DESCRIPTION OF THE AMITY QUADRANGLE.

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INTRODUCTION.

LOCATION AND RELATIONS OF THE QUADRANGLE.

The Amity quadrangle lies in the southwest corner of Pennsylvania, principally in Washington County, but it includes also a small part of Greene County. It extends from latitude 40° on the south to 40° 15′ on the north, and from longitude 80° on the east to 80° 15′ on the west, and therefore covers one-sixteenth of a square degree of the earth's surface, comprising 228.40 square miles. It is bounded by the following quadrangles of the United States topographic map: On the north by Carnegie, on the east by Brownsville, on the south by Waynesburg, and on the west by Claysville. The principal town is Washington, with a population in 1900 of 14,117.

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

GEOGRAPHY AND GEOLOGY OF THE NORTHERN PART OF THE APPALACHIAN PROVINCE.

A line drawn along the Allegheny Front across Pennsylvania, Maryland, and West Virginia, and continued along the eastern escarpment of the Cumberland Plateau across Virginia, Tennessee, Georgia, and Alabama, will divide the Appalachian province into two nearly equal parts. In the region lying east of the course of this line the rocks are greatly disturbed by faulting and folding. They are very old, and in many places are so metamorphosed that their original character can be determined only with difficulty. The rocks west of this line are arched into broad, gentle folds.

The physiographic divisions of the northern part of the province are indicated in fig. 1.

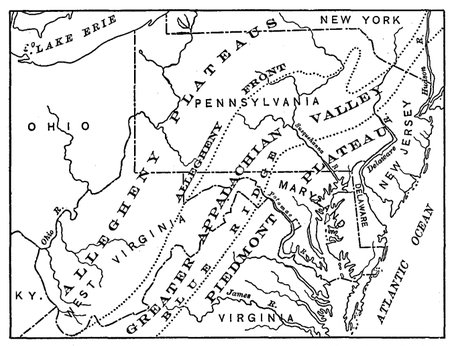

FIG. 1.—Diagram of northern portion of the Appalachian province, showing physiographic divisions.

The Amity quadrangle is in the southwestern part of Pennsylvania and lies wholly within the Allegheny Plateaus division.

In the area lying east of the Allegheny Front the surface consists of a series of alternating ridges and valleys, called the Greater Appalachian Valley, and still farther east it is a slightly dissected upland, known to geologists as the Piedmont Plateau. West of the Allegheny Front lies a rather elevated plateau region, broken by a few ridges where minor folds have affected the rocks, and greatly dissected by streams. To distinguish it from the lowlands of the Mississippi Valley, still farther west, and the rugged alternating ridges and valleys of the Appalachian Valley, this part of the province was called by Powell the Allegheny Plateaus. As the Amity quadrangle lies entirely within the Allegheny Plateaus, a somewhat detailed description of the province is given below, in order to present a clear idea of the physiography and geology of the quadrangle and its relations to the surrounding country.

ALLEGHENY PLATEAUS.

GEOGRAPHY OF THE PLATEAUS.

Drainage.—The Allegheny Plateaus are drained almost entirely into Mississippi River, but the northeast end drains partly into the Great Lakes and partly through Susquehanna, Delaware, and Hudson rivers into the Atlantic.

In northern Pennsylvania the arrangement of the drainage is due largely to conditions that existed during the Pleistocene epoch. It is supposed that before that time all of the streams north of central Kentucky flowed northwestward and discharged their waters through the St. Lawrence system. The encroachment of the great ice sheet closed this northern outlet and new drainage lines were established along the present courses of the streams.

Relief.—As the name implies, the surface of this division of the province is composed of a number of plateaus. The highest and most extensive of these plateaus lies along the southeastern margin of the division and extends throughout its length. It is very old and is consequently so greatly dissected by erosion that its plateau character is not everywhere apparent, but the hilltops are believed to be remnants of a very old land surface which, by long-continued erosion, had been reduced nearly to a plain and therefore can be properly called a peneplain. This peneplain is called the Schooley peneplain because it is well developed in the region of Schooley Mountain, New Jersey. It has been deformed by differential elevation of the land, and in most regions, on account of its great age, has been so completely dissected that its original character has disappeared. Its elevation in south-central Pennsylvania is generally about 2800 feet.

The Schooley peneplain is well developed in northern Pennsylvania, where considerable areas of it are still preserved in places where they were developed on the massive sandstones of the Pottsville formation, which have strongly resisted erosion. In northern West Virginia there are a few remnants of high, rather flat land surface, which appear to be parts of this plateau, but the region has been generally so dissected that the position of this old peneplain is marked only by hilltops. Throughout most of the province there are knobs and ridges that rise to a greater height than the surface of the old plateau. The Schooley peneplain corresponds with the Cumberland Plateau of Tennessee and adjacent States.

Along the western border of the Schooley peneplain, in large portions of Ohio, Pennsylvania, and New York, there are remnants of a second peneplain, younger than the Schooley. This surface has been called the Harrisburg peneplain, on account of its excellent development near Harrisburg, Pa. North of Ohio River this peneplain was developed on harder rocks than in Tennessee and Kentucky, and its surface is therefore less regular and its exact position more difficult to determine. It appears to rise from an altitude of 700 or 800 feet in Indiana to 1000 feet in Ohio, 1200 to 1300 feet in southwestern Pennsylvania, and probably 1600 to 2100 feet throughout northern Pennsylvania and southern New York. This peneplain corresponds to the Highland Plateau, or Lexington peneplain, of the southern part of the Appalachian province.

The Schooley and Harrisburg peneplains south of central Pennsylvania are generally separated by a westward-facing escarpment, which is rather pronounced in southern Pennsylvania, where the hard rocks of Chestnut Ridge rise abruptly above the plain formed in the softer rocks of Monongahela Valley, but generally the surfaces of the plateaus are so greatly dissected that the escarpment can be recognized only with difficulty. Toward the central part of the State the two plateaus seem to approach each other, and the escarpment is merged into a maze of irregular hills which represent all that now remains of the higher plateau.

West of the Harrisburg peneplain there is a third plain, which is developed in western Kentucky and Indiana.

GEOLOGIC STRUCTURE OF THE PLATEAUS.

General features.—The structure of the Allegheny Plateaus is simple. The strata lie nearly flat, and their regularity is broken only by small faults and low, broad folds. The plateaus are bordered on the west by a low, broad arch known as the Cincinnati anticline.

Structure of Appalachian coal field.—The geologic structure of the Appalachian coal field is very simple, the strata, particularly those at its northern extremity, lying in a general way in the form of a broad, flat, canoe-shaped trough. The deepest part of this trough lies along a line extending southwestward from Pittsburg across West Virginia to Huntington, on Ohio River. From both the northwest and the southeast the rocks dip toward the center of this trough. About the canoe-shaped northern end they outcrop in a roughly semicircular belt and dip in general toward the deepest part of the trough, which is situated in the southwest corner of Pennsylvania.

Although in general the structure is simple, the eastern limb of the trough is crumpled into a number of parallel wrinkles or folds, similar to the great folds east of the Allegheny Front, but on a very much smaller scale, and, as a rule, not broken by faults, as are many of the great folds farther east. These minor folds are a constant feature along the southeastern margin of the basin from central West Virginia to southern New York. They make the detailed structure somewhat complicated and break up the regularity of the westward dip, so that at first sight the more general structure is not apparent. Across the northern extremity of the basin the minor folds are developed in large numbers and extend at least halfway across Pennsylvania near its northern boundary. In the southern part of the State there are only six pronounced anticlines, and two of these disappear near the West Virginia line.

ROCKS OF THE APPALACHIAN PROVINCE.

PRE-CARBONIFEROUS ROCKS.

The oldest rocks of the Appalachian province are crystalline rocks, such as granite and gneiss, which outcrop along its eastern and northern margins and presumably underlie all the younger rocks of the entire province. Above the crystalline rocks lie thousands of feet of sandstone, limestone, and shale, comprising several systems. These rocks are exposed in the greatly folded and disturbed region east of the Allegheny Front and around the northern and western margins of the province, within the belt of crystalline rocks; but in the interior, as well as in the deep synclines of the Anthracite and Broadtop regions of the Greater Appalachian Valley, they are concealed beneath younger rocks.

CARBONIFEROUS SYSTEM.

The rocks exposed at the surface in the Allegheny Plateaus belong almost entirely to the Carboniferous system. They include the Pocono, Mauch Chunk, Pottsville, Allegheny, Conemaugh, and Monongahela formations and the Dunkard group. These will be described in the order of their age, beginning with the lowest.

Pocono formation.—At the base of the Carboniferous system lies the Pocono formation, the name of which is derived from Pocono Mountain, in the eastern part of Pennsylvania. In Pocono Mountain the formation is over 1000 feet thick, and rests conformably upon the red rocks of the Catskill formation, the uppermost member of the Devonian system. Over a large area in Pennsylvania the top of the Pocono is well marked by a calcareous and sandy stratum, known as the Loyalhanna ("Siliceous") limestone, but where this is absent the upper limit of the formation is not so well defined. The thickness of the Pocono on the Allegheny Front is about 1030 feet. Sandstone is its predominant constituent, but it comprises rather thick beds of gray sandy shale and occasionally beds of red shale, which, though generally thin, may be locally of considerable thickness. In southern Pennsylvania the formation is in most places under cover, but it has been penetrated by deep wells drilled for oil and gas. In this part of the State it possibly includes all the rocks between the top of the Big Injun sand and the bottom of the Fifty-foot sand of well drillers. In the southeastern part of the Appalachian field, in Virginia and West Virginia, the formation contains workable beds of coal of limited extent, and in parts of Pennsylvania it includes thin, worthless beds. Since it contains these coals and carries fossil plants similar to those of the later coal-bearing formations, the Pocono is placed in the Carboniferous system.

Mauch Chunk formation.—This formation outcrops on top of the Loyalhanna limestone on the Allegheny Front, along Conemaugh River east of Blairsville, and along Chestnut Ridge in Fayette County. It takes its name from Mauch Chunk, in the anthracite coal region, where it is over 2000 feet thick in the deep synclines and consists largely of red shale. On the Allegheny Front it is about 180 feet thick and is composed of grayish to greenish sandstone and soft red shale. Along the Conemaugh between South Fork and Johnstown it has this same character, but on Chestnut Ridge the sandstone beds disappear and the formation consists of red shale, in the lower part of which there is a bed of limestone carrying an abundance of marine fossils. This is the feather edge of the Greenbrier limestone of Virginia, and represents the upper part of the great Mississippian (Lower Carboniferous) limestone of the Mississippi Valley. The Mauch Chunk formation occurs as a thin stratum in several wells drilled in the vicinity of Blairsville in Westmoreland County, but north of that place it is known at only a few localities. It is present in wells in eastern Washington and Greene counties.

Pottsville formation.—This group of rocks derives its name from Pottsville, in the Southern Anthracite coal field. It is there 1200 feet thick and is composed mainly of a coarse conglomerate, which in some parts of the field carries several workable coal seams. In the eastern part of the bituminous coal field in Pennsylvania the formation consists of at least two sandstone members, separated in general by a bed of shale, which at many places contains several thin coals. The upper sandstone member is known as the Homewood, the lower as the Connoquenessing. In places the intervening shale contains a workable coal bed and locally also a valuable fire clay and one or more thin limestones. The shale and various associated beds are known collectively as the Mercer member, for the reason that they are well developed in Mercer County, Pa. Along the western border of Pennsylvania a third sandstone member occurs below the Connoquenessing and is separated from it by another shale bed, which contains locally a workable coal seam. This sandstone is called the Sharon sandstone or Sharon conglomerate, and the coal bears the same name, from Sharon, in Mercer County, where the rock and coal are conspicuously exposed. In most parts of the bituminous coal field in Pennsylvania the thickness of the Pottsville runs from 125 to 200 feet. In the extreme western and in parts of west-central Pennsylvania the Pottsville lies unconformably on the Pocono formation.

Allegheny formation.—This formation takes its name from Allegheny Valley, along which it is typically developed and well exposed. In character it is rather more variable than the lower formations in the Carboniferous system. It is especially distinguished by the fact that in the northern part of the bituminous field it contains a greater number of workable coal seams than any other of the lower formations in this region, and on that account was originally called the "Lower Productive measures." Nearly all the coal mined in Pennsylvania north of Pittsburg and east of Connellsville and Blairsville is taken from this formation. In addition to its coal it contains valuable beds of fire clay

and limestone. These members are separated by strata of sandstone and shale. The clay beds form the basis of important industries at several localities.

Conemaugh formation.—The rocks overlying the Allegheny formation rarely contain workable coal beds, and for that reason they were formerly known as the "Lower Barren measures," to distinguish them from a similar formation in the upper part of the Carboniferous rocks. They are now known as the Conemaugh formation, the name being derived from Conemaugh River, along which they outcrop extensively. In some parts of Pennsylvania, however, workable coals of limited extent occur in this formation, and at some places they are accompanied by thin limestones. The great mass of the formation is composed of alternating shale and sandstone. A large part of the shale is sandy. The sandstone strata are variable in thickness and occurrence, and in general form lentils which at many places grade horizontally into shale.

Monongahela formation.—This formation has been called the "Upper Productive measures," to distinguish it from the "Lower Productive measures," but in recent years the original name, from Monongahela River, has been revived. This formation overlies the Conemaugh in southwestern Pennsylvania and extends from the bottom of the Pittsburg coal below to the top of the Waynesburg coal above. Its thickness ranges from 290 to over 400 feet. It comprises several workable coal beds, of which the Pittsburg is by far the most valuable and best known. It is much less sandy and shaly than any of the other Carboniferous formations, but contains, on the other hand, far more limestone, which constitutes more than one-third its thickness. The formation underlies an oval-shaped area extending from Pittsburg, Pa., to the vicinity of Huntington, W. Va., and including considerable portions of Ohio and West Virginia adjacent to Ohio River.

Dunkard group.—This group of rocks was formerly known as the "Upper Barren measures," for the reason that, except at a few places, it does not carry workable coal beds. It lies higher up in the series than the "Lower Barren measures." The term Dunkard is derived from Dunkard Creek, in Greene County. The group includes the highest rocks of the Carboniferous system found in this region. It has a maximum thickness in the southwest corner of Pennsylvania of over 1100 feet, and consists mainly of shale and sandstone, though it contains also beds of coal and limestone. Some of the coals are locally workable, but most of them are worthless.

TOPOGRAPHY OF THE QUADRANGLE.

DRAINAGE.

General features.—The Amity quadrangle contains four principal drainage basins—those of Tenmile, Chartiers, Little Chartiers, and Mingo creeks. Branches of Peters Creek, South Fork of Tenmile Creek, Pike Run, and several smaller streams in the southeast corner of the area also rise within its borders. The streams are tributaries of Ohio River, but all of them flow first into Monongahela River east of the quadrangle, except Chartiers and Little Chartiers creeks, which reach the Ohio directly.

Unsymmetrical valleys.—A peculiar feature of the drainage of the quadrangle is the unsymmetrical nature of the basins. This feature is best shown on the sketch map, fig. 2. By comparing this with the topographic map it will be seen that the eastward-flowing streams do not lie in the center of their basins, but are situated within a mile or two of the watersheds of their southern tributaries. The southern side of the valleys is consequently steep and carries few tributaries, the longest being in every case on the north side of the trunk stream.

This feature is well illustrated by Tenmile Creek, which flows within 2 miles of the divide separating it from its South Fork. On the north side of the creek, however, the tributary streams are from 5 to 10 miles long. The same relation holds in the valley of Mingo Creek, where the northern divide is 3 to 4 miles distant, and the southern divide lies only one-half mile to 1 mile away. The main branch of Pigeon Creek lies within one-half mile to 2 miles of the southern watershed, while the northern watershed is 6 miles distant. The same condition is seen in all branches of Pigeon Creek and also in Peters Creek, Pike Run, and many of the minor streams.

This lack of symmetry in the drainage basins is rather strongly marked over several counties in southwestern Pennsylvania and eastern Ohio. In some areas the side of the valley having the longest tributaries lies toward the west or northwest instead of the north, as in this region. This is not due to

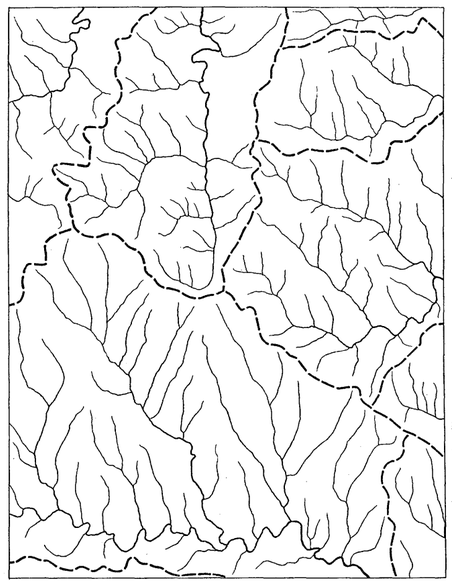

FIG. 2.—Sketch map of the drainage basins in the Amity quadrangle, showing their lack of symmetry. Watersheds are shown by heavy broken lines.

the geologic structure, because the larger creeks flow across anticlines and synclines alike. Neither can it be due to the character of the rocks, as their distribution shows no relation to the lack of symmetry. The only efficient cause would seem to be some form of warping or folding of the surface on a large scale. An uplift in Tertiary time along a northeast-southwest axis extending across Ohio and passing perhaps into northern Pennsylvania would be an adequate cause of the lack of symmetry.

SURFACE RELIEF.

The Amity quadrangle is an example of a maturely dissected region, or one in which the principal streams have eroded their valleys to a fairly uniform grade and the smaller branches have cut back so as to dissect the uplands into hundreds of narrow ridges between the streams. The surface of the quadrangle is therefore very hilly. The principal ridges are the divides between the drainage basins of Tenmile Creek and South Fork, between the Tenmile drainage and that of Chartiers and Pigeon creeks, and the divides separating Mingo and Pigeon creeks. The hilliest part of the quadrangle is near the southwest corner, and in general the surface in Washington and Greene counties may be said to increase in height and ruggedness toward the south.

By reference to the topographic map it will be seen that the altitudes in this quadrangle range from 820 feet to about 1520 feet. The highest summits are Mount Wheeler, 1523 feet, and the hills of Morris Township, in the extreme southwest corner of the quadrangle, which have about the same height. Scenery Hill rises to 1486 feet, and the hills midway between Bentleyville and Beallsville reach elevations of 1480 feet. Throughout the western part of the quadrangle most of the hilltops are between 1300 and 1400 feet.

Except in Scenery Hill ridge the general altitude in the eastern part of the quadrangle is less than in the western part. Half a dozen summits in the eastern part reach 1300 feet, but with these exceptions the general level of the hilltops in this portion of the quadrangle is between 1200 and 1300 feet. The hills and ridges at this level are much flatter than the hills farther west in the quadrangle, and on this account are noticeable. The general level can be recognized in the borough of Deemston and in Somerset and Nottingham townships. In its persistence over so large an area it strongly suggests a peneplain caused by an advanced stage of subaerial erosion at a time when the land stood at a lower level than at present, followed by uplift, and still later by the dissection of the plateau by streams. The general level noted above is supposed to correspond with the Harrisburg peneplain. The exact age of this peneplain is not known, but it is believed to date from early Tertiary time. It is not conspicuous in the western part of the Amity quadrangle.

Below this peneplain surface there are, along Tenmile, Pigeon, and Little Chartiers creeks, a number of rock shelves or terraces at altitudes varying from 900 to 1000 feet. Many of these occur at the ends of rock spurs that project into the valley. Although at some places, as at Lone Pine, they are dependent on beds of sandstone or other hard rock, their occurrence has commonly no particular relation to the nature of the underlying formation. On Tenmile Creek the terraces are well developed and range in elevation from 980 feet at Bissell to about 900 feet in the vicinity of Zollarsville. On Little Chartiers Creek, at Gambles and Linden, they range in altitude from 1000 to 1020 feet. These terraces are believed to be due to an uplift and a halt subsequent to the formation of the 1250- and 1100-foot levels. The lower terraces are covered locally with thin deposits of silts and gravels, which belong to the Carmichaels formation, well exhibited along Monongahela River, and which rest on a series of extensive rock terraces that are developed throughout this valley and other large valleys of western Pennsylvania at elevations between 900 and 1050 feet. They are the remnants of ancient valleys, broader than the present stream valley, that were formed during the last stages of the Tertiary period.

At present the streams are intrenched from 100 to 200 feet below the tops of the terraces, and have again reached a mature stage of erosion. The valleys of Tenmile and Mingo creeks are about 820 feet above sea level at the places where they leave the quadrangle. Pigeon Creek is about 920 feet, Chartiers 950 feet, and Little Chartiers Creek 900 feet above sea level. The creeks and larger runs have broadened their valleys somewhat, so that a space ranging in width from a few hundred feet up to one-fourth mile is at many points available for farming land.

DESCRIPTIVE GEOLOGY.

STRATIGRAPHY AND AREAL GEOLOGY.

With the exception of a few comparatively recent deposits in the valleys, the rocks exposed at the surface of the Amity quadrangle are all of Carboniferous age.

For convenience of economic and scientific study geologists have divided the strata into separate formations, distinguished from one another by their lithologic features and their fossils. The relative positions of the various beds in the formations are shown in the columnar section (p. 16).

Although the general relations of the strata remain fairly constant, there are considerable variations in details in different parts of the quadrangle. Sections several miles apart are likely to differ somewhat in the character and thickness of the various beds. This is especially true of the formations which do not outcrop but which are known only from well sections. Over widely extended regions, however, uniform conditions prevailed during certain periods, and sediments that show but slight variation were deposited at the same horizon. The Pittsburg coal, the Waynesburg sandstone, the Upper Washington limestone, the Salt sand, and the Big Lime are examples of strata that are persistent over wide areas.

The discussion of the rocks of this quadrangle may properly be divided into two parts, the first consisting of those that do not outcrop and the second of those that are exposed at the surface.

Rocks that do not Outcrop in this Quadrangle.

Sources of knowledge.—Information concerning the rocks that everywhere lie beneath the surface is derived wholly from records of deep wells bored for gas and oil and is therefore somewhat imperfect. The rocks most commonly recognized by the drillers are beds of sandstone, or "sands," as they are called. These have been given various fanciful names by the drillers and the terms have come into common use in the region, and are so applied here. Many well records have been carelessly kept, and beds that are important from a geologic standpoint—such as coals, bands of red rock, and limestones—have not been recorded. Frequently only the oil and gas sands have been noted, so that great gaps appear in the records. The methods of measurement used by the drillers and the difficulty of identifying rocks by the relative ease with which the drill penetrates them and by the drillings brought up in the sand pump are likely to cause considerable errors. To these conditions may be due in part the lithologic variations recorded in wells in neighboring territories. It may thus happen that important beds which are not recorded by well drillers are not really absent, but have been overlooked. A bed that is recorded as a heavy sandstone in one well might, in the interval to a neighboring well, change to a highly arenaceous shale or shaly sandstone and thus be recorded as "slate" or "shale." At best, the information derived from deep-well sections must be confined almost wholly to a record of the lithologic character of the rocks penetrated. It is in most cases impossible to learn anything of the fossils contained in these rocks, by means of which the ages of the rocks might be determined.

Thickness of the subsurface rocks.—The greatest thickness of rocks penetrated by the drill in the Amity quadrangle is in well No. 1 on the farm of Mrs. A. L. Hawkins, situated 1.2 miles southwest of Beallsville. This well is 3611 feet deep and extends 3186 feet below the Pittburg coal. As the lowest exposed horizon in the quadrangle is only a few feet below this coal, the thickness of the non-exposed rocks in the well may be said to be about 3150 feet.

Order of discussion.—The natural order in which to describe strata is from the bottom upward, in the order in which the various rocks were formed. In a region like Washington County, however, where correlation of the underlying formations is based on well records showing the intervals below a datum formation like the Pittsburg coal, it is deemed best to begin at the Pittsburg coal and to describe first the beds from that horizon downward, in the order in which they are pierced by the drill. Afterwards the beds above the coal will be described in order, as they appear in outcrop.

