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GEORGE OTIS SMITH, DIRECTOR

177

GEOLOGIC ATLAS

OF THE

UNITED STATES

BURGETTSTOWN-CARNEGIE FOLIO

PENNSYLVANIA

BY

E. W. SHAW AND M. J. MUNN

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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.

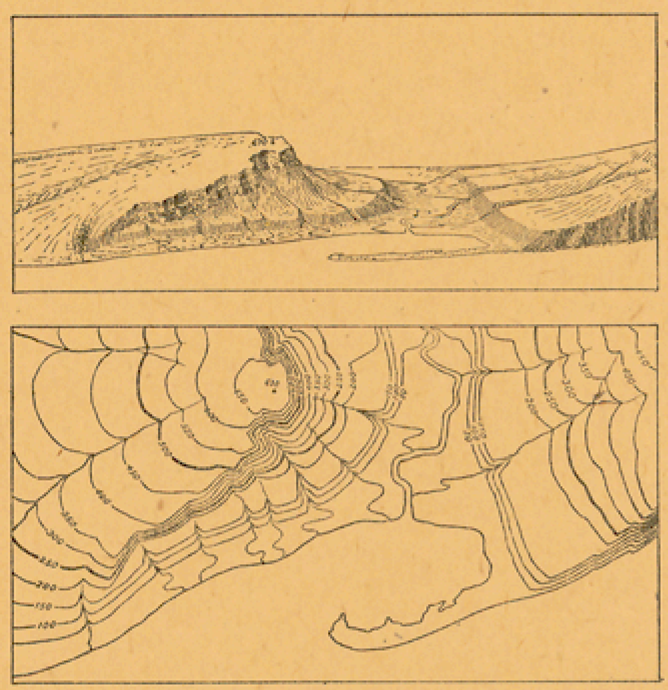


FIGURE 1.—Ideal view and corresponding contour map.

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*,

DESCRIPTION OF THE BURGETTSTOWN AND CARNEGIE QUADRANGLES.

By E. W. Shaw and M. J. Munn.[a]

INTRODUCTION.

LOCATION AND AREA.

The Burgettstown and Carnegie quadrangles lie in the western part of Pennsylvania. All of their area is in Washington and Allegheny counties except a small strip in the extreme northwest, which lies in Beaver County. They extend from

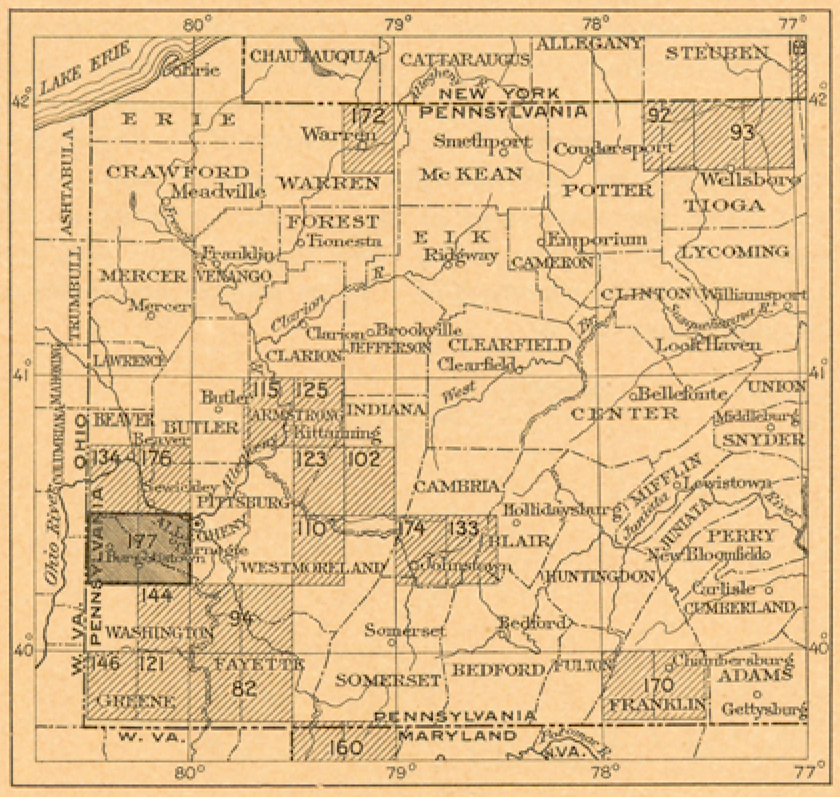


FIGURE 1.—Index map of western Pennsylvania.

Darker ruled area covered by Burgettstown-Carnegie folio (No. 177). Areas covered by other published folios indicated by lighter ruling, as follows: Nos. 82, Masontown-Uniontown; 92, Gaines; 93, Elkland-Tioga; 94, Brownsville-Connellsville; 102, Indiana; 110, Latrobe; 115, Kittanning; 121, Waynesburg; 123, Elders Ridge; 125, Rural Valley; 133, Ebensburg; 134, Beaver; 144, Amity; 146, Rogersville; 160, Accident-Grantsville; 169, Watkins Glen-Catatonk; 170, Mercersburg-Chambersburg; 172, Warren; 174, Johnstown; 176, Sewickley.

latitude 40° 15′ on the south to 40° 30′ on the north and from longitude 80° on the east to 80° 30′ on the west, the line of 80° 15′ being the boundary between them. Thus each covers one-sixteenth of a square degree of the earth's surface, the aggregate area of the two being about 455 square miles. As shown in figure 1, the area is bounded on the north by the Beaver and Sewickley quadrangles, on the east by the Pittsburg, on the south by the Claysville and the Amity, and on the west by the Steubenville. The principal towns of the Burgettstown quadrangle are Burgettstown, Midway, and Westland. Those of the Carnegie quadrangle are Pittsburg (in part), Carnegie, Castle Shannon, Canonsburg, Oakdale, and McDonald. The boundaries of the quadrangles have been exactly located from triangulation and plane-table stations, situated upon some of the most prominent hilltops of the region,[b] which have been connected by triangulation with astronomical stations at the Maryland Heights and Sugarloaf stations of the Coast and Geodetic Survey, computed on the United States standard datum.

APPALACHIAN PROVINCE.

GENERAL STATEMENT.

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

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

Immediately east of the Allegheny Front is a wide belt of deep valleys and high ridges termed the Appalachian Valley. East of this lie the Appalachian Mountains, and east of these is a belt of moderately dissected upland known as the Piedmont Plateau. West of the Allegheny Front and including the area occupied by the Burgettstown and Carnegie quadrangles is a more or less dissected plateau region designated the Appalachian Plateau. Eastward from the Allegheny Front the rocks are progressively more and more folded and metamorphosed; westward from it the rocks are only slightly folded and in the western portion of the province they become nearly flat.

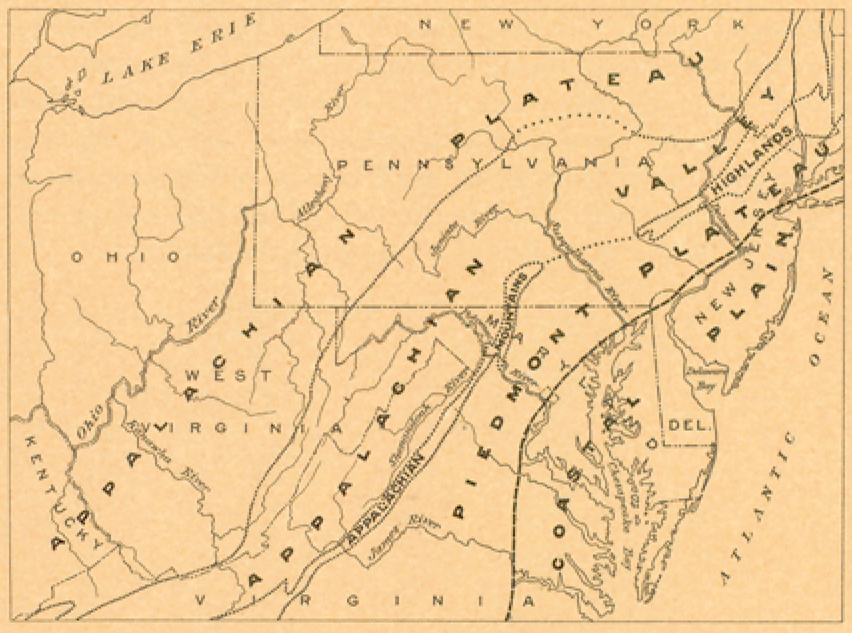


FIGURE 2.—Map of the northern part of the Appalachian province, showing its physiographic divisions and its relation to the Coastal Plain.

APPALACHIAN PLATEAU.

TOPOGRAPHY.

Drainage.—The Appalachian Plateau drains almost entirely into the Mississippi by way of Ohio River, only its northeast end draining into the Great Lakes and into rivers which find their way to the Atlantic Ocean.

The principal southern tributaries of the Ohio, named from west to east, are the Tennessee, Kentucky, Licking, Big Sandy, Great Kanawha, Little Kanawha, and Monongahela. These streams drain the higher part of the plateau and have forms imperfectly like the branches of a tree. Their gradients are in general adjusted, their profiles concave, and their fall considerable. Their courses are, however, somewhat meandering though in a large way not indirect. It is probable that many of the curves are inherited from those which the streams had when the plateau was a plain and the streams, being more sluggish, had winding courses.

The section of the plateau lying north and west of the Ohio is smaller and drains into that river by way of Scioto, Muskingum and Allegheny rivers and numerous smaller streams. These streams have both minor and major irregularities, though none of them are very indirect. They differ somewhat from the southern tributaries because they drain a lower district and because all of them have been called upon to carry glacial waters and glacial débris. The general slope of the surface in eastern and southern Ohio is to the northwest, away from Ohio River, and in preglacial time all the streams north of central Kentucky probably flowed northwestward and discharged their waters through the St. Lawrence system (fig. 7, p. 9); indeed, in preglacial time there was no upper Ohio. The encroachment of one of the earlier of the great ice sheets closed the northern outlet and caused new drainage lines to be established across old divides, so that the present courses of the upper Ohio and its principal tributaries have been forced upon them by glaciation; hence the streams are not so active as those coming into the river from the southeast. The valley through which the upper Ohio now flows is in part new and in part made up of sections of several preglacial valleys. As the Burgettstown and Carnegie quadrangles lie within the area of modified drainage, this feature will be described in some detail in the section on drainage of the quadrangles (p. 2).

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

Relief.—The surface of the Appalachian Plateau is in reality made up of a number of plateaus of different altitudes and extent. These plateaus are the uplifted and now much-dissected remnants of ancient peneplains. One of the oldest and highest seems to extend along the southeast margin of the plateau for nearly its whole length. In the north it is known as the uplifted Schooley peneplain because it is well preserved in the vicinity of Schooley Mountain, N. J., but in Tennessee and Alabama what appears to be the same surface is known as the Cumberland Plateau. It is quite possible, however, that further work will show that this surface is in reality made up of two or more plateaus of different ages.

In Pennsylvania the older plateau is so greatly dissected that its plateau character is not always apparent. Its elevation ranges from 2000 feet in the northern part of the State to about 2600 feet at the southern boundary; farther south it continues to rise as far as central West Virginia, where it reaches its culminating point at 4000 feet. In the north the sandstones of the Pottsville formation have held considerable areas intact, but in the south, where the rocks are soft, the plateau character of the surface has nearly disappeared. Throughout most of the province there are ridges that rise to a greater height than the surface of the plateau.

In general this plateau is separated from the next lower one on the west by an escarpment, but in western Pennsylvania it has been so worn down that both it and the escarpment are nearly imperceptible. In Pennsylvania this lower plateau is called the Harrisburg because of its development in the vicinity of Harrisburg. It has been correlated with the Highland Plateau of Tennessee and the Lexington Plain of Kentucky. In Tennessee the dividing escarpment has a height of 1000 feet, but it is not pronounced in Pennsylvania except along Chestnut Ridge, and there the surface of the upper plateau is so greatly dissected that it can be recognized only with difficulty. In the central part of the State the plateau surfaces approach each other and the escarpment merges into a mass of hills.

The Harrisburg plateau or upland apparently rises from an altitude of 700 or 800 feet in Indiana to 1000 feet in Ohio, 1200 to 1300 feet in southwestern Pennsylvania, and probably 1600 to 2100 feet throughout northern Pennsylvania and southern New York. The Burgettstown and Carnegie quadrangles lie in the region in which the Harrisburg peneplain seems to have been developed, but the irregularity in the altitude of the hilltops makes it doubtful if more than a vestige of the old plateau surface remains. However, its effect on the topography of the quadrangles is evident from the constancy with which the higher hills rise to nearly the same elevation, as shown by the level character of the horizon when viewed from some of the higher hilltops. Although this lower plateau is much dissected in Pennsylvania, it is better preserved than the upper one. In Kentucky and Tennessee it is a nearly featureless plain.

Below the Harrisburg plateau or upland other surfaces of concordant elevation seem to have been developed in later stages of erosion. One of these covers large areas in Tennessee, western Kentucky, and Indiana, but is obscure, if present at all, in western Pennsylvania. Another, though its aggregate area is very small, forms conspicuous terraces high above present streams. The old surface, of which the terraces are a part, was scarcely broad enough to be called even an incipient peneplain, but it marks a time when at least parts of many streams not only ceased to deepen their valleys, but began to make deposits.

STRUCTURE.

The structure of the Appalachian Plateau is simple. The strata lie nearly flat, and their regularity is broken only by small faults and low broad folds.

The most pronounced fold is a low broad arch known as the Cincinnati anticline. The main axis of this fold enters the Appalachian Plateau from the direction of Chicago, but a minor fold from the western end of Lake Erie joins the major axis near Cincinnati. From Cincinnati the anticline passes south to Lexington, Ky., and then southwest to Nashville, Tenn.

Between the anticline and the Allegheny Front lies a broad canoe-shaped basin, which contains the Appalachian coal field. The axis of this trough is along a line extending southwest from Pittsburg across West Virginia, and all the rocks in the

[a] Geologic mapping of Burgettstown quadrangle by W. T. Griswold and E. W. Shaw. Geologic mapping of Carnegie quadrangle by F. B. Peck, G. C. Martin, M. J. Munn, and E. W. Shaw. Descriptive text by E. W. Shaw and M. J. Munn.

[b] Bull. U. S. Geol. Survey No. 181, 1901, pp. 104–122.

basin dip in a general way toward this line. About the northern end of the basin the strata lie in a rudely semicircular line of outcrop and generally dip toward the lowest part of the trough, which is in the southwestern part of the State.

The eastern side of the basin is crumpled into a number of secondary folds which so break up the regular slope of the rocks that at first sight the general westward dip is not apparent. The bottom of each succeeding trough, however, is lower than the one on the east and the tops of the arches decrease correspondingly in altitude toward the central part of the basin, where beds that have an elevation of 2000 feet at the Allegheny Front extend below sea level.

The Burgettstown and Carnegie quadrangles lie in the northern end of the Appalachian coal basin and the general dip of the rocks is therefore to the south. Here, as on the eastern limb of the trough, the general dip is slightly modified by minor folds.

STRATIGRAPHY.

General statement.—The strata of the Burgettstown and Carnegie quadrangles belong to the Carboniferous and Quaternary systems. The Carboniferous system is divided into three series—the Mississippian below, the Pennsylvanian in the middle, and the Permian at the top. The Pennsylvanian series contains most of the coal-bearing rocks, or "Coal Measures," which make up the Appalachian coal field. In Pennsylvania the Mississippian series comprises the Pocono and Mauch Chunk formations; in the Foxburg and Clarion quadrangles, to the north, it has been found desirable to subdivide the Pocono and treat it as a group rather than as a formation, but in the region about Burgettstown and Carnegie the Pocono does not outcrop and will be treated as a formation. The Pennsylvanian series includes the Pottsville, Allegheny, Conemaugh, and Monongahela formations. The Permian rocks all belong to the Dunkard group, which is subdivided into the Washington and Greene formations. Above all come the Pleistocene and Recent deposits.

These formations will be described in order of their age, beginning with the oldest.

Pocono formation.—The Pocono formation derives its name from Pocono Mountain, in eastern Pennsylvania, where it attains a thickness of 1000 feet and rests unconformably upon the red rocks of the Catskill formation, the uppermost part of the Devonian system. Over a large area in Pennsylvania the top of the Pocono is well marked by a calcareous and sandy stratum known as the Loyalhanna ("Siliceous") limestone member; where this is absent the upper limit of the formation is not so well defined.

The thickness of the Pocono on the Allegheny Front is about 1030 feet. Sandstone is its predominant constituent, but it also includes rather thick beds of gray sandy shale, and in some places beds of red shale, which, though generally thin, may locally attain considerable thickness. In western Pennsylvania the formation is under cover, but it has been penetrated by deep wells drilled for oil and gas, and it probably includes all the rocks between the top of the Burgoon sandstone member and the bottom of the Fifty-foot sand of the well drillers. In the southern part of the Appalachian field, in Virginia and West Virginia, the formation contains workable beds of coal of small extent, and in parts of Pennsylvania it includes thin worthless beds. Since it contains these coals and carries fossil plants similar to those of the later coal-bearing formations, the Pocono is placed in the Carboniferous system.

Mauch Chunk formation.—The Mauch Chunk formation overlies the Pocono formation. At Mauch Chunk, the type locality, the formation is 2000 feet thick and is composed largely of red shale. On the Allegheny Front it is made up of about 180 feet of gray and greenish sandstone and red shales, but on Chestnut Ridge red shales predominate again. To the west the formation thins out and over large areas in western Pennsylvania deep-well records indicate that it is missing. In the Burgettstown and Carnegie quadrangles some well records show a few feet of it.

Pottsville formation.—The Pottsville formation is the lowest member of the Pennsylvanian series. Over much of western Pennsylvania where the Mauch Chunk is absent it lies unconformably upon the Pocono formation. At Pottsville, the locality from which it is named, it is mainly a coarse conglomerate 1200 feet thick. In the western part of the State the formation is 125 to 200 feet thick and consists generally of an upper sandstone called the Homewood sandstone member, and a lower sandstone called the Connoquenessing sandstone member. These sandstones are separated by a shale, which contains thin beds of coal and limestone and is known as the Mercer shale member. The coal is of no economic importance in Pennsylvania, but associated with it is a clay which locally develops into a bed of value. The beds between the sandstones are termed Mercer because they are well developed in Mercer County. In some parts of western Pennsylvania there is a shale below the Connoquenessing underlain by a third sandstone. The sandstone is termed the Sharon sandstone member, and a locally developed coal in the shale above is called the Sharon coal, because of its conspicuous exposure at Sharon, Mercer County, Pa.

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

Conemaugh formation.—The Conemaugh formation or, as it was formerly termed, the "Lower Barren Coal Measures" is well developed on Conemaugh River, from which it takes its name. It includes all the rocks from the top of the Upper Freeport coal to the bottom of the Pittsburg coal, ranging in thickness from 400 feet in southeastern Ohio to 700 feet southeast of Pittsburg. The rocks are prevailingly red and olive shales and massive argillaceous sandstones, with the shales greatly predominating. The lower part of the formation is commonly sandy and the middle or upper part is characterized by red and green shales, a number of thin limestones, and from six to ten thin coals. The formation is generally destitute of valuable coal beds, although in some parts of the State it contains workable coals of small extent, locally accompanied by thin limestones. The upper half of the Conemaugh outcrops in the Burgettstown and Carnegie quadrangles.

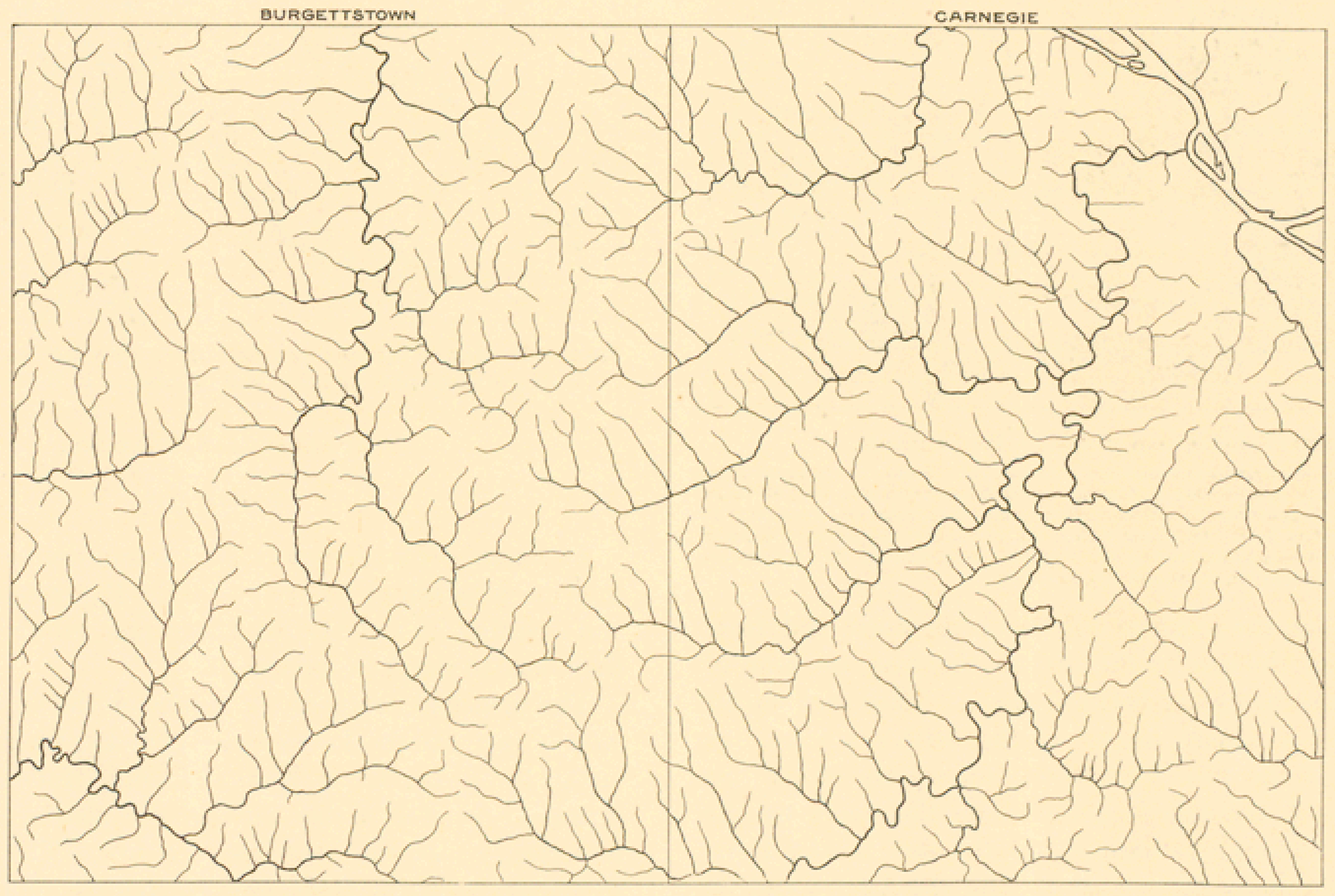


FIGURE 3.—Unsymmetrical drainage of Burgettstown and Carnegie quadrangles, showing long tributaries flowing southeast and short tributaries flowing northwest.

Monongahela formation.—The Monongahela formation extends from the bottom of the Pittsburg coal to the top of the Waynesburg coal. This formation has been designated the "Upper Productive Coal Measures," but the term Monongahela, adopted because of its excellent exposures on Monongahela River, is now used. Its thickness ranges from 300 to 400 feet. It occupies a comparatively small area in southwestern Pennsylvania and portions of West Virginia and Ohio adjacent to Ohio River. The formation contains a much larger proportion of limestone than the underlying Carboniferous formations, more than one-third of its thickness being composed of that rock. It contains several workable coals, of which the most important, not only in this formation but in the Appalachian Region, is the Pittsburg coal. Most of the rocks which outcrop in the Burgettstown and Carnegie quadrangles belong to this formation.

Dunkard group.—The highest rocks in the Carboniferous system comprise the Dunkard group, formerly called "Upper Barren Coal Measures." This group, which is divided into the Greene and Washington formations, has a maximum thickness of over 1100 feet. The name Dunkard is derived from Dunkard Creek in Greene County. As suggested by the old name, it does not contain workable coal beds except locally. The group caps the hills in the southern part of the Burgettstown and Carnegie quadrangles.

Quaternary deposits.—The unconsolidated rocks of the Appalachian province belong to the Pleistocene and Recent series of the Quaternary system. The Pleistocene includes all deposits of the glacial epoch, whether laid down by stream or glacial action. The glacial boundary in Pennsylvania is shown in figure 7 (p. 9). Northwest of this line the glacial till covers the surface almost continuously, but south and east of it the Pleistocene formations are confined to stream valleys. These southern and eastern deposits are of two general classes: one is made up of valley trains or glacial outwash and is found on terraces along valleys which lead away from glaciated territory; the other consists of terrace deposits of local derivation and is found along valleys which were never highways for the transportation of glacial débris. The two classes are found at about the same position in the valley and are believed to have a close genetic relation, which will be discussed later (p. 5).

The Recent series embraces only those deposits which have been laid down since the end of glacial time, including present-day flood plains.

GEOGRAPHY OF THE BURGETTSTOWN AND CARNEGIE QUADRANGLES.

DRAINAGE.

The region about Burgettstown and Carnegie is hilly and very well drained. Swamps and standing water are almost unknown and draintile is seldom used. The master stream is the Ohio, which is formed by the union of the Allegheny and Monongahela in the northeast corner of the Carnegie quadrangle. From this point the Ohio flows northwest, then west, and finally south, passing about 5 or 10 miles from the northern and western boundaries of the Burgettstown quadrangle. The Monongahela flows north through the Pittsburg quadrangle, a short distance east of the area under discussion. On account of this position of the large streams the drainage of the Burgettstown and Carnegie quadrangles is radial to the east, north, and west, being to the east and northeast in the eastern part of the area, to the north in the central part, and to the west in the western part. These features are shown in the sketch map (fig. 3).

The principal tributary streams in the Carnegie quadrangle are Chartiers Creek (with its branches, Campbells Creek, Robinson Run, Millers Run, Brush Run, and McLaughlin Run) and Montour Run, which, with a few smaller streams, flow into the Ohio. In the extreme eastern and southeastern parts of the area are several small stream courses leading to the Monongahela. The northern and central parts of the Burgettstown quadrangle drain north to the Ohio through Raccoon Creek; the western and southwestern parts drain west to the Ohio through Harmon and Cross creeks and several smaller streams; and a small area along the eastern boundary drains east to the Ohio through Chartiers Creek and Montour Run.

The discharge of the Ohio ranges annually from less than 2000 to several hundred thousand cubic feet per second and averages about 30,000. The range in depth is from 2 or 3 feet to about 35 feet.

On the whole the streams have adjusted concave gradients. The Ohio falls nearly $1\frac{1}{2}$ feet per mile and the tributaries have gradients ranging from 20 feet per mile or more near their sources to only 2 or 3 feet per mile near their mouths. Chartiers Creek and some other tributaries of the Ohio seem to have abnormally low rates of fall in the lower parts of their courses, this being probably due to filling in the lower ends of their valleys.

A peculiar feature of the region is the unsymmetrical shape of the drainage basins. This feature is best shown on the sketch map (fig. 3), but it may be seen on the topographic maps and may also be observed in the field. A large number of streams which flow east or west are situated not in the center but far to the south side of their basins. Their southward-flowing small tributaries are consequently much longer than those which flow to the north. As an illustration, Robinson Run is about 4 miles from Millers Run, but the watershed between them is only half a mile from the former (the most northerly) stream and 3½ miles from the latter (the most southerly) one.

RELIEF.

The Burgettstown and Carnegie quadrangles are examples of a maturely dissected region, or one in which the principal streams have eroded their valleys to a fairly uniform grade and the smaller branches have cut the uplands into hundreds of narrow ridges between the streams. The surface of the area is therefore very hilly. The highest points are Warriors Point, Bald Knob, and Quakers Knob, which range in altitude from 1300 to 1430 feet. The lowest elevation is found on Ohio River at about 690 feet above the sea.

The contours of the hills depend to some extent on the rocks of which they are composed. In areas where heavy sandstones predominate the hillsides are steep and rugged, and where sandstone is the cap rock the tops of the hills are broad and flat. But the majority of the outcropping rocks are shaly and hills made up of such rocks have rounded tops and gently sloping sides.

Although the entire area is hilly the extreme difference in altitude is scarcely 750 feet, and the summits of the hills show a general concordance in elevation. These features are not so striking in the Burgettstown and Carnegie quadrangles alone as they are in the western part of the State considered as a whole. Western Pennsylvania is comparatively rough country in detail, but in general it shows a gentle though persistent rise from an average altitude of 1200 feet in the southwestern part of the State to about 2000 feet at the northern boundary. The uniformity in the altitude of the upland surfaces may also be seen by viewing the country from a high elevation. These features are believed to have been produced by the dissection of an ancient peneplain.

Along the valleys of the larger streams are found stream-cut terraces. These are prominent features on Raccoon and Chartiers creeks and on Ohio River. They lie at different elevations above the streams and all of them slope downstream.

EFFECT OF TOPOGRAPHY ON COMMERCIAL AND AGRICULTURAL DEVELOPMENT.

The character and direction of man's activities are always modified by the topography of a region. Broad and deep rivers give opportunity for cheap transportation; rivers of steep gradient furnish water power; stream valleys offer favorable routes for railroads and cut into water-bearing strata, so that springs develop; they also afford easy access to outcropping beds of economic importance.

In the area under discussion Ohio River is the most important artery of commerce. It is navigable throughout the year, though in July and August it is often so shallow that traffic must be carried on by boats of less than 4 feet draft. However, dams are being built at many points with the purpose of preventing the river from falling below 6 feet in depth. Its course also affords an easy route and uniform grade for several railroads which have been built along its banks.

