DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

GEORGE OTIS SMITH, DIRECTOR

GEOLOGIC ATLAS

OF THE

UNITED STATES

FOXBURG-CLARION FOLIO

PENNSYLVANIA

BY

E. W. SHAW AND M. J. MUNN

WASHINGTON, D. C.
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GEOLOGIC ATLAS OF THE UNITED STATES.

The Geological Survey is making a geologic atlas of the United States, which is being issued in parts, called folios. Each folio includes topographic and geologic maps of a certain area, together with descriptive text.

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 of the most important ones 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 vertical interval represented by each space between lines being the same throughout each map. These lines are called *contour lines* or, more briefly, *contours*, and the uniform vertical distance between each two contours is called the *contour interval*. Contour lines and elevations are printed in brown. The manner in which contour lines express altitude, form, and grade is shown in figure 1.

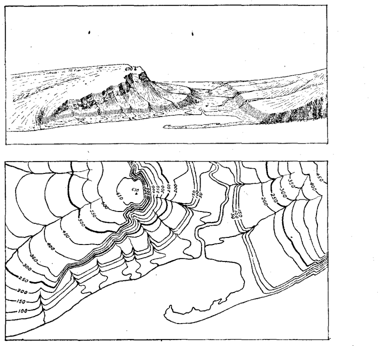


FIGURE 1.—Ideal view and corresponding contour map.

The sketch represents a river valley between two hills. In the foreground is the sea, with a bay that is partly closed by a hooked sand bar. On each side of the valley is a terrace. The terrace on the right merges into a gentle hill slope; that on the left is backed by a steep ascent to a cliff, or scarp, which contrasts with the gradual slope away from its crest. In the map each of these features is indicated, directly beneath its position in the sketch, by contour lines. The map does not include the distant portion of the view. The following notes may help to explain the use of contour lines:

1. A contour line represents a certain height above sea level. In this illustration the contour interval is 50 feet; therefore the contour lines 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 the sea—that is, this contour would be the shore line if the sea were to rise 250 feet; along the contour at 200 feet are all points that are 200 feet above the sea; and so on. In the space between any two contours are all points whose elevations are above the lower and below the higher contour. Thus the contour at 150 feet falls just below the edge of the terrace, and 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 the sea. The summit of the higher hill is marked 670 (feet above sea level); accordingly the contour at 650 feet surrounds it. In this illustration all the contour lines are numbered, and those for 250 and 500 feet are accentuated by being made heavier. Usually it is not desirable to number all the contour lines. The accentuating and numbering of certain of them—say every fifth one—suffices and the heights of the others may be ascertained by counting up or down from these.

2. Contour lines show or express the forms of slopes. As contours are continuous horizontal lines, they wind smoothly about smooth surfaces, recede into all reentrant angles of ravines, and project in passing around spurs or prominences. These relations of contour curves and angles to forms of the landscape can be seen from the map and sketch.

3. Contour lines show the approximate grade of any slope. The vertical interval between two contours is the same, whether they lie along a cliff or on a gentle slope; but to attain 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.

A small contour interval is necessary to express the relief of a flat or gently undulating country; a steep or mountainous country can, as a rule, be adequately represented on the same scale by the use of a larger interval. The smallest interval used on the atlas sheets of the Geological Survey is 5 feet. This is in regions like the Mississippi Delta and the Dismal Swamp. For great mountain masses, like those in Colorado, the interval may be 250 feet and for less rugged country contour intervals of 10, 20, 25, 50, and 100 feet are used.

Drainage.—Watercourses are indicated by blue lines. For a perennial stream the line is unbroken, but for an intermittent stream it is broken or dotted. Where a stream sinks and reappears the probable underground course is shown by a broken blue line. Lakes, marshes, and other bodies of water are represented by appropriate conventional signs in blue.

Culture.—The symbols for the works of man and all lettering are printed in black.

Scales.—The area of the United States (exclusive of Alaska and island possessions) is about 3,027,000 square miles. A map of this area, drawn to the scale of 1 mile to the inch would cover 3,027,000 square inches of paper and measure about 240 by 180 feet. Each square mile of ground surface would be represented by a square inch of map surface, and a linear mile on the ground by a linear inch on the map. 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 the inch" is expressed by the fraction $\frac{1}{63,360}$.

Three scales are used on the atlas sheets of the Geological Survey; they are $\frac{1}{250,000}$, $\frac{1}{125,000}$, and $\frac{1}{62,500}$, corresponding approximately to 4 miles, 2 miles, and 1 mile on the ground to an inch on the map. On the scale of $\frac{1}{62,500}$ a square inch of map surface represents about 1 square mile of earth surface; on the scale of $\frac{1}{125,000}$, about 4 square miles; and on the scale of $\frac{1}{250,000}$, 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, by a similar line indicating distance in the metric system, and by a fraction.

Atlas sheets and quadrangles.—The map of the United States 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 $\frac{1}{250,000}$ represents one square degree—that is, a degree of latitude by a degree of longitude; each sheet on the scale of $\frac{1}{125,000}$ represents one-fourth of a square degree, and each sheet on the scale of $\frac{1}{62,500}$ one-sixteenth of a square degree. The areas of the corresponding quadrangles are about 4000, 1000, and 250 square miles, though they vary with the latitude.

The atlas sheets, being only parts of one map of the United States, are not limited by political boundary lines, such as those of States, counties, and townships. Many of the maps represent areas lying in two or even three States. 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 are printed the names of adjacent quadrangles, if the maps are published.

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, by means of structure sections, their underground relations, so 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.—Rocks that have cooled and consolidated from a state of fusion are known as *igneous*. Molten material has from time to time been forced upward in fissures or channels of various shapes and sizes through rocks of all ages to or nearly to the surface. Rocks formed by the consolidation of molten material, or magma, within these channels—that is, below the surface—are called *intrusive*. Where the intrusive rock occupies a fissure with approximately parallel walls it is called a *dike*; where it fills a large and irregular conduit the mass is termed a *stock*. Where molten magma traverses stratified rocks it may be intruded along bedding planes; such masses are called *sills* or *sheets* if comparatively thin, and *laccoliths* if they occupy larger chambers produced by the pressure of the magma. Where inclosed by rock molten material cools slowly, with the result that intrusive rocks are generally of crystalline texture. Where the channels reach the surface the molten material poured out through them is called *lava*, and lavas often build up volcanic mountains. Igneous rocks that have solidified at the surface are called *extrusive* or *effusive*. Lavas generally cool more rapidly than intrusive rocks and as a rule contain, especially in their superficial parts, more or less volcanic glass, produced by rapid chilling. The outer parts of lava flows also are usually porous, owing to the expansion of the gases originally present in the magma. Explosive action, due to these gases, often accompanies volcanic eruptions, causing ejections of dust, ash, lapilli, and larger fragments. These materials, when consolidated, constitute breccias, agglomerates, and tuffs.

Sedimentary rocks.—Rocks composed of the transported fragments or particles of older rocks that have undergone disintegration, of volcanic ejecta deposited in lakes and seas, or of materials deposited in such water bodies by chemical precipitation are termed *sedimentary*.

The chief agent in the 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. Some of the materials are carried in solution, and deposits of these are 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 kinds of deposit named 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*, and rocks deposited in such layers are said to be stratified.

The surface of the earth is not immovable; over wide regions it very slowly rises or sinks, with reference to the sea, and shore lines are thereby changed. As a result of upward movement marine sedimentary rocks may become part of the land, and most of our land areas are in fact occupied by rocks originally deposited as sediments in the sea.

Rocks exposed at the surface of the land are acted on by air, water, ice, animals, and plants, especially the low organisms known as bacteria. They gradually disintegrate and the more soluble parts are leached out, the less soluble material being left as a *residual* layer. Water washes this material down the slopes, and it is eventually carried by rivers to the ocean or other bodies of water. Usually its journey is not continuous, but it is temporarily built into river bars and flood plains, where it forms *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 various processes, rocks may become greatly changed in composition and in texture. If the new characteristics are more pronounced than the old such rocks are called *metamorphic*. In the process of metamorphism the constituents of a chemical rock may enter into new combinations and certain substances may be lost or new ones added. A complete gradation from the primary to the metamorphic form may exist within a single rock mass. Such changes transform sandstone into quartzite and limestone into marble and modify other rocks in various ways.

From time to time during geologic ages rocks that have been deeply buried and have been subjected to enormous pressures, to slow movement, and to igneous intrusion have been afterward raised and later exposed by erosion. In such rocks the original structures may have been lost entirely and new ones substituted. A system of planes of division, along which the rock splits most readily, may have been developed. This structure is called *cleavage* and may cross the original bedding planes at any angle. The rocks characterized by it are *slates*. Crystals of mica or other minerals may have grown in the rock in such a way as to produce a laminated or foliated structure known as *schistosity*. The rocks characterized by this structure are *schists*.

As a rule, the oldest rocks are most altered and the younger formations have escaped metamorphism, but to this rule there are many important exceptions, especially in regions of igneous activity and complex structure.

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, an alternation of shale and limestone. Where the passage from one kind of rocks to another is gradual it may be 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 contains one or more bodies of one kind, of similar occurrence, or of like origin. A metamorphic formation may consist of rock of uniform character or of several rocks having common characteristics or origin.

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

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*.

Inasmuch as sedimentary deposits accumulate successively the younger rest on those that are older, and their relative ages may be determined by observing their positions. In many regions of intense disturbance, however, the beds have been overturned by folding or superposed by faulting, so that it may be difficult to determine their relative ages from their present positions; under such conditions fossils, if present, may indicate which of two or more formations is the oldest.

Many stratified rocks contain *fossils*, the remains or imprints of plants and animals which, at the time the strata were deposited, lived in bodies of water or were washed into them, 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. Where 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 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 many places difficult or impossible to determine the age of an igneous formation, but the relative age of such a formation can in general 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 may be 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 that of their metamorphism.

Symbols, 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.

Patterns composed of parallel straight lines are used to represent sedimentary formations deposited in the sea, in lakes, or in other bodies of standing water. 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 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 of series that have been given distinctive names, in order from youngest to oldest, with the color and symbol assigned to each system, are given in the subjoined table.

Symbols and colors assigned to the rock systems.

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

SURFACE FORMS.

Hills, 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; waves cut sea cliffs and, in cooperation with currents, build up sand spits and bars. Topographic forms thus constitute part of the record of the history of the earth.

Some forms are inseparably connected with deposition. The hooked spit shown in figure 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. 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 afterward 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. Lakes or large rivers may determine local base-levels for certain regions. When a large tract is for a long time undisturbed by uplift or subsidence it is degraded nearly to base-level, and the fairly even surface thus produced is called a *peneplain*. If the tract is afterward uplifted, the elevated peneplain becomes a record of the former close relation of the tract to base-level.

THE VARIOUS GEOLOGIC SHEETS.

Areal geology map.—The map showing the areas occupied by the various formations is called an *areal geology map*. On the margin is a *legend*, which is the key to the map. To ascertain the meaning of any color or 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 particular formation, its name should be sought in the legend and its color and pattern noted; then 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 names of 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.—The map representing the distribution of useful minerals and rocks and showing their relations to the topographic features and to the geologic formations is termed the *economic geology map*. The formations that appear on the areal geology map are usually shown on this map by fainter color patterns and the areas of productive formations are emphasized by strong colors. A mine symbol shows the location of each mine or quarry and is accompanied by the name of the principal mineral mined or stone quarried. If there are important mining industries or artesian basins in the area special maps to show these additional economic features are included in the folio.

Structure-section sheet.—In cliffs, canyons, shafts, and other natural and artificial cuttings the relations of different beds to one another may be seen. Any cutting that 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 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 to a considerable depth. Such a section is illustrated in figure 2.

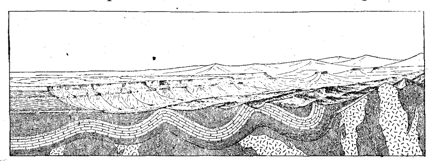


FIGURE 2.—Sketch showing a vertical section at the front and a landscape beyond.

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 patterns of lines, dots, and dashes. These patterns admit of much variation, but those shown in figure 3 are used to represent the commoner kinds of rock.

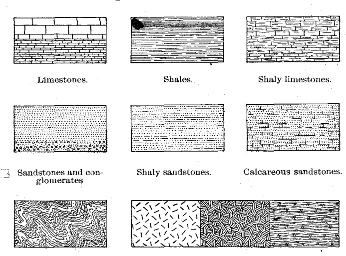


FIGURE 3.—Symbols used in sections to represent different kinds of rocks.

The plateau shown at the left of figure 2 presents toward the lower land an escarpment, or front, which is made up of sandstones, forming the cliffs, and shales, constituting the slopes. 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 of the intersection of a bed with a horizontal plane is called the *strike*. The inclination of the bed to the horizontal plane, measured at right angles to the strike, is called the *dip*.

In many regions the strata are bent into troughs and arches, such as are seen in figure 2. The arches are called *anticlines* and the troughs *synclines*. As the sandstones, shales, and limestones were deposited beneath the sea in nearly flat sheets, the fact 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 figure 4.

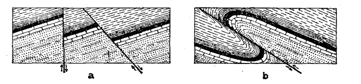


FIGURE 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* or *reverse* fault.

At the right of figure 2 the section shows schists that are traversed by igneous rocks. The schists are much contorted and their arrangement underground can not be inferred. Hence that portion of the section delineates what is probably true but is not known by observation or by well-founded inference.

The section also shows three sets of formations, distinguished by their underground relations. The uppermost set, seen at the left, is made up of sandstones and shales, which lie in a horizontal position. These strata were laid down under water but 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 uplifted. The strata of this set are parallel, a relation which is called *conformable*.

The second set of formations consists of strata that have been folded into arches and troughs. These strata were once continuous, but the crests of the arches have been removed by erosion. 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 shown at the left of the section. The overlying deposits are, from their position, evidently younger than the underlying deposits, and the bending and eroding of the older beds must have occurred between their deposition and the accumulation of the younger beds. The younger rocks are *unconformable* to the older, and the 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 folded or 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 were metamorphosed, they were disturbed by 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 figure 2 are ideal, but they illustrate actual relations. 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 that appears in the section may be measured by using the scale of the map.

Columnar section.—The geologic maps are usually accompanied by a *columnar section*, which contains a concise description of the sedimentary formations that 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 that state the least and greatest measurements, and the average thickness of each formation is shown in the column, which is drawn to scale. The order of accumulation of the sediments is shown in the columnar arrangement—the oldest being at the bottom, the youngest at the top.

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

GEORGE OTIS SMITH,
Director.

May, 1909.

DESCRIPTION OF THE FOXBURG AND CLARION QUADRANGLES.

By Eugene Wesley Shaw, Edwin F. Lines, and M. J. Munn.[a]

INTRODUCTION.

LOCATION AND AREA.

The Foxburg and Clarion quadrangles are in western Pennsylvania, mostly in Clarion County, but partly in Armstrong, Butler, and Venango counties. The quadrangles extend from latitude 41° to 41° 15′ and from longitude 79° 15′ to 79° 45′, the line of 79° 30′ being the boundary between them. (See fig. 1.) Thus each quadrangle includes one-sixteenth of a square degree of the earth's surface and measures approximately 17 miles from north to south by 13 miles from east to west, and the two quadrangles cover 450.12 square miles. The principal towns of the Foxburg quadrangle are Foxburg, Emlenton, Knox, St. Petersburg, Callensburg, Parkers Landing, West Monterey, Rimersburg, Petrolia, and Baldwin. Those of the Clarion quadrangle are Clarion, the county seat, from which the quadrangle takes its name, New Bethlehem, Sligo, and Strattonville. The exact latitude and longitude of the boundaries of the quadrangles have been determined from triangulation stations on the tops of some of the most prominent hills in the region. These stations have been connected by triangulation with Maryland Heights and Sugarloaf stations of the Coast and Geodetic Survey, computed on United States standard datum. Descriptions of these locations are given in Bulletin 181 of the United States Geological Survey (p. 68).

The general altitude and configuration of the surface of the quadrangles are shown by means of contour lines based on precise levels run by the Pennsylvania Railroad and by the United States Geological Survey. The elevations in the Foxburg and Clarion quadrangles are based on the Geological Survey precise-level line from Franklin to Pittsburg along Allegheny River. From this line at Parker and Redbank lines of primary level were run in 1905 to control the topography of the quadrangles. The bench marks set in that work are described in Bulletin 288 of the United States Geological Survey. The relation of the Foxburg and Clarion quadrangles to other quadrangles of western Pennsylvania is shown by the key map forming figure 1.

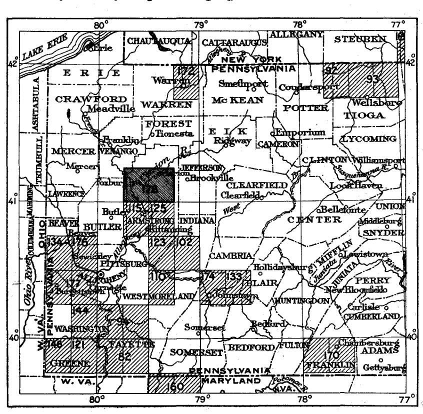


FIGURE 1.—Index map of western Pennsylvania.

Darker ruled area covered by Foxburg-Clarion folio. Other published folios indicated by lighter ruling, as follows: Nos. 82, Masontown-Uniontown; 92, Gaines; 93, Elkland-Tioga; 94, Brownsville-Connellsville; 102, Indiana; 110, Latrobe; 115, Kittanning; 121, Waynesburg; 123, Elders Ridge; 125, Rural Valley; 133, Ebensburg; 134, Beaver; 144, Amity; 146, Rogersville; 160, Accident-Grantsville; 169, Watkins Glen-Catatonk; 170, Mercersburg-Chambersburg; 172, Warren; 174, Johnstown; 176, Sewickley; 177, Burgettstown-Carnegie.

In their physiographic and geologic relations these quadrangles form a part of the Appalachian province, which extends from the Atlantic Coastal Plain on the east to the Mississippi lowlands on the west, and from the Gulf Coastal Plain on the south to a limit beyond the northern boundary of the United States.

To understand broadly the meaning of the physiographic and geologic features of so small an area it is necessary first to study briefly the physiographic and geologic features of the province in which it lies.

[a] Geology of the Foxburg quadrangle and surficial geology of the Clarion quadrangle by Eugene Wesley Shaw; pre-Quaternary geology of the Clarion quadrangle by Edwin F. Lines; geology of oil and gas deposits by M. J. Munn.

OUTLINE OF THE GEOGRAPHY AND GEOLOGY OF THE APPALACHIAN PROVINCE.

SUBDIVISIONS.

Topographically and geologically the Appalachian province is divided into two nearly equal parts by a line that follows the Allegheny Front through Pennsylvania, Maryland, and West Virginia, and the eastern escarpment of the Cumberland Plateau across Virginia, Tennessee, Georgia, and Alabama. In Pennsylvania this line passes in a northeast-southwest direction from southeastern New York to western Maryland, as shown in figure 2.

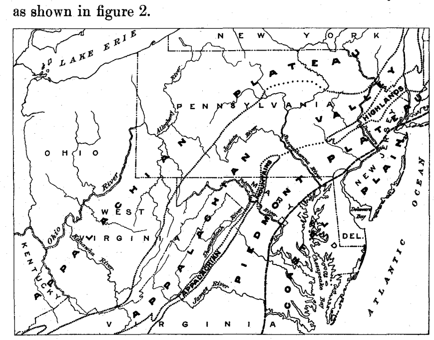


FIGURE 2.—Map of the northern part of the Appalachian province, showing its physiographic divisions and its relation to the Coastal Plain.

Immediately east of the Allegheny Front is a wide belt of deep valleys and high ridges termed the Appalachian Valley, and east of the Appalachian Valley in Pennsylvania is a belt of moderately dissected upland known as the Piedmont Plateau. The area west of the Allegheny Front, including that occupied by the Foxburg and Clarion quadrangles, is a more or less dissected plateau region, which was designated by Powell the Allegheny Plateaus, but more recently, by the United States Geographic Board, the Appalachian Plateau. The rocks east of the Allegheny Front are greatly folded and in part altered; the rocks west of it are only slightly folded, and those at the western border of the area lie nearly flat.

APPALACHIAN PLATEAU.

DRAINAGE.

The Appalachian Plateau is drained almost entirely into Mississippi River, but the northeast end of the region drains into the Great Lakes and into rivers that find their way to the Atlantic Ocean. The principal southern tributaries of the Ohio are, from west to east—the Tennessee, Cumberland, Kentucky, Licking, Big Sandy, Kanawha, Little Kanawha, and Monongahela. These streams drain the higher part of the plateau. Their gradients are in general adjusted, their profiles are concave, and their fall is considerable. Their courses are, however, somewhat meandering, though in the main direct. It is probable that many of the curves are inherited from the time when the plateau was a plain and the streams, which were then more sluggish, flowed in winding courses.

The section of the plateau lying north and west of the Ohio is smaller and drains into that river by way of Scioto, Muskingum, and Allegheny rivers and numerous smaller streams. These streams have both minor and major irregularities though none of them are very indirect. They differ somewhat from the southern tributaries because they drain a lower district and all of them have had to carry glacial waters and glacial débris. In eastern and southern Ohio the general slope of the surface is to the northwest, away from Ohio River, and hence the streams there are not so active as those coming into the river from the southeast. But in preglacial time all the streams north of central Kentucky probably flowed northwestward and discharged their waters through the St. Lawrence system. (See fig. 8.) The encroachment of one of the earlier of the great ice sheets closed this northern outlet and established new drainage lines across old divides, so that the upper Ohio and its principal tributaries have been forced into their present courses by glaciation. Indeed, in preglacial time there was no upper Ohio; the valley through which the upper river now flows is in part new and in part made up of sections of several preglacial valleys. As the Foxburg and Clarion quadrangles lie within the area of modified drainage, this feature will be described in detail under the heading "Drainage," on page 2.

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

RELIEF.

The surface of the Appalachian Plateau is in reality made up of a number of plateaus of different altitudes and extent. These plateaus are the uplifted and now much dissected remnants of ancient peneplains. One of the oldest and highest of the dissected plains seems to extend along nearly the whole length of the southeast margin of the plateau. A peneplain which is well preserved in the vicinity of Schooley Mountain, in northern New Jersey, is known as the Schooley peneplain. What appears to be the same surface in Tennessee and Alabama is known as the Cumberland Plateau. It is possible, however, that further work will show that this surface is in reality made up of two or more plateaus of different ages. This plateau is so greatly dissected that its real character is not everywhere apparent. In western Pennsylvania there seem to be two uplifted peneplains. One, which may correspond to the Schooley, is poorly preserved and ranges in altitude from 2000 feet in the northern part of the State to about 2600 at the southern boundary. Apparently this plateau continues to rise as far as central West Virginia, where it reaches its culminating height of 4000 feet. In the northern part of the plateau the sandstones of the Pottsville formation have held considerable areas intact, but in the southern part, where the rocks are soft, even the plateau character has nearly disappeared. Throughout most of the province there are ridges that rise to a greater height than the surface of this plateau.

The remnants of the higher peneplain slope toward the west, but are separated from the next lower plateau by an escarpment. In Pennsylvania this lower plateau is called the Harrisburg plateau, because of its development in the vicinity of Harrisburg. It seems to correspond with the Highland plateau of Tennessee and the Lexington Plain of Kentucky. In Tennessee the dividing escarpment has a height of 1000 feet, but it is not pronounced in Pennsylvania except along Chestnut Ridge, and there the surface of the upper plateau is so greatly dissected that it can be recognized only with difficulty. In the central part of the State the plateau surfaces approach each other and the escarpment merges into a mass of hills. The lower plateau seems to rise from an altitude of 700 or 800 feet in Indiana to 1000 feet in Ohio, 1200 to 1300 feet in southwestern Pennsylvania, and 1600 to 2100 feet throughout northern Pennsylvania and southern New York. The Foxburg and Clarion quadrangles lie in a region in which the lower peneplain was widely developed, but the irregularity in the altitude of the hilltops makes it doubtful whether more than a vestige of the old surface remains. However, its effect on the topography of these quadrangles becomes evident when it is noted how constantly the higher hills rise to nearly the same elevation, and it is visible to the eye in the level skyline seen from any of the higher hilltops. Although this lower plateau is much dissected in Pennsylvania, it is less so than the upper one, and in Kentucky and parts of Tennessee it is a nearly featureless plain.

Below the Harrisburg plateau there are surfaces of concordant elevation, which seem to have been developed in later stages of erosion. One of these, which covers considerable areas in Tennessee, western Kentucky, and Indiana, is obscure, if present at all, in western Pennsylvania.

High terraces and abandoned valleys.—Many of the larger valleys of the province, particularly those tributary to the Ohio, have broad high terraces ranging up to 300 feet above the present stream channels, and lying 300 feet or more below the general upland surface. The terraces, which are all rock shelves covered with gravel, have been described in many of the Survey's folios on that region, and have been discussed in numerous other publications. Some of them bear glacial outwash gravel and others are capped with material of local derivation, but as the two classes are closely related, they will be treated together. The gravel seems to be stream-deposited and commonly attains a thickness of 100 feet. The terraces are found outside the limits of glaciated country on the Allegheny, Kiskiminitas, Youghiougheny, Monongahela, Kanawha, Guyandot, Big Sandy, Kentucky, and Ohio rivers, and many of their tributaries. Associated with the terraces on all the above named streams are peculiar abandoned parts of valleys.

The formation on the terraces being unconsolidated, and to a large extent sand and silt, has yielded readily to erosion and has been deeply dissected. Only the resistance of the underlying rock has prevented its complete removal from large areas. The elevation of the upper surface of the terrace deposit is consequently irregular, but it is in few places less than 1000 or more than 1200 feet. In general the elevation increases upstream from the Ohio, and especially to the north, toward the glaciated area. The rock floors slope like the upper surfaces of the terraces. Both are uneven, but in general they slope downstream.

Elevations, in feet, of high terraces in western Pennsylvania.

Place.	Miles from Beaver.	Upper limit of gravel.	Rock floor.	Present stream.	Upper limit of gravel above present stream.
Foxburg quadrangle:					
1 mile north of Callensburg	110	1,180	1,100	970	210
Turniphole	108	1,170	1,120 to 1,160	930	240
Mouth of Clarion River	102	1,150	1,035	846	304
Mouth of Bear Run	99	1,145	1,025	840	305
Monterey	96	1,140	1,015	832	308
Kittanning quadrangle:					
Redbank	81	1,100	950	810	290
Ford City	58	1,025+	885 and 980	763	262+
New Kensington quadrangle:					
Tarentum	39	1,000+	975	725	275+
Carnegie quadrangle:					
Allegheny	22	1,000	898	698.4	300+
Beaver quadrangle:					
Beaver	0	978	890	672	306
Latrobe quadrangle:					
1 mile northeast of Blairsville	80+	1,060	....	900	160
Burgettstown quadrangle:					
1½ miles northeast of Burgettstown	28+	1,028	1,015	947	81

It will be seen from the foregoing table that on the large streams the upper limit of gravel is commonly a little over 100 feet above the rock floor; that on the smaller streams the deposit is thin and lies at less elevation above the stream, and that on such streams as carry no glacial material, particularly on the Clarion, the deposit thins upstream.

STRUCTURE.

The structure of the Appalachian Plateau is 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 main axis of this fold enters the Appalachian Plateau 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 anticline extends southward to Lexington, Ky., and then southwest to Nashville, Tenn.

Between the anticline and the Allegheny Front lies a broad canoe-shaped basin, which contains the Appalachian coal field. The axis of this trough lies along a line extending southwest from Pittsburg across West Virginia, and all the rocks in the basin dip in a general way toward this line. Around the northern end of the basin the strata lie in rudely semicircular lines of outcrop and generally dip toward the lower or southern part of the trough.

The eastern side of the basin is crumpled into a number of secondary folds which so break up the regular slope of the rocks that at first sight the general westward dip is not apparent. To the west the folds become low and irregular, and, in the central part of the basin, beds that have an elevation of 2000 feet at the Allegheny Front extend below sea level.

The Foxburg and Clarion quadrangles are situated in the northern end of the Appalachian coal basin. Here, as on the eastern limb of the trough, the general slope of the rocks is slightly modified by minor folds.

STRATIGRAPHY.

The strata of the Appalachian Plateau belong to the Carboniferous and Quaternary systems. The Carboniferous system is divided into three series, the Mississippian, the Pennsylvanian, and the Permian. The Pennsylvanian series contains most of the coal-bearing rocks, or "Coal Measures," which make up the Appalachian coal field. The subdivisions of the Mississippian series that are represented in Pennsylvania are the Pocono group and the Mauch Chunk formation. The term Pocono has been used in other folios as a formation name, but, as will be explained below, it has been found desirable to subdivide the rocks in northwestern Pennsylvania and treat them as a group rather than a formation. The Pennsylvanian series includes the Pottsville, Allegheny, Conemaugh, and Monongahela formations.

Mississippian series.—The Pocono group is of nonmarine origin and derives its name from Pocono Mountain, in eastern Pennsylvania, where it attains a thickness of 1000 feet. The strata comprising it form a lithologic unit and have therefore been treated as a formation. In Ohio the equivalent strata are of marine origin and are easily and naturally divisible into several units. In State reports and other publications these units have been treated as formations and given formation names, and the formations have all been included under the group name Waverly. In the Foxburg and Clarion quadrangles the predominant phase of the Mississippian rocks is nonmarine and therefore Pocono group is still appropriate, although in this area the Pocono group includes some marine deposits which comprise a part of the Waverly group to the west.

In the type locality the Burgoon sandstone is made up chiefly of coarse gray sandstone, but it contains also beds of gray and red shales. In a strip of country west of the Allegheny Front the top of the Pocono is marked by a sandy calcareous member known as the Loyalhanna or "Siliceous" limestone, and the upper boundary of the group is thus easily identifiable. But the Loyalhanna is absent from a large area in northwestern Pennsylvania, and there it is difficult to locate the top of the Pocono.

In other parts of Pennsylvania the Mauch Chunk formation overlies the Loyalhanna limestone. At Mauch Chunk, the type locality, the formation is 2000 feet thick and is composed largely of red shale. On the Allegheny Front it is made up of about 180 feet of gray and greenish sandstone and red shale, and on Chestnut Ridge red shale predominates again. Westward the formation decreases rapidly in thickness, and over large areas in western Pennsylvania deep-well records indicate that these rocks are missing entirely. This decrease in thickness is due mainly to erosion during the early part of the following period, during which the area was above sea level. The Mauch Chunk formation is not present in the Foxburg and Clarion quadrangles.

Pennsylvanian series.—The Pottsville, the lowest formation of the Pennsylvanian series, lies unconformably upon the Pocono in much of western Pennsylvania where the Mauch Chunk is absent. At Pottsville, the locality from which the name is taken, it is mainly a coarse conglomerate 1200 feet thick. In the western part of the State it is 125 to 200 feet thick and consists principally of the Homewood sandstone member and the Connoquenessing sandstone member. In some places these members are separated from each other by shales with thin beds of coal and limestone. At the base of the formation the Sharon conglomerate member is found along the western boundary, where it is separated by shale and coal from the Connoquenessing sandstone member. The studies of David White have shown that the Pottsville of western Pennsylvania corresponds in age to the upper part of the typical Pottsville section, this area having been an area of erosion rather than of deposition during early Pottsville time. The Sharon coal and shale and conglomerate members were not deposited in the Foxburg-Clarion quadrangles, where land conditions existed longer than in the region farther west.

