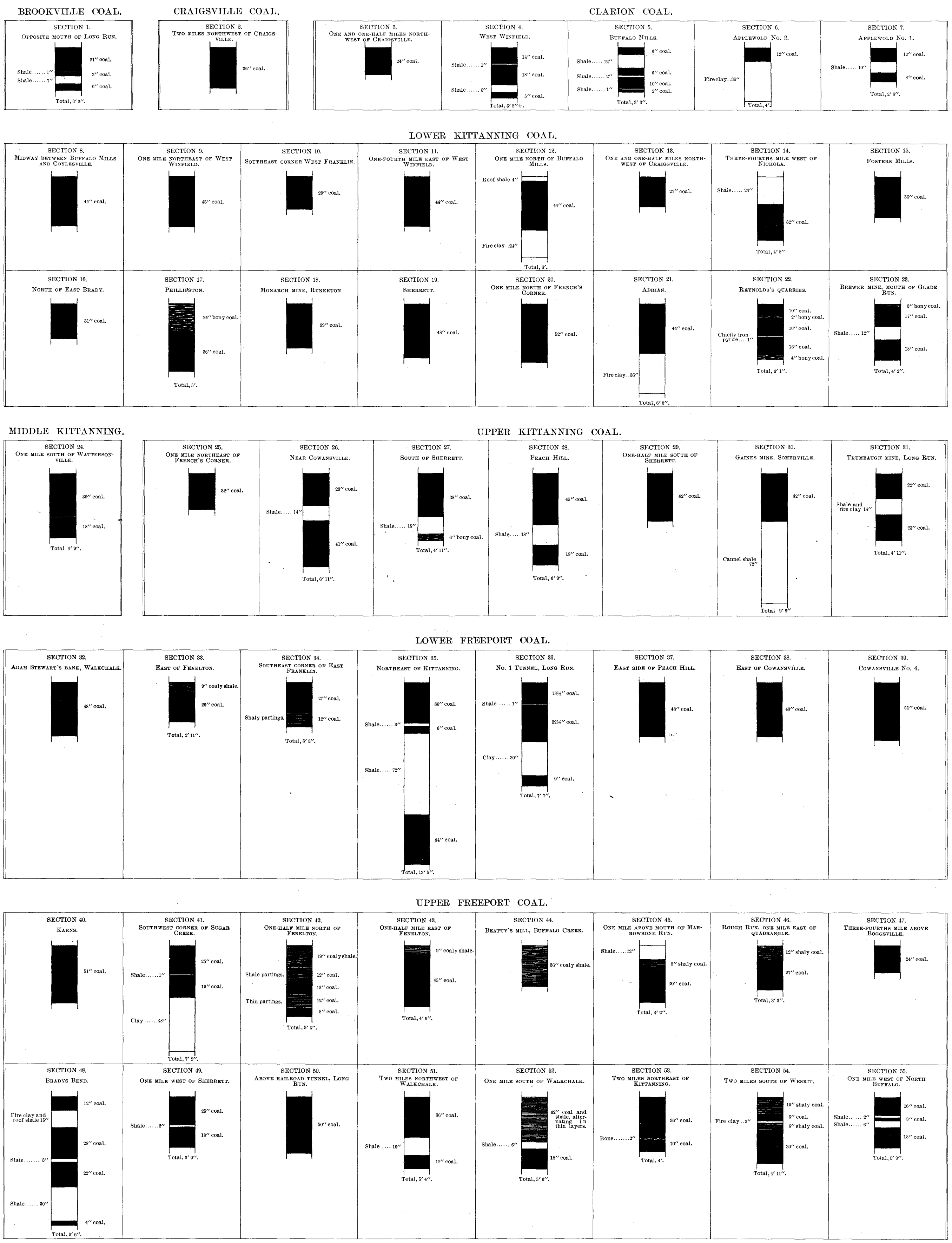
CHARLES BUTTS,

Geologist.

COAL SECTIONS

SECTIONS OF COAL SEAMS IN KITTANNING QUADRANGLE AND VICINITY.

SCALE: 1 INCH=5 FEET.



CHARLES BUTTS,

Geologist.