Railroad builders have also taken advantage of the valleys of almost all the larger tributaries. The main line of the Pennsylvania Railroad extends west from Pittsburg up Chartiers Creek, Robinson Run, Raccoon Creek (in part), and Harmon Creek; and a branch follows Chartiers Creek to Washington, Pa. The Wabash is built along Chartiers Creek, Millers Run, and South Fork of Cross Creek. The Charleroi electric line lies in large part along Sawmill Run and Piney Fork, and the West Side Belt Line along Sawmill Run and Lick Run. Besides these, many branch lines and spurs connect coal mines with the main railway lines, and almost every mile of these is built in the bottom of some valley. Wagon roads on the other hand are built both in valleys and on divides, the latter position being the most favored; in few places is there a road along the side of a valley.

The relation of valuable beds to the hills is such that very little shafting is done. The coal is mined by drifting and the clay and lime by stripping.

Farming is also influenced by topography. In these quadrangles the hills are rounded and the general surface not rugged. Very little good bottom land exists, for the flood plains are narrow, but the slopes of the hillsides are gentle and most of the land is under cultivation.

DESCRIPTIVE GEOLOGY.

GENERAL STATEMENT.

All the rocks of the Burgettstown and Carnegie quadrangles, including both those that outcrop and those that are known from well records only, are sedimentary.

The outcropping hard rocks belong exclusively to the Carboniferous system. They include a large part of the Conemaugh, all of the Monongahela and Washington, and a small part of the Greene formation, their total thickness being about 1100 feet. They consist of sandstone with a little conglomerate, shale, limestone, clay, and numerous beds of coal, only one of which, the Pittsburg coal, is of great economic value. The sequence and general character of the rocks are shown in the columnar section (at end of descriptive text).

Below the outcropping rocks are about 1000 feet of strata which have been frequently cut through by the drill and whose characters are known through the well logs. Still lower are several thousand feet which were penetrated in one very deep boring, of which a record is given on the columnar section sheet.

Above the outcropping rocks unconsolidated gravels lie along the larger valleys, extending from the present stream levels up for 300 feet. They were deposited long after Carboniferous time and are Quaternary in age.

The strata will be described from below upward in the order of their deposition.

CARBONIFEROUS SYSTEM.

The known Carboniferous rocks in the area embrace all the strata from the base of the sandstone known to drillers as the Hundred-foot sand up to the highest rocks that outcrop in this region.

MISSISSIPPIAN SERIES.

The Mississippian series is penetrated by the deeper drilled wells. It consists largely of sandstone with interbedded shale, belonging to the Pocono formation, overlain by a shale and limestone probably belonging to the Mauch Chunk. These rocks lie so far beneath the surface in the Burgettstown and Carnegie quadrangles that detailed information concerning them is not abundant, but to the north, east, and west they rise to the surface and have been described in reports on other districts.

PENNSYLVANIAN SERIES.

In the older Survey reports the upper Carboniferous rocks were named the Conglomeratic, Lower Productive, Lower Barren, Upper Productive, and Upper Barren Coal Measures. The same divisions are now given the geographic names Pottsville, Allegheny, Conemaugh, Monongahela, and Dunkard. Only the last three outcrop in the Burgettstown and Carnegie quadrangles.

POTTSVILLE FORMATION.

The lowest Pottsville strata seem not to be present in western Pennsylvania, but a thickness of 100 to 150 feet belonging in the upper part of the formation is present and is made up of three members, the Connoquenessing sandstone, Mercer shale, and Homewood sandstone. The Homewood sandstone member is generally known to the drillers in this region as the Gas sand and the Connoquenessing as the Salt sand. The Mercer shale member contains one or more beds of coal, which are locally workable.

ALLEGHENY FORMATION.

General statement.—The Allegheny formation overlies the Pottsville and is variable, but as a whole it is composed of repeated groups of coal, clay, and limestone, between which occur variable shales and sandstones. It is important because of the coal found in it, no less than nine beds being locally workable, and it is not uncommon for five or six Allegheny coals over 3 feet thick to be found in one locality. Sandstone does not form nearly so large a part of this formation as it does of the one below, and that which is present is sometimes called Salt sand by local oil drillers, though it is found at several different horizons. The formation has an average thickness of about 310 feet and outcrops throughout an extensive area north, east, and west of the Burgettstown and Carnegie quadrangles.

Brookville and Clarion coals.—At or near the base of the formation is the Brookville coal and clay. The coal is generally less than a foot thick, but at the type locality in Jefferson County it is 5 or 6 feet thick and in other districts it is workable. It is overlain by a variable bed of 50 to 60 feet of shale and sandstone with local coal lenses, extending up to the Clarion coal and clay. Like the Brookville the Clarion coal in these quadrangles averages less than a foot thick and in places is absent, but in general it is more valuable than the Brookville coal.

Vanport limestone member.—Between 15 and 35 feet of clay and dark shale, often bearing iron nodules, intervenes between the Clarion coal and the Vanport limestone member, which is 1 to 20 feet in thickness. This limestone is fairly continuous and is a valuable key rock to the stratigraphy. It is generally overlain by a bed of iron ore of irregular thickness.

Kittanning coals.—The Vanport limestone member is overlain by sandstone or sandy shale (the Kittanning sandstone member), which is in turn overlain by the Lower Kittanning coal and clay, both being persistent beds. The coal is generally less than 3 feet thick and the clay 2 to 12 feet. Both are valuable throughout much of their extent, and the coal in particular is worked at hundreds of mines in western Pennsylvania. Overlying the Lower Kittanning coal is 20 to 50 feet of shale upon which the thin and local Middle Kittanning coal rests. Above this last another layer of shale or sandstone 15 to 30 feet thick extends up to the horizon of the Upper Kittanning coal, which is also thin and only locally present.

Freeport coals.—The next higher coal bed is the Lower Freeport, which is separated from the Upper Kittanning by the Freeport sandstone member where present and by about 50 feet of shale where the sandstone is absent. The Lower Freeport coal is comparatively unimportant from an economic standpoint. It is local and is not known to have a thickness exceeding 18 inches anywhere within the quadrangles. It is overlain by 50 or 60 feet of sandstone (Butler sandstone member) and shale, upon which rests the Upper Freeport coal, clay, and limestone member. The Upper Freeport coal, which is the uppermost layer of the Allegheny formation, averages about 2 feet in thickness, but appears to thicken locally to 4 or 5 feet. Its position below the surface ranges from about 50 feet below the bottom of the Ohio River valley to more than a thousand feet below the tops of the hills in the southern part of the quadrangles.

CONEMAUGH FORMATION.

General statement.—The oldest rock outcropping in the Burgettstown and Carnegie quadrangles belongs to the Conemaugh formation, which takes its name from Conemaugh River. It is varied in character and few of its strata are uniform over any considerable area. In the bulk of the formation shale predominates over all other rocks, but sandstone is abundant and some limestone, clay, and coal occurs. Most of the shale is gray or greenish.

The Conemaugh formation extends from the top of the Upper Freeport coal to the base of the Pittsburg coal, an interval of about 550 feet. The lowermost strata are not exposed anywhere in these quadrangles, but the exposures in the river at Pittsburg are probably within 50 feet of the base. The upper part outcrops over the northern half of the area, on the higher hills, which contain the Pittsburg coal and are capped with the Monongahela formation.

Mahoning sandstone member.—The lowermost member of the Conemaugh is the Mahoning sandstone, which in some places lies on the Upper Freeport coal and in other places is separated from it by a few feet of shale. It is coarse and varies from yellowish to brown in color. It is separated into two parts, each 10 to 40 feet thick, by a bed of clay and in some places by beds of coal and limestone also. In the area under discussion the Mahoning member is found only in the bottom of the Ohio River valley.

Mahoning sandstone member and Brush Creek coal.—About 90 to 120 feet above the top of the Upper Freeport coal (the base of the Conemaugh) is found the Brush Creek coal. The interval is occupied by the Mahoning sandstone member and by more or less shale having a yellowish or olive cast. The coal is of little importance and is absent in many places, but its position is marked by a peculiar dark shale and in some sections by a bed of dark-blue limestone.

Buffalo sandstone member and Bakerstown coal.—Above the Brush Creek coal, separated from it by about 75 feet of sandy gray shale and thin sandstone a part of which is known elsewhere as the Buffalo sandstone member, is the Bakerstown coal, so called from Bakerstown, in Allegheny County, where it has been considerably mined. A limestone is found near this coal also. The coal is probably unminable anywhere in the Burgettstown and Carnegie quadrangles.

Saltsburg sandstone member.—The Saltsburg sandstone member is shown by well records to be a fairly persistent sandstone from 50 to 60 feet thick, the top of which ranges from 230 to 275 feet above the base of the Conemaugh formation. It is barely above drainage in the northeastern part of the quadrangles and its area of outcrop is very small. Where exposed it is argillaceous and in places contains considerable bodies of shale. In these quadrangles it is usually filled with fresh water, but farther south it contains important pools of oil and gas.

Ames limestone member.—One of the best horizon markers in the Conemaugh is the Ames ("Crinoidal") limestone, which is named from Ames Township in Athens County, Ohio. It is separated from the Saltsburg sandstone member by 15 to 50 feet of variegated red and green argillaceous shale. The limestone lies at about the middle of the Conemaugh formation and is a valuable key rock, for it is persistent and easily recognized. Marine fossils, especially crinoid stems and brachiopods, are abundant in it, showing that it was laid down in the sea. The fresh rock is greenish or bluish gray, but the weathered outcrop is light gray. The surface is rough because of the protuberance of crinoid stems and other fossils. The thickness varies from nothing to 8 feet; where thick it is separated into two distinct benches, the upper one being the most fossiliferous.

In the Burgettstown quadrangle the Ames limestone member outcrops almost continuously along Harmon Creek, being about 75 feet above the run at the west boundary of the quadrangle and passing beneath the stream nearly a mile west of Hanlin station. It is also exposed at Frankfort Springs on Aunt Clara Fork of Kings Creek, along Raccoon Creek up as far as the mouth of Brush Run, and on Wingfield and Potato Garden runs. In the Carnegie quadrangle the Ames is found in the river bluffs and for a short distance up Chartiers Creek.

Harlem and Berlin coals.—Associated with the Ames limestone are two coal beds, which are persistent but do not reach minable thickness in many places. The lower or Harlem coal is found from an inch or less to 20 feet below the limestone, and ranges up to 2 feet in thickness. The upper or Berlin coal is found about 20 feet above the limestone and is more variable. In a few places, as near Murdocksville, it is nearly 4 feet thick, but its average thickness is about 1 foot.

Interbedded with the limestone and the coals are very irregularly bedded sandstones, gray clays, and shales. These form beds about 40 feet thick which are easily distinguished from the more uniform strata above and below.

Birmingham shale member. — The stratum overlying the Berlin coal and extending up to the Elk Lick coal (or the Elk Lick clay where present) consists of shale, sandy shale, and a little sandstone and is 50 to 60 feet thick. It has been called the Birmingham shale by Stevenson, the type locality being at Birmingham station on Monongahela River, just west of Pittsburg. At this point the shale is fine grained, dark gray, and thinly laminated.

Elk Lick coal.—The Elk Lick coal takes its name from Elk Lick in Somerset County, the name being given to it in 1840 by J. P. Leslie. In some places in the Burgettstown and Carnegie quadrangles a thin coal bed is found underneath the Morgantown sandstone member, and since this occupies a stratigraphic position similar to that of the Elk Lick coal of Somerset County it is here given that name. Where present it is usually underlain by the Elk Lick clay.

Morgantown sandstone member.—Above the Birmingham shale member is the Morgantown sandstone member, named from Morgantown, W. Va., where it is extensively exploited for building purposes. In some places this sandstone is flaggy, but generally it is heavy bedded. It is overlain by reddish clay grading into sandy shale.

Little Clarksburg coal and Clarksburg limestone member.—About 150 feet above the Ames limestone member is a fairly persistent dark shaly limestone, containing ostracods and fish remains, known as the Clarksburg limestone member. Just above the horizon of this bed is a local deposit of coal, which on account of its position is correlated with the Little Clarksburg of West Virginia, though Griswold has given the coal the local name Bavington. Its maximum development is found near Bavington, where it reaches 7 feet in thickness. It is also present near Carnegie station and elsewhere. The area of its occurrence is, however, small and its thickness and quality variable.

Connellsville sandstone member, Lower Pittsburg limestone member, and Little Pittsburg coal. — Overlying the Little Clarksburg coal is a gray shale, a flaggy sandstone named the Connellsville sandstone member, and a layer of limestone, the Lower Pittsburg limestone member. In a few places this bed is overlain by the Little Pittsburg coal. Other beds of limestone are found from immediately below to 20 feet below the base of the Monongahela formation.

Unconformity at top of the Conemaugh formation.—In these quadrangles the Conemaugh was eroded to some extent before the deposition of the Monongahela, for there is an unconformity at the base of the latter (the base of the Pittsburg coal). The exposure at Woodville (see fig. 4) shows this unconformity

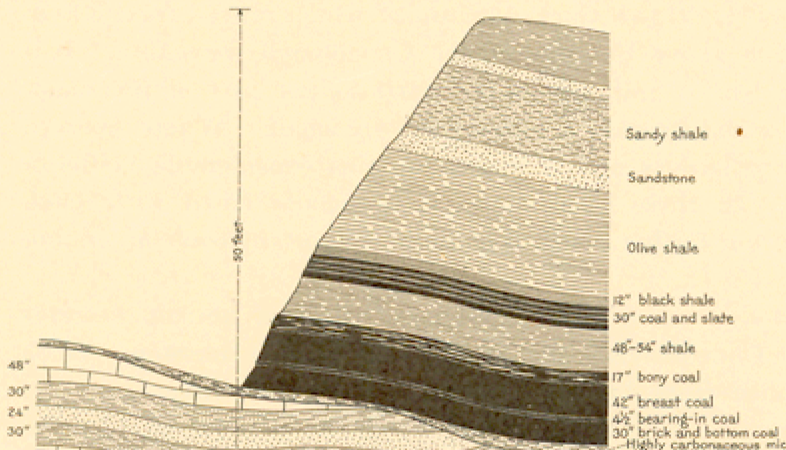


FIGURE 4.—Unconformity at the base of the Pittsburg coal, at Woodville station on Pennsylvania Railroad; looking east.

very clearly. The Pittsburg coal is found lying upon several different layers, showing that the surface upon which it accumulated was irregular. One very peculiar valley-shaped depression found south of Carnegie is shown by the structure contours. It will be described under "Structural geology" (p. 7).

MONONGAHELA FORMATION.

General statement. — The Monongahela formation, named from Monongahela River, extends upward from the base of the Pittsburg coal to the top of the Waynesburg coal, averaging about 280 feet in thickness. It is made up of gray shale, limestone, a small amount of sandstone, and three or more coal beds. Limestone is much more abundant than it is in the formations below.

The area of outcrop of the Monongahela in the quadrangles is more extensive than that of any other formation. It is found in all parts of both, appearing in the northern third as isolated patches on the Conemaugh, forming a continuous belt across the central part, and outcropping in the southern third in small areas where the overlying rocks have been eroded away.

Pittsburg coal.—As previously stated, the Pittsburg coal rests upon an eroded surface. However, between the coal and the eroded surface there is generally from a few inches to a foot or more of black, carbonaceous, sandy shale, which is taken to be the lowermost layer of the Monongahela formation.

The Pittsburg coal is the thickest bed of coal in western Pennsylvania and the most valuable in the bituminous coal field. It varies from 4 to 12 feet in thickness, averaging about 5 feet, and is divided into four and locally into five or more benches by thin partings of clay or shale. Over much of the area a coal known as the Pittsburg Rider or "Rooster seam" occurs a few feet above the main bed.

The upper division of the Pittsburg coal, which is present in most of the eastern three-fourths of the area, consists of alternate bands of shale and coal 6 inches to 2 feet in thickness extending for 7 or 8 feet above the main bed. Near Florence its thickness increases to 25 feet, and the Pittsburg Rider attains a thickness of over 7 feet, of which over a foot is made up of partings. West of this point the Pittsburg Rider is absent, and the Pittsburg coal is overlain with coarse friable sandstone 12 to 30 feet thick (Pittsburg sandstone member).

Redstone coal and associated rocks.—The interval between the Pittsburg coal and the next higher, or Redstone, coal averages about 50 feet and is occupied by light-gray shale and limestone and by the Pittsburg sandstone member. The limestone has a peculiar noncrystalline appearance, resembling flint clay as much as limestone. On weathering it breaks into small angular fragments, and displays more or less conchoidal fracture. At Bulger about half the rock between the Pittsburg and Redstone coals is limestone.

The Redstone coal is not persistent and is not workable in the quadrangles, though elsewhere its thickness locally reaches 4 feet or more.

Sewickley coal.—The Sewickley or Mapleton coal, which is equivalent to the Meigs Creek coal of Ohio, lies 50 to 60 feet above the Redstone and is separated from it by a body of shale which contains some sandstone and interrupted beds of limestone. In the quadrangles the coal ranges from nothing to 20 inches in thickness, but where it is absent its position is marked by 1 to 3 feet of black shale.

Benwood limestone member.—Above the Sewickley coal is a series of strata, aggregating in places 160 feet, which was formerly called the "Great limestone;" later, in accordance with the system of using geographic terms to designate geologic divisions, it was named the Benwood limestone,[a] from the town of Benwood, W. Va., a short distance below Wheeling. The name Benwood was later restricted to the lower limestones of this interval and the name Uniontown, already in the literature, was retained for the upper limestone. It is in the restricted sense that Benwood is here used. Between the Benwood and Uniontown limestone members is a shale interval of 15 to 20 feet.

In the Burgettstown and Carnegie quadrangles the Benwood member consists of several beds of limestone separated by thick layers of shale. To two of these limestone beds, which are valuable oil horizon markers, Griswold has given geographic names.[b] The lower bed, of cream-white limestone, which lies 35 feet above the Sewickley coal, he has called Dinsmore, from exposures at Dinsmore, Washington County, Pa. The upper brown limestone bed he has called Bulger, from typical exposures at Bulger, Washington County. The Dinsmore limestone bed has a thickness of 4 feet and the Bulger limestone bed a thickness of 1 to 2 feet. These two limestone beds are separated by about 20 feet of shale, olive green at the top and reddish or yellowish below.

Uniontown limestone member.—Above the Benwood, separated therefrom by 15 to 20 feet of coarse calcareous shale, lies the Uniontown limestone member, of which four separate beds can generally be identified, though none of them are well developed in these quadrangles. The first consists of about a foot of solid limestone, which shows a yellow surface when weathered and is blue when freshly broken; the weathered surface always shows small protuberances, due to the presence of particles that are more resistant than the surrounding matrix, which give it the appearance of being covered with small pimples and make it easily recognizable. Ten feet above this limestone is another, about a foot thick; it is composed of two slightly different materials, which on weathering produce a characteristic spotted surface which serves to identify the rock wherever found. From 16 to 18 feet above the last-mentioned bed is a blue limestone, which on weathering has a white residue of clay upon its surface but is nevertheless easily distinguishable from other white limestone because the blue generally shows through the surface color. A foot or so above this bed is the top stratum of the Uniontown limestone member. On weathered outcrops this is a soft yellow limestone, but on fresh fracture it shows brownish red. It disintegrates readily and is seldom found in a solid ledge, its outcrop usually being marked by the presence of brown limestone nodules.

The only fossils in the Uniontown limestone are fish remains and minute ostracods.

Uniontown coal and Uniontown sandstone member. — The Uniontown coal is a thin bed lying a short distance above the Uniontown limestone and about 220 feet above the Pittsburg coal. Its blossom may be seen at many places in the southern part of the area, from 40 to 80 feet below the top of the Monongahela, but it is nowhere over 20 inches thick. The strata overlying the Uniontown coal are made up of sandy shale and a dark sandstone named the Uniontown sandstone member.

Waynesburg limestone member and Little Waynesburg coal.—Above the Uniontown and about 40 feet below the Waynesburg coal is found a bed of limestone 4 to 20 feet thick known as the Waynesburg limestone member. Above this there is generally a layer of bituminous shale or thin coal called the Little Waynesburg coal.

Waynesburg coal.—The Waynesburg coal, the upper surface of which forms the top of the Monongahela formation, is found throughout much of the southern part of the area. It varies greatly in quality and thickness and commonly contains several partings of clay and shale.

PERMIAN SERIES.

DUNKARD GROUP.

GENERAL STATEMENT.

In the Appalachian Basin all the consolidated rocks that overlie the Waynesburg coal belong to the Dunkard group, which on paleobotanic evidence is regarded as Permian, though it is possible that its lower beds may belong to the Pennsylvanian.

About the headwaters of Dunkard Creek, near the boundary between Pennsylvania and West Virginia, the Dunkard extends 1100 or 1200 feet below its outcrop on the hilltops, but in the Burgettstown and Carnegie quadrangles its maximum thickness is but little over 300 feet.

The rocks of the Dunkard group are varied, like those of other Carboniferous formations below. Shale predominates, but beds of sandstone and limestone and several thin beds of coal also occur. The group was formerly considered a formation, but in western Pennsylvania the lower part is much more calcareous than the upper and contains several coal beds, whereas the upper part is almost barren. The two parts are distinct and mappable separately and are regarded as separate formations, the lower one being given the name Washington formation and the upper the name Greene formation. The boundary between them is drawn at the top of the Upper Washington limestone member.

WASHINGTON FORMATION.

The Washington formation, named from Washington County, Pa., includes the rocks from the top of the Waynesburg coal at the top of the Monongahela to the top of the Upper Washington limestone member. Its thickness in the Burgettstown and Carnegie quadrangles is about 290 feet. The formation outcrops in the southern part of the area and caps the highest hills in the central part.

Cassville shale member.—In some places the Waynesburg coal is overlain by sandstone, but generally a bed of shale intervenes, and this shale has become famous among paleontologists because of the fossil plants and insects it contains. It is named from Cassville, W. Va., near which place insect and plant remains are especially abundant. Scudder[a] has described five genera and fifty-six species of fossil cockroaches from the Cassville in this locality. In some places the upper part of the Waynesburg coal also contains fossil plants and insects.

Waynesburg sandstone member. — Above the Cassville, or above the Waynesburg coal where the Cassville is absent, lies a persistent, coarse, cross-bedded sandstone 20 to 50 feet thick. In some places a limestone bed about a foot thick lies between the shale and the sandstone. The sandstone is named the Waynesburg sandstone member from the town of Waynesburg, where it is well developed and has conspicuous outcrops. In some regions it is so thick bedded and resistant that it forms almost continuous cliffs, but in the Burgettstown and Carnegie quadrangles it is thinly laminated and in some places resembles shale.

In some parts of Washington County a limestone is found between the Waynesburg sandstone and the Waynesburg "A" coal, and this bed has been called the Mount Morris limestone, but it was not found in the quadrangles under discussion.

[a] Brownsville-Connellsville folio (No. 94), Geol. Atlas U. S., U. S. Geol. Survey, 1903, p. 10.

[b] Geology of oil and gas fields of Steubenville, Burgettstown, and Claysville quadrangles: Bull. U. S. Geol. Survey No. 318, 1907, pp. 69-70.

[a] Bull. U. S. Geol. Survey No. 124, 1895, p. 14.

Waynesburg "A" coal and Colvin limestone.—Above the Waynesburg sandstone member, 40 to 65 feet above the Waynesburg coal, lies the Waynesburg "A" coal. In these quadrangles it is nowhere minable, though in many places it occurs in two layers a few inches thick, separated by a layer of clay. A local bed of hard blue limestone, a foot or more thick, lying above the coal, is called the Colvin limestone, from Colvin Run in Greene County.

Waynesburg "B" coal and associated rocks.—Above the Waynesburg "A" coal an interval of 50 to 80 feet, occupied by shale, shaly sandstone, and local thin beds of limestone, includes in some places a bed of coal known as the Waynesburg "B," lying 30 to 40 feet above the Waynesburg "A." This coal is generally a foot or more thick, but is locally absent and here and there apparently splits into two small beds 10 to 12 feet apart. Above the coal is a sandy shale which grades into heavy-bedded sandstone. This is in turn overlain by a limestone, the bottom layer of which, about 18 inches thick, weathers to a light yellow and shows a mottled-gray color when freshly fractured. This layer resists weathering so well that it is usually found in rather bold outcrop. The top layer of this limestone is from 12 to 15 inches thick and is bluish gray, with a slight reddish tinge.

Little Washington coal.—From 8 to 20 feet above the limestone just noted is the Little Washington coal, which consists of 6 to 12 inches of hard blocky coal. It lies 6 to 15 feet below the Washington coal.

Washington sandstone member and Washington coal.—Above the Little Washington coal is a brown shaly to flaggy sandstone containing many remains of fossil plants. The surface layers of this rock are commonly oxidized to a deep red, but the interior is light gray and micaceous, with numerous black specks of carbonaceous matter. Overlying the sandstone is the Washington coal, the most persistent coal in the Dunkard group. It lies not far from the middle of the Washington formation, about 120 to 150 feet above the Waynesburg coal and just below the Lower Washington limestone member. It ranges from 4 to 8 feet in thickness, but contains several thick partings. The upper part is made up of alternating 6-inch layers of coal and shale or clay, and the lower part is a bench of solid coal 2 to 3 feet thick. The seams of shale and clay in the upper part of the bed seriously affect the economic value of the coal, but in no way detract from its value as a guide to geology. The coal is readily recognized by its lower bench and its upper clay and shale partings. At the top a 4-inch seam of coal lies on 1 to 2 feet of fire clay.

Lower Washington limestone member and associated rocks.—The lowest of the three principal limestones named from the town of Washington is 15 to 25 feet thick and is separated from the Washington coal by 1 to 15 feet of coarse black and brown shale. The bottom layer of 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. In general it is rather argillaceous and weathers to a bright yellow. Overlying it are several thin layers of gray shaly limestone having a total thickness of 2 to 3 feet, succeeded by 10 to 18 inches of yellowish-gray limestone, which shows on fresh fracture a steel-gray color. Overlying this limestone is from 5 to 6 feet of black or blue shale, containing in one or two places a few inches of shaly coal. The next two limestone layers above this shale are of about equal thickness, aggregating 4 to 6 feet. Both are somewhat cherty and have a steel-gray color on fresh fracture but are light gray where they have been exposed to weathering; they disintegrate readily into small roughly cubical blocks.

Above the Lower Washington limestone is a bed of dark to black carbonaceous or cannel-like shale 35 to 60 feet thick, which in some regions is fossiliferous. Near the bottom of this shale a thin bed of shaly coal is exposed in numerous localities. The black shale is capped by 6 to 8 feet of yellowish shale, which merges above into a reddish thin-bedded sandstone generally from 5 to 20 feet thick. This sandstone is separated from the Middle Washington limestone member by 4 to 6 feet of brown shale.

Middle Washington limestone member.—The Middle Washington limestone lies between the Lower Washington limestone and the Upper Washington limestone, the intervals to each being respectively 55 to 80 feet and 100 to 125 feet. It consists of several limestone layers separated from each other by a few inches to 2 or 3 feet of shale and has a total thickness of 10 to 30 feet. The limestone is hard, compact, gray to reddish, commonly brecciated, and contains numerous spots of crystalline calcite. It may be distinguished from other limestones by the yellow and reddish colors of some of its layers, due to their large content of iron; the upper layers are especially ferruginous.

Only four layers in the Middle Washington limestone are easily recognized—at the bottom a 2 to 6 inch deep-pink to earthy-colored ledge, about the middle two yellow ledges, and near the top a 6 to 8 inch cream-white layer, 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 twice as thick as the upper, is very prominently exposed, and may be easily recognized by its tendency to exfoliate when weathered. The other layers of this bed are commonly from 6 inches to 2½ feet thick, bluish to gray in color, and steel gray on fresh fracture.

Jollytown coal.—Lying above the Middle Washington limestone member, and separated from it by about 35 feet of shaly to thick-bedded sandstone, is a layer of shaly coal 2 to 20 inches thick. This coal was given the name Jollytown by J. J. Stevenson.[a] I. C. White[b] later used this term for the coal and the limestone above the Upper Washington limestone member, but Stevenson's use, having the right of priority, is retained here.

Jollytown limestone member.—From 20 to 30 feet above the Jollytown coal is a limestone which is only locally developed. It is hard, gray, in some places brecciated, and weathers to gray or yellowish. The thickness varies from nothing to 5 feet.

Upper Washington limestone member.—The Upper Washington limestone, the uppermost and most conspicuous member of the formation, lies about 145 feet above the Washington coal and 25 to 40 feet above the Jollytown limestone member. It is compact and resistant, but brittle, and in the small area of its occurrence in these quadrangles it seems to be about 17 feet thick. The only hills which reach high enough in the stratigraphic column to preserve it are Quakers Knob near Cross Creek and one or two hills near West Middletown. The bed consists of ten or twelve layers of limestone from 2 inches to 2 feet or more in thickness separated by partings of shale. The color is dark gray on fracture, but the weathered surface is rusty brown. In the central part is a layer of hard, thin-bedded, dark-brown limestone from 8 inches to 2 feet thick. The weathered surface rock has a rough, finely striated, file-like appearance, by which it may be easily recognized. The uppermost strata of limestone are less ferruginous than those below, weathered portions being in some cases quite white; the first surfaces are very dark gray.

GREENE FORMATION.

All the Carboniferous strata found above the Upper Washington limestone member in the Appalachian coal basin are included in the Greene formation. The maximum thickness is found in northern West Virginia, where about 800 feet are preserved. In the Burgettstown and Carnegie quadrangles, however, only the extreme lower part, less than 20 feet thick, is now present, and this part is found only on the highest hills which stand in the deepest structural basins. Only six small areas are known to occur, four of these being near West Middletown, and two near Cross Creek. On these hills the stratum consists of dark shale, with layers of coarse argillaceous sandstone. Elsewhere this dark shale is very fossiliferous, containing bivalve crustaceans, leaf impressions, and abundant fish scales, from which last it has frequently been called the "fish bed."