The Allegheny formation, although not so thick as the others, contains in Pennsylvania more workable coals than any other formation of the Pennsylvanian series. It reaches its fullest development of 370 feet in the Allegheny River valley in western Pennsylvania. The formation is made up of a series of sandstones and shales interbedded with coals, clays, and limestones, and does not have the strongly marked sandy and conglomeratic character of the underlying Pottsville. Though massive sandstones are developed locally, the prevailing sandstones are finer grained and thinner. In the early geologic reports the formation is called "Lower Productive Coal Measures" to distinguish it from the "Upper Productive Coal Measures," which contain the Pittsburg coal.

The Conemaugh formation, or, as it was formerly termed, the "Lower Barren Coal Measures," is well developed on the Conemaugh River. It includes all the rocks from the top of the Upper Freeport coal to the bottom of the Pittsburg coal, and in this area ranges in thickness between 600 and 700 feet. The rocks are predominatingly shale but include some sandstone. The formation is generally destitute of workable coal beds, although in some parts of the State there are workable coals of small extent, in some places accompanied by thin limestones

The Monongahela formation extends from the bottom of the Pittsburg coal to the top of the Waynesburg coal. In the early literature this formation was designated "Upper Productive Coal Measures." In thickness the formation ranges from 300 to 400 feet. It occupies a comparatively small area in southwestern Pennsylvania and portions of West Virginia and Ohio adjacent to Ohio River. The formation includes a relatively much larger proportion of limestone than the underlying Carboniferous formations, more than one-third of its thickness being made up of that rock. It contains several workable coals, of which the most important, not only in this formation, but in the Allegheny Basin, is the Pittsburg coal. None of the formation is present in the Foxburg and Clarion quadrangles.

Permian series.—The highest rocks in the Carboniferous system comprise the Dunkard group, formerly called "Upper Barren Coal Measures." This group has a maximum thickness of over 1100 feet. As suggested by the old name, it does not contain workable coal beds except in places where they have been locally developed. The formation is too high to appear in the Foxburg and Clarion quadrangles.

GEOGRAPHY.

RELIEF.

The surface of the Foxburg and Clarion quadrangles is hilly and well dissected by streams, the relief of almost every square mile amounting to several hundred feet. However, so little does the general altitude of the surface vary that the highest hilltop is only 915 feet above the lowest point in the area. The lowest point in the Foxburg quadrangle is about 815 feet above mean sea level and the highest is about 1650. In the Clarion the extremes of elevation are about 950 feet in Redbank Creek and 1730 in the Clarion-Redbank divide. The hilly character of the country has been produced by comparatively recent stream erosion, and the general concordance in elevation is due to the peneplanation which preceded the dissection.

Perhaps the most striking topographic features are the canyon-like gorges of the rivers. Two miles southeast of Emlenton the Allegheny Valley is scarcely a mile wide but is 660 feet deep. Flood plains are narrow or absent and the farming area is on the upland, where there is much gently undulating country. The rivers are crooked and have some very long curves where the streams double back, but the valleys are no shorter because the walls follow the streams around the meanders. The cause of the entrenching of these streams is not known. It was probably Pleistocene or Pliocene uplift or tilting of the region or increased volume of the Allegheny since the enlargement of its basin, or perhaps both.

The contours of the hills depend to some extent upon the rocks of which they are composed. In areas where heavy sandstone predominates the hillsides are steep and rugged, and where sandstone is the cap rock the tops of the hills are broad and flat. Topography of the latter type is well developed near Bonus, west of Foxburg, near Rimersburg, and generally in the northern part of the quadrangles. Elsewhere the rocks are prevailingly shaly, and the hills have rounded tops and gently sloping sides.

Surface features of another group consist of stream-cut terraces and abandoned channels, which are well developed along the lower part of the Clarion, and continue down along the Allegheny below the mouth of the Clarion. They are also developed to some extent along Redbank Creek.

Fall of streams in the Foxburg and Clarion quadrangles.

	Feet per mile.
Allegheny River	3½
Clarion River, lower 14 miles	11
Clarion River, next 15 miles	7
Redbank Creek, lower 12 miles	16
Redbank Creek, next 10 miles	8
Beaver Creek, lower 1 mile	110
Beaver Creek, next 5 miles	36
Bear Run, lower 4 miles	40
Bear Run, next 5½ miles	25
Binker Valley Run, lower two-fifths mile	560
Binker Valley Run, next 2 miles	130

From the above table, and also by reference to the topographic map, it will be seen that every stream which discharges into the Allegheny has a higher gradient near its mouth than it has farther back in its course. The topographic map shows also that the lower valleys of these tributaries are gullies and gorges, which widen upstream; and many of the small streams have flood plains near their sources. These features are a direct result of a rejuvenation which the Allegheny has undergone in Quaternary time.

DRAINAGE.

The region about Foxburg and Clarion is very well drained, swamps and standing water being almost unknown. The master stream is Allegheny River, the second largest stream in western Pennsylvania, and its principal tributaries are Clarion River and Redbank Creek.

The Foxburg quadrangle is divided into three segments by Allegheny and Clarion rivers. The run-off from the western segment reaches Allegheny River by way of Sugar Valley, Bear Creek, Binker Valley, Crozier Hollow, Birch, Armstrong, Whisky, Cove, and Pine runs, and many other streams and gullies. The principal streams in the northern segment are Shull Run, Mill Creek, and Richey Run, flowing into the Allegheny; and Turkey Run, Beaver Creek, and Canoe Creek flowing into the Clarion. In the southeast segment the Allegheny receives water from Fiddlers, Black Fox, and Catfish runs and several unnamed brooks; and the Clarion from Cherry Run and Licking Creek. A few small streams in the southeast corner of the quadrangle discharge into Redbank Creek.

About two-thirds of the Clarion quadrangle drains into Clarion River and one-third into Redbank Creek. Clarion River crosses the northwest corner of the quadrangle in a southwesterly direction. North of the river the principal tributary is Deer Creek. From the east and south the river receives Mill Creek, which drains the northeast corner, and Piney Creek, which drains the central portion of this quadrangle. Redbank Creek crosses the southeastern corner of the quadrangle from Mayport to New Bethlehem and then, except for one or two northward bends, remains south of the quadrangle. The principal streams that flow into the Redbank are, from west to east, Wildcat Run, Leatherwood Run, Leisure Run, and Town Run. The divide between Clarion River and Redbank Creek extends northeastward from Rimersburg station to the southern boundary of Monroe Township, and thence eastward along the southern boundary of Monroe and Limestone townships.

The average width of the Allegheny is about one-eighth of a mile, and its average discharge at Kittanning in 1906 was found to be 13,300 second-feet.[a] In 1907 the mean discharge was 16,100, and in 1908, 15,800 cubic feet per second. A careful estimate based on these measurements places the average run-off from each square mile of this region at 1.62 cubic feet per second.

Clarion River has not been accurately measured, but its width is about one-quarter that of the Allegheny. The streams are similar in many respects, but the volume of the Clarion is more variable. In dry seasons its discharge is known to fall below 90 second-feet. The volume of Redbank Creek is also low in times of drought and high in times of flood. This variation is ascribed to the cutting away of forests from the drainage basins of Clarion River and Redbank Creek.

RELATION OF PRESENT TO FORMER DRAINAGE.

In order to set forth clearly the meaning of certain drainage features of the Foxburg and Clarion quadrangles, it will be necessary to make some general reference to Allegheny River. It rises in northern Potter County in passes about 2500 feet above sea level, and flows through McKean County in a northerly direction into New York. The sources of some of its tributaries are within 7 miles of Lake Erie. After flowing westward through Cattaraugus County, New York, it enters Pennsylvania again at the northeast corner of Warren County, and passes in a southwesterly and southerly direction through Warren, Forest, Venango, and Armstrong counties, and thence southwest to its junction with the Monongahela at Pittsburg. The river is about 325 miles long and its drainage basin has an area of 11,100 square miles. The peculiar course of the river and the arrangement of its tributaries has been generally explained as a modification resulting from the presence of the great ice sheet.

PLATEAUS.

Although the entire area is hilly and appears at first sight wholly irregular, there is more or less uniformity in the altitudes of the hilltops. This becomes evident when the surface of the country is viewed from a high elevation. In such a view the minor surface irregularities are lost and the general concordance in elevation is apparent. The general uniformity of elevations can also be observed on the topographic maps, which show that except in the area through which the Kellersburg anticline passes, there are a large number of rounded and flat-topped hills, the majority of which range from 1440 to 1540 feet. The generally accepted explanation of the uniformity in elevation of the hilltops is that they are the dissected remnants of an ancient peneplain.

As a whole, this uplifted peneplain now has the shape of a low ellipsoidal dome, the highest part being in McKean and Potter counties in northern Pennsylvania. From an altitude of 2200 feet or more in that region the plateau descends to 1200 feet in southwestern Pennsylvania and 500 feet in the southeastern part of the State. The altitude of the hills in the Foxburg and Clarion quadrangles indicates that the present position of the old peneplain surface here is approximately 1500 feet above sea level.

As already noted, the hills on the Kellersburg anticline have a different altitude from those in the remainder of the quadrangles, averaging 100 feet higher than those elsewhere, a condition which suggests a ridge on the old peneplain.

In some parts of western Pennsylvania a substage of erosion has been recognized a hundred feet or so below the Harrisburg plateau, and has been called the Worthington. In the Foxburg quadrangle there is much territory lying at an elevation of about 1400 feet, and it may be that this surface is to be correlated with the Worthington. It is possible, however, that the agreement in altitude is merely a coincidence, since surfaces at this level are not widely developed.

[a] Water-Supply Paper U. S. Geol. Survey No. 205, 1907, p. 32.

PARKER STRATH.

The streams have cut sharp valleys below the plateau surfaces just described, but along the lower part of the Clarion and along the Allegheny below the mouth of the Clarion the steep slopes are broken by terraces, most of which stand between 200 and 280 feet above the present streams. They are rock terraces, capped by a layer of gravel, which in many places is over 100 feet thick. The rock floor under the gravel has a more or less plane surface and at the time when the river flowed at that level the Allegheny Valley was somewhat broad and with steep sides. The floor of such a valley is called a strath, though a typical strath is even broader than the floor of the old Allegheny Valley, which has been given the name Parker strath because of its excellent development at Parkers Landing, in the Foxburg quadrangle. (See fig. 10, p. 12.)

The Parker strath was not continuous, but the valley was in places so narrow that the floor had no strathlike characters. Such places were near the present sites of Dutch Hill and Fredell and 1 mile south of Catfish. The valley was broadest along the lower part of Clarion River, and here to-day are the broadest and most striking terraces.

Closely related to the high terraces are the abandoned stream channels common in western Pennsylvania. One of the best examples is the noted Oxbow across the river from Parkers Landing. A more detailed description of the terraces and abandoned channels and the statement of their probable origin will be found under the heading "Historical geology."

EFFECT OF TOPOGRAPHY ON COMMERCE AND AGRICULTURE.

The character and direction of man's activities are always modified by the topography of a region. Broad and deep rivers give opportunity for cheap transportation; rivers of steep gradient furnish water power; stream valleys offer favorable routes for railroads and cut into water-bearing strata and develop springs; and hills render outcropping beds of economic importance easily accessible.

The streams have deeply dissected the region about Foxburg and Clarion, and this process has not ceased. A careful estimate, based on hundreds of analyses of Allegheny River water at Kittanning, Pa., indicates that an average of 187 tons of mineral matter (139 tons in solution and 48 tons in suspension) are being carried away from each square mile every year. This is equivalent to saying that the average rate of denudation by water in this region is 1 foot in about 11,000 years.

In the area under discussion the Allegheny River valley is the most important artery of commerce. Though very little freight is transported by water, the valley bottom affords a uniform gradient for the Pennsylvania Railroad, which follows the eastern bank of the river, and much local and through freight is carried along this route. The river flows in a narrow gorge with a number of long curves, therefore the railroad, which follows the bank of the river in the bottom of the gorge, is much longer than if it followed a straight line, but the cost of building and operating the railroad over the long course, in which little cutting and filling was necessary, is much less than would be the expense of building a line across interstream areas, or even tunneling through the narrow necks, such as those at Wood Hill and East Brady.

The Clarion is even more crooked than the Allegheny, and though there is a narrow terrace which may correspond to the Wisconsin terrace on the Allegheny, no railroad has been built along the stream and there are very few public wagon roads in the bottom of the valley.

The valley of Redbank Creek is, however, used by the Low Grade division of the Pennsylvania (so called because it crosses the mountains at a lower altitude than the main line between Pittsburg and eastern cities). The stream is not so crooked as the Clarion, and the valley is more open.

Bear Creek valley, in the southwestern part of the quadrangles, is used by a branch of the Baltimore & Ohio Railroad. This road is standard gage as far as Foxburg and thence is a narrow-gage line with many steep grades. It runs through St. Petersburg, Knox, and Shippenville, to Clarion Junction. The Pittsburg, Summerville & Clarion Railroad finds a way over the comparatively smooth uplands between Clarion River and Piney Creek; and the Franklin & Clearfield Railroad has just been built along Deer and Piney creeks. The Sligo branch of the Pennsylvania Railroad runs near the boundary between the quadrangles from Redbank Creek up to Sligo, and forms an outlet for the product of several coal mines.

The making of Allegheny River navigable is a project which has often been considered, and the Government has made surveys with that end in view. But no improvement work has been done, and it is only at high water that any boats enter the Foxburg quadrangle. At low water there are many riffles where the water is less than a foot deep. The longest and most formidable rapid in the Allegheny between Olean, N. Y., and Pittsburg is located 3 miles north of Emlenton. Its length is 6900 feet, and the fall of water in this distance is 11.23 feet. Some timber is floated down the river in rafts, but almost all the freight along the Allegheny is handled by the railroad.

The relation of the coal beds and other underground economic resources of the quadrangles to the hills is such that over the greater part of the region no shafting is done. The coal is mined by drifting and the clay and lime by stripping. Iron ore, which was formerly an important product, was mined also by open cutting, or in some places by drifting.

Farming is also influenced by the topography. The stream valleys are so narrow that there is no good bottomland, and consequently farms are limited to the uplands. In the northern part of the Clarion quadrangle the country is much dissected by steep-sided, narrow valleys, and since the soil of the upland is poor in this region, cultivation is limited in extent, but in the southern part the hills are broadly rounded and cultivated farms are numerous.

Parts of the Foxburg quadrangle along the gorges of the rivers and some of the smaller streams are very rough, but the sandstone, which makes such rugged topography where streams have cut into it in the northern part of the Clarion quadrangle, has not been deeply dissected in the Foxburg quadrangle and forms broad flat areas well adapted for farming. Perhaps the best farming country is found on the terraces before described. Parts of these terraces are gravelly, but on the whole the soil is quite comparable to good bottom land.

In the Foxburg quadrangle the majority of farm houses are located very near a coal outcrop, not for convenient access to the coal, but because along coal outcrops there are many springs, and springs are often determining factors in locating farm houses. Coal beds are commonly underlain by clay, and this forms an impervious layer along which the ground water travels until it reaches the surface, where it appears in the form of a spring. It is not unusual to see the coal itself exposed in such springs.

GEOLOGY.

STRATIGRAPHY.

All the rocks of the Foxburg and Clarion quadrangles are sedimentary, and most if not all of the material which composes them was transported and deposited by water. The consolidated rocks now exposed belong to the Mississippian and Pennsylvanian series of the Carboniferous system. The unconsolidated stream gravels found along the river valleys from the present stream up to an elevation of 300 feet above it were deposited long after Carboniferous time, being of Quaternary age. The beds exposed at the surface in these quadrangles are underlain by a great thickness of older sedimentary rocks, the younger portion of which has been penetrated at many points by deep wells drilled in search of petroleum and natural gas. The strata will be described in the order of their deposition.

ROCKS NOT EXPOSED.

All that is known concerning the rocks that lie below the surface in the Foxburg and Clarion quadrangles has been learned by a study of the records of deep wells. The knowledge thus obtained is augmented by investigations made by other geologists of the concealed strata at places where they are exposed in other areas. A number of these deep wells reached depths of 3000 to 3500 feet, some of them passing through more than 2500 feet of unexposed strata. No direct paleontologic evidence is available to show the age of these beds, and the lithologic evidence is very general and is subject to more or less doubt. The limits of formations can not therefore be accurately determined. Correlation of the more prominent beds, however, can be made from well to well over large areas with a fair degree of accuracy. The result of this correlation is shown graphically on the columnar section sheet. The rocks penetrated by these wells are believed to embrace portions of the Portage, Chemung, and Catskill formations of the Devonian system, and possibly to represent a small part of the Mississippian series of the Carboniferous system.

DEVONIAN SYSTEM.

PORTAGE (?) FORMATION.

In a bulletin[a] on the geology of the oil and gas pools of the Clarion quadrangle, the lowest 800 feet of strata penetrated by wells and lying below the lowest red bed were grouped as Chemung. From later studies[b] it appears that about 450 feet of the lowest portion of this is probably Portage. Butts tentatively places the top of the Portage formation at the top of the Bradford oil sand group, which in turn is considered to be equivalent to the sandstones of the Foxburg and Clarion quadrangles called by drillers the First and Second Bradford sands. If this correlation is correct the greatest thickness of the supposed Portage rocks of which records are available is in the Bradys Bend well, located near Bradys Bend, in the southern part of the Foxburg quadrangle. On the columnar section sheet the record of this well is plotted to scale and

[a] Geology of the oil and gas pools of the Clarion quadrangle: Rept. Top. and Geol. Survey Comm. Pennsylvania, 1909.

[b] Butts, Charles, Rept. Top. and Geol. Survey Comm. Pennsylvania, 1906-1908, p. 200.

shown as section No. 6. The lower 1300 feet of rocks encountered in the well are assigned to the Portage formation. The rocks are prevailingly greenish or gray sandy shale but include some lentils of sandstone, which become more numerous and of wide extent toward the top. The most prominent sandstone is the Bradford (?) Second sand, which occurs with great persistency over both the Foxburg and Clarion quadrangles. This sandstone ranges in thickness from 10 to probably as much as 150 feet, averaging about 70 feet. It is white to grayish in color and is reported by drillers to contain local thin lenses of small white quartz pebbles.

CHEMUNG (?) FORMATION.

Overlying the sands which are believed to represent the Bradford oil sand group are about 200 feet of greenish to chocolate-colored shale in which lie two persistent sandstones, known to drillers as the Tiona and Speechley sands. The Tiona lies about 125 feet above the Bradford (?) sand and reaches a maximum thickness of about 75 feet, the average being about 30 feet. The top of the Speechley is about 100 feet above the Tiona. It is a very persistent sandstone throughout these two quadrangles and is seldom entirely absent. Its thickness ranges from 10 to 75 feet and averages about 40 feet. Both these sandstones are white to grayish in color and contain comparatively few lenses of quartz pebbles. The name "Sheffield" is locally applied to a sandstone lentil that is in some places noted between the Speechley and Tiona sands. Above the Speechley sand are about 600 feet of chocolate-colored shale and irregular sandstones up to the bottom of the first persistent red bed of the Catskill (?) formation. The most persistent of these sandstones is the group known locally as the Warren oil sands, which occur about 250 feet above the Speechley sand. In the mass of chocolate colored shale occur a few thin beds of sandstone and reddish shale, the latter being called by drillers "pink rock" or "red rock." These are considered by Butts to be Chemung and to correspond to the pink beds found in the upper portion of the Chemung at points where it outcrops. They should not be confused with the true red beds, which are believed to represent the Catskill formation.

CATSKILL (?) FORMATION.

The beds that are tentatively regarded as representing the Catskill formation consist of red and green shale interbedded with a number of white, gray, and reddish sandstones, which, together with the overlying Hundred-foot sand and Murrysville sand constitute the well known Venango oil sands. In a previous report[a] on the geology of the oil pools of the Clarion quadrangle, the beds lying between the Hundred-foot oil sand and the base of the lowest red rock reported in the well records, making a total thickness of about 1000 feet, were tentatively assigned to the Catskill formation. In the light of later studies of these beds,[b] the lowest reported red beds are considered to be Chemung, in which case the total thickness of the Catskill (?) formation is probably between 500 and 700 feet. In the Warren quadrangle, to the northeast, the Devono-Carboniferous rocks outcrop and have been mapped and described under the names Conewango formation (bottom) and Knapp formation (top). The latter formation is not believed to be represented in the Foxburg and Clarion quadrangles, but it is thought that the deposits here doubtfully assigned to the Catskill formation may represent in whole or part the Conewango formation of the Warren quadrangle.

Because of their great economic importance the correlation of the oil sands of this formation over western Pennsylvania has often been attempted, and while these studies have in general settled the stratigraphic position of the more prominent sandstone beds the work has not been done in sufficient detail to settle questions raised by local variations in them. The correlation of the sands has been discussed more fully in the report on the geology of the coal, oil, and gas of the Foxburg quadrangle,[c] to which the reader is referred.

In ascending order these sands are known to the drillers of the Foxburg and Clarion quadrangles, as Fifth, Fourth, Fourth Stray, Third or Gordon, Third Stray or Gordon Stray, Bowlder, Snee or Blue Monday, and Thirty-foot sands. Of these the Fifth, Fourth, and Third sands are the more persistent. The names applied to them by drillers are fairly consistent throughout these quadrangles, but with the smaller and more variable sands the nomenclature varies greatly depending upon the number and prominence of sands found in each well. The Fifth sand is from 350 to 450 feet below the top of the formation. The bottom of the Fourth is from 30 to 100 feet above the Fifth, the Third in turn being from 50 to 100 feet above the Fourth. The Third Stray, Bowlder, Snee, and Nineveh Thirty-foot are included in the 175 to 250 feet of red and green shales that overlie the Third sand. The sands are prevailingly white or gray in color. Rarely the Third sand and some of the other sands are entirely or partly red. Each contains thin lenses of conglomerate composed of small well-worn quartz pebbles, poorly cemented together. Red rock occurs very irregularly throughout the entire thickness of the formation, but the thickest and most persistent beds occupy all or a large portion of the interval between the Third and Fourth sands.

[a] Geology of the oil and gas pools of the Clarion quadrangle: Rept. Top. and Geol. Survey Comm. Pennsylvania, 1909.

[b] Rept. Top and Geol. Survey Comm. Pennsylvania, 1906-1908.

[c] Bull. U. S. Geol. Survey No. 454, 1911.

CARBONIFEROUS SYSTEM.

MISSISSIPPIAN SERIES.

POCONO GROUP.

In the Foxburg and Clarion quadrangles the Pocono group consists of about 700 to 900 feet of gray sandstone and shale extending from the base of the Hundred-foot sand to an unconformity at the top of the Burgoon sandstone (known to the drillers as the Big Injun or Mountain sand).

The Hundred-foot sand has been fairly conclusively shown[a] to be the basal member of this group and to be equivalent to the Berea sandstone of northeastern Ohio and the Venango First and Butler Second sands of Pennsylvania. This bed is one of the great sandstones of the Appalachian province and underlies thousands of square miles in Ohio, Pennsylvania, and West Virginia. The Hundred-foot sand has a total thickness of 25 to 150 feet, averaging about 100 feet, and is made up of two to three sandstone layers separated by irregular shale divisions. This is exclusive of the Murrysville or Butler gas sand, which is above what is generally considered to be the Hundred-foot and separated from it by 10 to 60 feet or more of gray or red shale. The Murrysville sand is the uppermost bed of a sandy phase of sedimentation at the base of the Pocono group which in the Foxburg and Clarion quadrangles has an average thickness of about 200 feet. Above this sandstone is soft sandy gray shale having a total thickness of 400 to 500 feet, which is thought to represent the Cuyahoga formation. This shale contains near the middle a fairly persistent sandstone averaging about 60 feet in thickness, which is regarded as the equivalent of the Sharpsville sandstone member of the Cuyahoga formation in Crawford County. It is called First sand by the drillers. The shale above the sandstone is darker and more reddish than that below. Many well records show thin beds of red rock in this upper shale. Above the Cuyahoga formation the rocks of the Pocono group consist chiefly of sandstone, which outcrops along the principal streams of these quadrangles and is therefore discussed at greater length under the following heading.

ROCKS EXPOSED.

CARBONIFEROUS SYSTEM.

MISSISSIPPIAN SERIES.

POCONO GROUP.

The lowest rocks exposed in the quadrangles under discussion belong to the nonmarine Pocono group of the Mississippian series and are the stratigraphic equivalent of a part of the marine Waverly group of Ohio. In other Pennsylvania folios the term Pocono has been used as a formation name, but in northern Ohio equivalent strata are naturally and readily divisible into several formations and some of the formations into distinct members. In the Foxburg and Clarion quadrangles one of these members has been identified and is mapped, and it thus becomes necessary to treat the Pocono as a group.

On the map of Erie County in Report Q4 of the Second Geological Survey of Pennsylvania, I. C. White gives the following section of Mississippian strata:

	Feet.
Cuyahoga shale:	
Shenango shale	30
Shenango sandstone	25
Meadville upper shale	25
Meadville upper limestone.	
Meadville lower shale	40
Sharpsville upper sandstone	50
Meadville lower limestone.	
Sharpsville lower sandstone	12
Orangeville shale	75

In the above classification it will be noted that the term Meadville is applied to a number of strata, namely, Meadville upper shale, Meadville upper limestone, Meadville lower shale, and Meadville lower limestone. Much work on these rocks has been done since White's classification was made, and his subdivision of the Cuyahoga has been more or less modified by new facts. At present the most favored usage of Cuyahoga is as the name of a formation which in northwestern Pennsylvania is made up of three members—the Meadville shale, the Sharpsville sandstone, and the Orangeville shale. The limestones are so thin that they are disregarded.

Owing to an unconformity there are nearly 300 feet of Pocono strata in the region about Foxburg which are not represented in White's section given above. Indeed, only the uppermost rocks of that section are exposed in the Foxburg and Clarion quadrangles, but the overlying 300 feet of Pocono strata are extensively exposed in the gorges of the rivers, and the larger part is known to the drillers as the Mountain or Big Injun sand. In the Kittanning folio this member was named Burgoon sandstone, and the reasons for assigning it to the Pocono are there discussed.

[a] Rept. Top. and Geol. Survey Comm. Pennsylvania, 1906-1908.

More or less soft, irregularly bedded shale is generally included in the Burgoon sandstone, but there is a shale below which has quite a different appearance. From fossils and stratigraphic position this shale is believed to belong to the Meadville, described by White and others, the name being taken from the town of Meadville, in northwestern Pennsylvania, where the member is well developed. In consideration of the foregoing facts the following classification of Mississippian strata has been approved for the Foxburg and Clarion quadrangles:

Mississippian series.
  Pocono group.
    Burgoon sandstone.
    Cuyahoga formation.
      Meadville shale member.
      Unexposed shales and sandstone.
    Hundred-foot sand (believed to be stratigraphic equivalent of Berea sandstone).

CUYAHOGA FORMATION.

The Cuyahoga shale is well developed over a large part of central and northeastern Ohio, and takes its name from Cuyahoga River, along which it outcrops extensively between Akron and Cleveland. In general it contains layers of sandstone in its central part, and in northwestern Pennsylvania this sandstone phase is so pronounced that the formation has been subdivided into three parts, as already described under "Pocono group."

Meadville shale member.—In the northwest corner of the Foxburg quadrangle there are cliffs of a uniform, dark-gray, hard, sandy shale, which appears very different from the other rocks of the quadrangles. There is a slight irregularity of bedding resembling cross bedding in sandstone, and at the top of the member is a stratum through which are scattered quartz pebbles averaging somewhat larger than a pea. These features, together with the general sandy character, suggest that the shale was laid down in shallow water. Some marine fossils were collected from the shale and have been identified by George H. Girty. They are: *Chonetes illinoiensis?*, *Rhipidomella oweni?*, *Sphenotus* n. sp., *Sphenotus* indet. On the basis of these fossils and the stratigraphic position and lithologic character of the rock, it is believed that this shale belongs to the Meadville shale member of the Cuyahoga formation as developed in northwestern Pennsylvania.

The Meadville shale is found only in the bottom of the Allegheny gorge, the outcrop extending from a point 3 miles north of Emlenton around the bend above Dotter to the west side of the quadrangle. The best exposure is in the form of a cliff on the west side of the river, 1 mile north of Dotter station and 5 miles north of Emlenton.

The conglomerate or pebbly stratum previously mentioned is very irregular in thickness, but is usually present, and is taken to mark the top of the Cuyahoga. The maximum thickness of strata exposed below the conglomerate is about 37 feet. It is probable that this thickness does not represent the entire Meadville shale member.

BURGOON SANDSTONE.

The Burgoon sandstone, named from Burgoon Creek, in Cambria County, Pa., is of nonmarine origin. It is irregular in most of its characters but consists principally of sandstone, though considerable amounts of shale also are included. This sandstone, known to the drillers as the Mountain or Big Injun sand, is nowhere evenly bedded, but layers 4 to 6 inches thick are common. On weathering the shale crumbles and is washed away, leaving projecting slabs of sandstone which make the outcrop appear like ruins of old masonry. The sandstone is generally coarse and not very clean. In some places, as near Foxburg, it displays considerable cross-bedding. It includes lenses of shale of all sizes, the largest 60 feet or more thick, and in the lower part of the formation this rock predominates. The shale is light gray or greenish, soft, and more or less clayey.

This formation outcrops along the gorges of the rivers and in many of the tributary valleys. It is almost devoid of fossils. In some places there is a layer of carbonaceous shale, or even thin coal near the top, containing plant remains.

In the Clarion quadrangle only part of the Burgoon sandstone lies above drainage, the maximum thickness exposed being 140 feet. The lowermost strata which outcrop are found at the point where Clarion River enters the quadrangle. The next exposure of this sandstone is in the bottom of Clarion River gorge, opposite the mouth of Piney Creek, where a cliff reveals 30 feet or more of alternating bands of greenish shale and gray flaggy sandstone.

In the Foxburg quadrangle the entire formation is exposed and the thickness is 300 to 320 feet. The lower limit is believed to lie at the top of the peculiar conglomerate previously described as forming the uppermost layer of the Cuyahoga formation. The upper limit of the Burgoon is not marked by any stratum which is always recognizable. Several factors are commonly considered in locating the boundary between it and succeeding formations. The coaly layer previously referred to is, where present, about 15 feet below the top of the Burgoon. A somewhat similar coaly bed, at many places lying between layers of heavy resistant sandstone, is found about 40 feet above the boundary. The horizon of the Brookville coal is about 130 feet, and the Vanport limestone member, to be described later, about 240 feet above the top of the Burgoon.

The indistinctness of this upper limit of the Mississippian is remarkable when we consider that there is good evidence of a great unconformity at this horizon. Probably hundreds of feet of Mississippian strata were eroded from this region before the deposition of the Pennsylvanian, but that erosion left such a smooth surface, and the succeeding strata were so much like those below that in few places, if anywhere, can the unconformity be located with exactness. For example, along the "brick road" opposite Emlenton there is a very good exposure of the Mississippian and Pennsylvanian strata adjacent to the unconformity, but no pronounced break is discernible. There are many minor breaks and it is probable that one of these is the unconformity. One in particular lies at the top of an irregular layer of sandstone, which has certain vertical markings suggesting that cracks had formed after the sand had consolidated and before the succeeding strata were laid down upon it. These cracks apparently were filled with sand when the layer above was deposited, but the data are not considered decisive of the unconformity.

The Burgoon sandstone outcrops in the Clarion quadrangle as a narrow band in the ravines of Clarion River, Deer Creek, Toby Creek, Mill Creek, and in the lower 4 miles of Piney Creek. The formation outcrops also in Redbank Creek, where it bends into the quadrangle at Leatherwood station, and for a distance of 1 mile up Leatherwood Creek.

In the Foxburg quadrangle the outcrop of the Burgoon occupies a large part of the gorges of Allegheny and Clarion rivers (see fig. 3), and extends for a short distance up the tributaries. It is found along the lower 3 miles of Mill Creek and the lower mile or two of Richey Run, Turkey Run, Beaver Creek, Canoe Creek, Licking Creek, and Bear Run.

