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

GEOLOGIC ATLAS
OF THE
UNITED STATES

SEWICKLEY FOLIO

PENNSYLVANIA

BY

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GEOLOGIC ATLAS OF THE UNITED STATES.

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

THE TOPOGRAPHIC MAP.

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

Relief.—All elevations are measured from mean sea level. The heights of many points are accurately determined, and those of the most important ones are given on the map in figures. It is desirable, however, to give the elevation of all parts of the area mapped, to delineate the outline or form of all slopes, and to indicate their grade or steepness. This is done by lines each of which is drawn through points of equal elevation above mean sea level, the vertical interval represented by each space between lines being the same throughout each map. These lines are called *contour lines* or, more briefly, *contours*, and the uniform vertical distance between each two contours is called the *contour interval*. Contour lines and elevations are printed in brown. The manner in which contour lines express altitude, form, and grade is shown in figure 1.

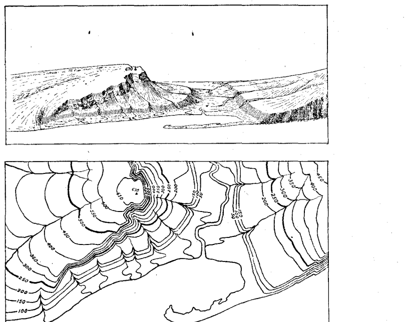

FIGURE 1.—Ideal view and corresponding contour map.

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

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

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

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

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

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

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

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

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

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

The atlas sheets, being only parts of one map of the United States, are not limited by political boundary lines, such as those of States, counties, and townships. Many of the maps represent areas lying in two or even three States. To each sheet, and to the quadrangle it represents, is given the name of some well-known town or natural feature within its limits, and at the sides and corners of each sheet are printed the names of adjacent quadrangles, if the maps are published.

THE GEOLOGIC MAPS.

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

KINDS OF ROCKS.

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

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

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

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

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

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

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

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

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

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

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

FORMATIONS.

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

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

AGES OF ROCKS.

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

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

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

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

It is many places difficult or impossible to determine the age of an igneous formation, but the relative age of such a formation can in general be ascertained by observing whether an associated sedimentary formation of known age is cut by the igneous mass or is deposited upon it. Similarly, the time at which metamorphic rocks were formed from the original masses may be shown by their relations to adjacent formations of known age; but the age recorded on the map is that of the original masses and not that of their metamorphism.

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

Patterns composed of parallel straight lines are used to represent sedimentary formations deposited in the sea, in lakes, or in other bodies of standing water. Patterns of dots and circles represent alluvial, glacial, and eolian formations. Patterns of triangles and rhombs are used for igneous formations. Metamorphic rocks of unknown origin are represented by short dashes irregularly placed; if the rock is schist the dashes may be arranged in wavy lines parallel to the structure planes. Suitable combination patterns are used for metamorphic formations known to be of sedimentary or of igneous origin. The patterns of each class are printed in various colors. With the patterns of parallel lines, colors are used to indicate age, a particular color being assigned to each system.

The symbols consist each of two or more letters. If the age of a formation is known the symbol includes the system symbol, which is a capital letter or monogram; otherwise the symbols are composed of small letters.

The names of the systems and of series that have been given distinctive names, in order from youngest to oldest, with the color and symbol assigned to each system, are given in the subjoined table.

Symbols and colors assigned to the rock systems.

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

SURFACE FORMS.

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

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

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

THE VARIOUS GEOLOGIC SHEETS.

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

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

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

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

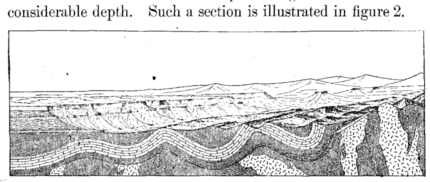

FIGURE 2.—Sketch showing a vertical section at the front and a landscape beyond.

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

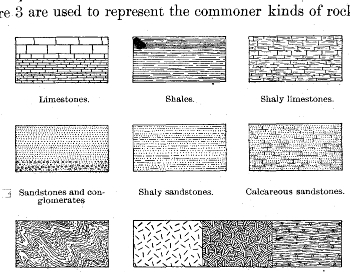

FIGURE 3.—Symbols used in sections to represent different kinds of rocks.

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

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

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

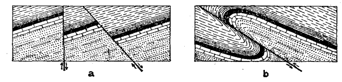

FIGURE 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* or *reverse* fault.

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

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

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

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

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

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

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

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

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

GEORGE OTIS SMITH,
Director.

May, 1909.

DESCRIPTION OF THE SEWICKLEY QUADRANGLE.

By M. J. Munn.

INTRODUCTION.

LOCATION AND AREA.

The Sewickley quadrangle is in western Pennsylvania, northwest of Pittsburg. (See fig. 1.) It extends from latitude 40° 30′ on the south to latitude 40° 45′ on the north and from longitude 80° on the east to 80° 15′ on the west, covering one-sixteenth of a square degree—an area of nearly 227 square miles. It includes parts of three counties—Allegheny, Beaver, and Butler, in its southern, northwestern, and northeastern portions respectively. The quadrangle is named from the town of Sewickley, which is in its southwestern part, on Ohio River.

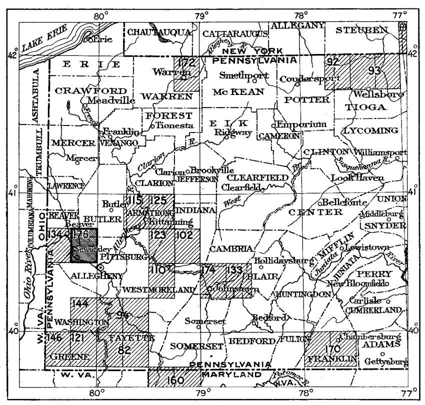

FIGURE 1.—Index map of western Pennsylvania.

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

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

GEOGRAPHY AND GEOLOGY OF THE APPALACHIAN PROVINCE.

GENERAL FEATURES.

With respect to topography and geologic structure, the Appalachian province may be divided into two nearly equal parts by a line following the eastward-facing escarpment known as the Allegheny Front through Pennsylvania, Maryland, and West Virginia and the eastern escarpment of the Cumberland Plateau (fig. 2) from Virginia to Alabama. East of this line the rocks are greatly disturbed by faulting and folding. West of the line the strata are but slightly wrinkled, the irregular folds in them decreasing in intensity toward the west.

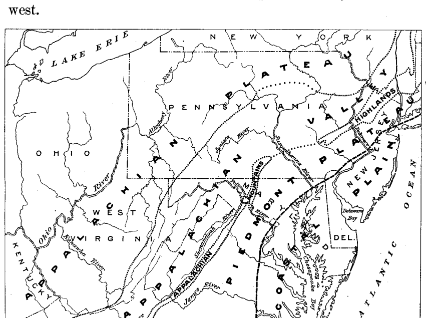

FIGURE 2.—Map of the northern part of the Appalachian province, showing its physiographic divisions and its relation to the Coastal Plain province.

Immediately east of the Allegheny Front lies a series of alternating ridges and valleys designated the Appalachian Valley, and still farther east are the Appalachian Mountains and a slightly dissected upland known as the Piedmont Plateau. West of the Allegheny Front and the border of the Cumberland Plateau lie more or less elevated plateaus, which are greatly dissected by streams and broken by a few higher ridges where minor folds affect the rocks. In contradistinction to the lowlands of the Mississippi Valley on the west and the ridges and valleys of the Appalachian Valley on the east, this part of the province has been called by Powell the Allegheny Plateaus. In current usage it is known as the Appalachian Plateau. The Sewickley quadrangle is in the Appalachian Plateau, which will therefore be described.

APPALACHIAN PLATEAU.

DRAINAGE.

The Appalachian Plateau drains almost entirely into Mississippi River, the waters in its northeastern part alone flowing either into the Great Lakes or the Atlantic Ocean through Susquehanna, Delaware, and Hudson rivers.

In the northern part of the province the arrangement of the drainage is due largely to glaciation. Before the glacial epoch all the streams north of central Kentucky probably flowed northwestward and discharged their waters through the St. Lawrence system. (See fig. 3.) The encroachment of the

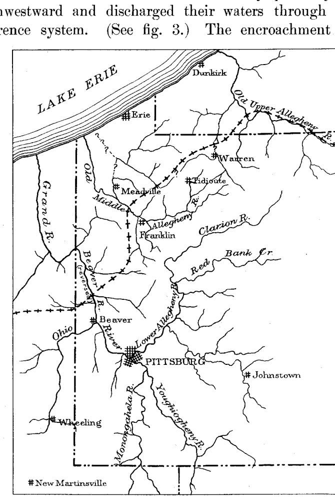

FIGURE 3.—Sketch map showing the probable preglacial drainage of western Pennsylvania. The terminal moraine is shown by broken crossed line.

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

great ice sheet closed this northern outlet, and the existing drainage lines were established. In the southern half of the province the westward-flowing streams not only drain the Appalachian Plateau, but many of them have their sources in the summits of the Blue Ridge and flow across the greater Appalachian Valley.

RELIEF.

The general surface of the Appalachian Plateau rises from an altitude of 1700 feet in southern Tennessee to 4000 feet in central West Virginia, and thence descends to an altitude of 2200 feet in southern New York. The surface also slopes in a general way to the northwest and southwest and merges into the Mississippi and Gulf plains. In the southeastern part of the plateau region, in Tennessee and Alabama, is the Cumberland Plateau. West of the Cumberland Plateau, in Tennessee and Kentucky, lies the Highland Rim, at an altitude of about 1000 feet above the sea. The region north of these well-defined plateaus as far as southern New York is greatly dissected and its plateau character is apparent only to one who takes a wide view from some elevated point and notes the nearly uniform height of the ridges and hills.

The surface of the Cumberland Plateau and perhaps also the summits of the higher ridges and hills, as well as extensive tracts of level surface at high altitudes in a broad belt along the southeastern margin of the Appalachian Plateau region, from the Cumberland Plateau to New York, are probably remnants of a peneplain, possibly the Schooley peneplain, developed on Schooley Mountain, in northern New Jersey. In the Allegheny, Monongahela, and Ohio valleys of western Pennsylvania, including the surface of the Sewickley quadrangle, there are portions of apparently broad table-lands at different elevations, which are probably remnants of former peneplains. In this region the tops of the highest hills appear to coincide with one of these old land surfaces which is probably younger than the Schooley peneplain and lies at a lower level. This surface is probably that of the Harrisburg peneplain, which is now well represented by the table-lands in the vicinity of Harrisburg, Pa. A broad upland along Allegheny, Monongahela, and Ohio valleys has been recognized as a portion of a third peneplain lower, younger, and less extensive than the Harrisburg. This peneplain was well developed between Worthington and Allegheny River in Armstrong County, Pa., and has therefore been called the Worthington peneplain.

STRATIGRAPHY.

The rocks of the Appalachian Plateau are mostly of Carboniferous age, underlain throughout the northern half of the region by the upper formations of the Devonian system. They are divided into three series—Mississippian, Pennsylvanian, and Permian. The Mississippian consists mainly of sandstones and shales, interspersed in the southeast and southwest with some thick limestone. The rocks of the Mississippian series outcrop around the border of the plateau and underlie the rocks of the Pennsylvanian series in its interior. The Pennsylvanian series, which is coextensive with the Appalachian coal field of western Pennsylvania, West Virginia, eastern Ohio, and eastern Kentucky, consists essentially of sandstones and shales but contains extensive beds of limestone and fire clay and is especially distinguished by its coal seams, one or more of which outcrop in nearly every square mile of its exposures from northern Pennsylvania to central Alabama. These coal-bearing rocks constitute the Appalachian coal field.

The Permian series consists of sandstones, shales, coals, clays, and limestone. The thickest and most extensive beds of coal and limestone are in the lower portion of the series and the shales and sandstones predominate toward the top. In the Appalachian coal fields Permian rocks cover a smaller area than the Pennsylvanian series below, being limited to the central part of the basin, in Pennsylvania, eastern Ohio, West Virginia, and northern Kentucky.

STRUCTURE.

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

Though in a broad way the structure is simple, the eastern limb of the trough is crumpled into a number of parallel folds that make the detailed structure somewhat complicated and break up and conceal the general westward dip. These undulations are similar to the great folds east of the Allegheny Front, but they are gentler and very much smaller and have been broken by only a few local faults. These minor folds are present along the southeastern margin of the basin from central West Virginia to southern New York. Many such folds also cross the northern extremity of the basin, the folded region extending at least halfway across Pennsylvania near its northern boundary. In the southern part of the State there are only six pronounced anticlines, and two of these disappear near the West Virginia boundary. Farther south the number is still less, until on Kanawha River the average westward dip is interrupted by only one or two small folds. Close examination shows that westward from the Allegheny Front the deformation decreases in intensity toward the axis of the great synclinorum, toward which also the crests of the anticlines stand at successively lower levels, so that formations or beds that are over 2000 feet above sea level at the Allegheny Front lie below sea level in the central part of the basin.

TOPOGRAPHY.

DRAINAGE.

The Sewickley quadrangle is drained by Ohio River, which traverses its southwestern portion from the head of Neville Island to the town of Freedom, and by tributaries of the Ohio. Most of the southern and western parts of the quadrangle are drained by short, rapid streams that flow directly into the river. The largest of these are Crows Run, Sewickley and Little Sewickley creeks, Killbuck Run, and Lowrie Run and its tributary, Bear Run, none of which are more than a few miles in length. Montour Run enters the Ohio from the south; nearly its whole length lies outside the quadrangle. An area in the eastern part of the quadrangle is drained by Pine Creek, which joins Allegheny River a short distance above Pittsburg. The streams north of Pine Creek basin drain into Breakneck Creek, which flows northward into Connoquenessing River, a tributary of Beaver River. The north-central portion of the quadrangle is drained by Brush Creek, which flows northwest to Connoquenessing River near its mouth. Breakneck and Brush creeks flow through broad, comparatively flat valleys, whose form presents a striking contrast to that of the narrow V-shaped valleys of many of the streams which flow directly into Ohio River.

The Allegheny is now tributary to the Ohio, and this in turn to the Mississippi. It is the main headwater tributary of the Ohio and drains an area of about 11,500 square miles, of which 2000 square miles lie in southwestern New York and 9500 square miles in northwestern Pennsylvania. Some of its affluents in Cattaraugus and Chautauqua counties, N. Y., and Erie County, Pa., have their sources on the southern slope of an elevation which overlooks Lake Erie at points only 7 to 15 miles distant from the lake, yet they take a course directly away from the lake and form no part of the St. Lawrence drainage. The apparently anomalous course of Allegheny River is due to the fact that it was formed by the union of a number of independent streams, some of which originally flowed northward into the basin of Lake Erie but were deflected by the ice sheet of the Pleistocene epoch. This is discussed more fully under the heading "Geologic history."

RELIEF.

The surface of the Sewickley quadrangle is hilly. In the portion drained by small streams flowing into Ohio River the valleys are very narrow and the bordering hillsides are precipitous at their bases, though they slope upward to flat or well-rounded summits. In this area farming is confined almost exclusively to the summits and to hillside terraces and most of the steeper slopes are forested. On the other hand, in the area drained by Brush and Breakneck creeks the valleys are wide and the hills, though as a rule flat-topped, have gentler slopes, so that almost the entire surface is arable. Most of the rocks are exposed in ledges and low cliffs along the sides of the valleys and appear near the summits at only a few places, being for the most part covered by a shallow blanket of residual soil containing rock débris.

Harrisburg upland.—Several high hills near the northern border of the quadrangle, in Cranberry Township, reach an elevation of 1360 to 1420 feet above sea level. Two hills near the northeast corner and one (Big Knob) near the northwest corner of the quadrangle reach 1380 feet. Below these high points the summits of a number of hills and ridges have elevations ranging from about 1320 feet on the eastern edge to about 1200 feet near the western edge. Nearly all these hills and ridges are flat-topped, are of small area, and are separated from one another by wide stretches of lower hills and valleys. They are sufficiently numerous, however, in Pine, Marshall, Adams, New Sewickley, and Cranberry townships to give the landscape the appearance of an undulating plain when the intervening valleys are overlooked. No wide stretch of imagination is needed to consider them the remains of a broad level surface that once stretched over the whole quadrangle, from which the higher peaks projected as well-rounded hills of low relief. This ancient surface is probably that of the Harrisburg peneplain. (See p. 10.)

The Harrisburg peneplain was the result of erosion for a long period, during which the crust of the earth in this region was subjected to little or no vertical movement. It was nearly horizontal and stood at a much lower level than its present remnants. Along the main streams of the Sewickley quadrangle, especially along Ohio River, this peneplain has been almost entirely obliterated by erosion. Numerous remnants of it occur along the ridge north and east of Lovi, where the surface of the ancient plain now coincides so closely with flat surfaces formed by the resistant Morgantown sandstone that it is difficult to distinguish between the two. Farther northwest the Morgantown sandstone rises and the surface of the peneplain becomes lower, so that it is more easily recognized. Big Knob, in New Sewickley Township, is an old residual peak which stands about 180 feet above the peneplain. This flat-topped hill is capped by a few feet of sandy shale that overlies 75 feet or more of Morgantown sandstone, which has preserved it from erosion. From this hill flat-topped ridges stretch away to the north, south, and west, standing at a uniform elevation of 1200 to 1220 feet. They are capped by hard and soft strata alike and clearly show the peneplainic nature of the surface.

Worthington upland.—About 100 feet below the Harrisburg peneplain level there are evidences of a substage of erosion over a considerable portion of the Sewickley quadrangle. This is indicated by the flat-topped hills and ridges on each side of Crows Run from its source to its mouth, at elevations ranging from 1080 to 1120 feet. It is also shown on Brush and Breakneck creeks by the top of a broad, flat terrace which stands at about 1120 feet and is especially prominent in the vicinity of Ogle and north of the road from Hendersonville to Mars. This old surface can be recognized on both sides of Ohio River from Freedom to Pittsburg. It forms a broad terrace-like belt along the tops of the river hills at elevations of 1080 to 1140 feet. This ancient surface is probably equivalent to the Worthington peneplain, described in the Kittanning folio.[a]

Parker strath.—On both sides of Ohio River from Freedom to Bellevue numerous remnants of a rock terrace capped with gravel lie 920 to 940 feet above sea level—that is, 240 to 260 feet above the river. This terrace is the remnant of a former broad, flat bottom of Ohio River. Traces of this old valley floor are found along the Ohio and Allegheny valleys from the Pennsylvania State line west of Beaver to Parker, in the northern part of Armstrong County. This rock terrace is unusually well preserved at Parker, from which it is named.

On the north side of the Ohio the broad gravel-strewn terraces southeast of the cemetery at Freedom, back of Conway and Baden, and, less strikingly apparent, in the river hills southward as far as Ambridge are remnants of the Parker strath. Between Ambridge and Bellevue it remains at many places as a narrow terrace. It is clearly marked on the steep bluff north of Leetsdale (though not represented on the topographic map) and it is marked by narrow gravel terraces at Haysville, Glenfield, Dixmont, Emsworth, Ben Avon, and Avalon. At Avalon it forms a gravel terrace on the point of the hill between Spruce Run and Ohio River, at a height of about 920 feet above sea level.

On the south side of the Ohio from Aliquippa to Coraopolis all that remains of the old valley floor is a narrow rock and talus strewn shelf a few yards wide nicked here and there in the precipitous wall of the valley. At a few points noses of hills opposite tributaries to the river carry thin deposits of river gravel at this level, and the valley walls of many of these tributaries show terraces for a considerable distance upstream. The valley of Logtown Run at Woodlawn carries remains of the abandoned valley of Raccoon Creek, which once emptied into Ohio River at this point.[b] Back of Coraopolis and Montour Junction the Parker strath is well marked by a broad bench at 900 feet above sea level, and it is also shown on the nose of the hill back of Groveton.

The Parker strath from Bellevue to Freedom shows no marked gradient. The rock benches on which gravel deposits still remain, and which are therefore intact, stand at an elevation of about 900 feet, except those at Conway and Freedom, which are probably a few feet lower.

Cut terraces.—Below the Parker strath along Ohio River a considerable number of small remnants of subsequent valley floors stand between 800 and 900 feet above sea level. These are not of uniform height and do not appear to represent periods of low gradient and consequently of horizontal cutting. They may best be considered remnants of the old valley floor that have escaped the meanderings of the river because of an increasing gradient that caused the river to deepen its bed and narrow its flood plain.

One such remnant—a broad, sloping cut terrace covered by glacial gravels—is 100 to 175 feet below the Parker strath, its higher side standing at an elevation of about 780 feet and its lower side, toward the river, at about 700 feet. This terrace is especially well developed on the north side of Ohio River. All the towns between Freedom and Osborne, as well as parts of Coraopolis, Emsworth, and probably Ben Avon, are built on it; and the higher of the two terraces at Aliquippa and Woodlawn seems also to be a part of it.

On a level with the lowest part of this terrace, at an elevation of 720 to 700 feet, is a built terrace having a capping of 60 to 80 feet of sand and gravel. It is well developed at at Leetsdale between the Pennsylvania Railroad and the river, where the deposit is 60 feet thick. This terrace forms the surface of Neville Island and is here composed of about 80 feet of unconsolidated sands and gravels. Possibly it forms the lower terrace at Woodlawn and Aliquippa, but the data on this point are not conclusive. The old valley floor on which this terrace is built lies about 40 feet below the present water level.

DESCRIPTIVE GEOLOGY.

The rocks in the Sewickley quadrangle comprise those not exposed at the surface and those that outcrop. The underlying rocks are revealed in deep wells sunk for oil and gas; those on the surface can be studied directly. The rocks available for examination in these two ways comprise strata having a thickness of about 3000 feet. They belong to the Pennsylvanian and Mississippian series of the Carboniferous system and to the Devonian system.

[a] Butts, Charles, Kittanning folio (No. 115), Geol. Atlas U. S., U. S. Geol. Survey, 1904, p. 3.
[b] Woolsey, L. H., Beaver folio (No. 134), Geol. Atlas U. S., U. S. Geol. Survey, 1906, p. 3.

ROCKS NOT EXPOSED.

GENERAL STATEMENT.

The records of deep wells furnish all available direct information concerning rocks not exposed within the quadrangle. The data are not sufficient to justify positive statements regarding the age and lithologic character of many of these rocks.

The thickness of the rocks penetrated by the drill below the lowest horizon exposed in the quadrangle is between 2400 and 2500 feet. The top of the exposed strata thus penetrated is at river level at Freedom, and a well 2500 feet deep in the Ohio Valley at that point would pass through them. The character of these rocks is shown by the well sections given in the columnar-section sheet. The well logs from which these sections have been made were selected from more than a thousand records of wells drilled within the quadrangle. All these borings penetrated rocks not exposed at the surface, but records of only a few were kept with sufficient accuracy and detail to be of much value. The drilling was done by churn drills, so that close measurements or detailed lithologic examinations of the rocks encountered were not possible. The drillers are not trained geologists and do not attempt to make close distinctions between different kinds of strata. They are interested especially in the oil-bearing beds, which lie at depths of 1200 to 2500 feet, and pay scant attention to the rocks near the surface, which contain no oil or gas. The result is that the zone from 300 to 500 feet thick which incloses the deeply buried oil sands is better known stratigraphically than the overlying rocks, several hundred feet thicker, which separate it from the rocks that outcrop. An unconformity in this intermediate mass of rocks and the small amount of trustworthy information available concerning them permit only general correlations and subdivisions.

CARBONIFEROUS SYSTEM.

PENNSYLVANIAN SERIES.

ALLEGHENY FORMATION.

The Allegheny formation extends from the top of the Upper Freeport coal downward to the base of the Brookville coal. It has an average thickness of about 325 feet. About 180 feet of the upper part of this formation, down to the base of the Lower Kittanning clay, is exposed at the surface and is discussed under the heading "Rocks exposed." The topmost unexposed beds are nearest the surface in Ohio Valley at Freedom. Farther west, in the Beaver quadrangle, all of the formation outcrops. In that area most of the 150 feet of strata below the Lower Kittanning clay consists of shales in which are included thin beds of sandstone, limestone, coal, and clay. So far as can be learned from well records, the general character of these rocks remains the same throughout the Sewickley quadrangle. The separate beds can be positively identified in but few records. A sandstone at or near the top of the interval is tentatively recognized as the Kittanning sandstone member. This is usually white in color and ranges from 10 to 50 feet in thickness. Below the Kittanning sandstone member and from 50 to 75 feet below the Lower Kittanning clay member, the drillers have sometimes recorded a black or gray limestone, which is probably the Vanport ("Ferriferous") limestone member. The fact that most of the detailed records show no limestone suggests that it may occur less commonly here than farther west.

Below the Vanport limestone member the formation is generally described in records as composed of "slate and shells," which usually means shale interbedded with thin hard layers of any kind of rock, commonly sandstone. In a few wells coals are reported near the top and bottom of this interval, respectively the Clarion and Brookville coals. The Clarion sandstone member, which underlies the Clarion coal, is rather thick in parts of western Pennsylvania, but in the Sewickley quadrangle it appears to be thin and of little importance and is seldom recorded in well logs.

POTTSVILLE FORMATION.

The Allegheny formation rests conformably on the Pottsville, which lies at the base of the Pennsylvanian series and is separated from the Mississippian rocks below by an unconformity. In adjoining portions of western Pennsylvania, where it has been studied, this formation consists of two sandstone members, the Homewood above and the Connoquenessing below, which are separated by the Mercer shale member and which locally include thin beds of coal and limestone. The thickness of the formation in this quadrangle probably ranges from less than 200 to more than 250 feet.

In the well-section sheet the horizon of the Ames limestone, an outcropping member of the Conemaugh formation, is platted at its approximate height above or below the mouths of the wells as determined by spirit level. In a few wells the interval between this bed and the top of the Homewood sandstone member ranges from 560 to 620 feet, and it is assumed to be within these limits throughout the quadrangle. Most wells drilled to this horizon encounter a rather coarse reddish to grayish-white sandstone ranging in thickness from a few feet to more than 100 feet and generally containing salt water. Less commonly the horizon is occupied by shales and thin-bedded sandstones, and in a few borings entirely by shales. Although it seems probable that this is the Homewood sandstone member, the evidence is by no means conclusive. It is possible that the Homewood is represented by the first sandstone below the upper limit of the Pottsville, as shown on the well-section sheet.