QUATERNARY SYSTEM.

GENERAL STATEMENT.

Of the long period between the Carboniferous and the Quaternary no sedimentary record is preserved in western Pennsylvania. If any strata were laid down in Triassic, Jurassic, Cretaceous, or Tertiary time they have since been removed or so far destroyed as to be unrecognizable. In the Quaternary period, however, terraces were formed along the sides of the larger valleys, and these bear deposits that may be classified according to age as (1) Kansan (?), including the Carmichaels formation and the early glacial gravel; (2) lower terrace and later glacial gravels, embracing all deposits laid down between early glacial and the beginning of Recent time; (3) Recent or present-day flood-plain deposits.

PLEISTOCENE SERIES.

GENERAL STATEMENT.

The oldest stream deposits are found 200 to 300 feet above the valley bottoms; they were laid down at about the time of the first ice advance, or very early in the Quaternary period. Similar deposits are found throughout much of western Pennsylvania, West Virginia, and adjacent territory, and may be divided into two general classes—first, those which contain glacial material, and second, those composed of pebbles of local origin. The two classes are found in similar topographic positions and are approximately, if not exactly, of the same age, but are of different origin. Gravels of the first class were deposited by streams overloaded with glacial débris, and thus represent ancient glacial valley trains, the principal cause of their deposition being the great increase of load which the streams were called upon to carry. Gravels of the second class were deposited by streams which never carried glacial gravel and whose load probably did not change greatly in size, their deposition being due to change of gradient rather than to change of load. Since it is not absolutely certain that the two classes of deposit were developed at exactly the same time, and since they differ in origin and probably in other features, they have been given different names. The first class is termed early glacial gravel and the second Carmichaels formation, from its excellent development near the town of that name in Greene County, Pa.

EARLY GLACIAL GRAVEL (KANSAN?).

Except a very few erratic bowlders, the early glacial gravel of the Burgettstown-Carnegie region is confined to the valley of the Ohio, in which the gravel terrace has a maximum width of about a mile. The formation is a heterogeneous mixture of well-weathered gravel and sand, varying in kind of rock and in size of pebbles and grains. Some of the pebbles are of granite and other igneous rocks that must have come from Canada. Others are of the peculiar deep-red Medina sandstone, which outcrops in New York but not within the drainage basin of the Allegheny. These pebbles are mingled with a mass of sand, silt, and clay, the proportionate amount of coarse material being larger than in the Carmichaels formation. Much of the gravel is doubtless of local origin. The bulk of the formation is derived from quartz and sandstone, and a very small amount from limestone, all being deeply decayed.

The upper limit of gravel in the vicinity of Pittsburg is nearly 1000 feet above the sea or 300 feet above the river; and the original surface of the formation was probably at about this position. Up the Allegheny this surface rises to an altitude of 1145 feet at Foxburg, about 80 miles north of Pittsburg. Owing to erosion, however, the gravel does not rise uniformly to a definite contour but thins out irregularly.

CARMICHAELS FORMATION.

The Carmichaels formation in the Burgettstown and Carnegie quadrangles is found on high terraces along streams tributary to the Ohio. It consists of sand, clay, and silt, in which are embedded many pebbles of sandstone and a very few of other rocks. None of the material is glacial. The principal areas of the formation are one-half to one mile in greatest dimension and are found along Raccoon and Chartiers creeks. As might be expected, since these streams are not large, the gravel is not well worn and none of it is coarse.

Terrace deposits are found at many different positions along Raccoon and Chartiers creeks, and it is difficult to determine the exact age of each deposit. It seems desirable to apply the term Carmichaels only to those deposits which are of the same age as the early glacial gravel on the Allegheny and Ohio, for the principal development of terraces on all streams lies at about the same topographic position and where the tributaries join the main river the terrace deposits seem to join without any break. Thus in general the upper limit of high-terrace gravels on streams tributary to the Allegheny and Ohio rises upstream from the upper limit of glacial gravel on those rivers; and similarly the base of the principal high-terrace deposits rises upstream from the base of the glacial gravel. But along medium-sized streams, such as Raccoon and Chartiers creeks, the record of events is not clear and it is difficult to determine the rate at which the upper and lower limits of deposits formed in early glacial time rises upstream. The principal high terraces on Chartiers Creek are between 900 and 1000 feet above sea near the mouth of that stream, and as nearly as can be determined they rise between 980 and 1020 feet near South Canonsburg. On Raccoon Creek the highest terrace deposits are found near Burgettstown at 1000 to 1040 feet. Therefore the lower limit of the Carmichaels formation has been drawn as rising from 900 feet at the mouth of the stream to 980 at South Canonsburg and the upper limit as rising from 1000 to 1020. It is assumed that these figures mark the limits of the Carmichaels formation, but it may be that some younger and perhaps some older deposits are included.

In general the coarsest part of the formation is found at the base. Above this the central part, comprising more than half the thickness, is made up of sand and silt, with embedded pebbles many of which are flat and arranged in parallel slanting positions; the pebbles are abundant in certain lenticular layers and are extremely scarce in others. The uppermost layers of the formation are commonly composed of sand and silt. On larger streams pebbles of quartz are common in the Carmichaels, but on the small streams in these quadrangles many exposures of the formation display material which looks much like rain wash and can only with difficulty be recognized as stream deposit. Few pebbles are well rounded and some of them show very little abrasion.

The terraces display a close relation to hard layers of rock, for a large proportion of them have sandstone for a floor, although the immediately adjacent wall of the valley is of soft shale. It seems probable that the development and preservation of the formation has been controlled largely by these hard layers of rock overlain by soft shale.

[a] Second Geol. Survey Pennsylvania, Rept. K, 1876, p. 48.
[b] Bull. U. S. Geol. Survey No. 65, 1891, p. 34.

LOWER TERRACE GRAVEL.

At many places below the Carmichaels formation and above the present flood plains are terraces of varying age, but younger than the Kansan and older than the Recent. They are rock shelves capped with gravel, sand, clays, and silt of local origin and are not so deeply weathered as the Carmichaels. Many of the pebbles are not well rounded, and the thickness of the formation in but few places exceeds 15 feet. Certain of the deposits seem to be too high to be synchronous in development with the latest glacial gravel, but the most extensive, such as those below 800 feet near the mouth of Chartiers Creek, are probably of Wisconsin age. At the time of their development the Ohio was overloaded with glacial débris, as it had been in early glacial time, and it built a new valley train which was in effect a gradually growing dam across the mouths of tributaries. Thus the greater part of the lower terrace gravels may have developed on account of the Wisconsin filling on the Ohio. In the Burgettstown and Carnegie quadrangles the lower terrace gravels do not extend far upstream, but merge into present flood plains in a short distance, though elsewhere on large tributaries they have much greater development. Thus to-day the tributaries are cutting into and carrying away the unconsolidated materials which they were forced, by the filling up of the Ohio, to leave in the lower ends of their valleys.

LATE GLACIAL GRAVEL (WISCONSIN).

Along Allegheny and Ohio rivers a continuous thick deposit of gravel, derived from Canada, New York, and Pennsylvania extends from approximately 100 feet above low water to 50 feet below. Thus the thickness to-day ranges up to 150 feet, and the original thickness was probably as great, perhaps slightly greater. The pebbles and bowlders are well rounded and constitute the most impressive part of the formation. In diameter they range up to a foot, though the majority measure only 1 to 3 inches. Most well records indicate that the lower part is finer than the upper, but according to some records the opposite is true. All the pebbles are embedded in a matrix of sand and clay, and even where the formation is coarsest a considerable part of the interstitial space is occupied by finer materials.

The pebbles are much less deeply weathered than those found on the high terraces and their upper surfaces have not been so deeply modified by stream corrasion. Though the Ohio is a large and powerful river, it has not cut through the deposit to its former position and is still laboring with its glacial overburden. These facts show that the deposit is to be correlated with one of the latest ice advances, and hence it is provisionally regarded as of Wisconsin age. In any case, it marks a time when the river was overloaded with glacial débris and left some of the coarser, less easily transported material in its bed and along its banks and in this way partly filled its valley. The numerous bowlders suggest that the river was larger than now and, indeed, was probably more or less of a glacial torrent.

The largest area of Wisconsin gravel is found in the lower part of the city of Allegheny, and in this connection it is interesting to observe that certain characters and relations of this deposit give it an important economic bearing. Its level surface is easily excavated, and though above the reach of high water is yet near the river, which is important for commerce, water supply, and power. It contains inexhaustible supplies of sand and gravel. It is usually present along both sides of the river and though generally narrow it locally broadens to a mile or more, thus presenting admirable sites for towns, manufacturing plants, and railroads.

RECENT DEPOSITS.

ALLUVIUM AND MADE LAND.

All of the streams of this region are making deposits as well as carving their valleys, but many of their deposits, although extensive in the aggregate, individually occupy areas too small to be mapped. However, mappable Recent alluvium is found along many streams, and in a few places man has added filling material, pushing the water back and making new land surface. These small areas of made land are mapped with the alluvium.

The Recent alluvium extends upward from the bottom of the stream channels to heights varying with the size of the stream. The maximum thickness ranges from less than 10 feet on the smaller runs up to nearly 40 feet on the Ohio. For the most part the deposit has been made at times of high water. It is composed of gravel, sand, and silt, the coarser material being at the base and in the stream channels. The central part is mixed coarse and fine and the top is mostly very fine silt.

The pebbles are of every sort of resistant material existing upstream from their present position. On the Allegheny and Ohio rivers scores of different kinds of rock are represented, but on the tributaries sandstone is by far the predominant constituent, shale having disintegrated and limestone being uncommon in the country rock.

The widest flood plain in the area is about a mile wide and is found at McKees Rocks. Compared to their size the tributaries have much broader flood plains than the Ohio, that of Chartiers Creek at Rosevale being nearly half a mile wide. For agricultural purposes the bottom land is the most valuable in the region. In addition to its favorable chemical composition, it is sandy, loose, and well drained, and yet holds moisture in time of drought longer than more elevated tracts. Its level upper surface also affords most desirable town sites.

STRUCTURAL GEOLOGY.

In western Pennsylvania the layers of rock are nearly horizontal, but have a general slope to the south of a few feet to the mile. This slope is not at all regular, but is interrupted throughout by low domes, basins, anticlines, synclines, and minor irregularities.

REPRESENTATION OF STRUCTURE.

METHODS.

Structure is commonly represented in two ways, by cross sections and by contour lines. Cross sections are best for a region in which the rocks are sharply folded and faulted, but for one where the folds are very low and there is little or no faulting they are of small value, for in them the structural features are almost imperceptible. In such a region contour lines show the structure much more clearly.

STRUCTURE CONTOURS.

Delineation.—For the delineation of structure by means of contours a reference stratum is chosen which has extensive outcrops and is easily recognized. The elevation and dip of its surface are determined at as many points as possible, and points of equal altitude are connected by lines drawn on the map in the same manner as topographic contour lines. In the Burgettstown and Carnegie quadrangles the reference stratum used is the Pittsburg coal, and the contour interval is 10 feet. In some places the elevation of the reference stratum may be observed directly in outcrops, mines, or wells, and in other places it is calculated from observations on some other recognizable stratum, for the layers of rock are approximately parallel, and the average interval between any two may be determined. Thus, if a stratum above the reference layer is found, its elevation may be determined and the elevation of the reference stratum calculated therefrom by subtracting the average distance (or the nearest measured distance) between the two. If the outcrop of a bed below the reference stratum is found the average interval is added, thus giving the approximate elevation at which the reference layer would lie if it were present. An intersection of a surface contour with a structure contour of the same elevation marks a point of outcrop of the reference stratum on the surface of the ground; in this area it marks the outcrop of the Pittsburg coal.

Use of structure contours.—The structure map is of use not only for the study of broad structural problems and for conveying an abstract knowledge of the structure of the region, but it is also of practical value for the aid it gives in locating and recognizing valuable beds and for the data it gives concerning their "lay." Since the strata are approximately parallel and the average spacing of valuable beds is now known it is not a difficult problem to calculate, from the elevation of the reference stratum, the approximate position of any bed at any point by adding or subtracting, according as the bed is above or below the key rock, the average distance between the two as indicated on the map. The map may be used in this way for locating coal, clay, limestone, and oil-bearing and gas-bearing rocks.

The structure map also serves to show the direction and amount of dip of the beds, a knowledge of which is most essential in all mining operations. Its importance is well illustrated by the numerous coal prospects which have been abandoned because the bed was found to dip away from the outcrop, and the expense for draining and hauling up the slope to the opening was considered too great to permit profitable work. In some places deep ditches have been dug to drain mines, whereas if the dip of the bed had been known they would have been opened in more favorable locations. Such errors may be avoided by study of the structure map.

Accuracy of structure contours.—The accuracy of the structure contours depends on three factors—first, the accuracy of the elevations obtained directly; second, the difference between the actual and the assumed interval to the key rock; third, the number and distribution of the elevations.

In the Burgettstown and Carnegie quadrangles the elevations of many outcrops were determined by spirit level. For other exposures of recognizable strata the hand level was used and for still others the barometer, but bench marks are numerous, and consequently the hand level and barometer determinations involved only short horizontal distances and small possibilities of error. Over considerable areas the coal has been worked out and accurate mine surveys are available, by the help of which the structure contours are drawn with great detail. The largest of such districts lies south of Carnegie. Smaller districts in which the structure is known to be mapped with great exactness are found at the various mines scattered over the area.

The second factor is more likely to lead to mistake, because the strata are not absolutely parallel. However, the intervals between the Pittsburg coal and other known strata do not generally vary more than 20 feet. Curiously enough, this variation does not seem to change with the distance of the stratum from the key rock. For example, though the Pittsburg Rider coal varies from 4 to 24 feet above the Pittsburg, yet the variation in the distance to the Washington coal is apparently little greater, though that bed lies nearly 400 feet above the Pittsburg.

Throughout both quadrangles the determined elevations of recognizable strata are numerous and comparatively evenly distributed, so that any inaccuracies arising from this factor are thought to be small. When all the possibilities of error are allowed for, it is assumed that the structure lines are correct within a contour interval, or 10 feet.

STRUCTURE IN THE BURGETTSTOWN AND CARNEGIE QUADRANGLES.

FORMER IDEAS.

In the report of the Second Geological Survey of Pennsylvania on Greene and Washington counties[a] Stevenson describes four principal anticlines and three main synclines, which control the structure in the area of the Burgettstown and Carnegie quadrangles. Their general trend was thought to be north-northeast. Their names and locations are: Pinhook anticline, in the extreme southeast corner of the area; Nineveh syncline, extending northeast from North Strabane Township, Washington County; Washington anticline, passing through Bower Hill, and just west of Washington; Mansfield syncline, about 3 miles northwest of the Washington anticline; Claysville anticline, running from Woods Run, on the Ohio, to Hopewell Township, Washington County; Bulger anticline, passing near the town of that name; and Burgettstown syncline, extending from Frankfort to Burgettstown.

PRESENT KNOWLEDGE.

In the present survey more irregular features than those suggested in the foregoing list were found, and these are described below.

Amity anticline.—Beginning at the southeast corner of the Carnegie quadrangle the first structural feature is the Amity anticline, which in the quadrangle is equivalent to the one called Pinhook in the old State Survey. But since it is a continuation of the Amity anticline, described in the Amity folio (No. 144), which treats the adjoining area on the south, that name is here retained.

Near the place where the fold enters the Carnegie quadrangle it rises to a height somewhat greater than elsewhere. This elevation may be spoken of as the Finleyville dome from its proximity to the town of that name.

McMurry syncline.—The northwest slope of the Amity anticline is uniform and steep, averaging about 80 feet to the mile. This carries the strata down into the McMurry syncline, a low east-west depression, pitching strongly to the west. It originates a mile northwest of Morganza in a low depression of the Nineveh syncline and extends east nearly to the Washington County line, where its course changes to northeast.

Nineveh syncline.—The Nineveh syncline is well known, having been described in the old State reports and in the Waynesburg (No. 121) and Amity (No. 144) folios and in Bulletin 304, on Greene County. It enters the Carnegie quadrangle in North Strabane Township, Washington County, and extends in a direction slightly east of north nearly to the confluence of the Allegheny and Monongahela rivers.

Its course is somewhat serpentine and it has several depressions along its axis or middle line. One a mile northeast of Morganza carries the Pittsburg coal down to less than 660 feet above sea level. On the west side of this depression the coal rises at the rate of about 100 feet per mile to an elevation of 1040 feet near Houston. Other smaller basins are found at Woodville and Rosevale. At the latter place the main syncline is crossed by the Panhandle trench, a remarkably narrow and abrupt trough, which is probably not a structural feature.

Cross Creek syncline.—Originating in the Burgettstown quadrangle in a deep basin near the town from which it takes its name, the Cross Creek syncline extends eastward and joins the Nineveh syncline about 3 miles south of Cuddy post office in the Carnegie quadrangle.

West Middletown syncline.—The most important structural feature of the Burgettstown quadrangle is the West Middletown syncline, which enters at the south edge east of West Middletown and extends in a direction about due north nearly to the north edge of the quadrangle. Here the trend changes to northeast. This syncline has been broken by the east-west folding into three important structural basins in this quadrangle. The northernmost is at Five Points, where the crossing of a shallow syncline in an east-west direction forms a depression of considerable extent. The next is at the crossing of the Cross Creek syncline, the most pronounced east-west break in the quadrangles; its center is about a mile east of Cross Creek village. The third basin is near the south edge of the quadrangle, a little east of West Middletown, on South Fork of Cross Creek.

[a] Rept. K, Second Geol. Survey Pennsylvania, 1876, pp. 29-33.

Panhandle trench.—A remarkable "swamp," or small structural depression, in the form of a narrow trough averaging about 40 feet in depth, is found in the Pittsburg coal between Beadling and Hickman, about 8 miles southwest of Pittsburg. Its deepest part is in the old Panhandle mine, near the town of the same name.

The coal has been extensively worked in this district, and a large amount of data, including detailed mine maps of extensive areas, is available. From these maps it appears that the trough is about one-third of a mile wide and plunges strongly to the west. (See fig. 5.) As shown on the structure map this plunge continues to the bottom of the Rosevale basin, whence the trough rises and extends northwest and north to a point slightly beyond Hickman.

It is unlike any other structural feature in the region. The so-called anticlines and synclines described above are so broad and low and their outlines are so flowing that they scarcely deserve the names of folds; dips of more than 2°, or 184 feet per mile, are uncommon. But this trench is very sharp and seems to bear no relation to the structure of the surrounding country.

Certain characters of the coal bed itself indicate that the depression existed at the time the coal was laid down. Chief among these is a thickening of the coal toward the middle of the swamp, as shown in figure 6, in which each bench of the coal thickens regularly toward the bottom of the swamp. The significance of this lies in the general fact that coal beds are thicker in original depressions than on elevations.

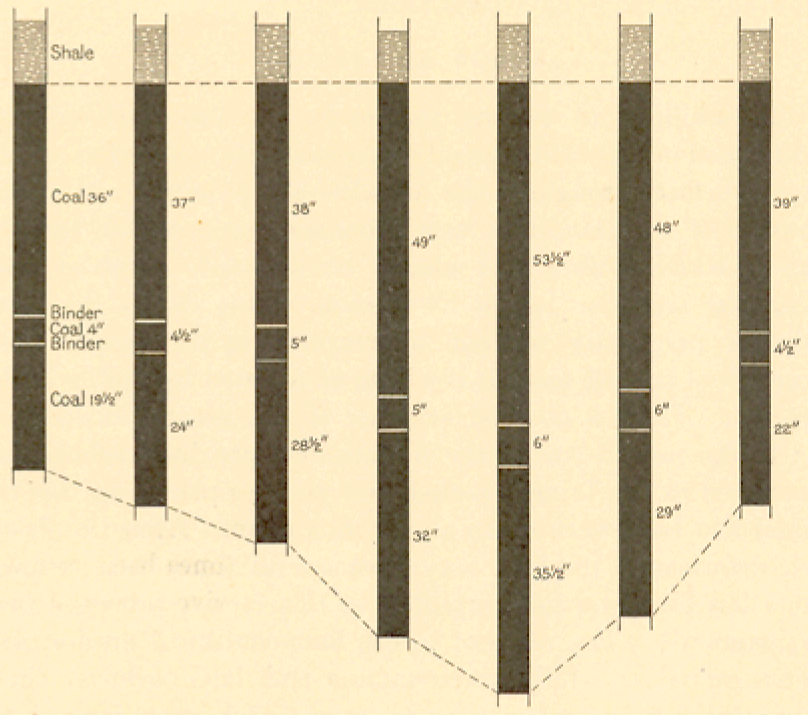


FIGURE 6.—Equidistant sections measured along the third face entry in O I C mine, showing the variation in thickness of the Pittsburg coal across the Panhandle trench from south (at the left) to north (at the right).

Scale: 1 inch=2¼ feet.

The trough is not symmetrical; in some places one side is the steeper and elsewhere the opposite side is the more abrupt. Along the rim of the depression there is generally a hard sandstone roll; in some places, particularly where the side is very steep, there are two or three such rolls. In the northwestern part of the O I C mine the coal is completely cut through by such a roll and is offset about 10 feet, as if faulted. The Pittsburg Rider or "Rooster" coal is said to thicken like the main bed, but reliable data on this point are meager.

If the swamp was an original depression, as its character seems to indicate, it must have been very much like a valley. Probably it has undergone some modification by warping since the deposition of the coal. Thus the basin at Rosevale seems to have been produced by the Nineveh syncline, which crosses at this point. The most remarkable conclusion arising from the assumption that the trough is an original depression is that the coal must have been deposited on a surface sloping in places as much as 1 in 5, or 11° 19′. This is a much steeper slope than coal is ordinarily formed upon.

Minor structural features.—The structure map of the Burgettstown quadrangle brings out prominently the existence of the two systems of folds, which are at right angles to each other with strikes a little east of north for the major system and north of west for the minor system. The east-west compression has formed anticlinal ridges and synclinal troughs, but the north-south compression has formed hardly more than monoclines and terraces, with the strong dips of the monoclines to the south. The combination of these two systems has formed a number of domes, terraces, and basins.

The basins have already been described in connection with the West Middletown syncline. East of the latter rise two important domes. One of them, the Candor dome, is located north of the village of Candor. From it, to the east, south, and west, the rocks descend steeply a vertical distance of over 100 feet; to the northwest they descend gently, the total amount being only about 30 feet. The Westland dome, at Westland, in the southeast corner of the quadrangle, is a small but pronounced feature from which the rocks descend in all directions.

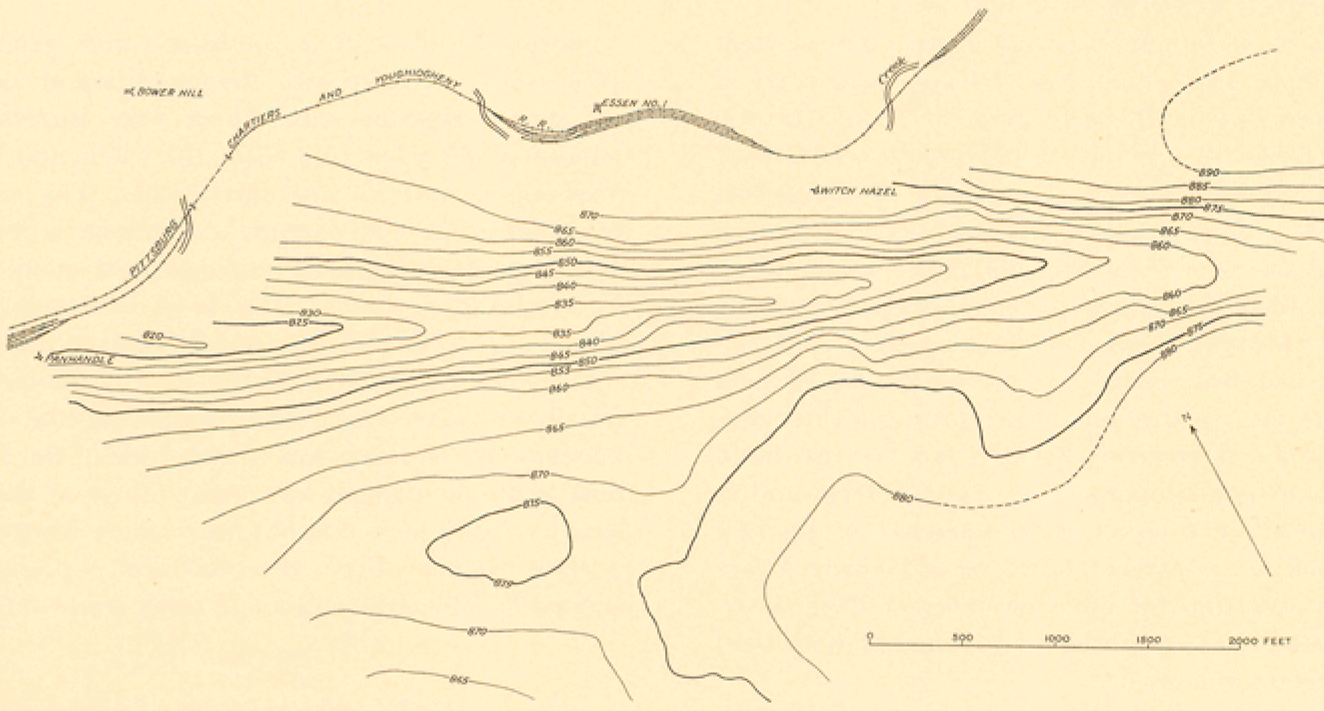


FIGURE 5.—Map of the east end of the Panhandle trench shown by contours on the base of the Pittsburg coal.

On the west side of the Burgettstown quadrangle from Eldersville southward the rocks remain comparatively high as far as Cross Creek. This produces an anticlinal nose, on the end of which is a very low dome, called the Gillespie dome.

The remaining structural features are so irregular and so ill-defined that they can scarcely be separately described. They are the product of (1) irregularities in the surface upon which each layer was deposited; (2) differential settling; and (3) warping at different times since deposit, including the time of the post-Carboniferous deformation. The general southward dip is, in part at least, the result of deformation since the rocks were laid down.

GEOLOGIC HISTORY.

GENERAL STATEMENT.

In the surface features of the earth—hills, valleys, and plains—and in the rock masses which underlie them is recorded the earth's history and that of its various inhabitants. The events thus recorded are the results of the general processes of deformation, erosion, deposition, and intrusion. These processes have modified the lands, waters, and climate and in this way have caused changes in living organisms. Study of the rocks and land surfaces discloses a vast succession of changes in the earth and in its forms of life.

Only two systems of strata, the Carboniferous and Quaternary, and no igneous or metamorphic rocks, are exposed in the Burgettstown and Carnegie quadrangles, so that in them the record is far from complete. But these quadrangles form a part of the Appalachian province, and their history is included in that of the larger area and may be learned by studying its more complete record. A brief outline of the history of the province is therefore given.

PALEOZOIC ERA.

PRE-CARBONIFEROUS TIME.

The early history of the Appalachian province must be read from the variations and extent of the different layers of rock, for practically no record of that time remains in the present topography. From the rocks it appears that in pre-Carboniferous time much of the province lay at the bottom of an ocean and a mediterranean sea which has been termed the Appalachian Gulf. The southeast side of the province, together with the present coastal plain and a considerable area now covered by the Atlantic Ocean, was at that time land.

The coast of the Appalachian Gulf did not occupy the same position during the Cambrian, Ordovician, Silurian, and Devonian periods but migrated more or less. The northwest coast in particular occupied all positions from central Pennsylvania and eastern Kentucky to Chicago, and the west coast at times lay at an unknown distance beyond the present basin of the Mississippi. The southeast coast was more stable, varying within 40 or 50 miles of the present eastern border of the Appalachian Valley. The land to the southeast of this has been called Appalachia.

The streams which drained Appalachia carried much sediment into the Appalachian Gulf. These materials were spread out in layers on the bottom and were later hardened into shale, sandstone, and conglomerate. The streams also carried many substances in solution, among them lime and salt, and these likewise accumulated in the gulf in great volumes. Part of the lime was extracted by the animals which grow calcareous shells and by plants which secrete lime carbonate. The remains of these organisms, together with such lime carbonate as may have been chemically precipitated, formed extensive beds of limestone. Most of the salt is still in solution in the sea.

Not only the sediments themselves but also the remains of living things buried in them yield important data in deciphering the history of the region. Geographic changes caused changes in sedimentation and were the indirect cause of profound changes in the plants and animals that inhabited the region. Thus, studies of fossil plants and animals make inferences possible regarding the geographic and climatic conditions at various times.

DEVONIAN PERIOD.

Before the opening of the Chemung, in fact during early Portage time, sediments now known as the Catskill formation began to accumulate in the vicinity of the Catskills, probably in an inclosed fresh-water basin, while Portage and Chemung strata were being laid down elsewhere. The area of Catskill deposition grew larger and finally the Chemung deposits were buried under its overlapping layers, which now extend over a large area in Pennsylvania and New York. In the type locality the Catskill is several thousand feet thick, but it thins to the west and in western Pennsylvania the deposits which are believed to represent this formation are only a few hundred feet thick. The Catskill formation of eastern New York is thus a shore or brackish-water phase of the Upper Devonian. It contains Chemung fossils and is equivalent to the Portage and Chemung, and possibly also to younger rocks. It is characterized throughout by beds of red shale, by which it is often recognized in oil wells. However, it contains a considerable thickness of sandstone that is not red, suggesting that the sand may have had a different origin from the shale.

It is in the upper or younger part of the pre-Carboniferous sediments and the lower part of the Carboniferous that oil and gas are found in various sandstone beds. Their origin is not known, but one of the most favored theories is that they are derived from organic matter buried in the rocks. In any case the porous sandstones form the reservoirs in which the oil and gas are now found.