CARBONIFEROUS SYSTEM.

PENNSYLVANIAN SERIES.

CONEMAUGH FORMATION.

Thickness.—The rocks known as the Conemaugh formation comprise all those included between the Pittsburg coal at the top and the Upper Freeport coal at the base, both coals being excluded from the formation. In Pennsylvania it generally ranges in thickness from 500 to over 700 feet. In the Amity quadrangle it is known only from well records, and as in the great majority of these no coal has been recorded below the Pittsburg bed few data are at hand by which to determine the position of the base of the formation. Some records, however, report the "Connellsville" coal, which is believed to be equivalent to the Upper Freeport bed of the Allegheny Valley. The C. M. Reed well, near Wylandville, in North Strabane Township, reports exactly 600 feet from the top of the Pittsburg to the top of the Freeport coal bed. In the Reed well in the borough of Washington the interval is 595 feet. If 8 feet be allowed for the probable thickness of the Pittsburg coal the thickness of the Conemaugh is 592 and 587 feet in these two wells, respectively. The records of a number of wells in the Zollarsville gas field also show the Freeport coal, and in these the intervals between the two beds are as follows:

Thickness of Conemaugh formation reported in wells in the Zollarsville gas field.

	Feet.
Matilda Davis No. 2	597
A. B. Crumrine	597
Oberholt	592
William Crumrine	578
J. L. Thompson No. 2	559
J. L. Thompson No. 3	595
J. L. Thopmson No. 4	592
Hiram Teagarten	570
William Ward	576
Uriah Hill heirs	590
Thompson & Seaman Coal Co	580
Average thickness	584

One mile northeast of Beallsville the Peter Nickerson well reports 604 feet. The S. F. Scott well, 2 miles north of Beallsville, makes it 574 feet, including the Pittsburg coal. The general average of all these measurements is 585 feet.

General character.—The Conemaugh formation consists principally of alternating shales, sandstones, and sandy shales, although it comprises also

thin limestones and occasional coal beds. In southwestern Pennsylvania a number of beds of red shale of variable thickness are scattered through the upper 400 feet of the formation.

Almost all deep-well records contain notes of occurrences of "slate and shells," "sand and shells," or simply "shells"—common expressions of the drillers. The "shells" referred to are not fossil shells of organisms, as in the ordinary sense of the word, but are thin layers ("shelly layers") of shale or sandstone, alternating with thicker layers of similar rocks.

Probably the most detailed section of the Conemaugh in this quadrangle is that contained in the record of the Matilda Davis No. 2 well, in the borough of Deemston. The section is as follows:

Section of Conemaugh formation reported in Matilda Davis No. 2 well, borough of Deemston.

	Feet.
Pittsburg coal.	
Lime	45
Slate	20
Lime	35
Slate	13
Lime	25
Red rock	10
Lime shells	45
Slate	10
Lime	13
Slate	5
Lime	15
Sand	8
Lime	25
Sand	25
Lime	8
Red rock	31
Lime	12
Slate	60
Lime	5
Sand	43
Slate	12
Lime	50
Slate	7
Lime	31
Slate	35
Lime	9
Total	597
Upper Freeport coal.	

The complete record of this well is given graphically among the well sections (p. 16). The record is given according to the driller's notes, without attempt at geologic correlations, and it is probable that some of the limestone noted is in reality hard sandstone, for in regions where the Conemaugh formation outcrops it contains a relatively small proportion of limestone. Possible discrepancies of this kind should be kept in mind in studying any record. Where the word "sand" occurs in these records and in discussions of the solid rocks of this area, it is used in the sense originated by the well drillers, meaning any bed of sandstone, or, frequently, sandy shale. In the same way, "lime" is used for limestone.

In the western part of the quadrangle the original Gantz well at Washington shows a fair section of the Conemaugh rocks. The base of the formation is there rather indefinite, however.

Section of Conemaugh formation reported in the Gantz well, Washington.

	Feet.
Pittsburg coal.	
Sandstone, soft	10
Slate	12
Shells, hard	2
Slate	10
Sandstone, hard, gray	11
Slate	30
Sandstone, white, soft	10
Slate	51
Sandstone, very hard	80
Slate	10
Limestone	5
Slate	15
Red rock, inclined to cave	60
Slate and shells	40
Red rock, caving badly	25
Slate	32
Red rock	25
Sandstone, white	20
Slate and shells	100
Sandstone, hard, gray	100
Total	648
Coal and slate (perhaps Upper Freeport coal).	

As this total is greater than the usual thickness of the Conemaugh formation, there is some doubt whether the "coal and slate" occupies exactly the Upper Freeport horizon, but the lower limit of the formation is approximately correct.

On page 16 are shown columnar sections of eleven wells in the quadrangle, the records of which may be regarded as typical, and by comparison of these the relations of the various beds described and the limits of the formation may be seen.

Sandstones in the Conemaugh formation.—Several sandstone horizons have been recorded in the Conemaugh formation and three of them have been named by the well drillers. The uppermost of these is known to well drillers in the southeastern part of the quadrangle as the Murphy sand. It occurs at intervals ranging from 170 to 220 feet below the Pittsburg coal, and varies in thickness from 25 to 120 feet. This sand probably corresponds with the Morgantown sandstone, which occurs at about that horizon in certain parts of southwestern Pennsylvania and northern West Virginia.

Another important sandstone is known to drillers as the Dunkard sand. This is frequently recorded as a double sand, in which case the upper and lower divisions are known as the Little Dunkard and Big Dunkard, respectively. The Big Dunkard sand at some places lies almost directly on top of the Upper Freeport coal, corresponding in position with the Mahoning sandstone, a conspicuous sandstone lentil found farther north and east in western Pennsylvania. The thickness of the Big Dunkard ranges from 30 to 100 feet. Where simply Dunkard sand is noted in records, the Big Dunkard is most commonly referred to; and this is believed to be the more persistent of the two. In some places, however, this sand is thick enough to include both divisions.

The top of the Little Dunkard sand usually occurs from 170 to 240 feet above the Upper Freeport coal, making this sand the probable equivalent of the Saltsburg sandstone, a lentil that forms a conspicuous surface feature over large areas in the western part of the State. The thickness of the Little Dunkard is generally 20 to 40 feet. These facts are in harmony with the occurrence of the Saltsburg and Mahoning sandstones in regions where they outcrop.

Red shale in the Conemaugh formation.—A number of well records note several beds of red shale in the Conemaugh. These are most numerous in the upper 400 feet of the formation, where there are, at some places, three or four of them, aggregating locally 60 feet in thickness.

Coals in the Conemaugh formation.—Coal beds are of infrequent occurrence in the Conemaugh formation, and most of them are thin, but some appear to be rather persistent. One of these occurs in Washington County, its geologic position being marked by a bed which is reported in several wells. Its depth below the Pittsburg coal varies with locality, being 445 feet below, in the Isaac Horn No. 1 well, near Zollarsville; 410 feet below in the Joseph B. Wise No. 1 well, in the same vicinity; and 384 feet below in the Luse well, near Beallsville. If the thickness of the Conemaugh formation in this vicinity is 584 feet—the average thickness reported in the Zollarsville gas field—the intermediate coal in these wells occurs at about 139, 174, and 200 feet, respectively, above the Upper Freeport coal. In the Horn No. 2 well another coal has been noted, 245 feet below the Pittsburg seam.

ALLEGHENY FORMATION.

Thickness.—Beneath the Conemaugh lies the Allegheny formation. This may be defined as extending downward from the top of the Upper Freeport coal to the top of the Pottsville sandstone.

Where exposed in western Pennsylvania this formation varies in thickness from 270 to 370 feet, averaging probably about 300 feet. In the southwest corner of the State, where it is under deep cover and where few complete well records have been kept, its thickness is difficult to determine, but the available records seem to confirm the estimate just given.

General character.—The Allegheny formation consists of sandstones, shales, coal beds, and occasional thin limestones. At most places where the formation is exposed in Pennsylvania it contains several valuable coal beds. The general character and sequence of beds in the formation are shown by several well sections in the borough of Deemston, two of which are given below:

Section of Allegheny formation reported in the J. L. Thompson No. 5 well, borough of Deemston.

	Feet.
Upper Freeport coal	5
Slate	25
Lime	15
Slate	80
Gas sand	45
Slate	25
Black slate	25
Sand	25
Lime	15
Black slate	50
Total	310

Allegheny formation reported in the A. B. Crumrine No. 1 well, borough of Deemston.

	Feet.
Upper Freeport coal	4
Slate	4
Lime	30
Slate	20
Sand	38
White slate	37
Black slate	40
Sand	55
Slate	30
Lime	20
Slate	9
Sand	25
Lime	5
Total	317

The limestone bed occurring near the top of these sections is probably the Upper Freeport limestone. The thin limestone 50 to 60 feet above the base of the sections may be the Vanport ("Ferriferous").

Coal beds in the Allegheny formation.—Except at a few places, only two coal beds are recorded in this formation in wells in the Amity quadrangle. These are the Upper Freeport (Connellsville), which is often noted and is probably very persistent, and a bed that occurs about 150 feet below it. This lower coal is reported only in the Elizabeth Morton No. 1, Winnet McCarthy No. 2, and Frank McCarthy No. 1 wells, in West Bethlehem Township. The intervals from this to the Pittsburg bed measure 755, 745, and 750 feet, respectively. In those wells the coal is reported as the Connellsville, but it is believed to be more probably equivalent to some coal bed of the Kittanning group. A coal which may be the same is recorded in the A. M. Wickerham well, in the borough of Deemston, but here the interval is only 721 feet. In the Luse well, near Beallsville, and in the Gantz well, at Washington, a coal is recorded 672 feet and 653 feet, respectively, below the Pittsburg. This is probably the Lower Freeport coal of the Allegheny Valley, which occurs about 40 feet below the Upper Freeport.

The only well in the quadrangle that shows three coals in the Allegheny formation is the A. C. Mitchell well, in West Pike Run Township. The section of the Allegheny formation in this well is reported to be as follows:

Allegheny formation reported in the A. C. Mitchell well, West Pike Run Township.

	Feet.
Coal (Upper Freeport)	5
Lime	29
Sand	10
Slate	24
Sand	32
Slate	14
Coal (Upper Kittanning?)	5
Slate	37
Coal (Middle Kittanning?)	8
Lime	20
Slate	25
Sand	45
Black lime	10
Slate	18
Sand	30
Slate	12
Total	324

Sandstones in the Allegheny formation.—The principal sandstone bed recorded by the drillers in the Allegheny formation is the Gas sand, which occurs about the middle of the formation. According to the well records it is variable in position, but in general it seems to correspond to the Kittanning sandstone, which lies between the Upper and Lower Kittanning coals. Between the Vanport limestone and the bottom of the formation, according to the records of many wells, there is another sandstone bed, which is correlated with the Clarion sandstone. A third bed, recorded near the top of the formation, probably corresponds with the Freeport, or perhaps in some wells with the Butler sandstone.

POTTSVILLE FORMATION.

Position.—The Pottsville is the lowest formation in the Pennsylvanian series. It occurs directly beneath the Allegheny formation, and at most places lies unconformably on the Mauch Chunk formation. In some areas, however, it lies directly on the Pocono (Big Injun) sandstone. It is the Salt sand of the well drillers.

Character and thickness.—In portions of Pennsylvania where it is exposed the Pottsville consists of two or more very massive and frequently conglomeratic sandstones, separated at some places by thin shales carrying fire clay and coal beds. As recorded in wells in the Amity quadrangle the formation generally is a sandstone ranging in thickness from 60 to 170 feet. In places it is double, its two sandstone members inclosing a bed of shale 10 to 30 feet thick. The two sandstone members seem to correspond to the Homewood and Connoquenessing sandstones and the intervening shales to the Mercer member of Beaver Valley. The formation is a great source of salt water, which is encountered in drilling.

MISSISSIPPIAN SERIES.

MAUCH CHUNK FORMATION.

Definition.—The Mauch Chunk formation may be defined as the rocks included between the Pottsville formation above and the Pocono (Big Injun) sandstone below. The lower part of the formation consists of a thick bed of limestone, known to drillers as the Big lime. This bed is identical with the Greenbrier limestone, which outcrops on Chestnut Ridge and Laurel Hill, farther east, and which was called by the Second Geological Survey the "Mountain limestone." It is the feather-edge of the Greenbrier formation of Virginia.

Character and thickness.—The Mauch Chunk formation shows a rather wide range in thickness in the Amity quadrangle, as may be seen from the sections given below. In many well records uncertainty exists as to its upper limit, but in the absence of definite information the top is regarded as coinciding with the bottom of the thick sandstone (Salt sand) overlying the red shale. The greatest thickness recorded is about 200 feet, in the J. L. Thompson and other wells in the Zollarsville field. From 50 to 90 feet of this is red shale, 50 to 100 feet at the bottom is limestone, and the rest is shale without distinctive color. The following records are typical of those in the Zollarsville field and vicinity:

Mauch Chunk formation reported in the A. C. Mitchell well, near Beallsville.

		Feet.
	Slate	29
	Red rock	10
	Slate	10
	Red rock	15
	Lime	11
	Slate	15
Greenbrier limestone.	Little lime	8
	Red lime	17
	White lime (Big lime)	45
	Total	160
	Big Injun sand.	

Mauch Chunk formation reported in the A. B. Crumrine well, borough of Deemston.

		Feet.
	Slate	10
	Lime	4
	Slate	6
	Lime	10
	Red rock	15
	Lime	6
	Red rock	24
	Slate	3
	Lime	12
	Slate	18
Greenbrier limestone.	Little lime	8
	Slate	5
	Big lime	50
	Total	171
	Big Injun sand.	

These sections show a fair agreement in the character of the formation, though it will be seen that there is considerable variation in occurrence of the red beds. No sections of the formation in the western and northwestern parts of the quadrangle can be given, on account of uncertainty as to its upper limit and the lack of complete records. In general the interval between the Salt and Big Injun sands becomes less in that direction. The thinning is illustrated by many of the well sections in the Burgettstown quadrangle, northwest of the Amity quadrangle. For instance, in the McKnight No. 3 well, in Chartiers Township, the interval from the top of the Salt sand to the top of the Big Injun is about 190 feet, but in wells in Smith Township it is in some places only 100 feet. Nowhere in this area are red shales reported in the interval. In two Caltergahn wells, in Chartiers Township, 35 and 103 feet of black shale are reported. In certain wells in the Burgettstown quadrangle the shale is entirely missing and the Salt sand rests directly upon the Big Injun.

Just where the Mauch Chunk formation disappears, whether the black shale between the Salt and Big Injun sands is Mauch Chunk or Pottsville, and whether all reports of the running together of the sands are correct are questions which can not yet be definitely answered.

Unconformity at top of Mauch Chunk formation.—The irregularity in thickness of this formation throughout western Pennsylvania is caused by an unconformity between the Pottsville and the Mauch Chunk formations, due to erosion after the deposition of the Mauch Chunk and before that of the Pottsville. This unconformity was first determined from evidence afforded by fossil plants. The Mauch Chunk is absent in the northern part of the State, where the massive sandstones of the Pottsville rest at many places upon almost equally heavy sandstones of the Pocono formation.

Greenbrier limestone.—From the well sections it will be seen that the limestone at the base of the Mauch Chunk is at many places double, and the division becomes more conspicuous toward the southwest. The upper bed is known to drillers as the Little lime and the lower bed as the Big lime, and they are at many places separated by a thin, soft shale into which the drill sinks rapidly after it has passed through the hard sandstone above. This shale breaks up in a peculiar manner into small pieces about the size of a lead pencil and tends to cave after the removal of the drill. For this reason the shale parting is known to drillers as the Pencil cave.

POCONO FORMATION.

General statement.—The Pocono is the lowest formation in the Mississippian series. Its top is coincident with the top of the Big Injun sand of the drillers, a bed that corresponds with the Burgoon sandstone of the Allegheny Front, from which it extends downward 300 to 900 feet, according to different authorities. Considerable doubt exists as to the true position of its base, as there is strong resemblance between its rocks and those of the Chemung formation at the top of the Devonian, and even where they outcrop it is difficult to draw any definite line of separation between them.

Base of Pocono.—In an exposure along the National Pike in the Uniontown quadrangle fossils were found only 2 feet below the bottom of the Burgoon (Big Injun) sandstone, which in that place had a thickness of 300 feet. The fossils are characteristic Chemung forms, and indicate that along Chestnut Ridge, in the southern part of the State, the Pocono may not be more than 300 feet thick. Accordingly, in that locality the top of the Chemung coincides approximately with the base of the Big Injun sand.

In the Latrobe and neighboring quadrangles a bed of red shale lies from 350 to 500 feet below the top of the Big Injun sand, and this bed has been correlated with the Patton red shale, which outcrops at Patton, on Redbank Creek, in Jefferson County. The Patton shale carries fossil plants of Pocono age. The Pocono formation in that region is therefore considered to be at least 400 to 500 feet thick.

The Pocono has been measured along the Pennsylvania Railroad east of Bennington, in Blair County, where it appears to be about 1000 feet thick. Fossils were collected at this place. Well sections at Johnstown and in Indiana and Armstrong counties show a mass of red shales 1000 feet below the top of the Burgoon sandstone, which were recognized as probably Catskill beds, and these shales and the beds between them and the top of the Burgoon have been correlated with beds in similar positions in the Bennington section. According to that correlation the post-Catskill beds in the Kittanning quadrangle are likewise of Pocono age. As these red beds lie not far below the Hundred-foot (Gantz and Fifty-foot) sand of that region, it follows that the Hundred-foot, Big Injun, and intervening sands are all to be included in the Pocono, and that the boundary between the Carboniferous and Devonian systems should be drawn at the top of the first red bed below the Hundred-foot sand.

In work on the Beaver quadrangle a large number of well sections have been compared and the horizons of the Hundred-foot sand and underlying red shale (Catskill) have been traced therefrom across Butler County to the Beaver quadrangle, where the beds have been found in similar relations. This would indicate that the upper limit of the Devonian is at the top of the first red shale below the Hundred-foot sand and that the Pocono in the Beaver quadrangle is 800 to 900 feet thick.

Between the Beaver and Amity quadrangles the strata seem to be more variable by reason of the dying out of the Mauch Chunk toward the northwest; but the top of the Big Injun sand is nearly everywhere definite, and this may be used as a datum surface for the comparison of intervals. From many well records in the Burgettstown quadrangle there seems to be little question that the Hundred-foot sand of the northern counties is equivalent to the Gantz and Fifty-foot of Washington and Greene. In the same way the Berea sand of Ohio, which lies there above the top of the Devonian, has been traced in wells across the Cadiz and Burgettstown quadrangles and found to occur at the same horizon as the Thirty-foot. Throughout this intervening region the sand occurs from 30 to 80 feet above a certain bed of red shale (Bedford?) which is useful in correlating.

Another argument in favor of the greater thickness of the Pocono is furnished by this red bed, which in the Beaver and Burgettstown quadrangles is frequently reported a short distance below the Thirty-foot sand. The same red shale has been recorded in a number of wells in the Amity quadrangle (see well sections, p. 16). It usually occupied a position about 50 to 75 feet above the Gantz sand and directly below the Thirty-foot. This bed has been traced by means of wells into the Beaver quadrangle, and from there by Mr. John F. Carll into Ohio (Rept. I[5], Second Geol. Survey Pennsylvania, 1890, pp. 93-96, Pl. V), and shown to be probably a part of the Bedford shale, of Mississippian age, though the correlation is not certain.

Further evidence regarding the base of the Pocono is furnished by a group of red shale beds similar to those called Catskill or sub-Blairsville in the Latrobe and Kittanning quadrangles. This group occurs in the Amity in all the detailed well sections which have penetrated that horizon. It is shown graphically on the columnar section sheet.

Thus, in approaching the quadrangle by tracings from various directions the conclusions do not agree. When traced from the Uniontown quadrangle there seems to be little question that the Pocono formation as a whole is equivalent to the Big Injun sand. When traced from the north and west the formation seems to be about three times as thick, and includes the Thirty-foot, Gantz, and Fifty-foot sands; and correlations of the Catskill or sub-Blairsville beds in the Latrobe quadrangle agree with this view.

From the above consideration it seems more probably correct to include the Gantz and Fifty-foot sands in the Pocono; and the base of the Carboniferous is accordingly drawn at the top of the group of red shales (Catskill) between the Fifty-foot and Bayard sands. It is probable that the discrepancies in estimating the thickness of the formation are due to indefiniteness of the division plane between the Devonian and Carboniferous rocks rather than to incorrectness in observations or to actual variation in the thickness of the Pocono formation.

Character and thickness.—Assuming the boundary defined above to be correct, the average thickness of the Pocono formation in the wells where its red shale base can be determined is 875 feet. One of the best sections of the Pocono is that of the J. L. Thompson No. 4 well, given below:

Pocono formation reported in J. L. Thompson No. 4 well, borough of Deemston.

	Feet.
Big Injun sand	60
Break	12
Bottom portion (Big Injun sand)	200
Slate	40
Squaw sand	130
Slate and shells	130
Thirty-foot sand	60
Red rock	10
Slate and shells	50
Gantz sand	20
Slate	20
Fifty-foot sand	25
Slate and shells	15
Sand	20
Slate and sand shells	40
Sand	10
Slate and shells	20
Total	862

Red shale (Catskill).

Sandstones of the Pocono formation.—This formation contains five principal sandstone horizons—the Big Injun, Squaw, Thirty-foot, Gantz, and Fifty-foot sands. The most important of these geologically is the Big Injun, Mountain, or Manifold sand, as it is variously called. In portions of Pennsylvania where it outcrops it now goes by the name Burgoon sandstone, from Burgoon Run, near Kittanning Point, on the Allegheny Front. In Washington County this sandstone as reported by the drillers averages 300 feet thick and is very persistent. Sometimes it contains a break of shale 0 to 20 feet in thickness and one-third of the distance from the top of the sand. The break has been reported as typical in the J. L. Thompson wells in the borough of Deemston.

In this region the top of the Big Injun sand is always in contact with the Greenbrier limestone and therefore affords a perfectly definite and very convenient datum for well drillers. The interval from the Pittsburg coal to the top of this sand varies from 1115 feet in the Culbertson well at Washington to 1292 feet in the Burkehammer well near Deemston. In general this interval thickens toward the southeast, owing largely to the increased thickness of the Mauch Chunk in that direction. The following table gives the general measurements in various parts of the quadrangle.

Thickness of interval between top of Pittsburg coal and top of Big Injun (Burgoon) sand.

Locality.	Least interval.	Greatest interval.	Average interval.	Number of records averaged.
	Feet.	Feet.	Feet.	
Washington field and vicinity	1100	1160	1139	16
North Franklin Township	1200	1225	1212	2
Sunset			1148	1
Lone Pine			1180	1
Fonner field	1171	1190	1179	3
Northwestern West Bethlehem Township	1135	1175	1155	2
Zollarsville field	1200	1286	1239	55
West Pike Run Township	1234	1245	1239	2
Somerset Township	1105	1217	1176	5
Nottingham Townhsip			1188	1
Hackett			1195	1
General average			1186	

At an interval from 20 to 50 feet below the bottom of the Big Injun occurs a rather persistent bed known to drillers as the Squaw sand. It is at many places 100 feet thick and in the J. L. Thompson wells thickens up to 130 feet. It is, however, irregular in occurrence, and in the Rogersville quadrangle is not often recognized.

Below the Squaw sand and 450 to 650 feet below the top of the Big Injun lies the Thirty-foot sand. The name Thirty-foot means nothing, however, in regard to its thickness, which is far less than that in some places and in others reaches 170 feet. The sand occurs rather irregularly and is not always present, but may be considered as corresponding approximately with the Berea sand of the Burgettstown and Beaver regions, to the Butler gas sand of northern Pennsylvania, and to the Berea sandstone of Ohio. The interval from the top of this sand to the Pittsburg coal varies from 1560 to 1865 feet, as shown in the following table:

Thickness of interval between top of Pittsburg coal and top of Thirty-foot sand.

