DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

GEOLOGIC ATLAS
OF THE
UNITED STATES

CLAYSVILLE FOLIO

PENNSYLVANIA

BY

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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.

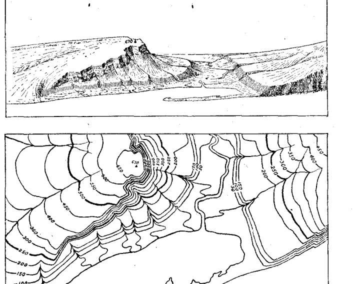


FIGURE 1.—Ideal view and corresponding contour map.

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		TR	Peacock-blue.
Paleozoic	Carboniferous	Permian Pennsylvanian Mississippian	C	Blue.
	Devonian		D	Blue-gray.
	Silurian		S	Blue-purple.
	Ordovician		O	Red-purple.
	Cambrian		Є	Brick-red.
	Algonkian		A	Brownish red.
	Archean		AR	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.

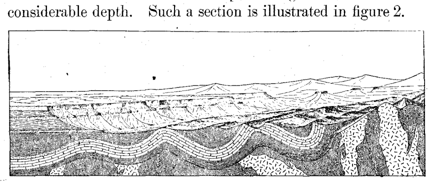


FIGURE 2.—Sketch showing a vertical section at the front and a landscape beyond.

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.

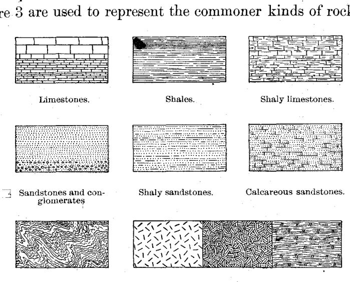


FIGURE 3.—Symbols used in sections to represent different kinds of rocks.

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.

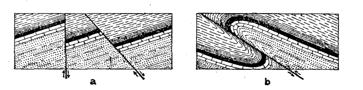


FIGURE 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* or *reverse* fault.

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 CLAYSVILLE QUADRANGLE.

By M. J. Munn.

INTRODUCTION.

GENERAL RELATIONS OF THE QUADRANGLE.

The Claysville quadrangle is in southwestern Pennsylvania, between latitudes 40° and 40° 15′ and longitudes 80° 15′ and 80° 30′, thus including one-sixteenth of a square degree, or about 228 square miles. It lies chiefly in Washington County, but a little of the southeastern part is in Greene County. The quadrangle is named from the town of Claysville, which stands near its center. (See fig. 1.)

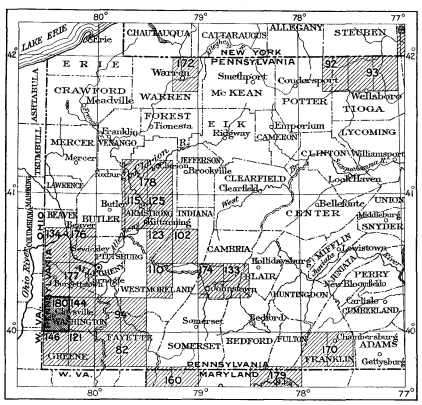


FIGURE 1.—Index map of western Pennsylvania.

The location of the Claysville quadrangle is shown by the darker ruling (No. 180). Published folios describing other quadrangles, indicated by lighter ruling are 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; 178, Foxburg-Clarion; 179, Pawpaw-Hancock.

In its geographic and geologic relations the Claysville quadrangle forms a part of the Appalachian province, which extends from the Atlantic Coastal Plain on the east to the Mississippi lowland on the west, and from central Alabama to Canada.

GEOGRAPHY AND GEOLOGY OF THE APPALACHIAN PROVINCE.

GENERAL FEATURES.

With respect to topography and geologic structure, the Appalachian province may be divided into two nearly equal parts by a line following the eastward-facing escarpment known as the Allegheny Front in Pennsylvania, Maryland, and West Virginia, and as the Cumberland escarpment from Virginia to Alabama. (See fig. 2.) East of this line the rocks are greatly disturbed by folding and faulting. West of it they are much

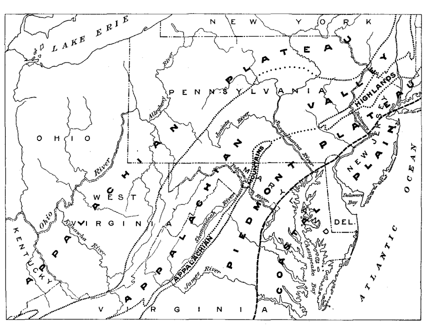


FIGURE 2.—Map of the northern part of the Appalachian province, showing its physiographic divisions and its relation to the Coastal Plain.

The Claysville quadrangle is situated in the Appalachian Plateau division, in the southwestern part of Pennsylvania.

less deformed, the irregular folds decreasing in intensity toward the west. Immediately east of the Allegheny Front is a belt of alternating ridges and valleys called the Appalachian Valley, and still farther east is a dissected upland known as the Piedmont Plateau. West of the Allegheny Front lie more or less elevated plateaus, which are greatly dissected by streams and broken by a few ridges where minor folds affect the rocks. In contrast with the lowlands of the Mississippi Valley on the west and with the Appalachian Valley on the east, this part of the province is called the Allegheny Plateau. The Claysville quadrangle lies within the Allegheny Plateau, which will therefore be described in detail.

ALLEGHENY PLATEAU.

The Allegheny Plateau is characterized by distinct types of drainage, surface features, and geologic structure.

Drainage.—The Allegheny Plateau is drained very largely into the Mississippi, but the streams of its northeastern part flow either into the Great Lakes or into the Atlantic Ocean through the Susquehanna, the Delaware, or the Hudson.

In the northern part of the Plateau region the present direction of the drainage is due in part to former glaciation. Before the glacial epoch all the streams north of central Kentucky probably flowed northwestward and united with the St. Lawrence system. (See fig. 3.) The encroachment of the great ice sheet closed this northern outlet and established the existing drainage lines.

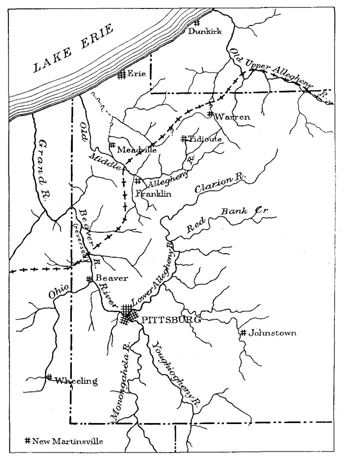


FIGURE 3.—Sketch map showing probable preglacial drainage of western Pennsylvania.

The terminal moraine is shown by broken crossed line. (After Frank Leverett; with slight changes and addition of terminal moraine.)

In the southern part of the Plateau region the westward-flowing streams not only drain the Allegheny Plateau, but many of them have their sources in the Blue Ridge east of the Appalachian Valley.

Relief.—The surface of the southern part of the Plateau region is highest along its southeastern margin, where the general surface rises from an altitude of 1700 feet in southern Tennessee to 4000 feet in central West Virginia, and thence descends to 2200 feet in southern New York. The surface also slopes in a general way to the northwest and southwest and merges into the Mississippi and Gulf plains. In the southeastern part of the Plateau region, in Tennessee and Alabama, is the Cumberland Plateau. West of the Cumberland Plateau in Tennessee and Kentucky lies the Highland Plateau, at an elevation of about 1000 feet. From these well-defined plateaus northward to southern New York the region is greatly dissected and its plateau character is apparent only in a wide view from some elevated point which affords a panorama showing the approximately uniform height of the ridges and hills.

The surface of the Cumberland Plateau and perhaps also the summits of the higher ridges and hills, as well as extensive tracts of elevated nearly level surface in a broad belt along the southeastern margin of the Allegheny Plateau from the Cumberland Plateau to New York, are all probably remnants of a peneplain, possibly the Schooley peneplain, named from Schooley Mountain in northern New Jersey, where it is notably developed. In the Allegheny, Monongahela, and Ohio valleys of western Pennsylvania, including the Claysville quadrangle, the tops of the highest hills probably coincide approximately with the surface of a second peneplain, younger than the Schooley peneplain and at a lower level. This peneplain has been named by Campbell the Harrisburg peneplain because it is well developed near Harrisburg, Pa. Along the Monongahela, Allegheny, and Ohio valleys a third peneplain has been recognized. This is lower, younger, and less extensive than the Harrisburg peneplain. This plain is well developed between Worthington and Allegheny River in Armstrong County, and has therefore been named by Butts the Worthington peneplain.

Stratigraphy.—The rocks of the Plateau region are mostly of Carboniferous age and are bordered by the upper formations of the Devonian system, which extend beneath the Carboniferous throughout the northern half of the region. The Carboniferous rocks are divided into three series, the Mississippian series below, the Pennsylvanian series above, and the Permian series at the top. The rocks of the Mississippian series are mainly sandstones and shales in the northern part of the region, but include thick limestones in the southeastern and southwestern parts. The rocks of this series outcrop around the margins of the plateaus and underlie the rocks of the Pennsylvanian series in the interior of the region. The rocks of the Pennsylvanian series are coextensive with the Appalachian coal field and consist essentially of sandstone and shale, but contain extensive beds of limestone and fire clay. The series is especially distinguished, however, by its coal seams, one or more of which is present in nearly every square mile from northern Pennsylvania to central Alabama. The Permian series consists of shale, sandstone, limestone, clay, and coal, named in the order of their thickness. These beds occupy the central part of the Appalachian coal field in southwestern Pennsylvania, northern West Virginia, and eastern Ohio. The maximum thickness of the series probably does not exceed 1200 or 1400 feet. The exposed rocks of the Claysville quadrangle are of the Pennsylvanian and Permian series, overlain by small surficial stream deposits of Pleistocene age.

Structure.—For the purposes of this folio the discussion of the geologic structure of the region may be confined to the bituminous coal field of the Appalachian province.

The structure of the bituminous coal field is very simple for the rocks form, in a general way, a broad, flat trough, notably at the northern extremity of the field. The axis of this trough lies along a line extending southwestward from Pittsburg across West Virginia to Huntington, on Ohio River. The rocks lying southeast of the axis dip northwest; those lying northwest of the axis dip southeast. In Pennsylvania the deepest part of the trough is in the southwest corner of the State and the inclination of the rocks is generally toward that point. About the northern end of this trough the rocks outcrop in a rudely semicircular belt, and at all points have a general dip toward the lowest part of the trough.

Although in general the structure is simple, the eastern side of the trough is crumpled into a number of parallel wrinkles or folds, which make the detailed structure somewhat complicated and break up and conceal the regular westward dip. These undulations are similar to the great folds east of the Allegheny Front but are on a very much smaller scale and have been broken by only a few local faults. These minor folds are present along the southeastern margin of the basin, from central West Virginia to southern New York. Across the northern extremity of the basin the minor folds are developed in large numbers, and the folded region extends at least halfway across Pennsylvania near its northern boundary. In the southern part of the State there are only six pronounced anticlines, two of these disappearing near the West Virginia line. Toward the south the number becomes less, until, on Kanawha River, the regular westward dip is interrupted by only one or two small folds. Close examination shows that west of the Allegheny Front each trough, as well as each arch, lies lower than the one on the east, so that formations or beds that are over 2000 feet above sea at the Allegheny Front lie below sea level in the central part of the basin.

TOPOGRAPHY.

DRAINAGE.

Ohio River roughly describes a semicircle from northeast to southwest around the Claysville quadrangle at a distance of 10 to 30 miles, and Monongahela River parallels the eastern border at a distance of 10 to 15 miles. The watershed between these rivers extends from the middle of the eastern border in a general southwestern direction across the quadrangle. The principal tributaries of the Ohio are Chartiers Creek, which drains the northeastern part of the quadrangle and flows northeastward; Buffalo Creek, which drains the northwestern part and flows westward; and Middle Wheeling Creek and Robison Run, which flow westward and southwestward and drain the southwestern part. Tenmile Creek, flowing eastward, receives all the drainage from this quadrangle to Monongahela River. The valleys of all the streams in this quadrangle are narrow, many of the flood plains being bordered by precipitous hillsides that rise to heights of 100 to 400 feet. Most of the surface of the quadrangle is in cultivation, the residual soil being at most only a few feet thick and of a clayey nature. The underlying rocks consist principally of shale, sandstone, and limestone with very low dips. All this tends to cause a relatively small portion of the water which falls on the surface to be retained as ground water. The small streams are therefore subject to rapid fluctuations in volume, and on the whole erosion is going on rapidly.

RELIEF.

General features.—The surface of the Claysville quadrangle is hilly. The hillsides bordering the lower courses of the principal streams are in many places precipitous at their bases, becoming less steep upward to comparatively flat or well-rounded summits. Relatively few of the hillsides are too steep for cultivation, though the steeper slopes are generally forested. Toward the heads of the streams the valleys are wider and the hills are less steep, the principal topographic features being large hills of smooth, graceful curves modified in places by inconspicuous terraces resulting from more resistant beds of sandstone or limestone. A few low cliffs, formed directly by stream cutting, occur along streams, and at a few places on hillsides there are other low cliffs due to the weathering of massive sandstones. The surface is generally covered by a mantle of residual soil resulting from the relatively rapid decay of the exposed rocks. When the land is cleared and cultivated erosion becomes much more rapid and the soil is removed very much faster than it is formed, the result being that many hill slopes are now almost barren of soil.

Harrisburg plateau.—The elevations of the higher ridges in the Claysville quadrangle range from about 1300 to 1560 feet above sea level, a large number being between 1300 and 1360 feet. The country shows a fairly horizontal sky line when viewed from this altitude, though several important ridges have an elevation of more than 1400 feet and a few peaks rise to heights exceeding 1500 feet. Campbell[a] has fixed the altitude of the Harrisburg peneplain at the mouth of Beaver River, about 30 miles north of the Claysville quadrangle, at 1200 feet, and on Monongahela River, 15 miles east of the quadrangle, at 1250 feet. From these points, according to his determinations, the peneplain slopes southwestward, thus bringing it about 100 feet below the general surface of the ridges of the Claysville quadrangle.

Worthington plateau.—Below the tops of the higher ridges numerous secondary ridges and hills near the main drainage lines have fairly uniform altitudes over considerable areas, but the data here are not sufficient to determine whether these are the result of uniform erosion or represent a peneplain condition of an old land surface. If the Worthington peneplain extended into this quadrangle it was evidently very poorly developed. If portions of this surface have escaped subsequent erosion they probably stand at an elevation of 1100 to 1150 feet and occur as small terraces along the larger streams.

Cut terraces.—Along Chartiers Creek and Buffalo Creek are remnants of cut terraces ranging from about 980 to 1060 feet above sea level, which seem to indicate an old valley floor of greater width and less gradient than the present valley. Upon these terraces lie thin deposits of clay and gravel of local origin, known as the Carmichaels formation. These terraces were probably formed during the last stages of the Tertiary period.

GEOLOGY.

STRATIGRAPHY.

The rocks recognized in this quadrangle include those not exposed at the surface as well as those that outcrop. The underlying rocks are revealed in deep wells sunk for oil and gas; the surface rocks can be studied directly. The entire thickness of the rocks thus examined is about 4000 feet. They belong to the Permian, Pennsylvanian, and Mississippian series of the Carboniferous system, and to the underlying Devonian system, the latter probably representing the Catskill and Chemung formations of the eastern part of the State.

ROCKS NOT EXPOSED.

Records of deep wells furnish all the direct information available regarding the rocks not exposed in this quadrangle. This material is not sufficiently trustworthy to warrant positive statements regarding the age and lithologic character of many of these rocks.

CHARACTER OF WELL-RECORD DATA.

The lowest stratum exposed at the surface in the Claysville quadrangle is the Pittsburg sandstone member of the Monongahela formation, which overlies the Pittsburg coal and outcrops in the channel of Chartiers Creek at the eastern border of the quadrangle. More than a thousand deep wells have been drilled to various depths below this stratum in search of oil and gas. The drilling was done by the churn-drill method, which does not permit detailed lithologic examinations of the rocks, nor the collection of fossils from them, so that in many places the boundary lines of formations are conjectural. Drillers watch carefully the sequence of the strata, noting differences in color, hardness, and composition, and where a well-recognized key stratum is present throughout a region they are thereby enabled to correlate prominent beds from place to place with considerable accuracy. Beds that are prominent for either economic or stratigraphic reasons have been named by drillers, and many of these names have come to be firmly fixed over thousands of square miles.

[a] Bull. Geol. Soc. America, vol. 14, 1903, p. 293.

The logs of the wells drilled in the Claysville quadrangle are of all degrees of completeness, from those giving nothing but the depth to the top of the oil-bearing bed to those showing the supposed character, thickness, and depth of each stratum passed through. Unfortunately, the percentage of detailed records is so small that the logs are not of great value to the geologist. Another source of trouble to the geologist in using well records for correlation is the fact that the drillers can not afford the time to make accurate (steel line) measurements to the tops and bottoms of strata that are comparatively near the surface and that are known not to contain oil and gas in commercial quantities. The result is that the deeply buried oil sands are better known than a mass of unexposed rocks several hundred feet thick just below the surface.

From the surface where the lowest rocks outcrop in the Claysville quadrangle downward the first 1100 feet of unexposed rocks consists principally of shale and sandstone, with many thin beds of limestone, clay, and coal. These rocks constitute the Conemaugh, Allegheny, and Pottsville formations of the Pennsylvanian series of Carboniferous rocks. With the exception of five or six massive sandstones, ranging from 25 to 150 feet in thickness, this zone is one of soft drilling. These rocks rarely furnish oil or gas in commercial quantities, and accurate measurements are seldom made to any of the beds. Below the Pennsylvanian rocks the drill encounters from 800 to 1000 feet of Mississippian strata, which are in many places capped by a thick limestone; below this is a massive sandstone from 150 to 400 feet thick, succeeded by three or more hard massive sandstones, embedded in gray or red shale, the lowermost sandstone being near the base of the series. These rocks constitute a zone of comparatively hard drilling. They represent the Mauch Chunk and Pocono formations. The sandstones contain pools of oil and gas, and their composition, thickness, and depth are in general accurately noted by the drillers.

Below the Pocono formation occurs a zone of soft drilling, containing thick beds of red, black, or green clay shale, alternating with thin gray or white sandstones. These beds are believed to represent the Catskill formation of the eastern part of the State. Most of the deep wells penetrate to some point in this zone, and many of them stop in the lower part or pass through it for a short distance into the chocolate-colored shale and thin, hard sandstones which are believed to represent the Chemung formation. The sandstones of the Catskill (?) formation and the sandstone at the base of the Pocono contain nearly all the oil and gas pools of the Claysville quadrangle.

DEVONIAN SYSTEM.

CHEMUNG (?) FORMATION.

Occurrence.—At many points in Pennsylvania north and east of the Claysville quadrangle strata believed to represent the Chemung formation have been penetrated by the drill for hundreds of feet. These beds consist of chocolate-colored shale and thin, hard sandstone. A deep well on the William Bedell farm at West Elizabeth, Pa., about 20 miles northeast of the Claysville quadrangle, reached a depth of 5700 feet below the Pittsburg coal, or about 3500 feet below the Fifth sand. In this well and in others in the vicinity of Pittsburg above 500 feet of "slate and shells" (thin, hard sandstone beds and soft shales) underlie the lowest red bed and below these there is about 800 feet of sandy shale, all of which are supposed to be of Chemung age. In the Rogersville quadrangle, south of the Claysville area, only a few wells have been sunk below the Elizabeth sand. These wells record only shale or "slate and shells" for a depth of 1000 to 2000 feet and in that distance the thickness of the Chemung (?) rocks could not be determined. Probably the best estimate of the thickness of the supposed Chemung strata over southwestern Pennsylvania has been made by Charles Butts,[a] who considers it to average about 1000 feet.

Elizabeth sand.—About 100 to 150 feet below the top of the Chemung (?) formation, or 200 to 250 feet below the Fifth sand, is a thin gray sandstone which has been found to contain gas pools of considerable size in the eastern portion of Washington County and in Greene County, where it is termed the Elizabeth sand. In the Claysville quadrangle hard sandstone "shells" at what is probably this horizon have been reported in a few wells, but the sand is not well recognized in this quadrangle.

Sixth or Bayard sand.—The Sixth or Bayard sand, lying about 100 to 130 feet below the Fifth sand, is at or near the top of the Chemung (?) formation. It has been found in many deep wells over the eastern part of Washington County and southwestward through Greene County into West Virginia. In the Claysville quadrangle it is reported in many wells as a hard gray sandstone, with a thickness not exceeding 20 feet.

CATSKILL (?) FORMATION.

Occurrence.—Above the Chemung (?) formation and below the Pocono formation occur thick beds of red, black, or green clay shale, alternating with thin gray or white sandstones, which are in many places rather soft. The stratigraphic position and deep-red color of some of these shales suggest strongly

[a] Rept. Top. and Geol. Survey Comm. Pennsylvania, 1906-1908, p. 202.

that they are equivalent to the Catskill formation of eastern Pennsylvania. The greenish shale and gray and white sandstone indicate conditions similar to those of the Conewango and Knapp formations of the Warren quadrangle,[a] of northern Pennsylvania. In some reports they are considered to be Chemung. The age and exact relations of these beds to the Catskill, Conewango, Knapp, and Chemung formations can not be determined, and in this folio they are called Devonian (?) and are tentatively assigned to the Catskill formation. The bottom of this group of beds is here fixed at the bottom of the lowest red bed noted by drillers, which is from 50 to about 100 feet below the deepest prominent oil sand (Fifth sand) of this quadrangle.

Fifth sand.—The Chemung (?) formation is overlain by soft red, green, and black shale which extends for about 70 to 130 feet, up to the base of the Fifth sand. Within the shale occurs here and there, from 40 to 70 feet below the Fifth sand, a thin lentil of sandstone which has no stratigraphic or economic value, except that it is sometimes mistaken for the Sixth or Bayard sand. The Fifth sand is a medium-grained gray or white sandstone, containing at many places thin lentils of white quartz pebbles. It is from 20 to 40 feet or more thick over the southeastern half of the quadrangle, and thins gradually toward the northwest, being either entirely absent or represented by a few feet of "slate and shells" in the western parts of Donegal, Blaine, and Hopewell townships and all of Independence Township. From 40 to 70 feet of red, green, and black shale separates the Fifth from the Fourth sand.