Below the Homewood member the rocks are prevailingly black or brown shales for 40 to 130 feet, but in this distance occur also thin lentils of sandstone, limestone, coal, and, more rarely, fire clay. Below these shales lies 5 to 100 feet of light-gray to white sandstone, in which occur small patches of small white and yellow quartz pebbles and in many places large quantities of salt water. This is probably the Connoquenessing sandstone member.

MISSISSIPPIAN SERIES.

MAUCH CHUNK SHALE.

Although about 2000 feet of red shales and sandstones belonging to the Mauch Chunk shale underlie the Pottsville formation in central Pennsylvania, the formation is believed not to exist in the Sewickley quadrangle, except possibly in some small patches. In early Pottsville time a large area in western Pennsylvania, eastern Ohio, and northern West Virginia was elevated above sea and the upper Mississippian rocks, including the Mauch Chunk, were exposed to erosion. The period of degradation was so long that the entire Mauch Chunk and portions of the Pocono were removed in the region north and northwest of the Sewickley quadrangle and probably in the Sewickley quadrangle as well. A few miles to the south and southeast of the quadrangle a single layer of red shales, having at the bottom a reddish sandstone and massive grayish limestone which is characteristic of the base of the Mauch Chunk, appears in the well logs and increases in thickness southward until at the southwest corner of Pennsylvania it is about 250 feet thick. It is believed that these shales represent the Mauch Chunk and that this formation is therefore not generally present in the Sewickley quadrangle, the only bed that can possibly be assigned to it being an 80-foot zone of shale immediately below the Connoquenessing sandstone member. This shale is grayish to black, showing none of the characteristic red color of the Mauch Chunk shale farther south, and the meager evidence available seems to connect it with the Pocono formation. This point is touched on in the following discussion of the Pocono.

POCONO FORMATION.

General statement.—In the Sewickley quadrangle the Pottsville formation rests unconformably upon the eroded surface of the Pocono formation, which is here assumed to include all the rocks from the base of the Connoquenessing sandstone member to the bottom of the Hundred-foot sand. No break in the sedimentation occurs between the Pocono rocks and those of the underlying Catskill (?) formation, and for lack of paleontologic and stratigraphic evidence it is manifestly impossible to draw a definite boundary line between them. Attempts to draw such a line have resulted in considerable variation in usage among geologists. Farther east in Pennsylvania, where the red beds of the Catskill are thicker, their top is generally regarded as the upper limit of the Catskill, for in that region the red beds below the Hundred-foot sand were formed from sediments derived from a land mass lying to the east and were laid down during a phase of sedimentation that was very different from that which furnished the sporadic incursions of red material which may have come from the west throughout Carboniferous time.

The thickness of the Pocono formation in the Sewickley quadrangle, as nearly as can be determined, ranges from about 650 feet at the western margin to about 900 feet along the eastern and southeastern borders. Roughly speaking, the upper half is composed of massive beds of sandstone separated by thin zones of dark-gray shales. Below this sandy zone lie 100 to 300 feet of strata, which, though prevailingly shaly, carry several thin lentils of sandstone, locally rather massive. From 100 to 300 feet of the lower part of the formation is made up of two massive sandstones separated by 5 to 100 feet of shale, a considerable portion of which is red.

Top of the Pocono formation.—The top of the Pocono is well marked throughout much of Pennsylvania by the Loyalhanna ("Siliceous") limestone member, but in the Sewickley quadrangle few records show limestone at this horizon. In well section No. 8 of the columnar-section sheet a limestone is shown at the top of what is called the Big Injun sand. If this limestone is the Loyalhanna, the 80 feet of overlying shale mentioned above as probably belonging to the Pocono is either Pottsville or an isolated patch of Mauch Chunk. If it is Mauch Chunk, it may possibly be an outlier of the Greenbrier limestone member ("Big lime"), which occupies the base of the Mauch Chunk farther south. The age of this shale member can not be determined from the data available, but, as stated above, the writer is inclined to consider it Pocono. If it is neither Pocono nor Mauch Chunk, it is very probably not the basal member of the Pottsville, in which case the lowest members of the Pottsville present within the quadrangle, and the base of that formation, must then be somewhere in the upper part of the sand that is called by the drillers in this region the Big Injun.

If, however, the boundaries as drawn on the well-section sheet are approximately correct, the Big Injun sand of the drillers is equivalent to the Burgoon sandstone[a] throughout the quadrangle, except over an area of unknown extent in its west-northwestern part, where the upper Mississippian rocks were almost entirely cut away by pre-Pottsville erosion and the Pottsville formation was laid down at about the same distance above the Hundred-foot sand as was the Big Injun in the eastern part. On the well-section sheet this change is illustrated in well sections 1 to 4, inclusive. Section No. 1, of the Cookson well, is the same as No. 34 of the Beaver folio, and in both the grouping of the Pottsville rocks is the same. In sections 2, 3, and 4 the line dividing the Pottsville and Pocono is drawn practically parallel to the Ames limestone member, which probably lies much more nearly parallel with the old Pocono land surface than the top of the Hundred-foot sand. In the western and northwestern part of the quadrangle the Big Injun sand is partly Pottsville and partly Pocono and is therefore probably made up of sandstones different from those of the eastern part, where the Big Injun is very probably entirely Pocono and is equivalent to the Burgoon sandstone. In either case the lower portion of the Big Injun is doubtless equivalent to the Burgoon. The Squaw and Papoose sands, which are separated from the Big Injun by overlying shale members, appear to coincide with or become a part of it farther east. The shale members are very thin or absent in the eastern part of the quadrangle but increase in number and thickness to the west.

Patton shale.—Below the Burgoon sandstone dark to gray shales in which thin lentils of gray sandstone occur predominate for 200 feet or more. These represent the Patton shale.

Murrysville or Butler Thirty-foot sand.—Below the Patton shale lie 100 to 200 feet of beds which are markedly more sandy than those above and in which there is at least one sandstone of considerable local thickness. In the Sewickley quadrangle this sandstone is known to drillers as the Murrysville or Butler Thirty-foot or Butler gas sand. The top of this sand lies from 160 to 200 feet or more below the base of the Burgoon and about the same distance above the top of the Hundred-foot sand. It is gray to white in color and contains conglomeratic streaks of small white quartz pebbles; its thickness is very irregular, ranging within relatively short distances from 5 to 80 feet.

This is the "Smiths Ferry" sand of the Beaver quadrangle and is probably equivalent to the Berea sand of eastern Ohio and northern West Virginia and Kentucky. In this connection it should be noted that the Berea sand of this region may not be the equivalent of the Berea sandstone at its type locality, Berea, Ohio, but may possibly have been deposited at a later period.

The Murrysville sand is thickest in the eastern and southern parts of the quadrangle, where it locally measures 125 feet. Toward the west it becomes shaly in its lower part and is replaced over a large area by a red shale which locally reaches a thickness of 75 feet. This red bed corresponds to that noted in the well sections of the Beaver folio (No. 134) and is found over a considerable area in eastern Ohio. The fact that the rocks at this horizon become sandy toward the east indicates that the red material composing them may have been brought from the west.

Hundred-foot sand.—The Hundred-foot sand is the most widespread and uniform sandstone of Pennsylvania, Ohio, and West Virginia. Thousands of wells in these States have penetrated it and show that it is remarkable because of its wide distribution and its persistent lithologic features.[b] It has been shown almost conclusively that the Hundred-foot sand of Venango and Clarion counties is the equivalent of the Berea sandstone of the type locality at Berea, Ohio. It has been traced by an almost continuous line of wells from those counties to the Sewickley quadrangle and thence southward into Washington and Greene counties; and there is reason to suppose that it is the equivalent of the Gantz and Fifty-foot sands of Washington County.

Within the Sewickley quadrangle the Hundred-foot sand ranges in thickness from 30 to 125 feet, including a shale parting 1 to 10 feet thick near the middle. In color it is generally gray or white above the parting and white, blue, or dark below it. Less commonly it is white throughout or reddish at the top. The sand is as a rule of medium texture, but in its mass occur thin, irregular lenses of coarse conglomeratic sand composed largely of pebbles of white or yellow quartz. In the Sewickley quadrangle more than 2000 holes have been drilled to its horizon, and so far as may be learned from hundreds of records none failed to find the sand.

[a] Butts, Charles, Kittanning folio (No. 115), Geol. Atlas U. S.
[b] Butts, Charles, Rept. Pennsylvania Topog. and Geol. Survey Comm. for 1906-1908, 1908, pp. 190-204.

There has been much uncertainty among geologists as to the correct correlation of the Hundred-foot sand, owing chiefly to the imperfect paleontologic evidence available and to the erratic nature of the upper red beds, which farther east more clearly mark the end of the Catskill phase of sedimentation. The general judgment seems to be that the Hundred-foot marks a transitional stage of deposition between the Devonian and Carboniferous systems.

DEVONIAN (?) SYSTEM.

For 325 feet or more below the Hundred-foot sand the rocks are prevailingly red and green shales interbedded with thin gray to reddish sandstones. These sands, together with the Hundred-foot sand above, are known to drillers as the Venango oil sands, which have yielded most of the oil and gas of western Pennsylvania. They range in thickness from 2 feet to 50 feet and are not continuous over wide areas, grading into sandy shale from place to place, though there are several definite zones in which more or less sandstone is nearly always encountered. In descending order, the more prominent of these sands are called the Nineveh Thirty-foot, Snee, Bowlder, Gordon or Third, Fourth, and Fifth sands, all of which occur within 325 feet below the bottom of the Hundred-foot sand. Along the Allegheny Front these rocks are largely red shales and sandstones, but in the Sewickley quadrangle the red beds are thin and of varying character, the larger portion of the rocks being gray or green shales.

In this area the lowest important producing oil or gas sand is the Fifth sand, and few wells have been drilled to any considerable depth below its horizon. Those that have been carried deeper have penetrated 300 to 600 feet of red, green, or chocolate-colored shales, which include numerous thin beds of hard gray or white sandstone.

ROCKS EXPOSED.

The outcropping rocks of the Sewickley quadrangle, except small surficial stream deposits of Quaternary age, belong to the Pennsylvanian series of the Carboniferous system. In general the beds of this region are much thinner than those of the older outcropping rocks around the edges of the Appalachian coal basin, the formations being made up principally of thin interstratified beds of sandstone, shale, clay, coal, and limestone. The sandstone and shale predominate, the limestone, coal, and clay constituting only a relatively small percentage of the section.

CARBONIFEROUS SYSTEM.

PENNSYLVANIAN SERIES.

ALLEGHENY FORMATION.

A general statement relative to the rocks of the Allegheny formation has been given under "Rocks not exposed." The upper 180 feet of these rocks outcrop as a narrow belt along the hill slopes on both sides of Ohio River at Freedom and extend upstream to the vicinity of dam No. 4, where the Upper Freeport coal at the top of the formation disappears under the terrace gravels, a few feet above water level. Within this small area the individual beds vary greatly in thickness and character. They are prevailingly shaly but include several coals with accompanying beds of clay or limestone, as well as lenticular sandstones of considerable local thickness.

Lower Kittanning.—The lowest bed exposed is the top of what is probably the Kittanning sandstone member, which appears in the bed of Crows Run, north of the railroad tracks east of Freedom. Above this sandstone is 8 feet of cream-colored fire clay which underlies 22 inches of coal believed to be the Lower Kittanning. This is the only exposure of these beds found.

Middle Kittanning (Darlington) coal and clay.—At the Crows Run locality described above the Middle and Lower Kittanning coals are 40 feet apart, the interval being made up of 25 feet of dark and brown shale at the base and 15 feet of Middle Kittanning fire clay above. The Middle Kittanning or Darlington coal seems to have a fairly uniform thickness of 17 to 19 inches. It outcrops on both sides of the valley of Crows Run near its mouth and upstream to a point within half a mile of Parks Quarries. From Freedom to Baden the rocks dip at a rate that carries this coal below railroad level at the east end of Conway.

On the pike leading over the hill eastward from Freedom a coal believed to be the Middle Kittanning outcrops about 130 feet above Ohio River. The coal is here only 8 feet thick and is overlain by 40 feet of sandstone that shows much cross-bedding and resembles closely the Freeport sandstone member at the mouth of Crows Run. In the Beaver folio an unconformity is described as occurring between the Middle Kittanning or Darlington coal and the Freeport sandstone in the run back of Freedom. An exposure of this coal and the associated rocks at this locality is represented by figure 8, on page 14.

Upper Kittanning coal.—The Upper Kittanning is the first coal bed above the Middle Kittanning coal and according to

Woolsey is separated from it by an interval of 13 to 30 feet. No bed found in the Sewickley quadrangle seems likely to be the Upper Kittanning coal, though this coal may be present as a thin local seam. There is some doubt whether the 8-inch coal mentioned as standing 130 feet above Ohio River on the pike east of Freedom may not be Upper instead of Middle Kittanning as correlated above. Elsewhere, however, the Upper Kittanning is probably absent and its horizon is occupied in most places by the Freeport sandstone member.

Freeport sandstone member.—On the west side of the valley of Crows Run, opposite the Pennsylvania Railroad, the Middle Kittanning coal outcrops in the bluff at street level and is directly overlain by 30 feet of thin-bedded sandstone identified as the Freeport sandstone member. This sandstone thickens to 60 feet within a few hundred feet to the north and grades into sandy shales and thin sandstone layers within half a mile. From this locality on Crows Run westward along the street to Freedom its lower portion changes rapidly into sandy shales, but it reappears as a sandstone on the pike at Freedom with a total thickness of 60 feet. Wherever observed the lenticular nature of this sandstone is apparent.

Lower Freeport coal, limestone, and clay.—The Lower Freeport coal lies from 70 to 80 feet above the Middle Kittanning coal in the few sections where measurements could be secured. The rocks below it to the top of the Freeport sandstone are shaly but include one or two thin limestones. The coal is generally underlain by 1 to 10 feet of soft and flint clays, which at some places include the upper layer of limestone. The clay is variable, changing to shale in short horizontal distances. The limestones are 1 to 3 feet thick and are separated by 3 to 8 feet of shale or clay. They are dark blue to gray in color and weather yellow or gray. These limestones are exposed on the west side of Crows Run from its mouth to Parks Quarries, a typical section occurring on the Freedom pike about 100 yards west of the store at Parks Quarries. In this vicinity the coal is probably absent, unless it is represented by a small coal blossom a few yards east of the bridge over Crows Run at Parks Quarries. The limestones are not present here, and at no place have both limestones and coal been found in the same exposure.

Southward from the mouth of Crows Run to the vicinity of Legionville the Lower Freeport coal is exposed at a number of places along the railroad cut. It is exposed at valley level in a small run 200 yards north of the post-office at Baden and at street level opposite the railroad station at that place. What seems to be the same coal appears at the level of the Pennsylvania Railroad in the bluff about one-eighth mile north of dam No. 4, where it is 15 inches thick. No exposure of this bed was found on the west side of Ohio River. What the writer considers to be this coal is exposed near a bend in the pike up Freedom Hill about 150 yards west of the entrance to the cemetery. It is here 1 foot thick and occurs at the base of 5 feet of dark shale, which is overlain by 20 feet of blue and yellow shales to the base of a massive sandstone. Reddish shales with thin lentils of sandstone prevail for 40 feet below the coal. This coal was noted in three places along the run back of Freedom, and at the point where it goes under cover the coal is known to be 25 or 30 feet below the base of the Mahoning sandstone member.

On Brush Creek the Lower Freeport coal is exposed on the road one-half mile south of Unionville, where it is underlain by 3 feet of fire clay above 15 feet of brown shale. South of this point, along the run, a bed of coal has been opened at two places; that at the northern opening is probably Lower Freeport. This coal is also exposed on the road north from Unionville opposite the schoolhouse, where it is from 1½ to 2 feet thick and has the limestone below. Outcrops of this coal occur at a number of places on both sides of Brush Creek as far east as the milldam at Oakgrove, where it goes under cover. Here it is 6 inches thick and is underlain by 6 feet of fire clay and flint clay and 10 feet of yellow limestone. A thin layer of iron ore also occurs near the base of the clay.

Butler sandstone member.—Along Ohio River the rocks between the horizons of the Lower and Upper Freeport coal are prevailingly shaly but contain in places a thin-bedded shaly sandstone. On Brush Creek the interval between these horizons is almost entirely filled by a gray sandstone, locally rather massive, which is known as the Butler sandstone member. This bed is from 10 to 30 feet thick in the vicinity of Unionville and appears to be somewhat thicker at Oakgrove.

Upper Freeport coal.—Although the horizon of the Upper Freeport coal, which marks the top of the Allegheny formation, is well known within the quadrangle, comparatively few outcrops of the coal itself were found. One notable outcrop is under the wagon bridge over Dutchman Run, 1½ miles north of Freedom. The coal is here about 18 inches thick, but within 100 yards downstream it is pinched out between the overlying Mahoning sandstone and 4 feet of limestone underlain by dark-reddish shales; farther south the limestone also pinches out and the heavy conglomeratic sandstone rests unconformably upon the dark shales. Half a mile still farther downstream the base of the Mahoning sandstone rests on black shale 20 feet above a coal described above as Lower Freeport. On the pike up Freedom Hill the base of the Mahoning rests upon dark shales 25 feet above the Lower Freeport coal. On this pike one-eighth mile west of Parks Quarries the Mahoning is underlain by 1 foot of yellowish to gray limestone, which is about 50 feet above the Lower Freeport limestone. North of Parks Quarries, on the small run entering Crows Run at that place, a coal 1 foot thick, which is embedded in reddish shale 35 feet below the base of the Mahoning sandstone, is probably the Lower Freeport. The Upper Freeport is not present at any exposures in Crows Run except as 2 inches of coal at the mouth of the tunnel. In Baden opposite the railroad station, 7 feet of clay inclosing 6 inches of shaly coal occurs 35 feet above the Lower Freeport coal. From this point southward along the river, terrace gravels conceal the horizon of the Upper Freeport coal to the place where it sinks below water level, between Legionville and Ambridge. This Upper Freeport limestone and iron ore are exposed in the bluff north of dam No. 4 and east of the Pennsylvania Railroad, where they are about 30 feet above the Lower Freeport coal. They are at stream level where the Beaver pike crosses Legionville Hollow, one-fourth mile east of dam No. 4.

On the west side of Ohio River an old opening at the west end of Aliquippa, across the Pittsburg and Lake Erie Railroad tracks from the Vulcan crucible-steel plant, is probably on the Upper Freeport coal. No other exposures of the coal were found on the west side of the river, and all possible outcrops are probably covered by terrace deposits from Aliquippa southward to the point where it sinks below river level.

On Brush Creek the Upper Freeport coal is exposed along both sides of the valley from Oakgrove to the northern edge of the quadrangle. Half a mile east of Oakgrove a bank in the coal has until recently been in operation a few feet above stream level. Here the coal is 3½ feet thick, with a massive sandstone cover and a soft clay floor. No other exposure of the Upper Freeport coal is positively identified in this valley, though a thin streak of plastic fire clay and one or two small coal smuts were found at about this horizon.

At the northern edge of the quadrangle, about a mile from the northwest corner, the Upper Freeport coal is absent and about 20 feet of dark shales occur above a thin-bedded sandstone and below the massive Mahoning sandstone, which at this place carries numerous quartz pebbles. This is the conglomeratic sandstone mentioned above as overlying the Upper Freeport coal at the bridge on Dutchman Run, back of Freedom. At Unionville the horizon of the Upper Freeport is marked by 2 to 6 feet of white fire clay and dark carbonaceous shale (see sections on columnar-section sheet) and is overlain by only 2 to 5 feet of sandstone. In the valley of Breakneck Creek the Upper Freeport coal comes to the surface at Callery and is exposed on both sides of the valley from that place to the northern edge of the quadrangle.

CONEMAUGH FORMATION.

General statement.—Except for local unconformities due to very brief interruptions in deposition, the Conemaugh formation lies conformably upon the Allegheny, occupying a thickness of 500 to 520 feet between the top of the Upper Freeport coal and the base of the Pittsburg coal. The rocks are prevailingly shaly but include beds of sandstone, coal, limestone, and clay. Three well-known sandstone beds are sufficiently thick and persistent to make good stratigraphic markers and to affect the topography of the country materially by their greater resistance to weathering. These are the Mahoning, Saltsburg, and Morgantown sandstone members, which are respectively located at the base, below the middle, and some distance above the middle of the formation. Portions of these sandstones are found to be massive at nearly all points of exposure, but locally they change greatly in thickness, different parts of each grading in many places into sandy shales.

The formation also contains six or more coal beds of irregular occurrence called in ascending order the Mahoning, Brush Creek (or Gallitzin), Bakerstown, Harlem, Elk Lick, and Little Clarksburg coals. These range from thin films to beds about 3½ feet thick. The limestones, which are thin and are unimportant except as easily recognized stratigraphic units, are the Mahoning, Lower Cambridge ("Brush Creek"), Upper Cambridge ("Pine Creek"), Ames ("Crinoidal"), and Pittsburg limestone members. Of these the Ames is remarkably persistent over wide areas and has individual characteristics which render it easily recognizable wherever it is exposed. The clays consist of thin soft beds, mostly unimportant, lying at different horizons, and of a flint clay locally 10 to 15 feet thick which occurs in the Mahoning sandstone. The more important members of the formation are described below.

Mahoning sandstone member.—The Mahoning sandstone member consists of two heavy sandstones lying near the base of the Conemaugh formation, separated by a thin shale in which coal, limestone, and fire clay locally occur. There has been much dispute among geologists as to whether one or both of these sandstones should be designated Mahoning. The general usage among writers of previous folios has been to consider the two members as a single sandstone, though in most places they represent two distinct periods of deposition separated by a more or less clearly marked time interval. Mahoning deposition was extremely variable, and the beds therefore present many local features probably not repeated elsewhere. In the Sewickley quadrangle the total thickness of this member has been determined at but few places with certainty, because of the indistinct line of demarcation at the top and the fact that the lower portion is usually below drainage level. The combined thickness varies between 40 and 100 feet, though in a few places one or the other sandstone alone measures more than 80 feet. In such places, however, the thickness of one varies inversely with that of the other.

Near the western edge of the quadrangle, 2 miles north of Freedom, the following section is exposed:

Section of Mahoning sandstone member 2 miles north of Freedom.

	Feet.
Upper sandstone	45
Coal	½
Black shale and clay	6
Lower sandstone	35
	86½

The base of the lower division of the Mahoning sandstone member rests directly upon the Upper Freeport coal or upon the underlying shale, as described above. It is generally massive and in the northwestern part of the quadrangle is in places conglomeratic. At Freedom it is 60 feet or more in thickness. North of Freedom, at the locality of the section given above, it contains many small quartz pebbles and rests directly upon the Upper Freeport coal. A number of fine exposures of the Mahoning occur in Parks Quarries, on Crows Run, where the sandstone probably represents the lower division of the Mahoning, a bed of fire clay separating it from the upper division, which is here very thin, its horizon being occupied by sandy shales and thin sandstones.

The lower part of the Mahoning is quarried in the valley of Logtown Run, near the Beaver-Pittsburg pike, less than one-half mile from dam No. 4. Here it is about 25 feet thick and is underlain by 10 feet of shale and overlain by 35 feet of clay, with 2 feet of iron ore near the middle and thin-bedded sandstone above. At Shousetown the base of the Mahoning member is below water level, but its body outcrops along the bottom of Flaugherty Run to a vertical distance of about 45 feet above the river. One mile up the run from its mouth and opposite the bridge the top portion of the upper sandstone is exposed, with the Brush Creek coal directly above. Along the Pittsburg and Lake Erie Railroad, east from Shousetown, the top of the lower part of the Mahoning sandstone is just below railroad level. Midway between Shousetown and Stoops Ferry two Mahoning coals are exposed in the bluff, separated by 25 feet of dark sandy shale. A short distance east of this point the lower coal is concealed below railroad level and sandstone lentils fill a portion of the interval between them. (See fig. 4.)

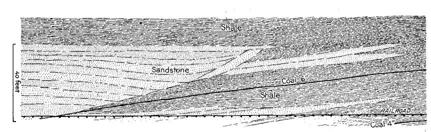

FIGURE 4.—Rocks of Mahoning sandstone member of the Conemaugh formation exposed in cut of the Pittsburg and Lake Erie Railroad west of Stoops Ferry.

Shows the abrupt termination of the sandstone beds and their replacement by shale.

At an old shale quarry just east of this section the Brush Creek coal and the Lower Cambridge ("Brush Creek") limestone member occur in typical outcrop 45 feet above the upper coal and the Ames limestone appears at its usual horizon, approximately 200 feet above the Brush Creek coal. The shale above and below the coal is cut entirely out and the coal disappears below track level between two massive sandstones. At Stoops Ferry only about 40 feet of the upper portion of the sandstone is exposed, the lower layers being very massive, some having a thickness of 15 feet. No exposures of the Mahoning coals occur, their horizons probably being below the valley. The sandstone is separated from the Brush Creek coal above by 6 to 8 feet of dark shale.

Eastward from Sewickley to the eastern edge of the quadrangle the upper part of the Mahoning sandstone member is above water level, and in places the shale and fire clay below the upper part are also exposed. The shoals in the river above dam No. 3 are probably caused by the resistance to downward cutting offered by the massive layers of the lower Mahoning. On the pike up Killbuck Run, half a mile from the railroad station at Glenfield, bowlders of reddish to gray limestone 3 or 4 feet thick occur at the horizon of the shaly part of the Mahoning. These are fossiliferous and have much the same appearance as the Cambridge and Ames limestones. At the mouth of Toms Run 10 feet of Mahoning fire clay outcrops at railroad level below 65 feet of massive gray to reddish sandstone belonging to the upper part of the Mahoning. From this point to Bellevue the base of the upper sandstone, resting upon the Mahoning fire clay and shale, is exposed at a number of places along the Pennsylvania Railroad. This sandstone paves the bed of Lowrie Run for a mile upstream from Ben Avon and forms the bluff on both sides of the river from Montour Junction and Emsworth eastward to the edge of the quadrangle.

The core from a diamond-drill hole at Sewickley was measured by I. C. White, who included the following section in the Mahoning sandstone:[a]

Diamond-drill section at Sewickley.

	Ft.	in.
Sandstone, micaceous, gray	13	8
Fire clay, sandy		6
Sandstone, light gray	22	
Shale, dark gray	8	4
Sandstone, gray		8
Shale, sandy	6	8
Shale, blue	6	5
Sandstone		8
Slate, gray	3	4
Fire clay, variegated at base, impure	25	11
Sandstone, gray, micaceous	38	5
Shales, sandy, blue	8	6
Sandstone, light gray	8	6
Upper Freeport coal.		