ILLUSTRATIONS

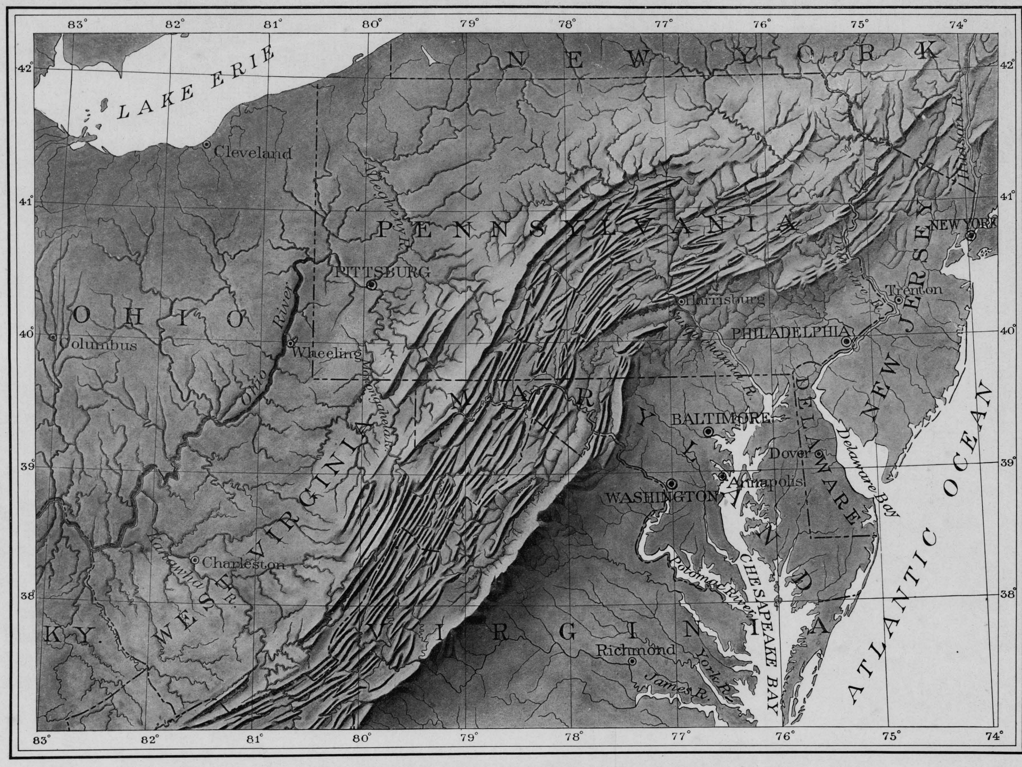


Fig. 10.—RELIEF MAP OF THE NORTHERN APPALACHIAN MOUNTAINS.

The Kittanning quadrangle is situated on the plateau lying west of the belt of valley ridges, in the west-central part of Pennsylvania.

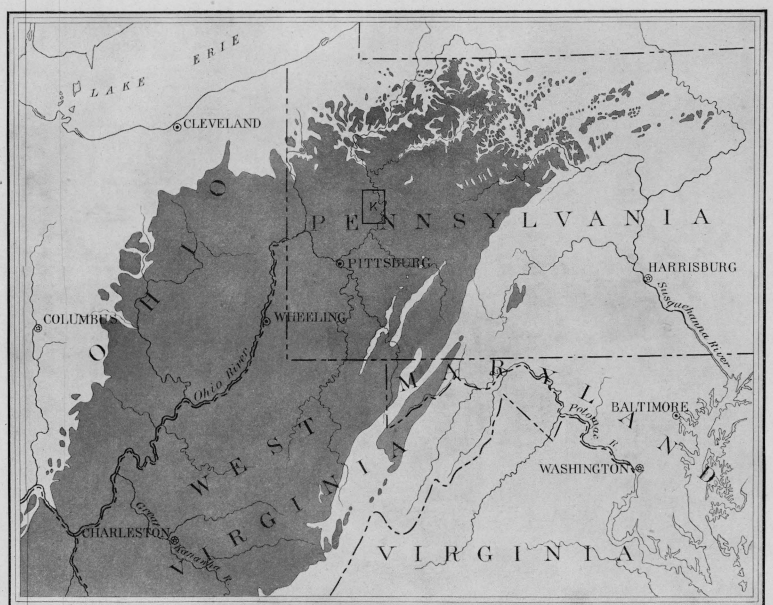


Fig. 11.—MAP SHOWING THE EXTENT OF THE NORTHERN PART OF THE APPALACHIAN COAL FIELD.

The position of the Kittanning quadrangle within the coal field is shown by the rectangle.

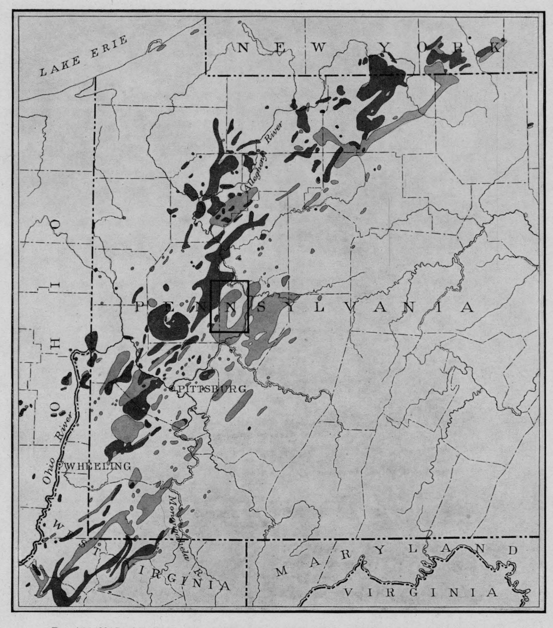


Fig. 12.—MAP OF THE OIL AND GAS PRODUCING AREAS OF THE NORTHERN APPALACHIANS.

Compiled from map by the Second Geological Survey of Pennsylvania, and from maps by the United States Geological Survey. Dark areas, oil; lighter areas, gas. The location of the Kittanning quadrangle is shown by the rectangle.

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