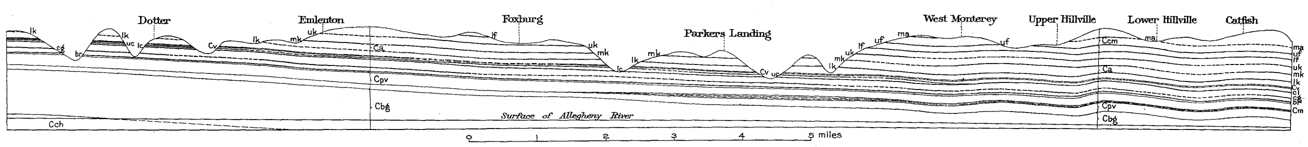


FIGURE 3.—Longitudinal section showing rocks outcropping along the east side of the Allegheny Valley in the Foxburg quadrangle.

Section projected on a medial straight line. Ccm, Conemaugh formation; ma, Mahoning coal; Ca, Allegheny formation; Cv, Vanport limestone member; uf, Upper Freeport coal; lf, Lower Freeport coal; uk, Upper Kittanning coal; mk, Middle Kittanning coal; lk, Lower Kittanning coal; cl, Clarion coal; cg, Craigsville coal; br, Brookville coal; Cpv, Pottsville formation; Cm, Mercer shale member; Cbg, Burgoon sandstone; Cch, Meadville shale member of the Cuyahoga formation.

Vertical scale exaggerated 10 times.

PENNSYLVANIAN SERIES.

POTTSVILLE FORMATION.

Although the Mauch Chunk formation has been eroded from this area, and the Pottsville rocks lie unconformably on the Burgoon sandstone, the line of separation is not lithologically clear and fossils are very scarce. In many places thick-bedded sandstones are found both at the top of the Burgoon and at the bottom of the Pottsville. Such sandstones are very similar in all characters, the grains of sand being of approximately the same size, and about equally rounded. The only visible difference is that the sandstones of the Pottsville formation are, as a whole, somewhat thicker bedded, are slightly coarser, and approach more closely to pure silica.

The similarity of the sandstones, taken in connection with the fact that in the northern part of the State the Burgoon was entirely removed by the erosion that preceded Pottsville time, brings up the question whether the sand of the Pottsville was derived by erosion from the Burgoon sandstone. By reference to figure 4 it will be seen that as far south as Tidioute the Olean conglomerate, which is the lowest member of the Pottsville in northwestern Pennsylvania, lies unconformably on the eroded edges of Mississippian strata, and that this conglomerate does not extend as far south as the Foxburg quadrangle. Thus, since the Pottsville of that quadrangle was deposited later than the Olean conglomerate, the erosion of the Mississippian strata was accomplished and their edges covered with the Olean conglomerate before Pottsville sediments began to accumulate in the Foxburg-Clarion region. Therefore, while it is possible that the Burgoon of the Foxburg area was reworked in Pottsville time, or that the sand of the Pottsville formation may have come from Burgoon lying to the southeast, it seems certain that the sand of the Pottsville was not derived from the area to the north, from which the Burgoon was eroded.

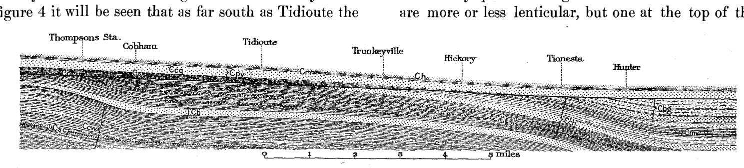


FIGURE 4.—Longitudinal section along Allegheny River from Thompsons station to Hunter, showing the unconformity at the base of the Pottsville formation.

Cpv, Pottsville formation; Ch, Homewood sandstone member; Cm, Mercer shale member; Ccq, Connoquenessing sandstone member; Cs, Sharon shale member; Co, Olean conglomerate member; Cbg, Burgoon sandstone; Cch, Cuyahoga formation; Cmv, Meadville shale member; Cb, Berea sandstone; Ccw, Conewango formation; Csc, Salamanca conglomerate member.

Vertical scale exaggerated 15 times.

The upper limit of the Pottsville is little more definite than the lower. Its approximate position can be located without difficulty, for it is above the sandstone of the Pottsville and below the Brookville coal; but difficulties arise from the fact that between the sandstone and the coal there is a variable thickness of shale, and also from the fact that the coal is absent throughout considerable areas. However, the coal bed holds a fairly uniform position with reference to other recognizable strata, so that its horizon can be located where it is absent. In the Foxburg and Clarion quadrangles the upper boundary of the Pottsville is drawn at the base of the Brookville clay, which underlies the Brookville coal.

In the southern part of the Clarion quadrangle the Pottsville formation outcrops in Wildcat Run up to a point about one-fourth mile north of Wildcat; as a narrow band above the Pocono, in the bank of Redbank Creek below New Bethlehem; on Leatherwood Run, as far north as Rockville; about 2 miles up Long Run; and on either side of Redbank Creek, east of Hawthorn. In the central portion of the quadrangle, the Pottsville outcrops on Licking Creek up to a point about 2 miles above Curllsville, and in the valleys of Piney Creek and its tributaries as a band from half a mile to a mile or more in breadth. On the axis of the Kellersburg anticline it reaches up the hillsides to an altitude of 1550 feet. In the northern portion of the quadrangle the Pottsville outcrops above the Pocono in the gorges of Clarion River and all its larger tributaries to the boundaries of the quadrangle.

In the Foxburg quadrangle the Pottsville is found along the gorges of the rivers just above the Burgoon, and extending a mile or two farther up the tributary streams. On Mill and Turkey runs, Beaver, Canoe, Licking, and Cherry creeks, and Bear Run, its upper limit varies from 4 to 7 miles from the main stream. At the north the Pottsville is 470 feet above the river, and at the south boundary it is only 175 feet. Along the Clarion gorge its upper limit is from 260 to 350 feet above the stream.

Connoquenessing sandstone member.—In the Clarion quadrangle the Connoquenessing sandstone, the lowest member of the Pottsville formation in this region, is a coarse-grained massive rock, similar to the upper portion of the Burgoon sandstone. It is exposed on Redbank Creek in the vicinity of Leatherwood, and in some of the ravines tributary to Clarion River and Piney Creek. The immense bowlders 15 or 20 feet thick in the sides of Clarion River gorge north of Clarion probably belong to this member, although their present position is 150 feet or more below the outcrop of this sandstone.

The Connoquenessing member in the Foxburg quadrangle is a thick-bedded, resistant saccharoidal sandstone, which ranges in color from buff to white and is nonfossiliferous. Some layers are not well consolidated and appear much like granulated sugar. On the whole the rock is very clean and free from everything but silica. On account of these characters it is extensively quarried for glass sand and silica brick. The beds are more or less lenticular, but one at the top of the member can be traced over a considerable area in the northwestern part of the quadrangle. This is a very resistant layer 2 to 6 feet thick, and is overlain by a shaly coal 4 inches to 2 feet 6 inches thick.

The thickness of the Connoquenessing sandstone ranges from 30 to 50 feet.

Mercer shale member.—In the midst of the Pottsville formation there is a series of shales, thin coals, and clays, which has received the name Mercer shale member, because in Mercer County the beds are a prominent part of the section and one of the coals is worked. The coal is locally workable elsewhere, and in some places the member contains a valuable bed of refractory clay. In these quadrangles the coal is not workable, and the clay seems to be of little value. The coal, however, is usually present in one or more beds, which range in thickness from an inch or less to 16 inches.

The thickness of the Mercer shale member varies from 6 inches to 40 feet or more. In the northwestern part of the Foxburg quadrangle the member seems to be represented by only 6 inches to 2 feet of coaly shale. Fossils of the Mercer consist almost entirely of plant remains and are comparatively abundant. They are very distinctive. In other States strata equivalent to the Mercer are much thicker than in Pennsylvania, and the flora of the member is not only different from that of strata above and below, but the member itself may be separated into two or more parts on fossil evidence.

The best Mercer exposure in the Clarion quadrangle is in the railroad cut one-half mile west of Mayport, where the section shows 20 feet of shale, in which are two thin beds of coal.

Homewood sandstone member.—The Homewood, the topmost member of the Pottsville, is a coarse-grained, massive sandstone, averaging about 40 feet in thickness. In some places, however, the member is represented by shale. This seems to be the case near Parkers Landing. In the Foxburg quadrangle the Homewood is generally a clean, white, finely cross-bedded and loosely cemented sandstone. In the more or less weathered outcrops the member is very white and porous, and the cross bedding is a prominent feature, the rock resembling a thin-bedded sand tilted to a high angle.

The Homewood sandstone makes a number of benches in the southern part of the Clarion quadrangle. The best exposures are above the Pennsylvania Railroad track between Hawthorn and Mayport, and on the Sligo branch of the Pennsylvania Railroad, in the vicinity of Wildcat Run. This sandstone is conspicuous also at numerous points along Piney Creek, particularly in the vicinity of Reidsburg. North of Piney Creek the presence of heavy sandstones above and below the Homewood make it less conspicuous.

ALLEGHENY FORMATION.

The Allegheny formation is composed of sandstone and shale, interbedded with coal, clay, and limestone. Economically it is by far the most important formation outcropping in the area. In previous surveys this formation was called the "Lower Productive Coal Measures," but it is now called Allegheny, from the river along which it is typically developed. Coarse sandstone is much less prominent than in the Pottsville and Burgoon, and in some localities no heavy sandstone occurs. The shale is predominantly brownish, owing to its large content of iron oxide, but olive tints are conspicuous in its central and upper parts.

The thickness of the Allegheny is from 345 to 370 feet, and it extends from the base of the Brookville clay to the top of the Upper Freeport coal. The formation is much more uniform in thickness than would be indicated by the variations of the members, but in a general way there is a slight thickening to the northwest. The Allegheny is found throughout both quadrangles and forms the body of almost all the hills, the outcrop of this formation occupying a far larger area than that of any other in the region.

It is not possible to make a tabular section of the Allegheny formation which will apply over the whole area, because the succession of strata varies considerably. A line drawn from a point about a mile and a half north of Sligo through Reidsburg, Frampton, and Day roughly divides the Clarion quadrangle into two parts which have a distinctly different succession of rocks. Similarly the Foxburg quadrangle is naturally divisible into three parts. The boundary between the northeastern and central parts runs from about 1 mile south of the point where Clarion River enters the quadrangle through a point about midway between Turkey City and Monroe to a point 1 mile southwest of Lamartine and thence slightly east of north to the boundary of the quadrangle. Between the central and the southern segments the line runs through Huey, 1 mile south of Toby, 1 mile north of West Monterey, and thence through Bruin to the western boundary of the quadrangle.

In a small area southwest of Shippenville, in the Clarion quadrangle, the succession of rocks is similar to that of the northeast corner of the Foxburg quadrangle.

The following are generalized sections of the Allegheny formation in these divisions:

Generalized section of the Allegheny formation in the northeastern part of the Foxburg quadrangle.

	Range.	Average.
	Feet.	*Feet.*
Shale, light-gray, sandy	35	35
Coal, lower Freeport	0- 3	2
Clay, Lower Freeport	4- 6	6
Sandstone, buff, and shale, sandy	50	50
Coal, Upper Kittanning	0- 3	2
Clay	0- 6	4
Shale, olive, with lenses of sandy shale and sandstone	35	35
Coal	0- 1½	1
Shale, dark gray, with lenses of sandstone	30	30
Coal	0- ¾	½
Shale, brownish-gray, and thin buff sandstone	30	30
Coal, Lower Kittanning	2- 3	2½
Clay, Lower Kittanning	4-10	7
Shale, brownish, and sandstone, pinkish	20	20
Coal	0- 2	1
Clay and iron ore	0- 6	4
Sandstone and sandy shale	20	20
Coal, Upper Clarion	0- 3	2
Shale	4-15	8
Coal, Lower Clarion	2- 4	3
Clay, Lower Clarion	3-12	8
Shale, with thick layers of coarse sandstone	30	30
Coal, Craigsville	0- 1½	1
Shale and shaly sandstone	32	32
Coal, Brookville, with thick partings of sandstone, brown shale, and cannel shale	6-18	12
Clay, sandy, Brookville	8-15	12
		357

Generalized section of the Allegheny formation in the central part of the Foxburg quadrangle.

	Range.	Average.
	Feet.	*Feet.*
Coal, Upper Freeport	3½ - 5½	4
Clay, Upper Freeport	4 -10	7
Limestone, Upper Freeport, and iron ore	0 - 8	4
Sandstone, coarse to fine, and shale	35 -45	40
Coal, Lower Freeport, with shale parting of 2 feet +	3 - 7	5
Clay, Lower Freeport	0 - 6	3
Sandstone, coarse red, with lenses of shale in lower part	35 -60	45
Coal, Upper Kittanning	0 - 3	2
Clay	0 -10	3
Shale, light to dark gray, and sandy shale	40 -60	55
Coal, Middle Kittanning	10/12- 1½	1
Clay	0 - 6	2
Shale, sandy, and thin sandstone	30 -45	40
Coal, Lower Kittanning	0 - 2	1
Shale, and thin sandstone	20 -45	35
Limestone, Vanport, and ore	0 -20	9
Shale, with concretionary iron ore	2 -30	12
Coal, Upper Clarion	1 - 3	2
Shale, hard gray to black	7 -20	12
Coal, Lower Clarion	2 - 6	4
Clay, Lower Clarion	2 -10	7
Sandstone, thick, coarse, and brown shale	25 -35	30
Coal, Craigsville	0 - 3	1
Clay	½- 2	1
Shale	20 -35	35
Coal, Brookville	0 - 2	1
Clay, Brookville, sandy clay, and clay shale	6 -12	8
		369

Generalized section of the Allegheny formation in the southern part of the Foxburg quadrangle.

	Range.	Average.
	Feet.	*Feet.*
Coal, Upper Freeport	0- 5½	3
Clay, Upper Freeport	3- 8	5
Limestone, Upper Freeport, and ore	0- 6	4
Sandstone, thin, and shale, gray	30-45	35
Coal, Lower Freeport	0- 4	2
Clay, Lower Freeport	0- 6	2½
Sandstone, coarse, ranging to fine gray conglomerate, with a little shale	30-60	40
Coal, Upper Kittanning	0- 8	2
Clay, Upper Kittanning	0- 5	2
Sandstone, sandy shale, and shale	35-50	40
Coal, Middle Kittanning	0- 2	1
Clay, Middle Kittanning	0- 6	3
Shale, olive, and sandstone, thin-bedded gray	20-40	30
Coal with shale partings	0- 2	½
Shale, sandy	35-60	45
Coal, Lower Kittanning	2- 4	3
Shale, and thin sandstone	25-45	30
Limestone, Vanport, and ore	0-18	9
Shale	20-40	30
Coal, Clarion	1- 5	3
Clay, Clarion	3- 8	5
Sandstone, coarse	0-15	6
Shale, with thin layers of sandstone	15-25	20
Coal, Craigsville	0- 2	1
Shale	20-30	25
Coal, Brookville	0- 2	1
Clay, Brookville	3-12	7
		355

Generalized section of the Allegheny formation in the northern part of the Clarion quadrangle.

	Thickness.	Average distance of coals above and below horizon of Vanport limestone.
	Feet.	*Feet.*
Coal, Middle Kittanning	0 - 1½	100
Clay		
Sandstone, gray, shaly, and shale	20 -30	
Shale, grayish brown, locally containing thin coals	30 -50	
Coal, Lower Kittanning (upper bench)	2 - 4	35
Clay, and clay sandstone	7 -30	
Coal, Lower Kittanning (lower bench)	½- 2	20
Clay, plastic and flint clay	10 -20	
Shale	5 -10	
Sandstone, massive gray, pinkish at top	30 -50	
Coal, Upper Clarion	0 - 1	30
Clay and black shale	15 -20	
Coal, lower Clarion	2 - 4	50
shale, gray	-20	
Coal, Craigsville	0 - ½	70
Shale, brown and gray	-30	
Coal, Brookville	0 - 4½	100
Clay and shale	-10	

Generalized section of the Allegheny formation in the southern part of the Clarion quadrangle.

	Thickness.	Average distance of coals above and below top of Vanport limestone.
	Feet.	*Feet.*
Coal, Upper Freeport	3½- 5½	240
Clay and limestone lenses	5 -15	
Sandstone, coarse, heavy, gray, and shale	30 -40	
Coal, Lower Freeport	0 - 7½	200
Clay and limestone lenses	5 -10	
Shale, olive, sandy, and sandstone, gray, shaly	35 -50	
Coal, Upper Kittanning	0 - 3	160
Clay and limestone lenses	0 -10	
Shale, olive, sandy	40 -65	
Coal, Middle Kittanning (upper bench)	0 - 2	110
Clay	0 - 5	
Sandstone, gray, shaly	20 -25	
Coal, Middle Kittanning (lower bench)	0 - 2½	85
Clay	0 - 6	
Shale, black and brown	25 -55	
Coal, Lower Kittanning	1½- 4½	35
Clay	0 - 8	
Shale, gray, and sandstone, thin-bedded	25 -50	
Coal	0 - 1	
Sandstone, gray, locally massive	0 -25	
Limestone, Vanport, and iron ore	0 - 8	0
Sandstone and shale, containing iron concretions	15 -30	
Coal, Upper Clarion	0 - 2	
Clay, Upper Clarion	0 - 3	
Shale, gray, sandy	10 -20	
Coal, Lower Clarion	0 - 1	40
Clay, Lower Clarion	0 - 2	
Shale, gray, and sandstone, thin-bedded	15 -25	
Coal, Craigsville	0 - 3	60
Clay	0 - 3	
Shale, drab, sandy	30 -40	
Coal, Brookville	0 - 1	100
Clay and shale	-10	

The economic value of certain beds of the Allegheny formation warrants a somewhat detailed description of the various members.

Brookville coal.—Lying above the Pottsville formation and separated from it by a few feet of clay, clay shale, or argillaceous sandstone known as the Brookville clay, is the Brookville coal. This bed is generally too thin to be workable, but in the northeast part of the area described it reaches a thickness of 4½ feet. In the Clarion quadrangle it varies from bituminous shale to shaly cannel and hard sulphurous coal containing thick partings of shale and pyrite. In the Foxburg quadrangle it is in places so free from sulphur that it has been used as a blacksmith coal, but there is commonly a peculiar argillaceous sandstone below or in the coal bed. Generally the underclay is very sandy and contains impressions of plant roots. Near Blairs Corners inclusions of argillaceous sandstone and partings of shale are especially abundant. The shale varies from cannel to a rock that is scarcely, if at all, carbonaceous. Four of these partings persist and thicken toward the north, so that at the road exposure 1 mile east of Knox it seems to be 18 feet from the top to the bottom of the Brookville coal, and 1 mile southwest of Shippenville the distance seems to be 24 feet.

Craigsville coal.—In a few places in the Kittanning quadrangle a coal occurs between the Brookville and the Clarion which has been named the Craigsville on account of its good development near the place of that name. It was found to lie 40 or 50 feet below the Vanport limestone member and 40 or 50 feet above the Brookville coal. In the Foxburg quadrangle, which joins the Kittanning on the north, a coal was found about 55 to 70 feet below the Vanport limestone and 20 to 30 feet above the Brookville, and it is assumed that this bed is the Craigsville coal. The beds between it and the Brookville are generally brown shale, containing much iron carbonate, sulphide, and oxide, usually in the form of concretions. In some districts the shale contains more or less sandstone. The coal is generally thin, and in a few places only is it underlain by clay. It is of irregular development and general distribution. Near Callensburg and northward to Knox it is very well developed, but is absent over much of the western part of the area. This coal also extends into the west-central part of the Clarion quadrangle, and near Sligo it attains a workable thickness.

Lower Clarion coal.—The interval between the Craigsville and the Lower Clarion, the next coal above, is generally occupied by shale, but in much of the southwestern quarter of the Foxburg quadrangle the Craigsville is absent, and a coarse, thick-bedded, resistant sandstone 5 to 20 feet thick is found 2 to 10 feet below the Lower Clarion coal. This sandstone so much resembles the typical Homewood sandstone member that in the older surveys it was in some places supposed to be that stratum; in other places it was called the Clarion.

Over most of the area of its occurrence the Clarion coal is known as a single bed. In 1880, however, Chance[a] called attention to an apparent split in this bed in Clarion and Venango counties. The evidence gathered for this folio sustains the view of Chance, but the members now known as Upper and Lower Clarion coals do not diverge as regularly as was suggested in that work. The distance between them is variable, in some places reaching 25 feet. The line marking the beginning of the separation seems to pass near Bruin, for there is but a single Clarion coal bed south of that town, whereas to the north there are two, and in a section at Bruin there is a parting of over a foot of shale.

The Lower Clarion coal is recognized in the field by its position, thickness, sulphur content, and binder. It lies about 40 to 70 feet above the Brookville coal and 30 to 50 feet below the Vanport limestone member. These are not the extreme figures, for just east of Alum Rock it is found within 20 feet of the limestone. The bed is of workable thickness almost everywhere in the Foxburg quadrangle and is the thickest coal below the Vanport limestone. It is nowhere free from iron pyrite or binders. A ½-inch to 2-inch binder near the middle of the bed is of wide extent. In roadside outcrops the coal is generally thin, with several feet of white plastic clay beneath.

In most of the southern part of the Clarion quadrangle the Lower Clarion coal is too thin to be workable, but in nearly all of the northern part of the territory it ranges from 2½ to 4 feet in thickness.

Upper Clarion coal.—The upper division of the Clarion coal is separated from the lower by a body of shale from 2 or 3 inches to 25 feet thick, and a similar body of shale separates it from the Vanport limestone above. In most sections there is no under clay, but the coal rests directly upon a hard, black, nonfissile mudstone. Except in a few places where there is a layer of sandstone, the strata between the Clarion coals consist of dark-gray shale, which on weathering turns brown.

The Upper Clarion is workable throughout much of the area where it is found, but in the Clarion quadrangle it is thin or absent. On the whole the quality seems to be somewhat above that of the Lower Clarion.

Vanport limestone member.—The Vanport limestone, sometimes designated "Ferriferous" limestone, is one of the most persistent and best known strata of western Pennsylvania. It takes its name from the town of Vanport, Beaver County, Pennsylvania, where it is typically developed. Wherever it is found it is a valuable key rock for identifying other rocks and for determining the position of oil and gas sands. The top of the limestone is 110 to 130 feet above the base of the Allegheny formation, the average distance being about 120 feet.

Most of the beds between the Clarion coals and the Vanport limestone are dark-drab shale containing numerous iron nodules. In much of the area a coarse sandstone occurs immediately below the Vanport. It is generally 1 or 2 feet thick, but locally is much thicker. In many places there is no sandstone below the Vanport, and it lies almost immediately upon the Upper Clarion coal.

In quality the Vanport limestone is very pure, an analysis showing about 95 per cent calcium carbonate, with little magnesium. The rock is dark gray and fossiliferous. Brachiopods and fragments of crinoid stems are abundant, and corals, pelecypods, and gastropods are common. All of these fossils indicate that the rock is of marine origin. The average thickness of the limestone in the Clarion quadrangle is about 7 feet. Drillers report 10 feet of limestone in places, but none of the sections noted in quarries exceeded 8 feet. In the Foxburg quadrangle the average thickness of the Vanport is about 10 feet, and this increases to 20 feet south of Callensburg. Figure 5 is a typical section of the Vanport limestone.

None of the limestone occurs as a solid unbroken mass. It is broken both horizontally and vertically by joints, which under light cover cause the limestone to weather into large bowlders. Near or at the top of the limestone there is com-

[a] Second Geol. Survey Pennsylvania, Rept. VV, p. 50.

monly a bed of chert about a foot thick. This chert, because of its resistance to weathering, indicates the presence of the Vanport at many places where the limestone itself can not be seen.

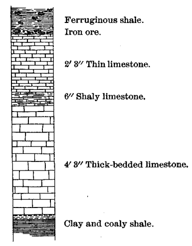


FIGURE 5.—Section of the Vanport limestone member in quarry 3 miles west of Emlenton.

Immediately above the limestone is a layer of iron ore in the form of siderite or limonite. The cherty layer usually found between the ore and the limestone has given the former the name burrstone ore, a term frequently used in Pennsylvania. Exposures in limestone quarries reveal only a few inches of the ore, and in some places, as, for example, 2 miles northwest of Knox, the ore is very fossiliferous.

Between Rockville and Blair schoolhouse and northward nearly to Independence schoolhouse, in the southern part of the Clarion quadrangle, there is a massive sandstone overlying the iron ore, but elsewhere the interval between the Vanport and the Lower Kittanning coal is occupied by sandy shale and beds of sandstone of variable thickness, with one or two thin coals locally in the vicinity of Squirrel Hill.

The limestone is found almost continuously along the Allegheny and up the Clarion as far as Callensburg, lying 100 feet or so higher than the old high terraces, or very near the top of the valley bluff. It is found also along most of the smaller streams. In the northeastern part of the Foxburg and northern part of the Clarion quadrangle and in several smaller areas the limestone is absent. Whether no calcareous material was ever deposited, or whether it was deposited and eroded before the succeeding sediments were laid down, is uncertain.

The evidence in favor of the assumption that the limestone never existed in the areas where it is now absent is given below:

First: The rounded, smooth outlines of such areas, resemble more the shape of basins of deposition than that of areas of stream erosion or wave cutting.

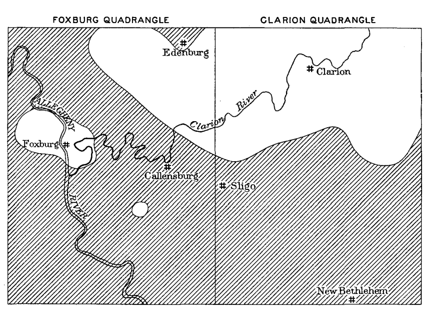


FIGURE 6.—Area in which the Vanport limestone member is known to be present or to have been deposited.

Second: Near the boundary of such limestone areas the strata below seem to thicken at the expense of the limestone and to occupy its position. For example, $2\frac{1}{2}$ miles south of West Freedom and 1 mile north of Concord Church a coarse sandstone seems to thicken and take the place of the limestone.

Third: The general varied character of the Carboniferous strata in western Pennsylvania shows that there was contemporaneous deposition of different kinds of sediment in different places. The Vanport is found throughout a large area, and its characters are fairly uniform. Its absence in certain localities may be explained by assuming either that such districts were above water or that wave action prevented the accumulation of calcareous sediment.

Fourth: As Butts has pointed out, the limestone is found over large areas as a very thin stratum, and it seems hardly possible that erosion proceeded in those places just far enough to remove all but the thin layer of limestone remaining.

Kittanning sandstone member.—In the large area in the northern part of the quadrangles where the Vanport limestone is absent, the interval between the Clarion coals and the Lower Kittanning coal is generally occupied by a more or less massive, coarse-grained, gray to pinkish sandstone about 50 feet thick, known as the Kittanning sandstone member. From considerable portions of the area the overlying softer rocks have been eroded, and the heavy sandstone forms extensive flat uplands, such as those south of Knox, north of Lamartine, and west of Marianville. The towns of Clarion, Knox (in part), and Lamartine are situated on this sandstone, and the long, nearly level stretches of the pike running east from Clarion are underlain with it.

In some parts of the general area underlain by the above sandstone, as for example between Knox and Shippenville, it is absent, and the interval is occupied by sandy shale and a number of thin beds of coal. A road section 1 mile southwest of Shippenville reveals the following succession.

Road section 1 mile southwest of Shippenville.

		Ft.	in.
1. Coal blossom, Lower Kittanning			
2. Plastic clay, with fragments of flint clay			
3. *Concealed*		35±	
4. Coal blossom, Upper Clarion			9+
5. Reddish brown shale		20	
6. Coal, Lower Clarion		1	8
7. Gray clay		5	
8. Red shale containing iron concretions		25	
9. Coal, Craigsville		1	
10. Clay, clayey sandstone, and sandy shale		11	
11. Coal in streaks 1 inch or less in thickness			3
12. Clay grading into red-brown shale		18	
13. Coal interbedded with shale	Brookville	2	
14. Clay and brown sandy shale	Brookville	10	
15. Coal	Brookville		8
16. Clay	Brookville		5
17. Sandstone	Brookville		6
18. Clay	Brookville		5
19. Coal	Brookville	5	
20. Reddish sandy shale and cross-bedded sandstone	Brookville	8	
21. Coal, bony at the top, Brookville	Brookville	1	6

Lower Kittanning clay.—The Lower Kittanning clay is gray and ranges in thickness from 3 to 8 feet. So far as known it is everywhere present in these quadrangles. Over most of the northern portion of the Clarion quadrangle a bed of flint clay also is found below the Lower Kittanning coal. This clay is persistent in the hills that are high enough to contain it. It varies in quality from good refractory clay to an impure and worthless deposit. The best clay is yellowish-brown, fine grained, and moderately hard. Weathered pieces are bluish gray on exposed surfaces. In places where the clay has been dug it is from 3 to 4 feet thick. Immediately above the flint clay, occupying an interval between it and the coal, is a deposit of plastic clay which is usually thicker than the flint clay. In the Foxburg quadrangle there is very little flint clay, though it is found near Zion Hill.

Lower Kittanning coal.—The Lower Kittanning coal lies generally about 35 feet above the Vanport limestone member, but the interval varies from 20 to 50 feet. The 50-foot interval prevails over a considerable area in the vicinity of Brinkerton. This coal, a bed famous for its uniformity and persistency, is mined throughout the southern half of both quadrangles. In most of this district it does not vary more than a few inches from 3 feet in thickness. In a belt several miles wide, extending from Leatherwood to Reidsburg and Frampton, there are no openings or good outcrops of the Lower Kittanning. The fact that on the edges of this belt there are several openings in which the coal is only 2 feet thick indicates a thinning out of the coal in this region. This indication is strengthened by the facts that in this area the interval between the coal and the Vanport limestone member is greater than usual, that occasional road blossoms show the presence of one or two thin beds of coal in the interval, and that in part of the district there is a heavy sandstone immediately above the limestone. It is probable that these irregularities in deposition lasted long enough to affect unfavorably the formation of the Lower Kittanning coal. The coal thins northwestward, and is very thin or absent in a large district containing Emlenton, Foxburg, and Parkers Landing, and extending eastward to Knox.

In the northern part of the Clarion quadrangle a coal bed about 18 inches thick lies below the main Lower Kittanning and is separated from it by 4 to 30 feet of clay and sandstone. In the northeast corner of the Foxburg quadrangle also there is a coal bed about midway between the Upper Clarion and the Lower Kittanning. Whether this bed should be considered a lower bench of the Lower Kittanning or a separate coal is not clear, but the intervals suggest that the Lower Kittanning splits near Sligo, and that the two benches diverge to the northeast and north throughout the area in which flint clay occurs. In a roadside exposure 3 miles northeast of Sligo the interval between the two coals is 11 feet, in one 2 miles east of Frampton it is 17 feet, and on the pike at Clarion Junction it is 28 feet.

Middle Kittanning coal.—Above the Lower Kittanning coal is 35 to 70 feet of shale, including in some places layers of sandstone and sandy shale, the upper strata especially tending to be sandy. The shale shows more or less strong olive tints and is prevailingly soft. Above this member is a coal bed, locally underlain with clay, but more generally resting upon a nonfissile, sandy mud stone.