At the northern border of the quadrangle, less than a mile from the northwest corner, the Mahoning coal is about 22 inches thick and is underlain by fire clay and by about 40 feet of the lower sandstone, carrying quartz pebbles at its base. The upper part of the Mahoning here consists of about 60 feet of thin-bedded sandstone and shale. The identity of the Mahoning at Unionville is doubtful, for little sandstone is found there at this horizon. (See surface sections 1 and 2 on columnar-section sheet.) It seems probable that the first bed of fire clay above the Butler sandstone member marks the horizon of the Upper Freeport coal and that the 3 or 4 feet of overlying reddish shale constitutes the sandstone phase of the lower part of the Mahoning. A thin white flint clay about 35 feet above this shale probably marks the horizon of the Mahoning fire clay, the two thin Mahoning coals above the upper sandstone of the Mahoning member being represented by a few feet of shaly sandstone below the Brush Creek coal. At Oakgrove the lower sandstone of the Mahoning member is somewhat massive but is probably less than 40 feet thick. At Callery the lower Mahoning horizon is occupied by yellowish sandy shales up to the Mahoning coal, which is 6 inches thick and lies about 60 feet above the Upper Freeport coal. Above this coal is 30 to 40 feet of upper Mahoning sandstone, usually thin bedded and shaly but locally massive. This sandstone is exposed in the valley of Breakneck Creek from Callery to the vicinity of Mars.

Brush Creek (Gallitzin) coal and Lower Cambridge ("Brush Creek") limestone member.—The name Brush Creek was applied by I. C. White[b] to a coal and limestone exposed along the valley of Brush Creek, Cranberry Township, Butler County. He identified the coal at a number of places in this vicinity and said that at the head of Crows Run, where it was opened by country banks, it occurs about 195 feet below the "Crinoidal" (Ames) limestone. At the head of Crows Run, about half a mile west of Lovi, the vertical interval between the Ames and this coal, as remeasured by the writer with a spirit level, is about 140 feet. After carefully eliminating the effect of dip between outcrops of these two beds about a mile southeast of Lovi, a similar measurement gave an interval of about 145 feet. This coal is no doubt the same as that described by White and considered by him to be between 185 and 200 feet below the Ames limestone member over a wide area in Butler, Beaver, and Allegheny counties, but instead of a uniform interval of 185 to 200 feet below the Ames over this area the distance varies from about 200 feet in the southern part of the quadrangle to about 140 feet in the northern and northwestern part. Because of this variation many poor exposures of the Lower Cambridge ("Brush Creek") limestone member can not be positively identified, since in many places the interval is more nearly that to the Upper Cambridge ("Pine Creek") limestone member, which is normally from 130 to 140 feet below the Ames. Unfortunately no outcrop of the Upper Cambridge limestone member could be found in the type locality of the "Brush Creek" limestone member.

White gives the following section of the Brush Creek coal and limestone in the type locality:

Section of Brush Creek coal and limestone in type locality in Cranberry Township, Butler County.

				Ft.	in.
Black limestone				1	
Dark shales					10
Coal	Coal	1		2	5
	Shale		1		
	Coal	1	4		

At Unionville the Brush Creek coal is 18 inches thick and is embedded in dark shales, the limestone lying 17 feet above in light-brown shale. The coal is here 140 feet above the Lower Freeport coal.

The Brush Creek coal and the overlying Lower Cambridge ("Brush Creek") limestone member outcrop at several points on both sides of Ohio River and along the tributaries to it, the beds seeming to be from 190 to 210 feet below the Ames limestone. (See outcrop of Ames limestone, areal-geology map.) In this part of the quadrangle the coal is generally between 10 and 18 inches in thickness and the limestone is from 1 to 2 feet thick, black and very hard, weathering with a slaty cleavage, and rarely more than 6 feet above the coal. An exception to this general appearance of the coal occurs in an exposure on the Shousetown-Stoops Ferry pike a mile southeast of Shousetown, where the pike crosses Flaugherty Run; here the coal shows the following section:

Section on Shousetown-Stoops Ferry pike near Flaugherty Run.

	Ft.	in.
Coal		3–12
Dark shale	4	
Black shale with streaks of coal	3	
Sandstone and shale	9	
Coal		4–6
Sandstone	0–10	

The coal has been mined at a number of places and is reported by owners to be 4 feet thick at one or two abandoned banks, but no outcrop of this thickness was found.

Buffalo sandstone member.—About 75 feet of sandstone and sandy shales, including in places a limestone known as the Upper Cambridge ("Pine Creek") limestone member, occur between the Lower Cambridge ("Brush Creek") limestone member and the Bakerstown coal. This sandstone was considered to belong to the upper part of the Mahoning by the First Survey. In the Second Survey reports it was called Buffalo sandstone by I. C. White (Rept. Q, p. 33). In the Kittanning folio Butts used the term Saltsburg for a sandstone extending from 40 or 50 feet below to 60 or 80 feet above the Bakerstown coal. He considered the portion below the horizon of the Bakerstown coal as the equivalent of the Buffalo sandstone of White and the portion above as the Saltsburg sandstone of Lesley,[a] but thought the sandstone mass as a whole corresponded best with the Saltsburg sandstone in its type locality. In the Sewickley quadrangle neither of the sandstones is important, most of the interval between the Brush Creek coal and Ames limestone being shaly, but as there is a distinct sandstone both above and below the Bakerstown coal and a persistent shale interval between them, it seems best to follow the original usage and apply the name Buffalo sandstone to the lower member and restrict the term Saltsburg to the sandstone above the horizon of the Bakerstown coal.

The Buffalo sandstone is extremely varied in character, ranging from sandy shales to massive sandstone within short horizontal distances. It is prevailingly gray or greenish, but where thin bedded or shaly the surfaces of the layers oxidize to a characteristic red. It is thinnest in the southwestern part of the quadrangle, where it consists of sandy reddish shale interbedded with thin reddish sandstone lentils. Toward the east and north it increases in thickness. Back of Emsworth, on the first road north from the valley of Lowrie Run, it is 60 feet thick and is massive at the base. It overlies 10 feet of dark to reddish shale above an outcrop of Brush Creek coal at the road forks, and is capped by 25 feet of dark to reddish shale up to the Bakerstown coal.

On the road 1 mile south from Union Church, near the northeast corner of the quadrangle, the Buffalo sandstone is 60 feet thick, somewhat massive toward the top and composed of thin-bedded sandstone and reddish sandy shale at the base; it is separated from the Brush Creek coal below by 15 feet of dark sandy shale and from the Bakerstown coal above by 10 feet of red shale overlain by about 80 feet of yellow to light-brown shale. On the road from Rehoboth Church to Crows Run, in Economy Township, 20 feet of reddish thin-bedded sandstone lying just below the horizon of the Bakerstown coal represents the entire thickness of sandstone at the Buffalo horizon. Below are reddish shales with a few sandstone lentils.

In the vicinity of Unionville the Buffalo sandstone is in places massive but generally consists of thin-bedded, closely laminated sandstone, reddish on exposed edges and gray to greenish on fresh surfaces. It is from 30 to 40 feet thick and forms the capping stone for a number of flat-topped hills that have an elevation of about 1200 feet. Between the Buffalo sandstone and the Bakerstown coal at some places a thin dark to gray fossiliferous limestone is embedded in light-brown or yellow shales. Where the Buffalo sandstone is thickest the limestone seems not to be present. It is believed to represent the Upper Cambridge limestone (Pine Creek limestone of White).

Bakerstown coal.—The Bakerstown coal received its name from Bakerstown, in Richland Township, Allegheny County, a few miles east of the Sewickley quadrangle, where a typical section was measured by I. C. White[b] as follows:

Section of Bakerstown coal at Bakerstown.

	Ft.	in.
Coal	1	6
Slate		$\frac{1}{4}$
Coal		4
Slate		$\frac{1}{2}$
Coal		3
Slate		
Coal (cannel)		6

White gives the interval between this coal and the Ames limestone member as 90 feet in the type locality. In the Sewickley quadrangle this bed is generally thin and of little importance but in places reaches a maximum thickness of about 3 feet. It is very irregular and appears in relatively few exposures. In the southern part of the quadrangle it lies from 65 to 85 feet above the Brush Creek coal and 120 to 145 feet below the Ames member. It is in many places accompanied by 1 foot to 6 feet of whitish underclay, which overlies reddish mealy shale or clay, and by dark to reddish shales above.

In many places a thin black to gray limestone occurs from 5 to 20 feet above the coal. Where gray this limestone is nodular and scantily fossiliferous; where dark it is from 1 to 2 feet thick, is very hard, weathers to a slaty cleavage, and is an almost exact duplicate of the Lower Cambridge ("Brush Creek") limestone member. Where the coal is absent the clay and limestone are frequently exposed. In many places this coal and limestone are lithologically indistinguishable from the Brush Creek coal and the Lower Cambridge limestone member. One such place is on the first road leading northwest from Lowrie Run, less than a mile back of Emsworth, Kilbuck Township; at this point the Bakerstown coal is 6 inches thick, with 1 foot of black limestone 4 feet above. The coal is 130 feet below the Ames limestone and 85 feet above the Brush Creek coal, which is exposed in the same section. It was not possible to trace the two horizons northward across the quadrangle in such way as to identify the coals positively as the Bakerstown and the Brush Creek, but the evidence in hand indicates that in Cranberry and Adams townships the interval between the Ames limestone and the Bakerstown coal is less than 100 feet and probably is only about 60 feet.

The Bakerstown coal is exposed in the quarry at the end of the railroad switch up Legionville Hollow, east of dam No. 4; it has a maximum thickness of 18 inches but pinches out within the length of the quarry. The coal is underlain by 18 feet of clay and sandy shale above 10 feet of Buffalo sandstone; it lies about 80 feet above the black Lower Cambridge ("Brush Creek") limestone exposed in the bed of the run below. The limestone above the Bakerstown coal is not exposed at this point, but a thin layer of iron ore from 1 to 6 inches thick probably marks its horizon. The Bakerstown coal was not found in the southwestern part of the quadrangle, though exposures of its horizon marked by clay, shale, and nodular gray limestone and locally by iron ore are abundant. An old coal bank at road level on the south side of Big Knob, New Sewickley Township, is about 70 feet below the Ames limestone member and probably is in the Bakerstown coal, though it seems to be somewhat high in the section. The coal is said to be 3 feet thick in this old bank. This may possibly be the "Stray coal" described by Woolsey in the Beaver folio as being 40 to 60 feet below the Ames. It is at this point about 100 feet above the Brush Creek coal. At Hendersonville a coal 70 feet below the Ames and from 18 to 30 inches thick is probably the Bakerstown. It is overlain by 25 feet of light-brown or yellow shale, above which is 20 feet of reddish shale; below the coal is 20 feet of reddish clayey shale. On the pike halfway between Hendersonville and Ogle a thin black shaly limestone closely resembling the one above the Brush Creek coal outcrops about 130 feet below the Ames limestone member. The Bakerstown coal outcrops at a number of places south of Plains Church, where it is 70 feet below the Ames, and on Wolfe Run, half a mile northwest of Plains Church, where it is about 120 feet above an outcrop of Brush Creek coal. In this vicinity the coal is sometimes in two seams separated by 10 feet of yellow fissile shale. At several places small smuts 60 to 70 feet below the Ames limestone member indicate a fairly persistent coal at that horizon. Though no conclusive data are available it seems probable that this coal is the Bakerstown, as the limestone is light gray and closely resembles the Ames in appearance.

Saltsburg sandstone member.—On the road south of Shanopin about 30 feet of rather massive gray sandstone overlies the horizon of the Bakerstown coal. Reddish sandy shale and thin-bedded sandstone occur 30 to 60 feet above this coal horizon at a number of places among the hills on both sides of Ohio River. Back of Emsworth this sandstone is 35 feet thick, very thin bedded, and bluish to gray in color. In the northeastern part of the quadrangle it is from 20 to 60 feet thick but everywhere retains its thin-bedded, shaly character.

Red shale.—Throughout the Sewickley quadrangle a persistent band of red clayey shale 15 to 35 feet thick encircles the hills with a broad belt of blood-red soil, the top of which is uniformly 10 to 20 feet below the Ames limestone member. This red shale is a valuable horizon marker, for it furnishes an unfailing means of identifying the Ames limestone in places

[a] Bull. U. S. Geol. Survey No. 65, 1891, p. 73.

[b] Second Geol. Survey Pennsylvania, Rept. Q, 1878, p. 74.

[a] Stevenson, J. J., Second Geol. Survey Pennsylvania, Rept. K3, 1877, p. 22.

[b] Second Geol. Survey Pennsylvania, Rept. Q, 1878, p. 32.

where otherwise one of the lower limestones that lithologically so exactly duplicate the Ames might be mistaken for it. These lower limestones are also accompanied by thinner shales of lighter-red color that occur irregularly from the top of the Buffalo sandstone member to the base of the Morgantown. There is some question whether the color of these lower red or reddish shales comes from oxidation on exposure or from red material deposited with the sediments. With the thick red bed below the Ames no such question arises; the muds from which it was formed were undoubtedly red when deposited, for the color is found in deep wells, where no oxidation could have taken place. It is possible that wells have shown some of the lower red shales to be true red beds, but data are not available to determine this point.

In the thick bed of red shale below the Ames limestone member Percy E. Raymond, of the Carnegie Museum, recently discovered near Pittsburg an interesting reptilian fauna which is closely related to Permian types. This discovery and evidence given by White[a] and by Scudder[b] raise the question, Where shall the line of division be drawn between the Permian and the Pennsylvanian series? The answer to this question, however, can not now be given. Many more data should be collected before any change of the present formation boundary can be seriously considered.

Harlem coal.—At many places a small coal has been noted above the band of red shale and clay and locally just below the Ames limestone member. It is commonly embedded in a yellow to light-brown fissile shale and has a maximum thickness of not more than 18 inches. Fewer outcrops of this coal are found in the western than in the eastern part of the quadrangle. In general the limestone is thickest where the coal is absent and thinnest where the coal is thickest.

Ames limestone member.—The type locality of this limestone is in Ames Township, Athens County, Ohio. It was described by Andrews[c] in 1873, though its equivalent in Pennsylvania had previously been described as the "Green crinoidal" or "Berlin" limestone. This limestone is the most persistent bed in the Conemaugh formation and has peculiar lithologic characteristics which make it easily recognizable over an area covering several thousand square miles in Pennsylvania, Ohio, and West Virginia. It is a dark-blue to greenish coarse granular limestone where pure, but where impure grades to buff or yellow and in a few places is little more than a calcareous shale. It is as a rule highly fossiliferous, being crowded with crinoid stems, brachiopods, and gastropods. The bed is in two layers having a total thickness of 1 to 5 feet, the average being about 2 feet, which is maintained over large areas. It is from 230 to 265 feet below the Pittsburg coal and probably between 270 and 300 feet above the Upper Freeport coal, the latter interval being uncertain because of few exposures of both beds where accurate measurements could be made.

The Ames limestone member outcrops in a continuous line along both sides of Ohio River and in the valleys of its tributaries from Bellevue to Baden, as well as at the headwaters of Pine Creek and Brush Creek. Farther north the outcrop line is higher and at the north edge of the quadrangle it encircles only the highest knobs. The limestone is thickest in the southern and western parts of the quadrangle and is thinnest in the southwestern part of Ross Township, where in places it degenerates into a yellowish fossiliferous band of shale from 6 inches to 2 feet thick. It is probably present in the range of high hills north of Ogle, but diligent search at and above the thick bed of red clay did not reveal it.

At a few places two beds of limestone seem to occur. At one of these, on the road three-fourths of a mile back of Glen Osborne, the beds are each about 3 feet thick and are separated by about 8 feet of red and yellow shale. The exposures are only a few yards apart and from their position the Ames does not seem to have been disturbed by a slip. At a number of places a thin fossiliferous limestone bearing a striking resemblance to the Ames occurs about 50 feet below it. On the east border of the quadrangle, about 1½ miles from the northeast corner, a fossiliferous limestone in every respect closely resembling the Ames occurs above 20 feet of red clay. Within 35 feet above it, however, are thin coal beds, the upper of which is doubtless the Elk Lick, and it seems possible that one of the others is Harlem. This limestone is doubtfully correlated with the Ames because of the fact that an unmistakable outcrop of Ames one-fourth mile farther east is 50 feet higher than this outcrop, although the dip between them probably amounts to less than 20 feet.

At nearly all places the Ames occurs in the midst of a light-brown or yellow fissile shale from 6 to 25 feet thick, above which is from 5 to 8 feet of very deep red clayey shale of ox-blood hue, overlain in turn by yellow shales extending up to the base of the Morgantown sandstone. In places within this mass of shale there are two or three coal beds ranging in thickness from 2 to 24 inches or more. The topmost of these, the Elk Lick coal, is fairly persistent and deserves special notice.

[a] Geol. Survey West Virginia, vol. 2A, 1908, pp. 622-632.
[b] Bull. U. S. Geol. Survey No. 124, 1895, p. 12.
[c] Andrews, E. B., Ohio Geol. Survey, vol. 1, pt. 1, 1873, p. 235.

Elk Lick coal.—The name Elk Lick was first applied by Lesley[a] to a coal lying 30 to 40 feet above the Ames limestone member on Elk Lick Creek, Somerset County. In the Sewickley quadrangle this coal has been opened by country pits at a number of places, but it was found to be too thin and too poor in quality to justify mining. Many exposures of it occur on Pine Creek, in McCandless Township, and in the vicinity of Perrysville. East of Perrysville, on the edge of the quadrangle, a bank on the Schlag farm, in what is probably this bed, is said to have a thickness of about 6 feet, with 40 inches of minable coal of good quality. The bank was filled with water at the time of the writer's visit and no measurements of the bed could be obtained, but the blossom measures more than 4 feet. This coal has also been opened at a number of places south of Duff City, in Franklin Township, where it ranges from 1 to more than 5 feet in thickness, the maximum exposure being on the Beaver-Pittsburg pike half a mile southeast of Bayne. It has been mined at several banks north of Pleasant Hill Church in Marshall Township, north of Mount Pleasant Church in the southeast corner of Cranberry Township, at Big Knob, and on a number of other high hills in the northern part of the quadrangle. The altitude of this coal above the Ames limestone member seems to range from 10 to 50 feet, and at a number of places two or more coals occur in the interval, all embedded in a yellow to reddish shale that underlies the Morgantown sandstone. It seems probable that one or more separate coals of local extent occupy the interval between the Ames limestone member and the Morgantown sandstone where this shale has its maximum thickness, and that the topmost one is the Elk Lick.

Morgantown sandstone member.—The base of the Morgantown sandstone member is from 10 to 60 feet above the Ames limestone member. It is from 20 to 100 feet or more thick and is the most prominent and widespread sandstone of the Conemaugh formation. It is present throughout the Sewickley quadrangle wherever its horizon is exposed, and to its superior resistance to weathering many of the bluffy slopes and flat-topped hills of the higher levels are due. It is rarely massive through its entire thickness, though it usually carries from 10 to 20 feet of thick layers near the bottom and is uniformly compact throughout in quarries, carrying little or no shale between layers. It is gray to greenish in color and weathers to layers from 1 to 2 inches thick, this character being remarkably persistent over the entire area. Toward the top of the bed the laminæ are thinner and merge above into sandy shales and thin layers of sandstone.

Little Clarksburg coal.—The top of the Morgantown sandstone is about 100 feet below the horizon of the Pittsburg coal; the interval is occupied by reddish shales and scattered thin beds of sandstone and clay. A short distance above it and between 75 and 90 feet below the base of the Pittsburg coal a thin coal smut was observed at a few places south of Ohio River. This is probably the horizon of the Little Clarksburg coal (called Bavington by Griswold in Bull. U. S. Geol. Survey No. 318, p. 120). In the central part of the quadrangle, from 1 to 2 miles northeast of Bayne, a coal about 120 feet above the Ames limestone member has been opened in two or three places and is said to be as much as 2 feet thick.

Pittsburg limestone member.—The upper 50 feet of the interval between the Morgantown sandstone and Pittsburg coal is made up of light-yellow sandy shales interbedded with thin streaks of red shale, with two or more thin beds of gray limestone that locally occur near the top and bottom. These limestones constitute the Pittsburg limestone member; few of them are more than a foot or two in thickness, and they appear to be irregular in occurrence.

MONONGAHELA FORMATION.

In western Pennsylvania, where the entire Monongahela formation is exposed, it ranges in thickness from about 280 to 380 feet, occupying the interval between the base of the Pittsburg coal and the top of the Waynesburg coal. In the Sewickley quadrangle a maximum thickness of only about 80 feet of the rocks of this formation remains uneroded. These rocks cap a number of high knobs in the vicinity of Carnot and Moon, in the southwest corner of the quadrangle, some isolated hilltops in the southeastern part of Franklin Township, three hills in the southern part of Pine Township, and a small area on the southern border of the quadrangle, near West View.

The Pittsburg coal has been mined wherever it has been found. A few country banks still mine small quantities, but much of it is inferior to that taken from the commercial mines a few miles farther south. The bed ranges in thickness from 8 to 14 feet, including partings, and includes 4 to 6 feet of minable coal. (See sections on columnar-section sheet.)

The beds above the Pittsburg coal are poorly exposed; hence their lithologic character can only be surmised. In many places a few feet of shaly sandstone overlies the coal, and the soil above indicates the presence of a relatively large amount of thin-bedded sandstone and reddish sandy shale.

[a] Second Geol. Survey Pennsylvania, Rept. H3, 1877, pp. xxxiii, 60.

QUATERNARY SYSTEM.

GENERAL STATEMENT.

In the Permian epoch the whole region, including the Sewickley quadrangle, was elevated above sea level and since that time it has been continuously a land area. During this long period erosion has been going on at the surface, and a large amount of rock material has been removed by the streams, transported to the sea, and again deposited as sediments. Erosion and deposition have been going on simultaneously over a large portion of the surface, and, strictly speaking, the residual material, much of which is frequently shifted from place to place toward its ultimate point of rest in a stratum laid down under the sea, constitutes a deposit. Such deposits are not generally mapped, for obvious reasons, but some of them which are due to certain peculiar subaerial conditions are of sufficient volume and permanency to justify special notice.

Except for temporary aggradations along Ohio River during the glacial epoch and for recent flood plains, the Sewickley quadrangle shows a history of unbroken degradation since Permian time. The glacial epoch marks the formation of the high and low terraces of this region, and the material then deposited is found to-day either occupying the rock shelves, which represent parts of the old floors of former valleys, or lying in broad gravel terraces in the present valleys. These deposits may be divided, according to age, into three general classes—(1) Kansan or possibly pre-Kansan, including the Carmichaels formation and the earlier glacial gravel; (2) Wisconsin, comprising lower terrace gravels and later glacial gravel; and (3) Recent, embracing the present-day flood plains. The first two are each composed genetically of two kinds of material, that of local derivation and that of glacial origin, and belong in the Pleistocene series. The third is composed of both and falls within the Recent series.

PLEISTOCENE DEPOSITS.

EARLIER GLACIAL GRAVEL.

The earlier glacial deposits of the Sewickley quadrangle occupy the highest gravel-covered terraces along Ohio River and are the remnants of the glacial valley train brought down by streams from the terminal moraines of the Kansan ice sheet. The formation consists of poorly stratified beds of gravel, sand, and clay. Most of the pebbles are of quartz, granite, and sandstone and have been transported for long distances from the north by glaciers and streams. These are mixed with gravels, sand, and clay of both local and foreign origin. The pebbles are well rounded and many of them are deeply etched by weathering. Deposits of the earlier glacial gravels generally range from 5 to 25 feet in thickness, though the maximum may reach 50 feet. The areas covered by this formation are small, forming the narrow shelf-like terraces of the Parker strath along the sides of the Ohio Valley at an altitude of about 900 to 1000 feet above sea level or 200 to 300 feet above the river. The largest areas covered by this deposit in the Sewickley quadrangle are in the western part, near Conway and Baden. Deposits of this formation to the east of this area, along Allegheny River, occur at successively higher altitudes toward the north, showing clearly the general gradient of the old valley train. From Foxburg to Pittsburg, a distance of about 80 miles, this gradient amounted to about 150 feet.

STRAY PEBBLES.

Within the Sewickley quadrangle pebbles of quartz, granite, and sandstone were seen at two places much higher than the gravel terraces mentioned above. One of these localities is on the ridge road northwest of West Economy, in Hopewell Township, Beaver County. At this point a number of granite pebbles the size of an egg and larger were found scattered on the top of the broad, flat terrace, at an elevation of about 1175 feet above sea and about 500 feet above Ohio River. The other exceptional locality at which pebbles are found is near the eastern border of the quadrangle, due east of Perrysville, on the ridge west of the Schlag coal bank, at an elevation of about 1260 feet above sea. No indications of a terrace deposit were observed. The pebbles were found along the top of a narrow level ridge on the upper layers of the Morgantown sandstone. The owner of the farm has picked up at this point half a bushel or more of pebbles varying from three-fourths of an inch to 2 inches in diameter. They are of quartz, granite, and sandstone, finely rounded and unusually symmetrical in comparison with pebbles of the earlier glacial gravels. Many of the sandstone pebbles are considerably etched by weathering, but the granite and quartz pebbles are fairly smooth and still retain their polished surfaces. These pebbles are doubtless of glacial origin, and it is believed that they were transported to this place by human agencies. The presence of an unusual number of flint relics on the Schlag farm, where the pebbles occur, suggests that they were collected by Indians.

CARMICHAELS FORMATION.

The valley train which carried the early glacial gravels aggraded the Allegheny Valley, thus blocking the mouths of tributary streams not carrying glacial material. This resulted in the silting up of the mouths of many of these streams and the formation of gravel-covered terraces when the streams resumed their downward cutting. These terrace deposits along tributary streams of the Ohio are composed of pebbles, sand, and clay of local origin. On streams not directly tributary to the Ohio, such as Brush Creek in the Sewickley quadrangle, the effect of the valley train on lateral stream cutting and gravel deposition is not evident. In such streams the highest terrace gravels are generally considered to belong to the Carmichaels formation, though they may differ considerably both in age and in character from place to place over western Pennsylvania and adjacent regions.

The only deposits of this formation of mappable size in the Sewickley quadrangle are located along the lower portion of Brush Creek, on terraces ranging in altitude from 940 to 1000 feet above sea level. The lowest limit of the Carmichaels deposits in this valley is not clearly marked, since at places they seem to merge into the alluvium of the present flood plains. The beds are usually from 5 to 10 feet in thickness and are composed principally of sand, with some pebbles and clay, the pebbles showing little effect of stream action and some of them being notably angular.