Locality.	Least interval.	Greatest interval.	Average interval.	Number of records averaged.
	Feet.	Feet.	Feet.	
Washington field and vicinity	1560	1654	1623	5
Lone Pine			1752	1
Fonner field			1766	1
Northwestern West Bethlehem Township			1758	1
Zollarsville field	1713	1865	1808	25
Somerset Township			1805	1
Hackett			1850	1
General average			1766	

The Gantz and Fifty-foot sands form a very prominent oil horizon, made famous by many bygone gushers in the Washington field. These sands are rather persistent and are recognizable in most of the well records. Toward the northwest they run together and are known as the Hundred-foot sand.

In position the Gantz sand ranges from 60 to 160 feet below the top of the Thirty-foot sand. The Gantz and Fifty-foot sands are supposed to be equivalent to the First sand of Oil Creek. The interval from the Gantz sand to the Pittsburg coal is more variable than that between any two persistent sands. Within the quadrangle it varies from 1790 feet in the Ross well in Chartiers Township to 1985 in one of the J. L. Thompson wells in the Zollarsville field. As with the upper sands, there is a gradual thickening of the interval from the northwest toward the southeast, as shown by figures in the various districts. The variation doubtless is due to the unconformity at the base of the Pottsville and the consequent increase in thickness of the Mauch Chunk formation toward the southeast. The limiting and average thicknesses are given in the following table:

Thickness of interval between top of Pittsburg coal and top of Gantz sand.

Location.	Least interval.	Greatest interval.	Average interval.	Number of records averaged.
	Feet.	Feet.	Feet.	
Washington field and vicinity	1790	1863	1829	53
North and South Franklin townships	1820	1880	1850	3
Sunset			1863	1
Lone Pine			1906	1
Fonner field	1900	1929	1912	6
Northwestern West Bethlehem Township	1877	1892	1887	4
Zollarsville field	1886	1985	1929	36
Somerset Township	1907	1940	1919	3
Nottingham Township			1925	1
Hackett			1967	1
General average			1899	

In its interval to the top of the Big Injun sand the Gantz varies from 574 to 751 feet, the extremes being, respectively, the well on the Harding lot at Washington and the Gamble well near Kammerer. In single instances considerably greater intervals occur, but those are believed to be due either to poor records or to a mistaken correlation of the sands. The variation is shown by the table given below:

Thickness of interval between top of Big Injun sand and top of Gantz sand.

Location.	Least interval.	Greatest interval.	Average interval.	Number of records averaged.
	Feet.	Feet.	Feet.	
Washington field and vicinity	574	710	674	13
North Franklin Township			595	1
Sunset			717	1
Lone Pine			726	1
Fonner field	725	740	735	3
Northwestern West Bethlehem Township	719	749	733	2
Zollarsville field	630	722	683	33
Somerset Township	714	751	733	3
Nottingham Township			737	1
Hackett			722	1
General average			711	

On comparing these groups of intervals, the most noticeable feature is that the second group, unlike the first, does not show any general thickening toward the southeast. This fact is in harmony with the view that the thickening of the strata is due largely to the unconformity at the top of the Mauch Chunk formation. The thickness of the Gantz sand varies from 10 to 60 feet and that of the Fifty-foot sand from 0 to 100 feet. Where they are developed separately they may occur as much as 80 feet apart, the break being greatest toward the southeast. The interval from the Pittsburg coal to the Fifty-foot sand varies from 1807 feet in the Matthew Linn well at Washington to 2057 feet in the Burkehammer well in the borough of Deemston, as shown in the following table:

Thickness of interval between top of Pittsburg coal and top of Fifty-foot sand.

Location.	Least interval.	Greatest interval.	Average interval.	Number of records averaged.
	Feet.	Feet.	Feet.	
Washington field and vicinity	1817	1930	1879	32
North and South Franklin townships	1890	1902	1891	3
Sunset			1913	1
Lone Pine			1940	1
Fonner field			1941	1
Northwestern West Bethlehem Township	1912	1927	1921	4
Zollarsville field	1940	2052	2009	39
Somerset Township	1940	1975	1958	2
Nottingham Township			1957	1
General average			1934	

The bottom of the Fifty-foot sand is usually not over 50 feet above the top of the group of red shales (which are considered the Catskill beds) at the top of the Devonian system. The Fifty-foot

sand is therefore probably the lowest sand in the Carboniferous system.

Red shale (Bedford?).—The red shale already mentioned as occurring between the Thirty-foot and Gantz sands and probably representing the Bedford shale of Ohio is recorded in many wells in the Burgettstown quadrangle, but it is given in only five wells in the Amity quadrangle. This may be due to the absence of the red shale, but it seems more likely to be due to the scarcity of complete records. In the J. M. Miller well, in West Pike Run Township, it is 5 feet thick; in the Luse well, near Beallsville, it is 20 feet thick; and in the J. L. Thompson wells Nos. 3 and 4 it is 10 feet thick. In the Gantz well it is present as 8 feet of reddish sand. In some wells it occurs directly below the Thirty-foot sand.

This red shale deserves more attention than it has hitherto received from geologists. As has been said, it is generally present beneath the Burgettstown quadrangle and has been noted in Beaver County. Toward the southeast, however, it is not known. Mr. John F. Carll (Rept. I[5], Second Geol. Survey Pennsylvania, 1890, pp. 93-96, Pl. V) has published a map showing the distribution of this bed, and has traced it by means of well records under Forest County, southern Venango County, and western Butler County in Pennsylvania, and in eastern Ohio as far west as its outcrop along the Cincinnati anticline. Since Carll's report was published considerable drilling has been done in the Amity and Burgettstown quadrangles and the red shale has been found some distance outside its southeastern boundary as mapped by him. It is possible that in the Amity quadrangle it may occur only in patches. In eastern Greene County it is not present, but in western Greene it is found in some places. Where best developed in western Pennsylvania its thickness runs from 80 to 120 feet. The application of the name Bedford to this red bed is questioned on account of the uncertainty in correlation with surface outcrops, but it is believed to represent the Bedford shale of Ohio.

DEVONIAN SYSTEM.

CHEMUNG FORMATION.

General character.—Throughout the Amity quadrangle the Devonian rocks lie far below the surface. As has been seen, the top of this system is very indefinite, but is provisionally regarded as occurring at the top of the first red shale below the Fifty-foot sand.

The Devonian rocks have been pierced by the drill to a depth of over 1000 feet. The strata thus far discovered seem to belong entirely to the Chemung formation. The deepest complete record is that of the A. C. Mitchell well, in West Pike Run Township. In this record the position of the top of the Devonian is rather doubtful, as the red beds are less conspicuous than in some of the neighboring wells. All beds up to the top of the Fifty-foot sand are therefore given in the accompanying partial section of this well. To be in harmony with other wells the top of the Devonian should be placed approximately 30 to 50 feet below the bottom of this sand.

Partial section of rocks penetrated by the A. C. Mitchell well, in West Pike Run Township.

		Feet.
Probably Carboniferous.	Sand, Fifty-foot	85
	Slate	5
	Sand	10
	Slate	14
	Sand	4
	Slate	14
	Sand	13
	Shells	10
Catskill.	Red rock	5
	Shells	20
	Sand, Stray	24
	Red rock	21
	Sand, Gordon	60
	Red rock	55
	Shells	30
	Slate	10
	Sand	15
	Slate	5
	Sand, Bayard	65
	Slate	27
	Shells and slate	38
	Sand, Elizabeth	6
	Slate	169
	Shells	167
	Total	872

One of the best known sections of the Devonian rocks is furnished by the J. L. Thompson No. 3 well, and this is given here for comparison.

Amity.

Section of Chemung formation reported in the J. L. Thompson No. 3 well, borough of Deemston.

		Feet.
Catskill.	Red rock	20
	Sand	20
	Slate and shells	30
	Red rock	10
	Slate and shells	55
	Red rock	55
	Dark slate	10
	Red rock	20
	Sand	25
	Slate and shells	52
	Sand, Bayard	15
	Slate and shells	69
	Sand, Elizabeth	12
	Slate	10
	Total	403

Catskill (sub-Blairsville) member.—In all the complete records which penetrate this formation in the quadrangle an interval of 100 to 300 feet near the top of the Chemung is occupied by two to five beds of red shale, separated by sandstones, shales, and "shelly" layers. Similar red beds, somewhat thicker, but occupying approximately the same interval—900 to 1100 feet below the top of the Big Injun—occur in the Latrobe quadrangle and vicinity, and have been named the sub-Blairsville member of the Chemung, for the reason that the wells in which they are found lie near the town of Blairsville, Indiana County. They are believed to be the westward feathering out of the Catskill formation, which in eastern Pennsylvania is several hundred feet thick, but which in this part of the State has thinned down and is dovetailed into the upper part of the Chemung.

The general character of the group containing the red beds can be seen from the well sections, p. 16. The individual beds vary from 10 to 60 feet in thickness, and the total amount of red in any one section usually foots up between 75 and 150 feet. In the Amity quadrangle the Catskill beds dovetail into the upper part of the Chemung formation proper. This fact explains the great variation in the red beds in different sections and shows why they do not always occur precisely at the top of the formation.

Sandstones of the Chemung formation.—Between the various layers of these red beds several oil and gas horizons, notably the Gordon, Fourth, and Fifth sands, are frequently reported. The occurrence of these sands between irregular red beds, which come and go and in some places thicken to the exclusion of the sands, indicates the nonpersistence of most of these sands in this region. It is probable that toward the northwest the Catskill beds become still more broken up, and that the Gordon and other sands are more persistent in that direction, as reported by drillers.

In the Pocono formation most of the sands commonly recognized by drillers seem to be regular in their occurrence and fairly persistent. As the drill descends into the underlying rocks, however, it penetrates beds of more and more variable nature; and even the most important oil and gas sands are encountered with much less regularity than those in the higher formations. These variations are so great that it seems probable that in the Chemung formation the sandstone beds are not persistent members, underlying the whole surface, but have somewhat the nature of lentils, similar to the sandstone lentils outcropping at the surface.

The principal sandstones recognized by the drillers in the Chemung formation are (from the top downward) Nineveh Thirty-foot, Gordon Stray, Gordon, Fourth, Fifth, Bayard, and Elizabeth sands. Of these the Bayard and Elizabeth are the only ones which are at all persistent, and they occur below the variable Catskill beds.

Near the top of the red beds a sand is sometimes reported by the name of Gordon Stray. Beds at about this horizon are also frequently designated Nineveh Thirty-foot, or simply Thirty-foot, Nineveh, or Stray. There is considerable doubt whether this horizon should properly be included in the Chemung formation or in the Carboniferous, but as thin red shales have been reported directly above it, the Gordon Stray is here considered one of the lentils in the Catskill beds. It is not supposed to be at all persistent.

The Gordon sand is somewhat more important, especially in the vicinity of Washington, where it has produced considerable oil and seems to be rather persistent. In the southeastern part of the quadrangle it is, like the Gordon Stray, dovetailed between variable red beds, and in places seems to disappear. The following sections of the Catskill and directly overlying beds are given to show something of the nature of the variations.

Partial section reported in Kountz No. 1 well, South Strabane Township.

		Feet.
Pocono ?	Sand, Gantz	104
	Slate	81
Catskill.	Red rock	10
	Sand and slate	10
	Slate	16
	Sand, Gordon	60
	Slate	19
	Sand	20
	Slate	3
	Total	323

Partial section reported in William Fonner No. 2 well, Morris Township, Greene County.

		Feet.
Pocono ?	Sand, Gantz	29
	Slate	2
	Sand, Fifty-foot	35
	Black slate	11
Catskill.	Red sand	15
	Slate	53
	Red rock	5
	Gray sand shales	15
	Pencil cave*	5
	Sand, Gordon	50
	Black slate	80
	Sand and shells	35
	Total	335

*This is not the usual "Pencil cave" horizon of the drillers, which occurs in the Mauch Chunk formation.

In thickness the Gordon sand ranges from 10 to 50 feet. The interval between it and the Pittsburg coal is variable in different parts of the quadrangle, as shown by the following table:

Thickness of interval from top of Pittsburg coal to top of Gordon sand.

Location.	Least interval.	Greatest interval.	Average interval.	Number of records averaged.
	Feet.	*Feet.*	*Feet.*	
Washington field and vicinity	2029	2129	2085	19
North Franklin Township	2070	2078	2074	4
Sunset	.....	.....	2123	1
Fonner field	.....	.....	2080	1
Northwestern West Bethlehem Township	2070	2095	2083	2
Zollarsville field	2110	2250	2188	25
Somerset Township	2160	2164	2162	2
General average	.....	.....	2114	

The Fourth sand, like the Gordon, is dovetailed into the Catskill beds about 40 to 140 feet below the top of the Gordon. Like the latter, it is irregular, and is probably not persistent as a definite bed. In thickness it ranges from 10 to 50 feet. The interval between it and the Pittsburg coal is as follows:

Thickness of interval from top of Pittsburg coal to top of Fourth sand.

Location.	Least interval.	Greatest interval.	Average interval.	Number of records averaged.
	Feet.	*Feet.*	*Feet.*	
Washington field and vicinity	2101	2160	2137	8
North and South Franklin townships	2121	2171	2145	4
Sunset	.....	.....	2208	1
Northwestern West Bethlehem Township	2102	2130	2116	2
Zollarsville field	2220	2350	2258	16
General average	.....	.....	2173	

The Fifth sand lies within the limits of the Catskill beds, but seems to be more persistent than either the Stray, Gordon, or Fourth sand. It occurs near the lower limit of the Catskill and sometimes has no red shale below it. The position of this sand is 250 to 400 feet below the top of the Gantz, and it is reported in nearly all wells which are deep enough to reach it, except in the borough of Deemston and in East Bethlehem Township, where a considerable number of records fail to mention any Fifth sand. This sand varies in thickness from 10 to 50 feet. The thickness of the interval from the Pittsburg coal in various parts of the quadrangle is shown by the table in the next column.

In the Zollarsville field and vicinity a great many wells penetrate the Bayard sand, which is usually reported 50 to 150 feet below the top of the Fifth. In thickness it averages about 20 to 30 feet, occasionally footing up to as much as 50 feet. In the Zollarsville field the interval from this sand to the coal varies between 2337 and 2479 feet, averaging 2404 feet; in a well southeast of Munntown it is 2400 feet and in North Franklin Township 2231 feet. Most of the wells in the western and northwestern parts of the quadrangle are not deep enough to reach the Bayard sand, and nothing is known of it. In Morris Township several wells pass into the Elizabeth without reporting the Bayard, but it is reported in one well in North Franklin Township.

Thickness of interval from top of Pittsburg coal to top of Fifth sand.

Location.	Least interval.	Greatest interval.	Average interval.	Number of records averaged.
	Feet.	*Feet.*	*Feet.*	
Washington field and vicinity	2174	2234	2204	19
North and South Franklin townships	2181	2208	2198	6
Sunset	.....	.....	2273	1
Northwestern West Bethlehem Township	2180	2205	2189	3
Zollarsville field	2272	2409	2330	23
Somerset Township	.....	.....	2300	1
General average	.....	.....	2249	

The deepest persistent sand is the Elizabeth, which lies 50 to 150 feet below the top of the Bayard. Both the Elizabeth and Bayard sands are frequently recorded as the Sixth sand. In general the Elizabeth is supposed to be somewhat more persistent than the Bayard, being reported in nearly every well that reaches its horizon. It is likewise one of the thinnest sands, its thickness rarely exceeding 20 feet and being usually much less. In the Waynesburg quadrangle it has never been known to exceed 7 feet. Notwithstanding its great depth this sand has been penetrated by many wells in the Zollarsville field, where its depth below the Pittsburg coal ranges from 2470 to 2530 feet, with an average of 2499 feet. It is 2482 feet in a well north of Bentleyville, 2506 feet at Lone Pine, and 2400 feet in the Fonner field.

By comparison with the thickness of the interval between the Bayard sand and the coal, it will be noticed that the Elizabeth is much more constant. In the Deemston field the interval from the Elizabeth to the top of the Gantz sand runs from 528 to 620 feet, occasional records showing as much as 743 feet. The greater amounts are generally due to indefiniteness regarding the top of the Gantz sand.

The deepest well in the Amity quadrangle penetrates to a depth of 2664 feet below the Pittsburg coal, or about 650 to 700 feet below the Elizabeth sand, but few data are given concerning the beds in that interval.

Rocks that Outcrop in this Quadrangle.

The rocks exposed at the surface in this quadrangle are all of Carboniferous age. They belong chiefly to the Monongahela, Washington, and Greene formations, but in two localities a few feet of the underlying Conemaugh formation reaches the surface. From the highest to the lowest exposed horizon the vertical thickness of the strata is about 1200 feet, the highest point stratigraphically being on the hills in Morris Township, Greene County. The rocks are chiefly sandstones; limestones, and shales, but in the Monongahela and Washington formations several beds of coal occur. The general sequence of beds is shown on the columnar section sheet. The intervals between various strata generally reach their maximum thickness in the southeastern part of the quadrangle.

The Conemaugh formation, lying below the Pittsburg coal, is described in connection with the rocks that do not outcrop (pp. 2–3). The overlying rocks are here described from below upward, in the order of their deposition.

CARBONIFEROUS SYSTEM.

PENNSYLVANIAN SERIES.

MONONGAHELA FORMATION.

Definition.—The Monongahela formation extends upward from the bottom of the Pittsburg coal to the top of the Waynesburg coal, and in this quadrangle varies from 290 to 360 feet in thickness.

Distribution.—The whole of the formation is exposed in both the northeast and the northwest corners of the quadrangle. The formation outcrops mostly near the northern and eastern edges of the territory, but reaches the surface also for about a

mile on Little Tenmile Creek near Lone Pine. In the northwest corner of the quadrangle it covers the entire area west and north of Chartiers Creek except small tracts along the main valley, where it has been eroded. Southeast of Chartiers Creek its outcrop forms a strip over a mile wide on the hillsides parallel with the creek. In the valley of Little Chartiers Creek it extends from the edge of the quadrangle as far south as Wylandville, outcropping up the side valleys for a distance of 2 to 3 miles on each side of the creek. Nearly all of the area north of the Williamsport Pike and east of a line drawn northward along Snipe Run is covered by rocks of this formation. A small area along Peters Creek consists of Conemaugh rocks. The Monongahela formation outcrops on the several branches of Pigeon Creek as far up as Emery and Vanceville, and nearly to Three and Four. It also includes the greater portion of the area southeast of Zollarsville and Spring Hill.

General character.—This formation consists of shales, limestones, and occasional sandstones, and contains at least three valuable coal beds. The best recorded section in Washington County was measured by Dr. I. C. White (Bull. U. S. Geol. Survey No. 65, p. 45) near West Brownsville, and is as follows:

Section of Monongahela formation near West Brownsville, Pa.

	Feet.	Inches.
Coal, Waynesburg (coal 0′ 10″; clay 0′ 3″; coal 2′ 6″)	3	7
Shale and sandstone	45	0
Bituminous shale, Little Waynesburg coal	1	6
Limestone, Waynesburg	10	0
Sandstone, shaly	40	0
Coal, Uniontown	3	0
Shale and sandstone	28	0
Limestone with thin shales	88	0
Coal, Sewickley, blossom	0	0
Sandstone, shaly	32	0
Limestone	30	0
Shales	20	0
Coal, Redstone	1	0
Sandstone and shales	45	0
Coal, Pittsburg, roof coal (coal 0′ 3″; clay 0′ 3″; coal 1′ 0″; clay 1′ 0″)	2	6
Coal, Pittsburg, main bench	7	0
Total	356	7

Record of diamond-drill hole near Bissell.

		Thickness. Ft.	Thickness. In.	Depth. Ft.
	Rocks of Washington formation			154
	Coal, Waynesburg	6	0	160
	Sandstone	14	0	174
	Limestone	11	0	185
	Limestone	5	0	190
	Blue shale	1	0	191
Benwood limestone.	Limestone	6	0	197
	Blue shale	12	0	209
	Sand shale	20	0	229
	Limestone	5	0	234
	Light shale	15	0	249
	Limestone	7	0	256
	Light shale	10	0	266
	Sandstone	14	0	280
	Sandstone	2	0	282
	Limestone	2	0	284
	Light shale	5	0	289
	Limestone	9	0	298
	Light shale	7	0	305
	Limestone	12	0	317
	Limestone	27	0	344
	Gray shale	4	0	348
	Sandy shale	8	0	356
	Gray sandstone	9	0	365
	Light shale	4	0	369
	Dark sandy shale	27	0	396
	Limestone	32	0	428
	Light shale	4	0	432
	Limestone	4	0	436
	Light shale	9	0	445
	Sandy shale	19	0	464
	Gray sandstone	7	0	471
	Black slate	2	0	473
	Coal	1	4	.....
	Black slate	1	2	.....
	Black slate	0	4	.....
	Coal	0	4	.....
	Black slate	1	4	.....
Pittsburg coal.	Fire clay	0	5	.....
	Black slate	0	9	.....
	Coal	0	6	.....
	Parting, slate	1	3	.....
	Coal	5	10	.....
	Bottom slate	0	11	487
	Thickness of Monongahela formation	333	2	
	Limestone.	3	0	
	Total depth of drill hole	490	2	

On the Moses Smith farm, in Amwell Township, one-fourth mile northwest of Bissell, a diamond drill was once sunk to the Pittsburg coal and a record of the Monongahela rocks penetrated by it is given in the preceding column for comparison.

From these sections it will be seen that the rocks of the Monongahela formation are predominantly limestone. In the West Brownsville section 140 feet of limestone occurs, and in the Moses Smith drill hole 120 feet. Along the various roads crossing the outcrop of the formation the limestones are very conspicuous by their débris. The formation also contains much interbedded shale, some sandstone, and at least four coal beds.

Thickness.—The principal evidence as to the thickness of the Monongahela formation comes from records of oil and gas wells. These show that the formation is not at all uniform in thickness. Following is a list of wells giving the measurements between the bottom of the Pittsburg coal and the top of the Waynesburg coal in various parts of the quadrangle:

Thickness of Monongahela formation given by well records.

Name of well.	Township.	Thickness. Feet.
Baker	Amwell	345
Moses Smith (diamond drill)	do	336
Mrs. A. L. Hawkins No. 2	Borough of Beallsville	340
Eaton Luse heirs No. 1	do	326
N. T. Clark No. 1	Borough of Deemston	339
Mrs. A. L. Hawkins No. 3	do	340
L. V. Martindale No. 2	do	338
J. L. Thompson No. 1	do	348
J. L. Thompson No. 2	do	366
J. L. Thompson No. 3	do	345
J. L. Thompson No. 4	do	347
J. L. Thompson No. 5	do	337
Blakely No. 1	do	363
Bristor Bros. No. 3	Morris, Greene Co.	353
Elmas Carey No. 1	Morris, Washington Co.	320
Meloy No. 1	do	321
J. C. Mounts	North Franklin	300
Washington Floral Company.	South Strabane	352
N. T. Clark No. 2	West Bethlehem	340
J. C. Martin No. 1	do	337
Joseph Ross No. 1	do	323
John C. Sargent No. 2	do	348
Thompson & Seaman Coal Co. No. 1.	do	350
S. F. Scott No. 1	West Pike Run	308
Average thickness		340

By comparison of these records it will be seen that while the lower averages occur in a general way more abundantly in the western portion of the quadrangle, there are also points in West Pike Run and West Bethlehem townships and elsewhere at which the thicknesses are but little over 300 feet, and thicknesses of 345 feet and 352 feet are reported in western Amwell and in South Strabane. In general, however, the Monongahela formation in southwestern Pennsylvania grows thinner toward the west and north. This can be seen by comparison of measurements in Fayette County, some of which reach 400 feet, with those in this region and northwestern Washington County. In the northern part of this quadrangle the interval seems to be rather low, and may average less than 300 feet.