At the close of Devonian time, when sediments had accumulated in the Appalachian Gulf to depths of thousands of feet, an earth movement occurred that formed a broad, very low fold extending through Ohio, Kentucky, and Tennessee, now known as the Cincinnati anticline. Along the fold a large area emerged from the sea and a long embayment was formed between the new uplift and the old land to the east. In this embayment the deposits that form the Allegheny coal basin were laid down.

CARBONIFEROUS PERIOD.

GENERAL STATEMENT.

The Carboniferous period is so named because formations of that age in all parts of the world commonly contain coal. Some of the Carboniferous rocks in the Burgettstown and Carnegie quadrangles are unquestionably of marine origin. The Ames limestone member, for example, is crowded with the remains of ocean shells. Other strata, such as the coal, must have been laid down on land, but there are great thicknesses concerning the origin of which little is known beyond the fact that they are sedimentary deposits. They may have been either marine or continental, and some of those that are continental may have been either deposited in lakes or been blown together by winds on the land. However, it is almost certain that there was at no time during the Carboniferous period very deep water or very high land in this region, but that the deposits were laid down very near the level of the sea. There were at different times submergence and flooding by the sea, emergence, development of extensive swamp areas, deposition of stream-transported material, and at least one interval of extensive erosion.

PRE-BURGOON TIME.

At the beginning of the Carboniferous period sand was spread over the bottom of the Appalachian Gulf in western Pennsylvania, the present thickness being 25 to 150 feet. This sand is known to the well drillers as the Hundred-foot sand and is probably equivalent to the Berea sandstone of Ohio. Upon the Hundred-foot sand were deposited layers of mud and sand, the character being different in different places and the material varying from time to time with changes in climate and attitude of the land. Two extensive bodies of sand were brought into the gulf. The lower is now known as the Murrysville or Butler Thirty-foot, and the upper as the

Squaw sand. The shales and sandstones between the Murrysville sand and the Burgoon sandstone member are believed to represent the Cuyahoga formation.

BURGOON EPOCH.

Throughout the epoch following the deposition of the shales and sandstones just referred to the sediments brought into the Appalachian Gulf were predominantly sandy. Mud was brought in at irregular intervals and formed lenticular masses of shale in the sandstone now known as the Burgoon sandstone member or Big Injun sand, though this sandstone includes a large amount of shale.

In the early part of Burgoon time the sand was deposited over a large area to a depth of about 25 feet. The resulting sandstone has been called by the Second Geological Survey of Pennsylvania the Shenango sandstone. In some localities fish bones, teeth, scales, and spines are abundant, so that the rock has been known as the fish bed. Overlying the sandstone is a shale, called Shenango shale by the Second Geological Survey of Pennsylvania, which is said to have an approximately uniform thickness of about 50 feet in Crawford County.

Imprints of land plants are also found in the Burgoon, and the great irregularity in sediments indicates coastal plain conditions. Some of the shale lenses contain marine fossils, but most of them do not, and it may be that western Pennsylvania was land during a considerable part of Burgoon time. Some of the sandstones are very irregularly cross bedded and may be wind deposited.

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

MAUCH CHUNK EPOCH.

By the close of the Pocono many thousands of feet of sediment had been spread over western Pennsylvania. No part of the area was much above the sea, but the surrounding country was higher and streams continued to bring their loads of material into the depression. In the early part of Mauch Chunk time the sea was widespread and the Greenbrier limestone member was formed. Later, deposits of red mud and sand, derived probably from highly oxidized land to the east, were piled up to a thickness ranging from 1000 to more than 2000 feet. This indicates further subsidence, for the character of the deposits is that of material laid down near sea level. Thus, there is no evidence of very deep water at any time, but it appears rather that the land gradually sank as the sand and mud accumulated on it. Few fossils are found in these rocks, and as noted elsewhere, no Mauch Chunk is exposed in the Burgettstown and Carnegie quadrangles. However, a thickness of shale, red rock, and limestone, from 1 to 100 feet thick, which is believed to represent the Greenbrier limestone member, is encountered in well borings.

At a time near the end or soon after the Mauch Chunk epoch important and widespread movements took place in the earth's outer layers and extensive areas throughout the world emerged from the sea. The great coastal flats which had for ages been receiving sediments rose and were subjected to destructive processes. This period of erosion lasted into Pennsylvanian time and is now recorded as a general unconformity between the Mississippian and Pennsylvanian strata.

POTTSVILLE EPOCH.

Early Pottsville erosion was more extensive in the west than in the east, and it is probable that in some parts of western Pennsylvania the Mauch Chunk was removed completely. Over extensive areas no trace of this formation can be found, the Pottsville deposits, predominantly of sand and gravel, resting unconformably on the older rocks.

While this erosion was progressing on the Mauch Chunk in western Pennsylvania the conglomerates of the Pottsville formation were being laid down in the southern Appalachian region, where also the first thick coal beds were being formed. By the time 1500 or 2000 feet of Pottsville rocks had accumulated in the southern Appalachian Basin, the Pennsylvania portion had subsided again and was also receiving conglomerate deposits. The deepest part of the basin was near the western border of the State, where the Sharon conglomerate member and the Sharon coal were deposited before the Connoquenessing sandstone member was laid down in the region that includes the Burgettstown and Carnegie quadrangles. The formation of the Connoquenessing sandstone was followed by another change to quieter conditions, during which the Mercer shale member, consisting of shale, limestone, clay, and coal, was formed. The epoch closed with the active deposition of the Homewood sandstone member.

ALLEGHENY EPOCH.

Conditions in the Allegheny epoch were generally much quieter than those in the Pottsville. Sandstones, though coarse and thick in some places, are not so extensive, and shale is the predominant rock. Coal beds make up a larger part of this formation than of any other in the Appalachian Basin; in some places, as in Clarion County, they comprise no less than one-fourteenth of the whole. The origin of coal has been the subject of much speculation. It seems to be evident, however, that coal is an accumulation of organic débris, most of which is vegetable. Most coals are, in fact, compressed, lithified, and more or less devolatilized peats. The question most debated is that regarding conditions of accumulation. The generally accepted theory, however, is that this took place in marshes, usually of wide extent and near sea level, and that the coal-forming vegetation grew in the areas where the coals now lie.

It appears that in Carboniferous time a great intermittent peat marsh developed in western Pennsylvania and parts of near-by States, persisting in the aggregate for about 100,000 years. It may have lasted for a much longer or a considerably shorter time, but the figure given is probably of the correct order of magnitude. At successive times conditions so changed that mud or sand was washed in over the peat—sometimes in thin films and at other times in deposits ranging up to many feet in thickness. Most of the bodies of sediment were lenticular in form and had little lateral extent, but groups of them so fit together as to make a stratum of fairly uniform thickness. Most of the sediment was probably brought into the coal basin by streams and then resorted and spread out by waves; and as each layer was spread out it began the compression of the peat that has been such an important factor in converting it into coal. There were also times of quiet clear sea or fresh water, during which limestones were formed, and times of both local and general emergence and erosion.

In much of the shale of the Allegheny formation a large number of concretions of iron ore occur. Such concretions are usually formed after the consolidation of the inclosing rock by iron that has slowly gathered from scattered sources and has redeposited in concentric layers upon some object that serves as a core.

CONEMAUGH EPOCH.

Conditions were less favorable for coal forming in the Conemaugh epoch than in the Allegheny, and the strata laid down consisted mainly of more or less sandy mud and interbedded sand. Peat forms to-day in quiet shallow ponds in climates which are neither very dry nor very warm, for in both such climates plant material decays. Presumably in the large marshes of Carboniferous time the water was kept quiet by the growing vegetation. But in the Conemaugh epoch peat-forming conditions seem to have been generally stopped by changes leading to sedimentation, the most usual of which is subsidence; and it is natural to suppose that at that time the water was generally a little too deep for peat-yielding plants. The presence of extensive red shales also points toward conditions under which oxidation and decay took place, as contrasted with the conditions of deoxidation and preservation of organic material indicated by the black and gray shales of the Allegheny. There were peat bogs in Conemaugh time, but they were not so extensive nor so long lived as those in Allegheny time.

The lower part of the Conemaugh contains marine fossils at many different horizons, indicating that the region lay under sea water a considerable part of the time. Limestones record times when the sea water was clear and marine invertebrate life abounded, the remains of many of the organisms being very well preserved. It was formerly supposed that the last sea incursion was about the middle of the Conemaugh, at the time of the deposit of the Ames limestone member, but in the Burgettstown and Carnegie quadrangles marine shells have been found in the uppermost part of the Birmingham shale member, and even above the Elk Lick coal there are Aviculopectens which suggest another return of salt water.

The epoch seems to have closed with the exposure of the region to denudational processes, for there seems to be an erosional unconformity between the Conemaugh and Monongahela strata. (See fig. 4, p. 4.)

MONONGAHELA EPOCH.

Erosion at the close of the Conemaugh did not proceed far, and at the opening of Monongahela time the Appalachian Basin was a nearly level land area which had again reached a poorly drained state. Plants seem to have taken almost universal possession of thousands of square miles and to have held sway for several centuries. Probably the climate was cool and humid, for the whole region became covered with disintegrated but not decayed vegetable material, which would have decomposed had the climate been warm or dry. The resulting coal is known as the Pittsburg and is the most valuable in the Appalachian coal field. Its growth marks the culmination of conditions favorable to coal making.

Throughout the remainder of the Monongahela epoch a succession of events similar to those of the Allegheny and Conemaugh epochs took place. The Redstone, Sewickley, Uniontown, and Waynesburg coals were laid down, all of them thin and of limited extent. Next in geologic importance to the accumulation of the Pittsburg coal was the formation between the Sewickley and Uniontown coals of the Benwood and Uniontown limestone members, a series of limestones which, with the interbedded shales, attained a thickness of 160 feet. Since no distinctly marine fauna has been found in these limestones they have generally been assumed to have been formed in fresh water, possibly by the chemical precipitation of lime salts but more probably from the remains of fresh-water plants which secrete lime. The development of the Waynesburg coal was probably the closing event of Pennsylvanian time in this region, and the succeeding strata were laid down in Permian time.

DUNKARD EPOCH.

During Dunkard time conditions were generally quiet, the epoch being taken up with the deposition of alternating shaly and sandy deposits, with which were interstratified several limestones and a few thin coals, the whole now making up the Washington and Greene formations. The most widespread development of coal-forming conditions is recorded in the Washington coal, which was deposited at about the middle of Washington time. The most extensive limestone was formed at the close of this same division of the Dunkard.

A fossiliferous shale near the base of the Greene formation contains bivalve crustaceans, fish scales, and leaves; but the remainder of the formation records little of the life of the times. Most of the limestones, like many others of the Carboniferous period, contain no shells, but no evidence has yet been adduced to show whether they were chemically precipitated or were secreted by blue-green algæ and other fresh-water plants.

MESOZOIC ERA.

POST-CARBONIFEROUS DEFORMATION.

Dunkard sedimentation was characterized by gentle oscillations in the earth's surface, but at its close movements of a much more profound nature took place. Tremendous stresses, due to shrinkage of the earth's interior, caused the rocks that thitherto had rested in approximately horizontal positions to bend into great folds running approximately parallel to the old shore lines. To the east of the Allegheny Front these folds are very pronounced, the anticlines being steep and high and the synclines narrow and low, but to the west of it the folds are low and irregular. Much faulting also took place, especially in the southern Appalachians; great blocks of the outer part of the earth slipped along each other in various directions, in some places for thousands of feet. The Burgettstown and Carnegie quadrangles, however, were not profoundly affected. Such folds as were produced in them are broad and low and no faults have been found.

UPLIFT AND EROSION.

In addition to folding the rocks the post-Carboniferous deformation probably greatly increased the elevation of the land surface throughout the Appalachian province. With the advent of this condition new processes began to act, and the areas which before had almost continuously received rock material began to lose it by erosion. This erosion has continued practically without interruption to the present time, though at several times it has been accelerated by uplifts of the region. There is no good evidence of any general subsidence.

In the eastern part of the Appalachian province deformation occurred in the Triassic period, and perhaps preceding this the land had been worn down almost to a plain. After the Triassic deformation the land may have several times been reduced to a low level and again uplifted, so that erosive processes were rejuvenated. The cycle of uplift, long-continued erosion that first carved the hills or mountains and later reduced them more or less to a plain, and again uplift, may have been repeated several times, for each planed surface—the record of one cycle—would be to a greater or less extent destroyed by the record of the next. Moreover, all possible stages occur in the process of reduction, and the less complete the cycle the more easily is the record destroyed.

One of the oldest and most perfect of the peneplains of which there is good record seems to pass beneath Cretaceous rocks in New Jersey and Alabama and hence must have been developed before the close of the Cretaceous period. It has been thought by many physiographers that parts of this peneplain are preserved in the tops of Schooley and Kittanning mountains in New Jersey and in many other even-crested mountains and hills in the Appalachian province, but every vestige of it is believed to have been destroyed throughout much of western Pennsylvania. Further careful work is necessary before this correlation can be relied upon; at present it does not seem probable that any part of a Cretaceous peneplain is preserved in the Burgettstown or Carnegie quadrangles.

CENOZOIC ERA.

TERTIARY PERIOD.

PENEPLAINS.

Near the opening of the Tertiary period a crustal movement is thought to have again raised the region. Following this, erosion of the surface proceeded with renewed vigor and continued until a lower but less extensive peneplain was formed.

This new surface has been correlated with the Harrisburg peneplain, which is well preserved about the city of Harrisburg. The highest hills in the Burgettstown and Carnegie quadrangles seem to approximate the present horizon of this elevated plain, but it is doubtful if any of the actual surface remains.

As a whole, the surface correlated with the Harrisburg peneplain now has the shape of a low ellipsoidal dome, the highest part being in McKean and Potter counties, in northern Pennsylvania. From an altitude of 2400 feet in that region the upland surface descends to 1200 feet in southwestern Pennsylvania and to 500 feet in the southeastern part of the State. The altitude of the hills in the Burgettstown and Carnegie quadrangles indicates that the present elevation of the former peneplain is there approximately 1300 feet.

In some parts of western Pennsylvania a substage of erosion has been recognized 100 feet or so below the remnants of the Harrisburg peneplain and has been called the Worthington peneplain. In the Burgettstown and Carnegie quadrangles much territory lies near the 1200-foot level, and it may be that this is to be correlated with the Worthington peneplain. It is, however, possible that the agreement in altitude is merely a coincidence.

PARKER STRATH.

Some time before the close of the Tertiary there was probably a considerable uplift and the streams were rejuvenated, for at the opening of the Quaternary they were flowing in valleys of medium width about 300 feet deep. The rock floor of these old valleys has been called the Parker strath, from Parkers Landing on Allegheny River in the Foxburg quadrangle, Pa. It bears a heavy deposit of Quaternary gravel, and remnants of it now form a terrace which can be traced down the Allegheny to Pittsburg, and thence along the Ohio River valley to Beaver. The Parker strath shows some resemblance to the typical broad but steep-sided old valleys in Scotland to which the term strath is applied, though it is much narrower. The rock floor under the gravels was the valley floor in Tertiary time. In places where this old valley was carved in sandstone it was narrow, but elsewhere it was about a mile wide.

UNSYMMETRICAL VALLEYS.

The cause for the lack of symmetry in the minor east-west drainage basins of the quadrangles (see p. 2) is doubtful. The feature is rather strongly marked over several counties in southwestern Pennsylvania, eastern Ohio, and northern West Virginia; and inspection of a large number of topographic maps of quadrangles in this region shows that the elongated southward-flowing tributaries flow in a general direction of about S. 20° E. This is not due to geologic structure, for the streams flow across anticlines and synclines alike. Neither is it produced by any particular hard stratum, for the feature is developed upon layers which have an aggregate thickness of 2000 feet or more. Under favorable conditions the early melting of snow on south slopes may greatly accelerate erosion on the south side of divides and so lengthen southward-flowing streams, producing asymmetry of drainage lines, but it seems improbable that this process operated in the area under discussion, for the long streams flow east of south, and further, the feature is not developed in adjoining areas where conditions must have been similar.

The only sufficient cause seems to be some form of warping of the surface. An uplift in Tertiary time along a northeast-southwest axis extending across northeastern Ohio and northwestern Pennsylvania, would be adequate, but at present there is no other recognized evidence of such an uplift; the general altitude of northeastern Ohio is not so great as that of the region of unsymmetrical drainage. Two possibilities remain; one is that elevation took place, followed later by subsidence that restored the surface to approximately its original position; the other and more probable is that northeastern Ohio was formerly much lower and the drainage adjusted, and that a warping movement brought the surface up to a height sufficient to cause modification in drainage, though not to one so high as that of the region in which the modification is now best shown.

RELATION OF PRESENT TO FORMER DRAINAGE.

Toward the close of the Tertiary the physical features of western Pennsylvania assumed the general form that they have to-day. Many details, however, particularly those relating to the drainage, were different. Allegheny and Beaver rivers now have their source on the northern slope of a region which would naturally drain to the north. In fact the headwaters of some of the tributaries are only a few miles from Lake Erie and yet they lead directly away from it. Moreover, the valleys of the Beaver and of the Ohio above the Beaver form a nearly straight north and south line and the Ohio below the Beaver flows almost due west. This unusual relation of main and lateral streams was recognized many years ago, and more detailed work along the Beaver Valley revealed the fact that the rock floor of the high terraces slopes northward. In view of these facts, Carll, Leverett, and others concluded that in Tertiary time the Ohio flowed northward into the basin now occupied by Lake Erie, through the Beaver Valley. (See fig. 7.)

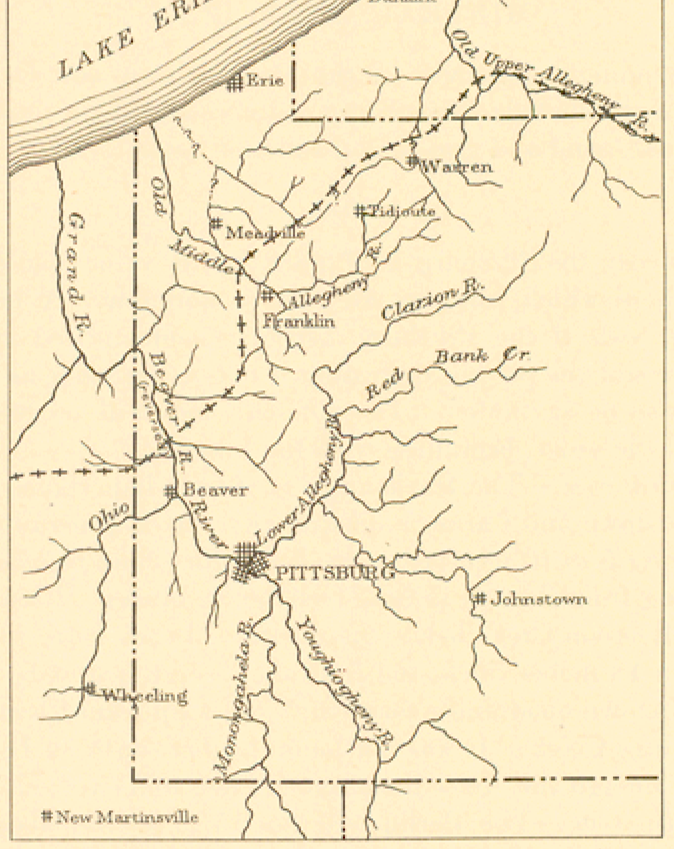


FIGURE 7.—Sketch map showing the probable preglacial drainage of western Pennsylvania. The terminal moraine is shown by broken crossed line.

(After Leverett; with slight changes and addition of terminal moraine.)

For this former stream flowing from the locality of Pittsburg to Lake Erie the name Anabeaver has been suggested, as expressing the idea that it occupied the valley of the Beaver but flowed in the opposite direction. Further investigation developed the fact that another stream nearly coincident with the present course of the Ohio between Wheeling and Beaver flowed northeasterly into the Anabeaver. The divide at the head of this stream was then in the vicinity of New Martinsville.

The evidence seems also conclusive that the present Allegheny River basin includes not only its ancient preglacial basin, but the greater part of two other preglacial basins. The map (fig. 7) shows the probable arrangement of these basins and their streams. What is now the Clarion was formerly Upper Allegheny River, and what are now the middle and lower portions of Allegheny River were parts of two preglacial streams (Middle and Lower Allegheny rivers), that discharged into the basin now occupied by Lake Erie.

At the close of the Tertiary, too, the river valleys were broader at the bottom than at present, though they did not have the extreme breadth that they attained later when they had been silted up. The valleys of the small tributaries were as broad throughout their length as the upper parts of these valleys are now.

QUATERNARY PERIOD.

DRAINAGE CHANGES.

The earliest glacier advanced within 15 or 20 miles of the Burgettstown and Carnegie quadrangles, covering all the northward drainage outlets of western Pennsylvania, probably to a depth of several thousand feet. This thickness was much more than sufficient to pond all surface water until southward outlets were found across existing divides. One of these divides was near Emlenton, just north of the present mouth of the Clarion; another, between the old Upper and Middle Allegheny rivers, was near Warren, Pa., and was uncovered as the glacier melted away but before northward outlets were opened; a third was near New Martinsville, W. Va. The ice covered the northward outlets of all three streams and kept them closed until the Upper Allegheny cut through to the Middle, the Middle to the Lower, and the Lower to a stream occupying the present position of the Ohio below New Martinsville. Numerous small streams were probably involved, and possibly several other similar divides were severed, but these were the main changes.

KANSAN (?) EPOCH.

The high stream terraces before described are the remnants of the floors of ancient valleys that had steep sides but broad flat bottoms. The term "Parker strath" has been applied to the rock floor under the stream deposits, but not to the bottom of the even more strathlike valley represented by the upper surface of the terraces. In Kansan (?) time all the larger valleys of western Pennsylvania displayed more or less strathlike features, for high rock terraces and abandoned channels are very generally present and have long been recognized. The terraces have been described in many of the United States Geological Survey folios on that region and have been discussed in numerous other places. They have been ascribed by different men to submerged and marine erosion, to a large ice dam at Cincinnati or Beaver, to normal stream work, and to local dams of ice. But certain general characters seem incompatible with any of these views and seem rather to indicate that the high terraces developed as a unit through an overloading of the Allegheny in early glacial time and a later redissection.

Since the Burgettstown and Carnegie quadrangles are only a small part of the region in which the high terraces are developed it will be well to describe briefly some of the general characters of the latter.

(1) Both the upper limit of gravel and the rock floor have an even downstream slope without regard to compass direction. This is characteristic of stream deposits. Lacustrine and marine strata are approximately horizontal until deformed, and deformation would not make a slope which would change direction at just the places where the course of the river changes. As a corollary it may be stated that the slope of the terrace deposits is greater on small rivers than on large ones.

(2) The gravels are concordant in elevation. Their base lies about 200 feet above stream channels and their top a little over 300. At each confluence of two streams the deposits along each join without a break.

(3) The terraces are almost continuous and of wide extent. Not one of the larger streams of the Lower Allegheny drainage system is without its high terrace deposit, which is interrupted only where cut through by erosion.

(4) The terrace deposits along the Allegheny and Ohio consist of coarse, nearly homogeneous glacial gravel and hold their thickness downstream; those of all tributary streams are coarse and heterogeneous at the base, but on the whole are finer above, are of local derivation, and decrease in thickness upstream.

In close association with the terraces are numerous abandoned parts of valleys carrying deposits that resemble terraces of the stream along which the abandoned valleys are found. In fact, at both ends of the abandoned valleys the deposits connect without break with those of the high terraces in the present valleys, just as the high-terrace caps of the tributaries connect with those of the master streams at the various confluences. As the thick terrace deposits bear witness, the valleys of the rivers were at one time partly filled, and it is easy to imagine that the waters may have risen to the height of low places in divides between small tributaries. In such cases the currents would be divided and the newly discovered routes occupied. Some of the new routes would be shorter than the old and others would be longer. Later, when redissection began, the streams would in general take the shortest routes and abandon the longer; former channels would not determine their courses.

In short, the view here set forth is as follows: The high terraces developed as a unit through the overloading of the Allegheny in early glacial time and the later redissection of its deposits. The overloaded condition of the Allegheny was probably due to several causes, among which the following may be mentioned as being more or less effective: First, an actual increase in load derived from (*a*) material fed more or less directly by the glaciers; (*b*) débris from the cutting of new gorges across old divides; (*c*) material brought after the ice melted by streams in the glaciated area as they cut new valleys. Second, a decrease in velocity and carrying power, produced by (*a*) the attraction of the ice mass; which within a degree of longitude of the ice front, may have so changed the water level that in a stream flowing away from the ice a gradient of $1\frac{3}{4}$ feet per mile might have been reduced to $1\frac{1}{2}$ or $1\frac{1}{4}$ feet per mile; (*b*) crustal deformation, due to the weight of the ice; (*c*) the crossing of divides or ice barriers, each of which would check the velocity and cause deposits for a short distance upstream. Third, a possible but not probable decrease in volume, arising from a change in climate. It is probable that during Kansan (?) time the river had a larger volume than now because it was carrying the run-off from a much larger territory.

In any case the aggradation of the Allegheny caused every tributary to build up to a gradient over which it was just able to carry its load. The coarseness, slope, and other characters of the deposit indicate that the tributaries built up as rapidly as the overloaded master stream. As the stream beds rose they reached the heights one after another of the lowest places in divides between small tributaries, and at such times and places the currents of the rivers were divided and the cols occupied. When final redissection began the rivers took the channels momentarily most desirable or if there was little difference in desirability used both for a time; thus many parts of valleys were abandoned.

ILLINOIAN (?) EPOCH.

In western Pennsylvania there are no very extensive deposits intermediate in age between the Kansan (?) and the Wisconsin and no certain record of the Illinoian ice sheet. Yet the most southern point reached by any Pleistocene glacier was touched by the Illinoian, when it covered over a thousand square miles south of the 38th parallel in southern Illinois, and its great extent makes it natural to suppose that it reached the drainage basin of the Allegheny. The Allegheny and Ohio may have been overloaded at the time of this great glacier, but apparently their overburdens were not then so large as they had been before nor even so large as they were later at the time of the latest glacial outwash. The intermediate gravels lie at such discordant elevations that it is not clear that they are remnants of a glacial valley train.

Between early and late glacial time Allegheny and Ohio rivers cut not only through their early glacial valley but down nearly 250 feet farther into hard rock. This suggests an uplift of the region, which may have taken place before or during the development of the high terraces, for until the rivers were able to dispose of their overload they were unable to record the uplift by downward cutting. In late Pleistocene time the Allegheny and Ohio were flowing about 40 feet below their present positions, and the lower part of the Monongahela and other tributaries were similarly intrenched, for to-day all these streams flow not in rocky channels but on a bed of gravel 40 to 50 feet thick.

The only record remaining of events between early and late Pleistocene is the great deepening of the valleys, altogether amounting to 350 feet, and the more or less fragmentary bodies of gravel, which are perhaps remnants of former flood plains that owe their preservation to favorable locations. The long sloping promontories on the inner side of river bends are sites where gravel could readily escape erosion, for in such places the river does not swing back and forth across its valley, but on account of its tendency to pursue a straight course presses in one direction only—away from the promontory. In general the early gravels are by erosion let down as a mantle over the valley side, obscuring the characters of the late gravels.

WISCONSIN EPOCH.

The Wisconsin ice sheet again overloaded Ohio River, apparently burying the pre-Wisconsin rock channel under more than 100 feet of gravel. The city of Allegheny is built on the late glacial outwash, which here and elsewhere extends above the 800-foot level. Its base lies 40 to 50 feet below the river surface, or at 640 to 650 feet, and thus there is good indication that the original thickness of the deposit may have been 140 feet or more. All the time during which this valley train was developing, the tributaries were choked or dammed and were therefore forced to drop parts of their loads, partly filling the lower ends of their valleys. Conditions, therefore, were not unlike those in the Kansan (?). The valleys, however, were narrower and deeper and the effect of the later filling was not so widespread. However, all surfaces less than 150 feet above the old channel of the Ohio were at one time or another covered with water, which left its flood-stage mark in the form of deposits of gravel or finer material; and on divides between tributaries all cols which stood below the flood level must have been crossed.

RECENT EPOCH.

The latest work of the Allegheny and Ohio has been to clean the Wisconsin glacial débris from the valleys, a work which is not yet complete. The lower parts of tributaries are likewise carrying out their late glacial surplus as rapidly as conditions on the master stream will allow. The upper sections are now, as they have been for a long time, working away on hard rock, undisturbed by the far-reaching accidents which have befallen their lower courses and master streams.

All the streams, whether on the whole building up or cutting down, have made deposits continuously, and these deposits are found along their banks to-day. Each stream swings back and forth across its valley, depositing on one bank and cutting on the other. Most of the work is executed in time of high water, when the river spreads over its flood plain, dropping the finer material where the land surface is high and the water shallow and the coarser where it is deeper. In consequence of this process an average section of flood-plain deposit is progressively finer from base to top.

The widest flood plain in the area is at McKees Rocks on the Ohio; its width is about a mile. In proportion to their size the tributaries have much broader flood plains than the Ohio, that of Chartiers Creek at Rosevale measuring nearly one-half mile. This relation holds generally in western Pennsylvania. The reason may be found in the fact that much of the time the master streams have been overloaded and hence have been able to do less lateral cutting than the tributaries whose work has not been modified by overload, but only by clogged outlet on the river into which they discharged. That the flood plains generally grow narrower downstream is probably an indication of more rapid downward cutting in that part, due to the interglacial rejuvenation of the region, which caused the river to narrow its gorge. The small streams, being much less powerful erosive agents, have not yet deepened their valleys throughout their length. The broad flat at Rosevale, for example, stands at an elevation just a little above that of the Wisconsin terrace on the Ohio, and its breadth is apparently due to the great length of time throughout which the creek has been held at approximately the same elevation. Below this point the stream has had to build up on account of the Wisconsin valley train and then to cut down again as the Ohio cut down. Higher up, the creek has probably been cutting down uninterruptedly, but in the vicinity of Rosevale it has not cut down nor built up appreciably since the opening of the Wisconsin epoch but has wandered aimlessly back and forth across the valley waiting for the obstruction on the Ohio to be cleared away.