At Carmichaels, on Monongahela River, in the type locality, the formation consists of unconsolidated clay, with some sand, gravel, and coarse bowlders. The proportion of these materials varies from place to place and also in vertical section, owing doubtless to variations in the strength of the currents which transported the sediments and in the local character of the rocks from which they were derived. In the Sewickley quadrangle the few Carmichaels deposits noted are made up largely of yellowish sand and sandy clay, with interbedded sandstone bowlders and gravels of local derivation.

No Carmichaels deposits of mappable size were noted along the streams tributary to Ohio River. It is possible, however, that a number of small deposits of this formation occur along Sewickley Creek, Lowrie Run, Montour Run, and Flaugherty Run.

GLACIAL GRAVEL.

Glacial material is not confined to the terraces of the Parker strath but is very abundantly distributed upon most of the better-preserved terraces below this old valley floor. Much of this material is doubtless reworked glacial wash derived by the river from the subsequent trenching of the old gravel-filled valley. Geologists who have made regional studies of the subject are agreed, however, that an influx of fresh glacial material was brought down by Allegheny River, the remnants of which now constitute the deposits of Wisconsin age. Two benches of these later glacial gravels are distinguished on the map. The lower deposits, which lie just above the flood-plain silts, are given the title "Latest glacial gravel" and are of Wisconsin age. The higher are regarded as somewhat older than Wisconsin and are mapped under the title "Later glacial gravel."

There seems some question as to the original depth of this material in Ohio Valley at the end of the Wisconsin stage of aggradation, since it is not positively known to what depth the river had carved its channel below the Parker strath before later filling began. If we assume that during these interglacial stages the river trenched out the present rock floor of the valley, a fairly good estimate of the original thickness of the Wisconsin filling can be made. At Ambridge the top of the later glacial terraces is about 800 to 810 feet above sea level. At Leetsdale many deep wells drilled for oil and gas on the high flood plain of the river at an elevation of 700 to 710 feet penetrated from 50 to 60 feet of unconsolidated "sand and gravel" before the rock floor of the valley was reached, showing the deposits to have been at least 150 feet thick along this part of the valley. Wells on Neville Island, where as much as 80 feet of sand and gravel are reported, furnish practically the same result.

It is possible, however, that the gravels on the rock terraces at elevations of 760 to 810 feet, shown on the map as "Later glacial gravels," were deposited during the time when the Ohio was narrowing and deepening its valley, prior to the influx of Wisconsin material.

It is known that the extensive sloping terrace, between 720 and 820 feet above sea level, on the east side of Ohio River from Conway to Sewickley is in many places a rock shelf upon which rests a considerable thickness of glacial material and that the terraces of the same general elevation at Aliquippa, Shannopin, Shousetown, and Coraopolis are also occupied by the later glacial gravels; but it is not definitely known that any of these conceal portions of the buried river channel with unbroken deposits of Wisconsin age from the height of these terraces to the rock bottom of the old valley floor. There is no doubt that the Wisconsin gravels at Coraopolis and eastward on both sides of the river are on rock shelves. This is also true of the deposits from Haysville to Lashells Ferry at Sewickley. At Edgeworth a well sunk between the Pennsylvania Railroad and the river found 56 feet of sand and gravel, the rock floor being about 25 feet below water level. From this point northwest to the mouth of Sewickley Creek, between the railroad and the river, sand and gravel extend from 25 to 30 feet below water level. At Shousetown the gravels rest upon a rock shelf of Mahoning sandstone several feet above water level. Though a number of oil and gas wells have been drilled through the Wisconsin gravels at both Shannopin and Economy, no records of the thickness of the gravels are available and so far as can be learned none were preserved. It is known, however, that a rock shelf above water level occurs at a number of places at both these towns. If the pre-Wisconsin river had succeeded in eroding its valley below the present rock terraces upon which undisturbed Wisconsin gravels occur, that channel was at most not more than 30 feet below the present bottom of Ohio River.

This glacial material consists largely of pebbles and bowlders, some of which have diameters of 18 inches or more, though the average size is between 1 inch and 3 inches. These pebbles are composed of quartz, quartzite, granite, sandstone, and some limestone. They are well rounded by water and, excepting the limestones, show little effect of weathering. They are embedded in a matrix of sand and clay, the latter appearing to increase in quantity toward the bottom of the formation.

No attempt has been made to differentiate the reworked glacial material from undisturbed remnants of the original deposits. The line between the later glacial gravels and alluvium is therefore an arbitrary one drawn at or near modern high-water mark of the river and does not indicate lithologic distinctions in the material.

RECENT DEPOSITS.

Under Recent deposits are included all unconsolidated rocks, silts, clays, gravels, and local rock débris which cover the surfaces of the present valleys below high-water level. No distinction is made between local and foreign material, and it is assumed that in Ohio Valley all material between high-water mark and the rock floor of the valley belongs under this classification; this despite the fact that there seems little doubt that if this valley was cut by a pre-Wisconsin stream a greater or less amount of undisturbed Wisconsin wash remains buried beneath a thin cover of Recent alluvium of mixed derivation. Little is known of the character of the concealed material. Hice[a] shows that at points farther west on Ohio and Beaver rivers the material at the bottom is prevailingly fine silt, which gradually gives place to successively coarser layers above to the top of the present built terraces. On Ohio River in this quadrangle records of deep wells drilled through this material for oil or gas are not in sufficient detail to be of much value. It is generally mentioned as sand and gravel or "drift," but in a few records the lower portion is described as "muddy," which to some extent bears out the observations made by Hice.

STRUCTURE.

INTRODUCTION.

The whole rock mass of the Sewickley quadrangle is slightly tipped to the south-southeast. The strata are also slightly wrinkled into a series of irregular folds having a north-south to northeast-southwest trend, all pitching gently toward the south. The dip of the beds varies from about 25 to about 125 feet per mile, the average being probably less than 50 feet. A relation of much interest that has apparently been revealed by the detailed study of the structure of the oil sands of this and neighboring quadrangles is that the older and deeply buried beds are slightly more folded than the surface beds. Whether this nonparallelism is due to original nonconformity, to subsurface drag in the isostatic adjustment, or to some other cause is not clear. The suggestion that the pre-Pottsville rocks were slightly folded during the early Pottsville uplift of this region, developing lines of weakness that were followed by the later post-Carboniferous folds, is of interest. This variation in intensity of folding in beds of different ages or of different attitudes when laid down is illustrated by the difference in dip of the Ames limestone member and of the Hundred-foot sand in this quadrangle, as shown in figures 5 and 6.

Representation of structure.—The shape or structure of the strata in this area is shown on the maps of this folio by contour lines which are drawn through points of equal elevation on the upper surfaces of the Ames limestone member and the Hundred-foot sand. The datum plane of the contours for the Ames limestone member is sea level and that of the Hundred-foot sand is 1000 feet below sea level. The contours show points of equal elevation above these datum planes. The contour interval, or vertical distance which separates contours, is 10 feet. Changes in dip of the beds are shown by variations in horizontal distance between the lines on the map. Where the lines are closest together the dip is steepest, because the least horizontal distance is traversed to give a rise or fall of 10 feet in the surface of the reference plane. The dip of the Ames limestone member in the Sewickley quadrangle was determined by finding with spirit level the elevation above sea level of the upper surface of this bed at a great many points of outcrop, all of which were platted upon the topographic base map with the appropriate elevation. Where no outcrops of the Ames occur elevations were determined on other outcropping beds having a determinable interval (within a small limit of error) above or below this reference surface, and the elevation of the horizon of the Ames limestone member was computed.

Contours drawn on the surface of the Hundred-foot sand were obtained by comparing records of steel-line measurements in hundreds of deep wells drilled for oil and gas over the quadrangle with the elevations of the mouths of the wells. In portions of the area these wells were sufficient in number to render it very probable that the limit of error is less than a contour interval. In other portions, where fewer wells have been drilled or poor records obtained, the probable error is much greater. It is obvious that the accuracy with which the contours are drawn depends directly on the number and position of the elevations obtained upon the reference surface and that perfect accuracy can be attained only when the relations of all points on this surface are available.

In many places where no wells have been drilled approximately correct elevations for the Hundred-foot sand might have been obtained by subtracting the large interval between that bed and the Ames limestone member, though most of such elevations might easily have been in error by more than twice the contour interval because of rapid changes in distance between these beds in relatively small areas. The two sets of contours are therefore drawn from practically independent data, and the difference in the intensity of folding is consequently fairly well represented by them.

CONVERGENCE BETWEEN THE AMES LIMESTONE MEMBER AND THE HUNDRED-FOOT SAND.

If it is true that the principal structural features of the Sewickley quadrangle had their origin in post-Pocono crustal movements and have developed continually with subsequent movements that have affected the area in such a way as to account for the difference in the amount of folding in the Ames limestone member and the Hundred-foot sand, it should be supposed that there exists a reciprocal difference in the distance between these beds, due to variations in the rate of deposition. Theoretically the interval between them should be greatest on the axes of the synclines and smallest along the anticlines. If variations in deposition had a tendency to produce such differences in interval, the very small dip at any time reduced it to the minimum, and all traces that might have been detected by the available means are disguised by unconformities. Figure 5 shows lines drawn through points of equal distance between the beds. These lines are not contours showing the shape of a surface but lines which show the thickness of the rocks lying between these key horizons. The numbers on the map give the distance by actual measurements, but these are too few to be of much if any value in detecting the relations of structure to rate of deposition, even if other factors were favorable. Figure 6 shows the positions of the axes of the principal anticlines and synclines of the quadrangle, as shown by contours on the key horizons. The variation in structure

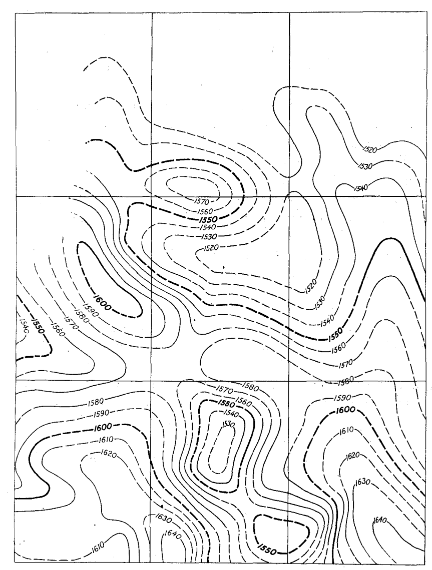

FIGURE 5.—Convergence map showing, by lines of equal distance, the vertical distance between the Ames limestone member and the Hundred-foot sand in the Sewickley quadrangle.

The lines are drawn to pass through points on the Ames limestone having an equal distance above the top of the Hundred-foot sand. In areas left blank the Ames limestone has been removed by erosion.

[a] Hice, R. R., Am. Jour. Sci., 3d ser., vol. 49, 1895, pp. 112-120.

of the two beds thus shown is probably an exaggeration of the true difference because of the unequal distribution of elevations taken on them. If it had been possible to secure elevations on both beds at exactly the same points, the variation of the structural contours would have been due mainly to the difference in the degree of wrinkling of the two beds, and it is probable that if the elevation of all points on both horizons were known the axes of the folds of each would almost or exactly coincide on the map. This, therefore, is a fair illustration of the accuracy of the structural contours. Over most of the quadrangle those of the Ames limestone member are correct within a vertical

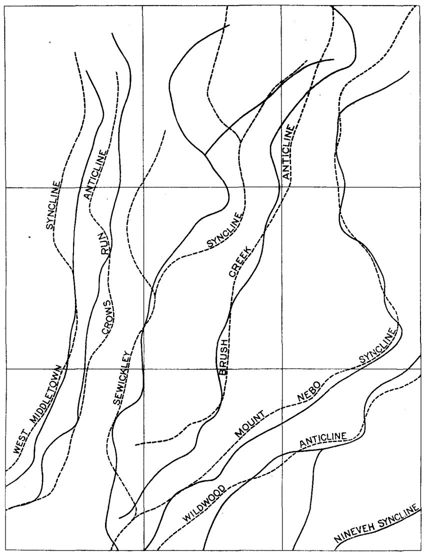

FIGURE 6.—Axes of folds in the Ames limestone member and the Hundred-foot sand in the Sewickley quadrangle.

Axes on the Ames limestone are shown by broken lines; on the Hundred-foot sand by solid lines. The variation shown is probably exaggerated by reason of lack of data. The beds are about 1600 feet apart.

distance of 5 feet. In those areas of 1 or 2 square miles where no elevations were secured on the limestone it may be found at certain points to be 20 or 30 feet higher or lower than the structural contours show. Between these extremes are all gradations of accuracy. In the areas where the Ames is eroded data for structural contours on the surface rocks are scarce and less reliable. From elevations on the Brush Creek coal and Upper Freeport coal the approximate elevation of the Ames horizon has been computed and broken contour lines with a 20-foot interval have been substituted where the structure is doubtful.

What has been said of the accuracy of the contours on the Ames in equally true of those on the Hundred-foot sand. These, where drawn solid, are in most cases correct within an error equal to the contour interval. Where broken contours are used the wells are few and not many reliable data could be secured, and the contours are intended to show no more than the general shape and trend of the main structural features.

FOLDS.

The structural contours on both key horizons show three well-defined anticlines and a corresponding number of synclines within the area. So far as known, only one of these, the West Middletown syncline, has until recently been named. In previous reports by the writer[a] the others have been called the Crows Run, Brush Creek, and Wildwood anticlines and the Sewickley, Mount Nebo, and Nineveh synclines.

West Middletown syncline.—The West Middletown trough has been traced northward from the vicinity of West Middletown, in Washington County, through the central part of the Burgettstown quadrangle, where it is broken up by cross folds into a chain of canoe-shaped basins that become successively less deep toward the north, across the southwest corner of the Beaver quadrangle to the point where it enters the Sewickley quadrangle near the southwest border. Here the trough on the Hundred-foot sand is more clearly defined than the one on the Ames limestone member, which apparently is about half a mile farther to the west.

From this point northward the bottoms of both troughs rise slowly. The axis in the Hundred-foot sand lies a short distance west of Leetsdale, within 200 yards of the old Economy distillery, whence it trends due north and rises at the rate of 30 to 40 feet to the mile.

[a] Munn, M. J., Geology of the oil and gas fields of the Sewickley quadrangle: Rept. Pennsylvania Topog. and Geol. Survey Comm. for 1906-1908, 1908, pp. 289-293; Studies in the application of the anticlinal theory of oil and gas accumulation: Econ. Geology, vol. 4, 1909, pp. 141-157.

The trough in the Ames limestone member is very flat and irregular. In running spirit-level lines over the roads along the course of this fold few outcrops of the Ames were seen, and the generalized trough in the Ames shown on the areal geology map is probably not very accurate, though the main features are essentially so. In New Sewickley Township structure lines on these two beds vary greatly, a portion of this difference being due to lack of sufficient data as to the Ames limestone member.

Crows Run anticline.—The arch which lies east of the West Middletown syncline has been called the Crows Run anticline, from the name of the largest oil pool through which its axis passes. In the Hundred-foot sand this axis lies roughly parallel to that of the West Middletown syncline, at a distance of less than a mile through the southern half of the quadrangle and of not more than 1½ miles farther north. An examination of the areal-geology map will show that the axis of this anticline in the Ames limestone member lies practically parallel with and almost above that of the Hundred-foot. In the center of Economy Township the axes of the arches in these beds cross; that in the Ames limestone member apparently curves sharply to the northwest for a short distance and thence northward the two axes gradually converge until they again almost coincide in the northern part of the Crows Run oil field. The evidence favoring this wide variation in the axis of the Crows Run anticline in the Ames is by no means conclusive, though in the field it was thought that enough data had been collected to settle the matter. There is a strong possibility that this arch in the Ames limestone member continues practically parallel with that in the Hundred-foot sand throughout its course.

Sewickley syncline.—Eastward from the crest of the Crows Run anticline the rocks dip to the trough of the Sewickley syncline, which is one of the most prominent and clearly defined structural features of the quadrangle. The axis of this fold crosses the southern boundary of the quadrangle about 1½ miles southeast of Coraopolis, passes northward through the town of Sewickley, thence half a mile east of the Sevins oil pool, crossing Sewickley Creek about a mile west of Duff City, and thence in a big bow northeastward to a point a mile west of Thorn Hill, where it curves sharply to the northwest to a point about 1½ miles southwest of Ogle. At this point the syncline apparently breaks up into two minor troughs, one keeping the general northwest trend but gradually bending northward to a point where it crosses Brush Creek, about half a mile east of Oakgrove Church. From this point northward its course can not be traced because of lack of good surface exposures and of records of oil wells drilled in that area. The other branch of this syncline has a northeast trend, the trough rising rapidly until it dies out against the side of the Brush Creek anticline about a mile southwest of Callery.

Brush Creek anticline.—This anticline, which is the most prominent fold in the quadrangle, lies east of the Sewickley syncline. In the Hundred-foot sand its crest passes half a mile west of Callery, about the same distance west of Hendersonville, midway between Thorn Hill and Brush Creek, half a mile east of Duff City, through the Grubbs oil field, and from this point pitches very rapidly southward to Ohio River about half a mile east of dam No. 3, at Coraopolis. Farther south the axis continues to pitch until the fold disappears near the junction of the Sewickley syncline with the Mount Nebo syncline, the next important fold to the east.

Mount Nebo syncline.—The Mount Nebo trough apparently branches off to the east from the Sewickley syncline a short distance south of the Carnegie quadrangle border, south of Coraopolis. From this point it has a northeast trend, passing to the east of the Brush Creek anticline. It crosses Ohio River at the west end of Neville Island, and from this point to the Mount Nebo oil field, through which it passes, the axis of the trough rises at the rate of 60 or 70 feet to the mile. From a point less than a mile northeast of Mount Nebo Church the trough pitches slightly to the bottom of a shallow basin about 2 miles southeast of Ingomar. From this basin the trough rises slowly, passing half a mile south of Keown, to a point about a mile west of the place where Pine Creek leaves the quadrangle. From this point the syncline apparently bends abruptly westward until the trend is a little west of north, though this may possibly be a minor branch of the main trough of the syncline, which may continue its northeast trend. Conclusive data on this matter are not at hand. This trough passes 1½ miles east of Brush Creek, rising at a rate of 40 to 60 feet to the mile, and runs less than a mile west of the Mars oil pool, where it has become narrow and rather shallow. The data seem to show that to the north this trough bends again to the northeast and leaves the eastern border of the quadrangle about 2 miles from the northeast corner, though this is by no means certain.

As shown on the areal-geology map, the Sewickley syncline, the Brush Creek anticline, and the Mount Nebo syncline in the Ames limestone member conform closely to those just described for the Hundred-foot sand. As already stated, the map probably shows a greater degree of variation than actually exists.

Wildwood anticline.—The axis of the Wildwood anticline' which lies to the east of the Mount Nebo syncline, enters the quadrangle from the east about half a mile south of Pine Creek. It trends southwest, running roughly parallel to the Mount Nebo trough and being usually less than 1½ miles from the axis of that fold. It crosses the plank road less than a mile north of Perrysville and there swings sharply to the west, passing near the southeast corner of Franklin Township. Between these points it forms the crest of a low dome, from which the axis pitches very rapidly to Ohio River in the vicinity of Glenfield, beyond which it becomes more and more obscure. From the western end of this dome a prominent minor anticline pitches off to the south and crosses the Ohio in the vicinity of Avalon, and from the eastern end another anticlinal nose projects to the southeast, passing a mile or more to the east of West View.

Nineveh syncline.—Southeast of the Wildwood anticline a syncline cuts across the corner of the quadrangle a mile or so southeast of Bellevue. This is a part of the Nineveh syncline, which is the principal structural feature in the Carnegie quadrangle, to the south of the Sewickley, though its main axis probably passes farther to the southeast.

GEOLOGIC HISTORY.[a]

The geologic history of this region resolves itself, in general terms, into two great cycles—one of construction and one of destruction—corresponding to periods of prevailing deposition and of prevailing erosion of strata. The time in which we are now living belongs to the latter, still unclosed cycle. Neither has of course been continuous, for each has often, for short intervals, been interrupted by reversions to the other; nor have both been of equal duration, for it is undoubted that the cycle of construction continued during a period very many times as long as that so far consumed by the present cycle of destruction. The events of the former are recorded in the consolidated rocks of the region, and the history of the latter may be read in the surficial rocks and in the topography.

SEDIMENTARY RECORD.

PRE-CHEMUNG AND CHEMUNG DEPOSITION.

The strata forming the consolidated rocks of western Pennsylvania are composed chiefly of sandstones, shales, and limestones, with scattered beds of coal and clay. The sea in which these sediments were laid down covered most of the Appalachian province and the Mississippi basin. The oldest rocks known in the Appalachian province are the crystalline rocks of the Blue Ridge and the Piedmont Plateau on the east. These are believed to have formed part of the oldest land on this continent of which there is any record. The western shore of this land area lay east of the present position of the Blue Ridge and the land extended to an unknown distance eastward, possibly far beyond the present shore of the Atlantic. To the northeast, in the Adirondack Mountain region, lay another area of crystalline rocks. North and west of the Adirondacks, reaching to the vicinity of Lake Superior, was the southern shore of a vast land area, now occupied by the crystalline rocks of Canada. The rocks of the two regions last mentioned are of the same age as those of the Blue Ridge. Thus in earliest geologic time there existed a land mass having a rudely V-shaped form and inclosing within its arms a body of water known to geologists as the interior Paleozoic sea.

Into this Paleozoic sea discharged rivers bearing the sediments of which the sedimentary rocks of the Appalachian province are composed. While these rocks were accumulating to the thickness of several thousand feet new species of animals and plants made their appearance from time to time and earlier forms became extinct. Later, land plants made their appearance and the conditions began which eventually resulted in the formation of the coal beds of the province.

After a great thickness of sediments had been accumulated uplift occurred, the axis of which extended from the Great Lakes to western Tennessee. This is known as the Cincinnati uplift. The sea bottom along a part or the whole of the axis was probably raised into dry land. A barrier was thus formed that still more completely inclosed the interior sea, which approached the form of a narrow embayment extending from Alabama to eastern New York and which is now appropriately called the Appalachian gulf. In this gulf sedimentation continued during a long period of repose or of gentle oscillations and a large quantity of fine sediment was laid down.

The sea bottom was slowly subsiding during most of this period, but at the beginning of Chemung time the sea became shallow either from crustal movements or from the accumulation of sediments, or both, so that most of the rocks of that formation were laid down in shallow water. In regions where the Chemung comes to the surface it is composed in large part of closely alternating beds of shale, sandstone, and impure

[a] The author presents this section as material compiled from previous folios, little of value being added by him; much of it is a direct quotation from matter published in the Kittanning, Rural Valley, and Ebensburg folios by Charles Butts and in the Beaver folio by Lester H. Woolsey.

imestone, shale predominating. Many evidences of shallow-water accumulation are found, and the abundance of fossils indicates that the conditions were favorable to life and that the sea floor swarmed with living beings. The observed facts indicate a broad expanse of comparatively shallow water which was receiving sediments from the adjacent lands, sometimes finer, sometimes coarser, now in abundance, now more sparsely, the kind and rate of sedimentation varying rapidly and producing the rapidly alternating strata and layers of the formation. In the Sewickley quadrangle a few deep wells probably penetrate to this formation, but no detailed records of them have been preserved.

CATSKILL (?) DEPOSITION.

Before the beginning of Chemung deposition (indeed, soon after the close of Hamilton time) the Catskill phase of sedimentation began at the northeast extremity of the Appalachian gulf, in what is now eastern New York, with the deposition of the Sherburne flagstone member of the Portage formation. From this time onward the deposition of these rocks continued, being contemporaneous at first with the marine Portage, later with the Chemung, and at the top probably with the bottom of the Mississippian deposits. At the same time the Catskill sediments spread farther and farther westward and southwestward, and toward the end of Catskill time the finer sediments extended into what is now western New York and Pennsylvania.

Thus it happens that the Catskill rocks, which have a probable thickness of several thousand feet in the Catskill Mountain region, where sedimentation was continuous from the beginning of the epoch, grow thinner as they extend westward, until in western Pennsylvania and New York their supposed representatives, which are characterized by beds of red shale, are only a few hundred feet thick.

In the Sewickley quadrangle the red rocks which are supposed to belong to the Catskill formation occur near the top of what is regarded as Catskill, and, to judge from the character of similar deposits in western New York, they probably consist of soft fine shales resulting from the consolidation of the finer material that was borne by the water farthest from the eastern shores of the Appalachian gulf, where it was discharged by the rivers of the bordering lands. The red rocks of the western margin of the formation lie in detached beds or lenses of greater or less extent and thickness in the midst of gray shales and sandstones that possibly had a different source. This mode of occurrence indicates that the sediments were transported intermittently at times of flood, when stronger currents bore them farther westward, or at times of great storms, when the supply of sediment was greater. Toward the close of the deposition of the red rocks the great beds of coarse gray sandstone that form many of the reservoirs for oil and gas in this part of western Pennsylvania were accumulated.

POCONO DEPOSITION.

Late Catskill and early Pocono time was marked by many slow oscillations of the Appalachian sea floor and probably of the land surfaces to the east. Such movements were so strong that, though parts of the sea floor never rose above water and parts of the old land area were never submerged, the shore line migrated backward and forward within wide limits. Along such a shore land plants probably flourished, died, and were buried. Their remains are still preserved in the Pocono coals farther south, but no record of them is known in the Pocono of the Sewickley quadrangle. Fresh-water conditions probably prevailed generally throughout the northern end of the Appalachian gulf, but the material brought in shows a decided change from that deposited in Catskill time, being prevailingly gray instead of red. In the part of Pennsylvania in which the Sewickley quadrangle is situated the heavy sandstones known as the Hundred-foot and Murrysville or Butler gas sands were among the first strata deposited. These were followed by gray shales with a few beds of red shale of local extent and by scattered sandstone lenses. During the later part of Pocono time vast quantities of coarse sand were brought into the Appalachian gulf and spread widely over the sea bottom, forming the coarse Burgoon sandstone (Mountain or Big Injun sand). As the deposition of this coarse sandy material was drawing to a close a large quantity of carbonate of lime was deposited with the sand, forming the Loyalhanna ("Siliceous") limestone, which is a widely extended and easily recognizable stratum at the top of the Pocono throughout southwestern Pennsylvania, but which is believed to be absent in the Sewickley quadrangle.

MAUCH CHUNK DEPOSITION.