Pittsburg coal.—The coal at the base of the Monongahela formation—the Pittsburg coal—is the thickest seam in western Pennsylvania and the most valuable in the bituminous coal field. Over most of this quadrangle it is deeply buried below the surface, but it outcrops in two small areas on Chartiers and Peters creeks. The outcrop follows both sides of Peters Creek below Venetia and of Chartiers Creek below McGovern, and also reaches the surface at Meadowlands. West of Chartiers Creek it extends nearly a mile up the side valleys between Meadowlands and Houston.

The Pittsburg coal varies from 6 to 13 feet in thickness. In the roads that cross it its outcrop appears as a black smut several feet wide, being more conspicuous than any other coal in the region. Little is known of its quality in the areas in which it is deeply buried, but it is reported in nearly every well, and is believed to be present in all. Owing to its great importance it will undoubtedly be reached in time in this quadrangle by numerous mine shafts.

Pittsburg sandstone.—The name Pittsburg sandstone was given by Prof. H. D. Rogers to a bed of sandstone, 0 to 70 feet in thickness, which at many places overlies the Pittsburg coal. Where best developed it is coarse and friable. This sandstone can be seen at several points on Chartiers and Peters creeks, but is there poorly developed. On Fishpot Run, at the edge of the quadrangle near its southeast corner, the sandstone is well exposed in cliffs that rise above the Pittsburg coal to a height of nearly 100 feet. At this place the sandstone occupies almost the entire interval between the Pittsburg coal and the Sewickley coal. In some localities the sandstone is separated from the Pittsburg coal by shale, but in others it rests directly upon the coal.

Redstone coal.—The Redstone coal is known at a few points in the northeast section of the quadrangle, where it occurs at an interval ranging from 20 to 80 feet above the Pittsburg coal bed. It is also present at a few places in other parts of the quadrangle, but is believed to be cut out in some localities by the Pittsburg sandstone. It is of some value, but has been little prospected. Its thickness reaches 4 feet at some places.

Fishpot limestone.—Beneath the Sewickley coal lies a bed of limestone which originally was named by Stevenson (Rept. K, Second Geol. Survey Pennsylvania, 1876, p. 67) the Fishpot limestone, from Fishpot Run, in the southeast corner of Washington County, where it occurs. The term Sewickley has since been applied to this limestone, but as the former name has the right of priority it is the one used here. The limestone has been observed underneath the coal on Fishpot Run and Mingo Creek.

The Enterprise mine shaft, 1½ miles north of Washington, records 30 feet of limestone directly below the Sewickley coal. The section of this shaft is as follows (Stevenson, Rept. K, Second Geol. Survey Pennsylvania, 1876, p. 240):

Section of Enterprise shaft, 1½ miles north of Washington.

	Ft.	In.
Soil	4	0
Benwood limestone	45	0
Sewickley coal	0	4
Fishpot limestone	30	0
Shale	45	0
Redstone coal	3	0
Pittsburg sandstone	20	0
Shale	1	0
Pittsburg coal (roof division 2′ 0″; clay 1′ 0″; lower division 5′ 10″)	8	10
Total	157	2

Thin sandstone beds frequently occur in the interval between the Redstone and Sewickley coals.

Sewickley coal.—The Sewickley coal is the bed known to drillers as the Mapletown seam, named from Mapletown, in southeastern Greene County. It occurs rather persistently beneath this quadrangle, its horizon being from 90 to 150 feet above the Pittsburg coal. It is at many places several feet in thickness and has been opened at a few points in the valley of Mingo Creek.

Benwood limestone.—In the reports of the Second Geological Survey the Benwood limestone was called the "Great limestone," but in accordance with the system of using geographic terms to designate formations it was later named Benwood limestone by M. R. Campbell, at the suggestion of I. C. White, the name being taken from Benwood, near Wheeling, W. Va.

The detailed section of the Benwood varies considerably, but it always consists of a lower and an upper member, separated by a considerable thickness of shale, both divisions being in turn divided into a number of layers of limestone separated by thin beds of shale. The Benwood limestone occurs between the Sewickley and Uniontown coal beds, and its base is from 100 to 130 feet above the Pittsburg seam.

The Benwood limestone, with its interbedded shales, has a maximum thickness of 160 feet. It is well exposed at a number of points in the Amity quadrangle, the exposures in several ravines northeast of Kammerer, in eastern Nottingham Township, and in Union Township off the edge of the quadrangle being especially good. At a point on a small run on the boundary of the quadrangle in Union Township the stream makes a perpendicular fall of 30 feet over one of the limestone strata, the fall being due to the hardness of the bed of limestone and the consequent undercutting of 25 feet of soft interstratified shale. Similar falls, of less height, occur on several other small streams in this vicinity. One of the best measured sections of this limestone is at the mouth of Brush Run, Peters Township, in the Carnegie quadrangle (Stevenson, Rept. K, Second Geol. Survey Pennsylvania, 1876, p. 226).

Section of Benwood limestone at mouth of Brush Run, Peters Township.

	Ft.	In.
Limestone	1	0
Sandstone	5	0
Limestone, brecciated	2	6
Concealed	15	0
Limestone	4	6
Sandstone	14	0
Concealed	15	0
Shale	5	0
Limestone	12	0
Shale	12	0
Limestone	50	0
Sandy shale, to creek	15	0
Total	151	0

In general the Benwood limestone is considerably broken up by shale, but the hard 30- to 50-foot layer near the bottom seems to be very persistent. The character of the limestone is variable. The upper part frequently contains 6 to 15 feet of an impure brownish to buff-colored limestone. The lower part is generally a hard, pure limestone of light-brown to gray colors.

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

Uniontown coal.—The Uniontown coal is a thin bed above the Benwood limestone and from 40 to 80 feet below the Waynesburg coal. It is not always present, and is usually unimportant, but it can be seen in blossom at a number of points in the northeast corner of the quadrangle.

Uniontown sandstone.—Above the Uniontown coal is a somewhat variable shaly to flaggy sandstone—the Uniontown sandstone. Usually it is not prominent, but in certain localities it is of such a character as to be easily mistaken for the Waynesburg member. In this quadrangle the sandstone is so inconspicuous that there is little danger of confusion.

Waynesburg limestone.—Above the Uniontown sandstone and 40 feet or less below the Waynesburg coal is a limestone 4 to 20 feet in thickness, which was named by Stevenson the Waynesburg limestone (Rept. K², pp. 35–36). Usually it is of a dark-gray color, and its outcrop can be seen at many points in the northeastern and southeastern parts of the quadrangle.

Little Waynesburg coal.—At many places in various parts of the quadrangle a slight coal blossom was seen from 10 to 20 feet below the Waynesburg coal. This bed is thin and unimportant, but has been called by Stevenson the Little Waynesburg coal (Rept. K², p. 34).

Waynesburg coal.—The topmost bed in the Monongahela formation is the Waynesburg coal, which is of considerable importance, partly from its economic value, but largely on account of its value as a key bed in determining the geologic structure and the depth of important beds below the surface. Throughout the eastern and southern parts of the quadrangle it is well developed, ranging in thickness from 3 to 7 feet. In the northwestern part it is nearly always thin and at some points appears to be missing.

Fossils of the Monongahela formation.—Very few fossils have been found in the Monongahela formation. According to Mr. David White it appears to be characterized by a great abundance of plants of the types of *Neuropteris scheuchzeri* and *Neuropteris ovata;* by pecopterids of the large pinnuled group, and by odontopterids of the type of *Odontopteris brardii.* In this formation the lepidophytes are waning, the genus *Lepidodendron* having nearly disappeared, and the genus *Sigillaria* being represented by the *S. brardii* group. The limestones which comprise so much of the formation show no marine fossils, and the fauna of the whole formation seems to be restricted to freshwater types.

PERMIAN SERIES.

DUNKARD GROUP.

Definition.—The Dunkard group includes all rocks from the top of the Waynesburg coal to the uppermost beds in the Appalachian basin. The rocks were formerly known as the "Upper Barren measures."

General character and thickness.—In the Amity quadrangle the greatest thickness of Dunkard beds,

about 750 feet, is in Morris Township, Greene County, in the extreme southwest corner of the quadrangle. The rocks dip toward the southwest and reach their maximum depth below the surface about the headwaters of Dunkard Creek, near the boundary between Pennsylvania and West Virginia. In that region some of the hills reach altitudes of at least 1100 to 1200 feet above the base of the group. How many feet of strata have been removed by erosion is not known, but the missing thickness is believed to amount to at least several hundred feet.

The rocks in the Dunkard group vary greatly in character in different regions. In general they consist of shales and shaly sandstones, but comprise also a few more or less persistent beds of rather massive sandstone and, in their lower portion, several important limestones. This lower part contains also several coal beds, but at present they are of little economic value. In Greene County the Dunkard carries many beds of red shale. These increase in importance toward the southwest and are most prominent in West Virginia, but toward Washington County they disappear, giving way to the ordinary drab or yellowish shales. Traces of the red shales can be seen on some of the highest hills in the southwestern part of the quadrangle.

Divisions of the Dunkard.—The Dunkard group was formerly considered a formation, like the Conemaugh and Monongahela. In some regions it is still necessary to map it as such, on account of the absence of any recognizable bed which can be traced for long distances and used as a dividing line. In this area, however, the lower portion of the group is much more calcareous than the upper portion and contains several minor coal beds, and is therefore considered as a formation distinct from the overlying strata. The line of subdivision is the top of the Upper Washington limestone, the most persistent and easily recognizable member of the group. The portion of the Dunkard group below this is known as the Washington formation, and that above as the Greene formation, from the respective counties in which they are typically developed. These names were first used by Stevenson (Rept. K, Second Geol. Survey Pennsylvania, 1876), who defines the "Washington County group" as the portion of the Dunkard below the top of the Upper Washington limestone, and the "Greene County group" as including all rocks above that limestone.

The only discrepancy between Stevenson's use of these names and their present use is that Stevenson defined the lower limit of the Dunkard as occurring at the top of the Waynesburg sandstone. In all subsequent publications the division line between the Monongahela and Dunkard has been considered as the top of the Waynesburg coal.

Fossils and age of the Dunkard group.—The fossils of the Dunkard consist of fossil plants in large numbers and ostracods with occasional occurrences of pelecypods and fish fragments. The flora is characterized by the abundant occurrence of such genera as *Neuropteris, Pecopteris, Sphenopteris, Sphenophyllum,* etc., with which are mingled representatives of *Callipteris* and *Equisetites,* together with late types of the common Pennsylvanian genera.

The precise age of the Dunkard group as a whole is still questioned by certain geologists. By some it is considered as simply an upper formation of the Pennsylvanian series. Most, however, now believe the deposits to be Permian in age, and they are so considered here. The basis for this conclusion lies largely in the discovery of many species of fossils which have been identified by W. M. Fontaine and by David White as characteristic of the Permian. The list of species given by David White is as follows (West Virginia Geol. Survey, vol. 2, 1903, p. 120):

Callipteris conferta Sternb.
Callipteris lyratifolia Goepp. var. coriacea (F. and I. C. W.)
Callipteris curretiensis Zeill.
Pecopteris fœminæformis (Schloth.) Sterz. var. diplazioides Zeill.
Pecopteris germari Weiss.
Alethopteris gigas Gutb.
Odontopteris obtusiloba Naum.
Caulopteris gigantea (F. and I. C. W.)
Equisetites rugosus Schimp.
Sphenophyllum fontaineanum S. A. Miller.
Sphenophyllum tenuifolium F. and I. C. W.
Sigillaria approximata F. and I. C. W.

The flora of the Dunkard group is regarded by Fontaine and I. C. White as practically identical with the flora of the Permian Wichita beds of Texas (West Virginia Geol. Survey, vol. 2, 1903, p. 121). The fossil insects of the Cassville shale, described by Scudder (Bull. U. S. Geol. Survey No. 124, p. 114), also tend to confirm this view.

David White, in a paper read before the Washington meeting of the Geological Society of America in 1902 (abstract in Bull. Geol. Soc. America, vol. 14, pp. 538–542), concludes that the beds above the Lower Washington coal are without doubt equivalent to the lower Permian of Europe. The data relating to the lower beds he regards as not yet conclusive.

The principal fossil-bearing bed of the Dunkard group is the Cassville shale, which is at some places present between the Waynesburg coal and the Waynesburg sandstone, and with which has been included, paleontologically, the upper shale parting of the coal. Other important fossiliferous beds are a sandstone below the Washington coal, a black carbonaceous shale just above the Washington coal, parts of the Upper Washington limestone, and the roof of the Jollytown coal.

WASHINGTON FORMATION.

Definition and thickness.—As stated above, the Washington formation includes all strata between the top of the Waynesburg coal and the top of the Upper Washington limestone, being bounded below by the Monongahela and above by the Greene formation. Its thickness varies, but in this quadrangle is generally 300 to 400 feet.

Distribution.—This formation covers a larger area in this quadrangle than any other formation. It occupies the surface of nearly all the central part, the exceptions being patches of the Greene formation which occur in the hilltops near the Waynesburg and Nineveh synclines. It also outcrops along the main branch of Tenmile Creek and up its tributary valleys to the north. On the eastern and northern borders of the quadrangle it forms the hilltops and crests of the ridges above the Monongahela formation.

General character.—The following generalized section of the formation is given by Stevenson (Rept. K, p. 44), and is believed to be a fair average of the thickest development of the formation in this region.

Generalized section of the Washington formation in Washington County.

	Thickness. Feet.
Upper Washington limestone	30
Sandstone	40
Coal	1
Sandstone	40
Middle Washington limestone	15
Sandstones and shales	60
Limestone	8
Sandstone and shale	20
Bituminous shale or coal	1
Lower Washington limestone	20
Washington coal	10
Laminated sandstone	12
Little Washington coal	1
Shale	6
Limestone	20
Waynesburg "B" coal	1
Sandstone	30
Limestone	8
Waynesburg "A" coal	2
Waynesburg sandstone	60

The most accurate detailed section of these rocks available within this quadrangle is given by the Moses Smith diamond-drill hole near Bissell. This record, however, includes only the lower 143 feet of the formation.

Lower part of Washington formation in diamond-drill hole near Bissell.

	Thickness. Feet.	Depth. Feet.
Surface clay	11	11
Sandstone	2	13
Limestone	8	21
Sandstone	5	26
Shale	2	28
Sandstone	6	34
Limestone	1	35
Sandstone	4	39
Limestone	9	48
Shale	4	52
"Soapstone"	5	57
Limestone	5	62
Sand shale	6	68
"Soapstone"	4	72
Limestone	2	74
Light shale	7	81
"Soapstone"	1	82
Coal, Waynesburg "A"	4	86
"Soapstone"	7	93
Limestone	6	99
Sandstone	29	128
Sandstone	24	152
Black slate	2	154

Waynesburg coal.

Amity.

Cassville shale.—The Waynesburg sandstone rests directly on the Waynesburg coal at some places, but at others a bed of dark-gray to black shale, a few feet thick, intervenes. This intervening bed is named from Cassville, Monongalia County, W. Va., where it contains great numbers of fossil plants and insects. These are also abundant in the upper partings of the Waynesburg coal. The insects are described by Scudder as belonging to 56 species of 5 genera, and comprise, among other forms, numerous fossil cockroaches (Bull. U. S. Geol. Survey No. 124, p. 14). Many of these are Permian types.

Waynesburg sandstone.—Lying generally above the Cassville shale, but at some places resting on the Waynesburg coal, there is a coarse, flaggy, cross-bedded sandstone from 20 to 70 feet thick. Its color is usually buff-yellow to light gray. Its name is derived from the town of Waynesburg, near which it is finely exposed. This is one of the most conspicuous and persistent sandstones in the upper part of the Carboniferous system, and furnishes a good guide to the position of the Waynesburg coal. Its outcrop can in certain areas be followed for miles in an almost continuous line of cliffs. This sandstone strongly resembles the Pittsburg sandstone, and the two beds are sometimes confused. The deposition of this sandstone is supposed to mark a great change in geologic conditions—a change that ushered in the Dunkard epoch. In some places the rock is of value for building stone.

In the Amity quadrangle the Waynesburg sandstone is probably most prominent on Little Tenmile Creek in the vicinity of Lone Pine, where it crops out in 30-foot cliffs directly above the Waynesburg coal. At this locality it forms a flat terrace, on which part of the village has been built, about 40 feet above the creek. The sandstone is also well exposed on Little Chartiers Creek between the National Pike and Linden, where it can be traced along the public road for several miles, in the neighborhood of Zollarsville, on Pike Run, in the borough of Deemston, and on South Branch of Pigeon Creek. On North Branch of Pigeon Creek, on Mingo Creek, and in areas farther north the sandstone is of little importance, usually occurring as a shaly sandstone or being replaced by shale. In the vicinity of Washington and Houston, and in general over the western part of the quadrangle, the sandstone is poorly developed or missing.

Waynesburg "A" coal.—Above the Waynesburg sandstone and 60 to 80 feet above the Waynesburg coal lies the Waynesburg "A" coal. It is rather persistent and at some places reaches a thickness of 2 feet or more, but has seldom been mined. It has sometimes been called the "Zollarsville" coal, but it is not the coal now mined at Zollarsville.

Local limestones.—Below the Waynesburg "A" coal and above the Waynesburg sandstone at some places there is a limestone, noted but not named by Stevenson, which is well exposed on Dunkard Creek at Mount Morris, Greene County, and which has therefore been called by I. C. White the "Mount Morris limestone." In Washington County it is at some localities 5 to 10 feet thick, but is not persistent. It can be seen at many points in the eastern half of the quadrangle. It is commonly blue-gray in color and weathers yellowish.

In places a buff-colored limestone occurs *above* the Waynesburg "A" coal. It is generally thin, but at some places reaches a thickness of 8 to 10 feet. I. C. White named it the "Colvins Run limestone," from Colvins Run, in Greene County.

Waynesburg "A" coal to the Washington coal.—Above the Waynesburg "A" coal is an interval of 60 to 90 feet, occupied by shales and shaly to flaggy sandstones and at many places comprising a thin coal bed 10 to 40 feet below the Washington coal. This bed is probably the Little Washington coal, described by Stevenson and White. They also give the name Waynesburg "B" to blossoms seen in this interval. Thin limestones occur locally. Directly below the Washington coal, or separated from it by a few feet of fire clay, is a brown shaly to flaggy sandstone containing many remains of fossil plants. This stratum was called by Stevenson the "Washington sandstone."

Washington coal.—The Washington coal is the most persistent coal in the Dunkard group. It occurs from 120 to 150 feet above the Waynesburg seam and directly below the Lower Washington limestone. Where best developed it is as much as 7 feet in thickness. The best exposure in the vicinity of Washington is in the Baltimore and Ohio Railroad cut in the western part of town, where it can be seen outcropping below the Lower Washington limestone.

Lower Washington limestone.—The lowest of the three principal limestones outcropping near Washington, and named after that town, generally forms the roof of the Washington coal. Occasionally, however, a few feet of shale intervene between the coal and the limestone. The Lower Washington limestone occurs from 150 to 220 feet below the top of the Upper Washington limestone. Washington County is the region of its best development, and here it sometimes attains a thickness of 30 feet. It is generally interstratified with much shale, as shown in the following section:

Section of Lower Washington limestone and associated shale on Smith Run.

	Ft.	In.
Limestone	9	6
Shale, black	0	5
Limestone	0	7
Shale, black	0	4
Limestone	0	1
Shale, black and soft	0	2
Limestone	0	2
Shale, black	0	2
Limestone, hard, blue-black, weathers white	0	9
Shale, soft, black	2	0
Fire-clay shale, dark	0	4
Bony coal	0	2
Shale, black	0	4
Fire-clay shale, dark	0	5
Total	15	5

The Lower Washington is at most places a hard, compact limestone, which has a light blue-gray to fleshy color aud usually weathers bluish white. The color is not distinctive, and in general it can be said that the color of none of the limestones in the Dunkard formation is a certain guide to the identity of the bed. The colors mentioned are characteristic, however, and usually assist in identification.

Above the Lower Washington limestone lies a black carbonaceous or cannel-like shale, which in neighboring regions is fossiliferous. In this quadrangle no fossils have been found, and the bed is more nearly a normal shale.

Middle Washington limestone.—Above the Lower Washington limestone occurs a thickness of 60 to 100 feet of shales and shaly sandstones. Occasionally this interval contains a thin bed of limestone. In places prominent sandstone beds occur locally. At the top of this interval and 100 to 140 feet below the Upper Washington limestone another bed of limestone generally occurs. It is a hard, compact, light-grayish or flesh-colored limestone, usually coarsely brecciated and containing numerous spots of crystalline calcite. This limestone generally can be recognized by the great quantity of iron it contains, which gives it a bright-yellow weathered surface. The weathered part frequently extends to a depth of several inches, and finally exfoliates and crumbles off. Some of the basal layers are more earthy and slaty and do not have this characteristic. The bed is in some places 10 to 20 feet thick. A trace of coal or black shale occurs at some localities in connection with the limestone.

The Middle Washington limestone has a wide distribution in the quadrangle, but occurs in typical form near Washington. In a cut on the Baltimore and Ohio Railroad in the eastern part of the town the large yellow bowlders from the bed are finely exposed. The upper or ferruginous part of the bed is richly fossiliferous, but the fossils are generally not identifiable. They are usually replaced by crystalline calcite and therefore can not be recognized on fresh fracture, and on the weathered surface their characteristics can not be determined. One of the best localities for fossils is the cut in the eastern part of Washington. Minute univalves and bryozoans and a diplodus-like tooth have been found here (Rept. K, p. 49).

Between the Middle and Upper Washington limestones some flaggy sandstone frequently occurs.

Jollytown coal.—The name Jollytown was first used by J. J. Stevenson (Rept. K, 1876, p. 48) for a coal that lies 20 to 75 feet below the Upper Washington limestone. The same term has been

used by I. C. White (Bull. U. S. Geol. Survey No. 65, 1891, p. 34) for a coal and a limestone above the Upper Washington limestone, but as Stevenson's use has the right of priority, it is the one retained here. The name was used in the same sense in the Waynesburg folio (1905) by R. W. Stone. In the Amity quadrangle this coal is not known except at a few points in Amwell and West Bethlehem townships, where it appears as a faint blossom 60 to 80 feet below the Upper Washington limestone. Its maximum reported thickness is 20 inches.

Jollytown limestone.—In accordance with the usage of Stevenson (1876) and Stone (1905) the term Jollytown limestone is applied to the limestone occurring above the Jollytown coal and 30 to 40 feet below the Upper Washington limestone. It is a hard, grayish, sometimes brecciated limestone, weathering light gray to dirty yellow, and is a good guide to the geology. It is at some places several feet thick, and appears below the Upper Washington limestone on most of the roads in the southwestern part of the quadrangle. It is also present elsewhere in the quadrangle.

Upper Washington limestone.—The topmost bed of the Washington formation is the Upper Washington limestone, which, with the exception of the Waynesburg sandstone, is the most conspicuous and persistent member of the Dunkard group. For this reason it was chosen as the best horizon at which to subdivide the group into formations. It occurs 630 to 710 feet above the Pittsburg coal and 280 to 400 feet above the Waynesburg coal. The variation is irregular, but in general the thinning of the interval from the Pittsburg coal seems to be toward the northwest.

The characteristics of the Upper Washington limestone are rather distinctive. It is hard, compact, and brittle, and is generally made up of a number of layers separated by thin beds of shale. Throughout the greater part of Washington County it consists, in its upper part, of a limestone which, on fresh fracture, is dark blue-gray, bluish black, or nearly black in color. Generally it contains drab and mottled layers. The rock as a rule is high in calcium carbonate. In some parts of the district it is easily recognized by its weathered surface, which is almost white, with a slight tinge of blue. It varies in thickness from 4 to 30 feet.

The best exposures of this limestone are in the vicinity of Washington, where it reaches a thickness of nearly 36 feet. The tunnel of the Baltimore and Ohio Railroad 1 mile east of town cuts through the bed, exposing at its western end the section given below. The limestone is quarried at this place.

Section of Upper Washington limestone and associated rocks at tunnel 1 mile east of Washington.