MINERAL RESOURCES.

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

COAL.

One coal, the Pittsburg, is of much greater value than any of the others, which, however, are locally workable. A bulletin on the coals of the Pittsburg district is contemplated and on this account the present discussion is not so extensive as might otherwise be warranted. The different beds will be described in geologic order, beginning with the lowest.

Harlem coal.—The Harlem coal is of little importance in the Burgettstown and Carnegie quadrangles. It is generally present, lying 5 to 10 feet below the Ames limestone member and breaking from the bed in long rectangular blocks. It outcrops along Raccoon Creek below the mouth of Brush Run, where it is about 18 inches thick, and from the western boundary of the Burgettstown quadrangle for about 2 miles up Aunt Clara Fork and Kings Creek. It was not found farther south on Harmon Creek, though the Ames limestone is there well exposed.

Berlin coal.—The Berlin coal lies 15 to 30 feet above the Ames and is locally workable. Near Murdocksville, where it has been opened at several places, part of it is of excellent quality, making satisfactory blacksmith coal. Its thickness there is about 3 feet.

Little Clarksburg coal.—In the northern half of the Burgettstown quadrangle a pockety coal is found in the shale about 100 feet below the Pittsburg coal. Locally this coal reaches 6 or 7 feet in thickness and is of good quality. It is described by Griswold and Munn[a] under the name Bavington coal, on account of its excellent development near the town of Bavington, but as it seems to lie at the stratigraphic position of the Little Clarksburg it is here regarded as equivalent to that bed. Near Bavington the coal abruptly thickens from a knife edge to 5 or 6 feet. At an outcrop near the iron bridge over Raccoon Creek on the valley road from Burgettstown to Bavington it has a thickness of 26 inches. On the east side of Martha McBride's farm at Bavington it is more than 5 feet thick and is opened for mining. In a small area southwest of Frankfort also it is thick enough for commercial mining.

Pittsburg coal.—Owing to its great extent, desirable thickness, and uniform good quality, the Pittsburg coal is of great value throughout a large area in western Pennsylvania, eastern Ohio, and northern West Virginia. It underlies most of the Burgettstown and Carnegie quadrangles and makes the district one of great economic importance. Here the bed maintains a thickness of over 5 feet and is divided by thin partings of clay or shale into four or locally five benches.

In the eastern three-quarters of the area 8 to 20 feet of alternating beds of shale and coal commonly occur above the main bed. One of the upper beds of coal commonly attains a thickness of 3 feet or more and is known as the Pittsburg Rider or "Rooster seam." It is of good quality and in many mines is taken down and shipped. It has also been opened separately at several localities. In the vicinity of Florence the Pittsburg Rider coal rises to 24 feet above the main bed and attains a total thickness of 7 feet, but is of very poor quality. Typical sections of the Pittsburg coal and associated beds are shown in figures 8 and 9.

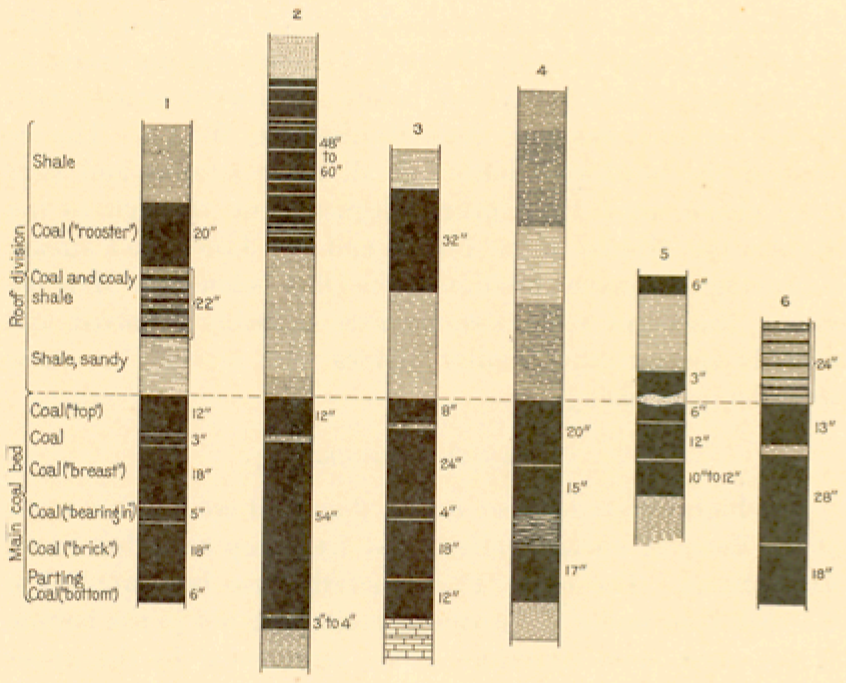


FIGURE 8.—Sections of Pittsburg coal in Burgettstown quadrangle.

Scale: 1 inch=5 feet.

1. W. K. Hays country bank, 2½ miles northeast of Bavington.
2. Francis mine, Pittsburg-Buffalo Company.
3. Armide mine, Raccoon.
4. Oscar Osborne country bank, 2 miles northeast of Burgettstown.
5. Plantz country bank, Florence.
6. O. C. Campbell country bank, 1½ miles northeast of Bavington.

[a] Griswold, W. T., and Munn, M. J., Bull. U. S. Geol. Survey No. 318, 1907, p. 120.

Along the southern margin of the area the Pittsburg coal appears above drainage about 1000 feet above sea level along Piney, Chartiers, and Cross creeks and for short distances up the tributaries of these streams. To the north, extending across both quadrangles, is a belt several miles wide, in which the surface is somewhat high and the overlying strata low, and the coal does not outcrop; in certain places it lies buried under

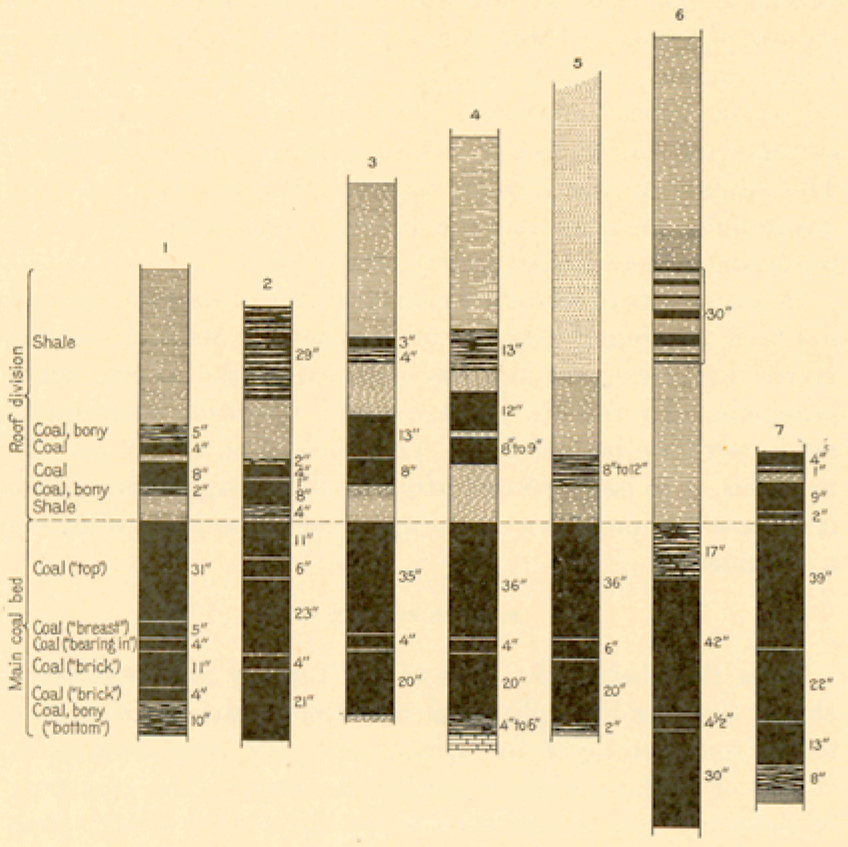


FIGURE 9.—Sections of Pittsburg coal in Carnegie quadrangle.

Scale: 1 inch=5 feet.

1. Ridgway mine, Bishop.
2. Champion mine, Noblestown.
3. Willow Grove mine, south of Sturgeon.
4. Creedmore mine, Cecil.
5. Exposure near Canonsburg.
6. Exposure near Woodville.
7. Briar Hill mine, south of McDonald.

600 feet of Monongahela, Washington, and Greene strata. It appears again in a belt extending east and west across the central portion of the area, and here it has been extensively mined, especially south of the Pennsylvania Railway. It outcrops along practically all the valley sides of this central belt. To the north the general elevation of the coal continues to rise and the area underlain by it grows less. Along the northern boundary it lies about 1200 feet above sea and is found only in the higher hills.

In the main bed of the Pittsburg coal the miners distinguish an upper and a lower portion, separated by what is known as the "bearing-in band," which is a bench about 4 inches thick, with a parting above and below. It thus separates the upper or breast coal from the lower or brick and bottom coal. The total thickness of the bed varies from 4 to 11 feet and is greatest in the "swamps." These swamps are apparently original depressions in the surface, in which the coal was deposited. One of the most remarkable is the Panhandle trench, which occurs along Painters Run. (See p. 7.)

In analyses of Pittsburg coal[a] the samples as received show about 5 per cent of moisture, 35 per cent of volatile matter, 50 per cent of fixed carbon, 10 per cent of ash, and 3 per cent of sulphur.

Redstone coal.—In a portion of the Burgettstown quadrangle the Redstone coal, a few inches in thickness, lies 60 to 70 feet above the base of the Pittsburg coal. It is underlain by an easily disintegrating limestone. In parts of Fayette and Somerset counties this coal attains a thickness of 3 to 5 feet. Recently it has been correlated with the Pomeroy bed of Ohio.

Sewickley coal.—The Sewickley or Mapleton coal, which is equivalent to the Meigs coal of Ohio, is only locally present, being generally represented by a foot or two of black shale. Where present it ranges in thickness from a knife edge to about 20 inches and appears to be of good quality.

Uniontown coal.—The Uniontown coal is a fairly persistent bed lying a few feet above the Uniontown limestone member. It is, however, doubtfully minable anywhere in the area. Locally, as at 6 miles southwest of Burgettstown, it attains a thickness of 3 or 4 feet, but in all such places it has numerous partings of clay. Commonly the coal is represented by several inches of impure coal and black shale. Its outcrop is in many places concealed by the heavy sandy shale above, which has a tendency to wash down and cover the coal.

Waynesburg coal.—The Waynesburg coal outcrops over the southern half of the area and ranges in thickness from 6 inches to 3 feet, in general being thicker to the south. Its quality seems to vary from place to place, but is generally poor, owing to the presence of many small partings of clay.

Waynesburg "A" coal.—The thin coal which is known as the Waynesburg "A" is only a few inches thick, but is persistent. In the southwestern part of the quadrangles it is separated into two layers, each 1 to 6 inches thick, by a parting of bluish clay 1 to 3 inches thick.

Waynesburg "B" coal.—The Waynesburg "B" coal is also persistent and is generally about a foot thick. Locally it is

[a] Prof. Paper U. S. Geol. Survey No. 48, pt. 1, 1906, pp. 244-245.

absent and here and there it is separated into two thin beds 10 to 12 feet apart.

Little Washington coal.—The Little Washington coal is found near the tops of the hills along the southern border of the quadrangles and seems to be uninterrupted. It is a hard, blocky coal, 6 to 12 inches thick, free from shale partings and apparently of good quality. In outcrop it makes little smut and is easily overlooked.

Washington coal.—Next to the Pittsburg the Washington coal is the most prominently outcropping and most readily recognized bed of the area, but it is found only in the southern part. Its general thickness is from 7 to 8 feet, made up of alternating 6-inch layers of coal and shale in the upper part and of a 2½ to 3 feet bench of solid coal in the lower part. The seams of shale in the upper part seriously affect the economic value of the coal, but in the future as coal resources are depleted it will probably become minable.

PETROLEUM AND NATURAL GAS.

DISTRIBUTION.

Petroleum and natural gas are important mineral resources in the Burgettstown and Carnegie quadrangles and have been discussed in special bulletins.[a] In addition to a number of small pools, these two quadrangles embrace some of the largest oil and gas fields of southwestern Pennsylvania. Of the 227 square miles in the Burgettstown quadrangle, about 42 square miles have been found to contain either oil or gas in paying quantities. Of this productive territory, about 20 square miles is occupied by oil pools, the remaining 22 square miles having produced gas only. In addition to this, gas has also been found in paying quantities in one or more beds in a considerable portion of the territory occupied by the oil pools. The Carnegie quadrangle of 227 square miles has about 64 square miles of proved productive territory, 44 square miles of which is occupied by oil pools and 20 square miles by gas pools.

A large percentage of this oil and gas has been found to occur in one or more sandstones of either the Pocono or the Catskill (?) formations. Named in ascending order, these beds are the Fifth, Fourth, Third or Gordon, Third Stray or Gordon Stray, and Nineveh Thirty-foot sands of the Catskill (?) formation and the Hundred-foot sand of the Pocono formation. These sandstones are a part of those collectively known to producers as the Venango oil sands, the name being derived from Venango County, Pa., where some of them contained the first large oil pools discovered in America. These sandstones with their inclosing beds of shale have a vertical range of about 500 feet and are reached by wells drilled to depths of about 1200 to 2800 feet. Small quantities of oil and gas have also been found in several other sandstones, among which are the Snee or Blue Monday and the Bowlder sands of the Catskill (?) formation, the Murrysville or Butler gas sand and the Big Injun sand of the Pocono formation, and the Salt and Gas sands of the Pottsville formation. The general character of all these beds and their stratigraphic position has already been discussed. (See pp. 3, 7, and 8.) As a rule the oil sands are of medium grain and porosity, but each of them includes lenses of coarser sandstone, often conglomeratic, which are generally very much softer and more porous than the surrounding sandstone. These porous lenses are from a few square feet to several square miles in extent and usually range in thickness from a foot or less to 15 feet or more. They constitute the "pays" or "pay streaks" in which the oil and gas are usually found. Infrequently, however, the softer and more porous sandstones at certain spots are found to contain oil and gas throughout their entire thickness, no special pay streak being noticed. Each pool of oil or gas appears to be limited by the extent of the particular area of porous rock in which it is found. In few, if any, places have the pools been confined to only a portion of the porous part of the sand, except where the other portion is occupied by salt water.

PRODUCTION.

The amount of oil produced from the two quadrangles can not be closely estimated. It is known that the McDonald field alone, which covers about 28 square miles and which contained the most prolific wells in the region, produced about 42,135,000 barrels of oil between March 1, 1890, and July 1, 1909. The amount of gas already taken from the two quadrangles can not be estimated even approximately. It is known, however, that many wells had an initial production of 5,000,000 to 30,000,000 cubic feet per day. Many of these have been producing constantly for 10 to 20 years and still furnish from 50,000 to 500,000 or more cubic feet per day.

Most of the pools were discovered between 1886 and 1904, and nearly all of them are fully exploited. The production of each pool reached its maximum at or before the time it was fully developed, since which time it has gradually diminished. The older pools are now approaching exhaustion, and many wells in them have been abandoned. Single wells that once produced from 100 to as much as 17,500 barrels of oil per day now average from 1 to 20 barrels. Outside the developed pools so many test wells have been put down that it seems probable that no large pools of either oil or gas remain undiscovered, though many small pools of sufficient size to be very profitable may yet remain, and small areas here and there around the margins of known pools doubtless still contain oil in paying quantities.

OIL AND GAS FIELDS.

In the Burgettstown quadrangle, the oil-producing areas are separated into four distinct fields—the Florence-Five Points field in the north-central part, the Burgettstown-Cross Creek field in the central part, and the McDonald and Imperial fields along the eastern border. The first two lie wholly within the Burgettstown quadrangle, but the larger part of the others lies in the Carnegie quadrangle to the east. The Eldersville, Hickory, and Burgettstown-Candor gas fields include most of the gas-producing areas of the quadrangles.

Florence-Five Points field.—The Florence-Five Points field comprises the Florence-Five Points and Murdocksville pools, these names having first been used to designate local areas of development which subsequent drilling proved to be continuous. The oil-producing territory is about 7 miles long and 2½ miles in maximum width. The oil is found in the Hundred-foot sand, which is here very thin, ranging from 8 to probably 30 feet in thickness, with a pay streak of coarse sand and small pebbles ranging from 1 to probably 20 feet. The normal thickness of the Hundred-foot sand farther to the south and southeast in the Claysville and Carnegie quadrangles is from 50 to 120 feet, with a shale "break" of 5 to 50 feet, which divides the bed into the Gantz and Fifty-foot sands. From the nature of the available well records in areas where the Hundred-foot is thinnest, it is not possible to determine definitely if both sections of the sandstone are represented. The productiveness of the Hundred-foot does not increase with its thickness from point to point, as might be supposed.

This field has been producing oil for more than 20 years, and possibly, with the exception of a few small extensions, it is fully developed. The latest development was in 1908, when a number of oil wells were secured in the southwestern part, just east and south of Florence, in territory formerly considered by oil men to be barren. Like extensions in other parts of the field may yet be found.

This field has long been down to what is called a settled production. Wells that produced from 100 to 500 barrels per day when first drilled now furnish from one-half to 5 or 10 barrels. These are slowly decreasing in productiveness from year to year and many wells have already been abandoned.

Burgettstown-Cross Creek field.—The central field consists of the Burgettstown and Cross Creek pools, which jointly cover a roughly triangular area measuring about 2½ to 3½ miles on a side, which extends southward from Burgettstown to Cross Creek village and eastward almost to the village of Cherry Valley. Not all of this area has been found productive. The Hundred-foot and Nineveh Thirty-foot sands, which furnish the oil, are made up in places entirely of hard, fine-grained sandstone with no pay streaks. None of the wells of this field were very large producers, the maximum daily production rarely, if ever, exceeding 100 barrels. The first wells were drilled near the northeast end of the field, from which the development extended southwest and west; in the latter direction a small amount of drilling was being done as late as May, 1909.

It is possible that other extensions of considerable value will be made in this field, especially southeast of Cross Creek.

Eldersville gas pool.—An irregular-shaped area about 4 miles long and one-half to 1½ miles wide, in the eastern part of Jefferson Township and extending southward into Cross Creek Township, has produced considerable quantities of gas from the Hundred-foot sand. Structurally, this pool is from 50 to 150 feet higher than the Cross Creek oil pool to the east. Its highest structural point is at about the same elevation as the lowest part of the Florence-Five Points oil field and is about 150 feet below the highest point in that field. In it the Hundred-foot sand is reported to be from 9 to 11 feet thick and to occur from 1780 feet below the Pittsburg coal in the northern part to 1846 feet below in the southern part. Near the southeast corner of the Carnegie quadrangle the Hundred-foot sand, together with the inclosed shale "break," is about 120 feet thick. If this rate of thinning continues the sand disappears a few miles northwest of the Eldersville field.

Hickory gas field.—A large gas-producing area in the southeastern part of the Burgettstown quadrangle, known as the Hickory gas field, has furnished enormous quantities of gas from the Hundred-foot, Gordon Stray, Gordon, Fourth, and Fifth sands. Attention was first directed to this field in March, 1882, when a well on the McGuigan farm, 2½ miles southwest of Hickory, was drilled to the Gordon sand and began producing at a rate variously estimated at 20,000,000 to 40,000,000 cubic feet per day. This well "blew wild" for more than a year before an attempt was made to utilize the gas. Finally, a 6-inch main was laid to Pittsburg and the gas used for manufacturing purposes. Since that time the field has been slowly extended eastward and southward until it now covers a large area in the southeastern part of the Burgettstown quadrangle and adjoining area in the Carnegie and Claysville quadrangles. The field is confined largely to the crest and sides of the high structural dome southeast of Hickory and the broad flat top of the Claysville anticline extending southward from it.

Burgettstown-Candor gas field.—A gas-producing area from 1 to 3 miles wide extends from Burgettstown northeastward to Frye, a distance of about 7 miles. Gas in this field comes principally from the Hundred-foot sand, but a number of wells furnish gas from the sandstones of the Pottsville formation. The Hundred-foot sand is thin, ranging from 10 to probably 30 feet, the production appearing to be confined to the lower or Fifty-foot portion. Little data are available as to the age and capacity of the wells.

McDonald oil field.—Both in area covered and in productiveness the McDonald field may be classed as one of the greatest of southwestern Pennsylvania. It is about 12 miles long and 1 to 3 miles wide, extending from a point 3 miles southeast of McDonald in Mount Pleasant Township northeastward across Cecil, North Fayette, and South Fayette townships to the center of Robinson Township. Some drilling was done in this field as early as 1890, but active development work was not begun until the spring of 1891, when several good wells were finished in McDonald. These wells were first sunk to the Gordon sand, from which some of them flowed oil at the rate of 100 barrels per hour. Later these wells were deepened to the Fifth sand and the flow greatly increased. The oil excitement which followed was intense. Hundreds of wells were completed within a year and the production increased from a few barrels per day in March, 1891, to a maximum of about 83,000 per day in November of the same year. Test wells in various portions of this great field became centers of development and received local names. These pools were blended into one great field by subsequent drilling, but still retain their individual pool names. In the area south of McDonald, the Gordon appears to have been the greatest producer, though the Fifth and Fourth sands furnished enormous quantities of oil, and the Hundred-foot sand some oil and considerable gas. Northeast of McDonald the Fifth sand furnished the greatest amount of oil. In some wells the daily production from this sand is said to have been as much as 10,000 barrels and the combined flow from the Gordon and Fifth sand as much as 730 barrels an hour.

In this portion of the field the Fourth sand is very irregular in thickness and distribution, and, though productive in a number of places, is of relatively little importance as an oil sand.

The oil-bearing area of the Fifth sand has a length of about 11 miles and a maximum width of about 3 miles. As a single accumulation of oil, this pool in the Fifth sand is classed among the greatest of the Appalachian region. The thickness of the Fifth sand ranges from 6 feet or less to about 40 feet and averages 20 feet; the coarse sand and pebbly pay streak in it, from which the oil comes, ranges from 1 foot to 25 feet and averages about 6 feet. The pay streak in the better wells appears to be hardly more than a bed of small white and reddish quartz pebbles, very poorly cemented together. The sandstone inclosing this pay streak is white or gray, hard, and fine grained. At the borders of the pool the pebbly pay streak disappears and a short distance to the northwest the entire sand changes to sandy shales, which farther in that direction appear as isolated lenses of sand, in places oil or gas bearing. Owing to the absence of the porous pay streak, many small patches of this sand are barren within the McDonald field, but most such are only a few acres in extent.

The Gordon sand oil pool in this field, though covering practically the same territory as that of the Fifth sand, does not appear to extend as far to the northeast from McDonald, for the McCurdy pool at the extreme northeastern end of the field produces entirely from the Fifth and Nineveh Thirty-foot sands. In this field, as in others of the Carnegie quadrangle, the Gordon and Gordon Stray sands are so closely associated that in many places they constitute a single sandstone from 25 to 65 feet thick. In other places they are separated into beds from 6 to 25 feet thick by a few feet of black shale. Both sands are frequently oil bearing and, where united so as to be indistinguishable in well records, in many places contain two pay streaks, one near the top and the other near the bottom. Because of the close association of pools in these two sands and the fact that they can not always be differentiated they are discussed as a single sand (p. 13).

All the pools in the Fourth sand in the McDonald field are small and, so far as known, all occur south of the Pennsylvania Railroad. The sand ranges from 10 to 20 feet thick with a comparatively thin pay streak near the middle.

Specific statistics of the oil produced from the McDonald field are not available, but it is known that its production, together with that of the smaller Venice, Cuddy, Lickskillet, Cecil, and

[a] Geology of the oil and gas fields of the Steubenville, Burgettstown, and Claysville quadrangles: Bull. U. S. Geol. Survey No. 318, 1907. Geology of the oil and gas fields of the Carnegie quadrangle: Bull. U. S. Geol. Survey No. 456, 1911.

Hopper fields, has been over 42,000,000 barrels since 1890. The output from this territory was greatest for the year 1892, being about 8,400,000 barrels. For the year 1909 the field probably furnished about 465,000 barrels. The curve in figure 10 shows graphically this variation in production.

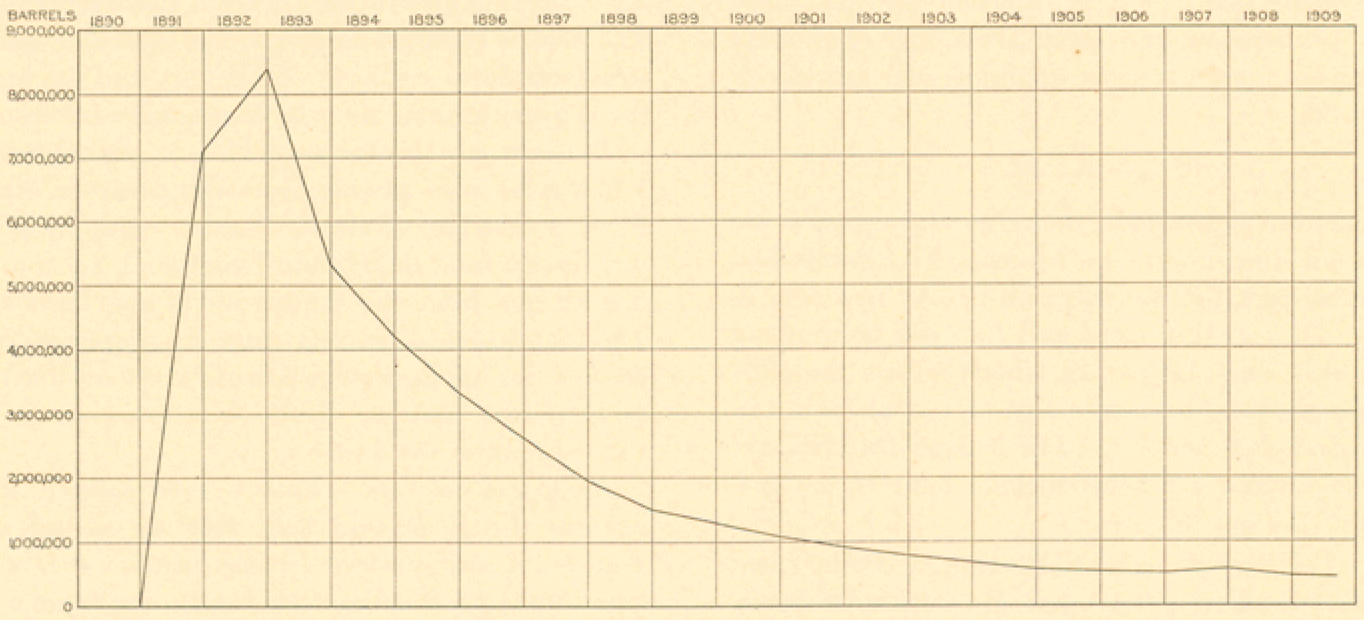


FIGURE 10.—Curve showing variation in production of the McDonald oil field from time of discovery in 1890 to July 1, 1909.

Gas in varying quantities has been found at a number of places in this field in the Fifth, Fourth, Gordon, Gordon Stray, Hundred-foot, Gas, and Salt sands, but the Fifth, Fourth, Gordon, and Nineveh Thirty-foot sands have probably furnished the greatest amount. Little or no salt water is found in the Fifth, Fourth, and Gordon sands in this field. The Hundred-foot sand carries more or less salt water throughout the area, and in many places the Big Injun sand and the sandstones of the Pottsville formation are heavily charged with it. Wells drilled below the Fifth report no water from deeper beds.

Venice oil and gas field.—The Venice field lies south of the McDonald field proper and may be considered a southern extension of it. The first wells produced gas from the Fifty-foot or lower portion of the Hundred-foot sand. About 1894 a large oil pool in the Fourth sand was tapped in this field, some wells yielding 100 barrels or more per hour. In the southern part of the field the Fifth sand supplied a comparatively small amount of oil in a few wells, but throughout most of the field the Fifth sand is either entirely absent or is represented only by a thin hard sandstone containing no pay streak. The Gordon sand yields some oil in many wells, the amount increasing northward from Venice. It also contains a small amount of salt water at a few places. The oil pool in the Fourth sand is about 5 miles long, with a maximum width of about 2 miles. Hundreds of wells in this sand have been producing constantly for 12 to 15 years and still furnish from 2 to 15 barrels per day.

Canonsburg oil and gas field.—The Canonsburg field lies in Cecil Township, northwest of Canonsburg. The Fifth sand contains the largest pool, but the Hundred-foot, Fourth, Gordon, and Gordon Stray sands are very productive at several places. The Hundred-foot and Fourth sands furnish most of the gas. The Gas sand has been found to contain some gas, but at most places it is heavily charged with salt water, which arose in some of the wells to a height of more than 1000 feet.

The Fifth sand in this field is from 6 to 20 feet thick, averaging about 13 feet. The Fourth sand in few places exceeds 20 feet and is absent in many wells. The Gordon and Gordon Stray sands, where separate, are each from 20 to 40 feet thick; where united, they are seldom found to exceed 50 feet. The Gantz and Fifty-foot sands, which together with the intervening shale break constitute the Hundred-foot sand, have a total thickness of about 80 feet. The average depth of the wells to the oil-bearing sands ranges from about 2200 to 2400 feet.