Fourth sand.—The Fourth sand closely resembles the Fifth, both in lithologic characteristics and in distribution. It is thickest in the southeastern part of the quadrangle and disappears toward the northwest. This bed is less persistent than the Fifth sand and is probably represented by a number of isolated lentils, except in the southeastern and southern parts of the area, where it ranges from 20 to 35 feet or more in thickness. The conglomerate lentils in the Fourth sand are not so thick or uniform in occurrence as those in the Fifth sand. Black, red, and green shales from 40 to 50 feet thick separate the Fourth sand from the overlying Third or Gordon sand.

Third or Gordon sand.—The Third or Gordon sand in this quadrangle covers about the same territory as that described above for the Fourth and Fifth sands. It appears to be from 20 to 40 feet thick over much of the southeastern part and thins out uniformly toward the northwest. It is white, gray, or reddish in color and carries lentils of quartz-pebble conglomerate from 1 foot to 15 feet thick. Over much of the central portion of the quadrangle, where this sand is petroliferous, it is rarely more than 15 feet thick, the inclosed lentil of conglomerate in few places exceeding 6 feet in thickness. This sand appears to occupy the same stratigraphic position as the Venango Third sand, in which oil was first discovered near Oil City in 1859. The name Gordon was first applied to it in 1885, when a well on the Gordon farm at Washington, Pa., found oil in it. This sand is overlain by a fairly persistent bed of black shale, which locally gives way to red or greenish shales, extending upward to the base of the Gordon Stray sand.

Stray, Third Stray, or Gordon Stray sand.—This sand, while generally known in the Claysville quadrangle as the Gordon Stray or Stray sand, received the name of Third Stray in Venango County, Pa., probably 25 years before it was known to exist in Washington County. It is a sandstone lentil of white, gray, or reddish color, ranging from a knife-edge to more than 50 feet in thickness. It is very irregular in distribution in the Claysville quadrangle. It is probably thickest toward the south and southeast and disappears entirely toward the northwest. This lentil appears to thicken at the expense of the underlying shale, and in some wells is separated from the Third or Gordon sand by a thin "break" of black shale, in places less than 1 foot in thickness. From 40 to 80 feet of red, black, or light-colored sandy shale separates the Gordon Stray sand from the Nineveh Thirty-foot sand above. Farther north, in Allegheny and Butler counties, this shale locally contains two thin sandstone lentils, known as the Bowlder and the Snee or Blue Monday oil sands, but these are apparently not present in the Claysville quadrangle.

Nineveh Thirty-foot sand.—This is the uppermost sand of the Catskill (?) formation. It lies from 90 to 110 feet above the Gordon sand and from 50 to 110 feet below the base of the Hundred-foot sand. It is usually a hard gray or reddish sandstone, fine to medium grained, with thin, coarse-sand and pebbly lentils occurring irregularly in it. The Nineveh Thirty-foot sand is from 15 to about 40 feet thick in the southeast half of the quadrangle but thins to "slate and shells" in much of the northwest half.

Upper beds of Catskill (?) formation.—Above the Nineveh Thirty-foot sand are soft shales to the base of the Hundred-foot sand. In these beds occurs a fairly persistent layer of red shale which most authorities consider to mark approximately the top of the Devonian system in this region. However, as the boundary between the Devonian and the Carboniferous in

[a] Butts, Charles, Warren folio (No. 172), Geol. Atlas U. S., U. S. Geol. Survey, 1910.

western Pennsylvania is not well established and as no direct evidence bearing on this question has been obtained in the Claysville quadrangle, the subject is not discussed here and all the beds lying between the two sands are tentatively assigned to the Devonian.

CARBONIFEROUS SYSTEM.

MISSISSIPPIAN SERIES.

As elsewhere throughout Pennsylvania except in the northwestern part, the Mississippian series is represented in this quadrangle by the rocks of the Pocono and Mauch Chunk formations, the former being regarded as the equivalent of a large part of the Waverly group of Ohio and northwestern Pennsylvania.

POCONO FORMATION.

The Pocono formation in the Claysville quadrangle consists of the Hundred-foot and the Murrysville or Berea sands near the base, an overlying series of thin sandstones and shales, and, at the top, the Burgoon sandstone member or the Big Injun sand.

Hundred-foot sand.—The name Hundred-foot was first applied to a sandstone near the base of the Pocono by drillers in Butler and Armstrong counties. In the type locality this sandstone ranges from about 60 to 150 feet in thickness, averaging about 100 feet. It is there a massive gray, white, or reddish sandstone, with one to five or more thin lenses of quartz-pebble conglomerate running through it. In many wells a thin "break" of shale, usually black, from 1 to 6 feet or more thick, was noted near the middle of this sand, and less commonly another thin shale bed occurs in it near the top. When traced southward by subsequent drilling, the shale break near the middle of the Hundred-foot sand was found to increase in thickness, thus separating the sandstone into two members. Later, when drilling began in Washington County, oil was first found in the upper member of this sand, in a well drilled on the Gantz lot in Washington, Pa., and it became known locally as the Gantz sand. The lower member, from its thickness in this vicinity, was called the Fifty-foot sand.

Throughout most of the Claysville quadrangle both members of the Hundred-foot sand are easily recognized by drillers. In some places the Gantz sand is represented by "slate and shells" (thin, hard layers of sandstone interbedded with soft shale), in which case the Fifty-foot is sometimes mistaken for it by drillers, and the Nineveh Thirty-foot sand below in turn recorded as the Fifty-foot. In like manner, where the Fifty-foot is absent, careless drillers sometimes record a higher sand (the Murrysville, Butler gas, or Butler Thirty-foot) as the Gantz and mistake the Gantz for the Fifty-foot. The maximum thickness of the Hundred-foot sand is about 150 feet, including as much as 80 feet of shale between the two sandstone members. The Gantz sand has an average thickness between 20 and 40 feet; the Fifty-foot is somewhat thinner.

Above the Hundred-foot sand is from 20 to 100 feet of soft red and gray sandy shale. The "red rock" at this horizon is from a knife-edge to more than 60 feet in thickness and should not be confused with the red bed below the Hundred-foot sand. It is fairly persistent over the quadrangle and thickens toward the west, thereby differing in distribution from the red beds of the Catskill (?) formation below, which thin and disappear in that direction. John F. Carll[a] traced this red bed by means of well records over Forest County, southern Venango County, and western Butler County, Pa., and in eastern Ohio as far west as its outcrop on the Cincinnati anticline. Since his report was published drilling has shown that the southeastern boundary of this bed passes across the northwestern part of Greene County, the central part of Washington County, and northward through Allegheny County, west of Pittsburg, into the western part of Armstrong County, and that it therefore extends somewhat farther in that direction than he supposed.

Butler gas or Butler Thirty-foot sand.—Upon the red shale mentioned above lies a sand that ranges in thickness from a knife-edge to about 75 feet, which is fairly persistent throughout the Claysville quadrangle. In southwestern Pennsylvania this sandstone is most generally known as the Butler gas or Butler Thirty-foot sand. It appears, however, to be equivalent to the Murrysville gas sand of Westmoreland County and to the Butler Thirty-foot sand or shells of Washington and Greene counties. Traced westward it seems to occupy the same stratigraphic position as the Berea sand of West Virginia and southeastern Ohio.

Charles Butts,[b] who has recently published some interesting facts relative to the correlation of the Berea sandstone of northern Ohio with the oil sands of Pennsylvania, considered the former to be equivalent to the Hundred-foot sand and therefore older than the Butler Thirty-foot sand of the Claysville and other quadrangles. There seems no reason for questioning this correlation for northern Pennsylvania. However, in tracing the Hundred-foot sand by well records from Venango County southward to the Claysville quadrangle, a gap is found to exist

[a] Rept. I 5, Second Geol. Survey Pennsylvania, 1890, pp. 93-96.
[b] Rept. Top. and Geol. Survey Comm. Pennsylvania, 1906-1908, p. 190.

between the western border of the Kittanning quadrangle and the northeast corner of the Sewickley quadrangle in which few detailed well records have been collected and studied, and it seems possible that the great sandstone supposed to be at the base of the Pocono and variously called the Venango First sand,[a] Butler Second sand,[b] Hundred-foot sand and Berea sandstone,[c] which throughout much of Venango and Clarion counties is a single bed of sandstone, may be divided by two shale "breaks" instead of one, as is generally supposed. If this is true, the sandstone group near the base of the Pocono in the Claysville quadrangle, composed of the Fifty-foot, Gantz, and Butler Thirty-foot sands, is the stratigraphic equivalent of the Hundred-foot sand or Berea sandstone of northern Pennsylvania. The Berea sand of southeastern Ohio and West Virginia, being equivalent to the Butler Thirty-foot sand, would then represent only the upper portion of the Berea sandstone of northern Ohio. On the other hand, it is possible that the Butler Thirty-foot or Butler gas sand is an individual sandstone bed, extending from Butler County southward, being absent farther north in Venango and Clarion counties. Additional field work is needed to settle this point.

Squaw sand.—Above the Butler Thirty-foot sand is from 275 to 350 feet of gray or dark sandy shale, in which thin, hard sandstone "shells" occur locally. These sandstone lentils are very irregular in occurrence and, being of no economic value, are seldom noted by drillers. One of the most persistent sandstone lentils occurring in this shale is the Squaw sand, which lies about 40 to 100 feet from the top. This sand appears to be variable in thickness, ranging from 10 to 100 feet or more within short distances.

Burgoon sandstone member (Big Injun sand).—Throughout southwestern Pennsylvania, adjoining portions of West Virginia, and much of eastern Ohio the top of the Pocono formation is marked by the Burgoon sandstone member or Big Injun sand, which is one of the thickest and most persistent sandstones of this region. In the Claysville quadrangle this sandstone is from about 100 to probably 350 feet in thickness, including in places a shale "break" from 10 to 80 feet thick near the middle. This sand is usually yellow, white, or gray, with a dark layer infrequently recorded near the bottom. It is usually found to contain from one to three lenses of coarse sand and small pebbles, which form the "pay streaks." In this quadrangle these lenses rarely contain oil or gas in commercial quantities but instead furnish in many wells large quantities of salt water. Over most of the quadrangle the Burgoon sandstone is overlain by the Greenbrier limestone member or Big lime and the dividing line is therefore an easily recognized horizon from which drillers estimate the depth to the lower sands.

MAUCH CHUNK FORMATION.

In the Claysville quadrangle the Mauch Chunk formation is supposed to include the Greenbrier limestone member and to mark the top of the Mississippian series, which is overlain unconformably by the Pottsville formation. On the Allegheny Front west of Altoona the Mauch Chunk is composed of 80 feet of greenish sandstone at the bottom and 100 feet of red and green shale at the top.[d] In Fayette County this formation is exposed on the Laurel Ridge anticline, where it is 250 feet thick and includes the Greenbrier limestone as a member near the base.[e] It is here composed of red and green shales and thin greenish sandstones.

Greenbrier limestone member (Big lime).—Within the Claysville quadrangle most of the wells drilled to the Big Injun sand have shown it to be overlain by a limestone having a maximum thickness of about 75 feet, which is called by drillers the Big lime or Mountain limestone. In the northwestern part of the area this bed is very thin and in some places lacking, but it thickens gradually toward the southeast. Over most of this territory it ranges from a knife-edge to about 60 feet in thickness and is reported as hard and compact. In the southern portion two limestones, known to the drillers as the Little lime and Big lime, are reported. Between these limestones occurs a shale "break" of 5 to 40 feet, which is known to drillers as the Pencil Cave, because of its tendency to break into pencil-shaped fragments and to cave into the wells drilled through it.

This limestone has been traced by well records westward from Maryland and from its outcrop on Chestnut Ridge and Laurel Ridge, Pa., where it has been correlated with the Greenbrier limestone of Virginia.[f]

In the Waynesburg quadrangle R. W. Stone[g] considered the Mauch Chunk to be represented by red shale, sandstone, and

[a] Carll, J. F., Rept. I 4, Second Geol. Survey Pennsylvania, pp. 31-48.
[b] Carll, J. F., Rept. I 3, Second Geol. Survey Pennsylvania, p. 272.
[c] Butts, Charles, Rept. Top. and Geol. Survey Comm. Pennsylvania, 1906-1908, p. 195.
[d] Butts, Charles, Rept. Top. and Geol. Survey Comm. Pennsylvania, 1906-1908, p. 196.
[e] Campbell, M. R., Masontown-Uniontown folio (No. 82), Geol. Atlas U. S., U. S Geol. Survey, 1902, p. 6.
[f] Geol. Atlas U. S., folios as follows: Campbell, M. R., Masontown-Uniontown (No. 82), Brownsville-Connellsville (No. 94); Clapp, F. G., Amity (No. 144), Rogersville (No. 146); Martin, G. C., Accident-Grantsville (No. 160).
[g] Waynesburg folio (No. 121), Geol. Atlas U. S., U. S. Geol. Survey, 1905.

a limestone at least 50 feet thick, the total thickness of the formation varying from 125 to 250 feet.

In the Rogersville quadrangle, south of the Claysville area, F. G. Clapp[a] included in the Mauch Chunk all the rocks between the Salt sand of the Pottsville formation and the top of the Big Injun sand. These rocks vary from 100 to 275 feet in thickness and include 30 to 100 feet of Greenbrier limestone at the base, followed by a few feet of soft shale, the Pencil Cave of drillers, which at the north is overlain by 20 to 70 feet of limestone, known to the drillers as the Little lime, but which farther south is reported to be succeeded by a sandstone, called by drillers the Salvation sand. In the southeastern part of the Rogersville quadrangle red shales are reported above the Salvation sand, but in most wells the shales are black and it is not known whether these shales are of Mauch Chunk or Pottsville age.

In the Claysville quadrangle the shale overlying the Big lime is rarely more than 125 feet in thickness. It generally measures 20 to 75 feet and its thickness differs greatly from well to well. No records report this shale as red, but a number mention it as black. The salt sand overlying this shale is considered to be the basal member of the Pottsville, but in places that formation may include some of the shale below the sand. The fact that in most places this shale is black and rarely if ever shows the characteristic red color of the Mauch Chunk also tends somewhat to weaken the assumption that all of the shale between the top of the Greenbrier and the base of the Salt sand is Mauch Chunk.

MISSISSIPPIAN-PENNSYLVANIAN UNCONFORMITY.

Previous geologic work in western Pennsylvania has clearly established the fact that an unconformity of wide extent exists between the rocks of the Mississippian and Pennsylvanian series. On Laurel Ridge, in Fayette County, the lowest member of the Pottsville formation lies unconformably on the Mauch Chunk. In Armstrong County the Connoquenessing sandstone member of the Pottsville rests directly upon the Burgoon sandstone member, the Mauch Chunk and Greenbrier limestone being entirely cut out. Farther north, along Allegheny River, the Burgoon disappears and the Pottsville rocks successively overlie older and older rocks, until at Corydon, near the New York State line, all of the Pocono formation is gone from the section and Pottsville rocks rest directly upon beds of Devonian age. North of the Claysville quadrangle the beds between the Big Injun sand and Salt sand grow thinner and finally disappear altogether from the section in Beaver and Butler counties.

In view of the magnitude of the deformation which must have been involved during the cycle of elevation, erosion, and depression represented by this unconformity, the parallelism of the strata above it to those below it is remarkable. This parallelism is well illustrated by the subjoined table, which shows the distance between the top of the Pittsburg coal and the top of the Big Injun sand as reported by well logs in this quadrangle.

Distance between top of Pittsburg coal and top of Burgoon sandstone (Big Injun sand) in Claysville quadrangle.

Township.	Distance in feet at different points.
Buffalo	1113, 1112, 1100, 1123, 1141, 1100, 1100, 1121, 1118, 1115.
Hopewell	1125, 1049, 1095.
Independence	1057.
Blaine	1055, 1115.
Donegal	1113, 1098, 1108, 1101, 1108, 1097, 1092, 1103, 1090, 1093, 1127, 1090, 1100, 1102, 1097, 1084, 1104, 1103.
Borough of Washington	1096.
Canton	1115, 1135.
South Franklin	1169, 1138, 1118, 1129, 1140, 1138, 1125, 1166, 1153, 1140.
East Finley	1094, 1132, 1130, 1161, 1160, 1168, 1155, 1133, 1140.
West Finley	1100, 1120, 1115, 1100, 1140, 1140, 1150.
Morris (Washington County)	1077, 1153.
Morris (Greene County)	1198, 1194, 1200.

These wells are rather uniformly scattered over the townships and probably show the maximum variations in distance between these beds throughout the quadrangle.

PENNSYLVANIAN SERIES.

POTTSVILLE FORMATION.

In portions of western Pennsylvania, where the Pottsville formation is well exposed, it consists of the Homewood sandstone member at the top, the Mercer shale member, the Connoquenessing sandstone member (including the Quakertown coal), and, below these, the Sharon coal and Sharon conglomerate member.

David White[b] has shown, however, that the Pottsville beds of this region represent only the younger rocks of this formation in the anthracite coal field and in the southern Appalachian coal field. The type locality of the Homewood sandstone is at

[a] Rogersville folio (No. 146), Geol. Atlas U. S., U. S. Geol. Survey, 1907, p. 5.
[b] Twentieth Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, pp. 755-918.

Homewood, in Lawrence County, where it consists of 65 feet of massive sandstone. The Homewood sandstone is underlain by the Mercer shale member, which in places is 15 feet or more thick and contains the Mount Savage fire clay, from one to three coal seams, and limestones.

At Homewood[a] the Connoquenessing sandstone is massive, having a maximum thickness of 90 feet, and appears to unite with the Homewood. At some other places the rocks at this horizon are thin bedded and shaly at the top, with a shale from 50 to 60 feet thick, containing the Quakertown coal, near the middle and a more persistent and massive sandstone below. Throughout much of western Pennsylvania, north of Ohio River, the Connoquenessing sandstone appears to be the basal member of the Pottsville, the Sharon shale and conglomerate members being absent. The Connoquenessing is thought to be a prominent sandstone in much of eastern Ohio. In southern West Virginia and eastern Kentucky Pottsville strata equivalent to the Sharon, Connoquenessing, Mercer, and Homewood are over 1000 feet thick. The total thickness of the Pottsville in Alabama probably reaches more than 6000 feet.[b] At the outcrop on Youghiogheny River in Fayette County, east of the Claysville quadrangle, the Pottsville rocks comprise two massive sandstones, the upper one being from 30 to 80 feet thick and the lower having a maximum thickness of probably less than 100 feet, with 20 to 60 feet of shale between. This lower sandstone is considered by M. R. Campbell[c] to be equivalent to the Connoquenessing sandstone of the Beaver Valley.

In the Claysville quadrangle the boundaries of the Pottsville formation can not be clearly defined from the available well records. The Salt sand, which is the first prominent sandstone above the Big Injun sand, is mentioned in all the detailed records with a thickness ranging from about 50 to 250 feet, averaging about 125 feet. This sand may be either the Sharon conglomerate or the Connoquenessing sandstone of Lawrence County, or both. The next prominent sand above the Salt sand is generally termed the "Gas sand." In a number of wells this "Gas sand" is separated from the Salt sand by 25 to 125 feet of shale, frequently recorded as black. This sand is from 10 to 70 feet thick—generally about 50 feet. In many other wells a "Gas sand" is separated from the Salt sand below by 175 to 250 feet of black shale, in which case it is very probably in the Allegheny formation. Where this interval of shale is present the "Gas sand" ranges from 60 to 208 feet in thickness, with an average of about 100 feet. These measurements suggest the possibility that the "Gas sand" noted in the records is in fact two lenticular beds at different horizons, of which the lower may be equivalent to the Homewood sandstone of Lawrence County but the upper is more likely to be in the Allegheny formation. The total thickness of these beds varies from about 140 to 400 feet but is usually about 340 feet.

Inasmuch as the average thickness of the Mauch Chunk, Pottsville, Allegheny, and Conemaugh formations, as shown above by the table of distances from the Burgoon sandstone member (Big Injun) to the Pittsburg coal, is approximately 1100 feet, a thickness of 340 feet for the Pottsville seems too great in relation to the known thickness of these formations where they outcrop. The Conemaugh formation appears to be not less than 575 feet thick in the Claysville quadrangle; the Allegheny formation averages about 300 feet over western Pennsylvania. If 75 feet is regarded as the lowest average for the Mauch Chunk formation the thickness for the Pottsville may be estimated at about 150 feet. The sandy zone generally grouped by the drillers as Salt sand, therefore, may represent the entire Pottsville formation of this area.

Section of supposed Pottsville formation and associated rocks in the original Gantz well at Washington, Pa.

	Feet.
Slate and shells	100
Pottsville formation:	
Homewood (?) sandstone member:	
Sandstone; hard, whitish, salt water	57
Slate, black; no grit	15
	72
Connoquenessing sandstone member:	
Sandstone, soft, whitish	10
Slate and shells	15
Sandstone, hard, bluish gray	10
Slate and shells	27
Sandstone; good gas, soon exhausted	10
	72
Total thickness of Pottsville	144
Mauch Chunk formation:	
Slate, black; no grit	10
Sandstone, hard, flinty	3
Slate, black; no grit	77
	90
Greenbrier limestone member (Big lime)	30
Pocono formation:	
Burgoon sandstone member (Big Injun sand)	32

ALLEGHENY FORMATION.

The Allegheny formation conformably overlies the Pottsville and extends approximately from the top of the Homewood sandstone member to the top of the Upper Freeport coal. In the northern part of the bituminous coal field it is about 300 feet in thickness and consists of variable beds of sandstone, shale, clay, limestone, and coal. From Ohio River northeastward the coals increase in thickness and number, no less than eleven distinct beds having been noted. South and southeast from Ohio River the formation dips below drainage level and the thin variable sandstones can not be traced by well logs. The coals also seem to grow thinner and more variable, some of them probably entirely disappearing, as few of them are mentioned in well records. The "Gas sand" noted in the records from 250 to 400 feet above the base of the Salt sand presumably is equivalent to one of the sandstones in the lower part of this formation, but in some logs it might be more closely correlated with the Butler sandstone member or the Freeport sandstone member, which are situated above the middle of the formation. The following detailed sections of this formation and associated rocks, taken from well logs, are fairly representative of the data from the more complete records.