		Ft.	In.
	Shale, dark, soapy	10	0
	Sandstone, hard, mottled, medium grained, gray	0	11
	Shale, black, sandy	1	9
Upper Washington limestone.	Limestone, blue-black	2	3
	Shale, black	0	2
	Limestone, blue-black	0	10
	Shale	0	4
	Limestone, blue-black, brittle	1	10
	Shale, black	2	2
	Limestone, hard, gray, and thin shale	5	4
	Shale, soft, dark	0	6
	Limestone, light brownish gray, very hard, to level of railroad	3	6
	Total thickness of Upper Washington limestone	16	11

On Cemetery Hill, in the southwestern part of Washington, just off the quadrangle, the total thickness of the limestone is 30 feet, as shown in a section by Stevenson (Rept. K, p. 46). A good partial section of the limestone is exposed in a quarry one-half mile northeast of town, on the Williamsport Pike, where it is now quarried and crushed for road metal. The limestone is well exposed on all the roads leading out of Washington toward the east and south, and outcrops at many points in the Nineveh syncline in South Strabane, northern Amwell, and South Franklin townships. In this region great care is necessary to avoid confusing it with a similar limestone which occurs 100 to 130 feet higher in the series. This limestone is also dark blue to black in color, and in thickness and other characteristics seems to be almost the exact counterpart of the Upper Washington.

A good exposure of the Upper Washington limestone occurs in a quarry on the hill just southeast of Washington. The bed is here 15 feet in thickness. On the uplands in the vicinity of Mount Wheeler the limestone is deeply buried, but it appears again for about a mile between Vankirk station and Chambers dam, and south of McCracken station is exposed along Bane Creek from 100 to 200 feet above the floor of the valley. In the vicinity of Amity, and in general throughout the southern part of Amwell Township, it is high on the hills. South of Tenmile Creek it is overlain by 200 to 400 feet of rock. Its outcrop extends along the valleys and ravines for the entire distance between Dunns station and Bissell.

Throughout West Bethlehem Township there are many outcrops of the limestone, but they all occur high on the hills, so that they appear on the map as mere patches. In the vicinity of Scenery Hill they are somewhat more extensive. One of the most continuous exposures of the limestone in the quadrangle is on a long ridge on which a road runs in a northeast-southwest direction about midway between Daniels and Plum runs, west of Beallsville. The bed here seems to be at least 30 feet thick and numerous fragments of dark blue-gray limestone appear for several miles near the top of the ridge. It has been quarried on a knob about a mile west of Beallsville and on the National Pike one-half mile northeast of Odell. Near by, on the same hill, the thickness of the limestone appears to be as great as 50 feet.

Near the middle of the Upper Washington limestone occurs a dark layer which contains great numbers of little bivalves and crustaceans. Fragments of mollusks also occur. The fossils are in general well preserved, but can rarely be broken out. This layer of the Upper Washington limestone gives a peculiar fetid odor when struck by a hammer.

GREENE FORMATION.

Definition.—Under the name Greene formation are classed all solid rocks above the Upper Washington limestone. In this quadrangle they include a maximum thickness of about 400 feet, reached in Morris Township, Greene County. In the southern part of Greene County and in northern West Virginia the thickness is much greater, at some places amounting to as much as 800 feet.

Distribution.—The Greene formation is best developed in the southern and western parts of the quadrangle. On the highlands along the boundary of Greene County, south of Tenmile Creek, it is continuous, having a thickness of 200 to 400 feet, and extending as far east as Bissell. North of Tenmile Creek and west of Bane Creek it is well developed through Morris Township and South and North Franklin nearly to Washington. In northwest Amwell and southern South Strabane it underlies the greater part of the area and in places attains a thickness of over 300 feet. It is present as far north as the Baltimore and Ohio Railroad, but beyond this line it appears only in small patches. Throughout West Bethlehem Township it caps many of the higher hills with a thickness of 100 to 150 feet, and patches of it occur as far north as Odell and nearly to Ellsworth. Several knobs in the vicinity of Denningsville are also capped by it.

General character.—In Washington County no good section of the Greene formation has been measured. In Report K (p. 35) Stevenson gives the following section from Center Township, Greene County, which may be regarded as fairly typical.

Generalized section of Greene formation.

	Thickness. Ft.	In.
Concealed	80	0
Limestone	Fragments.	
Reddish shale	80	0
Limestone	4	0
Sandstone	50	0
Limestone	10	0
Sandstone and shale	80	0
Limestone	2	6
Argillaceous shale	12	0
Sandstone	30	0
Nineveh coal	1	8
Sandstone	36	0
Bituminous coal	1	0
Limestone	2	6
Sandstone, shaly, massive	100	0
Dunkard coal	1	6
Limestone	6 to 15	0
Sandy shale	70	0
Limestone	2 to 5	0
Coal, local	1	8
Sandstone	19 to 30	0
Limestone	2	6
Sandstone	31	0
Shale and iron ore	10	0
Upper Washington limestone.		

Directly above the Upper Washington limestone there occurs at many places a dark, somewhat bituminous shale, often having a cannel-like fracture, which contains numerous bivalve crustaceans, fish scales, and fossil leaves. The type locality for this bed is at Washington. The "Fish bed," with its fossils, can be seen at the tunnel east of town and in a quarry on the hill southeast of the southern end of Main street.

On Cemetery Hill, Washington, a coal 18 inches in thickness occurs 5 feet above the Upper Washington limestone. Ten feet above the Upper Washington is an 8-foot bed of limestone.

Tenmile coal.—A thin coal occurs at many places about 30 feet above the Upper Washington limestone. This was called by I. C. White the "Jollytown coal," but it is not equivalent to the Jollytown of Stevenson, which occurs below the Upper Washington limestone. This coal has been noted at a number of localities throughout West Bethlehem and Amwell townships, but is best developed in the portion of the quadrangle south of Tenmile Creek, where it attains in places a thickness of 3 feet. For this bed the name "Tenmile coal" is here suggested, from the vicinity of its typical occurrence.

At an interval of about 80 feet above the Upper Washington limestone another thin coal occurs, which at some places reaches a thickness of 1 foot. Traces of a still higher coal bed have been noted at several localites at an estimated interval of 170 to 200 feet above the Upper Washington limestone, and this is probably equivalent to the Dunkard coal of southern Greene County.

Prosperity limestone.—Several limestones are distributed through the beds above the Upper Washington limestone, but only one seems to be at all important. This is a bed which occurs 100 to 180 feet above the Upper Washington at many points in South Strabane and Amwell townships. It is a hard, dark blue-gray to nearly black, compact limestone, in appearance almost the exact counterpart of the Upper Washington and easily mistaken for it. For this bed the name Prosperity limestone has been suggested by M. J. Munn, the name being taken from the village of Prosperity, in the Claysville quadrangle, Washington County. This limestone is supposed to reach a maximum thickness of 20 feet. It is not so persistent as the Upper Washington limestone.

Another thin limestone is found at some places only about 50 feet above the Upper Washington. This has been called by I. C. White the "Jollytown," but, as has been already explained, the name is no longer used for this bed. Massive sandstones are found at some places in the Greene formation, as on Scenery Hill, where bowlders several feet in diameter are exposed a short distance above the Upper Washington limestone.

QUATERNARY SYSTEM.

PLEISTOCENE DEPOSITS.

CARMICHAELS FORMATION.

Description.—Scattered deposits of clay, sand, and gravel occur upon the sides and rock terraces of many of the creek valleys of this region. They are not very extensive, but are similar to deposits that attain considerable importance along Monongahela River. The valley of this river is characterized by many abandoned channels which stand at higher levels than the present stream bed and in which the stream flowed before the present channel was cut. A typical abandoned channel occurs at Carmichaels, in Greene County, 7½ miles southeast of the Amity quadrangle, and from this place the sand and silt that constitute the valley filling have received the name of Carmichaels formation. The abandoned channels at Carmichaels may be taken as the type of an extensive system of similar channels which exist throughout the main valley of Monongahela River. Similar occurrences have been noted on Ohio River, Youghiogheny River, Conemaugh River, Loyalhanna Creek, and South Branch of Tenmile Creek.

Not only are deposits of clay, sand, and gravel found in the abandoned channels, but extensive deposits occur along the principal streams and in most of the tributary valleys above the level of their floors. This is the type found in the Amity quadrangle. As will be seen by referring to the geologic map, small areas of the formation are found up Tenmile Creek nearly as far as Hackneys. They have a maximum elevation of about 1020 feet, although the tops of individual deposits may not rise above 900 to 950 feet. In fact, in the vicinity of Zollarsville a number of flat-topped terraces have a rather uniform level of 900 to 920 feet, corresponding with the rock floors of the abandoned channels of Monongahela River, and suggesting that at a certain time the valley was broadened and that later the present channel was cut in the old valley floor, leaving remnants of this floor as rock terraces. Where seen, the surface of the terraces consists of silt with traces of gravel, generally very thin, resting on rock benches. On the north side of the creek just northeast of Zollarsville, partially separated from the main creek valley by a low knob, is a thin deposit that suggests a small abandoned valley of the Carmichaels type.

Traces of Carmichaels deposits were also seen on Pigeon Creek near Ellsworth and Bentleyville. In the valley of Chartiers Creek, north of the quadrangle, they are extensively developed, and they occur in small patches in the vicinity of Meadowlands and Houston and along Little Chartiers Creek. In a railroad cut on the Manifold branch of the Pennsylvania Railroad near Meadowlands a thickness of 14 feet of clay and gravel belonging to these deposits was measured.

Section of Carmichaels deposits near Meadowlands.

	Ft.	In.
Silt	3	0
Gravel	4	0
Clay, nearly white	1	0
Gravel, hard packed	5	0
Clay, white, sandy	0	2
Gravel, fine, black	0	10
Total	14	0

Just off the quadrangle, between Houston and Canonsburg, there is a narrow terrace of these deposits on the east side of the creek at an elevation of 980 feet. At this place the gravels and silts are about 18 feet thick, 7 feet of the upper silt being exposed at a brickyard, where it is utilized for brickmaking.

The underlying gravel is poorly exposed and the clay below can not be seen. The pebbles in the gravel have a maximum diameter of 2 inches, though most of them are smaller. They are mostly sandstone, but quartz pebbles up to five-eighths inch in diameter were found. Most of the pebbles are deeply weathered, and have a very old appearance. The presence of a few quartz pebbles seems to indicate that the deposits were in part derived from foreign material brought in from the north, as no quartz pebbles even approximating their size are known to have been found in any of the sandstones that outcrop along Chartiers Creek or its tributaries.

The silt forming the top of the deposits deserves special mention. Where seen in the clay pit it is a very tough, buff silt, a little gritty between the teeth, strongly resembling portions of the loess of the Mississippi Valley. Silt of this type is a constituent of nearly all the Carmichaels deposits in the Amity quadrangle and of Charmichaels deposits in general. It is a suggestive fact that silts of this nature have been found on similar terraces a short distance outside the glacial boundary on Beaver River, on Ohio River in the vicinity of Wheeling, and at several other localities.

Origin.—There is still some doubt as to the exact mode of origin of the Carmichaels deposits. They were without doubt laid down at a time when the water was at a higher level than at present and had probably little current, and the subsequent trenching of the old valley floor has left the gravels and silts on the rock benches. There are, however, three different theories to account for the deposits. The first theory was formulated in 1879 by Stevenson (Proc. Am. Phil. Soc., vol. 18, 1879, pp. 289–316), and accepted by T. C. Chamberlin in 1890 (Bull. U. S. Geol. Survey No. 58, pp. 13–38). This theory attributes the deposits to stream action. A second theory was postulated by I. C. White (Am. Geologist, vol. 18, Dec. 1896, pp. 368–379), who assumes that the sediments were deposited in an open lake occupying the entire Monongahela Valley. The third theory is that of M. R. Campbell, propounded in the Masontown-Uniontown folio. Before these deposits were laid down the drainage of this stream, the upper Ohio, and other streams in western Pennsylvania was tributary to Beaver River, which then flowed

northward into Lake Erie. The advent of the pre-Kansan, or first, ice sheet is supposed to have blocked this outlet, ponding the waters and causing them to overflow through a pass in the southern watershed of Monongahela River. According to Mr. Campbell's theory, the waters were raised locally by temporary ice dams at various points along the ancient rivers, and the main body of these sediments was deposited in the resultant ponds, while gravels and sands may have been deposited at higher levels in such a lake as that postulated by I. C. White.

The theory of ice dams accounts for the abandonment of the old channels and explains the occurrence of the deposits in many of the tributary valleys, like Chartiers, Tenmile, and Pigeon creeks, but certain conditions that exist over broad areas fail to harmonize with this theory. Opposed to the ice-dam theory are the occurrence of some gravels considerably above the main level, and the practical agreement in upper level of the sediments over considerable areas. It has been said that the upper level is rather uniform on all the principal creeks of the Amity and Waynesburg quadrangles. On Chartiers Creek the top is about 980 feet; on Little Chartiers Creek, 1000 feet; on Tenmile Creek, 1020 feet; on Little Tenmile Creek (at one point), 1060 feet; and in adjacent quadrangles to the east it is from 1020 to 1040 feet—in one or two instances up to 1070 feet.

Similar deposits have been observed at widespread localities outside the glacial boundary along Ohio, Allegheny, and Beaver rivers, capping rock benches and having the general character and relations of the Carmichaels formation. On Allegheny and Beaver rivers they grade toward the north into gravels supposed to be of pre-Kansan but possibly of Kansan age, capping rock terraces at elevations of 900 to 1000 feet. Furthermore, in the survey of the Rogersville quadrangle, in western Greene County, small patches of gravel and silt in every respect like the Carmichaels deposits were found up to an elevation of 970 feet covering rock terraces on Dunkard Fork of Wheeling Creek near Durbin.

Summarizing, we find that the elevation of the upper limit of the deposits classed as Carmichaels in all the valleys of southwestern Pennsylvania has a vertical range of but little over 100 feet. This fact seems to indicate that part of them, at least, were formed in standing waters ponded throughout southwestern Pennsylvania and parts of adjacent States. This ponding was probably due to the advance of the first or pre-Kansan ice sheet and the consequent damming of the northward-flowing rivers. After the waters fell below the general level, owing to retreat of the ice or to erosion of a new outlet, local ice dams may have been formed at Carmichaels and elsewhere, making possible the deposition of sediments at varying levels below the upper limit of ponding. Some of the differences in upper level, especially toward the southeast, may be due to erosion and slight tilting.

The weathered and aged appearance of the gravels in the Carmichaels deposits and their occurrence on the rock terraces on which the rivers flowed at the beginning of the Quaternary period corroborate their probable deposition in earliest Pleistocene time.

RECENT DEPOSITS.

ALLUVIUM.

The valleys of most of the streams in the quadrangle are so narrow that many of the flood plains are not a hundred yards wide—too small to map. Only the larger areas of alluvium are therefore indicated on the areal geology map. The best development of flood plains is along Chartiers, Little Chartiers, and Tenmile creeks. At a few points in these valleys flood plains locally are as much as one-fourth of a mile wide.

GEOLOGIC STRUCTURE.

STRUCTURE IN GENERAL.

Method of representing structure.—Geologic structure can be graphically represented in two ways. The older method—still commonly used—is that of cross sections, which show the strata as if cut through along a given vertical plane. In this method a difficulty arises from the fact that only a limited number of sections can be given on the map, and between them lie considerable areas concerning whose structure little or no information is given. Another objection to the use of the cross-section method in this district is that the dips are so gentle as to make a section ineffective without greatly exaggerating the vertical scale. In this report, therefore, the structure is represented by contour lines as follows:

The top or bottom of some persistent and easily recognizable stratum is selected as a datum surface, and its elevation above sea level is determined at as many points as possible. In the Amity quadrangle the horizon selected is the bottom of the Pittsburg coal bed, this being the best known and most persistent bed in the region. The structure is shown on the structure map by means of red contour lines. These are drawn at uniform intervals above sea level, and all points on a given contour have the same elevation. In other words, a given structure contour may be considered as the line of intersection of the datum surface with a plane, all points of which have the same elevation above sea level. For instance, the Pittsburg coal at all points along the 650-foot contour has an elevation of 650 feet above sea level. It descends in the direction of the 600-foot contour and rises toward the 700-foot contour.

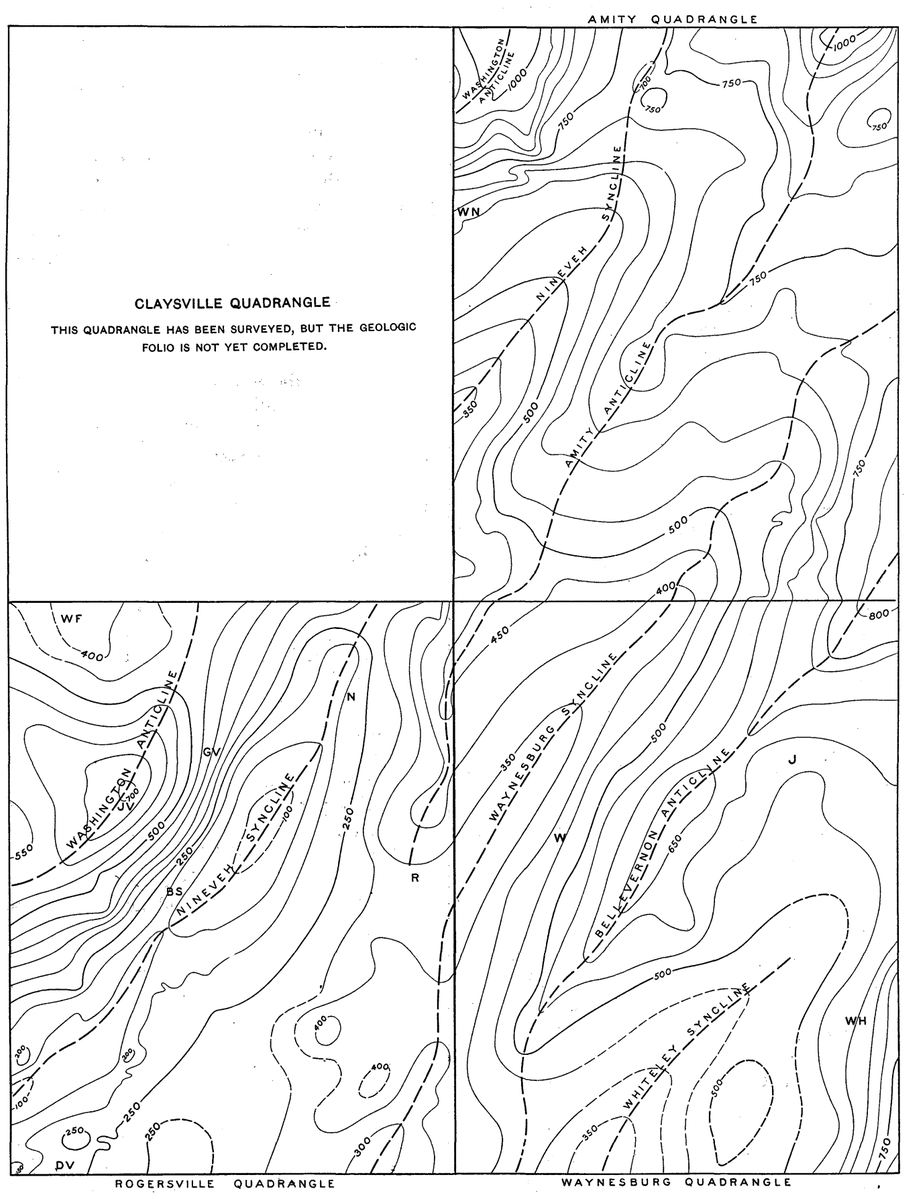

FIG. 3.—Sketch map of the Amity, Rogersville, and Waynesburg quadrangles, showing geologic structure by means of contour lines drawn on the floor of the Pittsburg coal. Contour interval, 50 feet.

BS, Bristoria; DV, Deep Valley; GV, Graysville; J. Jefferson; JV, Jacksonville; N, Nineveh: R, Rogersville; W, Waynesburg; WF, West Finley; WH, Whiteley; WN, Washington.

An intersection of a surface contour with a structure contour of the same elevation marks a point of outcrop of the Pittsburg coal. At points where the elevation of the surface is *greater* than that of the coal, the approximate depth of the coal below the surface can readily be found by subtracting the elevation of the structure contour from that of the surface contour. Where the elevation of the surface is *less* than the corresponding elevation of the coal, the latter has been removed by erosion. In case the depths of other beds than the Pittsburg are desired their intervals above or below this must be subtracted or added to the depths of the Pittsburg coal.

To illustrate the use of structure contours, suppose that the depth of the Pittsburg coal is desired at the junction of Daniels and Little Daniels runs, in West Bethlehem Township. As can be seen by the map, the elevation of the bottom of the valley at this point is about 890 feet, and the point is very close to the 500-foot structure contour; therefore the Pittsburg coal is here calculated to be about 890 minus 500 feet, or 390 feet below the surface.

Degree of accuracy.—It should be borne in mind that it is impossible to make structure contours strictly accurate in all parts of the field, and allowance for possible errors should therefore be made in using them. Over large areas there are no mines or wells by which the exact depth of the coal below the surface can be determined. In such areas it is necessary to depend upon estimated intervals between the coal and the beds which show in outcrop, and as the intervals are never constant over any considerable area, an error may be introduced which will affect the drawing of the structure contours. In this quadrangle, however, the inaccuracy is probably never very great. By reference to the map it will be noticed that in certain localities the contours have many waves and turns, while in other parts of the quadrangle they run for miles in long, regular curves. This difference is partly due to the fact that in certain places, as in the Ellsworth, Peters Creek, and Chartiers Creek mining districts, the contours are based on mine maps showing the elevations of the coal in the areas that have been worked. In regions where a great many well records have been available, as in the Zollarsville field, the structure is likewise more accurately shown than in other portions of the quadrangle. The Survey is indebted to many oil and gas operators who have generously furnished their well records, and to the various coal companies which have allowed the use of their mine levels.

Limits of error.—In general the structure-contour interval in a given area is decided by two factors—(1) the steepness of the dip, and (2) the accuracy with which the available data enable contours to be drawn. In a region like this, where the dips are all fairly gentle, only the second factor has to be considered. Obviously it is useless to make the interval less than the "limit of error." For example, if over a given area the elevation of the datum horizon were determined within 50 feet, it would be useless to draw contours with a 25-foot interval. Moreover, such a representation would be misleading to the reader, who would be led to believe that the elevation at any given point was accurate to within 25 feet, which would not be the case. In general, then, "the limit of error" for an area should not be greater than the contour interval.

This point has an important bearing on the structure of the Amity quadrangle as represented by the contours. With the exception of the wells in the Zollarsville gas field, nearly all of the wells in the quadrangle were drilled years ago, at a time when records were generally kept poorly or not kept at all. On account of the poor quality of records and the absence of wells, no figures are available in some parts of the quadrangle to determine the depth of the Pittsburg coal and to check surface tracings and correlations. It must be remembered also that the intervals between the surface rocks and the coal vary from place to place. Consequently there are few parts of the quadrangle in which it would be safe to say with certainty that the contours on the Pittsburg coal are accurate enough to justify a 25-foot interval.

STRUCTURE IN DETAIL.

Fig. 3 shows by contour lines on the Pittsburg coal the relations of the structure in this quadrangle to that in the Rogersville and Waynesburg quadrangles. The general structural features consist of broad anticlines and synclines, which are most pronounced along the eastern border of the Appalachian basin, and which become gentler in dip and less continuous toward the west.

The detailed structure of the Amity quadrangle in its relations to the geology and geography is best exhibited by the structure and economic geology map. The principal structural features shown on this are three anticlines and two synclines, trending in a general way in a northeast-southwest direction. These will be described in order from east to west.