At the close of Pocono time the Appalachian sea became deeper and clearer, little or no sandstone being laid down. Probably the submergence which brought the clear ocean waters into the region converted the lower courses of the rivers into estuaries in which the coarser part of the land waste was held. The open sea teemed with marine animals, the calcareous remains of which furnished the greater part if not all of the material of which the Greenbrier limestone member was formed. This bed ranges in thickness from a knife-edge in western Pennsylvania to over 2000 feet in eastern Pennsylvania.

An elevation of the continent to the east brought mud and sand into the clear marine waters and put an end to the deposition of the Greenbrier. The inherent red color of the shales formed from these sediments suggests that the conditions during their deposition were similar to those of Catskill time.

The thickness of the Mauch Chunk formation is over 2000 feet in northeastern Pennsylvania and diminishes toward the west. On the Allegheny Front west of Altoona it is 180 feet. At Blairsville, as recorded in deep wells, it is about 50 feet. At the southwest corner of Pennsylvania the formation is from 100 to 250 feet thick, but it thins northward and no definite indications of it are found north of Ohio River and west of Allegheny River in Pennsylvania. The recognized Mauch Chunk rocks nearest to the Sewickley quadrangle lie a few miles to the south.

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

POTTSVILLE DEPOSITION.

The Pottsville is one of the most important and interesting stages in the history of the province, since in it the accumulation of coal began on a large scale. If the movements of the earth's crust indicated in the preceding paragraphs took place, there existed at the beginning of Pottsville deposition a deep trough in eastern Pennsylvania and the region to the south, bordered around the north end and on both sides by land and on the southeast probably by high land. From these borders the rapid streams brought in immense quantities of coarse material, including large numbers of quartz pebbles, which were deposited in the thick, extensive, and coarse conglomerates of the Pottsville formation. It is believed that the Pottsville sediments were derived largely from the northern end and southeastern side of the trough, because there is no near-by source of quartz pebbles on the other side. This deposition of coarse material went on until about 1000 feet of strata had been laid down in the southern anthracite field. At times conditions were favorable to a luxuriant growth of plants, and thick, extensive, and valuable beds of coal were accumulated.

While 800 or 900 feet of the Pottsville sediments were accumulating in the southern anthracite field erosion had probably been going on from central Pennsylvania westward, and the land surface had been worn down nearly to sea level and then submerged, so that toward the close of Pottsville time sedimentation was resumed over the former land area. Thus it happened that the Connoquenessing sandstone member—the lowest member of the Pottsville in the Sewickley quadrangle—was deposited upon the Burgoon sandstone or upon the thin stratum of shales at the top of the Pocono formation, and to the south of this quadrangle upon the eroded surface of the Mauch Chunk formation. After the deposition of the Connoquenessing there was a change to quieter conditions, and the Mercer shale member, consisting of limestones, clays, and coals, was deposited. This period was followed by one of more active sedimentation, during which the Homewood sandstone member was laid down, marking the last episode in Pottsville history in western Pennsylvania.

ALLEGHENY DEPOSITION.

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

With the foregoing in mind, the sequence of events during the deposition of the Allegheny formation may be conceived to have been somewhat as follows: After the Homewood sandstone member of the Pottsville was laid down there was a slight subsidence and an accumulation of 10 to 30 feet of clayey sediments, which raised the bottom approximately to water level and caused marshy conditions over a large area. The vegetation of the time established itself on this marshy land and continued until the remains of many generations of plants had formed an extensive area of peat moss. From time to time different parts of this marsh were flooded and thin layers of sediment were deposited; these form the partings or binders of the resulting coal bed. The accumulation of vegetal matter varied in amount at different places, causing coal beds of varying thickness. After a long period of comparative quiescence the region was depressed, sedimentation was resumed, the plants were killed, and the vegetal matter was buried and, under the pressure of the superincumbent rocks subsequently deposited, was compressed and hardened into the coal seam now known as the Brookville (or "A") coal. The subsidence which led to the burying of the Brookville coal was accompanied by a deposition of shale and sandstone, the sea bottom was again raised to water level, and coal-forming conditions were restored, during which slight local oscillations of the surface permitted the lower and upper Clarion and the Craigsville coal beds to be successively laid down.

The deposition of these coal beds and their associated shales and sandstones was followed by another subsidence, apparently of considerable extent, which admitted sea water to a large area, over which the Vanport ("Ferriferous") limestone member was deposited. This limestone is known to have been laid down in salt water, as it contains fossil shells or the solid parts of other animals that live only in salt water, and it is probably composed almost entirely of carbonate of lime derived from such sources. This subsidence was apparently of great extent, for the limestone seems to have been deposited in water of considerable depth and at some distance from shore, as its purity indicates that it received no admixture of sediments from the surrounding land. Whatever may have been the cause, the bottom was raised to water level again, partly at least by sedimentation and probably also by elevation, another period of coal making began, and during alternating periods of local oscillation and repose the Kittanning group of coals, the Lower and Upper Freeport coals and their under clays, and the intervening beds of sandstone, shale, and limestone were formed.

It is reasonable to suppose that when elevations of the strata occurred which converted wide expanses of this shallow sea or gulf into fresh-water marshes suitable for the growth and preservation of coal-making plants, the upward movement did not cease every time when the sea bottom had been brought exactly to marsh level, but that in many localities the elevation was sufficient to expose the soft, unconsolidated strata to erosion for relatively short periods of time. Under such conditions the amount of material removed would be comparatively small, but it was probably sufficient locally to cause numerous slight unconformities when deposition was resumed. These unconformities are recognizable in comparatively few places, for as little or no distortion of the strata took place the bedding planes of the strata above and below them are practically parallel and no appreciable changes in fossils are noted. Such local unconformities probably account for the variation in the intervals between beds throughout the Pennsylvanian series and for most of the splits that occur in the coal seams.

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

CONEMAUGH DEPOSITION.

At the close of Allegheny deposition a more or less clearly marked change in the conditions of vegetation and deposition took place. Deposition continued during the laying down of the 600 feet or more of the sediments of the Conemaugh formation, but marine conditions seem to have prevailed locally, for salt-water fossils are found in some places in the roof shales of the Upper Freeport coal seam, at the top of the Allegheny. In the Sewickley quadrangle coal-forming conditions prevailed here and there at short intervals throughout Conemaugh time, though extensive marshes were rare and of comparatively brief duration. The beginning of Conemaugh time was marked by the accumulation of the Mahoning sandstone member, which resulted from a widespread submergence that carried the Upper Freeport coal below the surface. In places the accumulation of sand and local deposits of shale filled the basin to water level and one to three local coal seams were formed; but these were submerged and the deposition of sand continued. Over much of western Pennsylvania, however, sedimentation was continuous until a thickness of 150 feet of sand and mud was laid down.

The deposition of the Mahoning sandstone member was soon followed by widespread marsh conditions of short duration; at this time the Brush Creek coal was formed. Another incursion of sea water followed in which the Lower Cambridge ("Brush Creek") limestone was deposited, and marine conditions continued throughout the deposition of 50 to 70 feet of shales and sandstones. This again brought the basin to water level at many places and resulted in the formation of another coal bed—the Bakerstown—which, though of local occurrence, attains considerable thickness. Marine deposition of shale, sandstone, and scattered thin beds of limestone followed until strata having a thickness of 100 to 150 feet were laid down, at the top of which was a considerable thickness of red clayey shales very similar to the red beds of the Catskill formation. Local coal-forming conditions followed and were in turn succeeded by marine conditions of very widespread extent in which the Ames limestone member was formed. This bed was probably laid down in a broad, shallow sea surrounded by peneplainic land surfaces from which but little material was being removed. This limestone is said to mark the last recurrence of marine conditions in the Appalachian basin.

After the Ames limestone and a few feet of overlying shales had been deposited the bottom of the basin was again brought to the surface and an irregular deposit of coal of wide extent laid down. Subsidence followed, the land areas were elevated, and a period of comparatively rapid erosion brought in large quantities of sand and clay, which make up the remainder of the Conemaugh formation. At isolated points there were small swamps in which the Little Clarksburg or Bavington coal was formed, and at other places the water was sufficiently deep and free from currents to permit the deposition of one, two, or more thin limestones near the top of the formation.

MONONGAHELA AND DUNKARD DEPOSITION.

The deposition of the Conemaugh formation was succeeded by that of the Monongahela formation and the Dunkard group (Washington and Greene formations), which remain in the southwest corner of Pennsylvania but which, except for 60 or 70 feet of strata at the base of the Monongahela, have been eroded from the Sewickley quadrangle.

At the close of Conemaugh time the Appalachian basin was a vast level plain at or just below water level. Uniformity in conditions and long duration of luxuriant vegetation resulted in the formation of the Pittsburg coal, which was laid down in what was probably the most widespread and in many ways the most remarkable coal-forming period in the history of the Appalachian basin. A general submergence at its close put an end to the vegetal growth and covered the Pittsburg coal with mud. The elevation of adjacent land followed and a considerable thickness of sand, which forms the youngest consolidated rocks remaining in the Sewickley quadrangle, was deposited.

The strata above this horizon, in areas where they are still preserved, record a series of events similar to those already described for the Allegheny and the Conemaugh formations. Toward the close of Dunkard time the luxuriant vegetation which is so characteristic of the Carboniferous period gradually diminished and finally became extinct, and this great period, so important in the history of the earth, came to an end.

UPLIFT AND EROSION.

GENERAL STATEMENT.

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

The period of uplift in the Appalachian province began with an epoch of compression in a northwest-southeast direction, intensely folding the sedimentary rocks in the Great Appalachian Valley into a series of high anticlines and deep synclines and forming lower anticlines and shallower synclines in the bituminous coal fields west of the Allegheny Front. This was followed by continental uplift and tilting of the surface of the land toward the sea.

SCHOOLEY PENEPLAIN.

With the emergence of dry land degradation began. Eventually uplift was arrested, a long period of quiescence ensued, and it is believed that the surface of the Appalachian province was eroded approximately to a gently sloping plain near to sea level. This is called the Schooley peneplain because remnants of it are well preserved in Schooley Mountain, New Jersey. The level crests of many of the ridges of the Great Appalachian Valley, of which those just east of the Allegheny Front, in Blair County, are good examples, may approximately represent the surface of this peneplain. It was completed before the end of Cretaceous time at least, for in New Jersey it is found extending beneath deposits of Cretaceous age. In the Sewickley quadrangle this surface has been entirely removed by subsequent erosion unless the high flat-topped knobs in the north-central part of the quadrangle are remnants of it.

HARRISBURG PENEPLAIN.

After the reduction of the Appalachian province to form the Schooley peneplain uplift was renewed and erosion once more became active. Later the uplift ceased and extensive areas were again reduced, probably during early Tertiary time, to an approximately flat surface, already described (p. 2) as the Harrisburg peneplain. During this period of erosion the softer rocks of the Great Appalachian Valley were worn away, leaving the harder rocks as ridges.

WORTHINGTON PENEPLAIN.

Elevation was resumed and the streams renewed their activity, furrowing the former flat surface into valleys. When the land had risen about 100 feet the upward movement seems to have halted for a period, during which the Worthington peneplain was developed. This probably occurred in the later part of Tertiary time.

PARKER STRATH.

Another uplift followed, during which the streams of the region cut deep valleys below the Worthington peneplain. The upward movement then ceased and the larger streams excavated valleys of considerable width. The strath cut by Ohio River ranged from 1 to 2 miles in width, with a floor of very low gradient. Many of the longer tributaries of the Ohio also cut wide, flat valleys. It was at this time and during a short following substage that the valleys of Pine, Brush, and Breakneck creeks were brought to their present width. The formation of this strath, known as the Parker strath, probably marked the close of Tertiary time.

KANSAN OR PRE-KANSAN DEPOSITION.

The further development of the Parker strath was arrested, probably at the beginning of the glacial epoch, by the invasion of the Kansan or pre-Kansan ice sheet, which was the earliest stage of glaciation known to have affected this region. This ice sheet, moving from the north, transported great quantities of rock débris from the region over which it passed and deposited much of it as gravel, sand, and silt over northwestern Pennsylvania southeastward to a line roughly drawn from the point where Beaver River intersects the northern boundary of Beaver County to Oil City and thence northeastward along the north side of Allegheny River. From this drift sheet great quantities of material were washed down the Allegheny and deposited by the overloaded waters upon the Parker strath. The original thickness of this deposit is not known, as only a small portion of it remains upon the rock shelves which constitute the remnants of the Parker strath, but it is estimated to have been between 75 and 150 feet. Contemporaneously with the deposition of the glacial gravels the Carmichaels formation was locally laid down.

DRAINAGE MODIFICATIONS.

With the advent of a warmer climate the ice sheet receded, leaving the surface covered with drift and all the old valleys filled to great depths. This valley filling was so great in many places that the streams were deflected from their preglacial courses and new drainage relations were established.

The upper part of the preglacial Allegheny River found outlet to the northwest by Salamanca to Gowanda and thence down the Cattaraugus Valley into Lake Erie (see fig. 3, p. 1); the middle portion, from a point as far south as Emlenton, passed through Venango, Crawford, and Erie counties, Pa., along a channel now utilized in part by French and Conneaut creeks, and entered the Erie basin just east of the Ohio-Pennsylvania State line; and the waters of the Clarion and the lower Allegheny, with its tributaries, followed the present course of drainage to the mouth of Beaver River, where they turned to the north and followed an old valley occupied in part by Beaver and Grand rivers to Lake Erie. At the close of this stage of glaciation the Clarion-Allegheny, now the lower Allegheny, enlarged to four times its original volume, was flowing upon a bed of glacial débris. This material was attacked by the river and mostly removed, only those portions being left which have been described as covering the remnants of the Parker strath. The work of the river did not end, however, with the removal of these deposits; it continued until a trench over 200 feet deep had been excavated in the rock below the level of the strath.

Before the beginning of the glacial epoch the Ohio had its source in the vicinity of New Martinsville, W. Va., and flowed northward along its present course into Beaver River at Beaver. Beaver River, at its junction with Connoquenessing River, was at a considerably lower level than it is at present. Tributaries of the Connoquenessing, including Brush and Breakneck creeks, had steeper gradients and were more active than they are now. The invasion of the Kansan ice sheet blocked the drainage system (see fig. 3) and ponded the water behind this obstruction until it overflowed the lowest point in the southern divide in the vicinity of New Martinsville, W. Va. The new stream deepened its channel through the divide at such a rate that when the ice sheet retreated and disappeared its bed was lower than the old gravel-choked valley from Beaver northward, and the new drainage system therefore became permanent.

WISCONSIN DEPOSITION.

Between the earliest stage of glaciation, already described, and the latest or Wisconsin stage, two intermediate stages—the Illinoian and Iowan—have been recognized in the upper Mississippi Valley. No drift belonging to either of these stages is certainly recognized in western Pennsylvania, and it is presumed that these stages did not reach this region. During the Wisconsin stage the ice again invaded northwestern Pennsylvania and deposited its load of drift over approximately the same area as that covered by the earlier drift. Its margin lay nearly parallel to the margin of the older drift but not quite so far southwest. The outwash from this drift consisted of coarse pebbles and bowlders near the ice margin, but farther south, within the limits of this quadrangle, it consisted mainly of fine silts, which covered the bottom of the Ohio Valley to a depth of about 100 feet.

RECENT EROSION AND DEPOSITION.

During postglacial time the Ohio has been occupied in eroding its present channel in the Wisconsin outwashed deposits and in reworking them to a greater or less extent. The alluvium forming the modern flood plains was deposited by the Ohio and its tributaries as they widened their channels and overflowed their banks from time to time, just as they may be observed to do at the present day.

ECONOMIC GEOLOGY.

MINERAL RESOURCES.

The more important mineral resources of the Sewickley quadrangle are petroleum, natural gas, and coal; others of less importance are brick clay, limestone, building stone, and sand.

PETROLEUM AND NATURAL GAS.

General statement.—The principal mineral products of the Sewickley quadrangle are petroleum and natural gas, which are of such importance that a special bulletin has been prepared on them.[a] Of the 227 square miles embraced by the quadrangle about 25 have been found to be underlain by pools of oil with more or less gas and about 12 additional square miles have produced gas without oil. This productive territory is divided into more than 90 separate pools varying in size from a few acres to several square miles.

The oil and gas have been found to occur in seven or more sandstones of the Pocono and Catskill (?) formations, known to producers as the Venango oil sands. This name is derived from Venango County, Pa., where the first large oil pools discovered in America were found in them. These sandstones have a vertical range of less than 500 feet and are reached in the quadrangle by more than 2000 wells from 1200 to 2100 feet deep. In descending order, these sandstones are known to producers as the Hundred-foot (divisible in places into the Gantz and Fifty-foot), Nineveh Thirty-foot, Snee or Blue Monday, Bowlder, Gordon Stray, Third or Gordon, Fourth, and Fifth sands.

The general character of these beds has already been discussed under "Descriptive geology."

[a] Munn, M. J., Geology of the oil and gas fields of Sewickley quadrangle, Pennsylvania, prepared under the direction of the U. S. Geol. Survey and the Topog. and Geol. Survey Comm. Pennsylvania, and published by the latter.

As a whole the oil sands are of medium grain and porosity, but each of them includes lenticular masses of coarse, more or less conglomeratic sandstone, usually very much softer and more porous than the surrounding sandstone. These patches of poorly cemented sand are from a few square feet to a square mile or more in extent and usually range from 1 foot to 15 feet in thickness. (See fig. 7.) They constitute the "pays" or "pay streaks" in which the oil and gas are found, though the softer sandstones are in places found to contain oil and gas throughout their thickness.

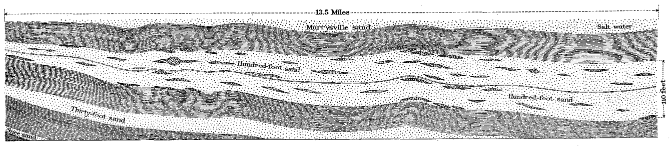

FIGURE 7.—East-west section across the Sewickley quadrangle from Freedom on the left to Salem Church on the right.
Shows conglomeratic sandstone lenses in the Hundred-foot sand. The darker lenses contain oil, gas, and salt water; the lighter ones are dry or contain only salt water.

Most of these pools have been producing for 8 to 20 years or more, and nearly all of them have been thoroughly tested. The production of each has long since reached its maximum, from which it is gradually diminishing as the pools approach exhaustion. The total production of the pools, however, has been very large, many of them when at their maximum yielding from 1000 to several thousand barrels a day. Some single wells flowed as much as 2000 barrels a day. Outside of the producing areas test wells are numerous and are so distributed that it is safe to say that no very large pools remain undiscovered and probably not many smaller ones. Most of the oil pools yet to be developed will be found to be more or less closely connected with those already found, as small extensions that have so far escaped detection.

Moon oil pool.—The Moon pool extends over about one-fourth of a square mile in the extreme southwest corner of the quadrangle, most of it being in the Beaver, Burgettstown, and Carnegie quadrangles, to the west, southwest, and south of the Sewickley. The oil in this pool occurs in the Third or Gordon sand. It is accompanied by considerable quantities of salt water, some of the wells producing ten times as much water as oil. The quantity of water increases with the life of the well, with a resulting decrease in the amount of oil. Many wells are said to have had an initial production of more than 100 barrels a day. The pool has been developed for a number of years and the wells are now almost exhausted. The Gordon sand in this pool is very thin, ranging from about 7 to 20 feet. It pinches out entirely within a few miles to the northwest. The pool seems to be entirely encircled by dry holes, so that there is little possibility of extensions to it being found.

Coraopolis oil pool.—The Coraopolis pool extends from Ohio River at Coraopolis southwestward within a mile of the Moon pool. It was developed in 1890 to 1893. The Gordon sand furnishes most if not all of the oil. The pool extends along the flank and crest of the Brush Creek anticline to the point where this fold disappears at the junction of the Sewickley and Mount Nebo synclines, thence crosses the Sewickley syncline and continues southwestward along the eastern limb of the Crows Run anticline. The lower edge of the pool lies practically level along the 1330-foot contour, but the upper edge varies between the 1360 and 1380 foot contours. The structural position of this pool indicates that the oil has accumulated at the top of a water-saturated portion of the Gordon sand, but well records show that water is also encountered above the oil in the Gordon sand at several places on the northwest side of the pool. These records, however, are very incomplete and do not state the amount and head of the water noted. Salt water makes its appearance sooner or later in all the wells, but the encroachment is much more rapid from the southeast, where many wells on the margin of the pool have been completely flooded and the flow of oil stopped.

One of the most difficult geologic problems connected with a study of accumulations of oil and gas is that of providing a logical explanation of the origin and behavior of the salt water in the oil sands. In the instance just cited it would naturally be supposed that this water is static and that it saturates the whole bed below the oil pool up to some definite level. This is not true, for only 2 or 3 miles farther south, in the Carnegie quadrangle, down the continuous dip of the bed, the Gordon sand has been reached in a large number of wells, where it is almost universally considered by drillers to be dry. It is to be regretted that more data are not available regarding this phenomenon.

The Fourth sand has yielded considerable quantities of gas from most of the Coraopolis pool and from an area northwest of it in the vicinity of Carnot. The wells are now old and the gas pressure has become so reduced that salt water has begun to appear in many of them. At a number of places within Moon Township the Hundred-foot sand has been found to contain small amounts of oil with much salt water, and occasionally a good gas well has been secured in it. The total production of both oil and gas from it in this pool is, however, unimportant.

Shannopin oil pool.—The Shannopin pool was developed in 1895–96, the oil being found in the Hundred-foot sand. The wells of this pool are located on the south side of Ohio River from Wireton to Shannopin and along the slope of the river hill back of these towns. Only a small proportion of the wells of this pool were located on the map during the field work for this folio. More or less salt water occurs in the Hundred-foot sand and is pumped out with the oil.

Leetsdale oil pool.—The Leetsdale oil pool is the only productive area of importance within Leet Township, and it occupies less than 160 acres in the Ohio River valley at Leetsdale. The oil comes entirely from the Hundred-foot sand and is accompanied by salt water in proportions that vary considerably, seemingly with changes in thickness and porosity of the bed. The thicker and more open portions of the pay streak generally furnish a greater ratio of water to oil. On the other hand, the amount of oil produced by a well is usually in direct ratio to the amount of salt water it pumps. As a rule, the best wells are those that produce the most water, and when the water is exhausted the flow of oil ceases.

Gas is found in the Fourth sand at a number of places in and surrounding the Leetsdale oil pool.

Phillips oil pool.—The Phillips pool is situated on Little Sewickley Creek about a mile northwest of Sewickley. It comprises but two producing wells encircled by a line of dry holes only a few hundred feet away. The oil come from the Hundred-foot sand and is accompanied by salt water. The wells have never been large producers, but they show a remarkably slow decrease in production. The pool seems to be confined to a very small lens of porous conglomeratic sand inclosed within the harder, closer sandstone. Neither water nor oil was found in the Hundred-foot sand until the drill touched the pay streak.

Sevins oil pool.—The Sevins pool is situated in the extreme southern part of Sewickley Township, about half a mile north of the Phillips pool. It includes six producing wells surrounded by nine or ten dry holes. The oil in this pool is obtained from the Hundred-foot sand under conditions similar to those in the Phillips pool. The variability of the soft porous pay streak within the Hundred-foot sand is so great that the extent of the pool can not be outlined, but it is doubtful if any large wells will be secured.

Grubbs oil pool.—The Grubbs pool is situated on the axis of the Brush Creek anticline about a mile north of Stonedale. The oil comes from what is said to be the Bowlder sand, though this correlation is open to some doubt. The oil-bearing bed may possibly be more nearly equivalent to the Gordon Stray sand. The wells in this sand made good initial flows, several wells ranging from 30 to 200 barrels or more a day. Southeastward from this pool the oil sands dip steeply to the axis of the Mount Nebo syncline.

The records of wells in this pool mention no water in the Bowlder sand. This is verified by both producers and pumpers, who are agreed in the statement that little if any water comes from this sand. From all available data it seems that this pool occupies a lens of open, porous sand which pinches out around the edges of the pool into a closer, harder sandstone and that the extent of the pool in every direction is limited to this pay streak. Oil is also found in the Hundred-foot sand, which carries more or less salt water. Here is an instance where two oil pools, of which one contains salt water and the other is apparently dry, occur one above the other on the axis of an anticline in different sands.

Mount Nebo oil pool.—The Mount Nebo pool was discovered and opened up in 1885–86. The first wells were of sufficient size to create considerable excitement among producers, but the pool failed to justify expectations. It is now producing a small amount of oil from about 15 wells, the entire yield coming from what is thought to be the Third or Gordon sand.

The pool lies squarely across the steep narrow trough of the Mount Nebo syncline in such a way as to discredit local structure as an important factor of accumulation in this sand. The oil-bearing sand has a maximum thickness of less than 30 feet, but the soft conglomeratic pay streak is rarely if ever 10 feet in thickness. Little or no water is found.

The gas wells to the west, south, and southeast of the Mount Nebo pool probably get most of their gas from the Fourth sand, though the Third and Fifth sands also furnish considerable amounts in a few wells. A show of oil with salt water has been noted in the Hundred-foot sand in one or two wells in the vicinity, but no paying wells have yet been found.

Glenfield oil pool.—The Glenfield is the largest pool yet found in the Fourth sand within the Sewickley quadrangle. Its eastern border extends for 2 miles parallel to and just west of the axis of the Mount Nebo syncline, the oil being found along the comparatively steep slope of the western flank of this fold. The oil-producing area is triangular in shape, each of the three sides being between $1\frac{1}{2}$ and 2 miles in length. The pool was opened up in 1895–96 and has produced a large quantity of oil. Many of the wells are said to have started off at more than 100 barrels a day.

The records secured of wells in this pool are very incomplete and furnish little data of value. The Hundred-foot sand seems to range from 80 to 100 feet in thickness and to carry a considerable amount of salt water. The Gordon sand is from 10 to 30 feet thick and in a few wells yielded both oil and gas. The wells are now down to a few barrels a day at most, and many of them have been exhausted and abandoned. Little or no salt water is found in the Fourth sand.

Haysville oil pool.—The Haysville pool is situated in the vicinity of Haysville, across Ohio River from the northern end of the Coraopolis pool, and is in reality in a northern extension of the Third or Gordon oil sand of that pool. The field now contains about 20 wells occupying less than 100 acres along the slopes and crests of the river hills back of Haysville. Several wells drilled in this town are said to have produced oil, but no records of them could be obtained. The wells are now making only a few barrels a day and many have already been abandoned.