Sections of the Allegheny formation and associated rocks as shown by records of wells in the Claysville quadrangle.

John Lewis well No. 1, Morris Township, Greene County.

	Feet.
Conemaugh (Big Dunkard sand)	60
Allegheny:	
Shale, white, soft	50
Sand, white, hard	25
Shale, black, soft	100
"Gas sand," white, soft, and very open	85
Slate, black, soft	32
	292
Pottsville (Salt sand, white, hard)	108
Mauch Chunk (shale, black, soft; to top of Big lime)	170

Hess well No. 1, South Strabane Township, Washington County.

	Feet.
Conemaugh (sandstone, gray, shale, and sandy beds)	172
Allegheny:	
Shale, gray, and sandy beds	40
Limestone, gray	5
Slate, dark gray, and sandy shale	25
Shale, gray, sandy	50
Coal	10
Shale, dark, and sandy shale	130
Sandstone, coarse, gray	57
Slate, dark, and sandy shale	23
	340
Pottsville:	
Sandstone, gray, gas in top	65
Shale, gray, sandy, and sandstone	35
Shale, dark, sandy, and sandstone	25
Sandstone, gray	40
Top of Big lime.	
	165

In the Hess well section the gray sandstone overlying the Big lime and the 60 feet of strata above it may be Mauch Chunk, in which case the Pottsville might include the 57 feet of sandstone near the supposed base of the Allegheny formation, thus reducing the total thickness of the latter formation to 270 feet. The coal is one of the Kittanning coals, probably the Lower Kittanning. Part of the 40 feet of gray shale and sandy beds at the top of the Allegheny may belong to the Conemaugh, as it probably contains the horizon of the Upper Freeport coal.

CONEMAUGH FORMATION.

The Conemaugh formation extends from the top of the Upper Freeport coal to the base of the Pittsburg coal, and on Ohio River, at the nearest point of outcrop to the Claysville quadrangle, it has a total thickness of about 500 to 550 feet. Southward from Ohio River the thickness increases and is between 600 and 700 feet in the Claysville quadrangle. The base of the Conemaugh formation is usually a few feet below the Mahoning sandstone member (Little and Big Dunkard sands), which is persistent and fairly easily recognized in deep wells over most of southwestern Pennsylvania. This member consists of two sandstones, which are usually separated by soft shale containing beds of fire clay, coal, and limestone. The sandstones are variable in outcrop, changing from thick massive gray or yellow sandstone to sandy shale within short distances.

Overlying the Mahoning member are thin limestones, coals, sandstones, and soft greenish or reddish shale, for 160 to 180 feet, up to the base of a very persistent bed of red shale from 30 to 80 feet thick, known to drillers as the Big Red or Red Cave. The first Cow Run sand of southeastern Ohio and West Virginia occurs about 80 to 140 feet below the top of the red shale, and is probably equivalent to the Saltsburg sandstone member of Pennsylvania. A short distance above the red shale is the Morgantown sandstone member (Mitchell sand), which is one of the most persistent and uniform sandstones of the Pennsylvanian series. It is generally a thin-bedded compact fine-grained sandstone, locally coarse and massive, which ranges from 40 to probably 200 feet in thickness over southwestern Pennsylvania. The Morgantown sandstone is overlain by 150 to 200 feet of reddish sandy shale, inclosing thin sandstone lentils, unimportant coals, and limestone and extending up to the base of the Pittsburg coal. The coals of this formation are thin or absent throughout most of southwestern Pennsylvania and at their outcrop are seldom of minable thickness and quality.

Sections of the Conemaugh formation as shown by records of wells in the Claysville quadrangle.

Hess well No. 1, South Strabane Township, Washington County.

	Thickness.	Depth.
Monongahela:	*Feet.*	*Feet.*
Coal, Pittsburg	9	260
Conemaugh:		
Sandstone, shaly	6	266
Limestone, hard, reddish	5	271
Shale, gray, and sandstone	100	371
Sand, coarse, gray	15	386
Shale, dark, sandy	28	414
Shale, light gray	5	419
Sandstone, gray	47	466
Shale, gray	5	471
Shale and sandstone	15	486
Shale, red and variegated	15	501
Shale, marly, gray	15	516
Shale, red	23	539
Shale, dark sandy	10	549
Shale, red	20	569
Shale, gray	10	579
Slate, black	10	589
Shale, gray and sandy	10	599
Shale, red	15	614
Shale, gray and sandy beds	40	654
Sandstone and sandy slate; amber oil	45	699
Sandstone, gray, shale, and sandy beds	172	871

Original "Gantz well," Washington, Pa.

	Thickness.	Depth.
Monongahela:	*Feet.*	*Feet.*
Coal, Pittsburg	5	344
Conemaugh:		
Sandstone, soft	10	354
Slate	12	366
Shells, hard	2	368
Slate	10	378
Sandstone, hard, gray	11	389
Slate	30	419
Sandstone, white, soft	10	429
Slate	51	480
Sandstone, very hard	80	560
Slate	10	570
Limestone	5	575
Slate	15	590
Red rock, inclined to cave	60	650
Slate and shells	40	690
Red rock, caving badly	25	715
Slate	32	747
Red rock	25	772
Sandstone, white	20	792
Slate and shells	100	892
Sandstone, hard, gray (Dunkard sand)	100	992

John Lewis well No. 1, Morris Township, Greene County.

	Thickness.	Depth.
Monongahela:	*Feet.*	*Feet.*
Coal, Pittsburg	10	945
Conemaugh:		
Lime, white, hard	100	1045
Shale, red, soft	55	1100
Lime, white, hard	100	1200
Shale, black, soft	135	1335
Sand (Little Dunkard) white, hard	15	1350
Shale, black, soft	100	1450
Sand (Big Dunkard) white, hard	60	1510

ROCKS EXPOSED.

CARBONIFEROUS SYSTEM.

PENNSYLVANIAN SERIES.

In the northern part of the Appalachian bituminous coal field the Pennsylvanian series comprises the Pottsville, Allegheny, Conemaugh, and Monongahela formations. Of these only a part of the Monongahela formation is exposed at the surface in the Claysville quadrangle, but the others have been penetrated by oil and gas wells as just described.

MONONGAHELA FORMATION.

Distribution and character.—The Monongahela formation includes the rocks between the base of the Pittsburg coal and the top of the Waynesburg coal. Its base is not exposed at the surface within the quadrangle, but it outcrops in Chartiers Valley so near the eastern border that the whole formation is treated herein as exposed. Its thickness varies from about 380 feet on Monongahela River to 200 feet along its western outcrop in Ohio and 400 feet in West Virginia. In the Claysville quadrangle no exact measurements were obtained, but it is probably between 260 and 300 feet thick.

The upper part of the Monongahela formation is exposed only in the northern half of the quadrangle. The southern outcrops of the Waynesburg coal, which marks the top of this formation, are in the valley of Dutch Fork near Budaville, Donegal Township, in the valley of Buffalo Creek just south of Taylorstown, and in Chartiers Creek near Washington.

[a] Rept. Top. and Geol. Survey Comm. Pennsylvania, 1906-1908, p. 187.
[b] Idem, p. 187.
[c] Masontown-Uniontown folio (No. 82), Geol. Atlas U. S., U. S. Geol. Survey, 1902, p. 7.

From these points northward, up the dip, the area of outcrop widens to the border of the quadrangle.

In this region about half of the Monongahela formation is limestone, the rest being sandstone, shale, and coal. The principal members are the Pittsburg coal, Pittsburg sandstone, Redstone coal, Redstone limestone, Sewickley coal, Benwood limestone, Uniontown limestone, Uniontown coal, Waynesburg limestone, Little Waynesburg coal, and Waynesburg coal.

Pittsburg coal.—The Pittsburg coal is the best known, most valuable, and most persistent coal bed of southwestern Pennsylvania. It usually has a total thickness, including clay and shale partings, of 8 to 14 feet, but in places it thickens to 22 feet. As a rule it contains from 4 to 7 feet of workable coal near the base. This coal has been found in normal thickness in wells in every part of the Claysville quadrangle, and, because of the ease with which it can be recognized in drilling, it has come to be used by drillers as a key horizon throughout the area in which it occurs. In part of the area where it outcrops or is mined the Pittsburg coal is found to lie unconformably on the Conemaugh beds below,[a] but so far as known this unconformity is local and appears to be due to the removal by streams almost at tide level of small portions of the newly deposited Conemaugh sediments. Upon this eroded surface the coal has been laid down with remarkable uniformity, both in thickness, quality, and internal structure, though in the main the swamps or valleys in the old surface received the thickest deposits.

Pittsburg sandstone member.—In many places the Pittsburg coal is overlain by a coarse yellowish massive sandstone, occurring locally in two members separated by a thin bed of shale, the whole being 25 to 70 feet thick. In Washington County, Ohio, the Goose Run oil sand appears to be equivalent to this bed. In the Claysville quadrangle it is exposed only along Chartiers Creek for a short distance, where it is thin and shaly.

Redstone limestone member.—This limestone occupies part of the stratigraphic position of the Pittsburg sandstone member where that bed is lacking, and ranges from 5 to 20 feet in thickness, the remainder of the interval between the Pittsburg coal and Redstone coal in such places being occupied by shale.

Redstone coal.—A small coal occurs from 30 to 85 feet above the Pittsburg coal at several places in the area. This variation is due to the varying character of the intervening beds. As a rule the greater intervals occur where the Pittsburg sandstone is locally massive. The Redstone coal is usually too thin for mining, but locally it reaches a thickness of 3 to 5 feet. In the Claysville quadrangle the horizon of this bed is exposed only along Chartiers Creek from the vicinity of Arden eastward, but no outcrop of the coal was observed.

Fishpot ("Sewickley") limestone member.—The interval of 40 to 60 feet separating the Redstone coal from the Sewickley coal above is usually occupied by sandstone, shale, and limestone. The limestone is in places from 20 to 30 feet thick and has been called both Fishpot limestone and "Sewickley" limestone. Fishpot, being the older term, has been adopted for Survey usage. A single exposure of this limestone was observed near the county infirmary in Chartiers Valley, but its thickness could not be ascertained.

Sewickley coal.—The Sewickley coal appears to be equivalent to the Meigs Creek coal of Ohio and the Mapleton coal of deep-well drillers. It is exposed only along Chartiers Creek in the eastern part of the quadrangle, where it is probably 3 feet thick and about 130 feet above the Pittsburg coal. A coal is mentioned in well records from 100 to 130 feet above the Pittsburg coal, but the data are too meager to furnish evidence of its continuity and thickness in the Claysville quadrangle. In the Burgettstown quadrangle, lying north of the Claysville, where the beds at the Sewickley coal horizon are widely exposed, it averages about 102 feet above the base of the Pittsburg coal.

Sewickley sandstone member.—Overlying the Sewickley coal at Big Falls, on the Monongahela, and at other places is a flaggy to massive sandstone from 20 to 60 feet thick. In the small area where the beds at this horizon outcrop on Chartiers Creek no sandstone is present. The interval between the Sewickley coal and the base of the Benwood limestone is here occupied by sandy shale.

Benwood and Uniontown limestone members.—The Benwood and Uniontown members include all the calcareous beds between the Sewickley and Uniontown coals and are equivalent to the "Great" limestone of the First Geological Survey of Pennsylvania. In southwestern Pennsylvania they have a combined thickness of about 160 feet and are composed of several thin-bedded limestones separated by soft calcareous shale. The lower series of limestone and shale forms the Benwood member and the upper series the Uniontown member. These two limestone members are separated by 20 feet of shale, yellow or red below and olive-green at the top.

Two of the limestone beds in the Benwood member are sufficiently prominent and characteristic in portions of this region to justify separate names, and they have been called the Dinsmore and Bulger limestone members. The Dinsmore and Bulger members are typically exposed in the Burgettstown quadrangle, where they have been studied in detail by W. T. Griswold.[a] In that quadrangle the lowest Benwood strata consists of thin-bedded limestone, which on weathering breaks up into slabs of a cream-white color. The spaces between the beds are filled with calcareous shale. Overlying this in a few localities is a massive light-blue limestone, 7 to 8 feet thick, but in most places this interval is occupied by yellow shale. About 35 feet above the Sewickley coal there is 4 feet of cream-white limestone in beds from 4 to 8 inches thick, separated by thin layers of calcareous shale that weather out and leave the limestone in bold relief. These are the layers described by Griswold as the Dinsmore limestone. Overlying the Dinsmore limestone is a few feet of shale, yellow or red below and olive-green at the top. This is succeeded by a bed of brown limestone 1 to 2 feet thick, to which Griswold gave the name Bulger. Above the Bulger limestone bed, and separating the Benwood member from the Uniontown member, is 15 to 20 feet of green shale. The limestones overlying this shale were designated by Stevenson[b] the Uniontown limestone, from their relation to the Uniontown coal. The lowest bed of the Uniontown member is a blue limestone which weathers yellow, with pimple-like protuberances over the weathered surface. Above this are 25 to 30 feet of calcareous shale and thin-layered limestone. The upper 10 feet is an impure thin-bedded buff-colored magnesian limestone, which appears to be the only limestone bed of the Uniontown member that extends as far south as Kanawha River in West Virginia.

In the Claysville quadrangle the Benwood and Uniontown limestone members are above drainage level east of Oak Grove on Chartiers Creek, but the beds are too poorly exposed to admit of detailed examination. The top layers form the bed of Georges Run from its mouth almost to Gretna. The beds are also exposed along Brush Run and Buffalo Creek in Hopewell and Blaine townships and at the mouth of Buck Run, south of Acheson, in Donegal Township.

The first 51 feet of the shaft at the Arden mine passes through 40 feet of limestone belonging to the Benwood member. The Uniontown limestone is exposed near the mouth of Georges Run in the following section:

Section of Uniontown limestone member on road west from mouth of Georges Run in Canton Township, Washington County.

	Ft.	in.
Limestone, dark blue, very hard; weathers yellowish white	1	4
Shale, yellow	2	
Limestone, yellow and hard, very impure	2	6
Limestone, steel gray; weathers yellowish to white		6
Shale, yellow	8	
Limestone, yellow		3
Shale, yellowish	8	6
Limestone, buff, very hard; weathers black	2	6
Sandstone, thin bedded	3	
Limestone, in several beds, steel gray; top bed pimply; bottom bed weathers in grooves and fantastic forms to yellowish-white color	3	
Shale.		
	31	7

The Uniontown limestone has been encountered in probably every well in the quadrangle drilled through this horizon, but as it is of no economic importance to the drillers, its thickness and depth have been recorded in few of the logs.

Uniontown coal.—From 1 foot to 10 feet above the Uniontown limestone occurs the Uniontown coal. It outcrops over practically the same area as that described above for the Uniontown limestone. This coal is seldom more than a foot thick and at several exposures was found to be represented only by a black carbonaceous shale.

Uniontown sandstone, Waynesburg limestone, Little Waynesburg coal, and Browntown sandstone members.—overlying the Uniontown coal is 80 to 100 feet of thin sandstone and reddish and yellowish shale up to the Waynesburg coal. At some localities in southwestern Pennsylvania a massive gray sandstone 10 to 20 feet thick, known locally as the Uniontown sandstone member, occurs near the bottom of this shale. The Waynesburg limestone member, ranging from a knife-edge to 16 feet in thickness, occurs at a horizon about 40 to 60 feet below the Waynesburg coal. Overlying this limestone in places is a thin coal, usually less than a foot thick, which is known as the Little Waynesburg coal. In West Virginia the Browntown sandstone member, hard, gray, and massive, from 20 to 35 feet thick, separates the Little Waynesburg and Waynesburg coals. In the Claysville quadrangle the following section, taken in Canton Township, is typical of this part of the Monongahela formation:

Section of Monongahela formation on road west of the mouth of Georges Run.

	Ft.	in.
Coal (Waynesburg) horizon: mostly shale	1	2
Sandstone, shaly, thin bedded, micaceous	10	
Shale, black (horizon of Little Waynesburg coal)	1	
Shale, clay, yellow, with thin beds of sandstone	40	
Shale, black, very coarse		4
Shale, brown	3	
Coal (Uniontown) horizon; coarse black shale with carbonaceous shale at bottom		6
Uniontown limestone.		

Waynesburg coal.—The upper boundary of the Monongahela formation is marked by the Waynesburg coal and its southern line of outcrop on this quadrangle is described above. This coal is thickest in Donegal and Hopewell townships on Buck, Dunkle, and Haynon runs, in the vicinity of Acheson, where it is of minable thickness. From this vicinity northeastward the coal varies greatly in thickness and appearance from point to point, but generally the bed grows thinner and becomes broken by thick shale partings until in the northeastern part of Canton Township and the southwestern part of Chartiers Township it either disappears entirely or becomes so thin that it can rarely be found even by diligent search. South of its line of outcrop this coal is seldom mentioned in records of wells but is probably present.

PERMIAN SERIES.

The Permian rocks of southwestern Pennsylvania and adjacent parts of Ohio and West Virginia are comprised in the Dunkard group, which includes the Washington and Greene formations. They were formerly called the "Upper Barren Measures." They conformably succeed the Pennsylvanian rocks and are known from their fossils to belong to the basal part of the Permian series as elsewhere developed.

DUNKARD GROUP.

WASHINGTON FORMATION.

The Washington formation extends from the top of the Waynesburg coal to the top of the Upper Washington limestone member. It has an average thickness of about 275 feet in the Claysville quadrangle. This formation is exposed in a broad belt across the northern half of the quadrangle, forming most of the surface in Chartiers, Hopewell, Blaine, Independence, Donegal, Buffalo, Canton, and North Franklin townships. On the south it is exposed in Chartiers Creek to the head and over a large area at the head of Tenmile Creek, but the dip of the rocks in that direction leaves only the upper portion of the formation exposed in narrow areas along the principal streams in the southern and southwestern parts of the quadrangle.

The most prominent and best-identified members of this formation are the Waynesburg sandstone near the base; the Waynesburg "A" and Waynesburg "B" coals, about 40 and 70 feet respectively above the base; the Little Washington and Washington coals, with the Washington sandstone, a little below the middle of the formation; and above these the Lower and Middle Washington limestones, the Jollytown coal, and the Upper Washington limestone.

Cassville shale member.—Directly overlying the Waynesburg coal is a thin dark or reddish shale with locally from 8 inches to 1 foot of gray limestone. This shale is notable because of the fossil plants which it contains.

Waynesburg sandstone member.—The type locality of the Waynesburg sandstone member is at Waynesburg, Greene County, Pa., where it is a coarse, flaggy to massive light-gray to yellowish-gray sandstone from 40 to 70 feet thick. It is one of the most conspicuous beds outcropping in Greene County. In the Claysville quadrangle, however, this sandstone is much less prominent and, though locally massive, is generally very thin bedded, in places so laminated as closely to resemble shale. Where present this sandstone is from 5 to 35 feet thick. In many places the sandstone is absent, its horizon being occupied by reddish sandy shale.

Waynesburg "A" and "B" coals and associated beds.—From 40 to 55 feet above the Waynesburg coal is a small coal which usually occurs in two layers, each less than 6 inches thick, separated by 1 to 3 feet of bluish clay. The coal locally attains a thickness of 2 or 3 feet. Above this coal, the Waynesburg "A," is found here and there a layer of hard blue limestone, rarely 2 feet thick, embedded in dark shale. Thin-bedded sandstone and reddish sandy shale extend for 20 to 30 feet up to the Waynesburg "B" coal. This seam is usually 12 to 18 inches thick but in places is represented by two small coals 10 to 12 feet apart.

The Waynesburg "A" and "B" coals are exposed at many places in Chartiers, Canton, Hopewell, Blaine, and Independence townships and are fairly persistent beds, though rarely over 2 feet thick.

Above the Waynesburg "B" coal is reddish sandy shale, replaced locally by a somewhat massive gray or yellowish sandstone 10 to 20 feet thick. Embedded in this shale is a limestone (the I b limestone of Stevenson[a]) which ranges from 3 feet to probably 6 or 8 feet in thickness. It is usually exposed in two layers. The lower stratum is about 18 inches thick, is mottled gray in color, and weathers light yellow. The top layer is 12 to 15 inches thick, has a bluish-gray color, and weathers with a reddish tinge. This limestone is separated from the Little Washington coal by 10 to 15 feet of soft reddish shale.

Little Washington coal and Washington sandstone member.—The Little Washington coal is a very persistent bed in the Claysville quadrangle. It consists of 6 inches to 1 foot of hard,

[a] Rept. Top. and Geol. Survey Comm. Pennsylvania, 1906-1908, pp. 154-159.

[a] Bull. U. S. Geol. Survey No. 318, 1907, p. 69.
[b] Second Geol. Survey Pennsylvania, Rept. K, 1876, p. 64.

[a] Second Geol. Survey Pennsylvania, Rept. K, 1876, p. 55.

blocky coal, free from shale partings and apparently of good quality. This coal is usually found embedded in reddish sandy shale, 6 to 28 feet below the Washington coal. In a number of places, as at Washington, the reddish shale between the coals is replaced by the Washington sandstone member. This sandstone is usually in thin layers which, when closely examined, are seen to be oxidized on the surface to a deep red, the interior of the layers being light gray and very micaceous, with numerous black particles of carbonaceous matter.

In the vicinity of Washington this sandstone is massive, with single layers as much as 5 feet thick, and a short distance west of Woodell it has been quarried. Here the major part of the carbonaceous matter is confined to indistinct layers roughly parallel to the bedding. In the railroad cut east of Woodell the upper surface of this sandstone dips gently and evenly to the west, whereas the bottom of the bed, overlying the Little Washington coal, rises and falls in a series of undulations, measuring from a few feet to 100 yards or more from crest to crest, and from 1 to 6 or 8 feet in height. The thickness of the Little Washington coal apparently remains the same throughout this distance.

Washington coal.—The Washington coal lies from about 90 to 125 feet above the Waynesburg coal and 156 to 168 feet below the top of the Upper Washington limestone member. The latter figures are the maximum and minimum results of more than 40 measurements with a spirit level in different parts of the quadrangle.