The older surveys assigned three coal beds to the Kittanning, which have been designated Lower, Middle, and Upper Kittanning, and were named from the type locality at Kittanning, Pa. However, in the eastern part of the area under discussion this succession evidently does not hold. On the west side of Squirrel Hill, the Kittanning strata contain four coals, and elsewhere, although the whole series is not exposed at one place, the intervals suggest the presence generally of four coals. As the distance from the Lower Kittanning to the third coal above is usually about 120 feet, it seems probable that this coal is the Upper Kittanning and that there are between the Upper and Lower Kittanning two coals instead of the one that is termed the Middle Kittanning. The first coal is about 45 feet and the second about 70 feet above the Lower Kittanning. Both the Middle Kittanning coals are thin, and in many sections one or both are absent.

Throughout most of the Foxburg quadrangle the Middle Kittanning coal is about 18 inches thick and is known as the 18-inch bed. The average distance of this bed above the Lower Kittanning is 51 feet. One and one-half miles east of Concord Church the distance is 53 feet; one-half mile west of Bela it is 51 feet; at Bruin the distance is about 35 feet. In general the Middle and Lower Kittanning beds seem to diverge eastward, the extra bed making its appearance between them.

Upper Kittanning coal and clay.—The Upper Kittanning coal, commonly called "Pot vein" or "Stray vein," lies from 130 to 180 feet above the Vanport limestone member. The coal is very irregular in thickness, dip, and quality, and is absent in large areas. The underclay seems to be more persistent than the coal. One-half mile east of Petrolia this coal is from 6 inches to 7 feet thick and dips more steeply than adjacent strata.

In the Clarion quadrangle the Upper Kittanning attains minable thickness in the vicinity of New Bethlehem.

Lower Freeport limestone member, coal, and clay.—Between the Upper Kittanning coal and the Lower Freeport coal (or the Lower Freeport limestone member where it is present) there are about 40 to 60 feet of rock, which varies from shale to conglomerate but is predominantly sandy, and which is widely known as the Freeport sandstone. Northeast of Catfish and elsewhere the sandstone is conglomeratic, containing many pebbles one-fourth inch and a few 1 inch in diameter.

On Myers Hill, southeast of Sligo, and on Squirrel Hill, fragments of limestone along the roadside indicate local developments of the Lower Freeport limestone member. It is not known to occur elsewhere in the quadrangles.

A bed of gray clay averaging about 5 feet thick is generally present between the sandstone and the coal. At a few points it contains small lenses of flint clay.

The Lower Freeport coal lies from 175 to 220 feet above the Vanport limestone member, and is called "Lost vein," "Pot vein," and "Willcott vein." It is irregular, but less so than the Upper Kittanning. It is developed to a limited degree near the tops of the hills in the southern part of the area, and in the vicinity of New Bethlehem it has been mined to a considerable extent. It is also mined to a small extent about midway between West Freedom and Rimersburg, where it is known as the "Willcott vein." In this district it is separated into two benches by a parting of shale 1 to 2 feet thick.

Upper Freeport limestone member and clay.—Above the Lower Freeport coal there is 30 to 50 feet of sandy shale and sandstone, grading locally into conglomerate. In the north edge of Rimersburg there is an outcrop of flint clay at the horizon of the Upper Freeport clay. The flint clay, however, is probably of very local development.

Of much wider occurrence, though it is irregular, is the Upper Freeport limestone member, which is accompanied by some plastic clay. It is present in Myers Hill, Squirrel Hill, and the hill 3 miles southwest of Limestone and is reported to have been quarried in one or two other places in the Clarion quadrangle, but all the deposits are of small extent. In the Foxburg quadrangle it was found at New Athens and Sandy Hollow, thence north to Concord Church, and locally from Petrolia north to Bear Creek.

Upper Freeport coal.—The Upper Freeport or "Summit" coal lies about 245 feet above the Vanport limestone member. It is a persistent bed, but variable in thickness. In perhaps half the area of its occurrence the overlying strata are shale, and here the thickness is uniformly $3\frac{1}{2}$ to 5 feet. Elsewhere the coal is overlain by sandstone, and the thickness in such districts varies greatly in short distances.

The stratigraphic position of the Upper Freeport coal is high, and consequently it is found only in those parts of the area where the higher rocks occur. It is worked in the hills in the vicinity of New Bethlehem, in the top of the hill $1\frac{1}{2}$ miles north of Brinkerton, and in Myers Hill. It is widely developed in the southern half of the Foxburg quadrangle, and is mined extensively in the vicinity of both Rimersburg and Petrolia, and in many other localities.

CONEMAUGH FORMATION.

The Conemaugh formation, widely known also as the "Lower Barren Coal Measures," takes its name from Conemaugh River, along which it outcrops in typical form. It extends from the top of the Upper Freeport coal to the base of the Pittsburg coal. It is, like the Allegheny below, varied in character, and few of its strata are uniform over any considerable area. The proportionate amounts of sandstone and shale are about the same as in the Allegheny, but there is relatively less limestone and much less coal.

The entire thickness of the Conemaugh is over 500 feet in this part of the State. Of this, 230 feet, or nearly one-half, is exposed in the Foxburg quadrangle, the highest rocks being found 2 miles southeast of Petrolia. The formation caps the highest hills and its distribution is very nearly that of the Upper Freeport coal, just described, for it lies immediately above that bed.

The strata above the Upper Freeport coal vary from olive shale to conglomeratic sandstone. Near Rimersburg the coal is overlain by 70 feet of uniform olive shale, with traces of black shale about 50 feet above the coal. Elsewhere the basal stratum of the Conemaugh consists of massive sandstone. This sandstone is found $2\frac{1}{2}$ miles west of Limestone, 2 miles north of New Bethlehem, 1 mile east of Lower Hillville, and one-half mile east of Sharpsburg Church. At the place last named the summit of the hill just reaches the sandstone, and about an acre is covered with huge bowlders 10 to 20 feet in diameter. The rocks are nearly enough in place to indicate that the stratum represented is about 30 feet thick. This sandstone is known as the Mahoning sandstone member, from its extensive outcrops along Mahoning Creek. In many places it is separated from the Upper Freeport coal by a few feet of shale, and its upper limit is likewise irregular.

Mahoning coal.—One mile northwest of Queenstown there is a coal bed 1 to 3 feet thick about 45 feet above the Upper Freeport coal, and there is also a "Second Summit vein" 2 miles southeast of Concord Church. In the last named place the coal is nearly 3 feet thick, and lies 60 feet above the Upper Freeport. Elsewhere there is clay and some indication of limestone at this position. The "Second Summit vein" is correlated with the Mahoning coal, known locally in Pennsylvania, West Virginia, and Ohio, and discussed elsewhere. The coal is generally found between two divisions of the Mahoning sandstone member.

Brush Creek coal.—About 75 to 110 feet above the Upper Freeport coal, or the base of the Conemaugh, is found the Brush Creek coal. The interval between the Mahoning sandstone member and this coal is occupied by shale with a yellowish cast. The coal is of little economic importance and is not persistent. The horizon is commonly marked by a peculiar dark shale, and in some sections by a bed of dark-blue limestone.

Bakerstown coal.—Above the Brush Creek coal, and separated from it by about 75 feet of sandy gray shale and thin sandstone, is the Bakerstown coal, so called from Bakerstown, in Allegheny County, where it has been considerably mined. A limestone also is found near this coal.

The highest consolidated strata that outcrop in the Foxburg and Clarion quadrangles are greenish sandy shale, which extends about 75 feet above the horizon of the Bakerstown coal.

TERTIARY SYSTEM.

In the Kittanning folio, which treats of an adjoining area on the south, there have been mapped three small areas of alluvium which is thought to be older than Kansan gravel, because it lies on rock shelves 100 feet higher than the Parker strath and no glacial gravel was found in it. A few scattered pebbles which seemed to be older than the Kansan were found in the Foxburg quadrangle, but the deposits were too small to be mapped. They are found at various elevations up to 50 feet above the main terrace deposits, but the rock floor underneath is very narrow and most of the pebbles are probably out of place, having been let down through erosion. They are thought to be Tertiary flood-plain gravels.

QUATERNARY SYSTEM.

PLEISTOCENE SERIES.

After the deposition of the Carboniferous rocks just described sediments continued to accumulate for an unknown length of time, but before the end of the Carboniferous period the region was uplifted and has remained a land area until the present time. During this long period the surface has been subjected to erosion, and although the streams have carried away much material, they have also made local deposits. Of such deposits practically none remain except those made in Quaternary time. These consist of unconsolidated gravel, sand, clay, and silt, and are found along the river valleys at various altitudes forming (1) high terraces, 200 to 300 feet above the present streams, (2) low terraces ranging up to 40 feet above present streams and (3) intermediate terraces at various positions between the high and low terraces.

With the exception of the few scattered pebbles which are perhaps remnants of Tertiary flood plain deposits, the highest and oldest of the terrace deposits is found 200 to 300 feet above the valley bottoms and was laid down at about the time of the first ice advance, or very early in the Quaternary period. Similar deposits are found throughout much of western Pennsylvania, West Virginia, and adjacent territory and may be divided into two general classes—first, those which contain glacial material, and second, those composed of pebbles of local origin. The two classes are found in similar topographic positions and are approximately if not exactly synchronous but are of different origin.

The gravels of the first class were deposited by streams overloaded with glacial débris, and thus represent ancient glacial valley trains. The cause of their deposition was the great increase of waste which was delivered to the streams by the melting ice. Gravel of the second class was deposited by streams which never carried glacial gravel, and whose load probably did not greatly increase. Their deposition was due to change of gradient rather than to greater load. Since it is not certain that the two classes of deposits were developed at exactly the same time, and since they differ in origin and probably in other features, they have been given different names. The first class is spoken of as the early glacial gravel, and the second has been called Carmichaels formation, from its excellent development near the town of that name in Greene County, Pa. In the Foxburg and Clarion quadrangles the early glacial gravel is extensively developed on the Allegheny, and the Carmichaels formation appears on Clarion River and on Redbank Creek.

EARLY GLACIAL GRAVEL (KANSAN ?).

Extent and composition.—The early glacial gravel of the Foxburg and Clarion quadrangles is confined to the valley of the Allegheny and lies on a rock shelf about 200 feet above the present stream. The formation consists of a heterogeneous mixture of well-weathered gravel and sand, varying in kind of rock and in size of pebbles and grains. Some of the pebbles are of granite and other igneous rocks that must have come from Canada. Others are of the peculiar deep red Medina sandstone, which outcrops in New York but not within the drainage basin of the Allegheny. These pebbles are embedded in a mass of sand, silt, and clay, and other gravel, much of it doubtless of local origin. The bulk of the deposit is derived from quartz and sandstone and a very small amount from limestone, all being deeply decayed and some of the limestone showing large solution cavities. The amount of coarse material is proportionately much larger than in the Carmichaels formation, and the deposit holds a fairly uniform thickness downstream. The width averages less than the width of the Carmichaels formation on the Clarion, and the upper limit of gravel does not reach so high an elevation.

Upper surface.—The upper surface of the gravel slopes downstream from 1145 feet near Foxburg to a little over 1130 feet at the south boundary of the quadrangle. Owing to erosion, however, the upper limit is not at a definite altitude, but the deposit thins out irregularly, and pebbles are commonly found lying on rock 30 feet above the general upper surface of the deposit. As a rule, the thinner parts are found at a higher elevation than the thicker, and this suggests that the difference in the upper limit of gravel may be due in part to a thinning of the formation since it was laid down. The total amount of thinning thus indicated is about 30 feet, or 20 per cent, the original thickness being 150 feet. (See fig. 10, p. 12.) The thinning may be ascribed to rain wash, settling, and solution by underground water. Rain wash carries away fine material and leaves the coarse. Where the deposit is thin the amount of available fine material is small and isolated pebbles are left scattered over bedrock. Where the formation is thicker the process goes further because of the larger amount of material, the coarse becoming concentrated at the surface. The amount of settling that has taken place may not be appreciable, but the part played by solution has probably been considerable. When the material was first deposited it was composed of glacially ground fresh rock of all kinds and hence it was in condition favorable for solution. Moreover, it caps a broad shelf on the side of the valley and has lain more or less in the course taken by underground water in its journey from the upland to the river. Its condition and location, therefore, have both favored solution by underground water, and the process is attested to-day by the large solution cavities in the more or less silicified limestone pebbles.

Origin.—The origin of the early glacial gravel seems to be clear. The formation is undoubtedly a stream deposit, and its development was contemporaneous and closely connected with the earliest glaciation. It is located in the old valley below the debouchure of a new glacial tributary, which was larger than the main stream, and it is composed of rudely stratified, irregularly assorted, coarse and fine material. The formation as a whole slopes downstream, and the material of which it is composed was carried through the newly formed gorge where the gradient was steep and spread out along the bottom of the old Allegheny Valley from Foxburg to and beyond Pittsburg. The deposit thus made was over 100 feet thick, possibly 150 feet.

CARMICHAELS FORMATION.

Extent and composition.—The principal development of the Carmichaels formation is in the lower 10 miles of the valley of Clarion River. Here it occupies terraces, many of them a mile or more wide. The formation consists of sand, clay, and silt, in which are embedded well-rounded pebbles of quartz and sandstone and a few unworn bowlders of sandstone. At different places estimates were made as to the proportionate amounts of gravel and fine material, and these range from 1:1 to 1:10. The coarsest parts of the deposit are at the base and at the surface, whence the fine material has been washed away. The thickness near Foxburg ranges from 120 feet down to a few inches. Upstream the maximum thickness decreases to 60 feet or less at Canoe Ripple, above which place there are only fragmentary remnants of the formation.

The upper limit of gravel along Clarion River rises from an elevation at Foxburg of about 1145 feet, or 300 feet above the stream, to 1180 feet, or 220 feet above the river north of Callensburg. At Callensburg there are scattered pebbles as high as 1210 feet, but these are above the main terrace formation and are presumably remnants of Tertiary flood plain deposits.

In the Clarion quadrangle there are several small areas of the Carmichaels formation. The largest in the valley of Clarion River lies just below Piney Creek, at an elevation of 1120–1160 feet. The deposit contains well-rounded pebbles of quartz and sandstone one-half inch to 2 inches in diameter. Along Redbank Creek the Carmichaels formation is found 30 to 90 feet above water level and consists of sand and somewhat rounded but not smooth pebbles, mostly under 3 inches in diameter, but some reaching 8 inches. Near Hawthorn the exposures show a thickness of only 3 or 4 feet.

Origin.—The evidence bearing on the origin and history of the Carmichaels formation is not so complete or decisive as that concerning the origin of the glacial gravels. Both seem to be stream deposits and, since they hold similar topographic relations and, indeed, are intermingled near Foxburg, it is inferred that they are synchronous. However, the Carmichaels formation contains no glacial gravel and therefore was not deposited by a stream overloaded with waste from the great ice sheet. In all probability the unworn sandstone bowlders above mentioned have not traveled far. The quartz pebbles were derived from a conglomerate (probably the Olean conglomerate) which outcrops in the Clarion basin in Cameron, Elk, and Forest counties. Such pebbles were well rounded in the conglomerate before the stream picked them up. The origin of the high terrace gravels will be more fully discussed under the heading "Geologic history."

INTERMEDIATE TERRACE GRAVELS.

Below the high terraces and above the outwash of the latest or Wisconsin glacier, there are at many places small deposits of gravel, particularly on long, sloping promontories on the inner side of the river bends. In some places, as at Callensburg, they lie on a rock floor; elsewhere, as at the great bend above Dotter, they are, simply, built terraces. There is less sand, clay, and silt, especially in those which occur on the Allegheny, than there is in the Carmichaels formation. The thickness of the deposit is never over 25 feet and generally less than 15.

Very small gravel terraces are found at Wood Hill 50 feet above the river; also at 90 and 170 feet. Three miles north of Dotter, on the opposite side of the river, there are others, 50, 80, and 150 feet above the water. These terrace deposits may have been produced by intermediate ice advances, but it seems quite possible, in view of their slight and irregular development, that they are normal stream deposits, which have not been eroded away in the course of the stream's downward and lateral cutting. Their preservation is probably due to the place of their occurrence being on the inner side of bends of the river, where the stream has swung laterally away from them, and consequently the attacks of erosion have not been severe. Similar deposits are found on the Clarion, at Martin's Mill, Stover's Mill, and Callensburg. They are the remaining part of deposits made at various stages of the stream's downward cutting.

RECENT ALLUVIUM.

The outwash of the Wisconsin ice sheet and the present flood plain deposits are so mingled and the area of each is so narrow that they can not be mapped separately. The former is found up to about 60 feet above the present stream channels, and consists of fresh, well-rounded pebbles of both local and distant origin. The proportion of crystalline pebbles is greater than in the earliest glacial outwash.

The thickness of the Wisconsin gravel is as great as 40 feet across the river from Foxburg, but it was at one time much thicker, for gravel is found to a depth of 30 or 40 feet below the surface of the present stream, indicating a pre-Wisconsin cutting, a Wisconsin filling up to 60 feet above the present channel, and a later cutting to the present position. The terraces thus produced are almost universally built terraces, there

[a] Rept. Top. and Geol. Survey Comm. Pennsylvania, 1907, p. 162.

being little evidence of lateral erosion at this stage. On account of its narrowness much of the deposit can not be mapped, and its effect generally is to make the valley side less steep, rather than to form a definite flat-topped terrace.

The flood-plain deposits are found along large and small streams but are in all places narrow. They were made by the streams at times of high water and are composed of gravel, sand, and silt. The coarser material is generally at the base of the deposits and in the stream channels. The central part is mixed, coarse and fine, and the top mostly fine silt.

The widest flood plain in the area is scarcely one-fourth of a mile wide and lies 1 mile north of Dotter, but other areas almost as wide are found on very much smaller streams and some distance from the river. The lower parts of the tributary streams have very narrow valleys and almost no flood plains. This feature is due to the uplift of the region and the enlargement of the drainage basin of Allegheny River, which caused the rivers to cut their narrow gorges. The small streams, being much less powerful erosive agents, have not yet deepened their valleys throughout their length. The flood plains along the upper part of the tributaries are developed in those portions of the valleys which have as yet scarcely felt the effects of renewed erosion.

A few of the tributary streams have flood plains along their lower courses. These may have developed because of the overloading of the Allegheny during Wisconsin time. As before stated, this river was flowing at a lower position in pre-Wisconsin time than it is at present. During this long period, when the main stream could not cut downward because of overload, some of the tributary streams may have constructed flood plains.

STRUCTURE.

In this region the layers of rock are nearly horizontal but have a general southward slope of 20 to 25 feet per mile. This slope is not at all regular but is interrupted by low folds in the southeastern part and by minor irregularities throughout the area.

METHOD OF REPRESENTING STRUCTURE.

Structure is commonly represented in two ways—by cross-sections and by contour lines. The former method is better for a region in which the rocks are sharply folded and faulted and the latter for a region where the folds are very low and there is little or no faulting, for the structural features in such a region are scarcely perceptible in a cross section, so that contour lines show the structure much more clearly. In representing structure by means of contours a reference stratum is chosen which has extensive outcrops and is easily recognized. The altitude, amount, and direction of slope of its surface are determined at as many points as possible, and lines, each of which connects points of equal elevation, are drawn on the map in the way in which topographic contour lines are drawn.

In this folio the second method is followed and the reference stratum used is the Vanport limestone member. The contour interval on the map in this folio showing the structural geology is 10 feet for the Foxburg quadrangle and 25 feet for the Clarion quadrangle. In some places the altitude of the reference stratum was obtained directly in outcrops, mines, or wells, and in other places it was calculated from observations on other recognizable strata, for the layers of rock are approximately parallel. The average spacing of the beds was obtained by measurements made at all places where two or more recognizable beds were found in outcrop or in a well boring. Thus, where a bed above the reference stratum was found, its altitude was determined and the average distance or the nearest measured distance to the reference layer was subtracted. Where the outcrop of a bed below was found the average interval was added, thus giving the approximate altitude at which the reference stratum would lie if it were present. An intersection of a surface contour with a structure contour of the same elevation marks a point of outcrop of the Vanport limestone member.

USE OF STRUCTURE CONTOURS.

The structure map is not only of value for the scientific study of broad structural problems but has also a practical use in locating and recognizing beds of commercial importance. Since the rock strata are approximately parallel and the average spacing of the valuable beds is known (see sections in this folio), it is not difficult to calculate the approximate position of any bed at any point. This is done by adding to or subtracting from the elevation of the reference stratum, as indicated on the map, the average distance between the two. The map may be used in this way for locating not only coal, clay, and limestone, but also the oil and gas-bearing rocks.

In all mining exploitation in stratified rocks it is essential to know the strike and dip of the beds. The importance of this knowledge is well brought out by the hundreds of coal prospects which have been abandoned because the bed was found to dip away from the outcrop. The expense for draining and hauling up the slope to the opening was considered too great to permit profitable work. In some places deep ditches have been dug to drain mines, whereas if the dip of the bed had been known they would have been opened in more favorable locations.

RELIABILITY OF STRUCTURE CONTOURS.

The reliability of the structure contours is affected by three factors—first, the accuracy of the altitudes obtained directly; second, the variability of the calculated intervals between the key rocks; third, the number and distribution of the points whose altitudes are known. In the Clarion quadrangle the elevations of practically all coal outcrops, mines, and country banks were obtained with a spirit level, so that the limit of error for the first factor is small, probably in most places less than 2 feet. In the Foxburg quadrangle the elevations were determined with a hand level, and the possible error is thought to average less than 3 feet. The limit of error for the second factor is much larger, because the different strata are not parallel.

The effect of the third factor varies in different areas. In nearly all of the Clarion quadrangle south of Piney Creek, points at which the altitudes of well-marked beds have been determined are numerous and evenly distributed, but north of the creek such elevations are comparatively few. When all the possibilities of error are allowed for, it may be assumed that the structure contours are correct within a contour interval. Thus, in the Clarion quadrangle the position of each contour line is thought to be in error less than 25 feet. On the Kellersburg anticline, however, between Day and Limestone, and from Day to the northern border of the quadrangle, the data are so meager that the error may be greater than 25 feet.

In the Foxburg quadrangle there are many places where the irregularities could not be shown with 25-foot contours, and consequently a smaller interval was used. It is thought that the extreme error is not more than 15 feet, and that the average is less than 5 feet. Certain districts are known to be mapped more nearly correctly than others in which the data are meager and scarcely sufficient to warrant 10-foot contour lines.

FORMER IDEAS OF STRUCTURE.

In the report of the Second Geological Survey of Pennsylvania on Clarion and Butler counties[a] Chance describes six anticlines and seven synclines, which cross the Foxburg and

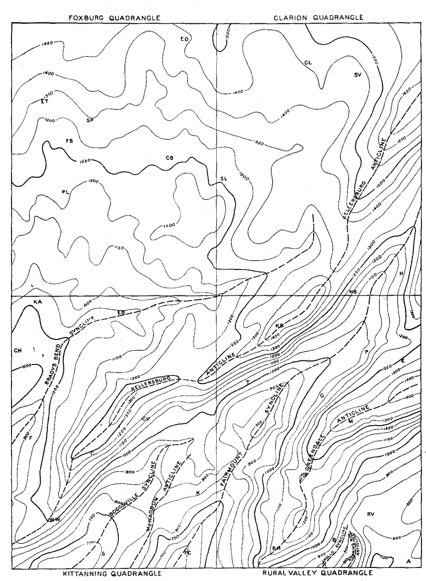


FIGURE 7.—Geologic structure of the Foxburg, Clarion, Kittanning, and Rural Valley quadrangles shown by contours on the Vanport limestone. Contour interval 50 feet.

A, Atwood; B, Blanco; BH, Blanket Hill; C, Craigsville; CB, Callensburg; CH, Chicora; CL, Clarion; CV, Cowansville; E, Eddyville; EB, East Brady; ED, Edenburg; ET, Emlenton; F, Fenelton; FB, Foxburg; FC, Ford City; G, Goheenville; H, Hawthorn; K, Kittanning; KA, Karns; KB, Kellersburg; M, Muff; NB, New Bethlehem; P, Putneyville; PL, Parkers Landing; RV, Rural Valley; S, State Lick; SL, Sligo; SP, St. Petersburg; SV, Strattonville; T, Templeton.

Clarion quadrangles. They may be represented by straight lines drawn approximately N. 35° E., and their names and positions, beginning at the southeast, are given below:

Fairmount syncline, lying just east of Fairmount City.
Antonys Bend anticline, passing about 2 miles west of New Bethlehem, and through Kingsville.
Centerville syncline, near Rockville and Frogtown.
Kellersburg anticline, passing through Limestone.
Lawsonham syncline, passing through the junction of Piney and Little Piney creeks.
Bradys Bend anticline, near Rimersburg and Reidsburg.
Bradys Bend syncline, just east of Catfish, Sligo, and Clarion.
Millerstown anticline, passing about 2 miles east of West Monterey, and through Callensburg and the junction of Paint and Deer creeks.
Millerstown syncline, about one-half mile northwest of the anticline.
Martinsburg anticline and syncline, about one-half mile apart, near Baldwin and Parker.
Harrisburg anticline and syncline, about one-half mile apart, and passing near Wood Hill station.

[a] Second Geol. Survey Pennsylvania, Rept. V, pp. 9–13; Rept. VV, pp. 23–30.

The present survey, instead of finding numerous straight and narrow parallel folds, worked out a few irregular, broad folds, which are described in detail below. The structure of the Foxburg, Clarion, Kittanning, and Rural Valley quadrangles is shown in figure 7.

FAIRMOUNT SYNCLINE.

Beginning in the southeast corner of the area, the first structural feature is the Fairmount syncline. The course of the axis or middle line of this syncline is shown on the structure sheet to be nearly the same as described by Chance in the Pennsylvania report. It enters the quadrangle opposite Fairmount City, crosses Redbank Creek between Town and Middle runs, and passes out of the quadrangle about 3 miles north of New Mayville. The dips of the rocks in this syncline are steeper than anywhere else in either quadrangle. On the east side of the anticline the maximum dip is about 150 feet per mile; on the west it is about 175 feet.

KELLERSBURG ANTICLINE.

West of the Fairmount syncline is the Kellersburg anticline. It crosses the area in approximately the course assigned to Bradys Bend anticline in the Pennsylvania reports, but it is a continuation of the Kellersburg anticline, as traced through the Kittanning and Rural Valley folios. The axis of this anticline enters the quadrangle about midway between Leatherwood Station and New Bethlehem, follows a slightly serpentine course which passes about one-half mile east of Frogtown, and then out through the east boundary of the quadrangle a mile east of Day. The southeast flank of this anticline dips 75 to 175 feet per mile; the northwest flank dips 50 to 125 feet per mile.

BRADYS BEND SYNCLINE.

The Bradys Bend syncline enters the Clarion quadrangle at the southwest corner, near the point of entrance assigned by Chance to the Lawsonham syncline, follows a nearly direct course to Rockville, then turns sharply to a direction a little east of north, and disappears near Brinkerton. The dip of the rocks in this syncline is 25 to 75 feet per mile.

RIMERSBURG ANTICLINE.

Northwest of the Bradys Bend syncline is a low anticlinal fold, which extends from Rimersburg to Sharpsburg Church and seems to be a limb of the Kellersburg anticline that is nearly cut off by the Bradys Bend syncline. The fold is best developed near Rimersburg but dies out a short distance west.

IRREGULAR STRUCTURAL FEATURES.

West of the Kellersburg anticline there is a broad, shallow depression, the main axis of which extends from Watson School through Reidsburg, just west of Frampton and Strattonville, and into Highland Township. Another long, shallow trough extends from Williamsburg toward Shippenville. The remaining structural features are the product of (1) irregularities of the surface upon which each layer was deposited; (2) differential settling; (3) warping at various times since deposit. Some features, such as the depression west of Knox, the one between Parker and Emlenton, and the one running north from Petrolia, suggest slight folding, but the structure as a whole is that of gently sloping layers with slight irregularities throughout. The general dip is probably the result of deformation since the rocks were laid down, but the irregularities of the northwestern part of the area are somewhat similar to those represented on coastal charts of such regions as that off Cape Henry or the central part of Chesapeake Bay, where there are broad, low swells and shallow depressions of irregular shape and arrangement. It is therefore considered probable that the irregularities of structure are due in part to the shape of the floor upon which each successive stratum was laid down.

The structure of the oil sands, which lie from about 1000 to 3000 feet below the Vanport limestone, on which the contours of figure 7 are drawn, is very similar to that of the surface beds, notwithstanding the fact that the two horizons are separated by a great unconformity. By comparing the structure of the oil sands with the structure of the Vanport limestone (see fig. 12, p. 15) it will be seen that the larger folds are very similarly located in the beds above and below the unconformity. It will be seen, also, that the degree of folding in the oil sands is appreciably greater than it is in the surface beds. This structural condition has been found to prevail over the Appalachian region wherever the folds in the surface beds and the oil sands have been studied in detail.

GEOLOGIC HISTORY.

In the surface features of the earth—hills, valleys, and plains—and in the numerous layers of rock that underlie them are recorded the earth's history and that of its various types of inhabitants. The events thus recorded are the results of general processes, such as deformation, erosion, and deposition. These processes modified the geography and climate and in this way produced changes in living organisms. The vast succession of geologic and biologic changes can thus be made out by a study of the rocks and land forms.

Only two systems of strata, the Carboniferous and Quaternary, are exposed in the Foxburg and Clarion quadrangles, and since the area is a small part of the Appalachian province, a brief outline of the history of the province will be given.

PALEOZOIC ERA.

PRE-CARBONIFEROUS TIME.

Since there is practically no record of pre-Carboniferous time in the present rock formations of the Appalachian province, it is evident that during this period much of the province lay at the bottom of an ocean or mediterranean sea. A narrow belt along the southeast side, together with the present Atlantic Coastal Plain and much territory covered by the Atlantic Ocean, was at that time land. This land extended to the north and west, so that western New England, northern New York, and most of Canada, including Lake Ontario, were land areas.

The coast of the mediterranean sea, or, as it has been called, the Appalachian Gulf, did not occupy the same position during the Cambrian, Ordovician, Silurian, and Devonian periods, but migrated more or less. The northwest coast in particular occupied all positions from central Pennsylvania and eastern Kentucky northwest as far as Chicago, and west to an unknown distance beyond the present position of the Mississippi. The southeast coast was more stable and for a considerable part of the time lay near the eastern side of the present Appalachian mountains. The land to the southeast of this has been called Appalachia.

The streams which drained Appalachia carried much sediment into the Appalachian Gulf. This material was spread out in layers on the bottom of the Gulf and was later cemented into shale, sandstone, and conglomerate. The streams also carried many substances in solution. Among these were lime and salt, and these likewise accumulated in the Gulf in great volumes. Part of the lime was extracted by animals which had calcareous shells and by plants which secreted calcium carbonate. The remains of these organisms, together with such calcium carbonate as may have been chemically precipitated, formed extensive beds of limestone. Not only the sediments themselves, but also the remains of living things buried in them, yield important data for deciphering the history of the region.

In early Portage time sediments began to accumulate in the vicinity of the Catskills, in New York, probably in an inclosed fresh-water basin. Sedimentation continued into Chemung time and the area of deposition grew larger. Finally the Chemung deposits were buried under the layers of a contemporaneous and overlapping formation which is now found throughout a large area in Pennsylvania and New York and is known as the Catskill formation. In the type locality the Catskill formation is several thousand feet thick, but it thins toward the west, and in western Pennsylvania the deposits which are believed to represent it are only a few hundred feet thick. It is thus a shore or brackish-water phase of the Upper Devonian and is the time equivalent of the Portage, Chemung, and probably the basal part of the Mississippian. It is characterized throughout by beds of red shale, and it is often recognized by this feature when found in oil wells. However, there is a considerable thickness of sandstone which is not red, and this suggests that the sand may have had a different origin from the shale.