Near the southwest corner of Aleppo Township and half a mile north of Osborne three or four wells are pumping a little oil from what seems to be a separate pool from that at Haysville. No records of any of these wells and but few other data regarding them could be obtained.

In the vicinity of Montour Junction and southward from that point to the edge of the quadrangle a number of wells have found oil in the Hundred-foot and Gordon sands and gas in the Fourth sand. The wells at Montour Junction and Groveton produce oil from the Gordon sand. Since the field work for this folio was finished a small oil pool has been found in the Hundred-foot sand on Moon Run, about a mile south of Groveton. From such information as could be obtained this pool seems to be small and to have a very erratic pay streak.

Neville Island field.—Neville Island has produced more or less oil and gas throughout its length. The oil wells at the western end of the island produce from the Gordon sand. Gas with some oil is found in the Hundred-foot sand; salt water is found in the western half of the island. Toward the east good oil wells occur in the Hundred-foot and some oil and considerable gas in the Gordon, Fourth, and Fifth sands.

Dixmont gas field.—This gas-producing area occupies the crest and southeast flank of the Wildwood anticline. It contains 18 or 20 gas wells which furnish gas from what are said to be the Bowlder, the Fourth, and possibly the Third sands. From such data as are available it appears that the Third and Fifth sands pinch out entirely from east to west across this field, the Bowlder being the only producer in the western part of the field.

Avalon oil and gas field.—In the eastern part of Kilbuck Township a considerable oil field has been developed in the Fourth, Hundred-foot, and Third sands, and gas has been obtained in the Fifth sand. These sands are named in the probable order of their productiveness. Few records of wells within this field are available and little is known of the thickness and porosity of the sands as determined by the drillers. This field has been developed for a number of years and appears to be almost exhausted, many wells having been abandoned.

West View oil and gas field.—The West View field comprises several wells in and to the south of West View which have furnished more or less gas from the Butler gas sand, Hundred-foot, Nineveh Thirty-foot, Snee, Bowlder, and Third sands and some oil from the Hundred-foot and the Nineveh Thirty-foot. Only the Hundred-foot sand carries salt water in sufficient quantities to be mentioned in well records.

Bellevue oil and gas field.—The Bellevue field lies off the southern edge of the quadrangle, in the vicinity of Bellevue, but wells of this field lie on the edge of the area south of West View. When first drilled some of these flowed from the Hundred-foot sand in such quantities as to justify extensive drilling. The Hundred-foot wells in this field, however, ran down rapidly in production and have been abandoned.

Hammerschmitt oil pool.—The Hammerschmitt pool is situated on the Hammerschmitt and Hartman farms, about three-fourths of a mile southwest of Perrysville, at or near the axis of a synclinal trough which plunges rapidly to the southeast and flattens out to the northeast against a dome of the Wildwood anticline. The Hundred-foot sand, from which the oil is produced, is about 100 feet thick and in some of the wells carries three distinct pay streaks, each ranging from 1 to 15 feet in thickness. This sand produces salt water with the oil, the conditions being similar to those already described for the Leetsdale pool. The daily supply of salt water is decreasing, and the indications are that when the water is exhausted the supply of oil will cease. This pool is developed by seven wells, the total production being small.

Since the field work for this folio was finished three or more oil wells have been drilled on or near the John Link farm, half a mile west of Perrysville. No records of these wells could be obtained and it is not known which sand produces the oil. Half a mile northeast of Perrysville the Third sand is said to produce from three or four wells on the Good farm. A well in this vicinity, on the David Real farm, got salt water in the Salt or Forty-foot sand, which is above the Big Injun, and gas in the Butler gas sand, which is called the Salt sand in the Sewickley quadrangle. A single well on the Thomas Hartman farm produces a small amount of oil from what is supposed to be the Hundred-foot sand, as the well pumps salt water with the oil.

Sandle oil pool.—The Sandle pool occupies a strip of country 1½ miles long from east to west and about half a mile wide near the southwest corner of McCandless Township. The Third sand, which is oil bearing in this area, is rarely over 25 feet and in many places less than 10 feet thick. In the records of a few wells two streaks of pay from 1 to 4 feet thick are reported. This pay is a fine conglomerate of white quartz pebbles which range in size from coarse sand to well-worn pebbles as big as large peas. No water has been found in this sand. Most of the wells were drilled in 1895. None of them were large; few produced over 50 barrels a day.

The pool has long been down to a settled production, many of the wells now being practically exhausted. In at least one well both oil and gas were found in the Fourth sand. In the other wells the Fourth sand, as well as the Hundred-foot, Snee, and Bowlder, appears to be barren.

The pool lies along the northern slope of the Wildwood anticline, about equidistant between the axis of that fold and that of the Mount Nebo syncline to the north. Practically no data are available regarding the dry holes which doubtless surround this pool.

Wildwood oil pool.—About half a mile east of the eastern end of the Sandle oil pool is the southern end of the Wildwood pool, which extends northeast to the vicinity of Wildwood, off the eastern border of the quadrangle. This pool is considered to be one of the largest ever found in the Third sand in southwestern Pennsylvania. It was discovered in 1889 or 1890 near the northern end and was developed southward. On January 19, 1891, its maximum output of 18,000 barrels of oil in one day was recorded. The first well, located on the Austin heirs' farm, began flowing at the rate of 1300 barrels a day. The development of this part of the pool was very rapid, and in a short time the oil-bearing area was encircled by a string of dry holes. All traces of these have long since been obliterated and no attempt was made to locate them on the map. The wells shown on the map indicate fairly well the present outline of the pool and include practically all the wells that are now pumping. The production of the field is now very small, the oil sand being almost entirely depleted.

The southern end of the pool is on the eastern side of the Wildwood anticline, at about the same elevation (1470 feet) as the eastern end of the Sandle oil pool. Few if any wells that touch the Hundred-foot sand below the 1450-foot contour have produced oil. The upper limit of the pool seems to rise higher and higher in the Third sand northward to Pine Creek, the oil in the J. M. Moon well at that point being at about 1510 feet. This location of the pool indicates a structural and water problem similar to that in the Coraopolis pool, but from all the data available, and they seem to be fairly conclusive, no water is found in the Third sand in any part of the Wildwood pool shown on the map, and it is said on good local authority that the dry holes to the southeast of this area, reaching the sand at a lower level, showed no water in the Third. It seems very reasonable to suppose that if this sand does contain water under pressure it would have made its appearance in those wells lowest down the slope of the sand and more nearly exhausted of their oil; no water, however, seems to have been found in wells along the southern margin of the pool that have been pumped dry of oil and abandoned. If the Third sand is really void of water, and there seems to be no evidence to the contrary, a theory of accumulation somewhat different from that applied in the Coraopolis pool, which the Wildwood so closely resembles in a structural way, is needed to account for the fact. In such cases, where structural conditions are so similar and yet one pool contains salt water and the other does not, a single theory can scarcely be equally applicable to both.

In the southern part of the Wildwood pool the Third sand is rarely 30 feet, in many places less than 20 feet, and here and there less than 10 feet in thickness. The pay streaks vary from 2 to more than 10 feet. It is remarkable that a sand with so thin a pay could have furnished such enormous flows of oil, but such a condition is especially characteristic of the Venango group of oil sands.

The Hundred-foot sand, which is from 100 to 140 feet thick in the Wildwood pool, is nearly always found to carry more or less salt water but no oil and not much gas. Salt water is also found in the Salt or Forty-foot, Big Injun, and Butler gas sands. The Snee and Bowlder sands are said to be without water, oil, or gas. The Fourth sand shows no water but carries some gas in certain wells. No records of wells in this pool mention the Fifth sand, though it is present in wells farther to the north.

Hartman oil field.—The Hartman field comprises four producing wells, three of which get their oil from the Hundred-foot sand and one from the Thirty-foot. The wells in the Hundred-foot sand pump salt water with the oil. The Thirty-foot sand does not contain salt water in perceptible quantities. The wells were small and are now almost exhausted of oil and salt water.

Ingomar oil pool.—The Ingomar pool gets its oil entirely from the Hundred-foot sand, which also produces water. The ratio of salt water to oil varies greatly in different wells in this pool but seems to bear no direct relation to structure. In a few wells more oil than water is pumped, but usually the proportion is from 5 to 50 barrels of water to 1 of oil. Some of the wells in the Ingomar pool made as much as 40 barrels of water to 1 of oil. Many wells in the Hammerschmitt, Sevins, Leetsdale, and other pools in this sand with practically the same thickness of pay streaks have made from one-half to one-tenth as much oil as water, though these pools are situated at points from 50 to 100 feet lower down the slope of the sand. The Hundred-foot sand is doubtless continuous throughout the distance between these pools.

The Ingomar pool is situated structurally well up the eastern flank of the Brush Creek anticline and has a northeast trend parallel to the strike of the rocks. Its northeastern extension, on the Wattenpool farm, was tapped in 1907, and at the time of the writer's visit gave promise of several good wells in the Hundred-foot sand. Less than a mile farther to the north a well on the Pegher farm got oil, gas, and salt water in the Hundred-foot sand 42 feet from the top. This belt of favorable oil territory extends northward to the Shenot and Sarver wells.

Duff City oil field.—The Duff City field lies along the axis and sides of a short anticlinal nose that juts west from the Brush Creek anticline. It comprises developed portions of pools in the Snee and Thirty-foot sands and a few wells in the Hundred-foot sand which form a southern extension of the Brush Creek field. The Snee, Bowlder, and Thirty-foot pools cover practically the same area and occupy nearly all the productive part of the Duff City field, which is tentatively considered as merging into the Brush Creek field at about the northern edge of Franklin Township, though no arbitrary line can be drawn between the two.

The first well in this vicinity getting oil in the Snee sand, and the one in which the sand first received this name, is located in the southern portion of the Duff City field. The Snee sand is believed to be the same as the Blue Monday sand of other parts of the oil region of Pennsylvania. In the Duff City field it ranges from 5 feet to probably less than 20 feet in thickness, but it is said to be very soft and porous where it carries oil and has furnished a number of good wells. The Thirty-foot sand in this field is thicker than the Snee, but its pay streak is usually thin and somewhat erratic in occurrence. It has been, however, a prolific producer in parts of the field. The Hundred-foot sand has shown more or less oil in a great many of the wells, but its pays are usually poor and it apparently carries less than the usual amount of salt water. In a number of wells the Bowlder sand has produced considerable oil. Perhaps the best well in this sand is the J. Swint No. 1, which is said to have yielded 400 barrels a day. This well is still pumping after producing for 18 years. The Bowlder sand also furnished more or less gas. Records of wells in the field are very incomplete and much valuable information has been lost beyond hope of recovery.

Though the Duff City field has been producing oil for several years, a little development work is still being continued by operators in cautious extensions to the southwest, and it is probable that a few more producing wells will be added in that direction.

Attention is again called to the fact that in this field the Thirty-foot, Bowlder, and Snee sands, which furnish nearly all the oil, are reported to be without water. Down the slope of the beds, in wells to the west and south, water has not to the writer's knowledge been found in any of these sands. In most of the dry holes the sand was not as soft and porous as that of the oil-bearing areas. Here are in reality three distinct oil pools in as many sands, that have all collected on the crest and sides of an anticline, apparently without the assistance of salt water as a transporting agent, through difference in gravity. In the same field and extending northeastward is also a more or less continuous pool of oil in the Hundred-foot sand, which contains salt water.

Wexford and English oil pools.—The Wexford pool is situated on the crest of a steeply pitching anticlinal nose that juts southeast from the Brush Creek anticline in the vicinity of Brush Creek. The Hundred-foot sand is found in wells in this pool at about the same elevation as in wells in the Ingomar pool and in the scattering wells between the Ingomar and the Wexford pools. In fact, wherever a good open pay with salt water is found in the Hundred-foot sand along this belt oil has been present. Northeast from the Wexford pool a more or less continuous line of oil wells marks the same level to the English pool, which is almost in the trough of the Mount Nebo syncline though still at the same level as the Wexford pool on the crest of an anticline. Only a single pay streak, ranging from 25 to 35 feet below the top of the Hundred-foot sand, is generally reported in records of wells in the Wexford pool. This pay in places reaches a thickness of 20 feet, though it is said to be commonly less than 10 feet.

The Wexford pool was opened up from 1894 to 1897. A number of good wells were struck in the Hundred-foot sand, but few of them are said to have made over 100 barrels a day. These are now pretty well pumped out, and some wells along the northern extension of the pool are abandoned. It is said that some of these wells were drowned out by an incursion of salt water from one of the upper sands, presumably because of faulty plugging in some abandoned well.

Fourth sand gas pool.—The Fourth sand contains gas throughout most of the eastern third of Pine Township. As a rule the wells are not large, though here and there a good well is found. The initial minute pressure in a 2-inch pipe in most of the wells ranged from 70 to 200 pounds, the maximum being probably about 350 pounds. The initial rock or closed pressure varied considerably within relatively short distances, the maximum being about 500 pounds to the square inch. The Fourth sand is very thin over eastern Pine Township, generally measuring not more than 15 feet and in many places not more than 5 or 6 feet. Considering the thinness of the sand and the minute pressure of the gas, the wells hold up remarkably; in many that have been drilled from 10 to 15 years the minute pressure is still from one-half to one-fourth and the rock pressure more than one-half the initial pressure.

The Third, Bowlder, and Snee sands are thin or entirely absent in Pine Township. In the northern part of the area the Snee and Bowlder have furnished oil in a number of wells. In a number of wells near the northern edge of Pine Township the Third sand was found to be from 4 to 10 feet thick, with a show of oil in a few wells.

Brush Creek oil field.—The Brush Creek field is the largest in the Sewickley quadrangle. Broadly, it includes a belt of productive territory from three-fourths of a mile to 1¼ miles wide stretching along the crest and eastern flank of the Brush Creek anticline from Duff City to the northern edge of the quadrangle north of Callery, a distance of more than 10 miles. This field is subdivided, however, into several local pools and fields that merge more or less completely into one another. One of the most important of these pools, and the one from which the field gets its name, occurs in the Hundred-foot sand in the vicinity of Brush Creek, in the northwest corner of Marshall Township. This pool also extends northward into Cranberry Township and southward entirely across Marshall Township into the Snee and Bowlder territory of the Duff City field. Within the territory occupied by this pool in the Hundred-foot sand, oil-bearing areas of minor extent in the Bowlder, Snee, and Thirty-foot sands have also been found.

Throughout this pool practically the same conditions prevail as in other pools in the Hundred-foot sand. The bed consists of 80 to 125 feet of hard, medium-grained sandstone, with a shale "break" 1 to 20 feet in thickness near the center. Within this sandstone occur lentils of a softer, more porous conglomeratic sandstone, which range in thickness up to 20 feet or more. As many as three of these softer zones are found in many single wells.

The ratio of water to oil throughout the field varies considerably even in adjacent wells. A well on the G. I. Sickles farm which had an initial production of 61 barrels of oil to 75 of water yielded after seven years fifteen times as much water as oil. Another well on the same farm made 7 barrels of oil to 5 of water but in seven years changed to 5 barrels of water to 1 of oil. Still another well on this farm made 4 barrels of oil to 15 of water when first drilled in, and after six years this ratio is still preserved. In each of these wells a single pay measuring respectively 14, 21, and 22 feet thick was found about 3 feet from the top of the sand. The well with the thickest pay holds up the best ratio of oil to water; the one with 21 feet of pay and with the greatest initial ratio of oil to water now pumps a greater ratio of water; and the one with the thinnest pay shows the greatest increase of water to oil. The sand in the first well mentioned is 4 feet higher than it is in the other two wells. Such conditions may be cited for well after well over the entire productive area of the Hundred-foot sand in this field.

The first six wells on the G. I. Sickles farm first produced from the Snee sand, which is said to have been very productive. When it was exhausted and abandoned the property was tested in the Hundred-foot sand with good results. No records of the Snee sand in this vicinity were obtained, but southward in this field to the township line the Hundred-foot, Snee, Bowlder, and Thirty-foot sands are oil bearing in a greater or less number of wells. Few records of wells in this area were found, and the detailed history of this portion of the field is not known.

Zimer oil pool.—In the extreme southwest corner of Marshall Township a small oil pool has been developed on the Zimer and Neeley farms. Oil in this pool comes from the Snee sand, which is about 15 feet thick. The wells are small and the area seems to have been thoroughly tested, though an extension for a short distance to the east and southeast is possible if the pay remains good. At the southern end of the pool a little water is reported above and considerable gas immediately below the shale "break" in the Hundred-foot sand. Oil was found in the top of the Snee sand.

Economy-Legionville oil and gas field.—Only a small portion of the wells in the Economy-Legionville field are located on the map. The pool occupies the pitching crest of an anticlinal spur lying west of the West Middletown syncline. The producing sand is the Hundred-foot, which ranges from 20 to 25 feet in thickness. In many wells gas accompanies the oil in such quantities as to flow the oil. Salt water is also present in many wells, though the amount is not as great as that observed in this sand in the Brush Creek field of Marshall Township, which is from 150 to 200 feet higher up the slope of the sand. Many wells of this field have been large producers, one having had an initial production of 100 barrels an hour. The total production of oil from this pool has been very great.

The pay streaks of the Hundred-foot sand bear a close resemblance to those described in other pools. They are rarely over 7 feet thick and usually range from the top of the sand to 10 feet below it. The wells decrease slowly after the initial pressure is relieved, and many of them seem destined to pump for several years to come. There is no way of determining whether the 20-odd feet of sandstone which makes up the total thickness of the Hundred-foot sand in this township really represents in full the horizon occupied by this bed where it is 100 to 140 feet thick; it is possible that either the top or bottom member is represented by sandy shale in this area and to the northwest. The Fourth sand is gas bearing over much of the Economy-Legionville field and several good wells have been secured in it. This sand is thin and irregular, however, and appears to pinch out altogether in many places a short distance to the northwest.

Davis oil pool.—The Davis pool is located on the A. M. and J. H. Davis farms, in the valley of Sewickley Creek, near the southern border of Economy Township. At the time of the writer's visit the pool was producing from only four wells, though a few other wells had furnished some oil and gas. Of these the J. H. Davis No. 7 flowed a barrel or so a day from the Bowlder sand. The two wells on the A. M. Davis farm are pumping a small amount of oil from the Hundred-foot sand. The J. H. Davis No. 2 gets gas in the Bowlder sand. Pay streaks in the Hundred-foot sand are lacking in most of the holes drilled, the sand being hard and close. In the producing wells the pay is thin and yields a small amount of water with the oil. Water was also found, with a show of oil, in this sand in the J. H. Davis No. 3. The Bowlder sand has shown no water in any of the holes.

The pool seems to be entirely developed, and there is little chance of finding an extension to it. It appears to occupy the crest of a slight anticlinal nose which juts out to the southeast from the Crows Run anticline.

Harmony pool.—Near the northeast corner of Harmony Township a considerable gas pool has been developed in the trough of the West Middletown syncline. No data were procured regarding the producing sand in this pool, but it is believed to be either the Bowlder or Fourth sand. Gas is found in the Bowlder sand in moderate quantities, occurring with less regard to the structural features than to the quality of the sand. The northwest edge of the Fourth sand is somewhere near this area, and it is possible that a small amount of gas has collected near the upper edge in an open patch of this sand.

Craig oil and gas pool.—The Craig pool comprises less than a dozen small wells situated a mile northeast of the Davis pool. Practically all the oil and gas come from the Bowlder sand, which is seldom more than 10 feet thick. Most if not all of the wells flow their oil with the escape of considerable gas. The wells were never large, and the total production of the pool is now only a few barrels a day. No salt water is found in the Bowlder sand.

The pool apparently lies slightly west of the bottom of the Sewickley syncline at about the same elevation as the Bowlder oil in the Davis pool. It is nearly encircled by unproductive wells, which, so far as could be learned, found the Bowlder sand less porous but with no water. The structural position of the pool is quite different from that in the Bowlder sand in the Grubbs pool, which is on the crest of the Brush Creek anticline. However, the actual elevation of the sand in the two pools shows a variation of less than 20 feet. The contrast is somewhat more marked when it is recalled that the Bowlder sand wells of the Grubbs pool are pumped and that those of the Craig pool flow their oil.

Cookson oil and gas pool.—The Cookson pool is located in the central part of Economy Township on or near the axis of the Crows Run anticline. The structure of the rocks has not been determined with as much accuracy as it has at some other points, but from the best information at hand the Hundred-foot sand, which contains the oil, appears to be folded into a rather steep, narrow arch which has a comparatively rapid pitch to the south. Oil and gas in the Cookson pool are confined entirely to the Hundred-foot sand, which in a number of wells carries little or no salt water. Many of the first wells flowed heavily from a pay above the shale "break," but wells drilled later filled up only a little way.

As is common in nearly all fields, the gas and oil had accumulated an enormous pressure before being tapped by the drill, but this was rapidly reduced by subsequent wells. Water has been found with the oil in a number of these wells, but the proportion of water to oil is very small, being apparently much less than in the Crows Run field, still higher up the anticline to the north. The salt water in the oil sand is considered to be unusually scant in this pool; most dry holes around the edges of the pool are said to have found no water in it. The top of the pay streak ranges from the top of the sand to 10 feet below it and from 1 to 10 feet in thickness. Little or no water and oil are found below the "break." The pool is now thoroughly developed, and the new wells are all pumpers and are down to a settled production.

Here is another pool in a comparatively dry sand occupying the crest of an anticline with a border of apparently dry sand surrounding it. It is the only Hundred-foot oil pool within the Sewickley quadrangle which does not contain a relatively large amount of salt water with the oil, and it seems probable that some of the wells furnish small amounts of water that have not been reported.

Crows Run oil and gas field.—The Crows Run field is situated in Economy and New Sewickley townships, and it embraces a large oil pool carrying considerable quantities of gas and salt water in the Hundred-foot sand and gas in the Bowlder sand. In this field the Hundred-foot contains in places as many as three distinct pay streaks, all of which carry gas, oil, and salt water in different ratios from well to well. The average ratio of salt water to oil is about the same as in the Brush Creek pool and the mode of occurrence in the two is very similar. The ratio of salt water to oil in the different pay streaks does not increase with depth nor down the dip of the sand. Probably the smallest ratio of water to oil occurs at the southern end of the field, nearest the Cookson pool, and the highest ratio near the center of the field. The best wells yielded from 300 to 500 barrels a day and a large number exceeded 100 barrels. From Crows Run northward the pay streaks are very erratic, many good wells being almost surrounded by poor or unproductive ones.

The central and southern parts of the field are located on the axis and eastern flank of the Crows Run anticline, and the northern part of the producing area lies west of this axis, the extreme northern end being almost in the bottom of the shallow pitching trough of the West Middletown syncline. This field, though comparatively young, is now down to a settled production, which will doubtless decrease so slowly that many of the wells will produce for years.

Dunn oil pool.—The Dunn pool comprises four or more small wells on the Dunn and Straube farms, about 1 mile north of Baden, which get oil from the Hundred-foot sand. This sand is here about 40 feet thick, with 4 feet of pay near the bottom.

Brenner oil field.—In New Sewickley Township, north of the Crows Run field, a more or less continuous belt of productive country has been developed along the strike of the rocks for about 2 miles to the northern edge of the quadrangle. This area is made up of a string of small pools in the Hundred-foot sand, separated by patches in which the sand has no pay streaks. At the northern edge of the quadrangle a well on the Zeno Geohring farm found, 25 feet below the top of the Hundred-foot, 54 feet of white sand with oil 16 feet from the bottom. In most if not all of these wells salt water is pumped with the oil, which occurs under conditions exactly similar to those in the Brush Creek and Crows Run pools described above. No very large wells were found in this field, but most of the wells were of such size as to prove profitable.

Dumbaugh oil pool.—The Dumbaugh pool consists of four or more small wells on the Dumbaugh farm, in the southwest corner of Cranberry Township. Few data were procured relative to this pool. The oil comes from the Hundred-foot sand. Some of the wells are said to have been very promising when first drilled, but their production declined rapidly and the pool was soon practically exhausted. It is now producing a very small amount of oil.

Garvin oil pool.—The Garvin pool was opened in the early nineties, and many of the wells first drilled are now pulled and abandoned. It is said that a number of good oil wells were found to the east of the territory shown on the map as productive, but this portion of the pool is now abandoned and no data regarding it were secured. Many of the wells shown on the map have been drilled within the last 10 or 12 years, some as late as 1904. Few of the records of wells in this pool gave the initial production, but it is said that many of the earlier ones made from 100 to several hundred barrels a day. The total output of the pool is great.

All the oil comes from the Hundred-foot sand, which has a total thickness of 80 to 130 feet. This sand is also water bearing, the ratio of oil to water being about the same as that already described for the Brush Creek field. This pool probably carries a greater proportion of water to oil than the pools in New Sewickley Township, especially the Cookson pool, which is about 250 feet lower on the sand. The principal pay streak is probably not the same as that of the Crows Run and Cookson pools. It occurs from 55 to 70 feet below the top of the sand, ranges from 3 to 10 feet in thickness, and is remarkably constant over the entire pool. In a few wells another pay from which considerable quantities of oil have been produced occurs near the top of the sand. In this pool from 10 to 30 feet of dark sand is reported at the top of the Hundred-foot, with gray or white sand below. The pays are composed of coarse sand and small quartz pebbles.

Crider oil field.—The Crider field contains two pools, one in the Hundred-foot above the other in the Snee sand, with gas in the Bowlder sand. It occupies a narrow belt about one-fourth mile wide by about 2 miles long, which lies to the west of and near the axis of the Brush Creek anticline. The trend of this belt is northeast and southwest, and the top of the Hundred-foot sand is between 35 and 40 feet higher at the northern end than it is at the southern. The pool in the Hundred-foot sand occupies only the northern third of the field, where it is said to carry more or less water with the oil. In a well on the J. Rowan farm the pay in the Hundred-foot is 51 feet below what is given as the top of the sand. Oil was found in the top of the Snee sand in this well. On the same farm the pay streak in the Hundred-foot is only 37 feet from the top of the bed. In this well, as in most others in the Crider field, the top of the Snee sand is oil bearing. In the Catherine Rice No. 1 well the Hundred-foot carried no oil or water, and no pay streak is mentioned in the record. This well made 7½ barrels from the Snee. South and southwest from this point the Hundred-foot sand is unproductive and apparently without water. The Thomas Robinson No. 1 well got oil in the Snee sand 6 feet from the top. At the extreme southwest end of the pool, in the Bertha Ulrich No. 1 well, 5 barrels of oil and no water were found 2 feet below the top of the Snee sand, and in an adjoining well on the same farm the Snee and Hundred-foot were both unproductive, but gas was found in the Bowlder. This gas showed an initial closed or rock pressure of 250 pounds.