This coal is by far the most prominent coal bed outcropping in this area. It is generally from 7 to 8 feet thick, this total thickness including alternate layers, about 6 inches thick, of coal and shale in the upper part of the bed and a bench of solid coal $2\frac{1}{2}$ to 3 feet thick in the lower part. Where the coal is exposed in section it can be readily recognized by the thick lower bench, the shale and clay partings along the center of the bed, and a 4-inch layer of coal at the top separated from the main seam by 1 to 2 feet of white or bluish fire clay. Its outcrop can be identified by the broad mealy smut, from 10 to 20 feet wide, which encircles the hills in a well-marked line wherever the horizon is exposed. The coal beds are thickest in the vicinity of Washington and thinnest in the southern portion of Donegal Township near Vienna, where they occur in two or more layers separated by 3 to 10 feet of yellowish shale.

Lower Washington limestone member and overlying beds.—Above the Washington coal is from 5 to 15 feet of coarse black and brown shale, overlain by the lower Washington limestone. The bottom layer of this limestone is from 10 inches to 2 feet thick and is bluish gray with reddish streaks. The thickness and texture of this layer differ greatly in many adjacent localities. It is, in general, rather argillaceous and in many places weathers bright yellow. Overlying it are several thin layers of limestone, having a total thickness of 2 or 3 feet. These rocks are usually gray and have a somewhat shaly structure. They are succeeded by 10 to 18 inches of yellowish-gray limestone, which shows a steel-gray color on fresh fractures. Overlying this limestone is 5 or 6 feet of black or blue shale containing, in one or two places noted, a few inches of shaly coal. The next two limestone layers above this shale are of about equal thickness, amounting together to 4 to 6 feet. Both are somewhat cherty, have a steel-gray color on fresh fracture, changing to light gray on weathering, and disintegrate very readily into small, roughly cubical blocks.

Directly overlying the Lower Washington limestone is a bed of dark to black fossiliferous shale from 1 to 6 feet thick. Near the bottom of this shale there is exposed in numerous localities a thin bed of shaly coal, which, at a few places near Taylorstown, attains a thickness of about 18 inches. This black shale is capped by 6 or 8 feet of yellowish shale, which merges into a reddish thin-bedded sandstone, usually from 5 to 20 feet thick. This sandstone varies greatly in thickness, in places being massive and filling the entire interval between the Lower and Middle Washington limestones, with the exception of a few inches of black and yellow shale at the top and bottom. In an old quarry once operated by the Baltimore & Ohio Railroad, on Buffalo Creek one-fourth of a mile south of the "S" bridge on the National Pike, the bed is between 40 and 50 feet thick, with a single 20-foot layer near the bottom. Above this sandstone is usually 4 to 6 feet of brown shale extending to the bottom of the Middle Washington limestone.

Middle Washington limestone member.—The Middle Washington limestone lies from 50 to 65 feet above the Washington coal. It consists of several limestone layers separated from one another by a few inches to 2 or 3 feet of shale and having a total thickness of 10 to 30 feet. There are but four layers in the bed that are at all easily recognized—a 2 to 6 inch deep-pink ledge at the bottom, two yellow ledges about the middle, and a 6 to 8 inch creamy-white layer near the top, which has a dark mottled color on fresh fracture, the white appearing on the outside as if the stone had been painted. The yellow layers are from 1 to 2 feet thick. The lower one is about double the thickness of the upper, is very prominently exposed, and may be easily recognized by its tendency to exfoliate on weathering. The other layers of the bed are usually from 6 inches to $2\frac{1}{2}$ feet thick, are bluish to gray and steel gray on fresh fracture, and weather gray and light yellow.

The Middle Washington limestone attains its greatest development in Independence, Canton, and Hopewell townships, where it is between 25 and 30 feet thick. It outcrops well toward the tops of the hills in both these townships and eastward into Mount Pleasant and Chartiers townships. It is finely exposed about half a mile north of the corner of Hopewell, Mount Pleasant, and Canton townships, as shown in the following section:

Section of Middle Washington limestone member on road from Buffalo to Gretna.

	Ft.	in.
Coal (Jollytown), shaly		6
Shale and sandstone	3	
Limestone, yellow		3
Sandstone, reddish, and shale	10	
Shale, soft, cream colored	5	
Limestone, hard, blue	1	
Limestone, slabby, white	1	6
Shale	3	
Limestone, gray, hard, and tough, fracturing flesh color	2	
Shale	3	
Limestone, single heavy yellowish bed, fractures flesh color with calcite crystals	2	
Shale	2	
Concealed.		

In Blaine, Buffalo, and Donegal townships this limestone is always present in outcrop, though it is thinner than in the townships toward the north, being in few places more than 20 feet thick. The heavy yellow ledge near the middle is as a rule prominently exposed and serves as an unfailing geologic marker, ranging from 70 to 82 feet above the Washington coal. Toward the southwest corner of the quadrangle, near Good Intent, this limestone appears to be represented by two or three thin layers embedded in brown shale.

Jollytown coal and associated beds.—For about 35 feet above the Middle Washington limestone the rocks are, in the main, shaly sandstones, which in places occur in massive layers from 3 to 5 feet thick. Above these sandstones is usually from 5 to 15 inches of soft shaly coal, the Jollytown coal of Stevenson.[a] In Independence Township this little coal is very thin and, being embedded in reddish shale, is easily concealed by weathering. In Hopewell Township the Jollytown coal, with the Middle Washington limestone below it, outcrops at several places along the West Middletown and Washington pike. It is here about 110 feet above the Washington coal. Near North Buffalo Church the Jollytown coal is in two layers 6 and 8 inches thick separated by 15 feet of yellowish shale. The lower coal lies 94 feet above the Washington coal and 58 feet below the base of the Upper Washington limestone.

In Blaine Township, north of Buffalo Creek, the Jollytown coal is fairly persistent and is 8 to 12 inches thick. South of that creek the coal was not seen, its horizon being marked by a few inches of block shale. In Donegal Township the Jollytown coal is usually present and appears to thicken toward the southwest. An exposure of this coal in the bed of Robison Run, just west of the boundary between East Finley and West Finley townships, shows the following section:

Section of Jollytown coal on Robison Run.

	Ft.	in.
Shale, yellow	10	
Coal		6
Shale, blue and yellow		6
Coal		6
Clay, red		2
Coal	1	

At most places in the Claysville quadrangle the Jollytown coal is overlain by 50 to 65 feet of reddish or yellowish sandy shale and thin sandstone, extending up to the base of the Upper Washington limestone. In a few places the sandstone thickens at the expense of the shale, and the entire interval is occupied by thin-bedded yellowish to gray sandstone, which locally contains massive layers. An unusual development of this sandstone occurs near the northern border of the quadrangle, in the eastern part of Mount Pleasant Township, where almost the entire interval of about 70 feet above the Jollytown coal is occupied by a very massive coarse conglomeratic sandstone, which strews the hilltop with bowlders 20 to 30 feet in diameter. Farther west, in the southern part of the Burgettstown quadrangle, on the ridge between the north and south forks of Cross Creek, this sandstone caps the higher points in a cliff-making ledge from 20 feet to probably 50 feet thick.

Upper Washington limestone member.—The Upper Washington limestone is the top member of the Washington formation. It is the most important guide rock above the Washington coal, from which it maintains a fairly constant distance of 162 feet. It is a heavy and persistent limestone bed, having two or three characteristic layers that render its identification easy. It is generally exposed throughout the Claysville quadrangle. This bed is thickest in the vicinity of Washington, where it consists of ten to twelve layers of limestone varying from a few inches to 3 feet in thickness and separated by partings of shale. The lowest layer of this bed is a rusty-brown limestone from 1 to 2 feet thick, which, on fresh fracture, is of a dark steel-gray color and shows numerous tiny crystals of calcite. The next three or four layers are nearly identical in general appearance. They have a total thickness of 6 to 7 feet and are of dark-blue to reddish-brown color, very hard and tough, and of irregular fracture. Some of the layers contain numerous calcite crystals. They generally weather to a rusty cream color, though a small layer toward the bottom of this group weathers locally to a light reddish yellow. Above this group is a hard thin-bedded dark-brown limestone from 8 inches to 2 feet in thickness. It is argillaceous in places, breaks rather easily with an uneven fracture, and weathers to a rusty cream color. This is the only layer in the lower portion of the Upper Washington limestone that may be easily recognized, and it is one of the important markers of the member. The weathered surface of this rock has a rough, finely striated, filelike appearance, by which, when it has once been identified in the field, it may be recognized at a glance. From 3 to 5 inches of coarse brown shale separates this layer from the one above, which is a dark reddish-brown limestone in two beds having a total thickness of about $2\frac{1}{2}$ feet. It is very hard and tough and weathers to a rusty cream color. The face of a fractured portion of this limestone presents a crimped appearance around the edges. Above these layers is from 6 to 8 inches of coarse black shale. The next limestone above is dark gray, very hard, and somewhat cherty and breaks easily under the hammer into small cubical blocks. Around Washington this layer is one of the thickest in the bed, being from $2\frac{1}{2}$ to 3 feet in thickness. It varies, however, both in quality and quantity, and in many localities is absent. Overlying this limestone is from 3 to 6 inches of coarse black shale, which in the type locality around Washington directly underlies a few inches of thin-bedded sandstone. In several portions of the Claysville quadrangle this shale and sandstone appear to thicken greatly at the expense of the underlying limestone. At a few places the shale was found to be rather carbonaceous, carrying tiny partings of coal, with a total thickness of 3 or 4 inches. The limestone layer directly overlying this shale is cream white but has a dark mottled appearance on fresh fracture. It appears locally as two ledges 1 to 2 feet thick, with a parting of calcareous shale. It is overlain by a layer of soft black shale from a few inches to a foot or more thick, which on weathering has a mealy, frosty-white appearance. Above this shale is a light-buff thin-bedded argillaceous limestone, from 1 to 3 feet in thickness, which weathers to a bluish white. This layer is thickest in the vicinity of Washington, where it assumes a massive appearance, but it is easily recognized by its tendency to break into thin sheets. In the vicinity of Good Intent this layer is very much darker and has the mottled appearance of the top layer, described below, resembling it closely both on fresh fracture and when exposed to the weather. Overlying this layer is from 1 inch to 3 feet of black shale, and this is in turn overlain by the top layer of the bed, which is from 6 inches to 2 feet thick, very hard and brittle, dark to black on fresh fracture, and cream to snowy white on weathering. Weathered portions of a ledge of this layer when broken present a peculiar brown-black mottled appearance, which, as already stated, is also characteristic of the third layer from the top. The three layers of this bed form a group whose outcrop is always easily recognized.

The Upper Washington limestone underlies the southwestern half of the Claysville quadrangle, except narrow areas along valleys of the larger streams. It is also barely above drainage level on Tenmile Creek east of Prosperity and is exposed on Short Creek only in the vicinity of Sparta. Up Tenmile Creek from Prosperity the outcrop of the Upper Washington limestone rises faster than the bed of the stream, and at the head of the valley it encircles the higher hills. Over much of the northern half of the quadrangle the horizon of this limestone is above many of the hilltops, only the higher points being capped by it. It appears to be thickest at the type locality in the vicinity of Washington, thinning somewhat toward the northwest in Canton, Chartiers, Hopewell, and Independence townships. Southwest of Washington the lower portion of this limestone becomes variable and in places does not outcrop.

The following section taken at Taylorstown, showing the exposed rocks between the Upper Washington and Middle Washington limestones, is typical of that vicinity:

Section on road west from Taylorstown.

	Ft.	in.
Sandstone, thin, and shale	6	
Limestone (Upper Washington)	9	
Sandstone, yellowish, and shale	9	
Concealed	13	
Limestone, buff colored, in two layers	1	6
Shales, black and reddish	5	
Sandstone, thin; shale and concealed	10	
Limestone, yellowish, very impure		6
Shale and sandstone	36	
Limestone (Middle Washington).		

[a] Stevenson, J. J., Second Geol. Survey Pennsylvania, Rept. K, 1876, p. 48.

GREENE FORMATION.

The Greene formation comprises the Permian rocks above the Upper Washington limestone member. These beds form the surface in the lowest portion of the bituminous coal basin in southwestern Pennsylvania and are the youngest rocks of the Carboniferous system in the central Appalachian province. In the southwestern part of Greene County this formation is 700 to 800 feet thick, but to the north, up the dip of the rocks, in the Claysville quadrangle, the thickness is reduced to a maximum of about 425 feet.

The Greene formation occupies about one-third of the surface of the Claysville quadrangle, chiefly in the southern half, though it caps the higher hills and ridges as far as the northern edge. The formation consists largely of shale and sandstone, the proportion of limestone and coal to the whole thickness being much less than in the Washington formation. The beds are also less extensive and locally show greater variations than those of the formation below. Because of this variability of beds from place to place, the following general descriptions, based on a moderate amount of field study, may not be found equally applicable in all sections.

Upper Washington coal and associated beds.—Above the Upper Washington limestone member, the top of which is the base of the Greene formation, the rocks differ in many adjoining localities. Dark shale with a thickness of 3 to 15 feet is most common, though the same interval is in many places filled by argillaceous sandstone. Above this is the Upper Washington coal, consisting of 1 to 5 feet of black bituminous shale, in which are embedded thin layers of coal. The shale is uniformly present, but the coal is variable, its maximum thickness being not more than 14 inches, including shale and clay partings. White[a] calls this the Jollytown coal, though Stevenson[b] designates a coal farther down in the series by that name and calls this the Upper Washington coal. Overlying the black bituminous shale is from 5 to 20 feet of gray laminated sandstone, with a few inches of shale above, to the Donley limestone member.

Donley limestone member.—For the most widespread and uniform limestone in the Greene formation throughout the Claysville quadrangle the name Donley has been adopted.[c] It is from 18 to 45 feet above the bottom of the formation, and in this quadrangle is invariably present where its horizon comes to the surface. In the vicinity of Donley, Donegal Township, a typical section shows this limestone in three or four layers having a total thickness of 5 or 6 feet. The characteristic feature is its dark, rusty, lichen-covered surface when weathered. The limestone is very hard and tough and fractures unevenly with a dark steel-gray to almost black color, having a very coarse grain and showing numerous calcite crystals. The bed is also distinguished by its peculiar jointing, which has a striking resemblance to that of dry mud, the blocks being irregular in shape and from 1 to 3 feet in diameter. The joints are usually very distinct, many of them being from 1 to 3 inches wide and filled with dark-red residual clay. The Donley limestone is generally overlain by a light-gray laminated sandstone, 15 to 20 feet thick, which locally becomes massive.

Tenmile coal.—The most important coal seam of the Greene formation in the Claysville quadrangle occurs from about 35 to 70 feet above the base, or 15 to 30 feet above the Donley limestone. A coal at about 30 feet above the Upper Washington limestone was noted by Clapp[d] in the vicinity of Tenmile Creek in the Amity quadrangle and named by him the Tenmile coal. Later he described a coal in the Rogersville quadrangle 60 to 100 feet above the Upper Washington limestone as the Tenmile coal. In the Claysville quadrangle this coal, with an average distance of probably about 50 feet above the Upper Washington limestone, was first considered by the writer[e] to be a separate coal, and it was therefore named by him the Sparta coal. In view of the above-mentioned correlations by Clapp it seems probable that this seam, though very lenticular, may be equivalent to the Tenmile coal, and until these exposures are definitely shown to be on different beds the name "Sparta" may be dropped. This coal ranges from 6 inches to 3 feet in thickness and in places is remarkably pure. It attains its greatest development in the vicinity of East Finley, where it was once mined.

Prosperity limestone member.—The next distinctive member above the Tenmile coal is a rusty-yellow limestone, having a maximum thickness of 10 or 12 feet, which has been named[f] the Prosperity limestone, from the village of that name in Morris Township. The top of this limestone is from 100 to 115 feet above the top of the Upper Washington limestone. The top layers are in places light bluish, fracturing irregularly with a dark-gray to rusty-black color, and are very coarse grained. The other layers are dark gray to buff on fracturing.

[a] Geol. Survey West Virginia, vol. 2, 1903, p. 111.
[b] Second Geol. Survey Pennsylvania, Rept. K, 1876, p. 48.
[c] Bull. U. S. Geol. Survey No. 318, 1907, p. 76.
[d] Clapp, F. G., Amity folio (No. 144), Geol. Atlas U. S., U. S. Geol. Survey, 1907, p. 8.
[e] Bull. U. S. Geol. Survey No. 318, 1907, p. 77.
[f] Idem, p. 77.

This limestone is fairly persistent over the southern half of the Claysville quadrangle, being present on all the hillsides in the vicinity of Pleasant Grove. Its heaviest outcrop is northeast of Pleasant Grove, along the top of the ridge between East Finley and South Franklin townships.

Dunkard (?) coal and associated rocks.—Above the Prosperity limestone member are reddish sandy shale and thin sandstone. About 125 feet above the bottom of the Greene formation there is a fairly persistent but thin layer of bituminous shale which locally occurs as a coal bed a few inches thick. This is probably the Dunkard coal, as named by Stevenson,[a] though owing to the few exposures noted this correlation is somewhat doubtful.

For 100 to 125 feet above the Dunkard (?) coal bed are reddish laminated sandstone and shale, with two or three thin beds of limestone. At one or two places in the vicinity of East Finley a small coal smut was noted in these rocks at about 155 feet above the top of the Upper Washington limestone, but the bed appears to be of only local extent.

Claysville limestone member and associated rocks.—From 205 to 225 feet above the base of the formation is a limestone, separated into two layers by 6 to 8 feet of yellow shale. The top layer is 6 to 8 inches thick, bluish white, and dark brown on fresh fractures. The bottom layer is here and there as much as 18 inches thick, weathers with a rough surface to a reddish or yellowish color, and is dark gray on fracture. This limestone underlies a considerable area in the southern and western parts of the Claysville quadrangle. In the northern parts of East and West Finley and Morris townships it is a rather compact bed, from 6 to 8 feet thick, the top layers being heaviest and all having a dark-gray color. As it can not be correlated with any bed previously named and is among the most prominent limestones of the Greene formation in this section, it has been called the Claysville limestone member, from the town of that name.[b]

Above the Claysville limestone is 50 or 60 feet of reddish and dark-colored shale, in which at irregular intervals are embedded thin layers of sandstone. This shale is overlain at many places by 2 to 6 feet of light-gray to brown limestone. The top layer is heaviest and on fracturing is light buff; the lower layers are very thin and easily disintegrate to small gray nodules. Above this limestone lie a few inches of carbonaceous shale and 25 or 30 feet of reddish shale, capped by 10 or 15 feet of thin grayish laminated sandstone.

Nineveh coal and Nineveh limestone member.—About 325 feet above the base of the Greene formation and 100 feet above the Claysville limestone is a rather persistent coal bed, from 6 inches to 1 foot in thickness. This is probably the Nineveh coal, though it does not occupy an area sufficiently large to permit definite correlation. It is usually underlain by about 10 feet of reddish shale, below which is 2 or 3 feet of bluish clay or shale, overlying 4 or 5 feet of bluish-white to cream limestone in two or three rather massive layers, very hard and tough, that is light buff on fracturing. This limestone caps many of the highest hills in Morris and East and West Finley townships and is known as the Nineveh limestone member.

A few feet above the Nineveh coal is a gray limestone a few inches in thickness. This small limestone is overlain by about 50 feet of laminated sandstone, which in turn is followed by a rather prominent layer of bluish-gray limestone, from $1\frac{1}{2}$ to $2\frac{1}{2}$ feet thick, very hard, and with a dark-brown mottled appearance on fresh fracture. This is the highest recognizable stratum of the Greene formation in the Claysville quadrangle. It is exposed only in the high peaks of the ridge that marks the boundary of Greene and Washington counties. Above it are a few feet of thin-bedded reddish sandstone and shale on the hilltops.

QUATERNARY SYSTEM.

PLEISTOCENE DEPOSITS.

CARMICHAELS FORMATION.

The rocks composing the Carmichaels formation are surficial deposits of unconsolidated clay and gravel that were formed along the principal streams when they flowed in valleys above the present flood plain. In the Claysville quadrangle the deposits which occupy the highest terraces along Chartiers, Buffalo, Brush, and Tenmile creeks and Dutch Fork are considered to belong to the Carmichaels formation and probably to be of Kansan age.

Another terrace on which clay and gravel of post-Carmichaels age were deposited occurs at a lower level. These deposits have not been correlated with the extensive terrace deposits found along Ohio and Monongahela rivers and therefore their age has not been determined.

RECENT DEPOSITS.

ALLUVIUM.

Thin deposits of silt, clay, gravel, and local rock débris cover the surface of the principal valleys for a few feet below high-water level. These have been generally classed as alluvium, regardless of the nature or origin of the material.

[a] Second Geol. Survey Pennsylvania, Rept. K, 1876, p. 35.
[b] Bull. U. S. Geol. Survey No. 318, 1907, p. 78.

STRUCTURAL GEOLOGY.

GENERAL FEATURES OF THE STRUCTURE.

The Claysville quadrangle is situated near the center of the great Appalachian synclinal basin, in a region where the strata have been but slightly subjected to deformation. These crustal movements have been sufficient to warp the strata from the fairly horizontal position in which they were deposited into a series of gentle irregular folds, the principal ones having a general northeast-southwest trend. The relation of the structure of this quadrangle to that of adjacent ones is indicated in figure 4, which shows by contour lines at vertical intervals of 50 feet the approximate position and deformation of the Pittsburg coal.

The structure of the Claysville quadrangle is shown in much greater detail on the economic geology map and the oil and gas map of this folio by contours representing intervals of 10 feet. On the structure and economic geology map the contours are drawn at the top of the Upper Washington limestone member (datum mean sea level) and show the structure of the beds exposed at the surface. The key horizon of the contours on the oil and gas map is the top of the Third or Gordon sand and the contours show the structure of the deeply buried oil sands. These contours are based on an assumed datum plane 2000 feet below sea level, in order to avoid the confusion likely to arise by the use of minus signs before the numbers on the contours, as this sand throughout this area is below sea level. The use of a separate set of structural contours for the oil and gas sands in this area is thought advisable in order to avoid the error, caused by convergence of the strata, involved in the use of contours drawn on outcropping rocks to show the shape of the oil sands. The amount of this convergence is illustrated by figure 5, which shows by lines the distance in feet between the top of the Upper Washington limestone and the top of the Gordon sand throughout most of the area of the quadrangle.