Bellevernon anticline.—What is here called the Bellevernon anticline was called the Waynesburg anticline by J. J. Stevenson in a report published in 1876, in which the same name was applied to the syncline lying west of the anticline. When the Brownsville quadrangle was surveyed, in 1901, there was some doubt whether the anticline crossing Monongahela River near Bellevernon was continuous with the one passing near Waynesburg, named by Stevenson. On account of this uncertainty and on account of the fact that the term Waynesburg had been applied to two structural features, this axis in the Brownsville quadrangle was named by M. R. Campbell (folio No. 94) the Bellevernon anticline, and this name was employed also by R. W. Stone in the Waynesburg folio (folio No. 121) a year later.

The Bellevernon anticline crosses the Amity quadrangle in its extreme southeast corner. That part of the axis lying within this quadrangle has a length of about 1½ miles. It trends N. 29° E., and the elevation of the Pittsburg coal on its crest is 800 to 840 feet.

Waynesburg (Pigeon Creek) syncline.—This syncline is a broad trough, approximately 10 miles wide, lying between the Bellevernon anticline on the east and the Amity anticline on the west. It was named the Waynesburg syncline by Stevenson, but on account of uncertainty as to its continuity with the syncline having the same relations in the Brownsville quadrangle, it was, in folio 94, called the Pigeon Creek syncline, after Pigeon Creek, in Washington County. Owing to the fact that Waynesburg is the original name and that the continuity of the syncline has been proved, the term Waynesburg is retained in this folio.

This syncline is a broad structural basin with generally low dips. The axis enters the quadrangle at Bentleyville and takes a slightly meandering

course, averaging about S. 40° W., to the southern edge of the quadrangle. From Bentleyville it follows the valley of Pigeon Creek to Three and Four, where it turns southward and passes half a mile east of Scenery Hill, winding across West Bethlehem Township and running directly through Bissell, south of which it leaves the quadrangle.

Where the axis of the trough enters the quadrangle from the east the Pittsburg coal is at an elevation of about 750 feet above tide, and from this it descends gradually toward the southwest until, at the Greene County line, the coal is below 400 feet. Throughout the basin the dips are gentle, averaging less than 100 feet per mile, except on the eastern flank between Zollarsville and Beallsville, where they are as much as 150 feet per mile for short distances. In this section the structure is largely interpreted from well records, and shows several rather peculiar nose-like projections from the flank of the anticline. These are presumably about as represented, as the well records seem to be mostly good, but in all cases due allowance should be made for the possibility of errors in the records. In the center of the trough, between Bissell and Scenery Hill, it is possible, owing to the scant data obtainable, that the basin is somewhat deeper in places than shown.

Amity anticline.—From the Waynesburg syncline the rocks rise gently northwestward to the crest of the Amity anticline. This was called the "Pinhook anticline" by Stevenson and White in their reports, the term being taken from a name formerly applied to the village of Lone Pine. As the designation Amity anticline, from the village of Amity, seemed more suitable, Stone described it as such in the Waynesburg folio.

Beginning at the south, this anticline crosses the Greene County line near the boundary between Morris and Washington townships. As it enters the quadrangle it takes a slight bend or offset to the east, then continues in an average course about N. 35° E., passing just east of Amity, through Lone Pine, and crossing the National Pike 4 miles southeast of South Strabane post-office. Here there is another slight eastward deflection, but within 2 miles the axis veers to the north again and takes a course averaging about N. 30° E., running just west of Vanceville, through Kammerer, and across Nottingham Township to Peters Creek at Anderson, where it passes through the Blanche mine of the Pittsburg Coal Company.

Where the axis enters the southern edge of the quadrangle the Pittsburg coal is at an elevation of a little over 450 feet, this point being on a structural col almost connecting the Pigeon Creek and Nineveh synclines. South of Tenmile Creek the axis commences to rise northward, averaging less than 50 feet per mile until, 1½ miles south of the National Pike, as determined by well records, it forms an imperfect knob with the Pittsburg coal at an elevation of somewhat more than 700 feet. Beyond this point the grade does not average more than 20 or 30 feet per mile, except north of Kammerer. A mile south of Peters Creek the axis suddenly rises, bringing the coal from less than 900 feet up to 1040 feet just outside the quadrangle. At its northern end this anticline is identical with the Peters Creek anticline of Stevenson.

East of the Amity anticline, in Nottingham Township, a local trough enters the quadrangle from the east and extends for a distance of over 2 miles. It trends west-southwest, directly toward another small indentation in the anticline from the west. This feature is evidently the cause of the rather sudden deflection of the Amity axis at Mingo Creek, and there seems to be a very slight col here. There is no true cross syncline, however.

At a number of localities on this anticline the lay of the coal is rather uncertain, owing to lack of available data, but the contours are believed not to differ greatly from their representation on the map. West of Lone Pine and Amity the dip is rather steep—100 to 150 feet per mile—toward the Nineveh syncline. Farther north it becomes less steep, except between Kammerer and Munntown, where it is estimated to be as much as 100 feet per mile toward the southwest.

Nineveh syncline.—The Nineveh syncline was so named by Stevenson from the village of Nineveh, Greene County, near which the axis passes. From there it runs northeastward and enters the Amity quadrangle west of the village of Sunset. It takes a course averaging N. 42° E. to about 2 miles north of South Strabane post-office, where it changes to N. 10° E. for several miles, to near Linden. Here it takes another slight bend to the east and leaves the quadrangle just east of Little Chartiers Creek.

The average breadth of this trough in the Amity quadrangle is about 9 miles, and in general the dips are very gentle. Near Sunset, where the axis enters the quadrangle, the elevation of the Pittsburg coal along the axis is supposed to be about 350 feet. From this point there is a gentle rise to the northeast as far as Gambles, where the elevation of the coal is a little above 700 feet. Between this place and the edge of the quadrangle is a broad, rather flat area, characterized by a slight knob and a similar little basin, represented on the map. These features are determined from well records and outcrops in the vicinity. East of Wylandville an arm of the basin shoots off to the east, as if to cut across the Amity anticline, but dies out before reaching Kammerer. In general the dips in the Nineveh syncline are very gentle, but on the flank of the Amity anticline, between Amity and Mount Pleasant, they amount to 150 feet per mile in some places, and on the Washington anticline reach an extreme of 250 feet in a mile for a short distance northeast of Washington.

Washington anticline.—This axis enters the Amity quadrangle just north of Chartiers Creek, and leaves it again half a mile west of Houston. The crest of the anticline is rather broad and flat, and the coal ranges in elevation from 950 feet at the south to nearly 1050 feet at the north. To the southeast it descends rather steeply toward the Nineveh syncline. This feature of the structure is interesting in view of the fact that the famous Washington oil field is situated along the strike of this flank. The numerous oil wells in this section have assisted materially in the interpolation of the structure contours in the vicinity.

Throughout the quadrangle all the folds plunge to the southwest, in conformity with the general dip, into the deepest part of the Appalachian coal field.

Lack of parallelism between beds.—In using the contours represented on the map it should be remembered that few beds are exactly parallel, and hence allowance must be made for increase and diminution of intervals in various directions. For instance, the interval between the Upper Washington limestone, one of the most persistent outcropping beds, and the Pittsburg coal varies in this quadrangle from 630 to 710 feet, and the interval between the Waynesburg coal and the Pittsburg varies from 290 to 350 feet. Some of the intervals between formations below the surface vary even more than this, as shown in the table of oil and gas sands. The causes of these variations are two-fold, (1) slight changes in the thickness of various beds, due to differences in sedimentation, and (2) marked variations in the thickness of the Mauch Chunk formation, owing to an unconformity at its top.

GEOLOGIC HISTORY.

PALEOZOIC ERA.

As has been said, the Amity quadrangle is situated near the center of the great Appalachian synclinal basin, in which the pre-Devonian rocks are buried so deeply below the surface that they have not been penetrated by the drill. The oldest rocks exposed at the surface belong high up in the Pennsylvanian series of the Carboniferous system, but the extensive exploitation of oil and gas in this part of the State has made it possible to study the underlying Mississippian and Devonian rocks, and the sequence of events has been determined with considerable accuracy.

DEVONIAN PERIOD.

CHEMUNG EPOCH.

As shown in the discussion of the stratigraphy, the oldest rocks penetrated by the drill in this quadrangle lie well down in the Chemung formation. At the time these rocks were formed a large part of what is now the continent of North America was covered by water. There was a great inland sea, which was bounded on the north by the Archean highlands of Canada and on the east by a land area lying somewhere along the Atlantic slope and probably crossing New England near its western border. This land extended far to the south, and it seems likely that it reached eastward considerably beyond the present Atlantic shore line. The great expanse of salt water in central United States had access to the open sea, but it did not have a fixed shore line or constant relation to the land for any great length of geologic time.

At the time this history begins the streams were bringing into the open sea, which probably existed throughout most of the Devonian period, extensive deposits of muddy sediments from land to the north or east. These muds were interbedded with layers of sand, derived probably in part from elevated land in which erosion was active, and in part from the reworking of sandy material already deposited. The frequent changes noted in well records from "shale" to "sand" or to "shells" and vice versa were changes in the character of sediments, probably caused by different rates of elevation or oscillating changes in climate which affected the volume of the inflowing streams; but their alternation is due largely to the sorting action of waves and currents, which arranged the coarser deposits into beds by themselves, in the forms of beaches or bars.

CATSKILL SUB-EPOCH.

At times during this long-continued deposition of alternating muds and sands, many hundreds of feet thick, the streams brought to the sea great quantities of red material, presumably derived from a deeply oxidized land area. These deposits are the Catskill beds. Formerly the time during which these red beds were deposited was supposed to be a distinct epoch. In this report it is treated as a subdivision of the Chemung epoch, for the red beds in this region are thin and occur entirely in that formation. In the Amity quadrangle the identification of the Catskill beds rests entirely upon the reports of well drillers. They have a thickness of 200 to 300 feet, as shown by some of the deep wells in this quadrangle. Most of the material is fine, being the sediments that were borne by the water from the eastern shores into the center of the Appalachian Gulf. The red rocks of this western margin of the formation lie in detached beds or lentils of greater or less extent and thickness, alternating with gray shale and sandstone which may have had a different origin, and near the western boundary of the State they die out. It seems probable that the deposits on the extreme western margin of the red rocks were transported intermittently at times of flood, and that the great beds of coarse gray sandstones that form the reservoirs for oil and gas in this part of Pennsylvania accumulated at other times.

After the red material had been laid down the conditions that preceded its deposition were repeated and another series of sandy and muddy sediments was formed in the sea.

CARBONIFEROUS PERIOD.

POCONO EPOCH.

Since it is not possible to obtain fossils from the beds which are deeply buried below the surface of the Amity quadrangle and are known only by the records of deep wells, no definite line of separation can be drawn between the Devonian and Carboniferous sediments. It is believed, however, as has been shown by the evidence given under the heading "Stratigraphy" (p. 4), that the true Pocono deposits began at about the time the Fifty-foot sand was deposited, soon after the close of the Catskill conditions in this region.

In general the strata deposited during Pocono time are rather more sandy than those formed during the preceding epoch. They comprise several thick beds of sandstone, the first two being the Fifty-foot and Gantz sands. In this quadrangle these sands are generally separate, but in many other regions they thicken up and run together, and this fact indicates the continuance of similar conditions during the whole of the Hundred-foot stage. The formation of these sands was followed by the deposition of gray shale with occasional beds of red shale and several sandstone lentils of rather indefinite extent.

During the latter part of Pocono time vast quantities of coarse sand brought into the inland sea formed the Burgoon (Big Injun or Mountain) sandstone, which in the Amity quadrangle averages 300 feet in thickness. It is supposed that the water in which the Pocono sediments were deposited was for the most part fresh.

A tilting of the coastal plain to the west at the beginning of Carboniferous time may have been the cause of the rapid delivery of this sand to the waters of the Appalachian Sea. The difference in the thickness of the formation in different parts of the province is due to differences in their distance from the shore.

MAUCH CHUNK EPOCH.

After the close of Pocono time there was an epoch in which little or no arenaceous sediments were deposited, the lack of these indicating that during that epoch the sea became deeper and clearer. Probably the coarser sediments brought down by the rivers were deposited in estuaries formed near their mouths. The open sea in the southern Appalachians then abounded with marine animals, and by their agency, aided perhaps by chemical precipitation, beds of highly fossiliferous limestone accumulated to a thickness of 40 to 80 feet in the Amity region. The result is the Greenbrier limestone, known to well drillers as the Big lime. The period during which the limestone accumulated was rather long and its deposits show no trace of crustal movements.

The deposition of the Greenbrier limestone was finally ended by an elevation of the continent sufficient to quicken erosion and to bring the coast line near to the region under discussion, so that quantities of mud and some sand were brought into the sea waters, forming sandy shales. These shales in this region are in some places 100 feet in thickness and are prevailingly red in color, suggesting a repetition of Catskill conditions. It is supposed that these red sediments were derived from a deeply oxidized land area in which the materials were much like those now found in southern United States. It is probable that the land from which they were derived lay toward the east. The conditions under which the red shales were deposited are supposed to have been rather unfavorable to life, for these rocks contain few fossils.

EARLY POTTSVILLE EROSION INTERVAL.

In northeastern Pennsylvania the Mauch Chunk formation is over 2000 feet thick, but its thickness diminishes toward the west. It is only about 200 feet thick in wells in the eastern part of the Amity quadrangle, less than 100 feet in the vicinity of Washington, and in areas still farther west it is absent. The decrease is not uniform in any particular direction, as only about 50 feet of the formation occurs in wells in the vicinity of Blairsville, in Indiana County.

The irregularity in thickness of the Mauch Chunk deposits and of the overlying Pottsville sandstone indicates an uplift which raised above sea level a large land area extending from southern New York at least as far east as the Allegheny Front. From this land area the upper part of the Mauch Chunk was eroded before the overlying Pottsville rocks were deposited. As illustrated by the well sections on the columnar section sheet, the erosion was greatest in the northwestern part of the area, decreasing toward the east. Just when this uplift occurred can not be definitely determined, but it probably took place at the close of Mauch Chunk time.

POTTSVILLE EPOCH.

The beginning of Pottsville time is marked by a change in the character of material deposited, fine reddish sands and clays having been then overlain by white and much coarser sands and gravels. The unconformity at the top of the Mauch Chunk formation indicates that at the beginning of the Pottsville epoch the greater part of western Pennsylvania was above sea level and that surface erosion was in progress on the resulting land surface.

The fossil plants of the Pottsville beds indicate that in the Southern Anthracite basin and in the Pocahontas field of Virginia sedimentation occurred continuously from the close of the Mauch Chunk epoch to the beginning of Allegheny time, whereas along the western margin of the coal basin the close of the Mauch Chunk was marked by an uplift that raised the main part of the bituminous field above water level, and hence there was an interval during which no rocks of Pottsville age were deposited in that portion of the field.

After two-thirds or more of the formation had been laid down in the Southern Anthracite basin,

the land in southwestern Pennsylvania and Ohio subsided and deposition was resumed in this part of the province. The Connoquenessing sandstone was deposited at this time. This period was followed by one in which the basin was covered with vegetation, the remains of which formed the Mercer coals, the coal-forming plants having been accompanied by a varying amount of muds, forming shales, and of calcareous matter, which formed limestones. After this the Homewood sandstone was deposited over most of the field, and this episode closed the Pottsville epoch.

ALLEGHENY EPOCH.

After the material composing the coarse sandstones of the Pottsville epoch had been deposited there came a time in which the beds now forming the shales, sandstones, limestones, and coal seams of the Allegheny formation were laid down. The great variations in the material of this formation indicate that it was deposited during periods in which large amounts of coarse sediments were swept into the basin and alternate periods in which little or no material was supplied except the abundant growth of plants whose remains now make up the coal beds.

The origin of the coal and the method of its accumulation in seams covering great areas are not well understood. That coal is of vegetable origin is almost universally acknowledged, but there is great difference of opinion as to the method by which the vegetable matter accumulated. It seems safe to say that the coal seams of the Appalachian province were in the main formed near sea level in marshes, which often extended over thousands of square miles.

The well records in Greene and Washington counties do not afford a very detailed history of this interesting epoch, but in general the sequence of events during the period of deposition of the Allegheny formation was somewhat as follows:

The deposition of the Homewood sandstone was followed by a slight subsidence and the accumulation of a few feet of clayey sediments. Then the sea was filled or its bottom rose approximately to water level and marshy conditions prevailed for a time over a large area. Upon this marshy land was formed an extensive peat bog, in which were accumulated the remains of many generations of plants. Different parts of this marsh were overflowed by water from time to time, when thin layers of sediments were deposited, forming the "partings" or "binders" of the resulting coal beds. After a long and comparatively quiet period the region was depressed and sedimentation was resumed, the sediments burying the vegetable matter and beginning the work of compressing and hardening it into coal seams. By re-elevation of the area, or by accumulation of sediments, the bottom was again gradually raised to water level, restoring the coal-forming conditions, and another coal bed was deposited.

During the Allegheny epoch these conditions were evidently repeated a number of times, for the rocks in various districts now comprise from 5 to 10 coal beds, with intervening layers of sediments. When marshes prevailed the material of which coal seams were formed was accumulated; when the region was depressed, the sands that formed sandstones were laid down; when the water deepened still more, muds that made shales were deposited, and in the clear water that occasionally occupied the basin the various marine limestone beds were formed. At some times these conditions were continuous over large areas, when beds of great extent, like the Upper Freeport coal, the Vanport ("Ferriferous") limestone, and the Clarion sandstone, were formed. At intervening times the basins, marshes, and beds were of very local extent, and beds were then laid down which now occur as mere lentils in the formation and can not be traced for long distances. Although the strata were undoubtedly elevated at times during the period of deposition of the Allegheny formation, the prevailing movement in that period was evidently one of subsidence, so that each coal seam was formed at the surface and then buried by overlying sediments.

CONEMAUGH EPOCH.

The close of the Allegheny epoch is marked by a change in conditions which permitted the deposition of about 600 feet of sediments with only a few minor seams of coal. On top of the Upper Freeport coal a considerable thickness of coarse sands was generally deposited, known on the surface as the Mahoning sandstone, and to drillers as the Big Dunkard or Hurry-up sand. In general the lower portion of the Conemaugh is very sandy, consisting of a number of overlapping lentils of sandstone. Above the Mahoning the more persistent of these is the Saltsburg sandstone member (Little Dunkard sand), which represents a thick deposit covering extensive areas in southwestern Pennsylvania.

For a time after the formation of the Upper Freeport coal marine conditions seem to have prevailed frequently, as salt water fossils have been found at several horizons in the lower part of the Conemaugh rocks. The Ames ("Crinoidal") limestone, which occurs midway in the formation and is spread over wide areas of western Pennsylvania and eastern Ohio, is full of marine fossils, showing that the sea at that time occupied a large area. This limestone is supposed to mark the last recurrence of marine conditions in the Appalachian basin.

The Morgantown sandstone, which lies above the Ames limestone, probably indicates a period of elevation. The series of red shales overlying this sandstone in southwestern Pennsylvania seems to record a time during which the land surface was once more deeply oxidized, as in the Catskill and Mauch Chunk epochs. At the close of the Conemaugh the greater part of the basin was once more brought near water level.

MONONGAHELA EPOCH.

The formations deposited after the close of the Conemaugh are all exposed in the Amity quadrangle. The beginning of the Monongahela epoch was marked by another great period of coal formation—that of the Pittsburg coal. During the accumulation of this bed the characteristic vegetation of the Carboniferous period was at its best. The Appalachian basin was at that time a level area, and the remarkable uniformity in conditions and the long duration of plant growth resulted in the formation of this coal over a great area. Such changes as took place, as, for example, the deposition of layers of mud, represented by partings in the coal, were likewise widespread in their extent. The swampy conditions finally ended by a broad submergence, which caused the deposition of the overlying shale and sandstone; but with the filling of the water to the surface, swamp conditions were restored and the Redstone coal was locally deposited.

After the growth and deposition of the Redstone coal vegetation the land sank, calcareous matter that formed limestone was deposited, and mud and sand filled up the basin and formed the surface on which the Sewickley vegetation grew. Again came a submergence, and for a long time a limestone, with some interbedded shale, was in process of formation, until a total thickness of about 150 feet had accumulated. This is the Benwood ("Great") limestone. For the accumulation of this limestone it seems necessary to assume the presence of deep water. The small amount of shale suggests that the area in which it was formed was some distance from shore, or that base-level conditions prevailed and very little detritus was being brought into the basin.

Directly on top of the Benwood limestone there was locally deposited a thin coal—the Uniontown. After this there was another submergence, and shale and sandstone, followed by the Waynesburg limestone, were laid down. With the deposition of more shale the waters again became shallow and conditions again favored plant growth. From the remains of this vegetation the Waynesburg coal originated. The accumulation of this bed, like that of the Pittsburg seam, was frequently interrupted by thin coverings of mud and clay. With this period of plant growth the Monongahela epoch ended.

DUNKARD EPOCH.

The plant growth that formed the Waynesburg coal was caused by another submergence and the accumulation of thick sediments. In places a few feet of mud gathered directly on top of the coal, but in general a thickness of 40 to 70 feet of coarse sand was spread over the basin. This is the Waynesburg sandstone, which formed a land surface on which the Waynesburg "A" coal was laid down. The formation of this coal was interrupted by a submergence marked by the accumulation of shale, sandy shale, and limestone, the character of the deposit varying from place to place according to the varying depth and character of the waters. Coal-making conditions seem to have recurred at intervals, but they were local and of short duration. One of the beds—the Washington—covers a wide area, but is much broken by partings, indicating a rather broad, swampy area, over which layers of silt were frequently swept.

After the accumulation of the Washington coal the conditions must have changed rapidly, for directly on top of the coal lies the Lower Washington limestone, which indicates clear, deep waters. Over this were spread great thicknesses of shale and fine sandstone. The lower part of the Dunkard formation appears to mark a general deepening of the whole basin, with few interruptions. When the waters became deep enough and clear enough the Middle Washington and Upper Washington limestones were formed, and on top of these fresh deposits of shales were accumulated.

Above the Upper Washington limestones are many feet of shale and sand-shale, containing thin local beds of limestone, sandstone, and coal. In Greene County and in West Virginia red shales are of frequent occurrence, indicating an oxidized condition of the surface rocks of the adjacent land areas. Sedimentation probably continued until the Appalachian Gulf was finally completely filled. The rocks in the deeper portions aggregated an unknown thickness, probably hundreds of feet more than the thickest sediments now remaining in the hills of southwestern Pennsylvania and northern West Virginia. Thus ended the Paleozoic deposition in this part of the world.

APPALACHIAN REVOLUTION.

The close of the Dunkard epoch marks the end of sedimentation in the northern end of the Appalachian trough and the beginning of a long-continued series of events of an entirely different nature. Ever since the beginning of deposition in the interior sea, subsidence had been going on intermittently, and sediments derived from the surrounding land were deposited to a great thickness, until thousands of feet of strata had accumulated. From the close of the Carboniferous period until the present time the reverse movement—elevation—has prevailed in this region, which, during that time, has been continuously a land area.

This change from subsidence to elevation occurred in a period during which compressive strains in the rocks warped them into great folds. The movement was most severe along the eastern side of the Greater Appalachian Valley, where the rocks were not only intensely folded, but the pressure was great enough to cause notable changes in them and in many cases to metamorphose them completely. In the region west of this zone of great disturbance the movement was less severe and the folds are smaller, but important folds are found as far west as the Allegheny Front. In a measure the Appalachian coal basin seems to have acted as a bulwark against which the rocks were crushed. The folding continued across the basin, but with greatly decreased effect. The rocks in the region under discussion were warped into broad, comparatively low folds, of which those in the Amity quadrangle are a mild type. The period of elevation and compression in which these folds were produced is known to geologists as the Appalachian revolution.

MESOZOIC ERA.