This field shows the same characteristics as the other pools discussed. The oil apparently occurs on the crest and sides of an anticline in a dry sand as well as in a wet one. Also the sand that produces oil and water together loses both at the same point going down the slope of the rocks, the existence of both in perceptible amounts being evidently dependent on the presence of a pay streak of greater porosity than the surrounding sandstone.

Duncan oil field.—The Duncan pool is situated about a mile northeast of Hendersonville, in Cranberry Township, on the axis and eastern flank of the Brush Creek anticline. The Hundred-foot, Snee, and Bowlder sands are oil bearing. Salt water occurs with the oil only in the Hundred-foot sand. The Bowlder sand also produces considerable quantities of gas in this vicinity. As a rule, though the wells have not yielded large quantities of oil, they have produced enough to make them profitable.

One of the best wells was the Joseph Geohring No. 1, which had an initial production of 210 barrels of oil and 600 barrels of water from the Hundred-foot. This well came in June 3, 1893. In 1897 it was flooded by fresh water from a well on an adjoining property that had been improperly plugged. At this time it was making 10 barrels of oil and 150 barrels of water a day. This invasion of fresh water took place only in the Hundred-foot sand. The water apparently spread out in all directions from the poorly plugged well, but it traveled much more rapidly to the south and southwest, the rate decreasing with the distance covered. Little evidence of value was procured regarding this interesting phenomenon. It is generally accepted as a fact that the water traveled about 1 mile southwestward to the vicinity of Hendersonville at an average rate of about 500 feet a year, the distances covered toward the north and west seeming to be much less. From what could be learned in the field, producing wells in the Hundred-foot sand that lay in the path of this invading water increased rapidly in daily production for a few days or weeks before the fresh water made its appearance, after which they pumped fresh water exclusively. From this it is apparent that a considerable portion at least of the oil and salt water contained in the pay streak was forced out ahead of the invading column of fresh water. In this area, where the wells were good, it is reasonable to suppose that if all the oil that would have eventually been pumped from those wells was in the pay streak at the time of the invasion of this fresh water the accumulation of oil and salt water ahead of this fresh water after it had traveled for a mile would have been enormous. The distance to which the fresh water can eventually penetrate depends on the height and capacity of its head, the porosity of the invaded sand, and the degree of saturation of the surrounding areas of oil and salt water previously contained in the sand. These forces tend to establish an equilibrium, though as long as the oil and salt water are pumped from the sand in adjacent areas and the supply of fresh water is constant there will continue to be more or less advance of the fresh water. If, then, the oil has been forced out of the pay ahead of the fresh water, the pool has simply been transferred from one spot to another and possibly concentrated into smaller space under much higher pressure. If such has been the case, wells in the path of the fresh water at a distance little less than a mile from the place where the invasion began should have shown a very much greater increase of oil and salt water than has been reported. In such a case it is reasonable to suppose that a well producing at the rate of 10 barrels of oil and 100 of salt water would rapidly increase to 100 or even 200 barrels of oil with a considerably less ratio of salt water. As this has not been found to occur, it may be tentatively assumed either that the fresh water did not force out a very large amount of the oil in its path or else that this pay streak did not contain at the time of the invasion all the oil and salt water that eventually would have been pumped from it had no invasion of fresh water occurred.

From a study of this and similar phenomena elsewhere, the writer doubts if all the oil was forced out of the pay streak when the invasion occurred. At the same time there is a possibility that in pools of the type common to the Hundred-foot sand of this quadrangle the total amount of oil to be produced from a given well is not all in the pay streak of that sand at any one time, and it is also possible that after the original head of oil and water has been pumped down in a pool the oil and water (as a more or less complete emulsion) seep slowly into the soft, porous stratum, not only from other parts of the sandstone but also in some places from the shale itself, the water originally coming from some associated water-bearing bed and the oil coming from the shale through which the water is forced.

Hendersonville oil and gas field.—But little information relative to the group of wells south of the Duncan field, in the vicinity of Hendersonville, was obtained in the field. It is thought that both the Hundred-foot and Snee sands are oil bearing here and that there is gas in the Bowlder sand.

The D. Hendrickson No. 1 well, situated near the northwest edge of the Duncan pool, got a little salt water at 64 feet below the top of the Hundred-foot and a strong flow of gas at 100 feet from the top, with a larger flow of salt water 2 feet below. Oil was found in the top of the Snee sand and a little gas in the Bowlder. Between this well and the Garvin pool to the northwest and the Ramsey pool to the north the canoe-shaped trough of the Sewickley syncline has furnished no productive territory.

Ramsey oil pool.—Most of the Ramsey pool lies north of the quadrangle, in Jackson and Forward townships. The oil comes from the Hundred-foot sand, which is here from 80 to 95 feet thick. The pay streak occurs below the shale "break" in this sand. Wells that do not pump a large amount of salt water do not produce much oil. When first drilled these wells filled up as much as a thousand feet from the bottom with oil and water, the height to which the fluid rose apparently depending on the nature of the pay streak and the amount of previous development in the pool, being highest in the first wells having the coarse, loose pay. Wells pumped down to a settled production and then left idle for a month or so show practically no head of water and oil.

Mars oil pool.—The Mars pool is situated about three-fourths of a mile west of Mars, on a secondary fold lying east of the Mount Nebo syncline. An almost continuous line of wells marks this pool from the Sarah Cote farm, about 1 mile southwest of Mars, northwest to a mile east of the quadrangle boundary. The production comes entirely from the Hundred-foot sand, which has a thickness here of 90 to 130 feet. From one to four pay streaks are found. These apparently vary in position and thickness from well to well in much the same way as in other pools described. In the Sarah Cote well the first pay was found 46 feet from the top of the sand and the second pay 25 feet below. The Nettie Campbell well No. 2 had three pay streaks 53, 69, and 80 feet from the top of the Hundred-foot. In the record of well No. 1 on the Campbell farm the pays are given as 28, 34, 49, and 53 feet from the top, the bottom pay being 24 feet thick. A peculiar fact noted in this well is that the second pay streak carries considerable salt water and the third pay streak produces gas. The writer assumes that the second pay is above the shale "break" and the third below it. The other wells of this pool of which records are given show practically as much variation in the location of the pay streaks. Unfortunately, few of these records show the depth to and thickness of the shale "break" in the sand. It appears, however, that at least one persistent pay streak occurs above and one below the break.

None of the wells of the Mars pool seem to have produced much over 100 barrels a day, but as a whole they have been very profitable. The pool is now down to a settled production, and at the present rate of decrease many of the wells are destined to pump for years. The salt-water conditions are similar to those already described for others in the Hundred-foot sand. Within the Mars pool the Snee and Bowlder sands appear to be barren. The Third, Fourth, and Fifth sands are generally absent, though in a few holes "shells" at the horizons of the Third and Fourth have been noted. So far as could be determined, no water, oil, or gas has been found in this pool below the Hundred-foot.

Lockwood oil pool. — The small Lockwood pool in the Hundred-foot sand is located on the crest of the Brush Creek anticline, in the western part of Adams Township. At the time of the writer's visit to this field not more than four or five of these wells were producing and no records of them could be obtained. It was learned that difficulty had been experienced with an invasion of fresh water similar to that in the Duncan field, but no data regarding it were obtained.

Callery oil pool.—The Callery pool is located west of the crest of the Brush Creek anticline, on a broad terrace which dips gently to the southwest toward the northern end of the Sewickley syncline. This is a comparatively young pool, and a little drilling is still being done in cautious extensions to it. The field seems to have been developed from the south northward, as a number of wells at the southern edge have already been abandoned. No records of wells obtained in this field, however, give the date of drilling, and few give more than the distance to the top of the Hundred-foot sand and its thickness and the depths at which pays were found. As a rule, the pay streak in this pool is from 40 to 70 feet below the top of the sand. It is also considerably thicker than those found in the Hundred-foot pools already described, and many of the wells have been fine producers.

So far as could be learned, the water conditions in the Hundred-foot sand in this field are very similar to those already described for the sand in the Ramsey field, a short distance to the northwest. The Butler gas sand seems invariably to carry a large amount of water, as it doubtless does over most if not all of the quadrangle.

The Callery pool and the Ramsey pool are closely related structurally. These pools are closely associated with the Evans City pool, most of which lies off the quadrangle northeast from the Callery pool. The southern wells in the Evans City pool, along the northern edge of the area, are shown on the map; all these wells get oil from the Hundred-foot sand.

COAL.

GENERAL STATEMENT.

In spite of the fact that all the outcropping rocks of the Sewickley quadrangle belong to the Pennsylvanian series, coal is not an important resource of this area. More than 95 per cent of the surface is covered by rocks of the Conemaugh formation in which only thin coals of generally inferior quality occur. In the Beaver quadrangle, to the west of the Sewickley, the coals of the Allegheny formation are widely exposed and are of considerable value, though generally thinner than they are farther east, where they attain their maximum thickness and are of very great value. But in the Sewickley quadrangle only the upper portion of the Allegheny formation is exposed, outcropping along short stretches of Ohio River and Brush and Breakneck creeks, where its coals seem to be exceptionally thin and of inferior quality. Of these coals the Middle Kittanning and the Upper and Lower Freeport beds seem thickest and best. The Pittsburg coal of the Monongahela formation, where found under sufficient cover, is of good quality and of great thickness; but its occurrence is limited to the tops of a few high knobs, the majority of which include at most only a few acres of coal. This has been mined by country banks for years and many of the deposits have long since been exhausted. There is not a commercial coal mine within the quadrangle, the output being confined to country banks, each of which is worked for short periods, as needs require, to supply the landowner and possibly in some instances a few of his neighbors.

The coals in the Sewickley quadrangle are those of the Conemaugh formation and of the upper part of the Allegheny. None of the coals below the Lower Kittanning are exposed, and little is definitely known of the economic value of any of them. A number of wells drilled along Ohio Valley and on Brush and Breakneck creeks, where the Brookville and Clarion horizons are within shafting distance of the surface, report one or more coals but furnish few reliable data for judging their value.

COALS OF THE ALLEGHENY FORMATION.

Lower Kittanning coal.—The Lower Kittanning coal was found exposed at but one point within the quadrangle—in Crows Run just north of the Pennsylvania Railroad, where it is 22 inches in thickness. A short distance farther north a shaft at the brickworks to the Lower Kittanning clay found the coal about 2 feet thick. It is not known to have been mined at any point within the quadrangle. Farther south in Ohio Valley several deep wells penetrated a coal reported to be from 3 to 6 feet thick that appears to be at the horizon of the Lower Kittanning coal. It is not possible to make close measurements of coal seams in wells sunk by the churn-drill method, and the general tendency is to overestimate the thickness, especially if the bed is associated with soft shales or clay that offer the same resistance to drilling. A diamond-drill core from a hole in Sewickley was found by I. C. White[a] to show the following section of the Lower Kittanning coal:

Section of Lower Kittanning coal at Sewickley, Pa.

	Ft.	in.
Coal	1	4
Slate		1
Coal		9

This is probably the average thickness of the bed throughout the quadrangle.

Middle Kittanning (Darlington) coal.—The Middle Kittanning coal is about 35 feet above the Lower Kittanning, and hence has a somewhat wider extent of outcrop. It is, however, confined to the Ohio Valley from Baden northward. It is exposed on both sides of the valley at the mouth of Crows Run and on the north side of the Beaver pike from that point to Conway. At all points where exposed it is from 17 to 20 inches thick. This coal has been mined in connection with its under clay on the west side of Crows Run and at an old bank opened years ago at valley level on Crows Run, about half a mile west of Parks Quarries. This bank was long ago abandoned. It was being operated in 1876, however, when I. C. White[b] found it to be 20 to 22 inches thick, of good quality, with 6 inches of slaty "cannel" coal above. The coal is also exposed in the run back of Freedom, where it lies unconformably beneath the Freeport sandstone member. (See fig. 8.)

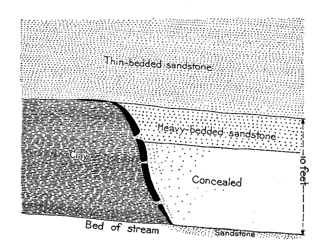

FIGURE 8.—Section of Middle Kittanning coal and associated rocks in bank of run half a mile north of Freedom.

The coal rests on a steeply inclined surface between a shale bed beneath and a sandstone above. Maximum thickness of coal bed 8 inches.

It is apparently variable in thickness and quality, and in the diamond-drill hole at Sewickley above mentioned it was found to be entirely absent, the horizon being represented by 8 feet of fire clay lying below 16 feet of sandstone.

Upper Kittanning coal.—No exposure of the Upper Kittanning coal was noted in the Sewickley quadrangle, though it is possible that thin blossoms may be found by careful search at a few points along the steep ravines in the river hills from Baden northward. If present, it is doubtless of no commercial value.

Lower Freeport coal.—The Lower Freeport coal seems to be one of the thickest and best seams of the Allegheny formation within the quadrangle. No outcrops are known except along both sides of Ohio River from Legionville northward. It is exposed in a bluff on the east side of the Pennsylvania Railroad north of Legionville, where it is 16 inches thick. In the valley of the run at the north end of Baden, 50 yards north of the Pennsylvania Railroad tracks, it is exposed at flood level, and is 30 inches thick and apparently of good quality. It has been opened at several places along this run, but the banks are now in disuse. I. C. White,[c] who visited these banks in 1876, reported it as being from 18 to 30 inches thick, with a local parting of shale 6 inches from the top, and of fair quality, though somewhat high in sulphur. It is exposed in the bluff north of the Pennsylvania Railroad tracks, opposite Mount Gallitzin Academy, where it is 22 to 25 inches thick. No outcrop of the coal was seen in the vicinity of Unionville, though the Upper Freeport is about 45 feet above the bed of Brush Creek at that point.

Sections of the Lower Freeport coal.

Opposite Mount Gallitzin Academy.

	Inches.
Coal	4-5
Shale	½
Coal	6-8
Shale	½
Coal, about	12

North of Baden.

	Inches.
Coal	30

Between Logan and Legionville.

	Inches.
Coal	16

[a] Bull. U. S. Geol. Survey No. 65, 1891, p. 112.
[b] Second Geol. Survey Pennsylvania, Rept. Q, 1878, p. 186.
[c] Idem, p. 182

Upper Freeport coal.—The Upper Freeport is one of the most variable coals exposed within the quadrangle. Its variability seems due in a great measure to slight unconformities at the base of the Mahoning sandstone, which in numerous places is found to rest upon the dark to reddish shales normally underlying the Upper Freeport coal and limestone. It is probable that in such places these beds were deposited but were subsequently removed by stream or wave erosion and the sandstone deposited in their stead. The coal has been opened for mining in a number of places along Breakneck Creek north of Callery, where it appears to be from 2 to 3 feet thick, though the banks were abandoned and no measurements could be secured. On Brush Creek this coal was once mined a mile east of Oakgrove, in a bank at the old mine site, where it is 3½ feet thick. It is said to be high in sulphur but otherwise of good quality and of unusual thickness. Westward from this point to the present milldam on Brush Creek the coal is barely above creek level, and at the dam it is not more than 6 inches thick. Two or more banks have opened up this seam in the vicinity of Unionville, where it is reported to be from 18 to 20 inches thick. On Breakneck Creek, at Callery, it was formerly mined at a number of places on both sides of the valley and is reported to have been from 24 to 30 inches thick, with 18 to 24 inches of very fair coal at the base and 4 to 6 inches of shaly impure coal above.

The Upper Freeport is also exposed at a few places along Ohio Valley (see p. 4), but at no place has it been mined in even small quantities. Entries have been driven at several places along Crows Run and in the river hills, but the coal has invariably been found to be too thin and of too poor quality for profitable working. No banks are now (January, 1909) taking coal from this seam within the quadrangle.

Sections of the Upper Freeport coal.

North side of Brush Creek at Unionville.	Inches.
Coal	19
South side of Brush Creek at Unionville.	
Coal	12
Oakgrove.	
Coal and black shale	6

At old mill site on Brush Creek 1 mile east of Oakgrove.	Inches.
Coal	18
Impure coal	12–18
Coal about	8–12
	38–48
Breakneck Creek north of Callery. [From White, I. C., Second Geol. Survey Pennsylvania, Rept. Q.]	
Cannel coal	4-6
Coal	24
	28–30

COALS OF THE CONEMAUGH FORMATION.

The coal beds of the Conemaugh formation are of little or no commercial importance, their economic value being confined to local areas, where the scarcity of coal of better quality may sometimes justify the mining for home use of small quantities of the best portions of some of the thicker beds. Only a few of the more important beds deserve more space than that devoted to them under "Descriptive geology."

Brush Creek coal.—The Brush Creek coal is generally too thin and too impure to be of value. Local pockets may be found, however, in which it is of minable thickness and, more rarely, of good quality. In general it is thickest in its type locality on Brush Creek and on the headwaters of Crows Run. One entry (Old bank), now abandoned, on the plank road at the south end of Ogle, is reported to have found it from 28 to 30 inches thick, comparatively free from partings, and of a fair quality. On the Freedom-Mars pike a mile east of Lovi this coal has recently been opened by a shallow shaft and found to be 26 inches thick. Within a mile north of Lovi several openings have been made and a considerable quantity of fairly good coal taken out. These banks have been worked in a desultory way for 30 or 40 years, but at no time has the output been large. The coal is from 30 to 35 inches thick in the best portions, with a thin shale parting about 6 inches from the bottom. What seems to be this coal was once mined in considerable quantities at a point about half a mile east of Oakgrove, on a tributary of Brush Creek from the north. No section of the coal at this point could be procured, but it is reported to have a maximum thickness of less than 3 feet. It is not more than 75 or 80 feet above the Upper Freeport coal, which has been opened a short distance to the south. Westward from Oakgrove the Brush Creek coal is generally not more than 1 foot in thickness.

In New Sewickley Township, a mile west of Boggs schoolhouse, the Brush Creek coal is about 14 inches thick and a thin "stray" seam lies 34 feet below. The coal is persistent over the northeast quarter of the quadrangle, but it is usually less than 18 inches thick. An outcrop of what appears to be the Brush Creek coal occurs on the road 1 mile northeast of Callery. The coal at this place is about 3½ feet thick and apparently of good quality, but no indications of old banks on it were observed.

This coal has been opened up at but few places along Ohio Valley. The greatest thickness reported is in an old bank on the pike 1 mile southeast of Shousetown, where it is said to reach a total thickness of about 5 feet, including shale partings. Landowners in this vicinity say that the coal was of ordinary quality and that the bank was soon abandoned.

Sections of the Brush Creek coal.

One mile northeast of Callery.	Inches.
Coal (shaly)	13
Shale	2
Coal	15
Shale	1
Coal (thin shale partings)	10
Half a mile northeast of Plains Church, Cranberry Township.	
Coal (good quality)	18
On Crows Run 1 mile north of Lovi. [White, I. C., Second Geol. Survey Pennsylvania, Rept. Q, pp. 187-188.]	
Coal	24
Shale	1
Coal	6
	31

At shaft 1 mile east of Lovi.	Inches.
Coal	26
Half a mile south of Unionville.	
Coal (shaly)	16
On plank road south of Ogle, Cranberry Township.	
Coal with 1 or 2 thin parings	29–32
One-fourth mile north of Unionville.	
Carbonaceous shale	12
One mile west of Boggs schoolhouse, New Sewickley Township.	
Coal	14
Half a mile north of Emsworth.	
Coal	8–12

Bakerstown coal.—The Bakerstown coal has been discussed at length under "Descriptive geology," and its economic value does not justify much additional consideration. The bed is extremely variable but in few places reaches a minable thickness. It is best developed in the eastern and northern portions of the quadrangle but has been opened by prospect entries at many places throughout the quadrangle. The amount of coal taken from this bed is very small. The following sections show measurements taken at points where the coal is sufficiently thick to attract notice:

Sections of the Bakerstown coal.

On pike west of Hendersonville, Cranberry Township.	Feet.
Coal with thin shale partings	2
One mile northwest of Hendersonville.	
Coal with shale partings	1
Shale	10
Coal	1

In quarry at brickworks at end of railroad spur up Legionville Hollow, Economy Township.	Inches.
Coal	0–18
Half a mile north of Emsworth.	
Coal	6

Elk Lick coal.—Though of little or no commercial value to-day, the Elk Lick coal is probably the most valuable coal in the Conemaugh formation. It occurs from 30 to 60 feet above the Ames limestone member and is persistent throughout the quadrangle where its horizon comes to the surface. The coal is generally from 16 to 24 inches in thickness and comparatively pure. It is seldom found less than 8 inches thick and it rarely exceeds 30 inches. Numerous banks have been opened on it and from a few of them considerable coal has been taken. The greatest thickness reported is at the Schlag bank, at the eastern edge of the quadrangle, directly east of Perrysville, where the coal at the mouth of the bank measures 43 inches, including 13 inches of clay and shale partings. At the time of the writer's visit the bank was flooded with water, which is said to have entered in such quantities as to prevent the profitable mining of what is considered to be an excellent bed of coal. It is possible that in the above measurements a certain portion of the lower part of the seam was not included. The owner reports an average of 80 inches of coal and partings, of which about 22 inches are partings, with 40 inches of good clear coal at the base. (See section below.) Half a mile northwest of this opening, on the opposite side of the hill, this coal consists of a foot or less of soft shaly coal. On Girty Run, northeast of Perrysville, it is in places less than 6 inches thick. It was once opened at Keown post-office in McCandless Township, where it is about 18 inches thick and somewhat shaly, though reported to be of very good quality in the vicinity. In the extreme eastern corner of Sewickley Township the coal has been opened in a few places; from the exposures along the roads it appears to be in two sections separated by 3 to 8 feet of clay and shale. On the Beaver-Pittsburg pike, half a mile southeast of Bayne, a somewhat recent opening in the coal exposes 61 inches of coal and partings, with the bottom of the bed concealed and with 30 inches of apparently good coal at the top. (See section below.) This bank is out of use and filled with water; little coal seems to have been taken out.

Sections of the Elk Lick coal.

At the Schlag bank, on the eastern edge of the quadrangle, Ross Township.	
At entry.	Inches.
Coal	4
Bluish clay	7
Coal	6
Clay	0–½
Coal	12
Clay	1
Coal and clay partings	12
Clay	1
Concealed.	
100 feet from mouth of entry.	Inches.
Coal	2
Shale	16
Coal	4
Treacherous fire clay and shaly coal	6
Coal, shaly	8
Coal (good)	40
Fire clay	6

At Keown post-office, McCandless Township.	Inches.
Coal with partings	18
In the eastern corner of Sewickley Township.	Inches.
Coal with numerous partings of yellow clay	8
Coal	12
Clay	20
Coal	3
Clay	36
Coal with several clay and shale partings	35
On Beaver-Pittsburg pike, half a mile southeast of Bayne.	Inches.
Coal (blocky)	30
Coal (bony)	12
Yellow clay	10
Coal	9
Concealed.	

Considerable quantities of the Elk Lick coal have been taken from two old banks north of Pleasant Hill Church in Marshall Township, where it is said to be from 2½ to 3 feet thick and of fair quality. In the northern half of the quadrangle the coal had been opened at many points where it is from 18 to 24 inches thick, but the total amount of coal taken out is very small.

COALS OF THE MONONGAHELA FORMATION.

Pittsburg coal.—The Pittsburg coal is present near the tops of a few high hills in the southeastern part of the quadrangle and in seven high knobs in the southeast quarter, north of Ohio River. It has been mined for a long time by country banks at every point where it occurs, and the supply remaining is very small. The bed is comparable in thickness with the Pittsburg bed farther south, where, because of its great thickness, excellent quality, and uniform occurrence, it is considered to be the most valuable in the region. Within the Sewickley quadrangle its quality is generally below that of its southern equivalent, for it seldom has more than a thin rock covering and has long been exposed to the deteriorating action of percolating surface waters. Even under these conditions, however, it is generally much superior to any coal of the Conemaugh formation and has been widely used by the farmers in areas adjacent to the high hills in which it occurs.

Many of the old banks on this coal have been worked out and abandoned and few good sections of the coal were secured. These sections as given below are supplemented by some made by I. C. White in 1876 or 1877, when many of the banks were being worked.

Sections of the Pittsburg coal.

Watt bank, 1 1-2 miles south of Coraopolis, Moon Township.		
Roof coal.		Inches.
Coal		36
Shale		0-1½
Coal (bearing-in bench)		4
Shale		0-1½
Coal (block)		27
Shale		½-2
Coal (slack)		3½
		72

On high knob half a mile southwest of Salem Church, Pine Township. [White, I. C., Second Geol. Survey Pennsylvania, Rept. Q, p. 170.]				
Slaty coal	1			
Shale		4		
Coal	1	2	3	3½
Slate		½		
Coal		9		
Shale			1	1½
Coal		8		
Slate		1		
Coal	2	4		
Slate		½		
Coal		4	5	7¼
Slate		½		
Coal		9		
Slate		¼		
Coal	1	4		
			10	¼

At old bank 1 1-2 miles south of Ingomar, Franklin Township. [By White, I. C., Second Geol. Survey Pennsylvania, Rept. Q, p. 173.]				
Roof division:	Ft.	in.	Ft.	in.
Coal	2	6		
Shale	1	6	6	6
Coal	2	6		
Shale			1	2
Coal	2	9		
Slate		½		
Coal		4	4	9¾
Slate		¼		
Coal	1	8		
			12	5¾

At cut on pike three-fourths mile south of Carnot, Moon Township.	Ft.	in.
Black shale and coal	1	
Clay and shale	1	
Coal with numerous thin shale and clay partings	5	11
Shale	1	1
Coal (good)	3	
Shale		½
Coal (bearing-in bench)		4
Shale		½
Coal (blocky)	2	
	14	5

CLAY.

Clay is at present of small economic value in the Sewickley quadrangle and probably never will be very important.

Clay as commonly understood originates from rocks containing minerals made up largely of alumina and silica. Of these minerals the feldspars, augite, hornblende, and the micas are the most abundant. On the disintegration of such rocks the minerals decompose and the resulting products, together with fragments of the minerals themselves, form the basis of most clays. Clay is either residual or sedimentary. Residual clay is that which still remains near its parent rocks. It is found in the uplands back from the rivers. Though locally present in the Sewickley region in small quantities on the outcrops of limestone and certain shale beds, it is not common and, as the upland rocks are generally of a sandy character, it is of no great commercial importance and has never been utilized. Sedimentary clays are those which have been carried away from the places where they were formed and deposited by water in favorable places in rivers, lakes, and seas. Nearly all the clay mined in the Ohio Valley in Pennsylvania is sedimentary, and the manner of its deposition explains the banding and the presence of grains of sand and other minerals in it. The regularly bedded deposits, such as usually occur in association with beds of coal, have received the general designation "under clays." The less pure and less uniformly graded deposits in the present stream beds and upon the terraces of former valley floors along them are also sedimentary, but are locally known as terrace clays where they are being worked to the west, in the Beaver quadrangle.