The data used in drawing the contours on the Upper Washington limestone consist of elevations of the top of that bed, accurately determined in the field with a spirit level at hundreds of places throughout the quadrangle. In areas where this bed does not outcrop the elevations of other beds having a known interval above or below the Upper Washington limestone were procured and the altitude of this key horizon thus determined. With these elevations platted on the topographic map, contour lines were drawn through points of equal elevation. The elevations needed for constructing the contours on the oil sand were procured by running spirit level lines to the mouths of wells. The distance to the top of the Gordon sand as shown by the record of each well was deducted from the elevation of its mouth and the elevation of the top of the sand thus obtained. In areas where there are no wells the elevation of the sand was obtained by using elevations taken on the Upper Washington limestone and deducting from them the approximate distance to the Gordon sand, as previously determined where the distance could be accurately measured and mapped. (See fig. 5.) In this way the error likely to arise in attempting to map the structure of the oil sands by elevations on surface rocks was practically eliminated. A comparison of the contours on the Upper Washington limestone with those on the Gordon sand will give a clear idea of the variation in structure of the two beds and at the same time show the degree to which the structure of the oil sands approximates that of the surface beds. On the oil and gas map the structure contours have not been drawn for a portion of the western part of the quadrangle, because no records of wells drilled in that area could be procured for determining the convergence of the key horizons. The structure of the surface beds is therefore the most accurate available means of determining that of the oil sands in that area.

IMPORTANT STRUCTURAL FEATURES.

Washington anticline.—The most prominent anticline crossing the Claysville quadrangle enters it from the east a short distance from Arden station on the Pennsylvania Railroad, 3 miles north of Washington. The crest of this fold, which is called the Washington anticline, pitches very steeply toward West Washington, reaching the bottom of a low saddle between two domes a mile southwest of this town, near the pumping station of the Citizens' Water Co. From this point the crest rises slowly to the southwest to a point about a mile west of Lagonda, where it culminates in a small dome. Thence the crest line changes its direction slightly toward the south and pitches again to a low divide, the bottom of which is at the point where the anticline crosses Tenmile Creek, $1\frac{1}{2}$ miles northeast of Pleasant Grove. The top of the next dome is about three-fourths of a mile south of this village, near the corner of East Finley, Morris, and South Franklin townships. Continuing southwest the crest pitches steeply to a point a little west of the Joint schoolhouse, from which it describes a sweeping curve to the south and southwest, leaving the quadrangle at a point almost directly south of East Finley. From the village of Gale southward the location of the crest is not clearly determined owing to the scarcity of recognizable outcrops.

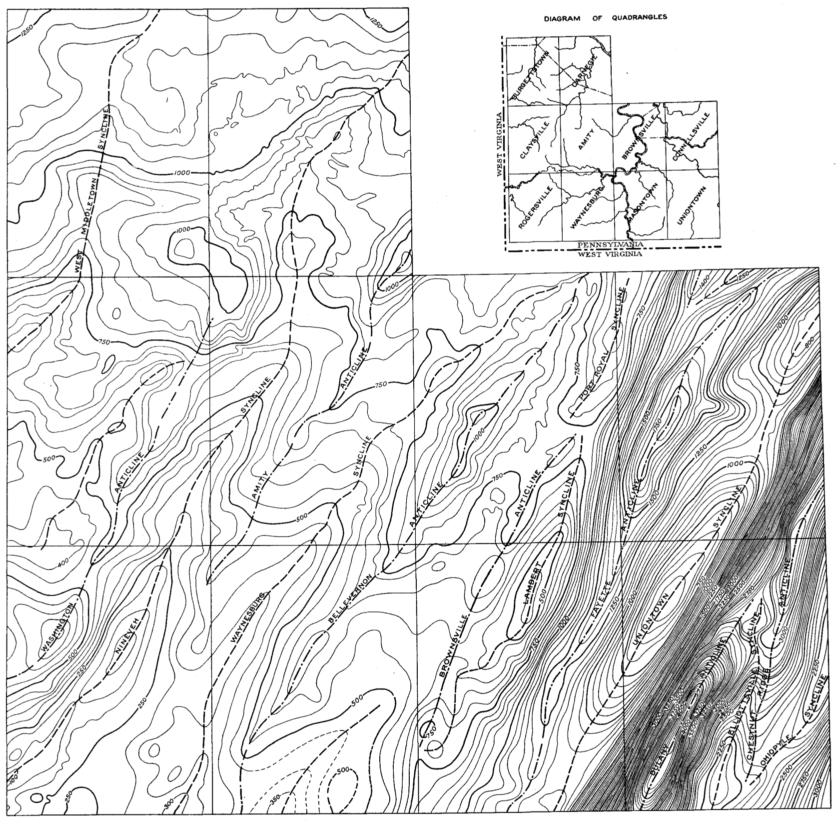


Figure 4.—Map showing general structural features in southwestern Pennsylvania by contours on the horizon of the Pittsburg coal.
Contour interval 50 feet. Datum is mean sea level. The relation of the more gently folded oil-bearing region to the more highly folded area to the east is shown.

Nineveh syncline.—The Nineveh syncline, which lies southeast of the Washington anticline, extends across the southeastern part of the quadrangle. It enters from the south 2 miles from the southeast corner and leaves the east border 2 miles directly east of Van Buren, near the Crossroads schoolhouse. Southeast from this trough the rocks rise again to the crest of the Amity anticline, which lies less than a mile beyond the southeast corner of the quadrangle. This trough is the axis of the great Appalachian synclinorium, the structurally lowest part of which is either in a small basin near the center of the Rogersville quadrangle or in another of almost equal depth in the same syncline in Center Township, Wetzel County, W. Va., about 10 miles from the southwestern corner of Pennsylvania.

Finney syncline.—Northwest of the Washington anticline is the Finney syncline, the bottom of which crosses the south

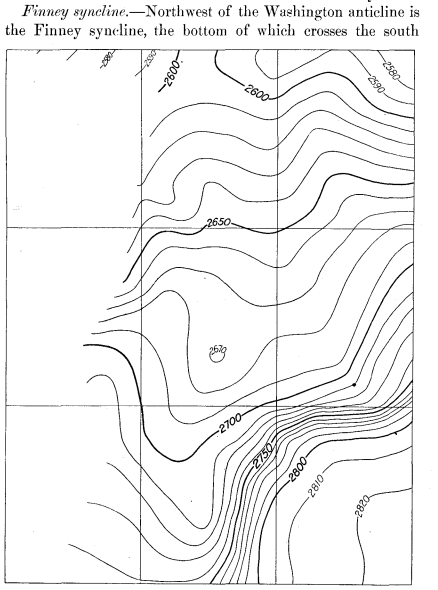


Figure 5.—Sketch of Claysville quadrangle, showing convergence of the top of the Washington limestone and the top of the Gordon sand by lines representing equal vertical distances between these horizons.

border of the quadrangle 2½ miles from the southwest corner, near the junction of Rocky Run and Templeton Fork. Its bottom is broad and irregular at the south line of the quadrangle but rises and narrows abruptly to the northeast, with the greatest contraction 1 mile south of Fargo, where a low cross fold, having an indistinct northwest-southeast trend, raises the bottom of the syncline sufficiently to form a small basin to the north. At the point where Buffalo Creek crosses the East Finley and Buffalo township line there is another shallow trough, and from this the bottom of the syncline rises 60 feet to the next basin, which extends from a point a short distance south of Coffeys Crossing to Woodell and a mile farther east. From the northeast end of this basin the bottom of the syncline swings northward in an almost direct line toward the northeast corner of the quadrangle, rising at the rate of about 100 feet to the mile until it dies out against the south side of the high Westland dome. Stevenson[a] calls this trough the Mansfield syncline, considering it the southward continuation of the one crossing the Pennsylvania Railroad at Mansfield, Allegheny County, but as it appears to be entirely cut off from that syncline in the Claysville quadrangle it seems advisable to give a new name to the portion that lies within this quadrangle and farther south.

Claysville anticline.—The next anticline west of the Finney syncline enters the quadrangle on its west border within 2½ miles of the southwest corner. From this point it has a general northeasterly trend, the crest line rising and falling in a series of domes and saddles but continuously gaining in elevation northward until it culminates in the Westland dome, the top of which lies in the Burgettstown quadrangle to the north of Gretna. This anticline covers the northern part of Chartiers and Canton townships and the eastern part of Hopewell Township to a point a mile south of Buffalo village, from which the rocks dip in all directions except to the northeast. Between this point and the high dome 1½ miles north of Claysville the crest line of this anticline is very indistinct. These domes are separated by a broad, low saddle in which rises a tiny steep-sided dome, only a few hundred acres in extent, lying half a mile north of Taylorstown. South of the dome near Claysville the crest pitches, with but a single small interruption, to the west edge of the quadrangle.

West Middletown syncline.—A trough whose axis enters the western border of the quadrangle near Buffalo Creek and trends northeastward, passing just east of West Middletown and thence into the Burgettstown quadrangle, has been called the West Middletown syncline. This fold has been traced northward for about 40 miles to its apparent termination near the northwest corner of the Sewickley quadrangle, in Beaver County. Southwestward from the point where it enters the quadrangle this fold appears to be equivalent to the Loudenville syncline mapped by R. V. Hennen,[a] which passes through portions of Ohio, Marshall, and Wetzel counties, disappearing a few miles west of New Martinsville, W. Va.

Aside from these more prominent structural features, there are a number of minor ones which are delineated by the contours and need not be described.

GEOLOGIC HISTORY.

The known geologic history of this region may be divided into two general chapters, the first treating of a period of construction, when deposition was the prevailing geologic process in the area, and the second of a period of degradation, when erosion was the prevailing process. The latter period has continued to the present time. Neither deposition nor erosion has been continuous, for each process has often been interrupted for short intervals by reversions to the other; nor have they continued for equal lengths of time, for the period of deposition undoubtedly lasted many times as long as has the present one of degradation. The events of the former are recorded in the consolidated rocks of the region, those of the latter in the surficial deposits and in the physiographic features.

PALEOZOIC ERA.

CHEMUNG AND EARLIER DEPOSITION.

The consolidated rocks of southwestern Pennsylvania are chiefly sandstone, shale, and limestone, with local beds of coal and clay. The sea in which these sediments were laid down covered the western part of the Appalachian province and the Mississippi basin. The oldest rocks known in the Appalachian province are the crystalline rocks of the Blue Ridge and of the Piedmont Plateau to the east. These rocks are believed to have formed the oldest land of which there is any record on this continent. The western shore of this land area lay at approximately the present position of the western flank of the Blue Ridge, and the land extended an unknown distance eastward. To the northeast, in the Adirondack Mountain region, lay another area of crystalline rocks. West of the Adirondacks, reaching to the vicinity of Lake Superior, was the southern shore of a vast land area, now occupied by the crystalline rocks of Canada. The rocks of the two regions last mentioned are of the same general age as those of the Blue Ridge. Thus, in the earliest recorded geologic time, there was in eastern North America a land mass having a deep reentrant on the southwest which inclosed a body of water known to geologists as the interior Paleozoic sea. Into this sea flowed rivers bearing the sediments of which the Paleozoic rocks of the Appalachian province are composed. While these sediments were accumulating to the thickness of many thousand feet new species of animals and plants made their appearance from time to time as the earlier forms became extinct. The earlier organisms were chiefly sea animals or the lower forms of plants, such as seaweeds. Later, land plants made their appearance and conditions began which eventually resulted in the formation of the coal beds of the province. After a great thickness of sediment had been accumulated, an uplift occurred, the axis of which extended from the Great Lakes to middle Tennessee. This is known as the Cincinnati uplift. The sea bottom in a part or possibly the whole of this area was raised above sea level. By the barrier thus formed the interior sea was still more completely inclosed, and became a narrow embayment, appropriately called the Appalachian gulf, extending from Alabama to eastern New York. In this gulf, during a long period of repose or of gentle oscillations, a great thickness of fine sediment was laid down.

A slow subsidence of the sea bottom occupied most of this period, but by the beginning of Chemung deposition the accumulation of sediment had raised the sea bottom to such an extent that most of the beds of that formation were laid down in shallow water. Where this formation is exposed it consists of many alternating beds of shale, sandstone, and impure shell limestone, the shale predominating. There are many evidences of shallow-water accumulation and the abundance of fossils indicates that the conditions were favorable to life and that the sea floor swarmed with living beings. The observed facts indicate a broad expanse of comparatively shallow water which was receiving sediment from the adjacent land, sometimes finer, sometimes coarser; now in abundance, now more sparsely; the kind and rate of sedimentation varying rapidly and producing the alternating strata of the formation. In the Claysville quadrangle a few deep wells probably penetrate to this formation, but no detailed records of them have been preserved.

[a] Second Geol. Survey Pennsylvania, Rept. K, 1876, p. 31.

[a] West Virginia Geol. Survey, Report on Marshall, Wetzel, and Tyler counties, 1909, map

CATSKILL DEPOSITION.

Before the beginning of the Chemung deposition—indeed, in early Portage time—the Catskill phase of sedimentation began at the northeast extremity of the Appalachian gulf, in eastern New York. From this time onward the deposition of these sediments continued, being contemporaneous at first with the marine Portage, later with the Chemung, and at the top probably with still younger deposits. At the same time the Catskill type of sediments spread progressively farther westward and southwestward until the finer sediments extended into western New York and Pennsylvania.

Thus it happens that the thickness of these beds, which is probably several thousand feet in the Catskill Mountain region, where this type of sedimentation was continuous from its beginning, diminishes from below as the beds extend westward, until in western Pennsylvania and New York they are represented by only a few hundred feet of strata characterized by beds of red shale.

In the Claysville quadrangle the red, green, and dark shales which probably represent the Catskill formation have, to judge from the character of similar deposits in western New York, resulted from the consolidation of the finer material that was borne farthest from the eastern shore of the Appalachian gulf, where it was discharged by the rivers flowing from the bordering land. The red rocks of the western margin of the formation lie in detached beds or lenses of greater or less extent and thickness in the midst of gray shale and sandstone that possibly had a different source. This mode of occurrence indicates that they were transported intermittently during floods when stronger currents bore the sediments farther westward, or during great storms, when the supply of sediment was greater. At times toward the close of the epoch of deposition of the red sediments, the great beds of coarse gray sand that now contain much of the oil and gas in this part of Pennsylvania were formed.

POCONO DEPOSITION.

Late Catskill and early Pocono time was marked by many slow oscillations of the Appalachian sea floor and probably of the land to the east. Such movements were so considerable that, though parts of the sea floor never rose above water and though most of the former land area was not again submerged, the shore line migrated back and forth within wide limits. Along such a shore line land plants probably flourished and at numerous times were buried. Their remains are still preserved in the Pocono coals farther south and east, but no such beds are known in the Pocono of the Claysville quadrangle. Fresh-water conditions probably prevailed generally throughout the north end of the Appalachian gulf, and there was a decided change in the character of the material deposited, which is prevailingly gray instead of red. In the part of Pennsylvania including the Claysville quadrangle the heavy sandstones known as the Hundred-foot and Butler gas sands were among the first strata deposited. These were followed by gray shale containing some beds of red shale of local extent and sporadic sandstone lenses. During the later part of Pocono time vast quantities of coarse sand were carried into the Appalachian gulf and spread widely over the sea bottom, forming the coarse Burgoon sandstone member (Mountain or Big Injun sand). As the deposition of this coarse sandy material was drawing to a close a large quantity of calcium carbonate was deposited with the sand, making the Loyalhanna ("Siliceous") limestone member, which is a widely extended and highly characteristic stratum at the top of the Pocono throughout southwestern Pennsylvania.

MAUCH CHUNK DEPOSITION.

At the close of Pocono time the Appalachian sea became deeper and clearer, for little or no sand was laid down. Probably the subsidence which brought the clear ocean waters into the region converted the lower courses of the rivers into estuaries in which the coarser part of the land waste was held. The open sea teemed with marine animals, the calcareous remains of which furnished the greater part if not all of the material of the Greenbrier limestone member. This bed ranges in thickness from a thin edge in western Pennsylvania to several hundred feet in the southern Appalachians.

An elevation of the continent to the east brought mud and sand into the clear marine waters and put an end to the deposition of the Greenbrier limestone. The inherent red color of the resulting shales suggests that conditions similar to those of Catskill time prevailed.

As mentioned under "Stratigraphy," the thickness of the Mauch Chunk formation is over 2000 feet in northeastern Pennsylvania, but it decreases to the west. On the Allegheny Front west of Altoona it is 180 feet. At Blairsville, as recorded in deep wells, it is about 50 feet. It is from 100 to 250 feet at the southwest corner of Pennsylvania.

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

POTTSVILLE DEPOSITION.

The Pottsville is one of the most important and interesting epochs in the history of the province, for in it the accumulation of coal on a large scale began. As a result of the uplift described in the preceding paragraph, there was at the beginning of Pottsville deposition a deep gulf extending southwest from eastern Pennsylvania, nearly surrounded by land at the north end and with probably high land on the southeast. From these land areas the rapid streams brought immense quantities of coarse material, chiefly the quartz pebbles which form the thick, extensive, and coarse conglomerates of the Pottsville formation. It is believed that the Pottsville sediments of this basin were largely derived from the land to the northeast and southeast, because there is no near source of quartz pebbles on the northwest. This deposition of coarse material went on until about 1200 feet of strata had been laid down. At times conditions were favorable to a luxuriant growth of plants, and thick, extensive, and valuable beds of coal were formed.

During the accumulation of 800 or 900 feet of the Pottsville sediments in eastern Pennsylvania, the surface of the land area in the central and western part of the State was being eroded, probably nearly to sea level. Toward the close of Pottsville time, through gradual submergence, sedimentation was resumed over this area. Thus it happened that the lowest Pottsville stratum in the Claysville quadrangle was deposited on the eroded surface of the Mauch Chunk formation. After the formation of the Connoquenessing sandstone member there was a change to quieter conditions, and the sediments of the Mercer shale member, consisting of shale, limestone, clay, and coal, were deposited. This period was followed by one of more active sedimentation, during which the Homewood sandstone member was laid down, marking the last episode in Pottsville history in southwestern Pennsylvania.

ALLEGHENY DEPOSITION.

The Allegheny epoch was marked by very rapidly alternating conditions. Its distinguishing characteristic was the formation of the coal seams. The origin of the coal and the method of its accumulation in seams of great areal extent are subjects that have provoked much discussion. That coal is of vegetal origin hardly anyone would now venture to question. As to the method of accumulation of the vegetal matter there is greater difference of opinion. It seems safe to say that in the main the coal seams of the Appalachian province were formed in marshes near sea level, many of them thousands of square miles in extent. Plants of various types grew very luxuriantly in these marshes. Their remains fell into the water and were preserved from decay until vast accumulations of vegetal matter resulted, not unlike the peat bogs in many parts of the world at the present day but much greater in extent. It is believed that the plants grew in or near water or very wet places, because this was necessary for the preservation of their remains from subaerial decay. That the water was shallow seems obvious, because the plants grew in the air with their roots in the soil below, which would have been impossible in deep water. That the water was fresh is evident from the fact that plants of the same classes at the present day do not grow in salt water. Finally, that this growth and accumulation of vegetal material covered large areas is shown by the great extent of single coal beds. The Pittsburg coal, for example, is known throughout an area exceeding 6000 square miles and in all probability originally extended over a far larger area, from much of which it has been eroded. It is further evident that these marshes were near sea level and were separated from the sea by barriers that, in places at least, were low, for numerous thin beds containing marine fossils are found throughout the coal-bearing formations in close proximity to coal seams, and even, in a few places, in the midst of the seams, showing that there were temporary incursions of sea water. That the coal beds accumulated near water level is further shown by the numerous partings of fine shale, clay, and other material, some of which are traceable over thousands of square miles. These partings indicate temporary flooding of large areas and the deposition of fine silt while the coal beds were in process of accumulation, and such extensive flooding by quiet water could take place only in areas standing approximately at water level. Along certain lines the coal-forming material might be eroded away at such times by a stream and the channel be subsequently filled with sand to form a "horseback" or roll in the coal bed.

With the foregoing discussion in mind, the sequence of events during the deposition of the Allegheny formation may be conceived to have been somewhat as follows. After the Homewood sandstone was laid down there was a slight subsidence and an accumulation of 10 to 30 feet of clay, which raised the bottom approximately to water level and caused marshy conditions in a large area. Vegetable growth established itself on this marshy land and continued until the remains of many generations of plants had formed an extensive area of peat. At times different parts of this marsh were flooded and thin layers of sediment were deposited, forming the partings or binders of the resulting coal bed. The accumulation of vegetal matter varied in amount at different places, causing coal beds of varying thickness. After a long period of comparative quiescence the region was depressed and sedimentation was resumed, burying the vegetal matter, which, under the pressure of the overlying deposits, was compressed and finally hardened into the coal seam now known as the Brookville or "A" coal. After this subsidence and deposition of shale and sandstone the sea bottom was again raised to water level, coal-forming conditions were restored, and the Clarion coal bed was laid down. The deposition of this coal bed was followed by another subsidence, which admitted sea water to a large area, over which the Vanport limestone member was deposited. This limestone appears to have been laid down in salt water, as it contains fossil shells and the hard parts of other marine animals, which were probably the chief source of the calcareous material. This subsidence was apparently of great extent, for the limestone seems to have been deposited in water of considerable depth and at some distance from shore, as its purity indicates that it received no sediment from the surrounding land.

Again the bottom was raised to water level, in part, at least, by sedimentation and probably in part by elevation; then another period of coal-making began and the Lower Kittanning coal was accumulated. By a repetition of such oscillations the Middle Kittanning, Upper Kittanning, Lower Freeport, and Upper Freeport coal beds, with their underclays, and the intervening beds of sandstone, shale, and limestone were formed. It is probable that when uplifts occurred which converted wide expanses of the shallow sea or gulf into fresh-water marshes suitable for the growth and preservation of coal-making plants, the upward movement did not always cease when the sea bottom had been brought exactly to marsh level, but that in many localities the elevation was sufficient to expose the soft unconsolidated strata to erosion for relatively short periods. Under such conditions the quantity of material removed would be comparatively small, but it was probably sufficient to cause numerous slight local unconformities when deposition was again resumed. These unconformities are recognized as such in comparatively few places, because little or no distortion of strata took place, the bedding planes of strata above and below the breaks are practically parallel, and no appreciable paleontologic changes are noted. Such local unconformities may account for the variation in the intervals between beds throughout the Pennsylvanian series and for most of the splits that occur in coal seams.