Oil and gas are found in the lower part of the Carboniferous sediments and in the upper part of the pre-Carboniferous, in strata which are believed to represent the Portage, Chemung, and Catskill formations. The sandstones of the Chemung (?) formation are known as the Tiona, Speechley, and Warren sands. The sandstones of the Catskill (?) formation are known as the Fifth, Fourth, Butler Fourth Stray, Third or Gordon, Bowlder, Gordon Stray or Butler Third Stray, Snee or Blue Monday, and Nineveh Thirty-foot. The origin of the oil and gas is not known, but one of the most favored theories is that they are products derived from the organic matter buried in the rocks. In any case, the porous sandstones form the reservoirs in which the oil and gas are now found stored.

At the close of Devonian time thousands of feet of sediment had accumulated in the interior sea, and at about this time occurred an earth movement that formed a broad, low fold, which extended through Ohio, Kentucky, and Tennessee and which is now known as the Cincinnati anticline. In this way a large area emerged from the sea and a long embayment was formed between the new uplift and the old land to the east. The rocks which outcrop in the Allegheny coal basin were laid down in this embayment.

CARBONIFEROUS PERIOD.

The Carboniferous period is so named because formations of that age in many parts of the world contain coal. Some of the Carboniferous rocks in the Foxburg and Clarion quadrangles are unquestionably of marine origin. The Vanport limestone, for example, is crowded with the remains of ocean shells. Other strata, such as the coals, must have been laid down on land, but there are great thicknesses of rock concerning the origin of which we know little more than that they are sedimentary deposits. They may be either marine or continental, and some of those which are continental may be either lacustrine or fluviatile, perhaps even eolian. However, it is very evident that there was at no time in the Carboniferous period very deep water in this region and that the deposits were laid down near sea level. At different times there were submergence and flooding by the sea emergence, development of extensive swamp areas, deposition of stream-transported material, and at least one period of extensive erosion.

At the beginning of the Carboniferous period sand was spread over the bottom of the Appalachian Gulf in western Pennsylvania, the resulting sandstone being 25 to 150 feet thick. This sand is known to the well drillers as the Hundred-foot sand and is probably equivalent to the Berea sandstone of Ohio. Upon the Hundred-foot sand were deposited layers of mud and sand, the character of the sediment being different in different places and the material varying from time to time with changes in climate and the altitude of the land. Twice extensive bodies of sand were brought into the gulf. One of these is called the Murrysville sand, Gas sand, Salt sand, and Butler gas sand. The other and later one is now known as the First sand. Above the First sand shales predominate again.

CUYAHOGA EPOCH.

As stated elsewhere, the oldest rocks which outcrop in the Foxburg and Clarion quadrangles belong to the Cuyahoga formation. They are sandy shales carrying marine fossils. At the close of the Cuyahoga epoch pebbles of quartz somewhat larger than a marble were brought into the Appalachian Gulf, and they are now found mixed through the upper foot or so of sandy shale. This implies a change from rather weak currents of water, which carried the mud and silt of the shale, to such strong currents as would be necessary to roll the pebbles. Moreover, the pebbles seem to have been carried a long distance, for they are well rounded. There may have been at this time a considerable geographic change.

BURGOON EPOCH.

Throughout the epoch following the Cuyahoga the sediments brought into the Appalachian Gulf were predominantly sandy. Mud was brought in at irregular intervals and now forms lenticular masses of shale in the sandstone which is known as Burgoon sandstone. The shale is not so resistant as that of the Cuyahoga and fresh exposures of it are not common, but the lenses range in thickness from a few inches to a foot and are 10 to 20 feet in lateral extent.

In the early part of Burgoon time sand was deposited over a large area to a depth of about 25 feet. The resulting sandstone was named Shenango sandstone by the Second Geological Survey of Pennsylvania. In some localities fish bones, teeth, scales, and spines are rather abundant, so that the rock has been called the fish bed. Overlying the sandstone is a shale, called the Shenango shale by the Second Geological Survey of Pennsylvania, which is said to have a uniform thickness of about 50 feet in Crawford County. In the Foxburg quadrangle these members are recognizable but irregular, there being more or less sandstone included in the shale and more or less shale in the sandstone. The Shenango shale and sandstone were buried under about 300 feet of sand with mud lenses which now constitute the main body of the Burgoon formation.

Imprints of land plants are also found in the Burgoon, and the great irregularity of kinds of sediment indicates coastal-plain conditions. Some of the shale lenses contain marine fossils, but most of them do not, and it does not seem probable that the Foxburg and Clarion quadrangles were submerged in sea water for any considerable part of Burgoon time. Some of the sandstones are very irregularly cross-bedded and may be wind-deposited.

At the close of Burgoon time calcareous material was added to the sandy sediments in certain regions, producing the Loyalhanna ("Siliceous") limestone. This rock is not found in the Foxburg and Clarion quadrangles. It may never have been deposited, or it may have been eroded away before succeeding sediments were laid down.

MAUCH CHUNK EPOCH.

By the close of the Pocono many thousands of feet of sediment had been spread over western Pennsylvania. No part of the area was much above the sea, but the surrounding country was higher and streams continued to bring their loads of material into the depression. In the early part of Mauch Chunk time the sea was widespread and the Greenbrier limestone was formed. Later, deposits of red mud and sand, derived probably from highly oxidized land to the east, were piled up to a thickness ranging from 1000 to over 2000 feet. This indicates further subsidence of this region, for it is difficult to imagine the accumulation of so great a thickness if the surface remained quiet. But few fossils are found in these rocks and, as has been noted elsewhere, no Mauch Chunk is found in the Foxburg and Clarion quadrangles.

POTTSVILLE EPOCH.

Of the rocks formed in the Pottsville epoch, sandstone and conglomerate greatly predominate, and over broad areas they are found to lie unconformably upon the Mauch Chunk and older rocks. From this fact the conclusion is drawn that before the opening of Pottsville time there was an uplift which resulted in the removal by erosion of a considerable part of the Mauch Chunk rocks and portions of underlying strata. The amount of erosion was greater in the west than in the east, and it is probable that in some parts of western Pennsylvania the Mauch Chunk was completely removed, because throughout extensive areas no trace of this formation can be found.

While this erosion was progressing on the Mauch Chunk in western Pennsylvania, the conglomerates of the Pottsville formation were being laid down in the southern Appalachian region. Here also the first thick coal beds were being formed. By the time 3000 or 4000 feet of Pottsville rocks had accumulated in the southern Appalachian basin, the Pennsylvania portion had subsided again, and was also receiving conglomerate deposits. The part of the basin which was submerged earliest was near the western border of the State, and here the Sharon coal and conglomerate member was deposited before the Connoquenessing sandstone member was laid down in the region that includes the Foxburg and Clarion quadrangles. The formation of the Connoquenessing sandstone, with its accompanying shales and coals, was followed by a change to quieter conditions, during which the shales, limestones, clays, and coals of the Mercer member were formed. The epoch closed with the active deposition of the Homewood sandstone member and accompanying shale.

ALLEGHENY EPOCH.

Conditions in the Allegheny epoch were much quieter than in the Pottsville. Sandstones, though coarse and thick in some places, are not so extensive. Coal beds make up a larger part of this formation than of any other formation in the Appalachian Basin. In the Foxburg and Clarion quadrangles no less than one-fourteenth of the Allegheny is made up of this valuable mineral. The origin of coal has led to much speculation, but evidence seems to be conclusive that it is derived from accumulated plant remains. The question most debated is that regarding conditions of accumulation. The generally accepted theory, however, is that the coal originated in marsh growths, usually of wide extent and near sea level.

Coal making began soon after the close of the Pottsville epoch, being the result either of the filling of the Appalachian Gulf by Pottsville sediments or of an uplift. The accumulation of this material was accompanied by somewhat irregular conditions, for many of the coal beds have numerous partings, indicating that from time to time the marsh was flooded and mud was deposited. Subsidence followed the deposition of the Brookville coal; then more shales and sandstones accumulated, thus beginning the compression that aided in the coal making. The shales and sandstones served as a base upon which the Craigsville and later the Clarion coals were formed. In the shale above the Clarion coals there are a large number of concretions of iron ore. Such concretions have usually been made after the consolidation of the inclosing rock, by the slow gathering of material from scattered sources and its redeposition in concentric layers upon some small object that served as a core.

After deposition of the Clarion subsidence took place which was geologically more important than any movement that had affected the region for a long time preceding, because it afforded an opportunity for the formation of a limestone of wide extent. This stratum, the Vanport limestone member, because of its persistence and characteristic qualities, is a valuable key rock. When 10 or 20 feet of limestone had been formed another tilting of the land occurred, which caused the limestone to be buried under shale and sandstone. A local deposit of flint clay is found in the northern part of the Clarion quadrangle, just above the limestone and seemingly replacing it to a greater or less extent. Flint clay is usually intimately associated with plastic clay and occurs in lenses. The two have practically the same chemical composition but differ greatly in physical properties. As compared with plastic clay, even of the same bed, flint clay is not only almost entirely lacking in plasticity but is many times harder and denser and more refractory.

With the completion of the deposits of sandstone, shale, and clay just described, land had taken the place of water and conditions had become favorable for extensive coal making. This period is marked by the formation of the Lower Kittanning coal, one of the most persistent and uniform beds in western Pennsylvania. The subsidence that caused the burying of the Lower Kittanning coal was followed by a number of comparatively frequent changes, which resulted in a series of shales and shaly sandstones interbedded with small coals. Further deposition of shale and sandstone laid the foundation for the Lower Freeport coal, which in turn was buried by silt and sand and was succeeded at the close of the epoch by the formation of the Upper Freeport coal.

CONEMAUGH EPOCH.

Conditions during the Conemaugh epoch were less favorable to coal forming than those of the Allegheny, so that, although the period was of long duration, much less coal was formed. The epoch commenced with a subsidence which allowed sand and mud to accumulate to a depth of 90 to 120 feet. This accumulation, the Mahoning sandstone member, is well developed over a wide area, and serves in some regions as a valuable key to the stratigraphy. At the same time that the sandstone was being deposited in some regions, shale was laid down in others, so that the thickness and the upper and lower limits of the Mahoning sandstone member are irregular. The sand was deposited in lenticular masses not over 30 or 40 feet thick. In some places no lenses of sand were included and the member is represented by shale. After the first 25 to 50 feet of strata had been laid down the vegetation forming the Mahoning coal developed, probably in local basins. But after the Mahoning coal was deposited sand sedimentation was resumed, forming the upper division of the Mahoning member. Then followed the deposition of the sandy olive shale which makes up the remainder of the Conemaugh and which is present in the Foxburg and Clarion quadrangles. In the midst of the epoch a subsidence took place that brought about a marine incursion and the formation of the fossiliferous Ames ("Crinoidal") limestone member, none of which is now found in the quadrangles under discussion.

The Conemaugh epoch closed with a long period of slow deposition of shale alternating with sandstone. Although it is probable that all of these strata were deposited in the Foxburg and Clarion quadrangles, a large part, probably 99 per cent, has been removed by later erosion. In the northern part of the area the formation is entirely absent, but in the southwestern part, near Petrolia, many hills, one of which extends 230 feet above the Upper Freeport coal, are capped with the Conemaugh.

MONONGAHELA EPOCH.

At the close of Conemaugh time the Appalachian basin was nearly a level area. In some districts, as, for example, near Pittsburg, there is indication of erosion just preceding the opening of the Monongahela epoch, but such erosion did not proceed far, for the Pittsburg coal, the basal layer of the Monongahela, was formed upon a nearly flat surface. This coal is the most extensive and valuable in the Appalachian coal field. Its growth marks the culmination of the conditions favorable to coal formation.

Throughout the remainder of the Monongahela epoch a succession of events similar to those described in the history of the Allegheny and Conemaugh occurred. The coals that were formed were the Redstone, Sewickley, Uniontown, and Waynesburg. These coals are generally thin and of small extent. The event next in geologic importance to the accumulation of the Pittsburg coal was the formation, between the Sewickley and Uniontown coals, of the Benwood limestone member and the Uniontown limestone member, which with a few interbedded shales attained a thickness of 160 feet. As these limestones contain no trace of marine organisms it is assumed that they were formed in fresh water, possibly by the precipitation of lime salts. There are no deposits of the Monongahela epoch in these quadrangles.

DUNKARD EPOCH.

During the Dunkard epoch the closing events of the Carboniferous period took place. Conditions during this time were generally quiet. Many alternating shaly and sandy deposits were laid down at short intervals, and with these were interspersed a few limestones and thin coals. At the end of the epoch sedimentation ceased in the Allegheny basin.

POST-CARBONIFEROUS FOLDING AND UPLIFT.

At the close of the period of sedimentation just described, which was characterized by gentle oscillations in the earth's surface, movements of a much more profound nature took place. Tremendous strains due to shrinkage of the earth's interior caused the rocks, which had hitherto rested in approximately horizontal positions, to bend into great folds, which run nearly parallel with the old shore lines. East of the Allegheny Front these folds were very pronounced—the anticlines were steep and high and the synclines were narrow and deep—but to the west the folds were low and broad, and in the Foxburg quadrangle they are scarcely appreciable.

MESOZOIC ERA.

In addition to folding the rocks the post-Carboniferous deformation probably greatly increased the elevation of the land surface throughout the Appalachian province. With the advent of this condition new processes began to act, and the areas which before had almost continuously received rock material began to lose it by erosion. This erosion has continued practically without interruption to the present time, and at several times it has been accelerated by uplifts of the region. There is no good evidence of any general subsidence. In the eastern part of the Appalachian province there was deformation in the Triassic period, and perhaps before this the land had been worn down considerably. After the Triassic deformation there may have been several other times when the land was reduced to a low level and again uplifted so that erosive processes were revived. The cycle of uplift, long-continued erosion that carved the land mass into hills or mountains which were later reduced nearly to a plain, and renewed uplift may have been repeated several times. The record of one cycle was to a greater or less extent destroyed in the next. Moreover, there are all possible stages in the process of reduction to a plain, and the less complete the cycle the more easily is the record destroyed.

One of the oldest and most perfect of the peneplains of which there is good record seems to pass beneath Cretaceous deposits in New Jersey and Alabama and hence must have been developed before some time in the Cretaceous period. It has been thought by many physiographers that parts of this peneplain are preserved in the tops of Schooley and Kittatinny mountains in New Jersey and in many other even-crested mountains and hills in the Appalachian province, though it is believed that throughout much of western Pennsylvania there is not a vestige of this surface. Further careful work is necessary before this correlation can be relied upon as correct. At present it does not seem probable that any part of a Cretaceous peneplain is preserved in the Foxburg and Clarion quadrangles.

CENOZOIC ERA.

TERTIARY PERIOD.

It is thought that a crustal movement again raised the region at a time near the opening of the Tertiary period, after which the erosion of the surface proceeded with renewed vigor until a lower but less extensive peneplain was formed. This new surface has been correlated with the Harrisburg peneplain, which is well preserved about that city. The highest hills in the Foxburg and Clarion quadrangles seem to approximate the present horizon of this elevated plain, but it is doubtful if any of the actual surface remains.

As a whole, the surface correlated with the Harrisburg peneplain now has the shape of a low ellipsoidal dome, the highest part being in McKean and Potter counties, in northern Pennsylvania. From an altitude of 2200 feet or more in that region the peneplain descends to 1200 feet in southwestern Pennsylvania and 500 feet in the southeastern part of the State.

QUATERNARY PERIOD.

At the opening of the Quaternary period the physical features of western Pennsylvania had the general form which they display to-day, but many details of the valleys were different. The belief is general that the present basin of Allegheny River includes not only its ancient preglacial basin but also the greater part of two other preglacial drainage basins. The map (fig. 8) shows the probable preglacial arrangement of streams. What is now the Clarion was formerly the upper part of Allegheny River, and what are now the middle and upper parts of Allegheny River were parts of two preglacial streams that discharged into a basin now occupied by Lake Erie. The Upper Allegheny flowed northwestward by Salamanca and Gowanda and thence down the Cattaraugus Valley. The old Middle Allegheny River had certain tributaries which rose near Emlenton and flowed northwestward through Venango, Crawford, and Erie counties, Pa., along a channel now occupied in part by French and Conneaut creeks, and entered the Erie basin just east of the Ohio-Pennsylvania line. The run-off from the region now drained by Clarion River and the lower part of the Allegheny flowed into the Lake Erie basin instead of to the Ohio and Mississippi, as at present. The course of the ancient Lower Allegheny followed the present course from the mouth of Clarion River as far as the mouth of Beaver River, where apparently it turned to the north and followed an old valley now occupied in part by Beaver and Grand rivers to the Lake Erie basin. The principal evidence of this former arrangement of drainage may be summed up as follows:

1. The gradation plain of the Lower Allegheny continues up the Clarion and the tributaries which discharge below the mouth of that stream, while above the Clarion the Allegheny flows in a narrow, deep valley, with no high terraces.

2. The tributaries of the Allegheny above the mouth of the Clarion have channels that were not deepened to levels in harmony with a gradation plain so low as that of the Clarion.

3. There is a high tract of country in the vicinity of Emlenton and Mariasville which resembles a low divide.

4. North of the Foxburg quadrangle is a gradation plain that slopes northward.

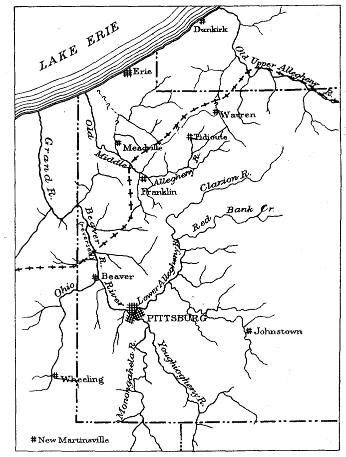


FIGURE 8.—Sketch map showing the probable preglacial drainage of western Pennsylvania. The terminal moraine is shown by broken crossed line.
(After Leverett: with slight changes and addition of terminal moraine.)

The river valleys were broader at the bottom than at present, though the extreme breadth was reached later when they had been silted up and widened slightly. The valleys of the small tributaries were as broad throughout their length as the upper parts of these valleys now are.

An early glacier advanced to within about 5 miles of the northwest corner of the Foxburg quadrangle, and blocked all northward drainage outlets of western Pennsylvania. The ice was probably several thousand feet thick and held all surface water until southward outlets were formed across old divides. One of these divides was near Emlenton, just north of the present mouth of the Clarion. The other, which was between the old Upper and Middle Allegheny rivers, was near Warren, Pa., and was uncovered as the glacier melted away, but before northward outlets were opened. Figure 9 shows the probable

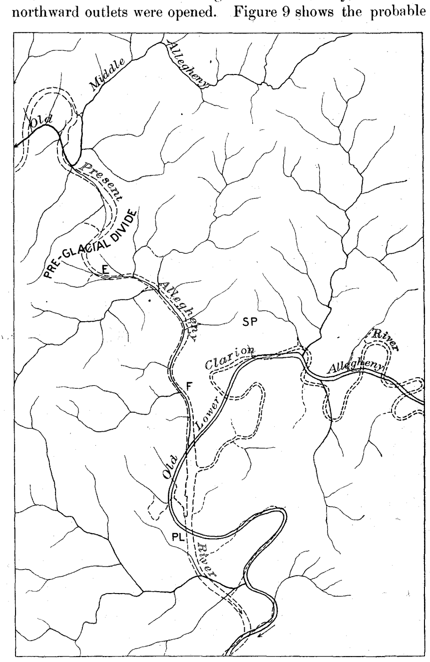


FIGURE 9.—Probable preglacial drainage of the northwestern part of the Foxburg quadrangle.
E, Emlenton; F, Foxburg; PL, Parkers Landing; SP, St. Petersburg.

preglacial drainage of streams in the northwestern part of the Foxburg quadrangle. Thus, the Upper Allegheny cut a channel through to the Middle, and the Middle to the Lower.

Numerous small streams were probably involved and possibly several other divides were severed, but these were the main changes.

KANSAN (?) EPOCH.

The high stream terraces before described are the remnants of the floors of ancient valleys which had steep sides but broad, flat bottoms. The term Parker strath has been applied to the rock floor under the stream deposits, though the valley bottom represented by the upper surface of the terraces was even more strathlike. (See fig. 10.) It seems that at one time

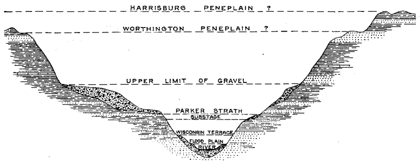


FIGURE 10.—Generalized section across the Allegheny Valley at Parkers Landing, showing various stages of erosion and valley fill. Vertical scale exaggerated five times.

all the larger valleys of western Pennsylvania displayed more or less strathlike features, for high rock terraces and abandoned channels are common and have long been recognized.

Origin of the high terraces.—The origin of the high terraces and abandoned channels and their gravels has been much discussed. Stevenson in 1879[a] called attention to benches along the valley of the Monongahela and its tributaries. He divided them into a higher series of twenty benches and a lower one of five. The higher benches do not bear gravel and were attributed to marine action. They are probably entirely above those now being discussed, and later study of them has shown that they are obscure and are probably due to hard layers of rock. The lower series of Stevenson seems to include the benches here discussed, and he refers them to stream action, without going into details of development.

In 1883 G. F. Wright[b] presented evidence of a large ice dam at Cincinnati, and shortly thereafter I. C. White[c] referred the terrace deposits of the Monongahela to that dam.

T. C. Chamberlin in 1890[d] showed that the upper series described by Stevenson could not be ascribed to the ice dam because of their great range in altitude. He pointed out also certain features of Stevenson's lower series which indicated that they were formed by streams, not lakes. He noted that—(1) the terraces slope with the present streams; (2) the material capping the terraces is distinctly fluvial; (3) they are rock platforms; (4) the form and the distribution of the terraces indicate fluvial, not lacustrine origin; (5) the abandoned channels must have been of stream origin.

In 1896 White expressed himself[e] as still convinced that the glacial Lake Monongahela did exist and that it formed the terrace deposits, but that the ice dam was probably in the vicinity of Beaver, Pa., and not at Cincinnati.

In the Masontown-Uniontown folio, published in 1902, M. R. Campbell advances the theory that the deposits and abandoned channels are due to local ice dams formed in Kansan (?) time. He points out the fact that it is an extremely difficult and slow process for a stream to cut off any of its meanders in a rugged region like Pennsylvania, and that in such a region it is impossible for a stream to establish a totally new course unless the conditions are very different from those which normally affect the development of streams.

Mr. Campbell's idea is that ice jams formed in glacial time, that these grew until they formed huge dams 100 or more feet high, that they persisted for centuries until deposits over 100 feet thick accumulated above them, and that many of these dams caused the rivers to abandon their old beds and cut new ones.

In the Amity folio F. G. Clapp expresses the belief that I. C. White's theory—that of ponded waters throughout much of western Pennsylvania—will best account for the phenomena. He points out the fact that the upper limit of the stream deposits in all the valleys of southwestern Pennsylvania and parts of adjacent States has a vertical range of but little over 100 feet. But in the survey just completed the gravel is found on Clarion River at an elevation of over 1180 feet, making the vertical range about 200 feet.

In the region about Foxburg the terraces are very well developed and preserved, and one of the much-discussed abandoned channels or oxbows lies just across the river from Parker's Landing, about 260 feet above the present stream channel. The region has been visited and studied by J. P. Lesley, H. M. Chance, G. F. Wright, T. C. Chamberlin, G. K. Gilbert, M. R. Campbell, E. H. Williams, Frank Leverett, and others.

[a] Proc. Am. Philos. Soc., vol. 18, pp. 289-316.
[b] Am. Jour. Sci., 3d ser., vol. 26, pp. 44-56.
[c] Proc. Am. Assoc. Adv. Sci., vol. 32, pp. 212-213.
[d] Bull. U. S. Geol. Survey No. 58, pp. 13-38.
[e] Am. Geologist, vol. 18, December, 1896, pp. 368-379.

Parker oxbow.—The old oxbow at Parker's Landing was first described by Chance,[a] who calls attention to the disproportionate size and breadth of the valleys to the two small streams which now flow in them from the oxbow and also to the fact that between the heads of the streams there is low, swampy ground. Glacial gravel of probable Kansan age is found almost continuously around the loop and in some places the deposit is over 50 feet thick. Chance inferred that at the time of the earliest ice advance this oxbow was occupied by Allegheny River and that at a subsequent time the neck was severed. G. F. Wright held that this channel was formed and abandoned before glaciation, and that the glacial material now found in the oxbow was deposited there at a time when the Allegheny, being overloaded with Kansan outwash, aggraded up to the level of the oxbow; that the gravel was carried into the ends of the loop, but that the river never reoccupied the entire loop. Wright has long advocated the idea that the Allegheny was cut in preglacial time to a level about 50 feet below its present channel, and that the Kansan valley train was thus about 350 feet thick, filling the inner gorge and part of the broad valley above.

Chamberlin and Gilbert studied the problem in 1889, and their conclusions[b] agree with those of Chance. In 1900 E. H. Williams[c] agreed with Wright that the river has not occupied the oxbow since the beginning of the glacial period, but he went so far as to hold that the river never flowed around the so-called oxbow. He ascribes the feature to the work of two small streams which "rise on opposite sides of a low col and debouch into the Allegheny gorge within a mile of one another, and in glacial time these two valleys were filled by overwash deposits mingled with material from the immediately adjacent slopes." He states also that the rock floor of the abandoned channel is not horizontal but slopes steeply toward the river.

Frank Leverett[d] considers E. H. Williams's view "more consistent with the features than the one presented by Chance."

The data gathered for this folio indicate, first, that the so-called Parker oxbow is an abandoned channel of Allegheny River and so is properly called an oxbow. The considerations which force such a conclusion are these: (*a*) The depression has a comparatively uniform width of about a mile, the bounding walls are from 100 to 300 feet high, the two small streams that drain it rise in a swamp, and these are the only two streams that rise in an area of swampy ground in the whole quadrangle; (*b*) the shape is that of a broad, smooth curve, with the side of the valley inside the loop gently sloping and that outside high and steep like the present valley around curves of the river—for example, the curve of the Clarion 1 mile south of Turniphole; (*c*) a current with something like the strength of a river must have flowed around the bend, for pebbles up to 6 inches in diameter are found at the most extreme part of the loop.

The data indicate, second, that the abandoned channel was occupied in a part of Kansan time. The presence of Kansan outwash on the floor, which is at nearly the same elevation as the floor under Kansan material nearby, indicates that the last great event before the abandonment of the oxbow was the advance of the Kansan ice sheet. The abandonment took place before the stream began to cut down again, for deposits are found around the loop almost as high as the highest gravel. The broad valley around the oxbow was cut before this time. One can only conjecture how long a period was necessary for this. There is some evidence that the rock floor of the east end of the loop is higher than the Parker strath. If this be true the oxbow must have been developed either in pre-Kansan time, before the stream had cut as low as the Parker strath, or after the Allegheny had aggraded until it was high enough to take this route. However this may be, the close association of the abandoned channel with the high terrace and the occurrence of Kansan material in the channel show that it was occupied and abandoned in Kansan time.

It appears, third, from the length, depth, and narrowness of the rock channel through which the river now flows across the neck of the oxbow, that the oxbow was not cut off in the way that stream meanders are ordinarily cut off; the evidence points rather to superposition of the stream. The present valley across the neck of the abandoned channel is a narrow rock gorge over a mile long, and the top of the gorge extends up to the level of the highest part of the old channel.

Origin of the high terraces of the Foxburg and Clarion quadrangles.[e]—In regard to the Allegheny Valley certain facts seem well established. The high terraces are rock shelves about 170 feet above the present stream, capped with 1 to 125 feet of deeply decayed gravel, sand, and clay, that were carried in by streams from an ice sheet, which was probably Kansan. The deposit slopes downstream from about 1145 feet at Parker to 1100 feet at Redbank. At many places it is 100 feet thick

[a] Second Geol. Survey Pennsylvania, Rept. VV, 1880, pp. 17-22.
[b] Bull. U. S. Geol. Survey No 58, 1890, p. 31.
[c] Bull. Geol. Soc. America, vol. 12, 1901, p. 463.
[d] Mon. U. S. Geol. Survey, vol. 41, 1902, p. 242.
[e] A more detailed discussion of the origin of the high terraces is published in the Journal of Geology, vol. 19, February-March, 1911.

and there is no doubt that the Allegheny at one time aggraded its channel to this depth. Considering the possible effects of erosion, including both surface wear and settling by solution, it seems not improbable that the original deposit may have been 150 feet thick.

The Parker strath or rock floor under the terrace deposit is uneven, and at several places the rock floor is higher away from the river than near it. This suggests that there was more or less lateral corrasion during the time of aggradation. It will thus be seen that the lower Allegheny Valley at the time of the first ice advance may have been narrower than the present width of the Allegheny Valley above the Parker strath.

The history of the Allegheny Valley below Foxburg seems to be about as follows: At the opening of the glacial period the stream had about the same position as the present 1000-foot level, 300 to 500 feet or more below the uplands. The site of the gorge of the Allegheny above Foxburg was occupied by a small tributary. The Kansan ice sheet caused an enlargement of the drainage basin and of the volume of the stream. Figure 10 shows the local drainage changes. The new river from the north was cutting a new valley and carried débris into the old valley, where the gradient of the stream was lower. In the old valley there was not only this large volume of material, but glacial outwash; and after the glacier melted away a new drainage basin was formed, comprising hundreds of square miles, covered with loose, easily transported glacial till, on which there were no established streams. Until the new river gorge was cut down nearly to the level of the old Allegheny River and drainage lines throughout the new part of the Allegheny basin were well established and had somewhat uniform grades great volumes of rock waste continued to be poured forth from the mouth of the new gorge into the old valley. Moreover, during the time when the glacier stood nearest this area, the efficiency of the river was lowered by the attraction of the ice mass. The change in water level produced by this attraction may have amounted in the Foxburg quadrangle to nearly half a foot per mile. Thus the Lower Allegheny was unable to carry the load thrust upon it and so swept along only a part of the waste, in general leaving the coarser part and carrying the finer, together with fine material derived from the weathering of its banks and the finer part of that which was brought to it by tributary streams.

As the new stream and its tributaries reached approximate adjustment, the volume of material brought to the Lower Allegheny diminished until the river was not only able to carry its load, but began to carry away part of the gravel which it had dropped. For a time it meandered about in its former deposits and formed the benches lower than the upper limit of gravel, one of the best of which is on the west side of the river 2 miles north of Parker's Landing and about 80 feet below the highest glacial gravel. Then followed the downcutting which produced the present gorge. The Allegheny may have aggraded at several times, perhaps at each ice advance, but little record of such aggradation is preserved except that of the Wisconsin stage. There are narrow interrupted terraces at several positions below the Kansan, and there are deposits of gravel about 40 feet above the river which are supposed to be a part of the gravel filling which took place in connection with the Wisconsin glaciation. The waterworn character of the quartz pebbles in the Carmichaels formation does not of itself prove that they were brought from a great distance, for they might have been derived from an existing conglomerate of well-worn pebbles, but no rock containing pebbles as coarse as these is found in the Clarion and Foxburg quadrangles, and probably not within 50 miles of them.

The mingling of the gravels of the Clarion and Allegheny rivers at the confluence of the two streams and the concordance of their upper elevations at that place indicates that they were developed at the same time. It is thought, however, that they are not due to the same cause, but rather that the gravel terraces on the Clarion were due to the building up of the stream into which it discharged. The mixture of pebbles showing varying degrees of wear—of angular bowlders with well-rounded pebbles from a distance—serves to distinguish this deposit from ordinary fluvial gravels in which the pebbles show an approximately uniform degree of rounding. There are many large angular sandstone bowlders which have scarcely been modified by the stream and which probably lie near their parent ledge in the valley wall.