The under clays of the Sewickley quadrangle have had a history vastly longer and more eventful than either the terrace or the basin clays. They have been exposed for ages to the solvent action of waters and for a time to the disintegrating action of a dense vegetation which grew upon them and which now remains as coal beds. As a result of these conditions the under clays are poorer in alkalies and iron than most terrace or basin clays. In addition, they have been subjected to many other influences. Frequent periods of long-continued submergence finally covered them with hundreds of feet of water-laid deposits, and the dynamic forces which consolidated these into hard sandstones and shales effected changes in the clay also. This clay, therefore, is in point of structure and hardness likely to differ from the terrace and basin clays, which are yet in their primitive state.

The only clays of economic importance at present are the sedimentary clays of the Allegheny formation, which underlie the Middle and Lower Kittanning coals. While these clays are doubtless widely distributed over the quadrangle, they outcrop only in a small area along Ohio River from Conway northward and are too deeply buried at other places to admit of successful exploitation. On the north side of the valley, at the mouth of Crows Run, the Lower Kittanning clay is said to have been extensively mined for fire and paving brick. It is now being used for this purpose by two extensive brick plants near the mouth of Crows Run, which constitute the entire clay manufacturing industry of the quadrangle.

At several places the clay horizon in the Mahoning member appears to be occupied by 8 to 15 feet of reddish flint clay, which may eventually be found to be of value in the manufacture of certain grades of brick, though it may contain a prohibitive amount of iron. This clay is especially prominent in the vicinity of Parks Quarries and directly overlies the thick lower sandstone of the Mahoning member, which is quarried at that point.

Small deposits of clay of Quaternary age may exist within the old terrace gravels along Ohio River, but if any are present they are not now being developed and will probably be found to be of small extent.

SHALE.

Through different degrees of induration clay passes insensibly into shale. It has been found that a mixture of clay and shale gives a better brick when strength and lasting qualities are desired than clay alone does. Therefore a considerable amount of shale associated with clays is always used in the manufacture of certain grades of brick, and in a great many places in the vicinity of Pittsburg bricks are manufactured entirely from shale. Within the Sewickley quadrangle the Conemaugh formation is composed largely of shale, and many beds of it are thought to be suitable for making building brick, and some, when mixed with local residual clays, for making good grades of paving brick.

Within the Sewickley quadrangle these shales have been put to economic use in but few places. The shale overlying the Lower Cambridge ("Brush Creek") limestone and the clayey shale underlying the Brush Creek coal have been used for the manufacture of brick at a point on the Pittsburg and Lake Erie Railroad a mile east of Shousetown. This quarry is now abandoned and the machinery removed. A brick plant manufacturing both building and paving brick is located at the end of the railroad switch up Legionville Hollow, northeast of dam No. 4, in Economy Township. This plant gets its shale and clay below the Bakerstown coal. In the northeastern part of the quadrangle, at Mars, building brick are made from the shale and clay of the Brush Creek horizon, and at Callery a sandy shale occupying the horizon of the Mahoning sandstone has been used in a small way for making building brick, but with poor success.

LIMESTONE.

The limestones of the Sewickley quadrangle are of comparatively small economic importance.

Outcropping limestones of the Allegheny formation are the Upper and Lower Freeport limestone members. These are generally thin but are exposed along the steep hill slopes of Brush Creek and Ohio River, where small areas are available for stripping. Limestones of the Conemaugh formation are generally less than 3 feet in thickness and of inferior quality and have been used only in a small way for road metal and for making lime. Of these the Ames limestone member has in a few places been burned by farmers for lime, and where especially convenient has also been used as macadam for building pikes. The lower beds of the Pittsburg limestone member, where present, are of good quality for road making and in a few places have also been burned into lime for fertilizer. Aside from these minor local uses, the limestones of the Sewickley quadrangle are not of sufficient importance to justify further notice.

SANDSTONE.

Abundance of sandstone suitable for rough masonry is found in the Sewickley quadrangle in both the Allegheny and Conemaugh formations. Each of the principal sandstones affords an ample supply of such material along its line of outcrop, and wherever needed for local building purposes this abundant supply has been drawn upon. The Freeport, Butler, Mahoning, and Morgantown sandstone members in a few localities contain layers of sufficient thickness and quality to justify their quarrying for dimension building stone.

The Freeport and Butler sandstones are locally well developed on both sides of Ohio River from the vicinity of Conway northward, but only small quarries for local use have been opened in them.

One of the most extensive sandstone quarries is in the Mahoning sandstone member, at Parks Quarries, on Crows Run, where an immense amount of low grades of building stone has been extracted. Some of the strata are from 2 to 10 feet in thickness, split readily into blocks, and apparently dress easily. The sandstone is coarse, somewhat conglomeratic in places, and gray to yellowish in color. For years this quarry furnished a large quantity of stone to cities and towns on Ohio River from Beaver to Pittsburg, but in the last few years the output has greatly diminished. This is probably due, partly at least, to the greater difficulties encountered in stripping, and partly to the fact that cement is increasingly taking the place of the stone formerly used in building.

Small quarries occur in the Mahoning and Morgantown sandstones at many convenient points along both sides of Ohio River. Most of this stone has been used in the construction of macadamized pikes (of which there are many throughout this area), as a foundation upon which the harder and more resistant limestone dressing is spread. At Stoops Ferry the Mahoning sandstone strata are rather massive, single beds measuring 15 feet or more in thickness. A considerable quantity of dimension stone might be secured at this point as well as at a number of places along the north side of the river from Sewickley to Bellevue.

Quarries in the Buffalo, Saltsburg, and Morgantown sandstone members are scattered over the entire quadrangle. They furnish road-building material and rough masonry for local use.

SAND.

Though some building sand is secured for local use along Ohio River and from the terrace deposits of Kansan and Wisconsin age, the amount is relatively small. It is possible that the terrace gravels contain small pockets of sand that is sufficiently pure for use in making certain grades of glass, but none of them are being used at present.

SOIL.

The soil of this quadrangle is made up almost entirely of residual rock waste coming from the disintegration of the rocks of the Conemaugh formation. Most of this soil now occupies approximately the horizontal position of the parent rock. The character of the soil therefore changes materially within short distances, for the underlying rocks may vary from sandstones to clays, or vice versa. As a rule, the soil is much deeper and more fertile than would be expected in a region of such bold relief. Back from Ohio River, where the hills have somewhat gentler slopes, the soil is well adapted to farming, fruit growing, and grazing, and most of it is used for these purposes.

TRANSPORTATION.

Ohio Valley is the great avenue of traffic through the Sewickley quadrangle. Transportation is effected by railroads and by water. There are three government dams across Ohio River within the quadrangle, all of which have recently been completed. These, together with others below and above, now afford a 9-foot stage of water from Pittsburg to Beaver. The completion of these dams has greatly stimulated river transportation, but to develop to the maximum this mode of transportation it is essential that the 9-foot stage of water be maintained by the necessary dams throughout the course of Ohio River from Pittsburg to Cairo. Under such conditions the movement by river of heavy freight, such as coal, steel, and heavy manufactured articles intended for southern trade, would be very great.

Ohio Valley is traversed on the north side of the river by the Pittsburg, Fort Wayne and Chicago division of the Pennsylvania Railroad system and on the south side by the Pittsburg and Lake Erie Railroad, both roads transporting an enormous tonnage west from the Pittsburg district. The northeastern portion of the quadrangle is traversed by the Pittsburg and Chicago line of the Baltimore and Ohio Railroad.

In addition to these steam railroad lines, three important electric railroads have recently been completed or are now being constructed within the quadrangle. One of these is the Pittsburg and Butler Electric Railroad, which parallels the Baltimore and Ohio Railroad from Pittsburg to Mars and thence northeast to Butler. Another electric line built since the topographic map was made extends from Pittsburg to Butler west of the Baltimore and Ohio Railroad. It crosses Ross Township along Girty Run, passes through western McCandless, southwestern Pine, and eastern Marshall townships to Brush Creek, parallels Brush Creek to the vicinity of Ogle, and thence runs northeastward across Cranberry and Adams townships via Plains Church and along Wolfe Run to Breakneck Creek at the northern edge of the quadrangle. A third electric line is being built along the north side of Ohio River from Pittsburg to Beaver and will closely parallel the Pennsylvania Railroad lines.

WATER POWER.

The available water power within the Sewickley quadrangle is small. In general the tributaries to the Ohio are short and have narrow valleys of practically uniform grade. The hilltops are mostly under cultivation and the relative amount of run-off to ground water is great. This is not favorable for the development of water power on small streams, as the steep gradients and narrow valleys do not furnish adequate reservoirs to hold the great run-off from floods, and what is lost in this way can not be replaced by the small continuous supply of ground water from springs. Another serious obstacle to the use of these streams for water power is the relative rapidity with which they silt up any reservoir by flood débris. For these and other equally vital reasons it seems very probable that except on Ohio River the obtainable water power within the quadrangle, though theoretically of some importance, can not be expected to come into much practical use until the coal, oil, and gas of the region are nearly or completely exhausted.

May, 1909.

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PENNSYLVANIA
SEWICKLEY QUADRANGLE

H.M. Wilson, Geographer.
Robt. D. Cummin and J.H. Jennings, in charge of section.
Topography by Robt. D. Cummin, E.B. Clark, J.H. Wheat, A.C. Roberts, E.G. Hamilton, J.S.B. Daingerfield, Ira M. Flocker, and E.W. McCrary.
Control by D.H. Baldwin and C.A. Clunet.
Surveyed in 1903 and 1905-1906.

SURVEYED IN COOPERATION WITH THE STATE OF PENNSYLVANIA.

APPROXIMATE MEAN DECLINATION 1905.

Scale $\frac{1}{62500}$

Contour interval 20 feet.
Datum is mean sea level.

Edition of May 1908. reprinted Nov. 1909.

AREAL GEOLOGY

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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 the larger streams)*

Pleistocene

Qg — Latest glacial gravel *(outwash sand and gravel of distant origin on lower terraces; probably of Wisconsin age)*

Qlg — Later glacial gravel *(outwash sand and gravel of distant origin on rock terraces)*

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

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

CARBONIFEROUS

Pennsylvanian

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

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

Ca — Allegheny formation *(shale and massive sandstone with beds of limestone and valuable seams of coal and fire clay)*

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Edition of Feb. 1910

Geology by M. J. Munn and E. W. Shaw, under the supervision of Geo. H. Ashley.
Surveyed in 1906-08.

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STRUCTURE AND ECONOMIC GEOLOGY

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SEWICKLEY QUADRANGLE

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Ca — Allegheny formation *(shale and massive sandstone with beds of limestone and valuable seams of coal and fire clay)*

Economic and structure data

Coal outcrops

pb, *Pittsburg coal*
lc, *Little Clarksburg coal*
el, *Elk Lick coal*
hl, *Harlem coal*
bt, *Bakerstown coal*
bc, *Brush Creek coal*
mh, *Mahoning coal*
uf, *Upper Freeport coal*
lf, *Lower Freeport coal*
mk, *Middle Kittanning coal*
lk, *Lower Kittanning coal*

⚒ *Quarries* — *sandstone, fire clay, and shale for brick*

X *Country coal banks*

1200 — *Structure contours on Ames limestone* *(interval, 10 feet; broken lines indicate approximate location)*

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TRUE NORTH — MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1905.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 20 feet.
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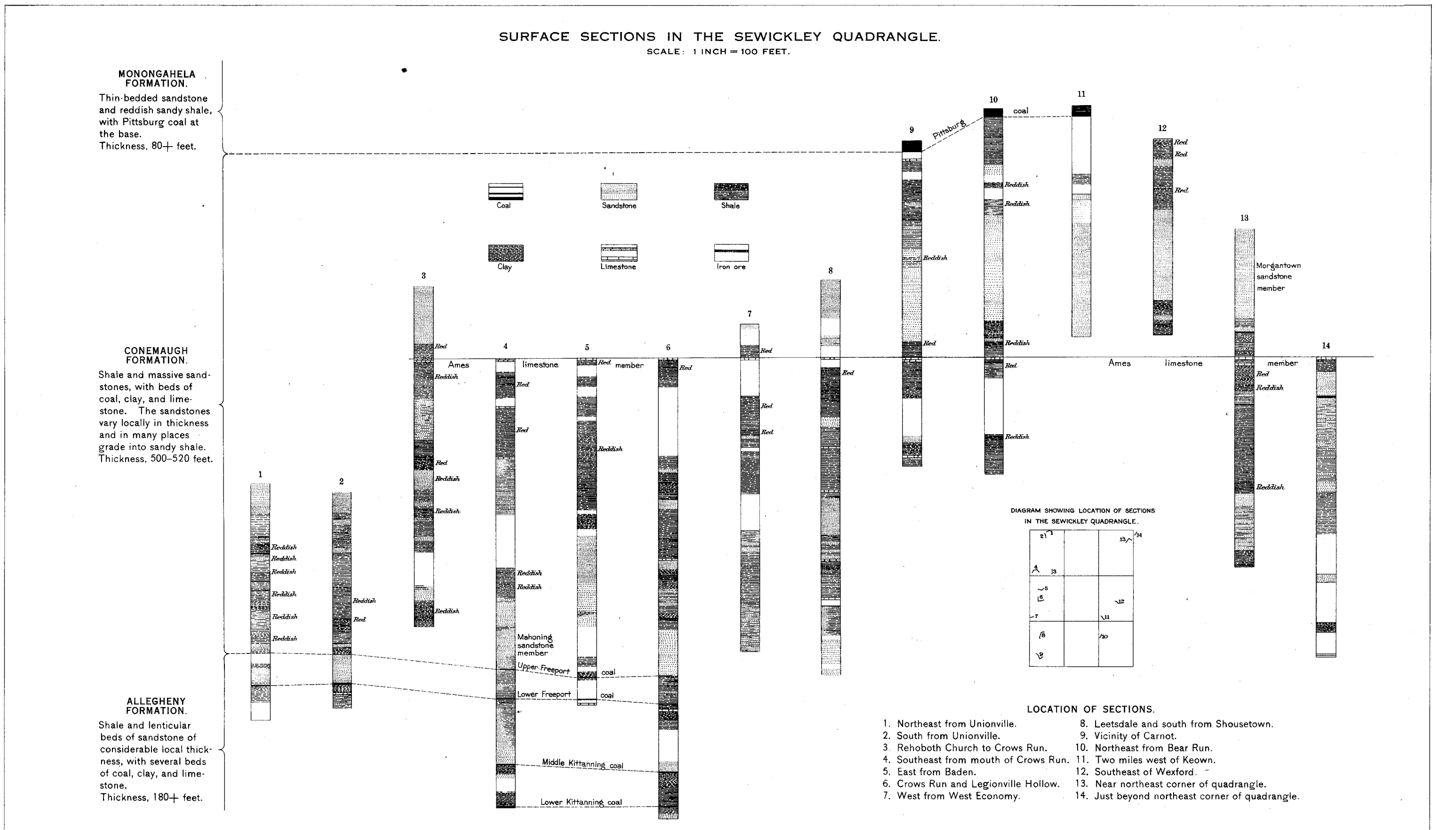
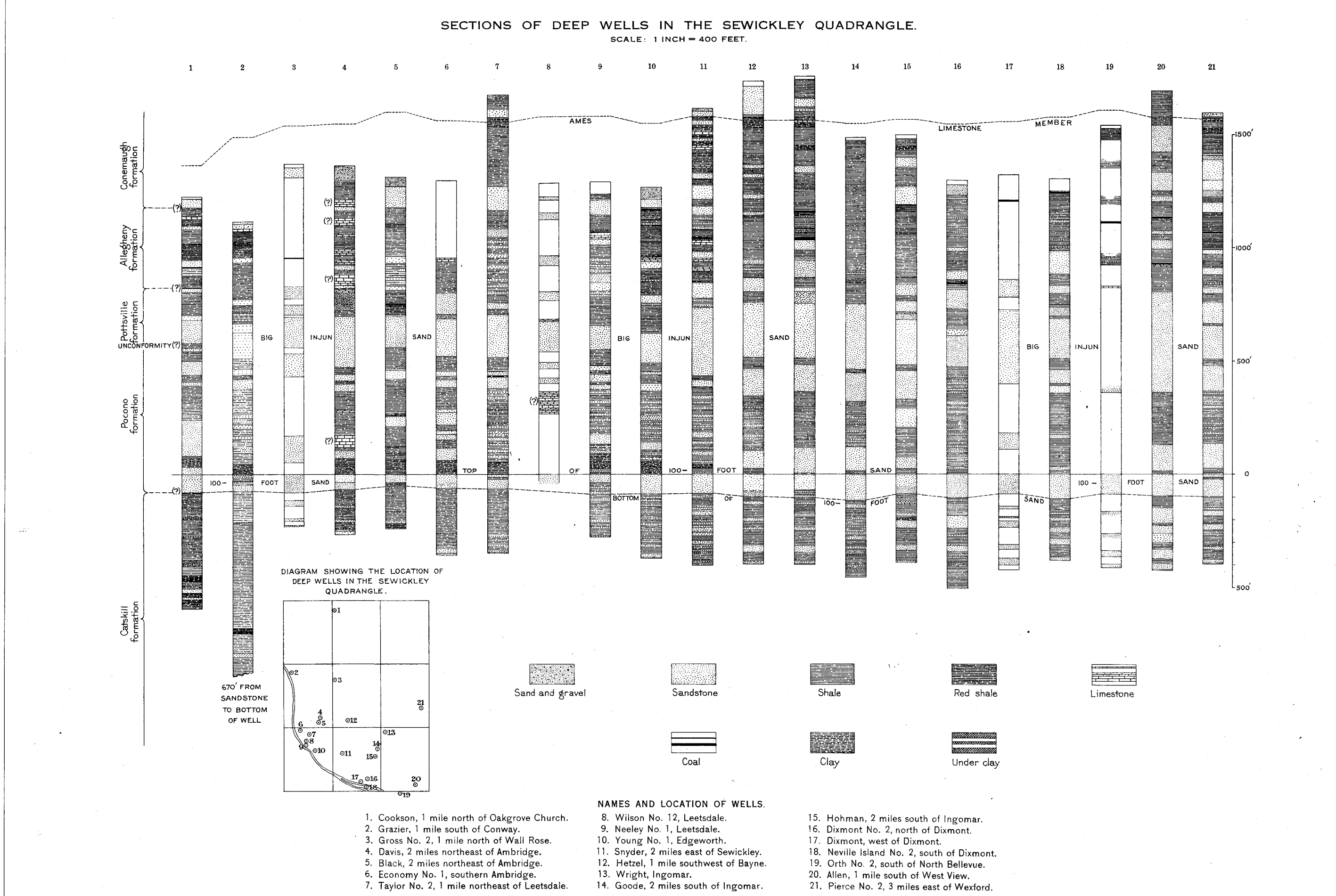
COLUMNAR SECTIONS





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‡10	Harpers Ferry	Va.-Md.-W.Va.	25
‡11	Jackson	California	25
‡12	Estillville	Ky.-Va.-Tenn.	25
13	Fredericksburg	Virginia-Maryland	25
14	Staunton	Virginia-West Virginia	25
‡15	Lassen Peak	California	25
16	Knoxville	Tennessee-North Carolina	25
17	Marysville	California	25
18	Smartsville	California	25
19	Stevenson	Ala.-Ga.-Tenn.	25
20	Cleveland	Tennessee	25
21	Pikeville	Tennessee	25
22	McMinnville	Tennessee	25
23	Nomini	Maryland-Virginia	25
24	Three Forks	Montana	25
25	Loudon	Tennessee	25
26	Pocahontas	Virginia-West Virginia	25
27	Morristown	Tennessee	25
28	Piedmont	West Virginia-Maryland	25
29	Nevada City Special	California	50
30	Yellowstone National Park	Wyoming	50
31	Pyramid Peak	California	25
32	Franklin	West Virginia-Virginia	25
33	Briceville	Tennessee	25
34	Buckhannon	West Virginia	25
35	Gadsden	Alabama	25
36	Pueblo	Colorado	25
37	Downieville	California	25
38	Butte Special	Montana	25
39	Truckee	California	25
40	Wartburg	Tennessee	25
41	Sonora	California	25
42	Nueces	Texas	25
43	Bidwell Bar	California	25
44	Tazewell	Virginia-West Virginia	25
45	Boise	Idaho	25
46	Richmond	Kentucky	25
47	London	Kentucky	25
48	Tenmile District Special	Colorado	25
49	Roseburg	Oregon	25
50	Holyoke	Massachusetts-Connecticut	25
51	Big Trees	California	25
52	Absaroka	Wyoming	25
53	Standingstone	Tennessee	25
54	Tacoma	Washington	25
55	Fort Benton	Montana	25
56	Little Belt Mountains	Montana	25
‡57	Telluride	Colorado	25
58	Elmoro	Colorado	25
59	Bristol	Virginia-Tennessee	25
60	La Plata	Colorado	25
61	Monterey	Virginia-West Virginia	25
62	Menominee Special	Michigan	25
63	Mother Lode District	California	50
64	Uvalde	Texas	25
65	Tintic Special	Utah	25
66	Colfax	California	25
67	Danville	Illinois-Indiana	25
68	Walsenburg	Colorado	25
69	Huntington	West Virginia-Ohio	25
70	Washington	D. C.-Va.-Md.	50
71	Spanish Peaks	Colorado	25
72	Charleston	West Virginia	25
73	Coos Bay	Oregon	25
74	Coalgate	Indian Territory	25
75	Maynardville	Tennessee	25
76	Austin	Texas	25
77	Raleigh	West Virginia	25
78	Rome	Georgia-Alabama	25
79	Atoka	Indian Territory	25
80	Norfolk	Virginia-North Carolina	25
81	Chicago	Illinois-Indiana	50
82	Masontown-Uniontown	Pennsylvania	25
83	New York City	New York-New Jersey	50
84	Ditney	Indiana	25
85	Oelrichs	South Dakota-Nebraska	25
86	Ellensburg	Washington	25
87	Camp Clarke	Nebraska	25
88	Scotts Bluff	Nebraska	25
89	Port Orford	Oregon	25
90	Cranberry	North Carolina-Tennessee	25
91	Hartville	Wyoming	25
92	Gaines	Pennsylvania-New York	25
93	Elkland-Tioga	Pennsylvania	25
94	Brownsville-Connellsville	Pennsylvania	25
95	Columbia	Tennessee	25
96	Olivet	South Dakota	25
97	Parker	South Dakota	25
98	Tishomingo	Indian Territory	25
99	Mitchell	South Dakota	25
100	Alexandria	South Dakota	25
101	San Luis	California	25
102	Indiana	Pennsylvania	25
103	Nampa	Idaho-Oregon	25
104	Silver City	Idaho	25
105	Patoka	Indiana-Illinois	25
106	Mount Stuart	Washington	25
107	Newcastle	Wyoming-South-Dakota	25
108	Edgemont	South Dakota-Nebraska	25
109	Cottonwood Falls	Kansas	25
110	Latrobe	Pennsylvania	25
111	Globe	Arizona	25
112	Bisbee	Arizona	25
113	Huron	South Dakota	25
114	De Smet	South Dakota	25
115	Kittanning	Pennsylvania	25
116	Asheville	North Carolina-Tennessee	25
117	Casselton-Fargo	North Dakota-Minnesota	25
118	Greeneville	Tennessee-North Carolina	25
119	Fayetteville	Arkansas-Missouri	25
120	Silverton	Colorado	25
121	Waynesburg	Pennsylvania	25
122	Tahlequah	Indian Territory-Arkansas	25
123	Elders Ridge	Pennsylvania	25
124	Mount Mitchell	North Carolina-Tennessee	25
125	Rural Valley	Pennsylvania	25
126	Bradshaw Mountains	Arizona	25
127	Sundance	Wyoming-South Dakota	25
128	Aladdin	Wyo.-S. Dak.-Mont.	25
129	Clifton	Arizona	25
130	Rico	Colorado	25
131	Needle Mountains	Colorado	25
132	Muscogee	Indian Territory	25
133	Ebensburg	Pennsylvania	25
134	Beaver	Pennsylvania	25
135	Nepesta	Colorado	25
136	St. Marys	Maryland-Virginia	25
137	Dover	Del.-Md.-N. J.	25
138	Redding	California	25
139	Snoqualmie	Washington	25
140	Milwaukee Special	Wisconsin	25
141	Bald Mountain-Dayton	Wyoming	25
142	Cloud Peak-Fort McKinney	Wyoming	25
143	Nantahala	North Carolina-Tennessee	25
144	Amity	Pennsylvania	25
145	Lancaster-Mineral Point	Wisconsin-Iowa-Illinois	25
146	Rogersville	Pennsylvania	25
147	Pisgah	N. Carolina-S. Carolina	25
148	Joplin District	Missouri-Kansas	50
149	Penobscot Bay	Maine	25
150	Devils Tower	Wyoming	25
151	Roan Mountain	Tennessee-North Carolina	25
152	Patuxent	Md.-D. C.	25
153	Ouray	Colorado	25
154	Winslow	Arkansas-Indian Territory	25
155	Ann Arbor	Michigan	25
156	Elk Point	S. Dak.-Nebr.-Iowa	25
157	Passaic	New Jersey-New York	25
158	Rockland	Maine	25
159	Independence	Kansas	25
160	Accident-Grantsville	Md.-Pa.-W. Va.	25
161	Franklin Furnace	New Jersey	25
162	Philadelphia	Pa.-N. J.-Del.	50
163	Santa Cruz	California	25
§164	Belle Fourche	South Dakota	25
§165	Aberdeen-Redfield	South Dakota	25
§166	El Paso	Texas	25
§167	Trenton	New Jersey-Pennsylvania	25
§168	Jamestown-Tower	North Dakota	25
§169	Watkins Glen-Catatonk	New York	25
§170	Mercersburg-Chambersburg	Pennsylvania	25
§171	Engineer Mountain	Colorado	25
§172	Warren	Pennsylvania-New York	25
§173	Laramie-Sherman	Wyoming	25
§174	Johnstown	Pennsylvania	25

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

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