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

CONEMAUGH DEPOSITION.

At the close of Allegheny deposition a more or less clearly marked change occurred in the conditions of vegetation and deposition, which continued during the laying down of the 600 feet or more of the sediments of the Conemaugh formation. Marine conditions seem to have prevailed locally after the formation of the Upper Freeport coal seam, for a few marine fossils are found in the roof shales of that bed. Coal-forming conditions prevailed locally at short intervals throughout Conemaugh time, though extensive marshes were rare and of comparatively brief duration. The beginning of Conemaugh time is marked by the formation of the Mahoning sandstone member after a widespread subsidence which carried the Upper Freeport coal under water. In places this accumulation of sand and local deposits of mud filled the basin to water level and one to three local seams of the Mahoning coal were formed and later submerged, to be buried by sand. In much of western Pennsylvania, however, sedimentation was continuous until 150 feet of sand and mud were laid down. The deposition of the sediments forming the Mahoning sandstone was soon followed by a short period in which widespread marshes existed and the Brush Creek coal was formed. Another incursion of sea water followed, in which the Lower Cambridge ("Brush Creek") limestone member was deposited. After this time marine conditions prevailed during the deposition of 50 to 70 feet of shale and sandstone, which again filled the basin to water level in many places and was followed by the formation of another coal bed, the Bakerstown, which, though of local occurrence, attains considerable thickness. Marine deposition of shale, sandstone, and, occasionally, thin beds of limestone followed, until 100 to 150 feet of beds were laid down, the top being a considerable thickness of red clayey shales, very similar to the red beds of the Catskill formation. Local coal beds were next formed and their deposition was followed by widespread marine conditions and the deposition of the Ames limestone member. This bed was probably laid down in a broad, shallow sea surrounded by base-leveled land surfaces from which little material was being eroded.

After the Ames limestone member and a few feet of overlying shale had been deposited the bottom of the basin was again brought to the surface and an irregular deposit of coal of wide extent was laid down. Subsidence followed; the last of the distinctly marine fauna is said to have been buried in strata about 50 feet above the Ames limestone member; then the land was elevated and comparatively rapid erosion furnished large quantities of sand and clay, which make up the remainder of the Conemaugh formation. At isolated points there were small swamps, in which the Little Clarksburg or Bavington coal was formed, and at other places the water was sufficiently deep and free from currents to permit the deposition of one or more thin limestones near the top of the formation; but molluscan faunas of plainly marine type have not been found in these higher beds.

MONONGAHELA DEPOSITION.

At the close of Conemaugh time the Appalachian basin was a vast level plain at or just below water level. Uniformity in conditions and long duration of luxuriant vegetation resulted in the formation of the Pittsburg coal. This was probably the most widespread and in many ways the most remarkable coal-forming period in the history of the Appalachian basin. A general submergence which put an end to the vegetal growth and covered the Pittsburg coal with mud was followed by elevation of the adjacent land and the local deposition of the sand and mud which make up the Pittsburg sandstone member, while at other places quiet waters prevailed in which the Redstone limestone member was deposited. When the basin was again filled with sediment, swamp conditions were restored in places, and the Redstone coal was deposited.

Another subsidence with the deposition of mud, sand, and calcareous material followed until swamp conditions again existed in much of southwestern Pennsylvania, and the vegetable matter forming the Sewickley coal was accumulated. During the next subsidence the water was probably clear and quiet. Though there was some deposition of fine mud from adjacent low-lying land areas, the conditions were especially favorable for the accumulation of the calcareous material of the Benwood and Uniontown limestone members. These limestones were probably deposited in shallow water, for they are in many places immediately succeeded by the Uniontown coal, which shows that marsh conditions must have prevailed in much of the area. Another submergence resulted in the deposition of shale, sandstone, and the Waynesburg limestone member. At many places local swamps existed for a short time in which the vegetation forming the Little Waynesburg coal accumulated. Thin layers of sand and mud finally brought large areas again to water level and in widespread swamps the vegetal growth forming the Waynesburg coal accumulated.

DUNKARD DEPOSITION.

The Dunkard epoch was opened by another submergence, during which thick beds of shale and sandstone were deposited, together with local thin beds of limestone. This sandstone and shale, represented by the Waynesburg sandstone member, formed the swampy surface on which the Waynesburg "A" coal accumulated. Successive cycles of submergence, deposition of sand, mud, and calcareous matter, and return to swamp conditions resulted in the accumulation of the sedimentary rocks of the Washington and Greene formations. Throughout the time involved in the formation of these rocks the conditions of deposition varied greatly, as shown by the thinness of the individual members, and by the wholly different character of adjacent strata. A limestone succeeds a coal or a sandstone and vice versa, with surprising abruptness when the different conditions under which each is supposed to have been deposited are taken into account. The limestones seem to have been deposited in shallow water. For example, the accumulation of the Washington coal followed that of the Washington sandstone member and shale and was in turn followed by that of the Lower Washington limestone member, which is in places immediately overlain by a coal, indicating a quick return to swamp conditions. Thus, from the Little Washington coal to the coal above the Lower Washington limestone two complete cycles are represented.

From the above discussion may be inferred a halting but continuous subsidence of the whole area since Pottsville deposition began. This inference, however, is not necessarily true. In many places slight elevations are indicated by local unconformities. Coals overlying limestones with a foot to a few feet of shale between indicate an elevation of the limestone after deposition, for it seems improbable that widespread beds of limestone could have accumulated in such extremely shallow water. It seems more probable that the long period of subsidence following the Pottsville uplift was in reality one of frequent slight oscillations of the surface near the base level, the sum total of which was a depression amounting to thousands of feet in the deeper portions of the Appalachian gulf and possibly involving a great thickness of sediment of which no trace remains, all of it having been removed from the surface by erosion since the final withdrawal of the sea from the region.

POST-CARBONIFEROUS DEFORMATION.

The close of the Dunkard epoch is supposed to have been marked by the end of sedimentation in the Appalachian trough and by the beginning of the long period of erosion which has continued to the present time. From the beginning of Pottsville deposition to the laying down of the uppermost Dunkard rocks subsidence was the prevailing regional movement. At the close of Carboniferous sedimentation subsidence was succeeded by uplift, which raised the surface of the entire region above sea level. This uplift was the result of compression of the earth's crust, probably exerted from the east and southeast, so intense that thousands of feet of strata in the Appalachian Valley were thrown into great mountain-making folds. Along lines of structural weakness the strata were closely folded and fractured and overthrust on great fault planes, resulting in the highly complicated structure of the rocks of the Appalachian Valley. Farther west, in the Allegheny Plateau, the compression was much less, and the strata now forming the bituminous coal basin were uplifted and wrinkled into the broad irregular folds described under "Structural geology." This relatively short period of rapid uplift and compression is known as the post-Carboniferous deformation.

CENOZOIC ERA.

TERTIARY PERIOD.

A long period of profound degradation followed the post-Carboniferous deformation, until in Mesozoic time the land surface was worn down nearly to sea level, forming the Schooley peneplain. This process was ended by an uplift of 800 feet or more. The streams of the region were rejuvenated and erosion commenced anew. During this period of erosion the harder rocks on the greater folds, like those along the Allegheny Front, were left in relief, while the areas of softer rocks were again reduced to a fairly even surface, known as the Harrisburg peneplain, from its development in the vicinity of Harrisburg, Pa. In the Claysville quadrangle this peneplain is not clearly defined. The time of the development of the Harrisburg peneplain is not known with certainty, but the available evidence seems to refer it to the early Tertiary period.

The development of the Harrisburg peneplain was checked by further uplift and the streams began again to deepen their valleys. This uplift was not uniform over the entire region. It was greatest in northern Pennsylvania and southern New York, where the vertical movement was from 400 to 700 feet more than in southwestern Pennsylvania and adjacent sections, where it was least. The streams dissected this uplifted surface and in favorable areas had carved out broad, flat valleys, which were beginning to approach the proportions of a peneplain when the entrenchment of the streams was again renewed. This partly base-leveled surface has been named the Worthington peneplain by Butts,[a] who recognized it in the Allegheny Valley at Worthington, where typical physiographic evidence of this stage is preserved. It probably dates from the later part of the Tertiary period. No evidence of this peneplain has been clearly recognized in the Claysville quadrangle.

After the Worthington stage the principal streams of the region cut down rapidly about 100 feet and then again broadened their valley, forming what is known as the Parker strath.[b] The small terraces along the principal creeks in the Claysville quadrangle can not be correlated with this strath, whose formation probably marked the close of Tertiary time.

QUATERNARY PERIOD.

At the end of the Tertiary period the Ohio flowed through Beaver Valley into Lake Erie. The stream which occupied the present valley of Ohio River south of Beaver to the region of New Martinsville, W. Va., flowed northward and joined the Ohio at Beaver. When the pre-Kansan ice sheet advanced into northern Pennsylvania and Ohio, the northward-flowing rivers were dammed by the ice and lakes extending up the valleys were formed. The water continued to rise until it overflowed to the south through the lowest gap, which was near New Martinsville, and found a new course to the Mississippi. The melting of the glacier along its southern edge greatly increased the volume of Allegheny River and its tributaries from the north and loaded them with glacial débris. Stream aggradation followed, and the valleys of these streams were filled to a considerable depth. Tributary streams from the south which carried no glacial débris had their grades reduced by the aggradation of the master stream. Deposition of sand, clay, and gravel of local origin along the valleys of these tributaries followed. These deposits are known as the Carmichaels formation, from a town on the Monongahela where they are typically developed. In the Claysville quadrangle deposits of sand, clay, and gravel on terraces along Chartiers Creek in the vicinity of Washington have been identified by E. W. Shaw as being of Carmichaels age. He has also tentatively classed the highest terrace gravels along Buffalo and Tenmile creeks and their tributaries as Carmichaels. Younger deposits along the streams probably correspond to later stages of deposition along Ohio and Allegheny rivers, but, because of their isolated position in the Claysville quadrangle, no correlation of them can now be made.[a]

During Recent time the level of the region has been gradually reduced by erosion, the only deposition being that of thin beds of alluvium in the valleys of the larger streams.

MINERAL RESOURCES.

OIL AND GAS.

DISCOVERY AND DEVELOPMENT.

The Claysville quadrangle lies within the Appalachian oil region, as indicated by the position of known pools on the sketch map (fig. 6).

Oil was first discovered in the quadrangle January 1, 1885, and the total production during the next two years was reported to be almost 3,500,000 barrels.[b] The first development in the Washington district was followed by another discovery of oil near Taylorstown. Since that time this great oil and gas field has been developed by hundreds of wells, the total production of which has been enormous. Though most of the large oil wells were drilled within a few years after the discovery of oil in this region, drilling has continued to the present time and in the last few years several valuable oil and gas fields have been found, in some of which development work still continues. The value of the oil and gas thus utilized far exceeds that of any other mineral resource of the quadrangle, though the potential value of the coal is probably greater.

WASHINGTON-TAYLORSTOWN OIL AND GAS FIELD.

The first oil development in the quadrangle was at Washington, where a well on the Gantz property was finished on January 1, 1885. This well produced about 50 barrels a day for a short time and then settled down to an output of 15 to 20 barrels. The oil came from what has since been shown to be the upper member of the Hundred-foot sand of Butler County, but at that time the Hundred-foot sand was unknown in Washington County and the oil-bearing bed was called the Gantz sand. The Gantz well caused little excitement, but a well completed August 21, 1885, on the Gordon farm about half a mile northwest of the Gantz well, began flowing oil at the rate of 100 barrels a day, from another unknown oil horizon (the Third sand) which was called the Gordon sand, lying 252 feet below the top of the Gantz. From this time forward drilling in the eastern part of the field became active. On October 31, 1885, a well was finished on the John McMannis farm, about 1½ miles north of Taylorstown, which began flowing from the Third or Gordon sand at the rate of 90 barrels a day. This was the first well in the western part of the field and served as an indication of the size and trend of the oil-bearing portion of the sand.

The following table, quoted by Carll[b] from the Petroleum Age, shows the increase in wells and production in this field during the year 1886:

	Barrels.
February, 1886, average daily runs (6 wells drilled)	497
September, 1886, average daily runs (94 wells drilled; 20 dry)	13,143
December, 1886, average daily runs (157 wells drilled; 36 dry)	8,841

The total runs of this field for the first two years are reported by the above-cited authority as being 2,418,872 barrels. The field reached its maximum production of 17,549 barrels a day in October, 1886, when it had probably less than 80 producing wells. A number of the better wells produced from 1000 barrels to probably 4000 barrels a day when at their best, but they soon declined to only a small part of that amount.[c]

This oil and gas field as outlined to date extends from a point about 6 miles northeast of Washington, in the Amity quadrangle, southwestward in a narrow belt to the vicinity of Claysville, a total length of about 15 miles. It reaches a maximum width of about 3 miles near Taylorstown, but the usual width is from 1 to 1½ miles. The Big Injun, Gantz, Fifty-foot, and Gordon Stray sands contained pools of oil and gas in this field, but the Gordon, Fourth, and Fifth sands supplied most of the production. Of the latter, the Gordon sand has been by far the most prolific.

From the oil and gas map it will be seen that the oil pool in the Gordon sand in that part of the Washington-Taylorstown

[a] Butts, Charles, Kittanning folio (No. 115), Geol. Atlas U. S., U. S. Geol. Survey, 1904, p. 3.

[b] Idem; also Foxburg-Clarion folio (No. 178).

[a] For a more detailed statement of the physiographic history of Allegheny and Ohio rivers and adjacent streams reference should be made to the folios on that section and to Leverett, Frank, Glacial formations and drainage features of the Erie and Ohio basins (Mon. U. S. Geol. Survey, vol. 41, 1902).

[b] Petroleum Age, quoted by Carll, J. F., Ann. Rept. Second Geol. Survey Pennsylvania, 1886, pt. 2, p. 623.

[c] For a brief history of development in the Washington-Taylorstown field see Clapp, F. G., Economic geology of the Amity quadrangle, in eastern Washington County, Pa.: Bull. U. S. Geol. Survey No. 300, 1907, pp. 45–47.

field which is within the Claysville quadrangle extends from Washington to the southwest end of the field near Claysville. This is the greatest single pool in the field. Structurally, it lies along the comparatively steep northwestern limb of the Finney syncline from Washington to Taylorstown station. In the vicinity of Taylorstown and toward the northeast and southwest from that point the dip is much less and this part of the pool occupies a structural terrace. The southern edge of the pool is roughly marked by the 580-foot structural contour; the northern and higher edge zigzags above and below the 650-foot contour, the highest and lowest points being at about 710 and 640 feet respectively. Farther up the slope of the Claysville anticline the Gordon sand contains pools of gas in the Buffalo field. Below the oil pool in the Finney syncline and farther toward the south and southwest this sand has almost always furnished salt water in wells drilled through it.

Throughout this pool in the Gordon this sand has an average thickness of not more than 15 feet, being rarely 30 feet. The oil in this sand was found confined in an open, porous pebbly stratum, which is from 1 to 10 feet thick and averages probably not more than 5 feet. Although both the Gordon sand and its pay streak are very thin, it has furnished many wells in this area with initial flows of 100 to probably 1000 barrels a day, and, after 10 to 25 years of constant pumping, many wells in this sand now furnish from half a barrel to 2 or 3 barrels a day. It should be noted that the pool is widest where the rocks have the least dip. In the vicinity of Taylorstown the top of the Claysville anticline is flat, the crest line being very indistinct, and, as shown on the map, it lies at least a mile farther to the west than the corresponding feature shown on the map of the surface structure. In the productive region along the east side of this anticline measurements were made directly to the sand in a large percentage of the wells, and the structure is mapped with great accuracy. The occurrence of several dry holes northeast of Taylorstown is inexplicable, so far as structure goes, all of them being clearly within the productive area as indicated by the oil and gas map. The nonproductiveness of this spot may be due to the character of the sandstone, though the fact that one of the wells in this area is a small gas well would be somewhat against this view. No mention is made of the condition of the sands in the records of these wells. East of this point the belt gradually narrows as the dip increases, and at the same time the productive area of the Fourth and Fifth sands overlaps more and more that of the Gordon sand until in the vicinity of West Washington and a mile or so farther west most of the wells have obtained at least a showing of oil in all the sands below and including the Gantz, many of them having been pumped from three sands.

At the east end of the basin at Finney the Fourth and Fifth sands produce oil in about the same territory as the Gordon sand, with the exception that the pool in the Gordon seems to extend farther to the south along the top and eastern slope of the Washington anticline. Most of the gas in the northern portion of this dome comes from the Fifth sand, but large quantities have also been found in the Gordon, Gantz, Fifty-foot and Salt sand. On the north side of the small basin west of Woodell the southernmost line of wells is in the Fifth sand. These all show salt water in the lower portion of the sand, with oil directly above.

In the bottom of the Finney trough to the east and south of Coffeys Crossing, the Fourth sand carries the greater amount of oil, though the Fifth is usually a good producer. In all the productive territory of the Fourth, it contains very much less salt water than either the Gordon or the Fifth sand. Along the crooked bottom of the trough southwestward from Coffeys Crossing, the Fifth sand soon becomes the prominent oil-bearing bed. In this trough south of the National Pike one well found this sand to be 22 feet thick, carrying two streaks of coarse pebbly pay sand, 2 and 5 feet thick, with gas above. This well yielded 353 barrels of oil in the first 24 hours from the Fifth sand and is still a good producer. In this area the Fourth sand carries gas, the Gordon salt water, and the Gordon Stray in many wells both gas and oil. The records of several wells located between Coffeys Crossing and the Children's Home were not obtained, and for this reason the representation of the structure of the small area surrounding them in which no wells are shown on the oil and gas map is to be taken with some allowance, though it is not far from correct. In this area the Gordon sand is doubtless filled with salt water, but there is no structural reason why both the Fourth and Fifth sands should not be productive. If these sands are of good quality within the area, probably portions of them contain oil.

The area in the bottom of the Finney syncline east of the Children's Home northeastward to Coffeys Crossing does not seem to carry much salt water in the Fifth sand. In the dry hole at Sugar Hill the Fifth sand was found to be completely saturated with salt water and it is likely to be found in that condition at all points within the basin below the 480-foot contour. Around the sides of the basin above this line there is a possibility that the sand carries more or less oil. South of the Children's Home the productive belt seems to lie principally between the 540-foot and 590-foot contours, the oil coming principally from the Fifth sand southward to a point within less than a mile of the northern edge of East Finley Township. It will be noted that a line of dry holes (records of which could not be obtained) marks the west side of this productive area.

East of this portion of the field a barren area separates it from the pools of oil and gas which are included in what the writer has termed the Lagonda oil and gas field, to be discussed below.

On the north side of this basin, the Fourth and Fifth sands have been found productive as far west as Buffalo Creek, but so far as could be ascertained none of the test wells put down west of this creek struck the sand at the right level to obtain oil.

Most of the oil coming from the Gantz and Fifty-foot sands is found in and to the west of Washington and around the head of the basin northwest of Woodell. These sands also carry more or less oil at a few other places, as shown on the map.

but is probably equivalent either to the Saltsburg sandstone or to the Saltsburg and Mahoning sandstones combined.

In Bulletin 318, pages 59–60, the writer has pointed out the fact that an area along the northern limb of the Washington anticline in the North Franklin Township and south of the National Pike had not been sufficiently tested for oil in the sands below the Gantz, especially the Fifth sand. Since that time a well on the Thompson farm has been drilled in the extreme east end of the area. This well found oil in the Gantz and has not been drilled deeper. On the south side of the area a well is said to have obtained gas in a shallow sand and has not been drilled deeper. The fact that the Fifth sand furnished a considerable amount of gas and some oil in a well about three-fourths of a mile south-southwest of Sugar Hill seemed to offer favorable indications of a pool in that sand east of that well, at a little lower structural position in the sand. A subsequent well on the David T. Moore farm touched the Fifth sand at a slightly lower level. This came in as a gas well in the Fifth, but it is said to have since sprayed sufficient oil to justify pumping as soon as the gas pressure is relieved. From the

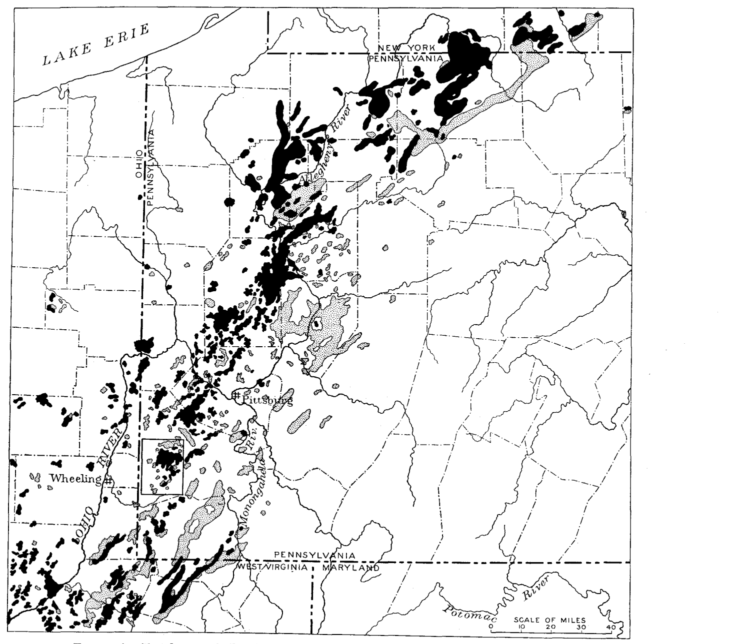


FIGURE 6.—Sketch map of oil and gas fields of western Pennsylvania and adjoining States.
Based largely on the folio maps of the United States Geological Survey. Black areas, oil. Dotted areas, gas. Location of the Claysville quadrangle shown by rectangle.