As the new land surface rose gradually out of the interior sea, owing to the action of the compressive forces, erosion commenced, and the streams that were formed on the surface began to carve valleys and carry away the sediments which had been deposited during Paleozoic time. This erosion has been going on continuously ever since. By the long-continued action of the streams and other subaerial forces during Mesozoic time the surface of the Appalachian province was eroded, before the close of the Cretaceous period, approximately to its base-level, in the form of a nearly horizontal plain. This is the Schooley peneplain, so called because remnants of it are well preserved in the Schooley Mountains of northern New Jersey. The Cumberland Plateau, the crests of many of the mountain ridges east of the Allegheny Front, and the summit of Chestnut Ridge are believed to be but slightly below the level of the Schooley peneplain. The age of this peneplain is known approximately from the fact that in New Jersey and Alabama it extends beneath deposits of Cretaceous age.

CENOZOIC ERA.

TERTIARY PERIOD.

After the Mesozoic land surface had been worn down nearly to sea level, elevation occurred, raising the Schooley peneplain to a height of 800 feet or more above the sea. On this surface the streams were rejuvenated and with their increased velocities peneplanation commenced anew. During this period of erosion the harder rocks on the greater folds, like Chestnut Ridge, were left in relief, while the softer rocks were again reduced to a fairly even surface, called the Harrisburg peneplain, from its development in the vicinity of Harrisburg, Pa. In the Amity quadrangle this peneplain is not conspicuous, but many remnants of it can be seen throughout the eastern part of the quadrangle in the form of hilltops and ridges whose summits stand at elevations between 1200 and 1250 feet. The western part of this quadrangle was not reduced to a peneplain at this time and consequently it stands somewhat above this level.

The date of origin of the Harrisburg peneplain is not certainly known. It is evidently later than the Schooley peneplain and earlier than certain broad valleys which seem to mark the closing stages of the Tertiary period. For these reasons it has been referred to early Tertiary time, and specifically to the Eocene epoch.

After the Harrisburg peneplain was formed its surface was raised and again erosion began to dissect it. This uplift seems to have been slight in southwestern Pennsylvania in general, but progressively greater northward, so that the Harrisburg surface was deformed, the deformation being indicated by the fact that in the northern part of the State it is 400 to 700 feet higher than in the southern part.

The next succeeding stage is not well marked, but in favorable localities, such as the southeast corner of the Amity quadrangle, there are mere traces of a surface about 100 feet below the Harrisburg level. This stage, like the greater stages of peneplanation, is thought to indicate a pause in the upward movement of the surface. From its development near Worthington, in the Allegheny Valley, it has been named in the Kittanning folio the Worthington peneplain. The origin of this surface probably dates from the latter part of the Tertiary period.

Soon after the Worthington stage another uplift of about 100 feet occurred, followed by a brief period of tranquillity during which the streams cut broad valleys. At this time the broad valley floor now represented by the rock benches of Monongahela, Allegheny, and Beaver rivers was formed, at elevations of 900 to 1000 feet. This feature has been called the Parker strath (Kittanning folio, pp. 3, 11), from Parker, in Armstrong County, Pa., where such benches are well developed. In the Amity quadrangle this stage is now represented by a few small terraces in the valley of Tenmile Creek, at an elevation of about 1000 feet. The formation of this strath probably marked the close of Tertiary time, for on it are found the deposits of the first stage of the Pleistocene epoch.

QUATERNARY PERIOD.

At the close of the Tertiary period another slight elevation of the land occurred, accompanied by cutting of the larger streams in the bottom of the broadened valleys mentioned above. At that time all the streams tributary to Monongahela River flowed through Beaver Valley into Lake Erie. When the ice of the pre-Kansan, or first, stage of Pleistocene glaciation advanced into northern Pennsylvania, ponding took place between the ice front and the southern and western watersheds of Monongahela and other northward-flowing rivers and their tributaries, and on the subsequent lowering of the water it is probable that local ice dams were formed in portions of these valleys. Whatever may have been the cause, there was an extensive ponding of water at 950 to 1050 feet above the present sea level, and in this lake or lakes were deposited the clays, sands, and gravels known as the Carmichaels formation.

The geologic history of western Pennsylvania

during Pleistocene time is described in the Kittanning folio. During the few thousand years which have composed post-Pleistocene time the region has remained substantially at its present level and the effects of erosion, owing to the shortness of the time, have been very slight.

MINERAL RESOURCES.

COAL.

Coal is destined to become the most important mineral resource of the Amity quadrangle. Owing to the depth of the Pittsburg coal below the surface it is mined at only a few places at the present time, but the demand for coal is increasing with its exhaustion near the surface, and more shafts will doubtless soon be sunk to this coal in this quadrangle.

The principal coal beds outcropping in the quadrangle are the Pittsburg, Redstone, Sewickley, Waynesburg, Waynesburg "A," and Washington coals. The Pittsburg bed is the only one now mined for shipment, but the Waynesburg is worked at many country banks, and the Redstone and Sewickley have been opened locally; the Waynesburg "A" probably is worthless, and the Washington coal is, in this area, of no value under existing conditions. Several seams below the Pittsburg have been penetrated by the drill in search for oil and gas.

PITTSBURG COAL.

The Pittsburg coal is the most valuable seam in southwestern Pennsylvania. From all the evidence available it seems to be everywhere of workable thickness and of good quality.

The Pittsburg coal lies at the base of the Monongahela formation. In this quadrangle the outcrop of the bed is only about 15 miles long, but the coal is believed to underlie the entire district except in two small patches, where it is cut by Chartiers and Peters creeks, so that it comprises an area of about 226 square miles.

The outcrop of the Pittsburg coal follows both sides of Peters Creek below Venetia and of Chartiers Creek below McGovern. It also reaches the surface at Meadowlands and extends nearly a mile up several tributary valleys west of Chartiers Creek. Well records show that the bed is present in all parts of the quadrangle. At Washington its average depth is about 450 feet below the valley; at Linden, 250 feet; at Wylandville, 350 feet; at Lone Pine, 330 feet; at Ellsworth, 270 feet; at Zollarsville, 350 feet; at Sunset, 550 feet; at Hackneys, 500 feet; and at Tenmile village, 440 feet. The variation in level of the Pittsburg coal in this quadrangle is shown on the structure map, and the method by which its approximate depth at any point can be determined is explained under the heading "Structure," on page 9.

Few mining operations are as yet in progress in the Amity quadrangle, but the coal is reached by drifts and slopes at a number of points along Chartiers and Peters creeks, and has been shafted to at the Manifold mine, at Ellsworth, and at Three and Four.

The thickness of the Pittsburg coal bed is rather variable, but its structure is fairly constant throughout this region. The arrangement of the benches is shown in the following section:

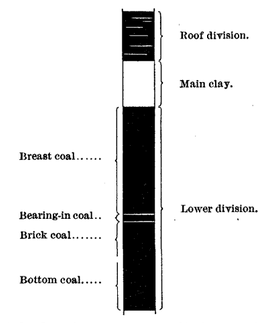

FIG. 4.—Sketch showing names applied to various portions of the Pittsburg coal bed.

The uppermost part of the seam is known as the "roof division," below which lie the "main clay" and the "lower division," the latter being the part of the coal mined for shipment. In the center of the lower division are two very persistent "slate" partings, separated by a thin layer of coal, the group being known to the miners as the "bearing-in coal." This bench is generally chosen by the miners as the best layer on which to work in before undercutting the overlying coal. These bands separate the lower division of the coal into the "breast coal," lying above the "bearing-in coal," and the "brick coal" and "bottom coal," lying below the bands. In most regions the "brick coal" and "bottom coal" are distinct and are separated by a thin binder, but in this quadrangle they can be distinguished in a few instances only.

The greatest thickness of coal known in the quadrangle is recorded in the Moses Smith diamond-drill hole near Bissell, and foots up to a total of 8 feet, excluding all partings. This section is No. 1 in fig. 5 and measures as follows:

Section of Pittsburg coal in Moses Smith diamond-drill hole near Bissell.

	Ft.	In.
Coal	1	4
Black "slate"	0	4
Coal	0	4
Black "slate"	1	4
Fire clay	0	5
Black "slate"	0	9
Coal	0	6
"Slate"	1	3
Coal	5	10
Total	12	1

Sections of the coal at the Ellsworth, Meadowlands, and Nottingham mines are also given for comparison.

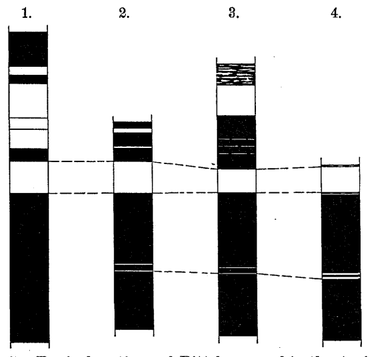

FIG. 5.—Typical sections of Pittsburg coal in the Amity quadrangle.
Scale: 1 inch=5 feet.
No. 1.—Moses Smith diamond-drill hole, near Bissell.
No. 2.—Meadowlands No. 1 mine.
No. 3.—Nottingham mine.
No. 4.—Ellsworth No. 1 colliery.

In quality the Pittsburg coal in Washington County is fair for a bituminous coal. Several analyses have been made and the following average has been calculated for this quadrangle. The average is computed from the composition of 8 samples. In taking these samples a section 2 inches thick was cut from roof to floor across as much of the seam as is mined for shipment, and all partings not included by the miner were thrown out. The sample was then thoroughly mixed and quartered to the bulk desired, sealed in an air-tight jar, and mailed to the chemical laboratory at the United States Geological Survey's coal-testing plant at St. Louis.

Average composition of Pittsburg coal in the Amity quadrangle.
[From 8 analyses made by E. E. Somermeier.]

Moisture	1.86
Volatile matter	35.95
Fixed carbon	56.26
Ash	5.93
Total	100.00
Sulphur	1.12

The proportion of fixed carbon in the coal of the quadrangle is only moderate, but the ash is rather low and the sulphur is not high. On Pigeon Creek the sulphur is nearly always less than 1 per cent, but on Chartiers and Peters creeks it runs from 1 to 2 per cent. The coal, however, would seem to be a steam coal rather than a coking coal. It is coked in the Brownsville quadrangle, but in the Amity quadrangle and farther west it appears in general not to be suitable for this purpose. The low percentage of sulphur on Pigeon Creek indicates that the coal would be worth coking in this part of the quadrangle. The coal appears to deteriorate in quality toward the west. It seems to be a good gas coal.

REDSTONE COAL.

The Redstone coal lies from 20 to 80 feet above the Pittsburg coal and outcrops at a number of points in the northeastern part of the quadrangle, where it seems to be a promising bed. At several points in the vicinity of Hackett and Finleyville it has been opened at country banks, and in one of these a thickness of 40 inches was measured. Elsewhere in the area it is little known. In an abandoned mine shaft between Washington and Meadowlands this coal is reported to lie 20 feet above the Pittsburg bed and 75 feet below the Sewickley, and has a thickness of 2 feet 6 inches.

An analysis of a sample of the Redstone coal from a country bank above the Nottingham mine at Hackett is as follows:

Composition of Redstone coal from country bank near Hackett.
[Analyzed by E. E. Somermeier at U. S. Geological Survey's coal-testing plant at St. Louis, Mo.]

Moisture	1.46
Volatile hydrocarbons	35.56
Fixed carbon	53.39
Ash	9.59
Total	100.00
Sulphur	2.05

This analysis indicates a coal of fair quality, showing that the Redstone coal, where persistent in this region, ranks next in value to the Pittsburg. The quantity of fixed carbon is high; the percentage of ash only slightly exceeds that in the Pittsburg coal, and the amount of sulphur is not great.

SEWICKLEY (MAPLETOWN) COAL.

The Sewickley coal is frequently reported in well records at a distance ranging from 90 to 140 feet above the Pittsburg coal, or near the base of the Benwood limestone. To drillers it is universally known as the "Mapletown" coal, the name coming from Mapletown, Greene County, where the bed is mined. In some parts of Greene County it is a valuable coal, but in the Amity quadrangle little is known regarding it except on Mingo Creek, where it has been opened at two country banks. The measurement at one of these showed 28 inches of clean coal.

The Sewickley coal is reported in a number of oil and gas wells in the quadrangle, and in order to show the intervals to the Pittsburg seam these are tabulated below:

Intervals between Pittsburg and Sewickley coals.
[From records furnished by the oil and gas companies.]

Name of well.	Township.	Depth.	Interval.	Reported thickness of Sewickley coal.
		Feet.	*Feet.*	*Feet.*
Bristor No. 3	Morris, Greene Co	.....	148	
James Thomas	Nottingham	230	102	5
Horn heirs	Morgan	345	120	
A. B. Crumrine	Borough of Deemston	85	123	4
J. L. Thompson No. 2.	.....do	410	96	5
N.T. Clark No. 1.	.....do	315	105	6
Mrs. A. L. Hawkins No. 1.	.....do	298	127	
Luse	Borough of Beallsville	318	116	2
Average interval		.....	117	

No analyses of this seam in the Amity quadrangle have been made, but several analyses from Greene County indicate that the percentage of ash is rather high. The coal is reported, however, to burn freely and to be marketable. In West Virginia it is a valuable seam.

WAYNESBURG COAL.

The Waynesburg coal is best developed in Greene County, but has a wide distribution. It can nearly always be recognized by the presence of a coarse, flaggy sandstone, 20 to 60 feet in thickness, which generally outcrops directly above it. Although occasionally missing, this sandstone accompanies the coal over wide areas. At some places they are separated by a few feet of shale.

In stratigraphic position the Waynesburg coal lies at the top of the Monongahela formation, an interval of 290 to 350 feet above the Pittsburg. This interval diminishes in a general way from Westmoreland and southeastern Greene counties toward western Washington County, but within the limits of the Amity quadrangle there seems to be no uniformity of variation in any particular direction. The least interval known is 292 feet in North Franklin Township, and the greatest interval is 355 feet in East Bethlehem Township, but intervals of 340 to 350 feet are widely scattered. The following table includes all available well records in the quadrangle in which the two coals are reported, and the intervals are measured between the tops of the respective coals. The thickness of the Monongahela formation can therefore be approximately determined in each instance by the addition of 6 to 10 feet for the thickness of the Pittsburg seam.

Interval between Pittsburg and Waynesburg coals.
[From records furnished by the oil and gas companies.]

Name of well.	Township.	Interval.	Thickness of Waynesburg coal.
		Feet.	*Feet.*
Baker	Amwell	337	
Moses Smith diamond drill.	.....do	323	6
Mrs. A. L. Hawkins No. 2.	Borough of Beallsville.	333	3
Eaton Luse heirs No. 1.	.....do	322	3
N.T. Clark No. 1.	Borough of Deemston.	330	4
Mrs. A. L. Hawkins No. 3.	.....do	333	3
L. V. Martindale No. 2.	.....do	330	4
J. L. Thompson No. 1.	.....do	340	2
J. L. Thompson No. 2.	.....do	356	5
J. L. Thompson No. 3.	.....do	335	6
J. L. Thompson No. 4.	.....do	337	4
J. L. Thompson No. 5.	.....do	330	3
Blakely No. 1.	East Bethlehem	335	
Bristor Bros. No. 3	Morris, Greene Co.	345	
Elmas Carey No.1.	Morris, Washington Co.	314	5
Meloy No. 1.	.....do	311	5
J. C. Mounts.	North Franklin	292	
Washington Floral Co.	South Strabane	345	3
N. T. Clark No. 2.	West Bethlehem	334	4
J. C. Martin No. 1.	....do	324	4
Jos. Ross No. 1.	.....do	315	
John C. Sargent No. 2.	.....do	340	
Thompson & Seaman Coal Co. No. 1.	.....do	340	5
S. T. Scott No. 1.	West Pike Run	346	
Average		332	

The outcrop of the Waynesburg coal is represented by the boundary of the Monongahela and Washington formations. Over the northeast quarter of the quadrangle the coal outcrops nearly to the top of the hills in all the valleys tributary to Monongahela River. This is also true east of Zollarsville and south of Beallsville, where the seam has been opened at many country banks. From Nottingham and Somerset townships westward, however, the coal decreases in importance. It is known at many points in the valley of Little Chartiers Creek, but on the hills east of Chartiers Creek it is probably absent or very thin. The coal also reaches the surface at Lone Pine.

In thickness the Waynesburg coal is variable, running from 0 up to 7 feet. A sample section taken at a country bank northeast of Scenery Hill measures as follows (No. 2 in fig. 6):

Section of Waynesburg coal one and three-fourth miles east-northeast of Scenery Hill.

	Ft.	In.
Coal	0	3½
Shale	0	1½
Fire clay	0	6
Coal	1	4
Fire clay	0	11
Coal	2	0
Total	5	2

In general the Waynesburg coal consists of three benches, separated by clays, as represented in the following sections:

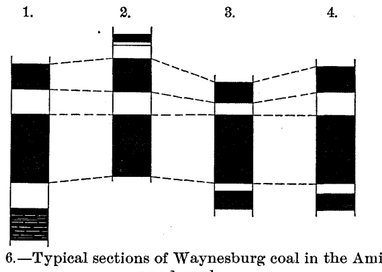

FIG. 6.—Typical sections of Waynesburg coal in the Amity quadrangle.
Scale: 1 inch=5 feet.
No. 1.—Three-fourths mile northwest of Bentleyville.
No. 2.—One and three-fourth miles east-northeast of Scenery Hill.
No. 3.—One and one-fourth miles southeast of Deemston.
No. 4.—One-fourth mile southeast of Lone Pine.

The middle bench is the one most commonly mined, the upper bench being generally rather poor and bony, and the bottom bench generally too thin. In quality the Waynesburg is greatly inferior to the Pittsburg coal. It is a hard block coal of little or no coking value, and usually contains 10 to 20 per cent of ash and 2 to 5 per cent

of sulphur, as indicated by the following analyses of the coal at Zollarsville. The analyses show the compositions of both the upper and main benches.

Analyses of Waynesburg coal at Zollarsville, Pa.
[E. E. Somermeier, analyst.]

Constituent.	Roof coal.	Main bench.
Moisture	2.90	2.27
Volatile matter	31.68	32.39
Fixed carbon	45.76	47.13
Ash	19.66	18.21
Totals	100.00	100.00
Sulphur	4.43	2.89

The upper bench is generally of poor quality, and when the roof consists of shale is sometimes left in by the miners for support.

The Waynesburg coal is used principally by farmers and is considered a fair fuel in sections where no better coal is obtainable.

WAYNESBURG "A" COAL.

The Waynesburg "A" coal is very persistent throughout the county and can usually be recognized by blossoms occurring 50 to 60 feet above the Waynesburg coal. It lies directly above the Waynesburg sandstone and is often associated with thin limestones. The Waynesburg "A" is generally thin, but occasionally its blossom becomes so conspicuous as to be mistaken for the Waynesburg in regions where the Waynesburg sandstone is absent. The only measurements of the Waynesburg "A" coal known in this area amount to 20 inches, 27 inches, and 37 inches, including partings. A section on North Branch of Pigeon Creek in Somerset Township measures as follows:

Section of Waynesburg "A" coal in Somerset Township.

	Ft.	In.
Sandstone.		
Coal	0	10
Clay	0	4
Coal, slaty	0	5
Clay	0	2
Coal and shale	1	4
Total	3	1

The Waynesburg "A" coal has been opened at one or two points, but is not mined.

WAYNESBURG "B" AND LITTLE WASHINGTON COALS.

These names have sometimes been applied to thin coal blossoms occurring between the Waynesburg "A" and Washington seams at various points in Greene and Washington counties. It is true that two coal seams occur in this interval, and in one or two places show thicknesses, as reported, of 1 to 2 feet, but it can safely be asserted that neither of the beds is of any value.

WASHINGTON COAL.

The Washington coal is so known from the locality of its typical occurrence. It lies from 110 to 160 feet above the Waynesburg coal and directly below the Lower Washington limestone. It is much more persistent than any other coal of the Dunkard group and at many places reaches a thickness of several feet, although it is of little value commercially on account of numerous shale partings. At no point in the Amity quadrangle is the bed now worked. The coal is known at a number of points along Little Chartiers Creek, on the ridge between North Strabane and Nottingham townships, and in West Bethlehem Township; and in the vicinity of West Amity and Dunns station it is reported in a number of oil and gas wells.

One of the best exposures of the Washington coal is in the Baltimore and Ohio Railroad cut just west of Washington, where it is 7 feet 1 inch thick and is overlain by the Lower Washington limestone. This section is represented in fig. 7.

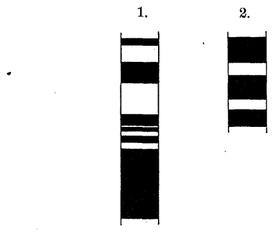

FIG. 7.—Sections of Washington coal in the Amity quadrangle.
Scale: 1 inch=5 feet.
No. 1.—Baltimore and Ohio Railroad cut west of Washington, Pa. (Second Geol. Survey Pennsylvania, Rept. K, p. 52.)
No. 2.—Tenmile village (Second Geol. Survey Pennsylvania, Rept. K, p. 187).

Amity.

Section of Washington coal in Baltimore and Ohio Railroad cut west of Washington, Pa.

	Ft.	In.
Coal	0	3
Clay	0	8
Bituminous shale	0	10
Clay	1	3
Coal	0	5
Clay	0	1
Coal	0	2
Clay	0	2
Coal	0	3
Clay	0	3
Coal	2	9
Total	7	1

At most places where the Washington coal can be seen in the quadrangle it is composed of many alternating layers of coal and shale, and is therefore generally a very inferior coal. In neighboring districts it is at many localities of fair quality and at some places equals the Waynesburg coal in value. No analyses of the coal in this quadrangle have been made.

TENMILE COAL.

About 30 feet above the Upper Washington limestone there occurs at many places a thin coal, which has been erroneously called the "Jollytown coal." This, however, is not the same coal as the Jollytown of Stevenson, which occurs *below* the Upper Washington limestone. The name Tenmile is here suggested for this upper bed. It has been noted at a number of points throughout West Bethlehem and Amwell townships, where it has been opened at several points and found to reach a thickness of 1 to 3 feet. At one point southwest of Tenmile village a thickness of 38 inches was measured. The coal occurs between a black shale and shaly sandstone and contains thin partings.

PETROLEUM AND NATURAL GAS.

DISTRIBUTION IN WESTERN PENNSYLVANIA.

Oil and gas fields are widely distributed in western Pennsylvania. With a few exceptions, they lie in a belt, approximately 50 miles wide, that extends in a northeast-southwest direction across the State from northern McKean County to the southwest corner of Greene County, and thence into West Virginia, as shown in fig. 8. All the fields lie west of the Allegheny Front. In western Pennsylvania all the prominent oil fields lie near the western side of this belt and all the larger

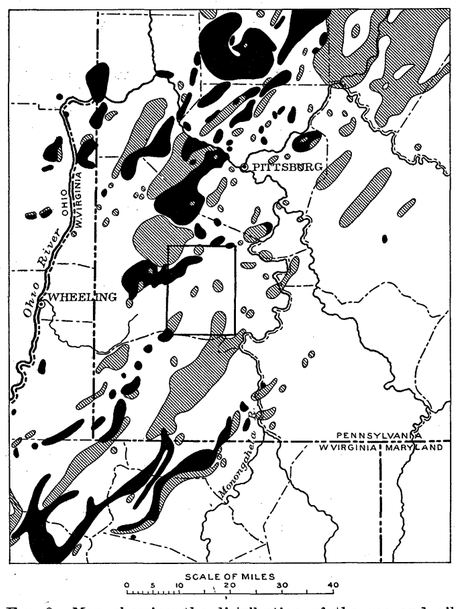

FIG. 8.—Map showing the distribution of the gas and oil fields in southwestern Pennsylvania.
Dark areas, oil; lighter areas, gas. The location of the Amity quadrangle is shown by the rectangle.

gas fields are near its eastern border. The Amity quadrangle lies near the eastern border of the belt, and hence the only oil fields are near the western side of the quadrangle, but gas fields are widely scattered through it. As shown by the figure, the gas field in the southeastern part of the quadrangle is nearly continuous with prominent fields in Greene County.

AGE AND CORRELATION OF OIL AND GAS SANDS.