Mawhinney oil pool.—The Mawhinney is a small pool in the Hundred-foot sand discovered in 1895 on the Mawhinney and P. S. Walker farms in the northeastern part of Cecil Township, Washington County. The pool at its maximum development probably did not contain more than twenty producing wells. In May, 1909, only three wells were still being pumped, the others having been exhausted and abandoned. The best well in this field (Mawhinney No. 2) began flowing from the Fifty-foot sand, the basal part of the Hundred-foot, at the rate of 160 barrels per hour from a depth of 2257 feet. Little or no water occurs in the producing sand of this pool.

Cecil oil pool.—During the oil excitement which followed the drilling of the Mawhinney No. 2 well another small oil pool was discovered at Cecil about a mile to the north. Before the discovery of the pool much of the land embracing it had been sold as town lots. When the excitement came, many adjoining lots were drilled, resulting in the sinking of many unnecessary wells and in the rapid depletion of the pool. At one stage of development more than one hundred wells were producing, but the supply of oil has long since been practically exhausted and all the wells abandoned, except one on the William Bekling lot, which still produces a few barrels of oil per week.

Hopper oil field.—The Hopper field is situated about half a mile northeast of Reissing, in South Fayette Township, Allegheny County. The oil comes principally from the Fourth sand and may be, in fact, the northeast extension of the Venice pool in that sand. Some oil is also found in a few places in the Gordon and Fifth sands. The best wells in the field flowed from 60 to 100 barrels per hour, but, as a whole, the wells were short-lived and many were abandoned after being pumped for five or six years. The Fifth and Gordon sands also furnished a few flowing wells in this field, but they were of relatively small capacity. The field has been practically fully developed since 1899 and is now approaching exhaustion.

Lickskillet oil and gas field.—Lickskillet is the local name for an oil and gas field situated in the central part of South Fayette Township east of the Hopper field. In this field the Hundred-foot sand is oil bearing, the field being first developed in this sand. Later, wells deepened to the Fourth and Fifth sands found valuable pools of gas. As in most of the other Hundred-foot pools of the Carnegie quadrangle, the lower division, or Fifty-foot sand, contains all the oil, the upper division, or Gantz sand, being represented by thin hard sandstone or sandy shale. The Fifty-foot sand is usually from 20 to 30 feet thick, but in one well it is reported to be 60 feet thick. The Gordon, Fourth, and Fifth sands range in thickness from about 5 to probably 25 feet. The pay streaks in all are thin and irregular. The gas pools of the Fourth and Fifth sands are structurally much lower than the oil pools in these sands in the Venice and McDonald fields. The Fourth and Fifth sands appear to be free from salt water, but the Fifty-foot contains more or less of it.

Cuddy oil and gas field.—The Cuddy, a small oil pool in the Hundred-foot and Fourth sands, lies south of Cuddy in South Fayette Township. The Fifth sand has furnished gas in considerable quantities from a number of wells. The Gordon sand, which is very variable in thickness and quality here, has proved barren in all wells drilled to it.

The Fourth and Fifth sands are from 20 to 30 feet thick, of normal quality, with pay streaks from 10 to 25 feet below their tops. The Hundred-foot sand appears to be represented by the Gantz sand, the Fifty-foot or lower member apparently being represented by sandy shales and thin sandstone. The Gantz, which is from 6 to 27 feet thick where it is oil bearing, carries a thin pay streak near the middle. Most of the oil wells in this sand furnish some salt water with the oil. The Gordon and Fifth sands are reported dry. The production of the best wells probably did not exceed 100 barrels per day; that of the gas wells is not known. The field has been developed for several years and the production is now down to a few barrels per day, a few wells having been exhausted and abandoned.

Imperial oil and gas field.—The Imperial field occupies an area along the northern edge of North Fayette and the southern parts of Moon and Finley townships, south and southeast of Imperial. The Nineveh Thirty-foot sand, which lies between the Hundred-foot and the Gordon, is the principal oil sand in this field, though the Hundred-foot sand is productive in a number of scattered wells. Some gas is found in the Gordon and Bowlder sands, the latter being a thin sandstone lentil overlying the Gordon Stray sand and underlying the Nineveh Thirty-foot. No large gushers have been found, the best wells making probably not more than 100 barrels per day and the average initial production being less than 25 barrels. Drilling has continued since 1898. In December, 1907, the field was being slowly extended toward the southwest; at that time it was about 4 miles long by three-fourths of a mile wide.

The Hundred-foot sand furnishes more or less water with the oil in this field, and the Big Injun and Salt sands are reported to yield large quantities of salt water. The Nineveh Thirty-foot and Gordon sands show no salt water. The Fourth and Fifth sands are absent or are represented only by thin hard sandstones and sandy shale.

McCormick oil and gas field.—The McCormick field consists of probably less than twenty wells, located in Moon Township 2 miles northeast of the Imperial field. The Hundred-foot and Nineveh Thirty-foot sands are oil bearing, and the Gordon, Fourth, and Fifth sands, all of which are present in normal thickness appear to have yielded more or less gas. Gas was also found in considerable quantities in what is called the Sixty-foot sand, which is probably one of the sandstones of the Pottsville. This gas was accompanied by large quantities of salt water, which soon shut off the flow. The McCormick field is now practically exhausted and most of the wells have been abandoned.

Ewings Mill oil and gas field.—Northeast of the McCormick field a few wells in the vicinity of Ewings Mill found gas in the Hundred-foot, Nineveh Thirty-foot, and Gordon sands, and some oil in the Gordon and Hundred-foot. The wells were flowing but were of small capacity and the total production was very small. The wells have been good gassers, however, and are still producing a sufficient quantity to justify the owners in keeping them turned into the pipe line.

Aten oil and gas field.—Northwest of the belt of productive territory formed by the Imperial, McCormick, and Ewings Mill fields is a generally barren area 2 to 3 miles wide, in which are found a few small pools of oil in the Hundred-foot sand and of gas in the Gordon, Fourth, and Fifth sands. The Aten field, which is perhaps the largest productive area in this belt, has furnished a few wells with oil from the Hundred-foot and gas from the lower sands. All of the producing sands change greatly in thickness and character from place to place within this barren zone; perhaps the most uniform are the Gordon and Hundred-foot, which seem to be continuous beds over the entire area. The Fifth and Fourth sands are represented by thin lentils of sandstone, which are wanting at many places. All the sands appear to be remarkably free from water. Though some water is frequently found in the Hundred-foot sand, none has been reported in the Gordon, notwithstanding the fact that up the continuous dip of the sand from the Aten field water in considerable quantities occurs in it at a distance of less than 2 miles. The Aten field is 10 to 15 years old and the production of oil is now down to only a few barrels per day and is approaching exhaustion. Some of the best gas wells are still attached to the pipe line, but the amount of gas from them is relatively small.

Moon oil and gas field.—The northwest corner of the Carnegie quadrangle and the northeast corner of the Burgettstown embrace about a square mile of the Moon field, most of which lies in the Sewickley and Beaver quadrangles to the north. The oil comes principally from the Gordon sand, with small quantities from the Hundred-foot, which, together with the Fourth sand, also furnishes some gas wells. Both the Hundred-foot and Gordon sands carry salt water; in many cases that in the Gordon gradually increases with the age of the wells until the supply of oil is permanently shut off.

McCurdy oil field.—The McCurdy pool, which lies at the extreme northeastern end of the McDonald field, was discovered in October, 1890, when a well on the McCurdy farm began flowing at the rate of 600 barrels per day. Other large wells followed, attracting producers from all over the Appalachian region. The best wells began flowing at the rate of about 200 barrels per hour. The oil comes entirely from the Fifth and Nineveh Thirty-foot sands. The Fifth is 10 to 80 feet thick, but averages not more than 20 feet. Despite this thinness this field has produced an enormous quantity of oil; after 18 years of constant flowing or pumping, the wells still furnish from 1 to probably 10 barrels per day. The Nineveh Thirty-foot sand furnishes a small amount of oil from a few wells; and the Gordon and Hundred-foot sands furnish some gas. The Fourth sand is of no importance.

Moon Run oil and gas field.—Moon Run is here used to designate the oil and gas producing territory lying in the immediate vicinity of the village of Moon Run and northward to Ohio River and eastward to Chartiers Creek. In this area the Gordon, Gordon Stray, Fourth, Fifth, and Hundred-foot sands contain many overlapping pools of both oil and gas. At Moon Run and eastward the Gordon sand furnishes most of the oil. Northward the Fifth is the principal oil sand and the Gordon and Gordon Stray sands carry gas. Many of the wells show small quantities of water in the Gordon and less in the Fourth and Fifth. The Fourth sand furnishes small amounts of oil from a few wells. The Gordon sand alone is in few places more than 30 feet thick, but where united with the Gordon Stray the combined thickness is in places as much as 70 feet, with two pays separated by a zone of hard sand.

In the central part of the Moon Run field, the Gordon and Fifth sands are the principal oil-bearing beds. From the center northeastward to Ohio River the Fifth and Gordon sands are rarely oil bearing, but in many wells they have produced large quantities of gas. In this area the Fourth sand is oil bearing and has supplied some of the best wells in the field, but farther northward this sand also becomes gas bearing. The Fourth and Fifth sands are unusually thick, ranging from 30 to probably 60 feet, with pay streaks from nothing to 28 feet thick, containing more or less pebbles. The pays occur at different places in the sands, but the most persistent in the Fourth is near the bottom. Over most of the northwestern portion of the field the Hundred-foot sand furnishes more or less oil. The Hundred-foot is here from 40 to 80 feet or more in thickness, the Gantz and Fifty-foot members being separated by a few feet of black shale. Most of the oil appears to come from a pay streak 4 to 8 feet thick near the bottom of the sand. South of Beacon in the western part of the field, the Nineveh Thirty-foot sand furnishes some oil, though most of it appears to come from the Gordon and Hundred-foot. Here the Fourth and Fifth sands are gas bearing.

Bellevue oil and gas field.—The Bellevue field at one time included most of the territory upon which the town of Bellevue now stands and extended northward into the Sewickley quadrangle. The oil and gas came principally from the Hundred-foot and Nineveh Thirty-foot sands. Some of the wells in the former sand are said to have flowed several hundred barrels per day when first drilled, but nearly all of them have been exhausted and abandoned and their locations obliterated by the growth of the town. Wells in the Nineveh Thirty-foot had a comparatively light daily output, but continued to produce for a much longer period. The exact size of these pools is not known. The Fourth and Fifth sands appear to range from 15 to probably 25 feet in thickness, though few measurements could be obtained. On Jack Run at the northern edge of the quadrangle, a small pool of oil and gas in the Hundred-foot sand was discovered on the Peter Ivory farm. This sand furnished also gas and salt water. The wells proved to be short lived, however, the field being exhausted and abandoned after three or four years.

Chartiers oil and gas field.—The Chartiers field is situated on Chartiers Creek, about a mile south of McKees Rocks. It is probably a northeast extension of the Gordon sand pool from the vicinity of Moon Run, as described above. Though the Gordon yields most of the oil in this field, the Hundred-foot has also been found productive of both oil and gas. The field is about a mile long by half a mile wide. It probably contained as many as seventy-five producing wells, but no data relative to the capacity of any of them are available. The field has been producing for a number of years and, though some drilling was going on in 1907, the total amount of oil then being obtained was small.

East and southeast of the Chartiers field for several miles the sands appear to be unusually barren of both oil and gas. Two or three small gas wells in the Fifth sand south of Ingram and Idlewood and a few others in the city of Pittsburg are all that have yet been found productive.

Woodville oil and gas field.—In the Woodville field most of the oil and gas were found in the Nineveh Thirty-foot sand, though both oil and gas were found in paying quantities in the Hundred-foot, and some gas in the Salt sand. One well (Joseph Campbell No. 1) is said to have produced gas for four years from the Gordon sand and then suddenly to have begun flowing oil from the same sand at the rate of 100 barrels per day. This statement, however, could not be verified by the owners of the well. Though many of the wells flowed when first drilled, they were not large producers.

The Nineveh Thirty-foot sand is hard and reddish in color, ranges from 30 to 40 feet in thickness, and lies at a depth of over 2000 feet; the top of the pay streak ranges from 9 to 23 feet below the top of the sand. The Hundred-foot sand has a maximum thickness of about 110 feet; it is described as reddish and somewhat limy. The Gordon seems to be represented only by "slate and shells." The Fourth and Fifth sands are respectively 5 and 20 feet thick. No salt water was encountered below the Hundred-foot sand, and this furnished only small quantities regardless of the fact that the field is structurally located in the bottom of a small basin of the Nineveh syncline. In some of the wells salt water was encountered in sandstones at depths of only 75 feet and 390 feet, the water entering the wells at the rate of 3 to 10 barrels per hour. In one well the pay streak in the Hundred-foot sand is reported by the drillers to consist of 25 feet of soft white sand carrying large pebbles. It contained no oil or gas and only a small amount of salt water. Northeast and east of the Woodville field the Nineveh Thirty-foot and Gas sands furnish gas in a number of scattered wells, but few data relative to them were obtained.

Castle Shannon gas field.—In the vicinity of Castle Shannon, in Scott Township, a number of wells have secured gas in commercial quantities from the Hundred-foot sand, which has a thickness of about 100 feet. Most of the gas comes from a pay streak below the shale break and is therefore from the Fifty-foot member, though the Gantz sand is said to furnish some gas in the eastern part of the field. One or two wells have reported gas and a little oil from a sand which lies a little over 300 feet below the top of the Hundred-foot and which is considered by drillers to be the Gordon. Only a few wells are still producing.

Bridgeville gas field.—The Bridgeville field is represented by twenty-five or thirty gas wells located in the vicinity of Bridgeville. The gas comes from a number of small pools in the Hundred-foot, Nineveh Thirty-foot, Gordon, Fourth, and Fifth sands, but does not appear to be continuous over the entire field. Few well records were secured and, therefore, the structural position of the sands have not been definitely determined; they appear to be of normal thickness and quality throughout the field. Many holes appear to yield gas from a single sand only, the others being barren of gas, oil, or water. The utmost irregularity appears to prevail in the position of these small pools, but the data are too meager to permit their delineation.

Clifton gas field.—The Clifton field is situated in the vicinity of Clifton. It has been developed by about twenty wells, which found most of the gas in the Hundred-foot, Nineveh, Thirty-foot, and Gordon Stray sands. The first well was drilled in 1887–88 for oil and proving to be a large gas well, considered at that time to be worthless, it was allowed to blow off in the air unchecked for more than a year. It is roughly estimated that between one and five billion cubic feet of gas was thus wasted from this well alone.

Within the last few years a number of wells have been put down in extending this field to the southwest and it now seems to be fully developed. Some of the wells are still vigorous and will probably continue to furnish gas in considerable quantities for many years.

Finleyville oil and gas field.—The southeast corner of the quadrangle covers a portion of the Finleyville field, which extends into the quadrangles toward the east, southeast, and south. Within the Carnegie quadrangle the field has produced no oil, unless from a few wells in Finleyville which are now abandoned; but a short distance south of the boundary at that place two wells on the Frye property have produced a heavy dark oil from the lower part of the Hundred-foot sand. The first of these wells began flowing at the rate of about 100 barrels per day, but subsequent drilling on all sides of it within 300 feet found the sand barren except in one well, which at its best produced only a few barrels per day.

Northward from Finleyville the Dunkard or so-called Gas sand, which lies about 660 feet below the Pittsburg coal, has furnished considerable quantities of gas in several wells. Small pools of gas have been found also in a number of wells scattered along the eastern border of the quadrangles north of Finleyville and east of Library. The gas comes principally from the Fifth sand.

Data relative to the thickness and quality of the oil sands are meager. The Fifth sand appears to be the most constant, ranging from 8 to 30 feet or more in thickness. The maximum thickness given for the Fourth sand is 14 feet. The Gordon and Gordon Stray sands appear to be represented only by "slate and shells." The Nineveh Thirty-foot sand is not mentioned in the well records, and the Hundred-foot ranges from "slate and shells" to a compact sandstone 100 feet thick. A gas-bearing sand lying about 200 feet below the Fourth sand is reported in two wells as 5 and 8 feet thick, respectively; it is probably either the Sixth or the Elizabeth sand of Greene County.

McMurry oil and gas field.—The McMurry field includes an oil and gas producing belt that extends from near the Washington-Allegheny county line southwest across the center of Peters Township to Little Chartiers Creek. The oil comes almost entirely from the lower part of the Hundred-foot sand and is accompanied by more or less salt water. The most important gas-producing sand is the Fifth, but pools of less size are found in the Gantz, Gordon, Gordon Stray, and Nineveh Thirty-foot sands. The field was first developed for the oil in the Hundred-foot. None of the wells were large producers and they declined rapidly to a few barrels per day within two to four years. Many of these were then deepened to the lower sands and changed to gas wells. The Salt and Big Injun sands contain large quantities of salt water in this field. Many wells flowed salt water and gas from the former when first drilled. Some of the salt water in the Hundred-foot sand comes from the Gantz or upper member, but most of it comes from the lower or Fifty-foot member, in some wells with a head of 300 to 400 feet. The records furnish little information regarding the salt water in the Gordon and Fifth sands, but it seems certain that a small quantity has been found by a few wells in the Gordon; and that a small quantity eventually makes its appearance in many Fifth sand gas wells. There is no way of ascertaining if this water is indigenous to the Fifth sand or comes from some higher bed.

Closed pressures of gas in the producing sands vary from about 125 pounds per square inch in the Salt sand to 900 pounds in the Fifth; it is not known if this pressure increases uniformly with the depth of the sands.

West of the McMurry field several scattered wells have furnished more or less gas from the Hundred-foot and Gordon Stray sands, but no well-defined pools or fields have yet been discovered.

GENERAL STRUCTURAL POSITION OF OIL AND GAS POOLS.

The structural positions of the oil and gas pools in each sand are shown on the oil and gas maps by contour lines, having a vertical interval of 10 feet, which are drawn on the top of the Hundred-foot sand in the Burgettstown quadrangle and on the top of the Gordon sand in the Carnegie. Only the analogy in position of some of the pools need be pointed out.

Fifth sand.—The largest accumulation in the Fifth sand, the McDonald pool, occupies a broad structural terrace extending northeast to southwest, from which the rocks dip relatively steeply toward the southeast to the axis of the Nineveh syncline. This terrace is broken by many small secondary folds of local extent and is limited on the northwest by a somewhat more rapid and uniform rise of the rocks. The dip along the major axis of the pool is about 140 feet in 11 miles or approximately 13 feet per mile. From northwest to southeast across the pool the dip varies at different points from about 20 to 65 feet per mile.

Northward, the oil pools in the Fifth sand in the Moon Run field occupy successively higher positions along the same structural terrace, which gradually assumes the form of a low arch pitching toward the south.

Still farther northward along this anticline, in the vicinity of Ohio River, the oil in the Fifth sand gives way to accumulations of gas. In the western part of the Moon Run field, south of Beacon, the gas in the Fifth is structurally slightly higher than the oil in the McCurdy pool, with which it seems closely connected, but is lower than that in the oil pool to the east on the crest of the anticline.

The Fifth-sand pool of the Canonsburg field occupies a small sloping terrace very similar to that occupied by the southern part of the McDonald pool, but lies about 100 feet lower down the slope and on the southern side of the Cross Creek syncline. Southwest of this pool, up the slope and on the crest of the Westland dome, occur the corresponding gas pools.

Northeast of the Canonsburg pool, along the strike of the oil sand, on the north side of the Cross Creek syncline, small gas pools, which appear not to be intimately associated with the accumulations of oil, are found in the Fifth sand in the Lickskillet, Hopper, Cuddy, and Bridgeville fields. In the McMurry field the gas accumulations discovered to date lie in a belt parallel to the strike of the rocks, the lower edge being at a slightly lower structural level than in the last-named pools and about 75 feet below the Canonsburg oil pool. This fact appears of greater structural significance when it is remembered that the Fifth sand rises southeastward from this belt to the crest of the Amity anticline, and that, so far as known, it is continuous over the area.

Generally speaking, the areas of accumulation of Fifth-sand pools in the quadrangles are structurally highest at the northwest and lie successively lower toward the southeast regardless of the size and height of the anticlines in the bed. Further, each separate accumulation tends more or less toward an arrangement by which its major axis lies parallel to the strike of the rocks.

Fourth sand.—The structural map of the oil and gas pools shows that the Fourth-sand gas pool in the Aten field, near the northwest corner of the quadrangle, lies squarely across the contour lines and therefore directly up the slope of the sand, covering a vertical range of about 90 feet between the 1040-foot and the 1130-foot contours. East of this pool, on the flat southward-pitching crest of the Wildwood anticline, a number of small gas pools have been noted between the 1000-foot and the 1100-foot contours. The Fourth-sand oil pool in the central part of the Moon Run field occupies the crest of a secondary anticline between the 1080-foot and the 1100-foot contours. On the next anticline toward the northeast a small gas pool, which is on the 1030-foot level, has been developed by two wells on the property of the Pressed Steel Car Co., at McKees Rocks.

South of this productive belt the Fourth sand is barren of oil or gas, except for one or two very small accumulations along the Fifth-sand terrace in the McDonald field, the next important accumulation being the great Venice-Hopper oil pool. This accumulation lies roughly between the 800-foot and the 900-foot contours, and its major axis extends along the strike of the rocks at an average elevation of 850 feet. It is to be regretted that the data at hand do not permit the tracing out of the Fourth-sand gas pools in the Hickory field. From the facts at hand it seems very probable, however, that these gas pools are at practically the same elevation in the sand as the Venice-Hopper oil pool; and that this whole area forms a productive belt between the 800-foot and 900-foot contours along the relatively steep western limb of the Nineveh syncline. The few small oil and gas pools in the Fourth sand in the Canonsburg district occur along this belt. Two gas wells in the Fourth sand about a mile east of Cecil and another in the Bridgeville field, 3 miles away, are all practically on the 760-foot contour, and so far as they go show a tendency toward another productive belt at a lower level in the sand than the Venice-Hopper field, though the two great belts mentioned above cover practically all of the known oil and gas pools in these quadrangles. Here, again, is seen the tendency of pools to accumulate in successively lower belts from northeast to southwest.

Third or Gordon sand.—The oil and gas pools in the Third or Gordon sand do not show such clearly defined belts of accumulation as do the sands previously described. The Moon pool at the northwest corner of the Carnegie quadrangle lies between the 1060-foot and the 1110-foot contours. The Aten gas field is between the 1070-foot and the 1080-foot contours, and northeastward the Coraopolis oil pool, just off the northern border, lies mostly between the 1060-foot and the 1110-foot contours, the most northern extension reaching up to the 1120-foot level.

In the Ewings Mill pool the gas is at an elevation of 1040 to 1050 feet, and in the pools in the vicinity of Neville Island it ranges from the 1100-foot to the 1150-foot contours. This producing belt continues to rise higher in the sand farther toward the northeast beyond the limits of the Carnegie quadrangle. South of the Beech Cliff mines in North Fayette Township three small gas wells in the Gordon sand are between the 1000-foot and the 1030-foot contours. This is also the height of a small pool in the western part of the McCurdy field. Eastward, the 1000-foot contour is found to mark fairly closely the southern border of the Gordon oil pool in the Moon Run field, though this pool extends upward along the pitching crest of the anticline for about 70 feet and ranges from the 990-foot to the 1060-foot contour in the Chartiers oil field.

The great Gordon sand pool in the McDonald field has the same general outline as the Fifth sand pool in that field. (See p. 13.) In the Carnegie quadrangle its upper or northern edge lies probably at about the 990-foot contour, from which it drops about 100 feet southwestward within the Carnegie quadrangle. At its northern end the lower line of the oil-producing area in this sand is about 940 feet, from which point it crosses the contours diagonally down slope to the southern edge, the 820-foot contour being about the lowest reached. The outline of the portion of the pool that lies in the Burgettstown quadrangle can not be traced. Down the dip of the sand from this pool, between the 840-foot and 860-foot contours, occurs the gas pool in the Hopper field.

In the Canonsburg district the principal oil pools lie at 800 and 840 feet, and the eastern extension of the great Hickory gas field at about 890 to 970. Several very small oil pools have been found at various levels along the western limb of the Nineveh syncline, where the Gordon sand has its greatest dip within the quadrangle.

East of the Nineveh syncline, a small gas pool occurs in the Bridgeville field at an elevation of about 770 feet, the same as that of the upper edge of the gas pool in the Clifton field 3 miles farther southeast. In the McMurry field, three of the six small pools discovered lie at the 650-contour, one at the 670-foot contour, and the remaining two are at the 620-foot and 510-foot contours, respectively.

Nineveh Thirty-foot sand.—The pool in the Bellevue field at the northern edge of the quadrangle is the highest, structurally, of any in the Carnegie quadrangle. It occupies the southward-pitching trough of the Nineveh syncline between the 1090-foot and 1120-foot contours. South of this pool in the same trough gas occurs in a well of the Pittsburg Forge & Iron Co. in Allegheny on the 1060-foot contour. The oil and gas pools in the Ewings Mill field occur about 20 feet farther down the dip. The Imperial pool, which is the largest in this sand in the Carnegie and Burgettstown quadrangles, lies along a belt of comparatively steep dip just north of the Mount Nebo syncline, with the major axis of the pool parallel to the structural contours. The upper edge of this pool is on or near the 1020-foot contour, the lower side being at an elevation of about 970 feet. The Burgettstown-Cross Creek pool in this sand is about 150 feet farther down the dip. On the opposite side of the Wildwood anticline from the Imperial pool, oil and gas pools in the Nineveh Thirty-foot sand occur south of Beacon on the 1020-foot contour. Oil has also been found in the McCurdy field in this sand in a small syncline on the eastern side of the Wildwood anticline at an elevation of 960 to 980 feet. The Nineveh Thirty-foot sand pool in the Woodville field lies squarely in the bottom of a small basin in the trough of the Nineveh syncline, at an elevation of 680 to 700 feet. The gas pool in this sand at Bridgeville can not be clearly outlined, but it appears to occupy the pitching end of a secondary anticline, at an elevation of about 740 to 780 feet. With this possible exception the Nineveh Thirty-foot pools show invariably a tendency toward accumulation in synclines; and so far as may be observed from scattered pools, show a fairly close structural arrangement for each belt of pools.

Hundred-foot sand.—The structural positions of the principal oil and gas pools of the Hundred-foot sand in the Burgettstown quadrangle have been already briefly pointed out. The axis of the Florence-Five Points pool, though conforming in a general way to the structural contours, shows no close alignment with them. The pool lies principally along the western limb of the West Middletown syncline, where the sand has a relatively steep dip. The northern end of the pool is structurally the highest, the upper limit of the producing area being about 150 feet above the southern end. Southwestward from this pool the sand becomes gas bearing in the Eldersville pool at the same structural level. The Burgettstown-Cross Creek pool shows a decided tendency toward a semicircular arrangement in the bottom and around the northwest side of the Cross Creek basin, with the upper edge about 150 feet below the lower end of the Florence-Five Points pool.

The Burgettstown-Candor gas pool, which occupies a similar structural position to the Eldersville gas pool, does not vary much from it in elevation. In both cases, the southern end of the pool is lowest. Traced northeastward, the Burgettstown–Candor gas pool shows another striking similarity to the arrangement of the oil and gas pools already mentioned by terminating in an oil pool in the Aten and Imperial fields at elevations somewhat above the gas pool. However, the Aten and Imperial pools appear to belong to separate productive belts, the former being between the 1040-foot and 1080-foot contours and the latter at the 990 to 1000, with a dry area between them. Traced eastward, these two productive belts appear to merge in the western part of the Moon Run field, where the larger pools lie between the 1020-foot and 1100-foot contours, along the pitching axis of a small anticline. Similar anticlines farther to the east also carry pools at successively high points in the sand.

Another belt of productive territory in the Hundred-foot sand is marked by a number of small gas and oil pools in the Venice and Canonsburg fields between the 800-foot and 840-foot contours. This may be traced in gas pools toward the southwest and south along the southern limb of the Cross Creek syncline, and toward the northeast through the Mawhinney, Cecil, Hopper, Cuddy, and Lickskillet oil fields, which collectively occupy a belt between the 690-foot and 840-foot contours. This belt may be continued across the Nineveh syncline in the vicinity of Woodville and thence southeastward through the Clifton gas pool, which lies between the 720-foot and the 780-foot contours. Farther to the southeast from this pool two small gas areas occur near the eastern border of the quadrangle, one on the 720-foot and the other on the 760-foot contour. From this point southwest along the strike of the rocks the producing belt in the Hundred-foot sand in the McMurry field occurs between the 650-foot and the 670-foot contours. This is one of the most striking structural alignments shown by pools within these quadrangles and is indicative of what has been found to occur in this sand in the Sewickley quadrangle, which joins the Carnegie to the north. On the Amity anticline, at the southern border of the Carnegie quadrangle, a single well secured a small amount of gas from the Hundred-foot sand between the 850-foot and 860-foot contours, and in the Finleyville field both gas and oil occur at elevations ranging from about 800 to 830 feet. This productive belt has not been traced farther to the northeast, but it presumably coincides with the Castle Shannon gas pool, which lies between the 830-foot and 860-foot contours.

Conclusions.—This brief discussion of the structural position of the pools indicates (1) that the individual study of pools by sands is of far greater significance than the general grouping of fields along folds without regard to the producing sands; (2) that areas found to produce from two or more sands are in many cases especially favored structurally, but that the fact that productive belts in one sand in most cases do not conform to those in another sand shows that other factors, probably even more important than structure, affect the position of the oil and gas pools; (3) that the structural analogy of pools in a given sand relates not so much to definite structural features, as anticlines or synclines, as it does to the height of the pools above some horizontal plane; (4) that each of the oil or gas bearing sands has a series of productive belts at structurally different heights and that these belts occupy successively lower elevations from northwest to southeast across these quadrangles, regardless of the heights or depths of the various folds with which they are associated; (5) that the pools in each productive belt show a general tendency to occur at successively higher structural levels from southwest to northeast; (6) that the gas pools in a given belt tend to occupy the higher portions, but that this tendency is marked by so many notable exceptions that it must be at least modified by other factors of accumulation; and (7) that future drilling, to be most effective in opening new pools, should be conducted along the structural lines of productive belts and not in the barren or less productive areas between them.