The Gantz sand is reported in all the detailed well records throughout the quadrangle, with a thickness ranging from 10 to 60 feet. Its greatest production comes from the eastern portion of the Washington-Taylorstown field. The Fifty-foot is also widespread and yields oil and gas in about the same localities as the Gantz. In only a few records is any mention made of salt water in these sands.

LAGONDA OIL AND GAS FIELD.

The Lagonda field extends southwestward from Washington along the axis of the Washington anticline to the vicinity of Tenmile Creek. At the northeast end of this field it blends with the Washington-Taylorstown field. The oil in the Fifth sand at this point changes to gas, and gas continues southwestward to a point on the Washington anticline opposite Lagonda. Gas pools in the Big Injun, Salt, Gas, Dunkard or Hurry-up sand, and even in the upper portion of the Monongahela formation, occur in this vicinity and to the southwest. The largest oil pools in the field occur in the Fifth and Gordon Stray sands near the headwaters of Tenmile Creek and southward along the strike of the rocks to a point near where the axis of the Washington anticline crosses Tenmile Creek. Development work is still cautiously extending this oil field southwestward from Tenmile Creek in the direction of the Dague field, and there appears to be no structural reason why the Gordon Stray sand pools in these two fields may not eventually be found to form portions of a single productive area, extending along the axis and northwestern slope of the Washington anticline.

Since Bulletin 318 of the United States Geological Survey was published (1907) a number of wells have been drilled for gas along the crest of the Washington anticline, opposite Lagonda. Most of these wells produce from the Salt sand, but a number have furnished gas in commercial quantities from a sand whose top lies about 425 feet below the Pittsburg coal. This sand is locally called the Hurry-up or Dunkard sand

position of these wells on the map it will be seen that the favorable area pointed out in Bulletin 318 has not been adequately tested and that a well located near the forks of the road on the hill about half a mile north of the David T. Moore well will have an excellent prospect of being a paying oil well in the Fifth sand, if this sand is of good quality, and will also have chances for oil in the Gantz, Gordon Stray, and Fourth sands.

POINT LOOKOUT POOL.

The Point Lookout pool contains only three producing wellls, all of which contain oil in the Fifth sand. No information in regard to the condition of the different sands penetrated in these wells could be obtained, and the records fail to show the fact of most vital importance in regard to the extension of the pool, namely, the amount of salt water occurring in the different sands. Two dry holes have been drilled near enough to this territory to be of value in determining the direction in which to prospect, but unfortunately the records of these dry holes are not available.

BUFFALO GAS FIELD.

The Buffalo gas field includes all the gas territory on the high dome north of the Washington-Taylorstown oil pool. From it has been produced an enormous quantity of gas, which comes in varying amounts from all the principal sands below and including the Salt sand. This field is the southern part of the great gas-producing area which surrounds and envelops the Westland dome southeast of Hickory in the Burgettstown quadrangle. Besides the Buffalo field this area embraces the Hickory gas field, in the vicinity of that town, and the Canonsburg gas field, lying southwest of Canonsburg in the Carnegie and Amity quadrangles, together with many small pools that have no names, each of which is represented by a few scattered wells.

Taken as a whole, this area is one of the greatest gas fields of southwestern Pennsylvania. After almost a quarter of a century of constant production, it still furnishes a large volume of gas. In the Claysville quadrangle most of the gas in this field comes from the Salt, Gantz, Gordon, Fourth, and Fifth sands. Southwest of Buffalo and in one or two wells to the north the Salt sand is a heavy producer. Northeast of Buffalo most of the gas comes from the Gordon, though some is from the Fourth and Fifth sands. Farther east the Gordon appears to be the most productive, so far as is shown by the records.

Information furnished by records of wells over this territory is meager, and the productive areas in each of the gas-bearing sands can not be shown in detail. The portion of this field in which the Gordon sand has produced gas is shown on the oil and gas map, but doubtless within the territory outlined there are many barren areas in this sand. In many records of gas wells of this field the sand furnishing the gas is not accredited with it, and it seems very probable that the Fifth, Fourth, Hundred-foot, and Salt sands are productive over much more of the area than has been shown. In this field the Fifth sand ranges from 5 to about 25 feet in thickness. The Fourth sand is seldom more than 20 feet thick and is gas bearing where its thickness is only 10 feet. The Gordon and Gordon Stray sands are frequently separated only by a thin parting of black shale, their combined thickness being 40 to 80 feet. For this reason no attempt has been made in this field to differentiate the pools in the two sands. Where the sands are separated by several feet of shale the Gordon sand is usually the thinner, being from 8 feet to probably 30 feet, the Gordon Stray ranging from 12 feet to about 46 feet in thickness. The Nineveh Thirty-foot sand is rarely mentioned in well records, but when its thickness is given it is 20 to 40 feet. The Gantz and Fifty-foot sands show great variation in thickness, each ranging from 10 to about 60 feet. The Salt sand has an average thickness of about 65 feet and is fairly uniform, so far as shown by the few well records that report it. The Big Injun is very thick and massive, being from 250 feet to probably 350 feet thick.

Few facts are available relative to the initial closed pressure of these oil wells. The closed pressure in the Fourth, Fifth, and Gordon sands when the field was first developed is said to have been from 600 to about 900 pounds to the square inch, and that in the Gantz and Fifty-foot sands was somewhat less. The maximum pressure from the Salt sand is said to have been about 350 pounds. By an examination of the oil and gas map it will be seen that between the northern boundary of the Washington-Taylorstown oil pool and the Buffalo gas field there is a narrow belt in which neither oil nor gas has been found. No explanation of this phenomenon is apparent.

CLAYSVILLE GAS POOL.

At the southwest end of the Washington-Taylorstown field a small pool of gas was found occupying the southeast side of a small dome in the Claysville anticline about a mile north of Claysville. The gas comes from the Gordon sand and is said to have had an initial closed pressure of about 900 pounds to the square inch. In 1907 this was down to probably less than 100 pounds and the wells furnished a relatively small daily production.

MEHAFFY GAS FIELD.

The Mehaffy gas field is situated about 3 miles northwest of Claysville, near the axis of a minor anticline which juts out to the west from the structural dome north of Claysville. This pool was discovered in 1906 by a well on the John Mehaffy farm, which found gas in both the Gordon Stray and Gordon sands and a showing of oil in the former. The well was an enormous producer from a very thin sand. The closed pressure of this gas is said to have exceeded 1250 pounds to the square inch, but the owners have not verified this statement. On May 10, 1910, the field contained about 22 producing wells and 5 dry holes around the margin. In the dry holes the Gordon and Gordon Stray sands are absent or are represented by 1 to 13 feet of hard sandstone.

A study of the records of these wells shows a fairly uniform decrease in distance between the Gordon sand and both the Pittsburg coal and Big Injun sand from south to north across this field. This change is shown in the table of intervals printed in the next column.

In these wells the Gordon sand is the principal gas-bearing stratum, but some gas was also found in one or more of the sandstones of the Conemaugh formation in the Salt and Gas sands, probably of Pottsville age, and in the Big Injun sand. The amount in the Big Injun sand was found sufficient in the W. C. Burig well to warrant its use for commercial purposes. The well has later been deepened to the Gordon sand.

The detailed structure of the Gordon sand is shown on the oil and gas map, so far as is possible from the data obtained from the well logs. The contours show that the gas pool occupies the crest and south side of an irregularly shaped anticline from which the rocks dip more or less steeply in every direction except southeastward. The facts that this gas field is near the northwestern edge of the Gordon sand and that this bed is probably lenticular in much of the territory near its northwestern border prevent the extension of structural contours with sufficient accuracy to be of value in future operations much beyond the area of probable productive territory already outlined by the drill. The extreme thinness of the Gordon sand (3 to 9 feet) in this field, together with the fact that it is subject to rapid changes in texture, renders the location of good wells in the future very uncertain.

Changes in distance between the top of the Gordon sand and the tops of the Pittsburg coal and Big Injun sand from south to north across the Mehaffy gas field.

Owner of well.	Company or farm No. of well.	Distance in feet from top of Pittsburg coal to top of Gordon sand.	Distance in feet from top of Big Injun sand to top of Gordon sand.
Joseph Hupp[a]	1	2107	955
Franklin Rogers[a]	1	2081	973
James Defiance	676	2070	970
W. J. Mehaffy	689	2076	975
Do	684	2085	979
John Deeds	3	2072	------
Miller heirs	2	2077	976
Do	3	2077	972
John Mehaffy	680	2076	949
Do	679	2069	967
Do	678	2070	980
Do	677	2061	972
Do	674	2065	968
John Deeds	1	2059	971
Miller heirs	1	2064	971
Morgan Miller[a]	1	2059	956
T. C. Snodgrass	1	2064	961
John Deeds	2	2070	978
William McPherson[a]	69	2054	951
Samuel Shaller[a]	687	2060	956
Dan McPherson	690	2049	936

[a] Dry hole.

DAGUE OIL AND GAS FIELD.

The Dague field is situated along the line between Morris and East Finley townships north of the village of Gale. The first well was drilled in this field in 1906 on the John Plants farm. It produced sufficient gas from the Big Injun sand to justify turning into the pipe line. The next well, on the Stewart Dague place, was drilled to the Fourth sand and began flowing at the rate of 400 barrels a day. The field at present contains less than 20 deep wells, including at least three dry holes. Most of the productive wells furnish gas, the larger amounts coming from the Gordon Stray, Big Injun, and Salt sands. The Fourth sand has produced the greatest amount of oil, most of which has come from the Dague No. 1 well. This sand has proved to be very erratic as an oil-bearing sand over most of Washington County and this characteristic is in evidence in the Dague field. The John Plants No. 2 well, one location north of the 400-barrel well on the Stewart Dague farm, showed only a little oil in the Fourth sand. The John S. Danley No. 1 well is said to have filled up 1500 feet with oil from the Fourth sand when first drilled, but the sand, though of fair thickness, is reported to be of poor quality and the daily production of the well is small. This sand is gas bearing in the George Croft No. 1 well. Both oil and gas have been found in a number of wells in the Gordon Stray sand in this field. A well on the Leroy Smith property came in as a gas well in the Gordon Stray sand but later began spraying oil, the amount of oil gradually increasing. Finally the well was put to pumping and made 20 barrels a day. Southwest of this well two wells on the John Irwin farm also furnish a few barrels of oil each from the Gordon Stray sand. In the valley of Templeton Fork the McCleary No. 1 produced large amounts of gas and several barrels of oil from the Gordon Stray sand. McCleary No. 2 also made a good showing for oil and gas in the Gordon Stray, but the well is said to have been spoiled by being drilled deeper, thereby letting in a flood of salt water from the Gordon sand below, which seems to have stopped the flow of oil. The Gordon sand in this field is found to be heavily charged with salt water, and where it is separated from the Gordon Stray by only a foot or so of soft shale it is very difficult to shut off the water effectively from the latter sand when the shale has been penetrated.

The Dague field is at present in a very interesting stage of its development. The sands have been tapped at a sufficient number of places to show that they can not be regarded as continuous oil-bearing beds, though, at the same time, it is obvious that the conditions favorable for accumulation are present in several sands in this area.

It is evident that producers must look for the oil in the Gordon Stray and Fourth sands in the southern and western parts of the field and in the Gordon Stray and Fifth sands in the northern extension southeast of Pleasant Grove. It is probable that the pools in these sands will not be found to extend southeastward very far beyond the present line of wells. The favorable territory lies chiefly northwest of this line and northeastward along its extension to the Fifth and Gordon Stray pools on Tenmile Creek. The facts that the well 1 mile north of Stony Point school had a show of oil in what is believed to be the Fourth sand and a show of gas in the Gordon Stray and that the two dry holes located northeast of this well near the axis of the Finney syncline south of Buffalo Creek had shows of oil in what is thought to be the Gordon Stray sand give evidence in favor of a general extension of these pools in that direction. Structurally, all the area southeast of these wells and eastward to the axis of the Washington anticline, where it crosses Tenmile Creek, is favorable territory and is worth careful testing.

In the Dague field the Gordon and Gordon Stray sands are separated by a very thin bed of dark shale. In contrast with their thickness of 3 to 9 feet in the Mehaffy gas field, they have a combined thickness here of 65 to 90 feet, the Gordon Stray sand being apparently much thicker than the Gordon.

The following table shows the variation in interval between the tops of the Pittsburg coal and Big Injun sand and the top of the Gordon Stray sand:

Distance between top of Pittsburg coal and Big Injun sand and top of Gordon Stray sand in the Dague field.

Name of well.	No. of well on farm.	Distance in feet from top of Pittsburg coal to top of Gordon Stray sand.	Distance in feet from top of Big Injun sand to top of Gordon Stray sand.
Stewart Dague	1	2093	938
John Plants	1	2085	925
John Irvin	1	2089	920
Do	2	2093	933
Do	3	------	930
Leroy Smith	1	2083	933
Ashbrook heirs	1	2088	935
George Craft	1	2070	920
J. M. Clark	2	2066	932
C. M. Manon	2	2063	929

COAL.

OCCURRENCE.

The horizons of at least 24 coal beds occur in the Conemaugh, Monongahela, Washington, and Greene formations, at the surface or within 1000 feet of it, in the Claysville quadrangle. It is very probable, however, that many of these coals are entirely absent in this area, and it is certain that most of those that are present are either so thin or so poor in quality as to have no present commercial value; indeed, it is questionable if the time will ever come when they can be profitably mined. There are a number of coals, averaging between 1 and 3½ feet in thickness and outcropping at the surface or lying at comparatively shallow depths below drainage level, which are not now of sufficient value to warrant mining but which may locally furnish more or less commercial coal at some future time, when the thicker and higher-grade coal seams shall have become exhausted or when better methods have been devised for mining and utilizing the poorer grades of coal. These beds include the Redstone, Sewickley, and Uniontown coals of the Monongahela formation, the Waynesburg "A," Waynesburg "B," and Little Washington coals of the Washington formation, and, possibly, the Upper Washington coal and Tenmile coal of the Greene formation. Though most of these beds are very inferior, both in thickness and in quality, each of them in places apparently contains a fair quality of bituminous coal. These favorable areas, however, are too few and the beds too thin and variable to justify at present the maintenance of country banks in them to procure fuel for local consumption. The entire output from these beds is confined to that obtained by stripping at favorable places along the narrow valleys, where the beds outcrop, and the total production to date from them probably does not exceed a few tons. These beds are usually regarded by landowners and coal operators as being worthless.

Within this quadrangle but three coal seams, the Pittsburg, Waynesburg, and Washington, are generally of minable thickness. Of these, only the first has been mined on a commercial scale.

PITTSBURG COAL.

The Pittsburg coal underlies the entire surface of the Claysville quadrangle. It is nearest the surface in the valley of Chartiers Creek at the eastern border of the quadrangle, where it can probably be reached within 50 feet. In the northern half of the quadrangle it ranges from 150 to 300 feet below the surface along the larger streams.

Because of the general dip of the rocks toward the south, the coal lies deeper in that direction. In the southern part of the quadrangle shafts from 500 to probably 700 feet below the larger valleys will be needed to reach it. This coal has been noted in hundreds of deep wells drilled for oil and gas, but, because of the method of drilling, the exact thickness of the seam could not always be determined. It is generally reported as having a thickness of 5 to 8 feet. No data relative to the character of the coal were collected.

The Pittsburg coal was first opened for mining at Washington, Pa., many years ago by a shaft sunk in the valley near the present Chestnut Street station of the Pennsylvania Railroad. This shaft reached the coal at a depth of about 345 feet. The mine was operated for a number of years and the coal is said to have been removed from a considerable area under what is now West Washington. Mining was found to be expensive, however, on account of the great amount of water encountered and other unfavorable conditions, which eventually resulted in the abandonment of the enterprise. Men who worked in this mine state that the minable portion of the coal is here about 5 feet thick and is a steaming coal of excellent quality.

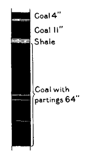


FIGURE 7.—Section of Pittsburg coal in Arden mine.
Scale: 1 inch=5 feet.

The Arden mine, 3 miles north of Washington, is the only commercial mine now being operated in the quadrangle. At this mine the coal is reached by a shaft about 180 feet deep. The average section of the coal in this mine is shown by figure 7. The exact area of coal removed from this mine is not known, but it probably does not exceed half a square mile.

Five diamond-drill tests have been made of this coal, all in the southwestern quarter of the quadrangle. As the work was done privately for business purposes, no authentic data relative to the thickness or quality of the seam have been made public. Three of these holes are along the Baltimore & Ohio Railroad—one at Claysville, another at Vienna, and the third near the western edge of the quadrangle. A well-credited rumor gives the workable part of the Pittsburg coal in the last-named hole a thickness of 59 to 63 inches. The other two diamond-drill holes are located on Templeton Fork in East Finley Township, one about 1½ miles from the southern border of the quadrangle and the other about a mile southwest of Pleasant Grove. The great number of deep wells which have penetrated this coal have clearly shown that it is of workable thickness throughout the quadrangle, but its value depends largely on its coking qualities, of which nothing can be learned except by analysis and actual tests. It is known that large areas of this coal in the Amity and Waynesburg quadrangles, east and southeast of the Claysville quadrangle, are sufficiently free from sulphur and other impurities to make good coke. Analyses of the coal to the north and northwest, in the Burgettstown and Steubenville quadrangles, show it to contain larger amounts of sulphur and to be noncoking, though a fine steaming coal. Subsequent tests may therefore show that a considerable area of the Pittsburg coal in the southeastern and southern parts of the Claysville quadrangle has coking qualities, and that the washed coal from most of the quadrangle will give a fair grade of coke.

The amount of the Pittsburg coal in this quadrangle yet unmined is estimated to cover about 226 square miles and to approximate 1,150,000,000 short tons.

The general shape of this coal seam is shown by the structure contours on the structure and economic geology map. The depth to the Pittsburg coal at any point on the surface can be determined approximately from this map in the following manner. At the point on the map at which the depth to the coal is desired, find the approximate elevation above sea level of the Upper Washington limestone member, as shown by the structure (dark brown) contours, which have a vertical interval of 10 feet. From this elevation subtract 550 to 575 feet for the interval between the Pittsburg coal and Upper Washington coal, if the given point is in the northern third of the quadrangle. This interval increases to a maximum of 650 feet in the middle portion and of 725 feet in the southern third of the quadrangle. After the approximately correct interval is subtracted, determine the elevation of the surface above sea level at the point selected, from the topographic (light brown) contours, which have a vertical interval of 20 feet. From this elevation subtract the figure previously obtained, and the remainder will be the approximate depth of the coal at the point selected.

WAYNESBURG COAL.

The Waynesburg coal ranges in thickness from a few inches to about 5 feet over the northern portion of the quadrangle, where it is exposed. It is below drainage level in the southern half and, as it is recorded in but few well logs, little is known regarding its thickness.

In Chartiers Township and the northern part of Canton Township the Waynesburg coal is very thin, being represented at many exposures by only a few inches of soft coal and shale. At several places in this area careful search revealed no trace of the coal. It thickens westward through Hopewell Township to the vicinity of Acheson, where it has been opened for country banks at a number of places. A sample of this coal taken from the Maloy bank, on the south side of Brush Run about half a mile east of Acheson, gives the following analysis:

Analysis of Waynesburg coal from Maloy country bank, east of Acheson.

Moisture	4.29
Volatile combustible	30.43
Fixed carbon	45.01
Ash	20.27
Sulphur	2.62
Air drying loss	1.70

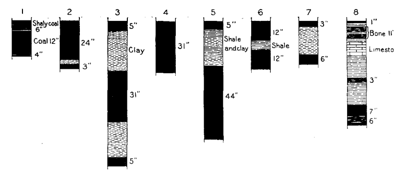


FIGURE 8.—Sections of Waynesburg coal in the Claysville quadrangle.
1. Near run, on south side of Washington-Buffalo pike, 1 mile northwest of Wolftown.
2. At forks in road in valley, three-fourths mile south of Garrett Hill.
3. On road running north from Brush Run, 1½ miles south-southwest of Buffalo.
4. South side of Buffalo Creek, one-half mile east of mouth of Polecat Hollow.
5. Abandoned coal bank on east side of Buck Run, 1 mile south of its mouth.
6. On Sugarcamp Run, 1 mile south of Manchester schoolhouse.
7. In run, three-fourths mile southeast of Budaville.
8. In Buck Run, 1 mile north of Donley.

Scale: 1 inch=5 feet.

The minable coal in this vicinity ranges from 30 inches to probably 60 inches in thickness, but, as indicated by the above analysis, it is of poor quality. From this vicinity the Waynesburg coal appears to thin toward the northeast, west, and south, in Independence, Blaine, and Donegal townships. The sections in figures 8 and 9 show the variation in thickness of this coal in different parts of the quadrangle where it is exposed.

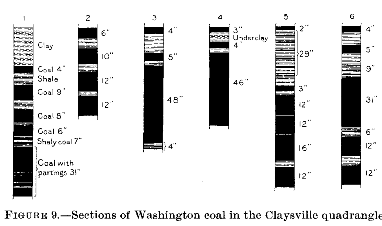


FIGURE 9.—Sections of Washington coal in the Claysville quadrangle.
1. In cut on Baltimore & Ohio Railroad, West Washington, Pa.
2. Country bank on run, one-fourth mile west of Chartiers Creek.
3. On road just west of Taylorstown.
4. On road, 1 mile north-northwest of Buffalo.
5. In small run between Narigan Run and Welch Hollow, one-half mile north of Buffalo Creek.
6. At waterfall on Dog Run about 1½ miles from its mouth.

Scale: 1 inch=5 feet.

At the point on Dutch Fork where the Waynesburg coal goes under cover it has a thickness of about 8 inches. On the road half a mile north of Taylorstown it is composed of about 30 inches of soft shaly coal. The thickest and apparently the best bed of this coal appears to have been found on the border between Independence and Hopewell townships on Haynon Run, just north of its junction with Dunkle Run. Here the coal has been opened both by drifts and by stripping in the bed of the run, where it is reported to have had 5 feet of minable coal. Considerable quantities have been taken out, but the openings have now fallen into disuse. The coal has been opened at many places along its outcrop in the northern part of the quadrangle, but the banks, after being operated for a short time, have almost invariably been abandoned.