In western Pennsylvania oil and gas occur in beds of sandstone, or "sands," as they are called by the drillers. The sands have been named and their names have come into common use. In order to show their relations in the Amity quadrangle the following table has been prepared, giving the driller's name for the sand or key rock, its depth above or below the Pittsburg coal, and the geologic formation to which it belongs.

In the Amity quadrangle oil and gas have been found in paying quantities at several of the horizons named. The principal oil sands are the Gantz, Fifty-foot, Gordon, and Fifth sands. The important gas sands are—in addition to the oil sands—the Bayard and Elizabeth. The Big Injun also occasionally contains gas and oil.

Names and correlation of oil and gas rocks.
[+, above Pittsburg coal; —, below Pittsburg coal.]

Formation.	Name applied by driller.	Geologic name.	Approximate maximum thickness in this area.	Approximate average interval to top of bed from Pittsburg coal.	Equivalent sands in neighboring fields.
			Feet.	*Feet.*	
Washington	Bluff sand	Waynesburg sandstone.	60	+390	
Monongahela	Waynesburg, or Pinhook, coal.	Waynesburg coal	5	+330	
	Mapletown coal	Sewickley coal	6	+110	
	Pittsburg coal	Pittsburg coal	10	0	
Conemaugh	Murphy	Morgantown sandstone.	100	—200	
	Little Dunkard sand	Saltsburg sandstone	30	—370	
	Big Dunkard sand	Mahoning sandstone.	100	—500	Hurry-up sand.
Allegheny	Connellsville coal	Upper Freeport coal	6	—600	
	Gas sand	Kittanning or Clarion sandstone.	70	—800	
Pottsville	Salt sand	Pottsville sandstone	180	—900	
MauchChunk	Red rock	Mauch Chunk red shale.	100	—1050	
	Big lime	Greenbrier limestone	60	—1150	
Pocono	Big Injun, or Manifold, sand.	Burgoon sandstone	300	—1200	Mountain sand.
	Squaw sand		130	—1530	
	Thirty-foot sand		170	—1750	Berea, or Butler County, gas sand.
	Gantz		60	—1900	First sand } Hundred-foot sand.
	Fifty-foot		100	—1950	}
Chemung	Nineveh Thirty-foot sand		30	—2050	Second sand.
	Gordon Stray sand		30	—2100	Gray, or Bowlder, sand.
	Gordon sand		50	—2130	Third sand.
	Fourth sand		50	—2200	
	Fifth sand		50	—2300	McDonald sand.
	Bayard, or Sixth, sand		50	—2400	
	Elizabeth sand		20	—2500	
			30	—2700	Warren First sand.
				—2750	Warren Second sand.

In assigning names to the various sands it is not supposed that all of them are continuous sandstone beds underlying the entire area. In fact, if they are like the sandstone beds at the surface in western Pennsylvania they occur mostly as lentils rather than as distinct and persistent beds, and grade laterally into sandy or even clay shales. Evidence of this is frequently reported in well records. Those sands that occur within the group known as the Catskill beds of the Chemung formation seem to be especially irregular and to dovetail into the red beds. In order to show the relations of the various beds, eleven deep-well sections are given on the columnar section sheet, where the geologic interpretations and correlations of the various beds are indicated.

DESCRIPTION OF THE SANDS.

Knowledge of the sands is necessarily fragmentary, but the records of a large number of wells in this territory have been obtained and compared, and from them considerable information has been compiled regarding the thickness, interval, and productiveness of the various beds. The Pittsburg coal, which underlies nearly the entire region, is several feet thick, and hence is easily recognized. For that reason the drillers use it as a datum horizon in measuring to the various sands. The coal lies at a distance ranging from zero to several hundred feet below the mouths of the wells. Unless otherwise stated, all intervals given in the following discussion are from top to top of the respective beds.

Dunkard sand.—A sand occurring in the Conemaugh formation 480 to 540 feet below the Pittsburg and 50 to 100 feet above the Upper Freeport coal has been called the Dunkard sand, from Dunkard Creek, Greene County, near the mouth of which an oil pool was found in 1861, when considerable oil was produced from this sand. In the Amity quadrangle the sand is not productive. It is generally reported as consisting of two members, known as the Little Dunkard and Big Dunkard sands.

Gas sand.—Near the middle of the Allegheny formation occurs an irregular bed of sandstone known to drillers as the Gas sand. It lies from 670 to 840 feet below the Pittsburg coal and varies in thickness from 15 to 70 feet. A small quantity of gas is occasionally encountered in this sand, but not enough to be of commercial importance.

Salt sand.—The Salt sand lies in the Pottsville formation and occurs from 870 to 990 feet below the Pittsburg coal. Its thickness varies from 100 to 170 feet. This sand sometimes contains a little gas, but is otherwise unproductive.

Big Injun sand.—The Big Injun, Mountain, or Manifold, sand lies at the top of the Pocono formation, directly below the Big lime, and corresponds with the Burgoon sandstone on the surface. This sand is always present and is easily recognized by the drillers. It varies in thickness from 250 to over 350 feet, and occurs from 1100 to 1292 feet below the Pittsburg coal. The interval from the coal to this sand, like the intervals to all the underlying sands, thickens from the northwest toward the southeast, owing to an erosional unconformity between the Mauch Chunk and Pottsville formations. In general the Big Injun sand is unproductive, but on the Manifold farm near Washington and at a few other localities it has produced oil. Gas is sometimes found in this sand.

Thirty-foot sand.—In the Pocono formation and about 450 to 650 feet below the top of the Big Injun lies an irregular sandy bed or group of beds, of varying thickness, known as the Thirty-foot sand. It lies from 1560 to 1865 feet below the Pittsburg coal and its maximum thickness is 170 feet. This sand corresponds approximately with the Berea grit of Ohio and the Butler gas sand of northern Pennsylvania. The Thirty-foot sand, so far as known, is not productive in the Amity quadrangle.

Gantz sand.—Next below the Thirty-foot sand is the Gantz, named from a farm at Washington where oil was first derived from a well sunk to it. In position the Gantz ranges from 60 to 180 feet below the top of the Thirty-foot sand and from 1790 to 1985 feet below the Pittsburg coal. The increase of this interval toward the southeast is well illustrated by numerous well records. The thickness of the Gantz sand ranges from 10 to 60 feet. In some wells it thickens up and unites with the Fifty-foot sand, and in such cases the combined sand is known as the Hundred-foot. This bed is supposed to be the same as the First sand of Oil Creek, Pennsylvania. The interval between the top of the Big Injun and the Gantz sands varies from 574 to 751 feet. Unlike the interval to the Pittsburg coal, this does not show any general increase toward the southeast, the variations being irregular over the quadrangle.

The Gantz sand has probably supplied a greater number of productive wells than any other sand in

this county. The great majority of wells in the Washington field have obtained their oil from it, and in the early days of the field it was the source of many gushers, which flowed hundreds and sometimes thousands of barrels the first day. Gas is produced from this sand at many widely scattered points in the quadrangle.

Fifty-foot sand.—Where it is distinct from the Gantz sand the Fifty-foot is separated from it by less than 80 feet of shale, the interval being greatest toward the southeast. Occasionally this sand is 100 feet or more in thickness, though it is generally much thinner. The interval between this sand and the Pittsburg coal varies from 1807 to 2057 feet. The distribution of oil and gas in this sand agrees very well with their distribution in the Gantz, owing partly to the fact that these two sands run together at some places and partly owing to the similarity of their geologic structure. This is probably the lowest sand in the Carboniferous system.

Gordon Stray sand.—Near the top of the Devonian system, interstratified with the upper part of the Catskill red beds, there is at some localities a nonpersistent sand known as the Gordon Stray sand. Although it is not generally classed as one of the productive sands, a number of wells derive gas from it. Beds at about this horizon are also frequently designated Nineveh Thirty-foot, or simply Nineveh, or Stray.

Gordon sand.—In the vicinity of Washington and in general throughout the western part of the quadrangle this is one of the principal oil sands. The name Gordon was taken from the Gordon farm, near Washington, where the sand was first found to be productive in 1885. The sand occurs near the horizon of the top of the Venango oil group and of the Third sand horizon of Oil Creek. In the Gantz well it was penetrated 245 feet below the top of the Gantz sand and is in most wells about the first conspicuous sand below the top of the Catskill red beds. In thickness it varies from 10 to 50 feet, and its interval to the Pittsburg coal is generally between 2000 and 2200 feet. The Gordon probably is not a continuous bed beneath the Amity quadrangle.

Fourth sand.—Like the Gordon Stray, the Fourth sand is irregular and not persistent. It occurs from 40 to 140 feet below the top of the Gordon and from 2100 to 2350 feet below the Pittsburg coal. In a few wells in widely separated parts of the quadrangle this sand has produced gas.

Fifth sand.—The Fifth sand is the lowest sand occurring within the limits of the Catskill beds. It seems to be more persistent than either the Stray, Gordon, or Fourth sands. Generally it has little or no red shale below it. It ranges from 250 to 400 feet below the top of the Gantz sand, and in thickness runs between 10 and 50 feet. The interval between this sand and the Pittsburg coal varies between 2174 and 2409 feet. With the exception of the Bayard and Elizabeth sands, the Fifth has been one of the most important gas-producing sands in the quadrangle, although the great majority of wells which produced gas from it are now abandoned. It has also produced some oil.

Bayard sand.—In the western and northern parts of the quadrangle the wells are in general not deep enough to reach the Bayard sand, and little is known regarding it. In the Zollarsville field, however, a great many wells penetrate this sand, which usually lies 50 to 100 feet below the top of the Fifth sand. Owing to its position, it is sometimes called the Sixth sand, but this name has also been applied to the Elizabeth. The Bayard sand averages 20 to 30 feet in thickness, and the interval between it and the Pittsburg coal ranges from 2231 to 2479 feet. A large part of the gas produced in the Zollarsville field comes from the Bayard sand.

Elizabeth sand.—The deepest productive sand yet proved is the Elizabeth, which lies from 50 to 150 feet below the top of the Bayard. The Elizabeth is reported in nearly every well that reaches its horizon. It is, however, one of the thinnest of the sands, since its thickness rarely exceeds 20 feet, and is generally much less. Where this sand has been penetrated in the Zollarsville field the intervals to the coal range generally from 2470 to 2530 feet, and one interval is as great as 2588 feet. The Elizabeth sand is at present the great gas producer of the Zollarsville field. Gas has also been produced from it in Somerset Township. Beneath the greater part of the Amity quadrangle the sand is unknown, as few wells are deep enough to reach its horizon.

DESCRIPTION OF THE OIL AND GAS FIELDS.

Washington oil field.—This field extends from a point near Claysville, in western Washington County, along the eastern flank of the Washington anticline through South and North Strabane townships nearly to Linden. The principal production of oil in this field was in the years immediately following its discovery, in 1885. The oil has been obtained mostly from the Gantz and Fifty-foot, but a few wells have found oil in the Gordon and the Fifth sands. The deeper sands have not yet been prospected. As explained under the heading Big Injun, that sand proved very productive in the Manifold well; hence the name Manifold sand. The deposit of oil in that sand appears to have been local, but a number of wells on the border of the Washington field have produced gas from this sand in considerable quantities. Many productive gas wells are also located on the flat-topped arch of the Washington anticline in the vicinity of Houston and Canonsburg.

Fonner oil field.—The Fonner oil field is small, producing about 50 barrels of oil a day from the Gantz and Fifty-foot sands. Some gas is also obtained in this field.

Zollarsville gas field.—The great gas field of the Amity quadrangle—the Zollarsville field—lies on the western flank of the Bellevernon anticline in West Bethlehem Township and the borough of Deemston and extends southward a short distance into Greene County. In this field a great deal of gas has been produced, principally from the Elizabeth and Bayard sands, though small quantities are found at all the important sand horizons.

Scattered groups and miscellaneous wells.—The Amity field properly includes only a few scattering gas wells lying on the crest of the anticline in the vicinity of Amity. A number of wells, however, are found along the northeastward extension of the anticline through central Amwell and northwestern West Bethlehem townships, and in central Somerset an unimportant field occurs. In general, gas wells are most abundant on the crest of the principal anticlines, as illustrated by the group in Chartiers and western North Strabane townships and in the vicinity of Canonsburg. An exception to the general rule is found in a small group of wells in what is sometimes known as the Linden field, in the northeastward extension of the Washington oil field, on a sort of structural saddle in the Nineveh syncline.

Besides the groups of wells mentioned, a number of isolated wells in various parts of the quadrangle have encountered considerable gas. The gas in these scattered wells occurs at no particular horizon, having been found in all of the sands from the Big Injun down to a sand below the Elizabeth. The most commonly productive are, however, the Gantz, Fifty-foot, Fourth, and Fifth.

GEOLOGIC RELATIONS OF OIL AND GAS.

General conditions.—A more or less definite relation of oil and gas to geologic structure in the Appalachian field has long been recognized. It has been observed that nearly all the prominent gas pools are situated near the crests of the anticlinal folds, while oil generally occurs part way down the synclinal slope or in the bottoms of the synclines. More frequently salt water occurs in the lowest part of the syncline and the oil is found only above the water level.

The "anticlinal theory" was definitely formulated by I. C. White in a paper on the Mannington oil field and the history of its development (Bull. Geol. Soc. America, vol. 3, April 15, 1892, pp. 187–216). The view is, in brief, that when the rocks are gently tilted the oil, gas, and water contained in them separate out in the order of their densities—water (if present) in the synclines, below; oil next above, and part way up the slope; and gas nearest the crests of the anticlines. In western Pennsylvania and northern West Virginia these deposits lie in belts that run in a general northeast-southwest direction, approximately parallel with the geologic axes.

Considerable doubt has been thrown on the anticlinal theory by the discovery of various apparent exceptions to its application, yet most geologists now accept it, not as absolutely indicating the limitations of the occurrence of oil and gas, but as expressing the general relations of the accumulation of oil and gas to geologic structure, these relations being subject, of course, to many modifying conditions. Some of the most important of these modifying contitions are—(1) the presence or absence of salt water; (2) the continuity and shape of the anticlines, and the direction and angle of their pitch; (3) the porosity of the oil rock (determining its capacity to hold oil) and the direction of the variation of the porosity or density; and (4) the height of the water line, below which the rocks are saturated.

Conditions in Pennsylvania.—The Pennsylvania folios of the Geologic Atlas of the United States which have been thus far published show that the distribution of these deposits corresponds in a certain degree to geologic structure. The gas fields occur generally on the anticlines; the oil fields, part way down the slope if water is present, and in the bottom of the synclines if water is absent. The evidence at present seems to warrant the following generalizations regarding the structural distribution of oil and gas in the Pennsylvania and northern West Virginia fields.

(1) When not affected by other conditions, accumulations of oil and gas show a definite relation to geologic structure.

(2) The longest diameter of the pools generally lies approximately parallel with the axes of the folds.

(3) Where both oil and gas occur they are distributed according to their densities, the oil being found in the lower and the gas in the higher portions of the strata.

(4) When water is present, oil may accumulate in the part of the stratum that lies directly above the water level.

(5) Oil may occur at the crests of anticlinal folds below water level.

(6) When water is absent the occurrence of oil is more irregular and more affected by other conditions. It may accumulate along the synclinal axes or at many points over the slope.

(7) Oil may be found on a structural slope at points where the dip changes from gentle to steep.

(8) Gas occurs most commonly on the higher portions of the anticlinal arches, above the upper level of the oil.

(9) Gas also occurs in widely scattered localities, its place being determined by small local folds or changes in porosity.

Structure is not the only factor determining the occurrence of gas and oil. The structure may be favorable, yet neither oil nor gas may be found. The chief condition other than those stated above is the presence of rock of such character as to act as a reservoir.

RELATION OF OIL AND GAS RESERVOIRS IN THE AMITY QUADRANGLE TO GEOLOGIC STRUCTURE.

Washington field.—The geologic map of the Amity quadrangle affords a basis for certain statements with reference to the distribution of oil and gas which hold good with respect to all the fields. The Washington oil field, for example, is located on the eastern flank of the Washington anticline, which it follows in this quadrangle for a distance of 5 miles. The position of the field agrees closely with that of the lower portion of the steepest grade of the anticlinal slope. Most of the wells are grouped within a belt about a mile wide, their product being derived from a zone that lies just above the line where the structural grade changes from gentle to steeper. A noselike projection from the axis occurs directly east of the Manifold mine, and a projection of the oil field coincides with this. The dip of the rocks here is unusually steep—about 200 feet to the mile, the steepest continuous dip in the quadrangle. Such an occurrence is exceptional in an oil field.

The relations of one small area in the Washington field—that comprising the group of wells west of Gambles—are out of harmony with those of the rest of the field. This area is at the northern end of the Washington field, at a point where the belt takes a bend to the east, and oil occurs even down to the bottom of the syncline. As operations in this part of the Washington field were finished long ago, it is difficult to obtain data for conclusions regarding the cause of the peculiar conditions here. It is suggested, however, that if the rocks directly below this pool are dry the oil may have descended from places farther up the slope, and the relations of this field may be thus accounted for. A most peculiar feature of this field is the occurrence of a number of gas wells in the bottom of the syncline north of Linden. Such an occurrence is exceptional, as gas is more often found on an anticline. The gas here, however, lies above the oil, as would be expected.

The Fonner oil field is on the western slope of the Amity anticline, not far from its crest, in the southwest corner of the quadrangle.

Anticlinal tendency of gas.—A typical illustration of the structural relations of reservoirs of natural gas is afforded by the scattered wells that lie high up on the anticline in Chartiers and western North Strabane and South Strabane townships, where they occur over a broad arch in the strata. The Canonsburg gas field is a continuation of this belt.

Perhaps the best illustration of the anticlinal tendency of gas is afforded by the Amity anticline, between the Greene County line and Kammerer. This anticline is a rather broad arch with gentle dips at the crest, and along it there are a large number of gas wells, grouped in the Amity, Somerset, and smaller fields.

Zollarsville field.—The principal gas field of the quadrangle—the Zollarsville field—can not be said to hold any definite structural position. Instead of lying southeast of Deemston, high up on the anticline, as might be expected, it lies west of the anticline, stretching over nearly the entire synclinal flank southwest of Beallsville, and a few wells occur nearly to the center of the basin. This apparent discrepancy may perhaps be due to a nonparallelism of the oil sands with the Pittsburg coal, but the data in hand do not permit the accurate drawing of contours on any one sand. Near the axis of the syncline, southwest of Beallsville, oil has been struck in several wells.

Summary.—Taking the quadrangle as a whole, the distribution of oil and gas can be said to show a fair agreement with the geologic structure. The most favorable location for oil seems to be on the flanks of the anticlines; that for gas, either on the broad anticlinal arches or on the upper part of the synclinal slopes, always, however, higher up the slope than where the oil is found.

LIMESTONE.

Throughout the Monongahela and Washington formations there are a great many limestone beds; and in the Monongahela such beds make up nearly one-half the thickness of the formation, as illustrated by the record of a drill hole near Bissell, given on page 6. Probably very few of these limestones will ever be of economic importance, as they are generally interstratified with shale and most of them contain large amounts of impurities; but the stone from several beds has been tested and has proved to be suitable for use. The Benwood limestone contains near its base 40 to 50 feet of rock that comprises very little shale, and where accessible this can be used for road metal or railroad ballast. It contains too large a proportion of magnesia to be suitable for making Portland cement. The Sewickley limestone from outside this region has been analyzed and shown to be low in magnesia and other impurities, and this rock is possibly worth considering as cement-making material. The Upper Washington limestone has been analyzed several times, and its composition indicates that it would be suitable, perhaps, for the same use. At several points near Washington this bed is quarried for road metal and railroad ballast. It is burned in many places for fertilizer. Other prominent limestones, which have not been tested, are the Waynesburg, Lower Washington, and Prosperity limestones.

SANDSTONE.

In general the sandstones of the Amity quadrangle are of little value commercially, being mostly flaggy to shaly and unsuitable for building purposes. A number of beds, however, are massive in places, and one or two of them have been quarried. The only important quarry in the Amity quadrangle is at a place between the

National Pike and the railroad tunnel east of Washington. The bed of sandstone quarried at this place lies about 130 feet above the Upper Washington limestone, which outcrops at the entrance to the tunnel. The rock in this quarry is a good, hard, massive sandstone, and is used for curbing and bridge construction.

CLAY AND SHALE.

Two classes of material suitable for brickmaking are found in this territory. They are clay and shale, the former being a surface deposit and the latter composing a large proportion of the hard rocks.

Clay.—Local clay deposits occur in stream valleys in this quadrangle, but so far as could be learned none of these have been used. Similar deposits, however, have been used at a small brickyard just off the northern border of the quadrangle, at a point between Houston and Canonsburg. The clay is a tough, buff, silty layer that caps a rock terrace and is part of the Carmichaels formation. The material is somewhat gritty to the teeth, but contains no pebbles. Below the clay lies 6 inches to 3 feet of gravel, overlying 8 feet of hard clay. The lower bed is not known to have been utilized. The top clay is said to make very good bricks, which are used for building in Canonsburg. This clay occurs at several points in the quadrangle. It may be present on any of the terraces mapped as Carmichaels, but the deposits are probably too thin, too gravelly, and of too small extent to be of commercial importance.

Shale.—Shale of fine texture is abundant in the Dunkard group and occurs over wide areas. In other parts of the country some of these shales have been used, and they have produced bricks of good quality. They might also be used in connection with limestone for making cement. At only two points in the quadrangle is shale known to have been utilized. One of these is in the southern part of the town of Washington, near the Baltimore and Ohio Railroad; the other is near Vance station on the same railroad, a few miles northeast of Washington. Both these plants make a great number of red bricks.

WATER.

The Amity quadrangle contains no large streams, but its entire area is cut up by a fine network of small streams that run in rather deep valleys. All except a few of the large creeks generally run dry in the summer months, and even those which contain water the year round consist for several months of a series of mud holes.

The grade of most of the streams is too slight to make them serviceable for the production of power, but some of the creeks are used as a source of water power, as Bane Creek, at Chambers dam. There are small reservoirs on South Branch of Pigeon Creek just above Three and Four, and on Center Branch near Ellsworth. On Chartiers Creek a few miles southwest of Washington there are several reservoirs owned by the Citizens Water Company and used for supplying the town of Washington with water. The water is collected in four reservoirs, which have a total capacity of 723,000,000 gallons, and is passed through sand filters and pumped to a high-service reservoir that stands 293 feet above the lowest point in the town. The water seems to be of good quality and is well guarded against danger of contamination, although, like other surface waters, it sometimes has a disagreeable odor and taste during the summer months.

Many of the villages of the quadrangle obtain their water supply from wells, nearly all of which are considerably less than 100 feet in depth, the majority being only a few feet deep. The farming communities use both springs and wells. The former are abundant and most of them furnish plenty of water. In the valley bottoms and on the flatter ridges and hilltops wells are more numerous, but in general it is not necessary to go very deep for water. A number of wells drilled for oil or gas have been nonproductive, and the upper part of these have subsequently been utilized as water wells.

Few data are at hand regarding water-bearing strata, for the water wells in this quadrangle are as a rule shallow surface wells and have little or no connection with the underlying rock, and the records of only a few of the oil and gas wells show water horizons. In general the water at any great depth is salty, and is thus not suitable for ordinary purposes.

SOIL.

The soil of Washington County is much better adapted to farming than that of Greene, Beaver, or Allegheny counties. In general it is best in the eastern and northern parts of the quadrangle, where the Benwood limestone and the limestones of the Washington formation are well exposed. These form a thick, strong soil, which makes Washington County one of the best farming counties in this part of the State. The greater regularity of the surface also assists in making Washington County better for agricultural purposes than Greene. On account of the great abundance of limestones and the large amount of lime in the soil little fertilizer is used. Corn, grain, and grass are raised in abundance and in parts of the county productive fruit orchards have been planted. Sheep are raised, though not so many as in Greene County, and the best days of this industry are past. Some of the finest soils lie on the alluvial flats in the valleys of Tenmile and other creeks, and these are often planted with corn. The forests of the area were long ago removed.

March, 1906.

Amity.