WELL RECORDS.

Partial records selected from a large number as typical of the localities from which they were taken are shown in the table at the end of the text.

CLAY AND SHALE.

The workable clays that outcrop in this area are confined largely to the Quaternary and residual deposits. The clays underlying the Conemaugh, Monongahela, and Washington coals are not nearly so valuable nor so extensive as those underlying the Allegheny coals. However, the Quaternary deposits and weathered shales afford clay suitable for ordinary brick making. In the Burgettstown quadrangle they have been used to a very slight extent. A few buildings, for example Robinson Church, 3 miles southeast of Murdocksville, are built of brick from local clay. In the Carnegie quadrangle Quaternary clay has been worked extensively half a mile southwest of Canonsburg.

Shale is abundant in the area and with limestone furnishes inexhaustible supplies of the raw materials of Portland cement. Its variety is great and it would not be difficult to find almost any kind and grade desired. The soft shale lying just above the Pittsburg coal is worked at Canonsburg for brick.

LIMESTONE.

Limestone is abundant in the quadrangles, and much of it is favorably situated for working. In structure it ranges from coarse grained and very fossiliferous to fine grained and lacking in fossils, and in color through many shades of gray and blue and from nearly black to white. The different beds have been described under Geology, the columnar section shows graphically their thickness and vertical distribution. Most of them are usable for road metal and concrete. The following analyses were made of limestone in this area.

Analyses of limestones from Burgettstown quadrangle, Pa.

	1.	2.	3.
Insoluble in hydrochloric acid	6.51	24.01	1.66
Alumina and iron oxide	1.68	5.79	.67
Lime	49.43	29.08	53.46
Magnesia	.10	11.04	.31

1. From beneath Pittsburg coal.
2. From lower portion of Benwood limestone member.
3. From upper part of Benwood limestone member.

SANDSTONE.

Sandstone is the most valuable building stone in the area, but, though abundant, not all of it is suitable for this purpose. Generally, Carboniferous sandstones are suitable only for rough masonry, few being regular enough in bedding to be desirable for dimension stone. Those of chief value for masonry are the Morgantown, the Pittsburg, and the Washington sandstone members. A small quarry has been opened on a local sandstone half a mile southwest of Bavington, the rock from which was used for bridge abutments and foundations. There is little, if any, sandstone in this area pure enough to yield sand for molding or glass.

SAND AND GRAVEL.

The sand of the quadrangles is of two principal varieties. That from Allegheny River is sharp and hard, and that from Monongahela River "soft" and round grained. The difference is probably due to the derivation of the two kinds. Much of the sand of the Allegheny comes almost direct from the igneous rocks of Canada, in which the quartz is not at all rounded. All of the sand of the Monongahela has come from sandstones, the grains of which have perhaps been reworked several times. The sharp sand is used extensively for plate-glass grinding.

Immense amounts of gravel have been taken from the river beds and terrace deposits and used for concrete, street foundations, and all the many varied uses to which gravel is put.

SOILS.

Genetically the soils of this region are of two general classes —sedentary soils, which have developed in place by the weathering of the hard rock formations, and stream-transported or alluvial soils. The sedentary soils vary according to the rocks from which they are derived, sandy or even rocky soils overlying sandstones and finer mudlike soils overlying shales and limestones. The outlines of the areas occupied by the various kinds of soils do not, however, coincide with the geologic boundaries of the rocks, principally because there is much creep at the surface. The region is hilly and all disturbances of surface particles, such as are brought about by frost, rain beat, wind, upturning of trees, plant growth, and operations of animals, result in a downhill movement of greater or less extent. On the whole, however, there is a fairly close relation, both chemically and physically, between the soils and the underlying rocks.

The early studies of soils were based almost entirely on their chemical content, but the present consensus of opinion seems to be that the physical characters are also very important, and these are controlled by geologic conditions quite as much as is the chemical constitution. In broken country, where erosional processes are active and the slopes are steep, the soil is necessarily thin. Rocky soils arise from underlying formations which break up into blocks of considerable resistance and also from torrential streams and glaciers. Capillarity and porosity, which depend on size and shape of constituent particles, although modified by the work of plants and animals, are largely controlled by geologic processes.

The weathering products of sandstone are loose and porous; certain shales, particularly clay shales, weather to a heavy, tight clay, other more arenaceous ones give looser products; and limestones commonly yield rich black loamy soils. In some places, especially where the climate is dry and the country low, so that solution goes on slowly but thoroughly and transportation is nearly at a standstill, the resulting earth is red and more or less barren. There are no such soils in this district to-day, but there is some evidence for believing that the layers of red shales which are to be seen at many places were derived ages ago from the erosion of red earths produced by slow leaching, perhaps in a desert climate.

The hillsides in the northern part of the area are commonly somewhat rocky for the reason that here the Morgantown sandstone member outcrops extensively. Most of the soils of a belt extending across the central portion of the area are finer grained and more fertile. They are derived from shale and limestone strata which form the upper part of the Conemaugh and the lower part of the Monongahela. The hills in this belt are capped by the Benwood and Uniontown limestone members, which weather, largely through solution, to a silty loam containing an abundant supply of lime, an essential constituent of fertile soils. In the western part of the area the Pittsburg coal is overlain by a heavy sandstone which yields a sandy soil very different from that covering the same strata farther east.

The rocks of the upper part of the Monongahela and the higher formations yield sandy loams, here and there containing beds of sandstone and almost invariably an ample supply of lime.

Another class of soils, the alluvial, is found along stream courses in all parts of the area. These soils are made up of thoroughly mixed products of the weathering of many kinds of rocks. The alluvial soils are in some places stony and in others compact and clayey, but they are generally loose and fertile.

WATER SUPPLY AND WATER POWER.

The surface water supply for this region is derived from Ohio River and its tributaries. The supply from the Ohio is practically unlimited, but on account of the large amount of manufacturing waste and sewage in the water it should not be used for household purposes without being thoroughly purified. The supply obtainable from the small streams, if controlled by storage reservoirs will probably furnish sufficient water for commercial and household uses, but in all places except where the supply comes from a sparsely inhabited drainage basin, the water should be treated to remove contamination from sewage and other impurities.

The water supply of Pittsburg is taken from Allegheny River about 7 miles above the junction of the Allegheny and Monongahela. Here it is put through a new filtration plant consisting of fifty-six 1-acre filters, the beds being of gravel and sand about 4 feet thick and the walls of concrete.

The average rate of fall of the Ohio between Pittsburg and Beaver is 1.433 feet per mile and its discharge is 1600 to 440,000 cubic feet per second. About 10 miles below Pittsburg the river falls 9 feet in less than 2 miles. The Federal Government has built and is building dams as an aid to navigation in the region, and at these dams considerable water power is available at low and medium stages of water. At present the possibility of utilizing this power is questionable, as the cost of constructing plants capable of withstanding the high floods would undoubtedly make such projects expensive, and during floods no power would be available, as the water wheels would be submerged. In the future, however, as sources of water power become of greater consequence it is probable that the energy of the Ohio will be utilized.

The small streams that drain the region are not considered important sources of power at present. Their flow is so small that in ordinary dry seasons they do not furnish enough water even to supply the demands of small power plants. They have, however, considerable fall, and were utilized to some extent as a source of power before coal was so generally used for steam making. Old mills stand here and there along the streams and it is reasonable to expect that in centuries to come, when the coal beds are depleted and water power becomes again important, the small as well as the large streams will again be utilized.

Partial well records from Burgettstown and Carnegie quadrangles.

County and township.	Name.	Owner.	Altitude of collar.	Formation.	Depth to top.	Thickness.	Remarks.
WASHINGTON COUNTY.			Feet.		Feet.	Feet.	
Hanover	Peterson No. 1	Lawrence Gas Co	1189	Connellsville coal[a]	630		
				Salt sand	860	70	
				Big Injun sand	1000	280	Water in Big Injun sand at 1200 feet.
				Squaw sand	1360		
				Bitter Rock sand	1520		
				Red rock	1736		
				Hundred-foot sand	1836	12	Depth of well, 1876 feet.
Mount Pleasant	Robert Cowden No. 2	Manufacturers Light & Heat Co.	1149	Pittsburg coal	140		
				Salt sand	1013	......	Gas in Salt sand at 1013 feet.
				Gantz and Fifty-foot sands	1962	42	
				Gordon sand	2171	15	Gas in Gordon sand at 2172 feet.
				Fourth sand	2220	......	Gas in Fourth sand at 2221 feet. Depth of well, 2232 feet.
Woodrow	McCorkle	Ohio Valley Gas Co	......	Mapletown coal[b]	180	5	
				Pittsburg coal	268	5	
				Gas sand	830	40	
				Salt sand	1140	15	Water at 1155 feet.
				Salt sand	1275	75	
				Big lime	1350	50	
				Big Injun sand	1390	170	Water at 1330 feet.
				Red rock	2000	60	
				Hundred-foot sand	2102	6	Oil at 3580 feet. Depth of well, 4618 feet.
Jefferson	L. E. Stewart		1207	First Pittsburg coal	228		
				Second Pittsburg coal	240		
				Third Pittsburg coal	250	5	
				Freeport coal	906		
				Salt sand	1052	......	Break in Salt sand at 1125 feet.
				Bitter Rock sand	1530		
				Hundred-foot sand	2035	7	
				Fifth sand	2416	......	Depth of well, 2510 feet.
Cross Creek	John Studa		1028	Pittsburg coal	65	5	
				Salt sand	870	125	Water at 955 feet.
				Big Injun sand	1235	60	
				Red rock	1780	50	
				Hundred-foot sand	1865	9	Depth of well, 1874 feet.
Cross Creek	Buchanan		1050	Coal	278		
				Red rock	450		
				Brown sand	617		
				Gray limestone	675		
				Red rock	2000		
				Gas sand	2090	......	Gas and little oil at 2260 feet.
				Sand	2260		
				Red rock	2492		
				Brown sand	2825		
				Sand	3600	......	Oil at 3600 feet.
				Red rock	3960		
				Soapstone	4010		
				Bradford (?) sand	4303		
Mount Pleasant	McGuigan		1145	Coal	180	5	
				Coal	285	15	
				Red rock	470		
				First sand	762	40	
				Second sand	865	35	
				"Third" sand[c]	988	40	
				"Fourth" sand[c]	1100	55	
				"Fifth" sand[c]	1266	234	
				Red rock	1965		
				Soapstone	1995		
				Hundred-foot sand	2035	5	
				Gordon sand	2245	......	Gas at 2245 feet.
Mount Pleasant	J. V. Rea		1032	Pittsburg coal			
				Salt sand	970	90	Water at 1050 feet.
				Big Injun sand	1112	214	
				Thirty-foot sand[d]	1693	59	Little gas at 1205 feet.
				Gantz sand } Hundred-foot	1845	15	
				Fifty-foot sand } Hundred-foot	1864	36	
				Gordon sand	2068	19	Gas at 2078 feet.
				Fourth sand	2116	14	Gas at 2188 feet. Depth of well, 2224½ feet.
				Fifth sand	2177	15	
Mount Pleasant	J. R. and Joseph Lyle		1161	Pittsburg coal	226	10	
				Freeport coal	923	6	
				Salt sand	1200	58	Salt water at 1215 feet.
				Big Injun sand	1304	178	
				Thirty-foot shell[d]	1800	65	
				Red sand	1910	22	
				Hundred-foot sand	2016	15	
				Blue Monday sand (Thirty-foot)[e]	2217	9	Gas at 2224 feet.
				Gordon sand	2336	4	
				Fifth sand	2446	4	Depth of well, 2474 feet.
Cross Creek ?	Abram Pry		1262	Pittsburg coal	420	5	
				Slate, limestone, and red rock	425	425	
				Hurry-up sand	850	25	
				Slate and limestone	875	125	
				Hurry-up sand	1000	25	
				Gas sand	1210	......	Very little gas at 1210 feet.
				Salt sand	1250	50	
				Big Injun sand	1406	203	Water at 1460 feet.
				Squaw sand	1700	25	
				Red rock and slate	2088	185	Depth of well, 2190 feet.
				Hundred-foot sand	2173	13	

[a] Probably Upper Freeport coal.
[b] Probably Sewickley coal.
[c] These are the Third, Fourth, and Fifth sands of the Venango group.
[d] Butler Thirty-foot sand.
[e] This is probably the Nineveh Thirty-foot sand.

Partial well records from Burgettstown and Carnegie quadrangles—Continued.

County and township.	Name.	Owner.	Altitude of collar.	Formation.	Depth to top.	Thickness.	Remarks.
WASHINGTON CO.—Con.			Feet.		Feet.	Feet.	
Mount Pleasant	Parkinson		1228	Pittsburg coal and black slate	185	30	
				Limestone and slate	215	70	
				Sand and limestone	645	20	
				Big lime	1260	42	
				Keener sand	1302	10	
				Big Injun sand	1329	106	
				Bitter Rock sand	1740	10	
				Berea sand[a]	1835	13	
				Hundred-foot sand	1973	42	
				Gordon sand	2198	7	
Chartiers	J. C. McNary	Manufacturers Light & Heat Co.	1175	Pittsburg coal	60		
				Gantz sand	1385		
				Fifty-foot sand	1910		
				Gordon Stray sand	2074		
				Gordon sand	2125		
				Fourth sand	2174		
				Fifth sand	2230	......	Depth of well, 2410 feet.
Chartiers	T. Thompson	Philadelphia Co	1212	Pittsburg coal	205		
				Salt sand	1070	80	
				Big Injun sand	1317	230	
				Thirty-foot sand[b]	1870	50	
				Gantz sand	2000	15	
				Fifty-foot sand	2030	56	
				Gordon sand	2300	40	
				Hundred-foot sand[c]	2380	20	Depth of well, 2451 feet.
Chartiers	T. H. Sharp No. 1		978	Pittsburg coal	135		
				Gas sand	900	20	Gas in Fifth at 2360 feet.
				Salt sand	1085	90	
				Big Injun sand	1275	215	
				Thirty-foot shells[b]	1800	100	
				Gantz sand	1960	35	
				Fifty-foot sand	2005	40	
				Gordon Stray sand	2190	25	
				Gordon sand	2117	23	
				Fifth sand	2355	10	
Cecil	C. Carter	J. W. Conrad & Co	1035	Pittsburg coal	225	6	
				Salt sand	1180	120	Salt water rose to 150 feet of top.
				Gantz sand	2089	35	
				Fifty-foot sand	2124	50	
				Thirty-foot sand[d]	......	......	Slate and shells. Runs into Gordon.
				Gordon Stray sand	2305		
				Gordon (?) sand	2354	13	
				Fourth sand	2295	20	Mostly slate and shells.
				Fifth sand	2458	14	Six-foot sand at top; rest slate and shells. Depth of well, 2506 feet.
Cecil	S. Conners No. 3	Manufacturers Light & Heat Co.	1012 +10	Pittsburg coal	134	6	
				Murphy sand	315	40	
				Sand	505	25	
				Hurry-up sand	550	10	
				Coal	705	5	
				Coal	800	5	
				Sand	860	15	
				Sand	900	5	
				Sand	1000	50	
				Salt sand	1075	85	Water at 1090 feet.
				Sand	1170	20	
				Sand	1225	10	Salt or Gas sand.
				Coal	1235	5	
				Big Injun sand	1296	184	
				Squaw sand	1540	20	
				Sand	1600	15	
				Thirty-foot sand[b]	1815	70	
				Gantz sand	1972	22	
				Fifty-foot sand	2007	60	
				Thirty-foot sand[e]	2125	25	Gas at 2008 feet.
				Stray sand	2185	38	
				Gordon sand	2225	33	Oil at 2237 feet.
				Fourth sand	2280	11	Slate "break" at 2287-2291 feet.
				Fifth sand	2343	16	Oil at 2347 feet.
Cecil	Annie Scott No. 1	South Penn Oil Co	1038	Pittsburg coal	180		
				Fifty-foot sand	2060		
				Gordon sand	2280	20	
				Fourth sand	2338	10	
				Fifth sand	2403	16	Depth of well, 2434 feet.
Cecil	Robins No. 2	South Penn Oil Co	1174	Salt sand	1108	175	
				Big Injun sand	1340	130	Slate and shells for 55 feet.
				Squaw sand	1525	100	
				Fifty-foot sand	2000	60	
				Hundred-foot sand	2140	60	
				Gordon Stray sand	2332	15	(Gordon (?) sand.)
				Gordon sand	2366	21	(Fourth sand.) Depth of well, 2394 feet.
Upper St. Clair	J. V. Gilfillan No. 1	Manufacturers Light & Heat Co.	1140	Pittsburg coal	287	6	Depth of well, 2350 feet.
				Salt sand	1187	138	Water at 1275 feet.
				Big lime	1388	37	
				Big Injun sand	1425	235	
				Thirty-foot sand[b]	2025	42	
				Gantz sand	2159	35	
				Fifty-foot sand	2195	65	Gas at 2200 feet.
				Gordon Stray sand	2315	25	Gas at 2334 feet.

[a] Or Butler Thirty-foot sand.
[b] Butler Thirty-foot sand.
[c] Probably Fourth sand.
[d] This is probably the Nineveh Thirty-foot sand.
[e] Nineveh Thirty-foot sand.

Partial well records from Burgettstown and Carnegie quadrangles—Continued.

County and township.	Name.	Owner.	Altitude of collar.	Formation.	Depth to top.	Thickness.	Remarks.
WASHINGTON CO.—Con.			*Feet.*		*Feet.*	*Feet.*	
Upper St. Clair	J. A. Fife No. 1	Manufacturers Light & Heat Co.	......	Pittsburg coal	270	6	Depth of well, 2365 feet.
				Gas sand	963	17	
				Salt sand	1165	185	Water at 1250 and 1320 feet.
				Big Injun sand	1420	250	
				Thirty-foot sand [a]	2040	20	
				Gantz sand	2171	34	
				Fifty-foot sand	2205	32	
				Thirty-foot sand [b]	2255	15	Gas at 2220 feet.
				Gordon Stray sand	2315	34	
Upper St. Clair	Espy Heirs No. 1	Manufacturers Light & Heat Co.	1068	Pittsburg coal	200	7	Depth of well, 2270 feet.
				Salt and	1170	55	Water at 1215 feet.
				Big Injun sand	1340	245	
				Thirty-foot sand [a]	1880	60	
				Gantz sand	2078	22	
				Fifty-foot sand	2100	78	Gas at 2126 feet.
				Thirty-foot (?) sand [b]	2236	34	Gas at 2258 feet.
Titus and North Strabane	H. B. McMurry No. 1	Lyle & McClay	991	Pittsburg coal	188	......	Depth of well, 2505 feet.
				Salt sand	1110	80	Water.
				Big lime	1310	40	
				Big Injun sand	1350	250	
				Thirty-foot sand [a]	1900	75	Shells.
				Gantz sand	2080	40	
				Fifty-foot sand	2128	6	Oil and water.
				Gordon Stray sand	2260	30	
				Gordon sand	2345	30	
				Fourth sand	2395	25	
				Fifth sand	2445	35	Some gas.
Titus and North Strabane	M. Douglas No. 1	Manufacturers Light & Heat Co.	1062	Pittsburg coal	242	......	Depth of well, 2560 feet.
				Salt sand	1061	225	Gas and water at 1086 feet.
				Big Injun sand	1375	300	
				Gantz sand	2131	12	
				Fifty-foot sand	2155	45	
				Thirty-foot sand [b]	2284	42	Gas at 2303 feet.
				Gordon sand	2391	54	
				Fourth sand	2480	20	
				Fifth sand	2523	36	Gas at 2528 feet.
Titus and North Strabane	C. R. McMurray No. 1	Lyle & McClay	1000	Pittsburg coal	208	......	Depth of well, 2566 feet.
				Salt sand	1160	65	Water.
				Big lime	1355	30	
				Big Injun sand	1385	235	
				Thirty-foot sand [a]	1930	100	Shells.
				Gantz sand	2110	35	
				Fifty-foot sand	2145	13	Oil and water at 2150.
				Gordon Stray sand	2280	20	
				Gordon sand	2360	30	
				Fifth sand	2465	35	
Titus and North Strabane	Williams No. 1	Lyle & McClay	1050	Pittsburg coal	310	......	Depth of well, 4475 feet (cable measurement).
				Salt sand	1295	25	
				Big Injun sand	1470	240	Water at 1295 feet.
				Thirty-foot sand [a]	2000	140	Shells.
				Gantz sand	2195	45	
				Fifty-foot sand	2240	5	Dry.
				Gordon Stray sand	2380	20	
				Gordon sand	2450	40	
				Fifth sand	2567	30	Gas at 2572 feet.
Titus and North Strabane	J. H. McMurray No. 3	Lyle & McClay	1085	Pittsburg coal	296	......	Depth of well, 2233 feet.
				Salt sand	1210	80	
				Maxton sand	1420	20	Gas at 1270 feet.
				Big lime	1440	20	
				Big Injun sand	1460	240	
				Thirty-foot sand [a]	1950	100	
				Gantz sand	2170	40	Oil and water at 2217-2224 feet.
				Fifty-foot sand	2210	23	
Titus and North Strabane	J. L. McNairy No. 2	Manufacturers Light & Heat Co.	1050	Pittsburg coal	245	6	Depth of well, 2860 feet.
				Gas sand	1140	45	
				Salt sand	1220	30	Water at 1240 feet.
				Mountain lime [c]	1355	12	
				Maxton sand	1367	5	
				Big lime	1372	38	
				Big Injun sand	1417	233	Show of gas at 1521 feet.
				Thirty-foot sand [a]	1990	60	
				Gantz sand	2123	30	
				Fifty-foot sand	2153	20	Show of oil at 2168 feet; best sand at 2175-2183 feet.
				Thirty-foot sand [b]	2340	20	
				Stray sand	2375	16	
				Gordon sand	2395	25	Gas at 2397 feet.
				Fourth sand	2450	13	
				Fifth sand	2492	35	Gas at 2505 feet.

[a] Butler Thirty-foot sand. [b] Nineveh Thirty-foot sand. [c] Little lime.

Partial well records from Burgettstown and Carnegie quadrangles—Continued.

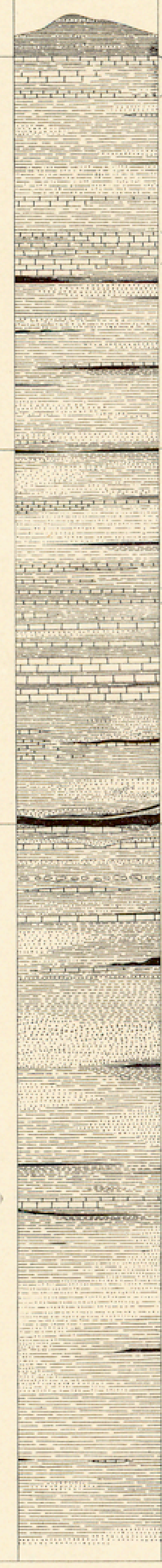
County and township.	Name.	Owner.	Altitude of collar.	Formation.	Depth to top.	Thickness.	Remarks.
WASHINGTON CO.—Con.			*Feet.*		*Feet.*	*Feet.*	
Titus and North Strabane	J. McDowell No. 1	Lyle & McClay	910	Pittsburg coal	215	......	Depth of well, 2614 feet.
				Salt sand	1180	45	
				Big lime	1370	20	
				Big Injun sand	1390	240	
				Thirty-foot sand [a]	1930	90	Shells.
				Gantz sand	2100	33	Gas at 2120 feet.
				Fifty-foot sand	2143	38	Gas and show of oil at 2150 feet.
				Gordon Stray sand	2250	20	
				Gordon sand	2350	30	Gas at 2250 feet.
				Fourth sand	2410	20	
				Fifth sand	2468	12	
ALLEGHENY COUNTY.							
North Fayette	McMurry No. 4	South Penn Oil Co	1054	Pittsburg coal	75		
				Salt sand	940	255	
				Big Injun sand	1195	250	
				Hundred-foot sand	1955	61	
				Gordon sand	2183	23	
				Fifth sand	2307		
				First pay	2313	11	
South Fayette	J. C. Stonescraper No 1	......	1187	Pittsburg coal	60	5	
				Hurry-up sand	142	38	Upper Freeport coal 612-620 feet; Lower Freeport at 640 feet; gas in Stray.
				Salt sand	965	225	
				Big Injun sand	1200	100	
				Thirty-foot sand [a]	1785	30	
				Hundred-foot sand	1973	45	
				Thirty-foot sand [b]	2088	26	
				Stray sand	......	15	
				Gordon sand	2180	28	
				Fourth sand	2254	15	Pay at 2264 feet.
				Fifth sand	2317	15	Depth of well, 2335 feet.
South Fayette	Troutman No. 1 (formerly Stewart No. 1).	......	890	Hurry-up sand	350	......	Water.
				Salt sand	850		
				Gantz sand	1615	......	Black oil and water.
				Hundred-foot sand	1651	40	
				Thirty-foot sand [b]	1774	23	
				Gas sand	1808	19	
				Gordon sand	1907	42	Gas at 1911 feet.
Stowe	Nichol No. 2	S. D. Robison	1110	Big Injun sand	985	280	
				Squaw sand	1325	60	
				Gas sand	1600	103	Water at 1633 feet.
				Hundred-foot sand	1740	110	
				Thirty-foot sand [b]	1910	34	
				Stray sand	1969	28	Gas at 1993 feet.
				Gordon sand	2006	21	
				Fourth sand	2062	33	
				Fifth sand	2129	40	Oil and gas at 2141 feet; oil flowing 40 barrels per hour at 2147 feet.
Pittsburg	Gas Well No. 2	Pittsburg Forge & Iron Co.	724	Big Injun sand	630	250	Bottom of well, 1799 feet.
				Squaw sand	920	110	
				Salt sand	1250	110	
				Hundred-foot sand	1380	122	Oil and gas.
				Thirty-foot sand [b]	1556	31	Small gas.
				Third sand	1660	18	Little gas.
				Fourth sand	1706	37	Nothing; rock very hard.
				Fifth sand	1768	......	Strong gas in Fifth sand at 1790 feet.
Collier	Mary Gordon No. 1	......	1047	Pittsburg coal	68	......	Depth of well, 2350 feet.
				Salt sand	960		
				Hundred-foot sand	2005		
				Thirty-foot sand [b]	2122		
				Gordon red sand	2190		
				Gordon white sand	2211		
				Fourth sand	2285		
				Fifth sand	2340		
Collier	F. B. Nimick	Philadelphia Co	850 +4	Big Injun sand	1120	300	Depth of well, 2255 feet.
				Squaw sand	1485	80	
				Hundred-foot sand	1842	110	
				Thirty-foot sand [b]	2010	22	
				Gordon sand	2080	45	
				Fourth sand	2160	20	
				Fifth sand	2220	13	
Scott	W. Hope No. 1	J. L. Downing	......	Gas sand	848	......	No gas.
				Salt sand	890	......	Dry; at 900 feet large flow of gas; 905-940 feet salt water.
				Big Injun sand	1135	50	
				Squaw sand	1415	125	
				Hundred-foot sand	1865	......	Show of oil at 1975 feet; salt water and light gas.
				Thirty-foot sand [b]	2030	30	
				Gordon (?) sand	2180		
				Fourth (?) sand	2200	......	Dry.
				Fifth sand	2285	20	

[a] Butler Thirty-foot sand. [b] Nineveh Thirty-foot sand.

COLUMNAR SECTION

GENERALIZED SECTION OF THE ROCKS EXPOSED IN THE BURGETTSTOWN AND CARNEGIE QUADRANGLES.

SCALE: 1-INCH=100 FEET.

System.	Series.	Formation.	Symbol.	Section.	Thickness in Feet.	Minor Divisions.	Character and Distribution of Minor Divisions.	General Character of Formation.
CARBONIFEROUS	PERMIAN (DUNKARD GROUP)	Greene formation.	Cg		40+			Dark shale and coarse argillaceous sandstone.
		Washington formation.	Cw			Upper Washington limestone member.	Dark bluish-gray compact limestone; weathers light gray.	Sandstone, shale, limestone, and thin coals; Washington coal near middle.
					(0-5)	Jollytown limestone member.		
						Jollytown coal.	Thin coal, local.	
						Middle Washington limestone member.	Hard brecciated and fossiliferous limestone.	
					275	Lower Washington limestone member.	Light bluish-gray compact limestone; weathers yellowish.	
						Washington coal, 7 to 8 feet thick.	Persistent, with many thick partings.	
						Washington sandstone member.		
						Little Washington coal, 6 to 12 inches thick.	Thin coal, local.	
						Waynesburg "B" coal.	Thin coal, local.	
						Waynesburg "A" coal.	Persistent coal of medium thickness.	
						Split of Waynesburg "A" coal.		
						Waynesburg sandstone member.	Coarse flaggy sandstone.	
						Cassville shale member.		
	PENNSYLVANIAN	Monongahela formation.	Cm			Waynesburg coal.	Mined for local use.	Gray shale and limestone and some sandstone; Waynesburg coal at top and Pittsburg coal at base.
						Little Waynesburg coal.	Thin coal or bituminous shale.	
						Waynesburg limestone member.		
						Uniontown sandstone member.	Sandy shale and local hard layers of sandstone.	
						Uniontown coal, 0 to 2 feet thick.	Fairly good coal in places, generally underlain by clay.	
						Uniontown limestone member.	Alternating shale and lenticular beds of limestone.	
					260	Bulger limestone bed. / Dinsmore limestone bed. } Benwood limestone member.	Nonfossiliferous fine-grained gray compact limestone, with interbedded shale and sandstone.	
						Sewickley coal.	Thin coal, local.	
						Redstone coal.	Thin coal.	
						Pittsburg sandstone member.	Shale and sandstone, in part cross-bedded.	
						Pittsburg Rider or Rooster seam.	Variable coal, locally workable.	
						Pittsburg coal.	Valuable coal bed.	
		UNCONFORMITY						
		Conemaugh formation.	Ccm				Concretionary shale.	Gray or greenish shale, sandstone, thin coals and some limestone.
						Little Pittsburg coal, 0 to 1 foot thick.		
						Lower Pittsburg limestone member.	Thin, irregular limestone.	
					(5-30)	Connellsville sandstone member.		
						Little Clarksburg coal, 0 to 7 feet.	Pockety coal; locally valuable bed.	
					(1-3)	Clarksburg limestone member.		
						Morgantown sandstone member.	Coarse variable sandstone.	
						Elk Lick coal, 0 to 18 inches thick.	Thin coal.	
						Elk Lick clay bed.		
						Birmingham shale member.	Considerable sandy shale and some sandstone.	
					500+	Berlin coal.	Thin to thick coal.	
			(Cam)			Ames limestone member.	Greenish-gray impure limestone, locally workable.	
						Friendsville or Harlem coal, 0 to 2 feet thick.		
						Saltsburg sandstone member.	Shaly sandstone	
						Bakerstown coal.	Thin coal, local.	
						Brush Creek coal.		
						Mahoning sandstone member.	Heavy-bedded coarse sandstone.	