WASHINGTON COAL.

The Washington coal is the thickest and most conspicuous seam outcropping within the quadrangle, having a total thickness in places of 4 to 6 feet, exclusive of partings. The sections in figure 10 are typical of this coal in the vicinities from which they are taken.

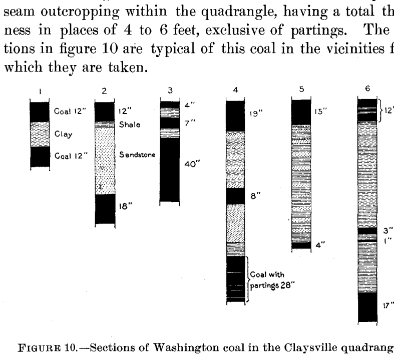


FIGURE 10.—Sections of Washington coal in the Claysville quadrangle.
1. On private road, 1 mile east-southeast of Budaville.
2. On run, one-fourth mile west of Dutch Fork and three-fourths mile south of mouth of Ralston Run.
3. On road running east from road on Dutch Fork, 1¼ miles below Vienna.
4. At Vienna.
5. On road running north from National Pike, three-fourths mile east of Vienna.
6. Just north of National Pike, 1 mile west of Claysville.

Scale: 1 inch=5 feet.

In the northeastern part of the quadrangle and as far south as it outcrops on Chartiers Creek this coal makes an imposing appearance in outcrop, and the purer, lower portion is everywhere of minable thickness. It has been opened at hundreds of places in this area, but, because of its poor quality, due to its large percentage of ash and sulphur, most of the banks have been abandoned after small quantities of coal have been removed. Probably a fair example of the banks that have been worked is one on the Imhoff farm, situated one-fourth mile north of North Buffalo Creek in Buffalo Township. From this opening has been taken probably the greatest amount of coal from a single mine on the Washington coal within the quadrangle. The minable coal here ranges from 3½ to 4 feet or more in thickness. The following analysis of a sample from this bank is probably fairly indicative of the quality of the better areas of this coal.

Analysis of Washington coal from the Imhoff bank, Buffalo Township, Washington County, Pa.

Moisture	4.45
Volatile combustible	33.53
Fixed carbon	49.51
Ash	12.51
Sulphur	3.04
Air-drying loss	2.10

In Hopewell and Independence townships, north of Buffalo Creek, the Washington coal is as thick and of as good quality as it is in the northeast quarter of the quadrangle. It is also of normal thickness west of Dutch Fork and north of Ralston Run. In the area southwest of Buffalo Creek and on Dutch Fork south of Ralston Run the coal is variable, as indicated by the sections given in figure 10.

LIMESTONE.

The limestones of the Washington and Greene formations outcrop throughout the quadrangle and some of the beds are present on almost every farm. They have been principally used in road making, but in a few places small quantities have been burned for fertilizer. As a road metal the Lower, Middle, and Upper Washington limestones and the Donley limestone have been widely used in the construction of macadamized pikes throughout the quadrangle. The National Pike, which crosses this area from east to west, was built of this material, most of the limestone coming from convenient outcrops of the Upper Washington limestone along the route.

The pikes from Washington to Prosperity and from Washington to West Middletown are also largely built of limestone from the Upper Washington. Some of the upper layers of this bed are generally preferred, because of their hardness, brittleness, and supposed tendency to cement together under wear. No samples of limestone were procured for analysis, but the Upper Washington limestone has been analyzed many times and parts of it are reported to be apparently suitable for making Portland cement, although so far as known, no attempt has been made to utilize it for that purpose. The Benwood, Waynesburg, Prosperity, and Claysville limestones also may locally prove to be of economic value in road building, which is very probably the greatest future use to which limestones of the quadrangle will be put.

SANDSTONE.

In general the sandstones of the Claysville quadrangle, though abundant, are flaggy and shaly and therefore of little economic value. The flaggy sandstone has been locally used as a foundation for macadamized roads, and for rough masonry. In a few places the sandstone overlying the Washington coal is massive and has been utilized for stone bridges, piers, and foundations for buildings. The most important occurrence of this sandstone is on the east fork of Buffalo Creek just south of the National Pike, where there are single ledges 20 feet or more in thickness. This sandstone was extensively quarried here for the stone bridges along the National Pike, the famous "S" bridge over the east fork of Buffalo Creek being built of it. This quarry was later used by the Baltimore & Ohio Railroad for stone for bridge building, and a switch was built to it from the main line. The railroad company also took out a large amount of flag and cut stone from another quarry in this sandstone situated in a small valley three-fourths mile northwest of Coffeys Crossing. This sandstone has also been quarried in the valley about one-fourth mile west of Woodell station, and, in a lesser way, at many other places within the quadrangle.

CLAY AND SHALE.

The clay beds outcropping in the Claysville quadrangle are apparently of little or no commercial value, though it is possible that local deposits of value in brickmaking may be found in the Carmichaels formation along Chartiers Creek near Washington, but to the writer's knowledge no such deposits have yet been utilized.

Beds of shale are abundant in all the formations exposed, and there is reason to believe that some of these may be utilized in brickmaking.

WATER.

The Claysville quadrangle is well drained by numerous small streams tributary to Buffalo, Chartiers, Tenmile, and Middle Wheeling creeks. These are fed by numerous springs which, together with shallow wells, furnish ample water for domestic uses. In pioneer days many of the larger streams furnished small water powers for grain and small lumber mills, but these were superseded by the steam engine, which, in turn, has to some extent given way to the gas engine for power. At the present time water is being utilized for power in a small way at Lindleys Mills on Tenmile Creek.

SOIL.

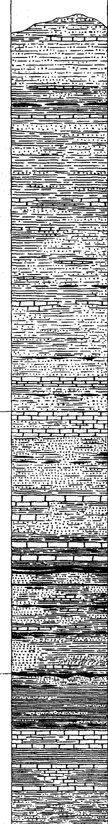
Except for thin deposits of alluvium along the valleys, the soil of the Claysville quadrangle is residual, being derived from associated beds of clay, shale, sandstone, and limestone. This soil was originally very fertile, but after being deprived of its forest covering and being subjected to the drain of continuous cultivation for long periods, together with heavy loss of fertility through excessive surface run-off of water from rains, the soil of the larger portion of this area is gradually becoming depleted of its fertility. This is indicated by several abandoned farms and by the appearance of many spots in fields where the soil has become so poor as to require heavy fertilization and careful rotation of crops to render farming profitable. The country is practically all under fence, and probably 90 to 95 per cent of it is under cultivation. Grass, hay, wheat, oats, corn, potatoes, rye, and barley are the principal crops.

June, 1910.

COLUMNAR SECTION

GENERALIZED SECTION OF THE ROCKS EXPOSED IN THE CLAYSVILLE QUADRANGLE.

SCALE: 1 INCH = 100 FEET.



System.	Series.	Group.	Formation.	Symbol.	Section.	Thickness in feet.	Minor divisions.	Character of minor divisions.	General character of formation.
CARBONIFEROUS	PERMIAN	Dunkard	Greene formation.	Cg		425	Nineveh coal.	Thin and of no importance.	Prevailingly shaly sandstone and sandy shale, with thin beds of limestone and a few thin coals of little value.
							Nineveh limestone member.	Light-buff limestone; weathers bluish white. Very hard and tough.	
							Claysville limestone member.	Brown or gray limestone; weathers bluish white at top, reddish or yellow below.	
							Dunkard (?) coal.		
							Prosperity limestone member.	Dark rusty-brown to bluish limestone.	
							Tenmile coal.	0 to 3 feet, variable; locally of good quality.	
							Donley limestone member.	3 to 6 feet, massive coarse-grained limestone.	
							Upper Washington coal.	Thin and unimportant.	
			Washington formation.	Cw		270	Upper Washington limestone member.	Massive bluish-black and brown limestone; generally weathers white or yellow.	Soft sandy shales with thick limestones, a few massive sandstones, and coal seams of fair thickness but poor quality.
							Jollytown coal.	Thin and unimportant.	
							Middle Washington limestone member.	Massive yellow, brown, and gray limestone with interstratified shale.	
							Lower Washington limestone member.	Light-gray cherty limestone at top; reddish to gray at bottom.	
							Washington coal.	4 to 6 feet, poor coal.	
							Little Washington coal.	6 to 12 inches, good coal.	
							Waynesburg "B" coal.	0 to 30 inches, poor coal.	
							Waynesburg "A" coal.	0 to 18 inches, poor coal.	
							Waynesburg sandstone member.		
	?						Cassville shale member.		
	PENNSYLVANIAN		Monongahela formation.	Cm		260+	Waynesburg coal.	0 to 5 feet, generally poor coal.	Limestones, shales, and sandstones, with several coal beds, including the Pittsburg coal at the base, not exposed in the quadrangle. The most important coal-bearing formation in southwestern Pennsylvania.
							Little Waynesburg coal.		
							Uniontown coal.	Thin and unimportant.	
							Uniontown limestone member.	Locally massive limestone.	
							Benwood limestone member.	Poorly exposed limestone with yellow and green shales in middle.	
							Sewickley coal.	Soft and shaly coal.	

TOPOGRAPHY

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PENNSYLVANIA
CLAYSVILLE QUADRANGLE

LEGEND

RELIEF
printed in brown

- 1276 — 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
- Reservoirs and dams

CULTURE
printed in black

- Roads and buildings
- Churches, school houses, and cemeteries
- Private and secondary roads
- Railroads
- Electric railroads
- Tunnels
- Bridges
- County lines
- Township lines
- City, village, and borough lines
- Triangulation stations
- BM × Bench marks

H. M. Wilson, Geographer.
Robt. D. Cummin, in charge of section.
Topography by M. J. Munn, Assistant, E. W. McCrary.
Control by D. H. Baldwin and B. J. Green.
Surveyed in 1904 and 1905.

SURVEYED IN COOPERATION WITH THE STATE OF PENNSYLVANIA.

TRUE NORTH / MAGNETIC NORTH 3°
APPROXIMATE MEAN DECLINATION 1905.

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 April 1907 reprinted Mar. 1911

AREAL GEOLOGY

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PENNSYLVANIA
CLAYSVILLE 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 *(sand and silt in flood plains of the larger streams)*

Pleistocene

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

Kansan ?

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

CARBONIFEROUS

Permian — Dunkard group

Cg — Greene formation *(shale and sandstone with thin limestones and beds of coal)*

Cw — Washington formation *(sandy shale and coarse sandstone with limestone and beds of coal, Washington coal near middle)*

Pennsylvanian ?

Cm — Monongahela formation *(limestone, shale, and sandstone with Waynesburg coal at top)*

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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 Mar. 1911.

Pre-Quaternary geology by M. J. Munn;
Quaternary geology by E. W. Shaw;
under the supervision of George H. Ashley.
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STRUCTURE AND ECONOMIC GEOLOGY

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PENNSYLVANIA
CLAYSVILLE QUADRANGLE

(Steubenville) (Burgettstown) (Carnegie)

(Wheeling) (Amity)

(Cameron) (Rogersville) (Waynesburg)

LEGEND

SEDIMENTARY ROCKS

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

QUATERNARY

Recent

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Pleistocene

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

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Cw — Washington formation *(sandy shale and coarse sandstone with limestone and beds of coal, Washington coal near middle)*

Pennsylvanian ?

Cm — Monongahela formation *(limestone, shale, and sandstone with Waynesburg coal at top)*

ECONOMIC AND STRUCTURE DATA

Coal outcrops
wht, *Washington coal*
wb, *Waynesburg coal*

Structure contours on the limestone at the top of the Washington formation
(contour interval is 10 feet; datum is mean sea level)

⚒ *Coal mine*
x *Country coal banks*

Note: *The Pittsburg coal at the base of the Monongahela formation does not outcrop, but in general lies at a depth below the surface of 300 to 700 feet throughout the quadrangle; other coals, clay and shale for brick and tile, limestone for cement materials, and building stone occur throughout all the consolidated formations; the stream and terrace deposits yield gravel, sand, and clay. Distribution of oil and gas wells and pools shown on separate map.*

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OIL AND GAS

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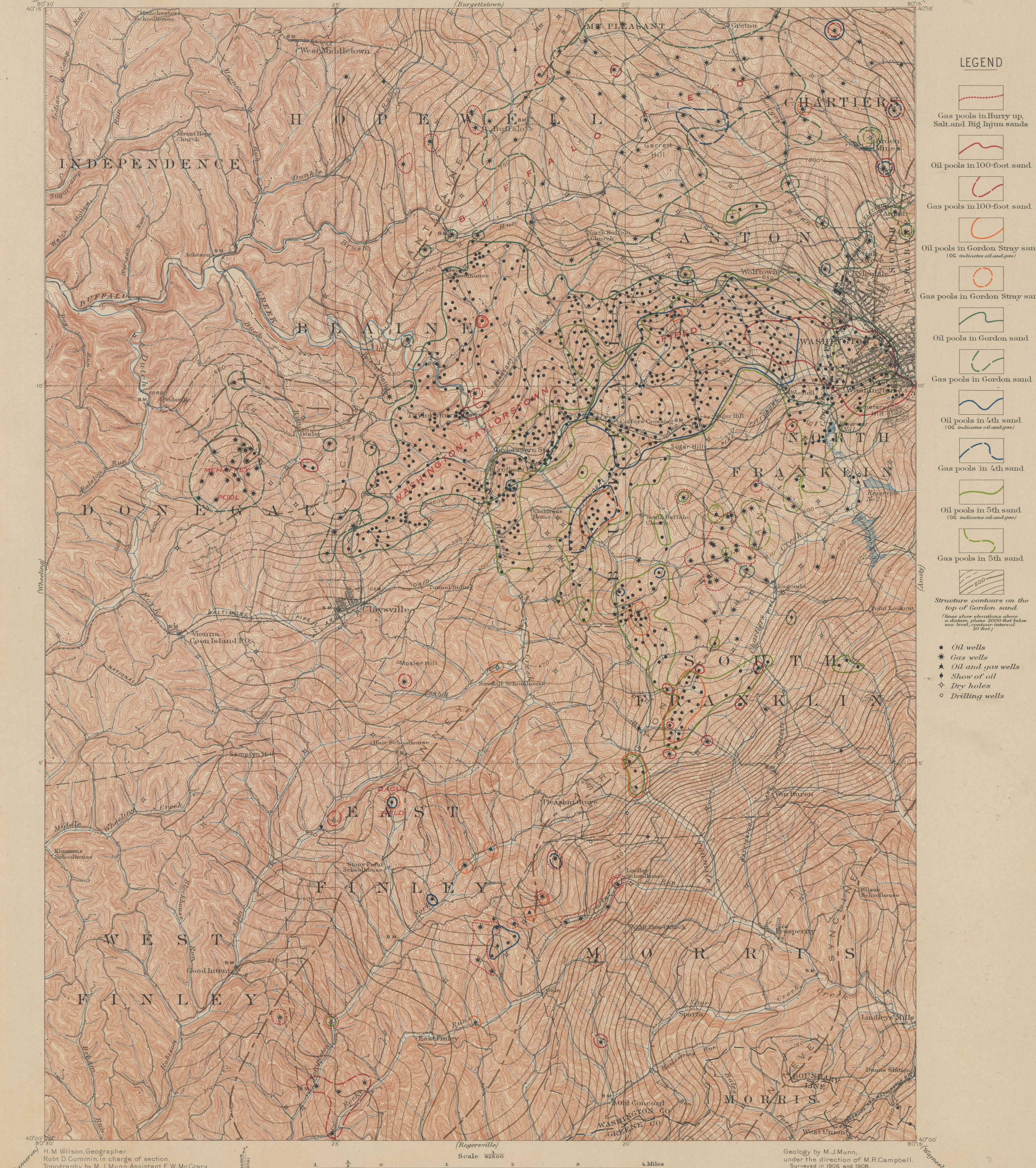
PENNSYLVANIA
CLAYSVILLE QUADRANGLE



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Scale $\frac{1}{62500}$

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Geology by M. J. Munn,
under the direction of M. R. Campbell.
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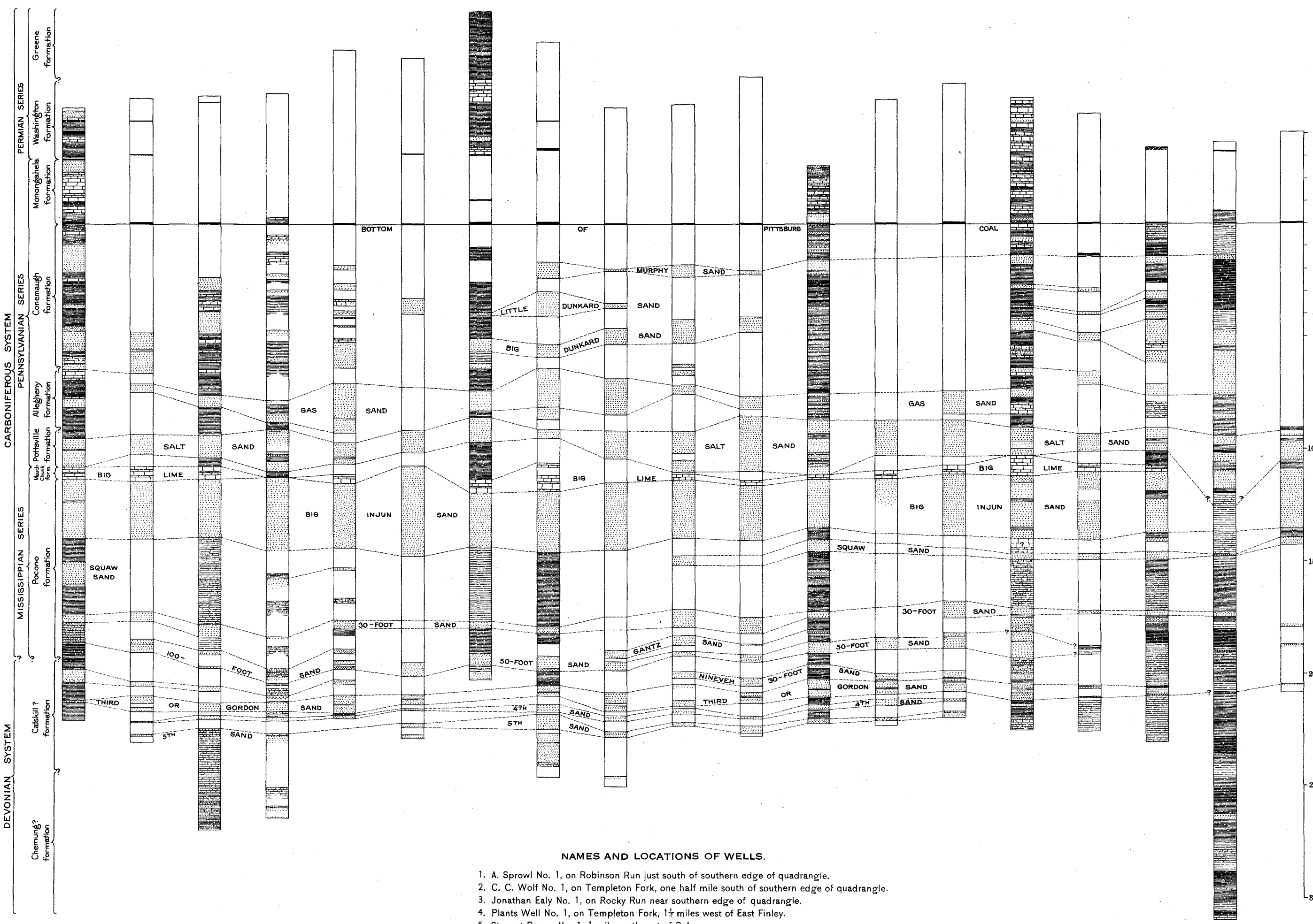
SECTIONS OF DEEP WELLS IN THE CLAYSVILLE QUADRANGLE.

SCALE: 1 INCH = 400 FEET.



NAMES AND LOCATIONS OF WELLS.

1. A. Sprowl No. 1, on Robinson Run just south of southern edge of quadrangle.
2. C. C. Wolf No. 1, on Templeton Fork, one half mile south of southern edge of quadrangle.
3. Jonathan Ealy No. 1, on Rocky Run near southern edge of quadrangle.
4. Plants Well No. 1, on Templeton Fork, 1½ miles west of East Finley.
5. Stewart Dague No. 1, 1 mile northwest of Gale.
6. Ben Farabee No. 1, 1 mile north-northwest of Old Concord.
7. John Lewis No. 1, 2 miles southeast of Old Concord, beyond southern edge of quadrangle.
8. James Dunn No. 1, on Bates Fork, 1 mile west of West Union.
9. Harvey Andrew No. 2, on Crafts Run, 1 mile southwest of Lindley Schoolhouse.
10. Eliott No. 3, 1½ miles west-northwest of Van Buren.
11. B. F. McClain No. 2, 1 mile southwest of Point Lookout.
12. Hess No. 1, on Chartiers Creek in northern part of Washington.
13. S. K. Weirick No. 12, 1½ miles west of Washington.
14. J. H. and J. E. Wilson No. 2, one-half mile southeast of Coffeys Crossing.
15. A. Brownlee No. 3, on branch of Buffalo Creek, 1½ miles south-southeast of Crothers.
16. Morgan Miller, three-fourths mile southwest of Donley.
17. Samuel Shaler No. 1, one-third mile east of Budaville.
18. John Rush, 1½ miles southeast of Middletown.
19. David Davidson No. 2, 1½ miles north-northeast of Buffalo.

DRILLER'S TERMS.

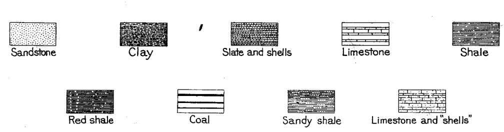
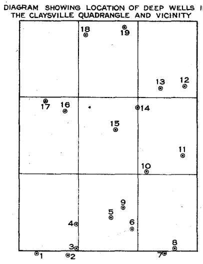


DIAGRAM SHOWING LOCATION OF DEEP WELLS IN THE CLAYSVILLE QUADRANGLE AND VICINITY



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53	Standingstone	Tennessee	25
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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
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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
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105	Patoka	Indiana-Illinois	25
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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
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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
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§ 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.