As the top of the glacial valley train along the main stream rose the deposit on the Clarion grew thicker and lengthened upstream. This process continued until the Allegheny ceased to build up. The evidence that the valley train did not dam the Clarion and produce a lake lies in the fact that coarse materials are found throughout the Clarion deposits, especially at the base. The coarsest gravel seen was found at the upper end of the terrace at Canoe Ripple. The fact that the upper limit of gravel is not at the same elevation but rises upstream from 1145 feet near Foxburg to over 1180 feet near Callensburg, 8 miles upstream, of itself indicates that at least the upper part of the deposit was laid down by the stream.

If the terraces of the Clarion were above the Kansan material, their greater width, as compared with those of the Allegheny, might be explained by assuming an eastward tilting of the earth's surface in this region, decreasing the gradient of the westward-flowing Clarion and increasing the gradient of the southward-flowing Allegheny, but there should be other evidence of such a tilt, and such evidence seems to be lacking. Moreover, the close connection of these terraces with those of the Allegheny indicates that they are genetically closely related.

The thickness of the terrace gravels of Clarion River can be gotten only from well records, and reliable records are not abundant. There are enough, however, to show that the thickness varies greatly in short distances and to indicate that the filled part of the old valley of the Clarion was much narrower than the part above the fill. The present very crooked course of the stream and the terraces at many different elevations show that the stream has had much lateral swing, and it may be that much lateral corrasion took place while the Clarion was waiting for the Allegheny to carry out its load and resume the work of downward cutting.

The part which differing rock hardness has played in the development of the Clarion Valley has probably been considerable. The rock floor of most of the terraces is sandstone (Pocono or Pottsville), whereas the sides of the valleys above the terraces are composed largely of shale. South of St. Petersburg a heavy sandstone lies above the terrace levels, and here the valley is so much constricted that for a mile terraces are lacking. However, the narrower terraces of the Allegheny can not be accounted for by a difference in underlying rock, for the rocks are practically the same along both rivers.

Some lower terraces, such as the one 65 feet above the river southeast of Callensburg, may also have been cut at a time when the Allegheny was overloaded with later glacial débris, perhaps Illinoian. However this may be, it would seem that the overloading of the Allegheny in early glacial time must have lasted much longer than in any later epoch, for the higher terraces are much the wider.

The cause of the abandonment of the channel just southeast of Callensburg is not evident. It is fully 100 feet below the high terrace deposits and only 65 feet above the stream. The present gorge through the neck of the loop seems a little too narrow to have been cut through from one side by the river, but the neck is short. No evidence was found at this place either of an ice dam or of silting up and superposition.

There are but few terrraces on the Allegheny above the mouth of the Clarion. The gorge is very narrow, and its narrowness is due principally to its comparative youth, but the valley may be narrower than it would have been if the rock strata along its walls had been no more resistant than the underlying rock near Parkers Landing. Probably the most resistant rocks in the Foxburg quadrangle are the sandstones of the Pottsville and the Pocono in the vicinity of Emlenton. At Foxburg these sandstones are finely cross-bedded and much less coherent, while at Parkers Landing both the Pottsville and Pocono are composed largely of shale. Not only do these formations become more resistant to the north, but they are found at a higher elevation. At Parkers Landing the top of the Pottsville is 100 feet higher than the Parker strath, and it is 140 feet higher still at Emlenton.

The features of the high terraces and abandoned channels of the Foxburg quadrangle may be summarized as follows: There seems to be no evidence of local ice dams and no evidence of a general ponding of waters; on the other hand, no features were observed which could not be satisfactorily ascribed to aggradation and to the degradation which followed, together with the ordinary work of streams.

LATE GLACIAL AND RECENT EVENTS.

Since the high terraces were formed no extensive deposits have accumulated in the Foxburg and Clarion quadrangles, and the erosion which has taken place is shown clearly in the depths of the river valleys below the high terraces. The earth's surface in this region does not seem to have been deformed at all in Recent time, except, possibly, by a general uplift. The rock strata have never been greatly faulted or folded and the old stream deposits have a uniform slope. The deep river gorges indicate regional elevation, but the elevation may have taken place before or during the development of the high terraces.

The meanders of the rivers have been and are still increasing in size, as is shown very clearly by the gravel-bearing promontories on the inner sides of the bends, gently sloping from the high terrace down to the present channel, and by the steep wall of the valley on the outer sides of the bends.

Some other changes in drainage have taken place since early glacial time. One and one-half miles west of Turniphole are two small streams, the severed parts of a larger one which once flowed very near Clarion River and parallel to it, but the river valley widened as it deepened, and the river itself swung slightly toward the smaller stream, which was flowing in a shallow valley because it was unable to cut down as rapidly as the large stream. A gully or wash cut across the narrow divide which separated them and the small stream was beheaded.

Formerly Clarion River flowed almost completely around the high point of land on which Callensburg is situated, but before Wisconsin time the neck which joined this promontory to the high land on the north was severed, and the old course was left an abandoned channel or oxbow.

Still another change involved Mill Creek, in the northwestern part of the Foxburg quadrangle. This stream formerly discharged into the river at Dotter station, having a course parallel to the river, similar to the stream near Turniphole. Here the river swung laterally, captured the small stream, and gave it an outlet $1\frac{1}{2}$ miles above its old one. The river absorbed about a mile of Mill Creek valley and is now unusually wide at this place, while immediately above Dotter a high isolated hill separates the old valley of the tributary from the present river valley.

Before the last glacier advanced the Allegheny had cut probably 40 or 50 feet lower than its present channel, for it now flows not over bedrock, but over a gravel deposit 40 to 50 feet thick. The Wisconsin ice sheet again overloaded the stream and its channel seems to have been buried under nearly 100 feet of gravel, but the valley was narrow and this body of gravel was not nearly so great as the volume of the Kansan outwash. The latest work of the Allegheny has been cleaning this Wisconsin glacial débris from its valley—a work which is not yet completed.

MINERAL RESOURCES.

The mineral resources of the Foxburg and Clarion quadrangles include coal, oil, gas, clay, shale, iron, limestone, sandstone, sand, gravel, soil, and water.

COAL.

Mines have been opened on no less than eleven different beds of coal, four of which, the Lower Clarion, Lower Kittanning, Lower Freeport, and Upper Freeport, are known to be of workable thickness throughout considerable areas. Openings have also been made on the Mercer, Brookville, Craigsville, Upper Clarion, Middle and Upper Kittanning, and Mahoning coals. The following figure shows representative sections of the more valuable beds.

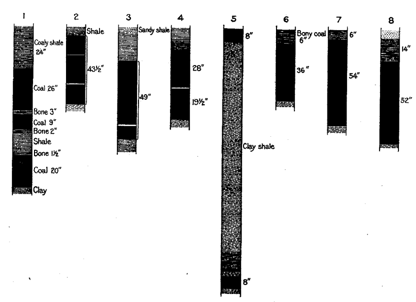


Figure 11.—Sections of coals in Foxburg and Clarion quadrangles.

1. Clarion coal, one-half mile south of Bruin.
2. Lower Clarion coal, 1 mile northeast of Emlenton.
3. Upper Clarion coal, Richland Coal Co. mine, St. Petersburg.
4. Lower Kittanning coal, Catfish mine.
5. Lower Kittanning coal, 3 miles north of Callensburg.
6. Lower Kittanning coal, one-half mile west of Frampton.
7. Upper Freeport coal, 2 miles northeast of Petrolia.
8. Upper Freeport coal, 1⅛ miles northeast of Truittsburg.

Scale: 1 inch=5 feet.

A bulletin on the coal, oil, and gas of the Foxburg quadrangle is in press[a] and on this account the present discussion will not be as extended as might otherwise be warranted.

MERCER COAL BEDS.

The Mercer coal beds are thin and shaly and are consequently of little value. At several places—as, for example, 1 mile southeast of Callensburg—drillers report a bed of black, carbonaceous material 4 to 8 feet thick at the position of the Mercer, but no such thickness of Mercer coal was seen in outcrop, and it seems probable that the carbonaceous bed is black shale or shaly coal and not good coal. The Mercer seems to be best developed and the coal thickest along a belt extending from Callensburg to Parkers Landing.

BROOKVILLE COAL.

The Brookville coal is somewhat thicker on the average than any of the Mercer coal beds, but is generally too thin to be workable. In many places it is broken up by thick partings, and in some places its sulphur content is large.

In the northeast corner of the Clarion quadrangle, near its type locality, the Brookville coal is $4\frac{1}{2}$ feet thick. In a country bank 2 miles southeast of Madison schoolhouse it measures 2 feet 9 inches, including a 7-inch parting of shale and pyrite in the middle. The Brookville coal is also exposed in a bank 2 miles west of Williamsburg, where it is 2 feet 4 inches thick. Another small drift on the Brookville coal is on the Russell farm, 3 miles southeast of Emlenton. At this place the coal is over 15 inches thick and parts of the bed resemble cannel.

At many places the Brookville is divided into several members or benches, notably in the vicinity of Knox, where the distance from the top of the highest bench to the bottom of the lowest is apparently 15 feet. Other sections, particularly those measured in the vicinity of Shippenville, show a similar division of the coal, but toward the south the partings decrease in thickness and disappear.

CRAIGSVILLE COAL.

Except in one or two small areas the Craigsville coal is of no economic value in these quadrangles. Where seen and recognized it ranges in thickness from 3 inches to 38 inches. Southeast of Knox there are several abandoned prospects on this bed, in which the coal is reported to be 3 feet thick. Its greatest thickness observed in the Foxburg quadrangle was in the weathered outcrop 1 mile east of Callensburg, where it measures 20 inches. At Sligo there are two mines on this coal, which is here about 3 feet thick.

LOWER CLARION COAL.

The Lower Clarion coal is sulphurous and carries one or more binders, but it is 2 to 7 feet thick, is persistent, and is the most extensive and valuable bed in the Foxburg quadrangle. It probably underlies the whole quadrangle except where it has been removed by erosion. The bed contains a large amount of iron pyrites or sulphur—so large that it serves to identify the coal and has given rise to the name "Sulphur vein."

In the northern part of the Clarion quadrangle the coal lies below a heavy sandstone, which makes a strong roof. There is, however, a shale or clay between the coal and the sandstones, which ranges in thickness from a few inches to 2 feet. The sandstone forms a marked physiographic feature in this area, and its benches indicate clearly the horizon of the coal. There is such a bench at the northeast edge of the town of Clarion, and another is prominent south of the pike about one-half mile east of Clarion Junction.

In the southern half of the Clarion quadrangle the Lower Clarion coal is generally thin, but in openings 1 mile south of New Mayville and 3 miles west of New Bethlehem it measures 26 and 27 inches, respectively.

UPPER CLARION COAL.

The Upper Clarion coal, which seems to be a split from the Lower Clarion, is present throughout much of the area and is locally minable. In the southwest corner of the Foxburg quadrangle the Clarion coals form a single bed but elsewhere in the quadrangle they consist of two beds (the Upper Clarion and the Lower Clarion) which generally are about 10 feet apart—too far to premit both to be mined from the same opening. Between Parkers Landing and St. Petersburg the coal is in places nearly 5 feet thick and has been shipped from two mines.

LOWER KITTANNING COAL.

In the Clarion quadrangle and the southern half of the Foxburg, the most important coal is the Lower Kittanning. It is persistent and uniform in thickness throughout wide areas. No regular partings occur in the coal and the irregular partings are thin, few of them being over half an inch thick. In about half of the sections measured no bedded impurities were noted. In the others a splinty binder, one-half to $2\frac{1}{2}$ inches thick, occurs from 6 to 12 inches below the top of the coal. It is readily distinguished on fresh surfaces of the coal, but in mining no attention is paid to it.

The average thickness of the Lower Kittanning coal is 3 feet, as shown by measured sections in the Clarion quadrangle and the southern part of the Foxburg quadrangle, but its upper part, which generally consists of clean coal, is 32 to 34 inches thick. In the northern part of the Foxburg quadrangle the coal is broken up by partings and over considerable areas is thin or absent. In the vicinity of Emlenton there is scarcely a trace of it.

Wherever seen, the bed has a shale roof and clay floor. Analyses of the coal generally show that it is high in sulphur and moderately high in ash, but it contains less sulphur and is more valuable than the Clarion coals. In the vicinity of Wentlings Corners it is unusually free from sulphur and has been used as a blacksmith coal.

Over the greater part of the region the coal bed is in such a position that it can be mined by drifting. In the northern third of the area it is found only in a few isolated patches, and these are now practically worked out, but south of a line drawn through Clarion and Parker the coal bed occurs in nearly all the hills.

As noted under the heading "Geology," there is an area several miles wide between Leatherwood and Frampton where

[a] Bull. U. S. Geol. Survey No. 454, 1911.

there are no openings on the Lower Kittanning, and in this region the coal is probably not thick enough to be mined profitably. On the J. H. Strickler farm, 3 miles south of Clarion, an opening has been made on a coal which appears to be the lower of the two beds assigned to the Lower Kittanning horizon in the geologic section.

From Sligo northward to Clarion River there appears to be nothing but clay between the two beds, but in the northeast corner of the Foxburg quadrangle there are two coal beds separated by shale and sandstone near the position of the Lower Kittanning. The upper one is the more valuable and shows very unusual local dips. Near Wentlings Corners there is said to be a drop of 30 feet in a distance of 40 rods.

Much of the coal that is shipped from these quadrangles is taken from the Lower Kittanning bed. It is used as a domestic and steam coal in northwestern Pennsylvania and western New York, and a small amount goes to Canada.

MIDDLE KITTANNING COALS.

As already stated, there are in the Clarion quadrangle two coals between the Lower and Upper Kittanning, and a few local mines are opened on each of them. In these mines the coal is from 2 feet to 2 feet 4 inches in thickness, except in a bank on the upper coal about 1 mile north of New Bethlehem, where it is 4 feet thick and of excellent quality. In the central and southwestern part of the Foxburg quadrangle the Middle Kittanning is 12 to 30 inches thick, averaging about 16 inches. It is commonly held as a reserve supply by farmers when they sell the Lower Kittanning. There are several small country banks on this coal.

UPPER KITTANNING COAL.

The Upper Kittanning coal is variable in thickness and quality and is worthy of the name "Pot vein," by which it is also known. Except for one or two banks this coal is found only in the southern half of the quadrangle. In most of the few openings it is thin and dirty, but in a bank 2 miles north of New Bethlehem it is 3 feet thick. Near Petrolia also it is minable, but in one place its thickness decreases in 200 yards from 5 feet 6 inches to 7 inches.

LOWER FREEPORT COAL.

The Lower Freeport coal has been worked commercially only in the vicinity of New Bethlehem but has been opened in a number of country banks. This coal is absent from large areas and where present it is generally too thin to be mined. In the New Bethlehem region the coal ranges in thickness from 3½ to 7½ feet and is of good quality, but it is nearly worked out.

About 3 miles southeast of West Freedom the Lower Freeport coal is known as the "Willcott vein." It is mined here in several country banks and its quality is, as usual, very good, but a parting of shale about 2 feet thick separates the coal into two benches, each about 2 feet thick.

UPPER FREEPORT COAL.

Next to the Lower Kittanning and Clarion coals the Upper Freeport is the most valuable in the Foxburg quadrangle. It is persistent and is of minable thickness in perhaps half of the area in which it occurs. There are no shipping mines on this coal, but in the vicinity of Redbank, just south of the area, it has been mined extensively for the last fifty years, and much of it has been coked. The coke was not of superior quality but was used in iron smelting. The Upper Freeport is found near the tops of the hills; consequently it occurs in many isolated areas and its outcrop is long and irregular. It is extensively worked in the vicinity of Rimersburg and near Baldwin.

In the Clarion quadrangle the Upper Freeport coal, besides being worked in approximately the same areas as the Lower, is also opened in the hill 2 miles north by east from Truittsburg; in the ridge 2 miles west of this town; on the Clarion-Redbank divide, 1½ miles west of Sloan Gap; and in Myers Hill, 2½ miles south by east from Sligo. All the openings are on small bodies of coal, near the hilltops. The thickness ranges from 3½ to 5½ feet.

MAHONING COAL.

The Mahoning coal seems to be unworkable in these quadrangles. It has been prospected near Queenstown and 3 miles southeast of West Freedom, where it is known as the "Second Summit vein." But the coal lies under light cover and scarcely reaches workable thickness. It is, however, reported to be of very good quality.

COAL ANALYSES.

The following analyses of coals were made at the United States Geological Survey's fuel-testing plant at St. Louis, Mo., from samples properly cut and quartered in accordance with the practice of the Survey, and shipped in air-tight cans.

Analyses of coal samples from Clarion quadrangle, Pennsylvania.

	Upper Freeport.		Lower Freeport	Upper Kittanning.		Lower Kittanning.				Clarion.	Brookville.
	A.	B.	C.	D.	E.	F.	G.	H.	I.	J.	K.
Laboratory No.	4111.	4171.	4172.	4176.	4177.	4116.	4170.	4055.	3951.	4173.	3953.
Analysis of sample as received:											
Moisture	3.98	5.56	3.30	5.89	4.09	2.87	2.73	4.09	3.36	4.84	2.35
Volatile matter	33.70	30.72	33.79	30.46	30.24	34.51	34.77	34.79	35.94	37.86	37.47
Fixed carbon	54.50	57.14	56.83	48.66	57.37	54.31	52.20	55.32	52.05	50.28	49.01
Ash	7.82	6.58	6.08	14.99	8.30	8.31	10.30	5.80	8.65	7.02	11.17
Sulphur	2.18	1.10	2.73	1.60	1.01	1.36	3.66	2.39	2.30	3.93	4.04
Loss of moisture on air drying	2.30	3.30	1.80	3.90	2.10	1 00	1.30	2.60	1.70	3.20	1.10
Analysis of air-dried sample:											
Moisture	1.72	2.34	1.53	2.07	2.03	1.89	1.45	1.53	1.69	1.69	1.26
Volatile matter	34.49	31.76	34.41	31.70	30.89	34.86	35.23	35.72	36.56	39.11	37.89
Fixed carbon	55.79	59.09	57.87	50.63	58.60	54.86	52.89	56.80	52.95	51.95	49.56
Ash	8.00	6.81	6.19	15.60	8.48	8.39	10.43	5.95	8.80	7.25	11.29
Sulphur	2.23	1.13	2.78	1.66	1.03	1.37	3.71	2.45	2.43	4.11	4.08

A. Two miles south of Sligo.
B. Three miles northeast of New Bethlehem.
C. Three miles northeast of New Bethlehem.
D. Five miles southeast of Sligo.
E. One mile northwest of New Bethlehem.
F. Two miles southeast of Strattonville.
G. One mile north of Oak Ridge.
H. One mile south of Rimersburg station.
I. At Sligo.
J. One and one-half miles northwest of Clarion.
K. At Sligo.

PETROLEUM AND NATURAL GAS.

The Clarion and Foxburg quadrangles lie within the great petroleum and natural gas region of western Pennsylvania, and from this area enormous quantities of both of these products have been obtained. Drilling was begun here as early as 1865, when a well was sunk on Clarion River at the mouth of Deer Creek, in which oil was found. Between 1865 and 1870 a number of wells were drilled at that point, some of which flowed oil in small quantities. Several hundred barrels of this oil were shipped by barges to Pittsburg. The wells were not cased and much trouble was experienced with salt water; the wells produced only for a short time, until the gas pressure was relieved, and were then drowned out. The development of the larger pools began at Foxburg in 1869, when the first well in the great Petrolia-Elk City field was completed. Soon after this well was brought in another was drilled at the head of Armstrong Run, in Perry Township, Armstrong County, which began flowing at the rate of 2000 barrels per day. These wells initiated one of the great oil excitements, which have frequently occurred in Pennsylvania since Drake's discovery at Oil Creek in 1859. Development work was so rapid that as early as 1875 the great Petrolia-Elk City and the Cross Belt fields were fairly well outlined, and more than 1700 wells had been drilled having a total daily production of more than 20,000 barrels. Since that time thousands of deep wells have been sunk in these quadrangles, both in search of new pools and in retesting areas partly depleted during the early oil excitement. This drilling has thoroughly tested most of this territory, though there still remain a number of small isolated a reas which may be found to contain pools of considerable value.

The oil and gas is found in greater or less quantities in nearly all of the sandstones from the base of the Burgoon down to and including the oil sands at the top of the Portage (?) formation, which are believed to represent the Bradford oil sands.

Practically all of the oil and most of the gas found in commercial quantities occur, however, in the Venango oil sands of the Catskill (?) formation and the lower Pocono. Named in the order of their productiveness these are the Third or Gordon, Fourth, Hundred-foot, Third Stray or Gordon Stray, Murrysville, Bowlder, Nineveh Thirty-foot, Fifth, and First sands. The Speechley, Tiona, and Bradford (?) sands are exclusively gas producers in these quadrangles, though an oil pool of considerable value occurs in the Speechley just beyond the western border of the Foxburg quadrangle in the vicinity of Baldwin. From the maps showing the oil and gas pools, it may be seen that most of the great oil pools are confined to the Foxburg quadrangle and that the largest distinct gas pools occur toward the eastern border of the Clarion quadrangle, where the folding is more pronounced. In a general way the tendency of the oil pools to lie west of and apart from the great gas producing areas is characteristic of these accumulations throughout the entire Appalachian region and especially in Pennsylvania. The geologic reasons for this tendency are not apparent.

POOLS IN THE BRADFORD (?) SANDS.

So far as known the two sands that are called by the drillers in this region the First and Second Bradford sands contain no commercial oil pools in the Clarion and Foxburg quadrangles, though small quantities of oil have been reported in them in several wells. The principal gas pools in these sands are in the central part of Monroe Township, Clarion County, and in the Greenville field, which is located along the crest of the Kellersburg anticline in Limestone Township. In these areas a number of good gas wells are producing from each of the Bradford (?) sands. Where productive the sands range from 15 to 60 feet in thickness. The initial closed pressure of the gas generally ranges from about 300 to more than 400 pounds per square inch. Some of the better wells had an initial daily capacity of probably more than 1,000,000 cubic feet.

In addition to these pools a number of wells, widely scattered over both quadrangles, produce more or less gas from these sands. Of these wells a number occur in the eastern and central portions of Clarion Township and a few others in the Bittenbender and Piolett fields of Porter Township. In the Foxburg quadrangle a few wells get small quantities of gas from the Bradford (?) sands, but these wells are of little importance.

POOLS IN TIONA SANDS.

The first well-recognized sand above the Bradford (?) oil sand group is called the Tiona sand. The distance between them is about 150 feet. In northwestern Pennsylvania this sand has produced enormous quantities of both oil and gas, but in the Foxburg and Clarion quadrangles it is barren except in two or three small gas wells in Limestone Township, Clarion County. Small quantities of gas have been found in this sand at a number of other places in both quadrangles, but so far as known the amount was too small to be utilized. The Tiona sand is fairly continuous throughout both quadrangles, though generally too fine grained and hard to afford a good reservoir for either oil or gas.

POOLS IN THE SPEECHLEY SAND.

The Speechley sand, which lies about 100 feet above the Tiona, does not furnish oil in paying quantities in these quadrangles. It is, however, an important source of gas throughout the whole area, though nearly all the larger pools have been found in the Clarion quadrangle. Most of this gas comes from a depth of 2000 feet to 2400 feet and has a closed pressure ranging from 400 to more than 900 pounds per square inch. The initial daily production of some of these wells is reported to have been more than 10,000,000 cubic feet.

The Greenville field on the crest of the Kellersburg anticline is the largest pool in this sand. The Kifer pool in Monroe Township, the Leatherwood field of Porter Township, and a number of wells in Paint Township have furnished considerable quantities of gas from this sand. In the Foxburg quadrangle numerous small pools of gas under high pressure have furnished many good wells at a number of places throughout the area. The sand is almost invariably found to carry gas in greater or less quantities, the amount depending on its thickness and porosity.

POOLS IN THE FIFTH SAND.

There is some doubt as to the correct identification of the Fifth sand by drillers in most of the wells where it is recorded. This sand is generally thin and of little importance for either oil or gas. The Exley oil pool, in the northwest corner of Beaver Township, Clarion County, is the only oil reported in this sand, though it is highly probable that several other small pools have been overlooked in areas where better pools occur in other sands. Gas is found in small quantities in the Fifth sand at several points, but the total production from that source is small.

POOLS IN THE FOURTH SAND.

With a single exception the Fourth sand is the most prolific source of oil and gas in this area. From it came most of the tremendous flow of oil yielded by the great "Cross Belt" pool of Armstrong and Butler counties, in the southwestern part of the Foxburg quadrangle. Many of these wells produced from 1000 to 2000 barrels of oil per day, the maximum daily output of a single well being about 3000 barrels. In the Petrolia-Elk City oil field are a number of important oil-bearing areas in the Fourth sand which are so closely associated with the Third sand pools that they can not now be accurately outlined. One of these is the Triangle pool, which furnished wells with an initial daily production of 100 to 400 barrels. Some Fourth sand oil is also found in the Emlenton-Richey Run field. The Miola pool, in Paint and Highland townships, Clarion County, is said to furnish oil exclusively from the Fourth sand. In this instance the writer doubts the correctness of the drillers' correlation. In this pool and in the Clarion pool the Fourth sand is said to be separated from the Third sand above by only a few feet of shale, and in places drillers report that the sands are united. Taking all the available stratigraphic evidence into account it seems probable that these two sands represent more nearly the Third sand and Third Stray sand. Oil was discovered in the Miola pool in December, 1906, when a well which had been producing gas for eight years from the upper of the two sands mentioned above, which is probably the Third Stray, was drilled 10 feet deeper, through 2 feet of shale into the so-called Fourth sand. This well began flowing at the rate of 80 barrels per day. Aside from this questionable Fourth sand production, no oil has come from this sand in the Clarion quadrangle, except in a few small wells in the Shamburg field, Piney Township, where the same doubt exists as to the correct identification of the sands. Gas in paying quantities has been found in a number of scattered wells throughout both quadrangles. The maximum closed gas pressure in this sand was about 500 pounds per square inch.

POOLS IN THE THIRD OR GORDON SAND.

The sand generally called by drillers the Third sand has been the source of an enormous supply of oil within these quadrangles. This sand has been found to be oil-bearing in a belt from 1 to 3 miles wide extending from Petrolia in the southwest corner of this area northeastward to Elk City, just outside the opposite corner of the Foxburg quadrangle. This field has been opened up since 1875. The first well was drilled at Foxburg in 1869. Hundreds of these old wells are still producing after 30 years of steady pumping.

The Emlenton-Richey Run field also gets most of its oil from the Third sand, as do also the Bly and Beals pools, farther north. The Elk City pool embraces the northwest corner of the Clarion quadrangle and extends some distance farther north. Most drillers report that the oil sand in this pool is the Third and that the Fourth lies a few feet below. These sands are more comparable, however, to the Third Stray and Third sands. The same sand is productive in the Clarion pool, and in both places the lower (Third) sand yields considerable salt water and little or no oil. The Clarion pool was discovered in 1888 and in that year attained its maximum daily production—about 3000 barrels. The largest well produced at the rate of 90 barrels per hour for a short time. It is said that the pay streak is very erratic in this pool. The lower sand, called by drillers the Fourth sand, appears to furnish the salt water which is slowly encroaching upon and flooding the oil wells in the sand above, thus rendering them worthless. This is the only instance noted in either quadrangle where the salt water in the oil sands appears to advance upon the oil in such quantities as to injure the wells. In the Elk City, Manor, and other pools where water occurs in the Third sand, it is slowly exhausted with the oil and is thought to increase the life of a well, those producing the most water being the best wells.

The Manor pool is situated in the southwest part of Paint Township, Clarion County. This pool embraces less than a dozen wells scattered over about 100 acres. The largest well had an initial production of about 60 barrels per day and held that rate for about one year. No records of wells in this pool are available. The oil is generally thought by drillers to come from the Third sand. Less salt water is found with the oil in this pool than at either Elk City or Clarion, which are structurally higher. The Shamburg pool also furnished a few small wells from a sand believed by drillers to be the Third. The total production from this pool, however, has been small. In Monroe Township near Reidsburg several wells have found small quantities of oil, some of which is said to come from the Third sand, though from the available data it seems probable that the oil-bearing sand belongs higher in the geologic column.

Gas occurs in the Third sand in all of the oil pools but usually in quantities too small to justify piping away. Large quantities are utilized in boilers and gas engines and for domestic purposes in the oil fields. This gas, however, has a low closed pressure and hence can not be profitably utilized in the large high pressure pipe lines. In the southeast half of the Clarion quadrangle, however, there are several small gas pools in the Third sand which have an initial closed pressure of 180 to 275 pounds per square inch, the average probably being below 200 pounds. Most of the gas from the George pool in Limestone Township, as well as the gas from a number of scattered wells in Porter, Monroe, Toby, Madison, Richland, and Salem townships, Clarion County, is thought to come from the Third sand.

POOLS IN THE THIRD STRAY SAND.

The oil and gas pools in the Third Stray sand are so closely associated with those of the Third sand that no separation can be made with the available data. In general, the oil pools in the true Third Stray are far less in number and in productiveness than those of the Third. It seems probable that in many cases the Third and Third Stray have been confused by drillers, production being accredited to one which came from the other.

POOLS IN THE BOWLDER AND THE NINEVEH THIRTY-FOOT SANDS.

These sands occupy a part of the interval between the top of the Third Stray sand and the bottom of the Hundred-foot sand. There is much confusion among drillers as to the application of these names and it is not possible to find the same usage among drillers even in small pools. This is due to the variability of the sands themselves and to that of the shale and red rock which separate them. These sands are oil-bearing at many places within the Petrolia-Elk City field, the largest pools probably being along the southwest margin in the vicinity of Bruin. A sand generally recognized by drillers as the Bowlder furnishes oil in a large number of wells along the northern margin of the Emlenton-Richey Run field, and in occasional small pools throughout most of that field. This sand is especially productive in the vicinity of Mariasville and to the east of Lamartine. Gas is found in both of these sands at many places in the northwestern half of the Foxburg quadrangle, but the pools are generally small. In the Clarion quadrangle no oil pools are known in these sands and the production of gas is of little importance, being confined to a few scattered wells.

POOLS IN THE HUNDRED-FOOT AND THE MURRYSVILLE SANDS.

The top of the Hundred-foot sand in the Clarion quadrangle is about 350 feet above the Third sand. This sand has an average thickness here of about 100 feet and is divided near the center into two fairly distinct sandstones by a "break" of shale ranging from almost nothing to 50 or more feet in thickness. The Murrysville sand averages about 25 or 30 feet thick in this quadrangle, its top averaging about 85 or 90 feet above the top of the Hundred-foot. These sands are best developed in the southeast half of the Clarion quadrangle. They thin out quite rapidly toward the north and west so that in the Foxburg quadrangle the individual members are represented in some places by a number of thin lenticular sands, and in other places one or more of the three sandstone beds is entirely replaced by sandy shale alternating with thin, hard layers of sandstone.

In the Foxburg quadrangle the Hundred-foot and Murrysville sands therefore lose their identity to a great extent and are grouped by drillers as the Second sand. In so grouping this sandstone phase of the lower Pocono rocks some of the drillers confuse the lower member of the Hundred-foot sand with the Nineveh Thirty-foot sand, or, less frequently, with the Bowlder sand. In a few instances the name Red Valley sand has also been applied to what seems to be the lower member of the Hundred-foot sand, but this may be more nearly equivalent to the upper member. What many drillers here call the Second sand may be more nearly comparable to the Murrysville sand than to the upper member of the Hundred-foot. So much confusion exists among drillers as to the proper names of these sands that no exact correlation is possible from the available well records, as may be seen by an examination of the plate of well sections. The pools of oil and gas found in them, some of which are important, are therefore considered as being in the sands to which they are assigned by producers.