SECTIONS OF DEEP WELLS IN THE BURGETTSTOWN AND CARNEGIE QUADRANGLES

SCALE: 1 INCH = 400 FEET

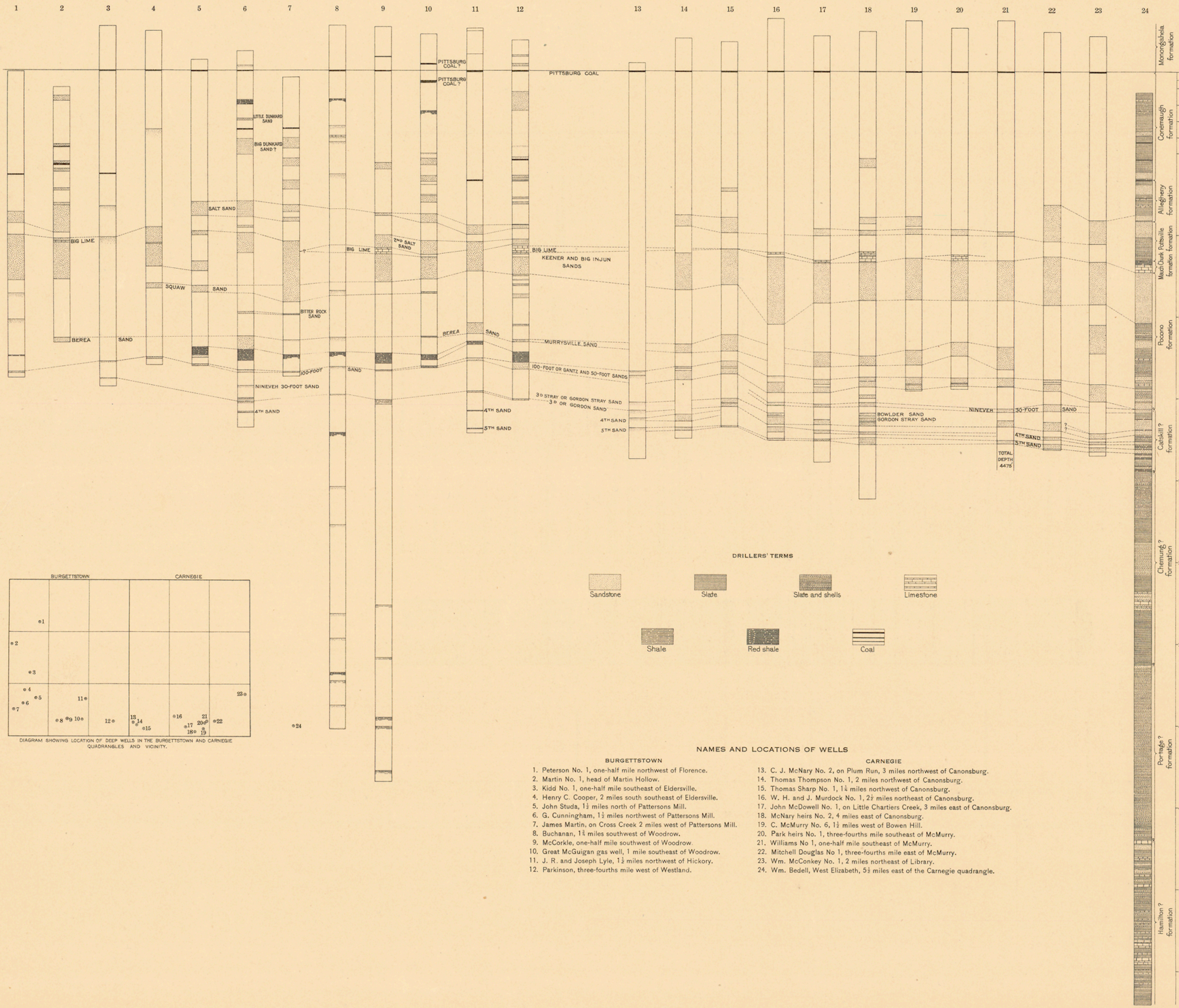


DIAGRAM SHOWING LOCATION OF DEEP WELLS IN THE BURGETTSTOWN AND CARNEGIE QUADRANGLES AND VICINITY.

NAMES AND LOCATIONS OF WELLS

BURGETTSTOWN

1. Peterson No. 1, one-half mile northwest of Florence.
2. Martin No. 1, head of Martin Hollow.
3. Kidd No. 1, one-half mile southeast of Eldersville.
4. Henry C. Cooper, 2 miles south southeast of Eldersville.
5. John Studa, 1½ miles north of Pattersons Mill.
6. G. Cunningham, 1½ miles northwest of Pattersons Mill.
7. James Martin, on Cross Creek 2 miles west of Pattersons Mill.
8. Buchanan, 1¾ miles southwest of Woodrow.
9. McCorkle, one-half mile southwest of Woodrow.
10. Great McGuigan gas well, 1 mile southeast of Woodrow.
11. J. R. and Joseph Lyle, 1½ miles northwest of Hickory.
12. Parkinson, three-fourths mile west of Westland.

CARNEGIE

13. C. J. McNary No. 2, on Plum Run, 3 miles northwest of Canonsburg.
14. Thomas Thompson No. 1, 2 miles northwest of Canonsburg.
15. Thomas Sharp No. 1, 1¼ miles northwest of Canonsburg.
16. W. H. and J. Murdock No. 1, 2½ miles northeast of Canonsburg.
17. John McDowell No. 1, on Little Chartiers Creek, 3 miles east of Canonsburg.
18. McNary heirs No. 2, 4 miles east of Canonsburg.
19. C. McMurry No. 6, 1½ miles west of Bowen Hill.
20. Park heirs No. 1, three-fourths mile southeast of McMurry.
21. Williams No 1, one-half mile southeast of McMurry.
22. Mitchell Douglas No 1, three-fourths mile east of McMurry.
23. Wm. McConkey No. 1, 2 miles northeast of Library.
24. Wm. Bedell, West Elizabeth, 5½ miles east of the Carnegie quadrangle.

TOPOGRAPHY

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COMMISSIONERS

PENNSYLVANIA
BURGETTSTOWN QUADRANGLE

LEGEND

RELIEF
printed in brown

Figures
showing heights above mean sea level instrumentally determined

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

Depression contours

DRAINAGE
printed in blue

Streams

Lakes, ponds, and reservoirs

CULTURE
printed in black

Roads and buildings

Churches, school houses, and cemeteries

Private and secondary roads

Railroads

Tunnels

Bridges

County lines

Township lines

City, village, and borough lines

Triangulation stations

Bench marks

H. M. Wilson, Geographer.
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Topography by M. J. Munn, Assistants, E. W. Mc Crary, and J. H. Wilkie.
Control by D. H. Baldwin and W. T. Griswold.
Surveyed in 1904.

SURVEYED IN COOPERATION WITH THE STATE OF PENNSYLVANIA.

APPROXIMATE MEAN DECLINATION 1904.

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 1906, reprinted July 1910.

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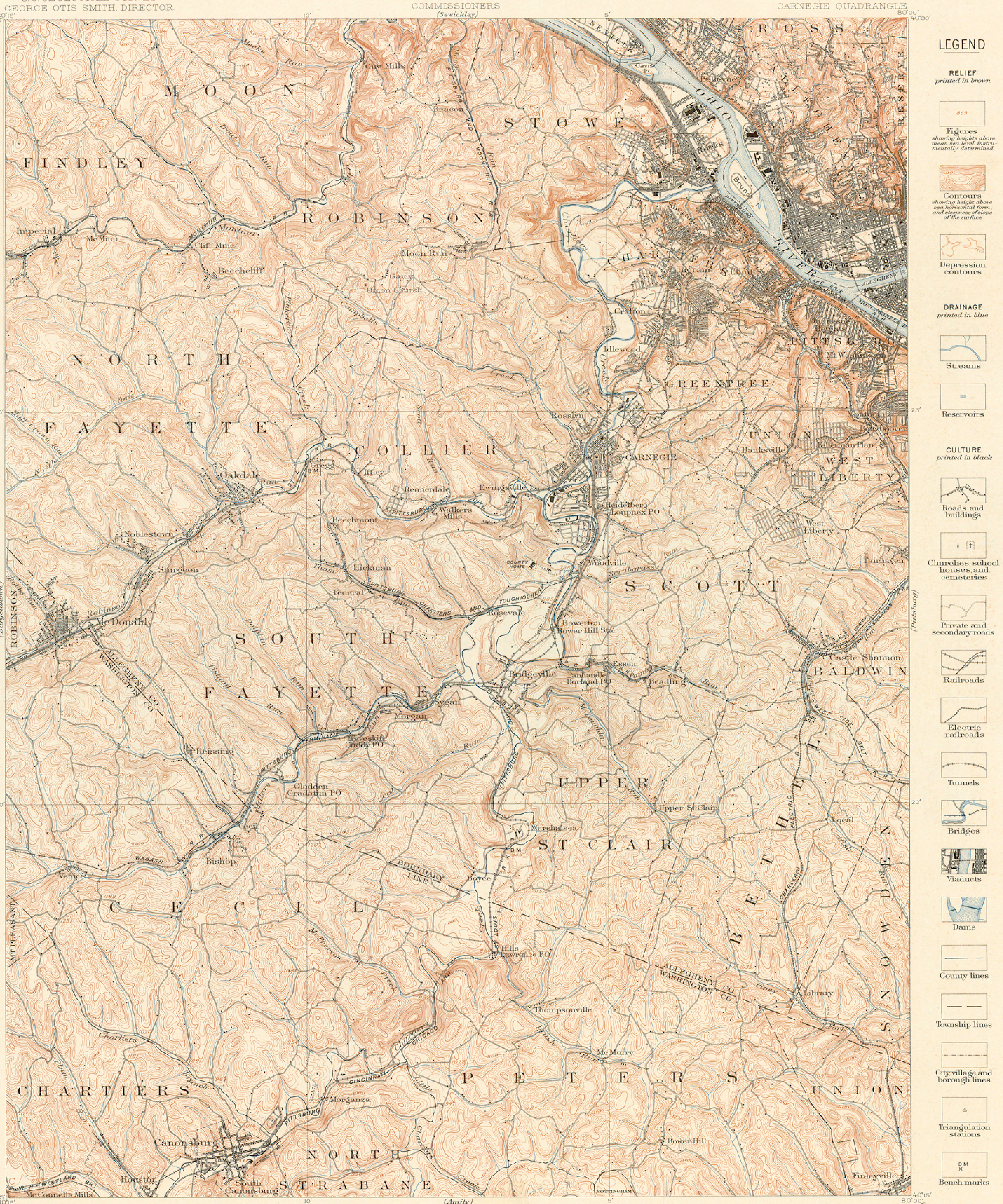
CARNEGIE QUADRANGLE



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AREAL GEOLOGY

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PENNSYLVANIA
BURGETTSTOWN QUADRANGLE

LEGEND

SEDIMENTARY ROCKS

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

QUATERNARY

Recent

Qal — Alluvium *(in flood plains of present streams)*

Pleistocene

Wisconsin?

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

Kansan?

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

CARBONIFEROUS

Permian

Dunkard group?

Cg — Greene formation *(dark shale and coarse argillaceous sandstone)*

Cw — Washington formation *(sandstone, shale, limestone, and thin coals; Washington coal near middle)*

Pennsylvanian

Cm — Monongahela formation *(gray shale and limestone and some sandstone, Waynesburg coal at top and Pittsburg coal at base)*

UNCONFORMITY?

Ccm — Conemaugh formation and Ames limestone member *(gray or greenish shale, sandstone, thin coals, and some limestones)*

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CARNEGIE QUADRANGLE

LEGEND

SEDIMENTARY ROCKS

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QUATERNARY

Recent

Qal — Alluvium *(in flood plains of present streams)*

Pleistocene

Wisconsin?

Qlg — Late glacial gravel *(gravel, sand, and silt of glacial and local material on low river terraces)*

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

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

Kansan?

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

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

CARBONIFEROUS

Permian

Cw — Washington formation *(sandstone, shale, limestone, and thin coals, Washington coal near middle)*

?

Pennsylvanian

Cm — Monongahela formation *(gray shale and limestone and some sandstone, Waynesburg coal at top and Pittsburg coal at base)*

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Ccm, Cam — Conemaugh formation and Ames limestone member *(gray or greenish shale, sandstone, thin coals, and some limestones)*

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SURVEYED IN COOPERATION WITH THE STATE OF PENNSYLVANIA.

3½° TRUE NORTH MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1904.

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1 ½ 0 1 2 3 4 Miles

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STRUCTURE AND ECONOMIC GEOLOGY

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PENNSYLVANIA
BURGETTSTOWN QUADRANGLE

40°15′ 80°30′ — 80°15′ 40°15′

H. M. Wilson, Geographer.
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LEGEND

SEDIMENTARY ROCKS

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

QUATERNARY

Recent

Qal — Alluvium *(in flood plains of present streams)*

Pleistocene

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

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

CARBONIFEROUS

Permian — *Dunkard group*

Cg — Greene formation *(dark shale and coarse argillaceous sandstone)*

Cw (wht) — Washington formation *(sandstone, shale, limestone, and thin coals, Washington coal near middle)*

Pennsylvanian

Cm (wb, pb) — Monongahela formation *(gray shale and limestone and some sandstone, Waynesburg coal at top and Pittsburg coal at base)*

UNCONFORMITY?

Ccm (Cam) — Conemaugh formation and Ames limestone member *(gray or greenish shale, sandstone, thin coals, and some limestones)*

ECONOMIC AND STRUCTURE DATA

Outcrop of workable coals
wht, Washington coal
wb, Waynesburg coal
pb, Pittsburg coal

900 — *Structure contours drawn on the bottom of the Pittsburg coal* *(Contour interval is 10 feet; datum is mean sea level)*

⚒ *Coal mines*

Note: The most valuable coal is the Pittsburg, at the base of the Monongahela formation; 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.

STRUCTURE AND ECONOMIC GEOLOGY

STATE OF PENNSYLVANIA
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CARNEGIE QUADRANGLE

LEGEND

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SURVEYED IN COOPERATION WITH THE STATE OF PENNSYLVANIA.

TRUE NORTH / MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1904.

Scale $\frac{1}{62500}$

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OIL AND GAS

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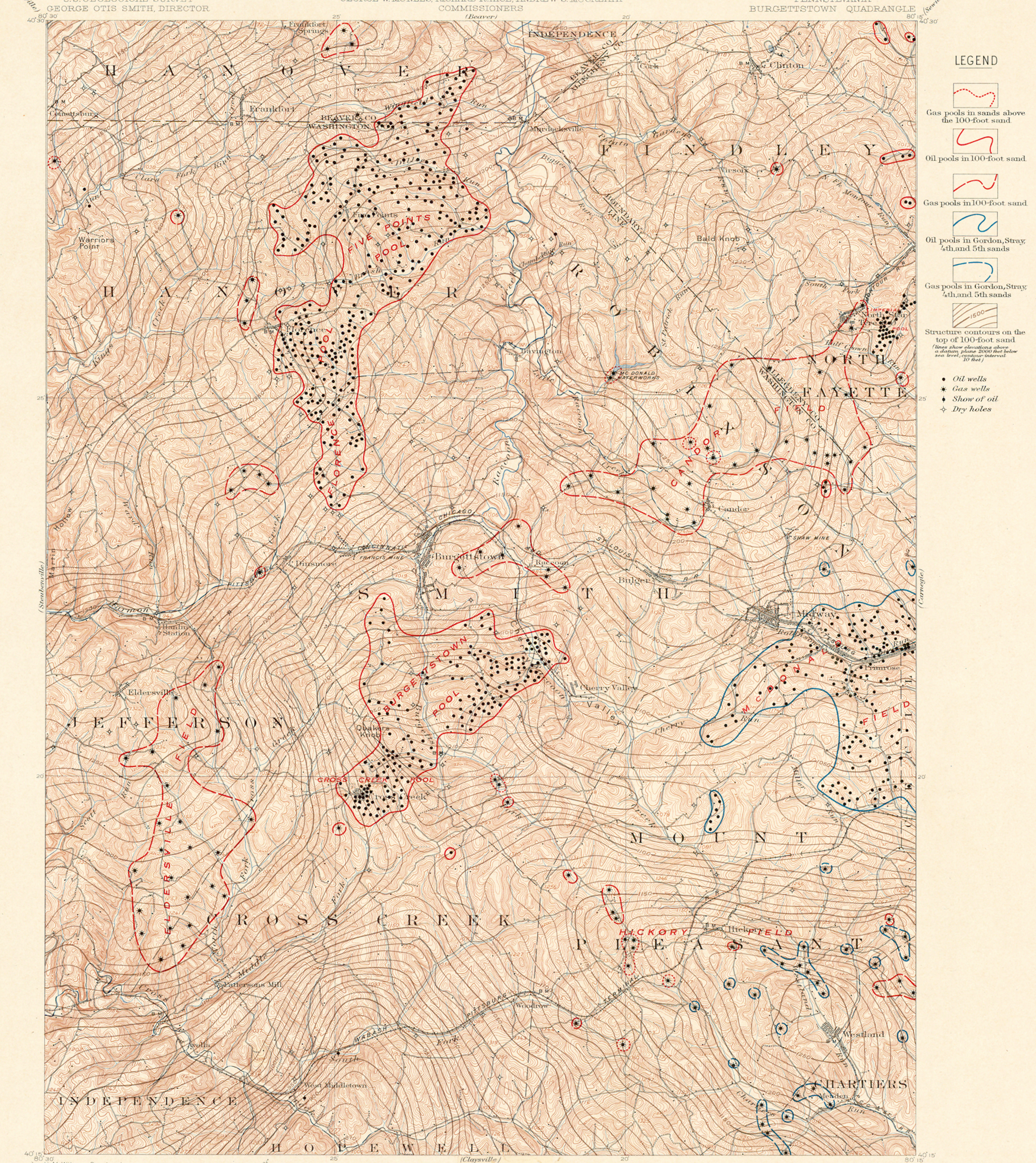
PENNSYLVANIA
BURGETTSTOWN QUADRANGLE



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Edition of Dec 1910.

Geology by W. T. Griswold, and M. J. Munn, under the direction of M. R. Campbell.
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OIL AND GAS

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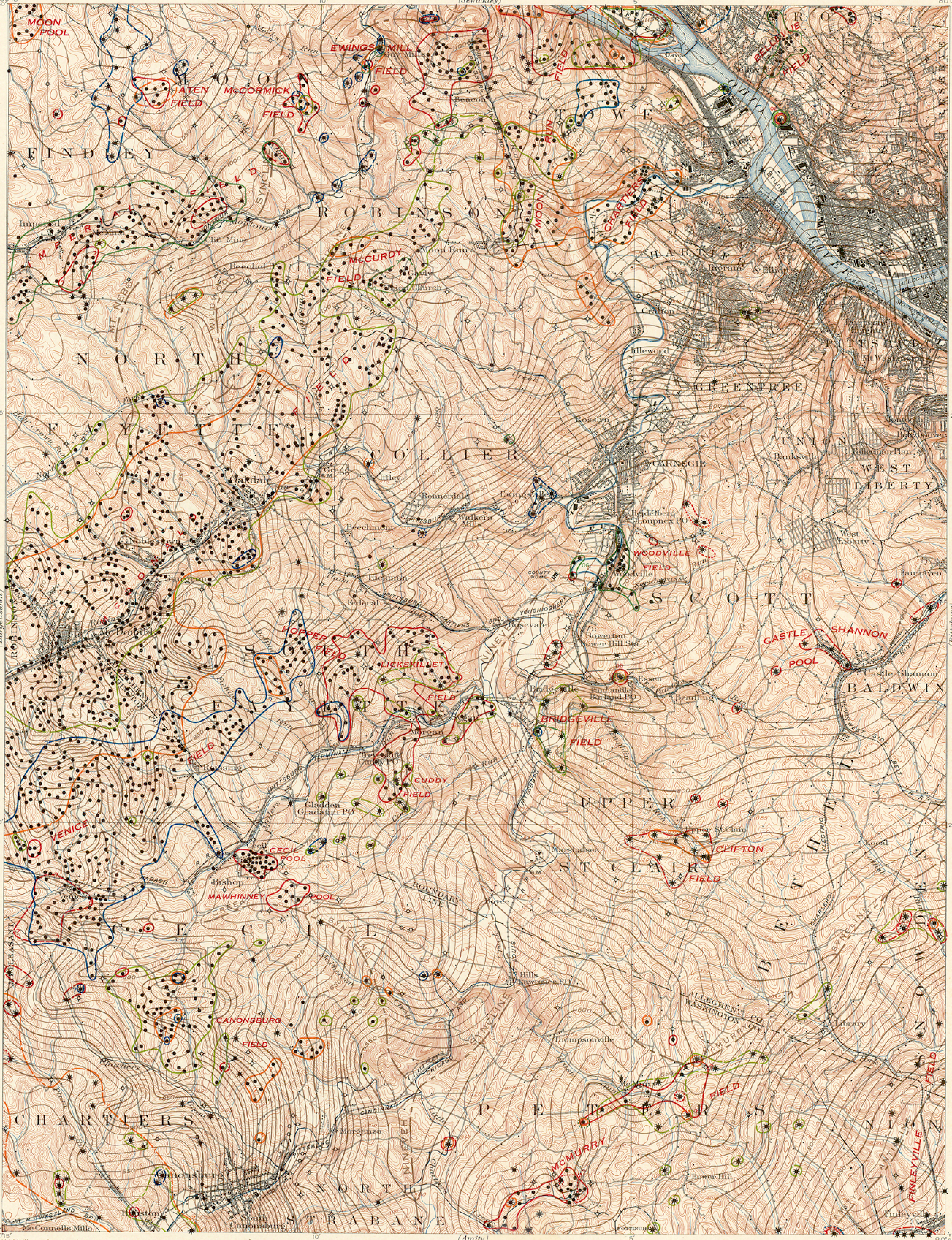
PENNSYLVANIA
CARNEGIE QUADRANGLE



LEGEND

- Oil pools in Salt sand
- Oil pools in Big Injun sand
- Gas pools in Big Injun sand
- Oil pools in 100-foot sand (OG, indicates oil and gas)
- Gas pools in 100-foot sand
- Oil pools in 30-foot sand (OG, indicates oil and gas)
- Gas pools in 30-foot sand
- Oil pools in Gordon and Stray sands
- Gas pools in Gordon and Stray sands
- Oil pools in 4th sand
- Gas pools in 4th sand
- Oil pools in 5th sand (OG, indicates oil and gas)
- Gas pools in 5th sand
- Structure contours on the top of Gordon sand (lines show elevations above a datum plane 2000 feet below sea level, contour interval 10 feet)

Oil wells
Gas wells
Oil and gas wells
Show of oil
Show of gas
Show of oil and gas
Dry holes
Holes about which nothing is recorded

(Claysville)

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SURVEYED IN COOPERATION WITH THE STATE OF PENNSYLVANIA.

(Brownsville)

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 in 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		Ꞧ	Peacock-blue.
Paleozoic	Carboniferous	Permian Pennsylvanian Mississippian	C	Blue.
	Devonian		D	Blue-gray.
	Silurian		S	Blue-purple.
	Ordovician		O	Red-purple.
	Cambrian		Ꞓ	Brick-red.
	Algonkian		A	Brownish red.
	Archean		Æ	Gray-brown.

SURFACE FORMS.

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

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

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

THE VARIOUS GEOLOGIC SHEETS.

Areal geology map.—The map showing the areas occupied by the various formations is called an *areal geology map*. On the margin is a *legend*, which is the key to the map. To ascertain the meaning of any color or pattern and its letter symbol the reader should look for that color, pattern, and symbol in the legend, where he will find the name and description of the formation. If it is desired to find any particular formation, its name should be sought in the legend and its color and pattern noted; then the areas on the map corresponding in color and pattern may be traced out. The legend is also a partial statement of the geologic history. In it the names of formations are arranged in columnar form, grouped primarily according to origin—sedimentary, igneous, and crystalline of unknown origin—and within each group they are placed in the order of age, so far as known, the youngest at the top.

Economic geology map.—The map representing the distribution of useful minerals and rocks and showing their relations to the topographic features and to the geologic formations is termed the *economic geology map*. The formations that appear on the areal geology map are usually shown on this map by fainter color patterns and the areas of productive formations are emphasized by strong colors. A mine symbol shows the location of each mine or quarry and is accompanied by the name of the principal mineral mined or stone quarried. If there are important mining industries or artesian basins in the area special maps to show these additional economic features are included in the folio.

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

The geologist is not limited, however, to natural and artificial cuttings for his information concerning the earth's structure. Knowing the manner of formation of rocks and having traced out the relations among the beds on the surface, he can infer their relative positions after they pass beneath the surface and can draw sections representing the structure to a considerable depth. Such a section is illustrated in figure 2.

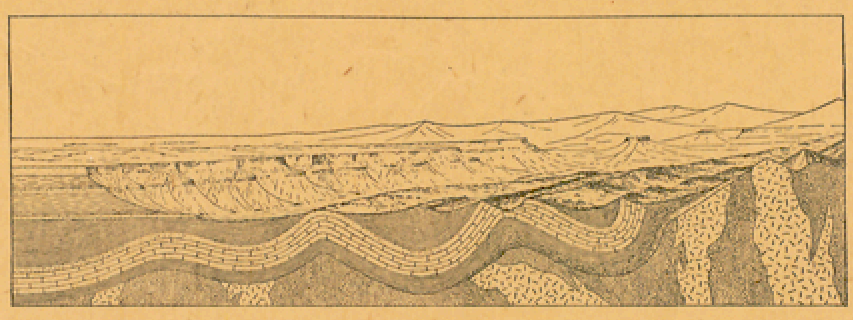

FIGURE 2.—Sketch showing a vertical section at the front and a landscape beyond.

The figure represents a landscape which is cut off sharply in the foreground on a vertical plane, so as to show the underground relations of the rocks. The kinds of rock are indicated by appropriate patterns of lines, dots, and dashes. These patterns admit of much variation, but those shown in figure 3 are used to represent the commoner kinds of rock.

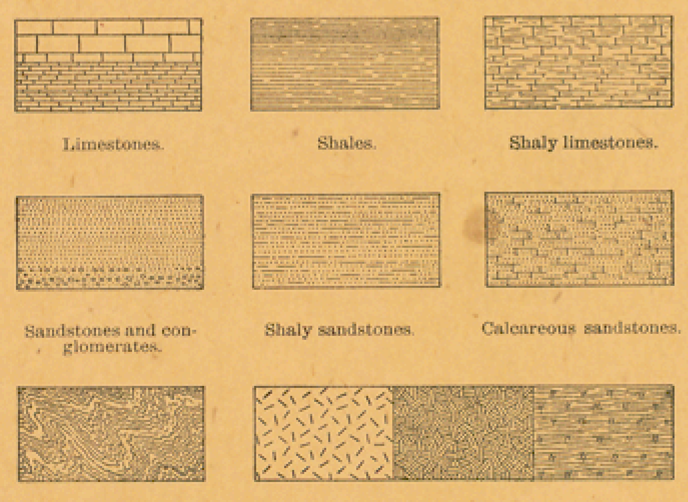

FIGURE 3.—Symbols used in sections to represent different kinds of rocks.

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

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

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

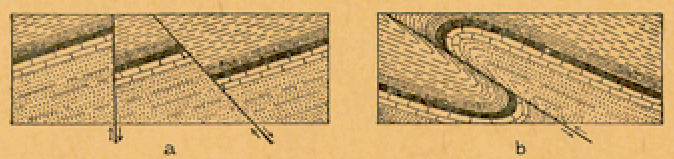

FIGURE 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* or *reverse* fault.

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

The section also shows three sets of formations, distinguished by their underground relations. The uppermost set, seen at the left, is made up of sandstones and shales, which lie in a horizontal position. These strata were laid down under water but are now high above the sea, forming a plateau, and their change of elevation shows that a portion of the earth's mass has been uplifted. The strata of this set are parallel, a relation which is called *conformable*.

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

The horizontal strata of the plateau rest upon the upturned, eroded edges of the beds of the second set shown at the left of the section. The overlying deposits are, from their position, evidently younger than the underlying deposits, and the bending and eroding of the older beds must have occurred between their deposition and the accumulation of the younger beds. The younger rocks are *unconformable* to the older, and the surface of contact is an *unconformity*.

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

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

Columnar section.—The geologic maps are usually accompanied by a *columnar section*, which contains a concise description of the sedimentary formations that occur in the quadrangle. It presents a summary of the facts relating to the character of the rocks, the thickness of the formations, and the order of accumulation of successive deposits.

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

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

GEORGE OTIS SMITH,

Director.

May, 1909.

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