The Hundred-foot has not been found to contain oil in paying quantities within the Clarion quadrangle, though good shows have been found at various points, especially in the Piolett field and the Blair pool in Porter Township. Most of the gas found within this township comes from those sands, the Bittenbender pool being the most productive of these yet discovered. The gas wells in the extreme southeast corner of the quadrangle are said to produce from both the Hundred-foot and the Murrysville, and the latter sand yields a large percentage of the gas from the Greenville field and from a number of the wells in Clarion Township south of Strattonville. These sands appear to be practically barren in the northwest half of the Clarion quadrangle, in which area they are thin and less porous.

The Rosenberry, Rattlesnake, and Black Hill pools have furnished most of the oil found, though numerous smaller pools within and near the Petrolia-Elk City field have also proved profitable. The oil-bearing sand of the Black Hill pool, as well as that of a small pool northeast of Pollock, is locally known as the Red Valley sand. The stratigraphic evidence is not conclusive on this point, but it seems very probable that this sand is part of what the drillers call the Second sand, though a closer correlation can not be made. Most of the gas from the pool lying north of the Emlenton-Richey Run field comes from what is called by drillers the Second sand, as well as an immense amount from oil wells in both the above field and the Petrolia-Elk City field.

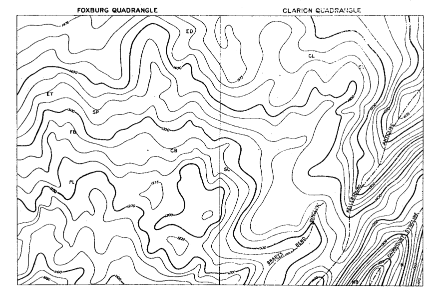
In the Foxburg quadrangle the oil-bearing areas in the Murrysville and Hundred-foot sands also almost invariably carry more or less salt water, which is exhausted with the oil. So far as known to the writer, however, this water has in no well encroached upon the oil with pumping to the exclusion of the oil. In general the best oil wells in this sand appear to be those that furnish the greatest amount of salt water. In the Clarion quadrangle both the Murrysville and Hundred-foot sands in places contain salt water in considerable quantities and under sufficient head in some wells to cause it to rise several hundred feet in the wells.

POOLS IN THE FIRST SAND.

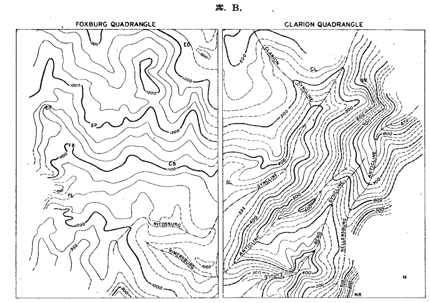
The top of the First sand is about 150 to 200 feet above the top of the Murrysville sand in the Clarion quadrangle. The sand has an average thickness of about 65 feet. Small gas pools have been found in this sand at a number of places in both quadrangles, but the total production has been of little importance. The sand is also frequently found to carry more or less salt water. Above the First sand no oil and little gas have been discovered in this area. Some gas has been found in other thin sandstones that are thought to belong to the Cuyahoga formation and in the Big Injun sand, but not in sufficient quantities to justify exploitation for commercial purposes.

RELATION OF STRUCTURE TO THE ACCUMULATION OF OIL AND GAS.

The oil pools of the Foxburg and Clarion quadrangles show no marked relation to the structure of the rocks. Individual pools appear to be somewhat affected by the structure but these instances of apparent conformability are so rare and insignificant in comparison to the total productive territory in the quadrangles that in such cases the position and extent of the pools is probably only slightly, if at all, the result of structural influence. The structure of the oil-bearing rocks is shown by contours in figure 12, which also shows, for comparison, the structure in the surface rocks.



B.



A.

FIGURE 12.—Structure of the oil-bearing sands and of the rocks at the surface of the Foxburg and Clarion quadrangles. Contour interval 25 feet.

A. Generalized contours on the top of the Third sand in the Foxburg quadrangle and on the Hundred-foot sand in the Clarion quadrangle.
B. Contours on the Vanport limestone member.
CB, Callensburg; CL, Clarion; ED, Edensburg; ET, Emlenton; FB, Foxburg; H, Hawthorn; NB, New Bethlehem; PL, Parkers Landing; SL, Sligo; SP, St. Petersburg; SV, Strattonville.

Salt water is present with the oil in the Rosenberry field, and according to the generally accepted anticlinal theory of accumulation, the oil, under such conditions, should be found on the side or crest of an anticline. This is true of the Rosenberry pool, but this rule will not hold good for other pools in what is called by drillers the Second sand within the quadrangle. The Rattlesnake pool, on Allegheny River north of West Monterey, is an example where the oil occurs with salt water almost exactly in the bottom of a shallow syncline. There is little or no doubt that what is called by drillers the Second sand is continuous between the Rattlesnake and Rosenberry pools, though it is not oil-bearing.

The great oil pools in the Third and Fourth sands, which furnish by far the larger part of the oil in the quadrangle, signally fail to conform to the structural features. The position of the pools in the Third sand is determined to a very great extent by the thickness of the sand, which in general serves also as an index of its porosity. These pools in the Third sand can not be explained by the generally accepted anticlinal or structural theory of oil and gas. This theory, in brief, provides that, starting with an open porous sandstone lying practically horizontal with impervious beds above and below filled with a mixture of oil, gas, and salt water, and assuming that this bed is subsequently thrown into slight folds, ultimately the oil and gas, being lighter than the salt water, will separate out and arrange themselves along the arches of the folds in the order of their gravity, the gas at the top above the oil and the salt water below the oil. In these pools no such arrangement can be detected. The oil seems to occupy all open, porous patches of the Third sand within the broad producing belts regardless of the position of the folds. This is a marked exception to the condition found over broad areas in the Hundred-foot sand farther to the south, where the oil pools lie remarkably parallel to the trend of the structural axes.[a]

[a] Bulletin on oil and gas in the Sewickley quadrangle, Pa., Top. and Geol. Survey Comm. Pennsylvania; Bull. U. S. Geol. Survey No. 318, 1907; Sewickley folio (No. 176), Geol. Atlas U. S., U. S. Geol. Survey, 1911.

The difficulty of explaining the Third sand pools of these quadrangles by the anticlinal theory, is made greater by the fact that the data in hand indicate that the Third sand is comparatively free from salt water throughout the entire area, except in the vicinity of Elk City and eastward to the Clarion and Miola pools, in Clarion County, where salt water is pumped with the oil. The salt water area in this region is in the structurally highest portion of the producing belt of the Third sand, a fact that is in direct opposition to the idea of accumulation by difference in gravity of oil, gas, and salt water.

In these old fields it is now impossible to collect sufficient facts to get a clear understanding of the minor geologic details under which the oil and gas pools occur. These facts are of the utmost importance in explaining the positions of these pools. One fact may be pointed out, however, to which some significance is attached: there is in this field (as in almost every other field so far examined in the Appalachian region) at some height above the oil sand a bed saturated with water which is usually saline. It is believed by the writer that this persistent and almost universal feature of the stratigraphy of producing territory bears a greater part in the accumulation of oil and gas than geologists have heretofore thought.

The fundamental principle of the anticlinal theory, namely, the accumulation of pools through difference in gravity of oil, gas, and salt water, would not seem to be applicable to these pools, even if they showed a marked structural arrangement, because, with the very slight dip of the rocks, averaging less than 75 feet to the mile, the maximum pressure that could have been exerted by a globule of oil toward movement along the bedding planes could not have been more than about five-thousandths of the weight of the globule. The resistance to this force offered by the water-logged pores of the sandstone was doubtless amply adequate to prevent the accumulation of these great pools under pressure ranging from 100 to probably 1000 pounds per square inch.

The force exerted by a body of water slowly soaking downward through drier, close-grained shale and sandstone from a water-bearing stratum above is entirely adequate to push along ahead of it a considerable portion of the oil and gas scattered throughout the shale mass and from which the oil and gas of the pools have doubtless been derived. This water would travel by a combination of hydraulic and capillary pressure. Such a body of water might in this case have come as easily from below as from above, provided a water-bearing bed is available in that direction. In either case the body of water would have continued to move out into the drier rocks from the water-bearing bed until the supply became exhausted, or until the hydraulic (not hydrostatic) element of pressure became reduced to zero by friction and the capillary pressure, also exhausted by the advancing line of saturation, encountering open porous beds where the force exerted by capillarity would be greatly reduced. Under such conditions the water would have a tendency to move the oil vertically from the close-grained shales into the more porous patches of any sandstone which might happen to be favorably situated at or near the zone where both the hydraulic and capillary pressures became exhausted. In areas where the hydraulic pressure of the water is not entirely exhausted by friction more or less water will appear in the wells with the oil.

By following out this suggestion a satisfactory explanation can be had of many of the variable structural relations manifest in the oil and gas fields of these quadrangles, and with a full knowledge of underground water conditions in these quadrangles it is believed that the whole scheme of accumulation would be so clear as to be unquestionable. If it is assumed that the oil pools have been accumulated in some such manner as suggested above, it seems probable that the water movement was downward through the Cuyahoga formation and that the original source of the water was largely from above, probably from either the First sand or the Burgoon sandstone. It is assumed that these sandstones derived their supply from distant intakes where they are exposed at the surface and that the invasion occurred at some definite, short, clearly marked geologic time. In areas where oil pools were formed the water from this sandstone is assumed to have slowly soaked downward through shale by capillarity augmented by hydraulic (not hydrostatic) pressure and to have gathered in front of it a zone of oil and gas. Slow downward movement of the water and oil zones would continue, however, until the oil zone should come to an open porous bed just beyond the point where the water could no longer exert hydraulic pressure because of loss of head by leakage and friction. At the upper edge of this porous bed the capillary pressure of the overlying water would also cease to exert its full force because of the increased size of the pore spaces of the rock, and an equilibrium would be established between the remaining capillary water pressure and the resistance offered by the oil to movement. The same result would be reached if two bodies of capillary water should meet on opposite sides of a porous stratum.

Probably most oil and gas pools were formed by the movement of two or more bodies of water in different directions. The first stage was the transfer of the oil and gas from the shale to a more porous sandstone above or below by water invading the shale in more or less vertical direction, as stated above. The second stage, from an economic viewpoint far more complicated, was the subsequent invasion by water of the porous bed into which oil and gas had been driven. In this stage the water must have traveled along the bedding planes by hydraulic pressure, thus still further concentrating the accumulations of oil and gas into pools. The source of the water may have been the same in both stages, or it may have come from entirely different sources during each stage. If from the same source, the water which invaded the sandstone parallel to its bedding plane was derived from the water-bearing bed above or below, at distant points through fissures, faults, etc., and, having encountered less resistance, retained sufficient hydraulic pressure to have caused it to move horizontally along the porous sandstone. The points where water was thus derived may have been few or many, and the radial movement from these points of intake may have been, therefore, relatively great or very small. In all cases where oil and gas pools were formed, the vertical invasion of the first stage must have preceded the horizontal invasion of the second stage, and the accumulating effect of the second was supplementary to that of the first.

The horizontal movement of water by hydraulic pressure through the oil-bearing sandstone from the point or points of invasion could not have been uniform in all directions, because of variations in porosity of the sandstone and of structural features. Hence, each puddle retained a ragged margin at all stages of this invasion. The oil and gas forced ahead of the water around the margin of each puddle traveled by the hydraulic pressure of the water behind, but their resistance to movement was largely capillary in nature and this resistance must have increased in proportion to the increase in size of the oil and gas body, while the hydraulic pressure of the water decreased with distance from the source of supply. In such a movement the gas, being less dense and offering less resistance to movement than the oil, would collect in advance of it and farther away from the water.

Such a movement of water would offer opportunity for the formation of oil and gas pools under many different local conditions. The simplest of these would be of pools formed along the line of contact between two bodies of water moving in opposite directions from different points of intake in the porous sandstone. Along such a line the pools of commercial value would occur only at places where the sandstone was sufficiently porous to furnish a flow into the wells under the closed pressure of that particular pool. Pools would also be likely to form along the sides or crests of anticlines, especially in domes where the base of the fold in the oil-bearing sandstone was first surrounded by the invading water which subsequently encroached upon it from all sides, pinching the oil and gas in the top. These examples, which are the simplest types of pools, are cited to illustrate the principles involved. Other factors equally effective in controlling the position of pools would be the pinching out of the sandstone member, the encountering of barriers of much finer sandstone occupied by capillary water derived from the associated shale from which the supply of oil was originally derived, or the formation of dams in the sandstone by the foremost portion of the moving body of oil itself occupying through capillarity fine-grained areas to such a distance as to offer a relatively great resistance to the water at the point of contact in the porous portion of the bed. In all cases the water pressure must be considered to have been hydraulic and not hydrostatic. In areas where no water is now found in the productive sand around the margin of a pool, the water at the edge of the pool may have subsequently lost all hydraulic pressure through reduction of the supply of water or the decrease in head due to structural changes. In either case the capillary resistance offered by the water to backward movement would have been too great to change materially the position of a pool after it was once formed. The great closed pressures of pools probably are due to chemical changes in the oil body after it was collected, thereby increasing the volume of gas in the pool.

A thorough discussion of this theory and of others relative to oil and gas accumulation is not germane to the subject in hand, since it would involve regional studies that are not at present sufficiently complete to admit of positive deductions being made. It may be shown, however, that the idea of oil and gas accumulation by moving water under a combination of hydraulic and capillary pressure is easily applicable to all types of oil and gas pools, but physical facts to substantiate it can not be readily secured in old producing areas similar to those of the Foxburg and Clarion quadrangles.

CLAY AND SHALE.

Clay and shale are exploited in both the Foxburg and the Clarion quadrangles. The clay includes both the flint and plastic varieties, but neither is used extensively.

SHALE.

The only shale that is being developed commercially at present is the one below the horizon of the Clarion coal. The Canton Tile & Hollow Brick Co. has a pit on this shale about three-quarters of a mile west of New Bethlehem and uses it in connection with the underlying clay in the manufacture of hollow building blocks and drain tile. A section of the pit is as follows:

Section of pit of Canton Tile & Hollow Brick Co.

	Ft.	in.
Shale, olive, fissile, iron stone	3	
Carbonaceous layer (Clarion coal ?)		4
Sandstone, argillaceous		10
Shale, dark drab	18	
Clay, dark, soft	5	
Clay, drab, hard, sandy	5	
Shale, olive, sandy	10	
Sandstone		

Other deposits of shale of possible commercial value occur above the Lower Kittanning coal. This shale is usually fine-textured, and exposures indicate that it averages between 30 and 50 feet thick. Good sections occurring on or near railroads are exposed at the railroad crossing between Fairmount City and Hawthorn, in the hill 1 mile south of Sligo, and in the hill 1 mile south of Strattonville.

CLAY.

Clay in Mercer shale member.—In some parts of western Pennsylvania the Mercer shale member contains valuable clay which is presumably equivalent to the Mount Savage clay of Maryland, but in the Foxburg and Clarion quadrangles there is very little clay in this member. There is, however, much clay shale, and some dark-gray clay, none of which has been worked. The member outcrops along the gorges of Clarion and Allegheny rivers and the larger tributary streams. In the northeastern part of the area it is very thin.

There is no good exposure of flint clay in the Mercer member in the Foxburg and Clarion quadrangles, but south of this area, at Climax and St. Charles, flint clay from the Mercer is used in making high-grade fire brick. At one point within the area, namely, on the west side of Leatherwood Run, about 1 mile north of St. Charles, fragments of flint clay which are probably from the Mercer have been found in the field. Several prospect holes have been sunk here, however, without finding the source of the fragments.

Brookville clay.—The Brookville coal is underlain by a bed of clay 1 to 10 feet thick, and the clay is present in many places where the coal is absent. It is generally very sandy and of little value.

Clarion clay.—One of the most conspicuous clay beds in the western part of the area is found below the Lower Clarion coal. It is plastic and generally white in weathered outcrop. The thickness ranges between 3 and 10 feet. In some districts the Upper Clarion coal is also underlain by clay. A section on the run near the schoolhouse about 2 miles southwest of Piney shows 5 feet or more of clay, below each of the Clarion coals. In the vicinity of New Bethlehem this clay is being used, as already stated, with the overlying shale in the manufacture of building blocks and tile by the Canton Tile & Hollow Brick Co. Clay found below the Lower Clarion coal in one of the mines at Sligo is used as a bond in the manufacture of fire brick.

Kittanning clays.—In some localities there are at least four Kittanning coals, each underlain by clay beds. The upper clays are, so far as known, unimportant. The plastic clay below the Lower Kittanning coal is as yet undeveloped, but road crops and mine sections throughout the area indicate that except in the northwestern part, it is persistently present. Only a partial thickness of the clay is anywhere seen, but the exposures are suggestive of considerable deposits. Among the best road exposures is one $1\frac{1}{4}$ miles east of Jack schoolhouse, and about 4 miles northwest of New Bethlehem, where 3 feet of reddish stained clay outcrops, and another 1 mile east of Frampton, where 8 feet of light-drab clay is exposed. At Huey a drift exposes $7\frac{1}{2}$ feet of clay, with both top and bottom concealed. The thickness of the clay here indicates that possibly equally thick deposits are accessible along the Sligo branch of the Pennsylvania Railroad, wherever the numerous mines show that the clay occurs above drainage level.

The only plastic clay in present use from the Kittanning beds comes from the Middle Kittanning. This clay is used at Hawthorn in the manufacture of stoneware, and the supply is obtained from a stripping just north of the town. The clay lies under 4 to 10 feet of cover, and ranges between 4 and 6 feet in thickness. The upper portion of the bed is soft, quite free from sand, and has a chalky appearance, due to weathering, while the lower portion is rather hard and sandy, and greenish in color. The Middle Kittanning clay was formerly stripped on Town Run, opposite the opening of the No. 2 mine of the Alcola Coal Co. This was reported to be an excellent pottery clay.

Flint clay occurs below the Lower Kittanning coal in a belt that extends from just west of the Foxburg-Clarion boundary to the north border of the area. This belt has a width of from $1\frac{1}{2}$ to $2\frac{1}{2}$ miles on each side of Clarion River, except north of the town of Clarion. Owing to the height of the clay in the hills, however, only a small portion of the area is actually underlain by it. The clay is persistent in its occurrence but has a wide range in quality. The best clay is light yellowish brown, fine grained, and moderately hard. Weathered pieces are bluish gray on exposed surfaces and are easily broken.

Formerly the clay was stripped and hauled by wagon to railroads, by which it was shipped to the fire brick manufactories, but for a number of years the practice has been discontinued, and now the old strippings are largely covered.

The following chemical analyses of samples taken from a newly opened drift on the C. B. McQueen farm show the average composition of this clay.

Analyses of air-dried samples of flint clay from C. B. McQueen farm.

[P. H. Bates, analyst, U. S. Geological Survey laboratory.]

	A.	B.
Ultimate analyses:		
Silica (SiO_2)	58.96	56.46
Alumina (Al_2O_3)	25.60	27.69
Ferric oxide (Fe_2O_3)	3.32	2.55
Manganese oxide (MnO)	.07	.09
Lime (CaO)	.70	.42
Magnesia (MgO)	.25	.28
Sulphuric anhydride (SO_3)	.07	.14
Soda (Na_2O)	.15	.06
Potash (K_2O)	.36	.52
Water at 100° C	.80	1.40
Ignition loss	9.90	10 64
	100.18	100.25
Rational analyses:		
Free silica	25.75	20.50
Clay substance	59.00	64.50
Feldspathic substance	4.50	3.00
Ignition loss	10.75	12.00
	100.00	100.00

Sample A in the above table represents the upper foot, and sample B the lower 2 feet of the section. Sample A has a very siliceous appearance, shows a rough surface, and breaks irregularly rather than with the conchoidal or shell-like fracture characteristic of flint clay. Sample B is like the type of best clay described above, except that instead of being homogeneous it contains a small percentage of bluish inclusions. In some cases it shows streaks which resemble bedding planes. Wherever cracks occur in the clay the surfaces so formed are strongly stained with iron. As is shown by the analyses, the percentage of iron is high for fire clay. This feature makes a good deal of the clay unsuitable for use in the manufacture of refractory articles. The clay at the bank from which the samples for analysis were taken is used at Sligo in the manufacture of fire brick. Clay from the north of the river has not been used south of the Wagner and Bell farm, the reported reason being that the clay in that region contains so much iron that it is worthless. In the area south of the river the best clay is said to have been taken from the Finnefrock farm. Considerable amounts of clay have also been taken from the Miller farm, 2 miles north of Sligo.

Freeport clays.—Both of the Freeport coals are usually underlain with clay, but the area of their occurrence in these quadrangles is small and the clay is not valuable. Flint clay is found below the Lower Freeport coal 1 mile west of Piolett and on the ridge road 2 miles southeast of Sharpsburg Church. It is also locally developed below the Upper Freeport and may be seen near the top of the hill one-fourth mile northwest of Rimersburg station. This flint clay occurs in quantities so small that it is not commercially important in the Foxburg and Clarion quadrangles.

IRON ORE.

Immediately above the Vanport ("Ferriferous") limestone member, and coextensive with it, occurs a bed of iron ore sometimes termed "burrstone ore" because of the chert associated with it. The ore is siderite except near the outcrop, where it is altered to limonite.

Chance[a] reports that the usual thickness of the ore is from 6 to 14 inches, averaging 10 inches, and that exceptionally the bed is 2, 3, 4, or even 6 feet thick. A partial analysis of ore from a point near Sligo is as follows:

Analysis of iron ore near Sligo.

Metallic iron	36.55
Metallic manganese	1.63
Sulphur	.06
Phosphorus	.28

The average content of metallic iron is 33 per cent.[b]

The ore was obtained in considerable quantity by stripping, and more rarely by drifting. The waste from the old workings is in evidence at a great many localities and well marks the ore stratum. The industry died out when the more economically handled and higher grade Lake Superior ores were opened up. With the exhaustion of the latter the deposits in Pennsylvania may again become valuable.

In the Foxburg quadrangle "ore balls" are found in considerable amounts at various places in the Allegheny formation. Some of these have been mined from below each of the Freeport coals, but the principal sources were in the lower part of the formation, between the Homewood sandstone member and the Lower Kittanning coal. In this interval brown ferruginous shale predominates, and much ore has been taken out by stripping. In the northwestern part of the quadrangle an almost continuous bed of iron ore is found about 10 feet below the Brookville coal. This stratum has been worked extensively, and the old pits east, west, and north of Emlenton follow nearly the course of a level line around the hills. A little ore has been mined in the Mercer shale member of the Pottsville formation.

Iron ore was mined in western Pennsylvania principally between 1830 and 1860. It was smelted in charcoal furnaces, ruins of which form a picturesque feature of the area. The extensive forests of those days were used in making the charcoal, by piling up 20 to 40 cords of wood, covering it with soil, and burning it. About 20 pounds of charcoal were obtained from each 100 pounds of wood, and about 200 bushels of charcoal were required for each ton of iron.

LIMESTONE.

VANPORT LIMESTONE MEMBER.

Except in certain areas already described (see fig. 6) the Vanport limestone member is persistent throughout both quadrangles. The limestone ranges in thickness from 6 or 8 feet in the eastern part of the area to 10 or 20 in the central and western. In many localities the upper portion of the bed is cherty.

[a] Chance, H. M., The geology of Clarion County, Second Geol. Survey Pennsylvania, Rept. VV, pp. 54, 196.
[b] Chance, H. M., idem, p. 196.

Where the limestone is removed from drifts this cherty layer which is usually about 1 foot thick and separated by a parting from the strata below, makes an excellent roof.

Formerly the limestone was used in the old iron furnaces as a flux. Very little of it has been used for building, but just now thousands of tons are being used in the construction of the macadamized road from Foxburg to Alum Rock. An analysis of a sample of the limestone by McCreath follows:[a]

Analysis of limestone from Vanport member.

Calcium carbonate	95.23
Magnesian carbonate	.41
Oxide of iron and alumina	1.31
Phosphorus	.06
Insoluble residue	2.19

The lime is of great value as a fertilizer and is, fortunately, of general distribution. Many farmers have individual quarries. The limestone is not burned in or near the quarries but is hauled out and burned in the field in which it is to be used. Some of it has been hauled 8 or 10 miles.

FREEPORT LIMESTONE MEMBER.

Limestone occurs below each of the Freeport coals, but the deposits are limited to small broken lenses. In some cases bowlders below the Upper Freeport coal have been dug and burned for fertilizer. The only quarries now open on this limestone are one on Myers Hill, 2 miles south by east from Sligo, and one about 3 miles southeast of West Freedom. However, much limestone is obtained from the weathered outcrops without opening quarries.

SANDSTONE.

Sandstone suitable for a great variety of purposes is abundant in the Foxburg and Clarion quadrangles. The Burgoon, Connoquenessing, Homewood, Freeport, and Mahoning are the most persistent members, but there are local developments of sandstone at many other horizons. The Connoquenessing and Homewood sandstones are quarried by the Black Fox Silica Brick Company near Upper Hillville, and by the Foxburg Sand and Stone Company north of Foxburg, and have been opened at several other places. The rock is commonly white and composed of almost pure silica. The grains of sand are angular or slightly rounded and generally loosely cemented. At the Black Fox quarry the rock is treated as ganister. It is ground and made into silica brick for use in iron and glass furnaces. The output of the quarry near Foxburg is shipped as sand and used for molding and other furnace work, for grinding plate glass, and for locomotive use. The quarries are near the top of the river bluff and the rock is let down by inclines to the railway.

The Kittanning sandstone has been used to some extent for building stone. The rock is medium coarse grained, and much of it when freshly cut has a pleasing pinkish color. It weathers, however, a dull gray. There is a quarry about 2 miles south of Strattonville at which this sandstone is cut into curbing.

An abundant supply of desirable sandstone for making concrete, for road foundations, bridge abutments, etc., is found throughout the area. A new macadamized road is being built from Foxburg to Alum Rock, and the road bed is first covered with a thick layer of Burgoon sandstone, taken from nearby residual bowlders. There seems to be very little rock in these quadrangles which is suitable for dimension stone.

May, 1910.

[a] Second Geol. Survey Pennsylvania, Rept. VV, p. 54.

TOPOGRAPHY

U.S. GEOLOGICAL SURVEY
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STATE OF PENNSYLVANIA
GEORGE W. MCNEES, RICHARD R. HICE, ANDREW S. MCCREATH
COMMISSIONERS

PENNSYLVANIA
FOXBURG QUADRANGLE

(Kittanning)

Scale $\frac{1}{62500}$

Contour interval 20 feet.
Datum is mean sea level.

APPROXIMATE MEAN DECLINATION 1907.

Frank Sutton, Geographer in charge.
Topography by R.D. Cummin, R.H. Reineck, and E.W. McCrary.
Control by E.L. McNair and C.G. Anderson.
Surveyed in 1905-1907.

SURVEYED IN COOPERATION WITH THE STATE OF PENNSYLVANIA.

Edition of Oct. 1908, reprinted July 1910.

(Rural Valley)

U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

AREAL GEOLOGY

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PENNSYLVANIA
FOXBURG 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 and late glacial gravel *(gravel, sand, and silt in flood plains of present streams and forming low terraces; on the Allegheny contains much glacial gravel of probably Wisconsin age)*

Pleistocene

Qig — Intermediate glacial gravel *(gravel, sand, and silt of local and foreign material on terraces of medium elevation)*

Qit — Intermediate terrace deposits *(sand, silt, clay, and well-rounded pebbles of local derivation, on terraces of medium elevation)*

Kansan?

Qeg — Early glacial gravel *(deeply decayed high terrace gravel, sand, and silt of glacial and local material derived from sedimentary and igneous rocks as far north as Canada)*

Qcm — Carmichaels formation *(high terrace sand, silt, clay, and deeply decayed water worn pebbles of local derivation)*

CARBONIFEROUS

Pennsylvanian

Ccm — Conemaugh formation *(soft olive shale, sandy shale, and locally heavy sandstone near base, with thin coals and limestones)*

Ca, Cv — Allegheny formation and Vanport limestone member *(iron-bearing shale, fine-grained to conglomeratic sandstone, limestone, and valuable beds of coal and fire clay)*

Cpv — Pottsville formation *(massive sandstone with large shale lenses and thin seams of coal)*

UNCONFORMITY

Mississippian (Pocono group)

Cbg — Burgoon sandstone *(massive to thin-bedded sandstone with many small lenses of soft shale and thin seams of coal)*

Cmv — Meadville shale member of the Cuyahoga formation *(hard black to gray sandy shale with pebble layer at top)*

Frank Sutton, Geographer in charge.
Topography by R D Cummin, R.H. Reineck, and E.W. McCrary.
Control by E.L. McNair and C.G. Anderson.
Surveyed in 1905-1907.

SURVEYED IN COOPERATION WITH THE STATE OF PENNSYLVANIA.

TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1907.

(Kittanning)

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 20 feet.
Datum is mean sea level.
Edition of Oct. 1910.

Geology by E.W. Shaw.
Surveyed in 1908.

SURVEYED IN COOPERATION WITH THE STATE OF PENNSYLVANIA.

(Rural Valley)

STRUCTURE AND ECONOMIC GEOLOGY

STATE OF PENNSYLVANIA
GEORGE W. MCNEES, RICHARD R. HICE, ANDREW S. MCCREATH
COMMISSIONERS

U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

PENNSYLVANIA
FOXBURG 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 and late glacial gravel
(gravel, sand, and silt in flood plains of present streams and forming low terraces; on the Allegheny contains much glacial gravel of probably Wisconsin age)

Pleistocene

Qig — Intermediate glacial gravel
(gravel, sand, and silt of local and foreign material on terraces of medium elevation)

Qit — Intermediate terrace deposits
(sand, silt, clay, and well-rounded pebbles of local derivation, on terraces of medium elevation)

Kansan?

Qeg — Early glacial gravel
(deeply decayed high terrace gravel, sand, and silt of glacial and local material derived from sedimentary and igneous rocks as far north as Canada)

Qcm — Carmichaels formation
(high terrace sand, silt, clay, and deeply decayed water worn pebbles of local derivation)

CARBONIFEROUS

Pennsylvanian

Ccm — Conemaugh formation
(soft olive shale, sandy shale, and locally heavy sandstone near base, with thin coals and limestones)

Ca, Cv — Allegheny formation and Vanport limestone member
(iron-bearing shale, fine-grained to conglomeratic sandstone, limestone, and valuable beds of coal and fire clay)

Cpv — Pottsville formation
(massive sandstone with large shale lenses and thin seams of coal)

UNCONFORMITY

Mississippian (Pocono group) (Clarion)

Cbg — Burgoon sandstone
(massive to thin-bedded sandstone with many small lenses of soft shale and thin seams of coal)

Cmv — Meadville shale member of the Cuyahoga formation
(hard black to gray sandy shale with pebble layer at top)

ECONOMIC AND STRUCTURE DATA

Coal outcrops and area underlain by workable coal

uf, *Upper Freeport coal*
lf, *Lower Freeport coal*
uk, *Upper Kittanning coal*
mk, *Middle Kittanning coal*
lk, *Lower Kittanning coal*
cl, *Clarion coal*

1400 — *Structure contours drawn on the top of the Vanport limestone*
(contour interval is 10 feet, datum is mean sea level)

⚒ *Mines and quarries*
(coal unless otherwise specified)

Note: *Most of the workable coals are in the Allegheny; thin coals in Conemaugh and Pottsville; limestone and cement materials in Allegheny and Conemaugh; clay and shale for brick and tile in all Carboniferous formations; building stone in Burgoon, Pottsville, Allegheny, and Conemaugh; iron ore in Pottsville and Allegheny; glass and building sand in Pottsville and Burgoon; gravel and sand in alluvium and terrace deposits. Distribution of oil and gas wells and pools shown on separate map.*

Frank Sutton, Geographer in charge.
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Surveyed in 1905-1907.

SURVEYED IN COOPERATION WITH THE STATE OF PENNSYLVANIA.

TRUE NORTH — MAGNETIC NORTH — $3\frac{1}{2}°$
APPROXIMATE MEAN DECLINATION 1907.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 20 feet.
Datum is mean sea level.
Edition of Oct. 1910.

Geology by E.W. Shaw.
Surveyed in 1908.

SURVEYED IN COOPERATION WITH THE STATE OF PENNSYLVANIA.

OIL AND GAS

STATE OF PENNSYLVANIA
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U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

PENNSYLVANIA
FOXBURG QUADRANGLE

LEGEND

- Gas pools in 1st sand
- Oil pools in Red Valley sand
- Gas pools in Red Valley sand
- Oil pools in 100-foot sand (in places called 2nd sand)
- Gas pools in 100-foot sand (in places called 2nd sand)
- Oil pools in Nineveh 30-foot sand
- Oil pools in Bowlder sand
- Gas pools in Bowlder sand
- Oil pools in 3rd sand (OG indicates oil and gas)
- Gas pools in 3rd sand
- Oil pools in 4th sand
- Gas pools in 4th sand
- Oil pools in 5th sand
- Gas pools in 5th sand
- Gas pools in Speechley sand
- Structure contours on the top of the Vanport limestone member (contour interval is 50 feet; datum is mean sea level. Generalized structure of 3rd sand shown in most figures)
- Oil wells
- Gas wells
- Oil and gas wells
- Show of oil
- Show of gas
- Show of oil and gas
- Dry holes
- Oil tanks

Frank Sutton, Geographer in charge.
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SURVEYED IN COOPERATION WITH THE STATE OF PENNSYLVANIA.

APPROXIMATE MEAN DECLINATION 1907.

Scale $\frac{1}{62500}$

Contour interval 20 feet.
Datum is mean sea level.
Edition of Oct. 1910

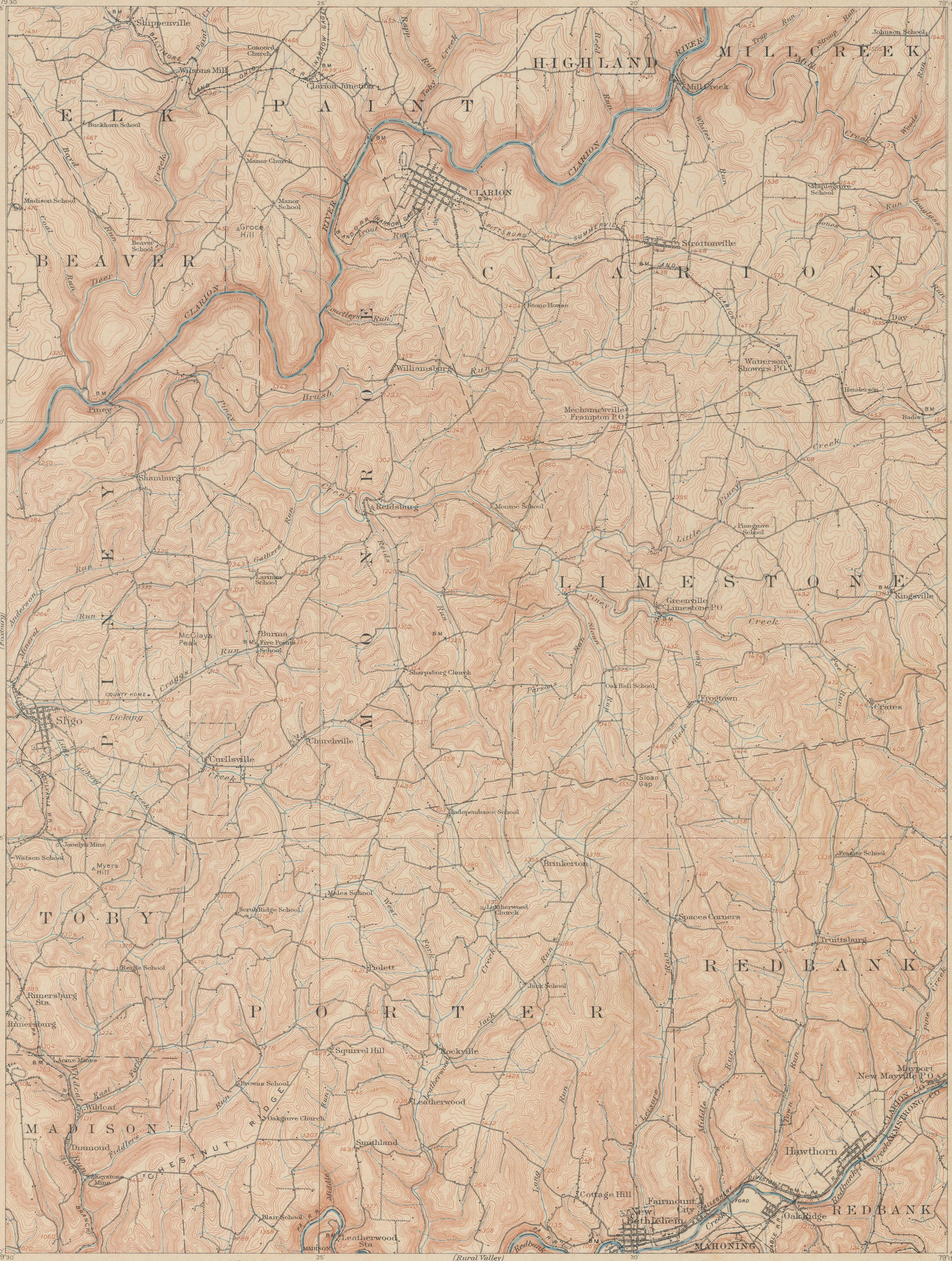
Geology by M.J. Munn,
under the supervision of Geo. H. Ashley.
Surveyed in 1908.
SURVEYED IN COOPERATION WITH THE STATE OF PENNSYLVANIA.

TOPOGRAPHY

STATE OF PENNSYLVANIA
GEORGE W. MC NEES, RICHARD R. HICE, ANDREW S. MC CREATH
COMMISSIONERS

U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

PENNSYLVANIA
CLARION QUADRANGLE



H. M. Wilson, Geographer.
Robt. D. Cummin and J. H. Jennings, in charge of section.
Topography by Robt. D. Cummin and E. W. McCrary.
Control by E. L. McNair and W. T. Griswold.
Surveyed in 1905 and 1906.

SURVEYED IN COOPERATION WITH THE STATE OF PENNSYLVANIA.

TRUE NORTH
MAGNETIC NORTH
4°
APPROXIMATE MEAN DECLINATION 1906.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 20 feet.

Datum is mean sea level.

Edition of Dec. 1907, reprinted July 1910.

LEGEND

RELIEF
printed in brown

1264
Figures
showing heights above mean sea level instrumentally determined

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

Depression contours

DRAINAGE
printed in blue

Streams

Lakes, ponds, and reservoirs

CULTURE
printed in black

Roads and buildings

Churches, school houses, and cemeteries

Private and secondary roads

Trails

Railroads

Bridges

Fords

County lines

Township lines

City, village, and borough lines

Triangulation stations

BM ×
Bench marks

AREAL GEOLOGY

STATE OF PENNSYLVANIA
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GEORGE OTIS SMITH, DIRECTOR

PENNSYLVANIA
CLARION QUADRANGLE

(Kittanning) H.M. Wilson, Geographer.
Robt. D. Cummin and J.H. Jennings, in charge of section.
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Surveyed in 1905 and 1906.

SURVEYED IN COOPERATION WITH THE STATE OF PENNSYLVANIA.

4° TRUE NORTH / MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1906.

(Rural Valley)

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 20 feet.
Datum is mean sea level.
Edition of Nov. 1910.

Pre-Quaternary geology by E.F. Lines.
Quaternary geology by E.W. Shaw.
Surveyed in 1907 and 1910.

SURVEYED IN COOPERATION WITH THE STATE OF PENNSYLVANIA.

(Smicksburg)

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 — Wisconsin? and pre-Wisconsin

Qlt — Lower terrace deposits *(sand, silt, clay, and rounded pebbles of local derivation on low terraces)*

Kansan?

Qcm — Carmichaels formation *(high terrace sand, silt, clay, and deeply decayed water worn pebbles of local derivation)*

CARBONIFEROUS

Pennsylvanian

Ccm — Conemaugh formation *(soft olive shale, sandy shale, and locally heavy sandstone near base, with thin coals and limestones)*

Ca Cv — Allegheny formation and Vanport limestone member *(iron-bearing shale, fine-grained to conglomeratic sandstone, limestone, and valuable beds of coal and clay)*

Cpv — Pottsville formation *(massive sandstone with large shale lenses and thin seams of coal)*

UNCONFORMITY

Mississippian (Pocono group)

Cbg — Burgoon sandstone *(massive to thin-bedded sandstone with many small lenses of soft shale and thin seams of coal)*

STRUCTURE AND ECONOMIC GEOLOGY

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PENNSYLVANIA
CLARION QUADRANGLE

LEGEND

SEDIMENTARY ROCKS

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

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ECONOMIC AND STRUCTURE DATA

Coal outcrops and area underlain by coal (dashed lines represent coals not known to be workable)

uf, Upper Freeport — cl, Clarion
lf, Lower Freeport — cg, Craigsville
uk, Upper Kittanning — br, Brookville
lk, Lower Kittanning

1400 — Structure contours drawn on the top of the Vanport limestone (contour interval is 25 feet; datum is mean sea level)

⚒ Shipping coal mines (unless otherwise specified)

Note: *Most of the workable coals are in the Allegheny; thin coals in Conemaugh and Pottsville; limestone and cement materials in Allegheny and Conemaugh; clay and shale for brick and tile in all Carboniferous formations; building stone in Burgoon, Pottsville, Allegheny, and Conemaugh; iron ore in Pottsville and Allegheny; glass and building sand in Pottsville and Burgoon; gravel and sand in alluvium and terrace deposits. Distribution of oil and gas wells and pools shown on separate map.*

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TRUE NORTH — MAGNETIC NORTH — 4°
APPROXIMATE MEAN DECLINATION 1906.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 20 feet.
Datum is mean sea level.
Edition of Nov. 1910.

Pre-Quaternary geology by E. F. Lines.
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OIL AND GAS

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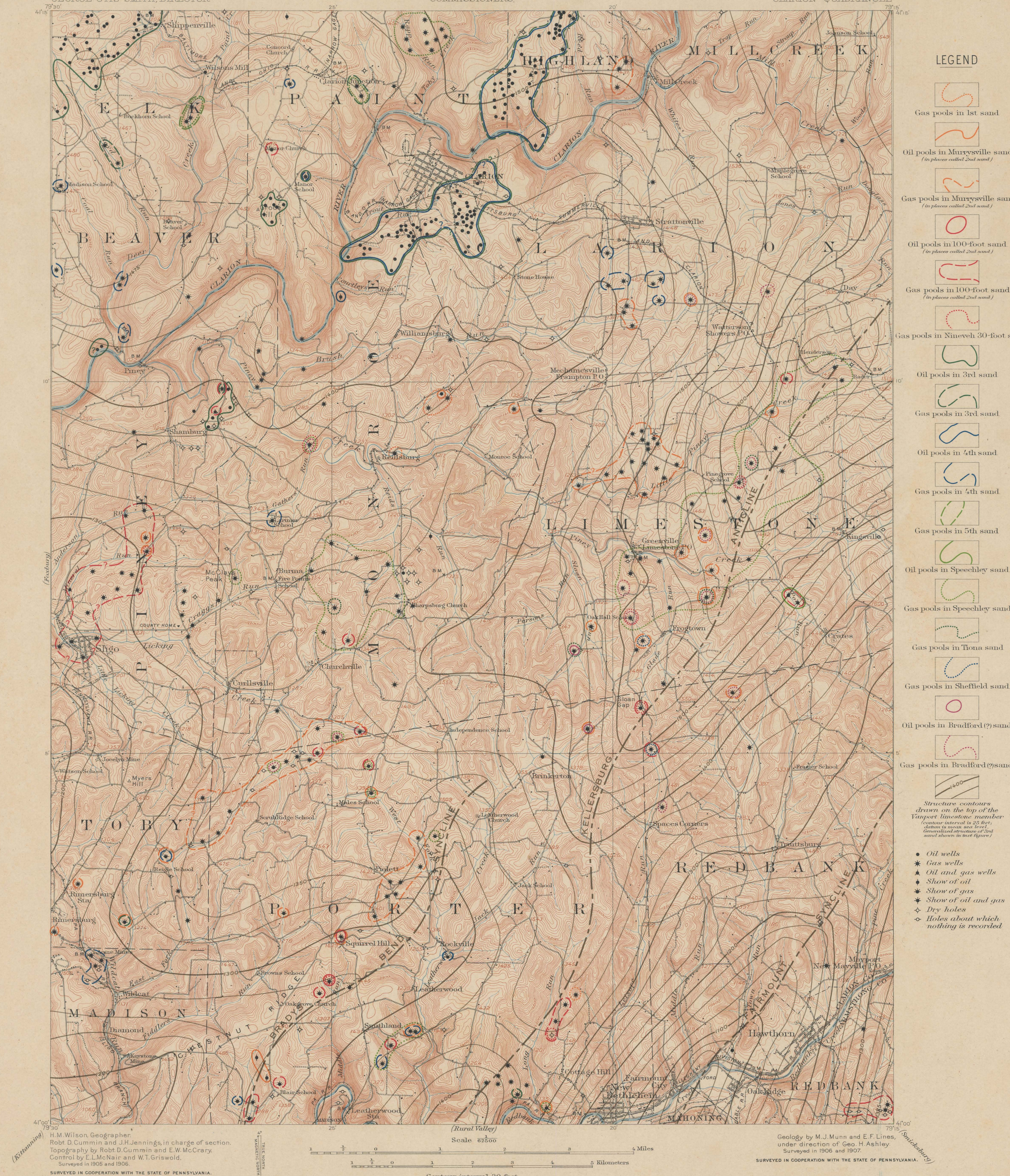
U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

PENNSYLVANIA
CLARION QUADRANGLE



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APPROXIMATE MEAN DECLINATION 1906.

Scale $\frac{1}{62500}$

Contour interval 20 feet.
Datum is mean sea level.
Edition of April 1911

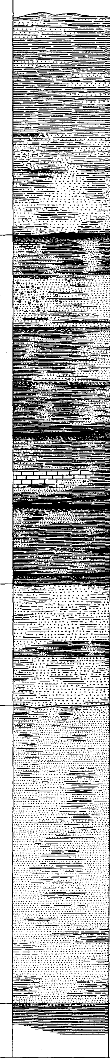
Geology by M.J. Munn and E.F. Lines, under direction of Geo. H. Ashley.
Surveyed in 1906 and 1907.

SURVEYED IN COOPERATION WITH THE STATE OF PENNSYLVANIA.

COLUMNAR SECTION

GENERALIZED SECTION OF THE ROCKS EXPOSED IN THE FOXBURG AND CLARION QUADRANGLES.

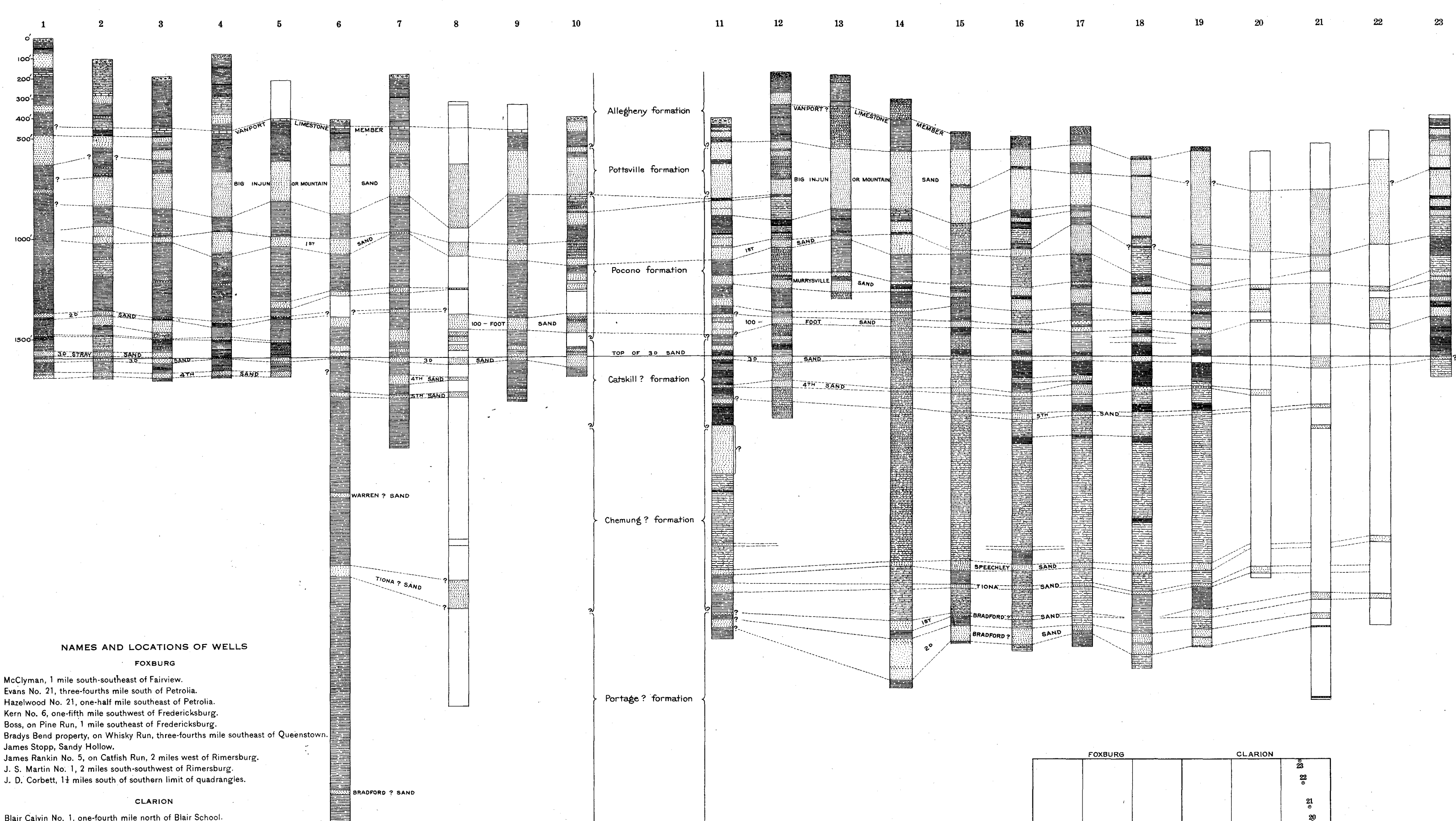
SCALE: 1 INCH=100 FEET.



System.	Series.	Group.	Formation.	Symbol.	Section.	Thickness in feet.	Minor divisions.	Character and distribution of minor divisions.	General character of formation.
CARBONIFEROUS	PENNSYLVANIAN		Conemaugh formation.	Ccm		230±			More or less sandy olive to gray shale with thin to thick beds of sandstone, sometimes conglomeratic, thin coal, and clay.
							Mahoning sandstone member (upper part).		
						(0-3)	Mahoning coal.	Coal of good quality, but local.	
							Mahoning sandstone member (lower part).	Brown, heavy and conglomeratic to shaly; variable in development.	
			Allegheny formation.	Ca		345-370			Iron-bearing shale, fine-grained to conglomeratic sandstone, limestone, and valuable beds of coal and clay.
						(0-7)	Upper Freeport coal.	Excellent coal, low in sulphur and other impurities.	
							Upper Freeport clay.	Generally gray, pliable; locally flint clay. Both above and below limestone.	
						(0-13)	Upper Freeport limestone member.	Light-gray limestone, generally thin but in places thick and of good quality.	
							Lower Freeport coal.	In western part of area commonly split by a parting of clay or shale.	
							Lower Freeport clay.	Thick-bedded yellowish to dark-gray clay.	
							Lower Freeport limestone member.	Very local.	
							Freeport sandstone member.	Generally coarse, very resistant sandstone or fine conglomerate.	
							Upper Kittanning coal.	Local, but its horizon usually marked by a trace of coal or under clay.	
							Upper Kittanning clay.	Dark gray, plastic clay.	
							Thin coal.	Possibly a split from Middle Kittanning coal north of Rimersburg.	
							Middle Kittanning coal.	Good coal, but thin; present over most of area.	
							Middle Kittanning clay.	Generally sandy gray clay.	
							Lower Kittanning coal.	Excellent coal in southern two-thirds of quadrangles; uniform in thickness.	
							Lower Kittanning clay.	Gray to white, generally plastic; 0-6 feet in northern half of Clarion quadrangle.	
							Kittanning sandstone member.		
				(Cv)			Vanport limestone member.	Gray fossiliferous limestone.	
							Upper Clarion coal.	Sulphurous; probably a split from the Lower Clarion coal.	
							Upper Clarion clay.	White plastic clay; local.	
							Lower Clarion coal.	Generally workable and persistent; contains pyrite.	
							Lower Clarion clay.	White, yellow, or gray clay, generally plastic, and over 5 feet thick.	
							Clarion sandstone member.	Coarse resistant thick-bedded to massive gray or pinkish sandstone. Well developed along Bear Run and locally elsewhere.	
							Craigsville coal.	Locally attains minable thickness but is sulphurous.	
							Brookville coal.	Generally good coal but thin; at some places it resembles cannel coal.	
			Pottsville formation.	Cpv		120-130			Resistant sandstone with irregular beds of shale. Equivalent to the uppermost beds of the Pottsville in the type locality.
							Homewood sandstone member.		
							Mercer shale member.		
							Connoquenessing sandstone member.	Thin to thick bedded resistant sandstone with lenses of shale.	
			UNCONFORMITY						
	MISSISSIPPIAN	POCONO	Burgoon sandstone.	Cbg		310			Fine, more or less impure sandstone with thin to very thick lenses of shale.
			Cuyahoga formation.			35+	Meadville shale member.		Hard gray shale with pebbles near top.

SECTIONS OF DEEP WELLS IN THE FOXBURG AND CLARION QUADRANGLES

SCALE: 1 INCH = 400 FEET



NAMES AND LOCATIONS OF WELLS

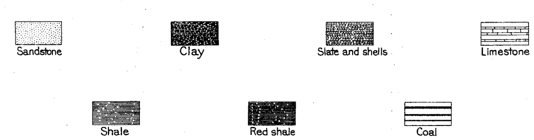
FOXBURG

1. McClyman, 1 mile south-southeast of Fairview.
2. Evans No. 21, three-fourths mile south of Petrolia.
3. Hazelwood No. 21, one-half mile southeast of Petrolia.
4. Kern No. 6, one-fifth mile southwest of Fredericksburg.
5. Boss, on Pine Run, 1 mile southeast of Fredericksburg.
6. Bradys Bend property, on Whisky Run, three-fourths mile southeast of Queenstown.
7. James Stopp, Sandy Hollow.
8. James Rankin No. 5, on Catfish Run, 2 miles west of Rimersburg.
9. J. S. Martin No. 1, 2 miles south-southwest of Rimersburg.
10. J. D. Corbett, 1½ miles south of southern limit of quadrangles.

CLARION

11. Blair Calvin No. 1, one-fourth mile north of Blair School.
12. George Delp, one-half mile east of Oakgrove Church.
13. C. A. Spindler, one-half mile southeast of Piolett.
14. Wm. Sheridan, three-fourths mile southwest of Leatherwood Church.
15. M. T. Bodenhorn, at head of Glade Run, 1¼ miles south-southwest of Frogtown.
16. A. A. Stewart, on Sloan Run, one-half mile south of Oak Hall School.
17. N. P. Sloan, one-half mile south of Greenville.
18. G. E. and G. R. Spur, 1 mile east-northeast of Greenville.
19. Stewart Snyder, one-half mile east of Pinegrove School.
20. John Moyer No. 1, one-half mile southwest of Henderson.
21. J. Frank Ross No. 1, two-thirds mile north-northeast of Watterson.
22. Wm. Knight No. 1, one-half mile west-northwest of Maplegrove School.
23. George Wood No. 1, 1½ miles northeast of Mill Creek.

DRILLER'S TERMS



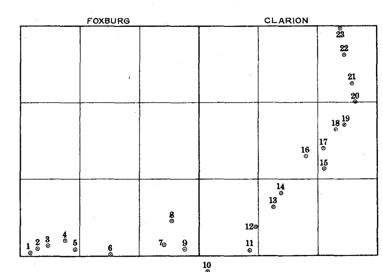


DIAGRAM SHOWING LOCATION OF DEEP WELLS IN THE FOXBURG AND CLARION QUADRANGLES AND VICINITY

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‡5	Sacramento	California	25
‡6	Chattanooga	Tennessee	25
‡7	Pikes Peak	Colorado	25
‡8	Sewanee	Tennessee	25
‡9	Anthracite-Crested Butte	Colorado	50
‡10	Harpers Ferry	Va.-Md.-W.Va.	25
‡11	Jackson	California	25
‡12	Estillville	Ky.-Va.-Tenn.	25
13	Fredericksburg	Virginia-Maryland	25
‡14	Staunton	Virginia-West Virginia	25
‡15	Lassen Peak	California	25
16	Knoxville	Tennessee-North Carolina	25
‡17	Marysville	California	25
18	Smartsville	California	25
‡19	Stevenson	Ala.-Ga.-Tenn.	25
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21	Pikeville	Tennessee	25
22	McMinnville	Tennessee	25
23	Nomini	Maryland-Virginia	25
24	Three Forks	Montana	25
25	Loudon	Tennessee	25
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27	Morristown	Tennessee	25
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29	Nevada City Special	California	50
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31	Pyramid Peak	California	25
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35	Gadsden	Alabama	25
36	Pueblo	Colorado	25
37	Downieville	California	25
38	Butte Special	Montana	25
39	Truckee	California	25
40	Wartburg	Tennessee	25
41	Sonora	California	25
42	Nueces	Texas	25
43	Bidwell Bar	California	25
‡44	Tazewell	Virginia-West Virginia	25
45	Boise	Idaho	25
46	Richmond	Kentucky	25
47	London	Kentucky	25
48	Tenmile District Special	Colorado	25
49	Roseburg	Oregon	25
50	Holyoke	Massachusetts-Connecticut	25
51	Big Trees	California	25
52	Absaroka	Wyoming	25
53	Standingstone	Tennessee	25
54	Tacoma	Washington	25
55	Fort Benton	Montana	25
56	Little Belt Mountains	Montana	25
‡57	Telluride	Colorado	25
58	Elmoro	Colorado	25
59	Bristol	Virginia-Tennessee	25
60	La Plata	Colorado	25
61	Monterey	Virginia-West Virginia	25
62	Menominee Special	Michigan	25
63	Mother Lode District	California	50
64	Uvalde	Texas	25
65	Tintic Special	Utah	25
66	Colfax	California	25
67	Danville	Illinois-Indiana	25
68	Walsenburg	Colorado	25
69	Huntington	West Virginia-Ohio	25
70	Washington	D. C.-Va.-Md.	50
71	Spanish Peaks	Colorado	25
72	Charleston	West Virginia	25
‡73	Coos Bay	Oregon	25
74	Coalgate	Indian Territory	25
75	Maynardville	Tennessee	25
76	Austin	Texas	25
77	Raleigh	West Virginia	25
78	Rome	Georgia-Alabama	25
79	Atoka	Indian Territory	25
80	Norfolk	Virginia-North Carolina	25
81	Chicago	Illinois-Indiana	50
82	Masontown-Uniontown	Pennsylvania	25
‡83	New York City	New York-New Jersey	50
84	Ditney	Indiana	25
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No.*	Name of folio.	State.	Price.†
			Cents.
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98	Tishomingo	Indian Territory	25
99	Mitchell	South Dakota	25
100	Alexandria	South Dakota	25
101	San Luis	California	25
102	Indiana	Pennsylvania	25
103	Nampa	Idaho-Oregon	25
104	Silver City	Idaho	25
105	Patoka	Indiana-Illinois	25
106	Mount Stuart	Washington	25
107	Newcastle	Wyoming-South-Dakota	25
108	Edgemont	South Dakota-Nebraska	25
109	Cottonwood Falls	Kansas	25
110	Latrobe	Pennsylvania	25
111	Globe	Arizona	25
112	Bisbee	Arizona	25
113	Huron	South Dakota	25
114	De Smet	South Dakota	25
115	Kittanning	Pennsylvania	25
116	Asheville	North Carolina-Tennessee	25
117	Casselton-Fargo	North Dakota-Minnesota	25
118	Greeneville	Tennessee-North Carolina	25
119	Fayetteville	Arkansas-Missouri	25
120	Silverton	Colorado	25
121	Waynesburg	Pennsylvania	25
122	Tahlequah	Indian Territory-Arkansas	25
123	Elders Ridge	Pennsylvania	25
124	Mount Mitchell	North Carolina-Tennessee	25
125	Rural Valley	Pennsylvania	25
126	Bradshaw Mountains	Arizona	25
127	Sundance	Wyoming-South Dakota	25
128	Aladdin	Wyo.-S. Dak.-Mont.	25
129	Clifton	Arizona	25
130	Rico	Colorado	25
131	Needle Mountains	Colorado	25
132	Muscogee	Indian Territory	25
133	Ebensburg	Pennsylvania	25
134	Beaver	Pennsylvania	25
135	Nepesta	Colorado	25
136	St. Marys	Maryland-Virginia	25
137	Dover	Del.-Md.-N. J.	25
138	Redding	California	25
139	Snoqualmie	Washington	25
140	Milwaukee Special	Wisconsin	25
141	Bald Mountain-Dayton	Wyoming	25
142	Cloud Peak-Fort McKinney	Wyoming	25
143	Nantahala	North Carolina-Tennessee	25
144	Amity	Pennsylvania	25
145	Lancaster-Mineral Point	Wisconsin-Iowa-Illinois	25
146	Rogersville	Pennsylvania	25
147	Pisgah	N. Carolina-S. Carolina	25
‡148	Joplin District	Missouri-Kansas	50
149	Penobscot Bay	Maine	25
150	Devils Tower	Wyoming	25
151	Roan Mountain	Tennessee-North Carolina	25
152	Patuxent	Md.-D. C.	25
153	Ouray	Colorado	25
154	Winslow	Arkansas-Indian Territory	25
155	Ann Arbor	Michigan	25
156	Elk Point	S. Dak.-Nebr.-Iowa	25
157	Passaic	New Jersey-New York	25
158	Rockland	Maine	25
159	Independence	Kansas	25
160	Accident-Grantsville	Md.-Pa.-W. Va.	25
161	Franklin Furnace	New Jersey	25
162	Philadelphia	Pa.-N. J.-Del.	50
163	Santa Cruz	California	25
§164	Belle Fourche	South Dakota	25
§165	Aberdeen-Redfield	South Dakota	25
§166	El Paso	Texas	25
§167	Trenton	New Jersey-Pennsylvania	25
§168	Jamestown-Tower	North Dakota	25
§169	Watkins Glen-Catatonk	New York	25
§170	Mercersburg-Chambersburg	Pennsylvania	25
§171	Engineer Mountain	Colorado	25
§172	Warren	Pennsylvania-New York	25
§173	Laramie-Sherman	Wyoming	25
§174	Johnstown	Pennsylvania	25
§175	Birmingham	Alabama	25
§176	Sewickley	Pennsylvania	25
§177	Burgettstown-Carnegie	Pennsylvania	25
§178	Foxburg-Clarion	Pennsylvania	25

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

§ These folios are also published in octavo form.

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