INTRODUCTION.

LOCATION AND AREA.

The Foxburg and Clarion quadrangles are in western Pennsylvania, mostly in Clarion County, but partly in Armstrong, Butler, and Venango counties. The quadrangles extend from latitude 41°13' to 41°15' and from longitude 79°10' to 79°45'; the line of 79°30' being the boundary between them. (See fig. 1.) Thus each quadrangle includes one-sixteenth of a square degree of the earth's surface and measures approximately 17 miles from north to south by 13 miles from east to west, and the two quadrangles cover 430.12 square miles. The principal towns of the Foxburg quadrangle are Foxburg, Ementon, Knox, St. Petersburg, Callensburg, and Baldwin. Those of the Clarion quadrangle are Clarion, the county seat, from which the quadrangle takes its name, New Bethlehem, Shaler, and Stratton. The exact latitude and longitude of the boundaries of the quadrangles have been determined from triangulation stations on the tops of some of the prominent hills in the region. These stations have been connected by triangulation with Maryland Heights andnegroad stations of the Coast and Geodetic Survey, computed on United States standard datum. Descriptions of these locations are given in Bulletin 181 of the United States Geological Survey (p. 68).

The general altitude and configuration of the surface of the quadrangles are shown by means of contours drawn on precise levels run by the Pennsylvania Railroad and by the United States Geological Survey. The elevations in the Foxburg and Clarion quadrangles are based on the Geological Survey precise-level line from Franklin to Pittsburgh along Allegheny River. From this line at Parkers and Rodbank lines of primary level were run in 1905 to control the topography of the quadrangles. The bench marks set in that work are described in Bulletin 280 of the United States Geological Survey. The relation of the Foxburg and Clarion quadrangles to other quadrangles of western Pennsylvania is shown by the key map forming figure 1.

APPALACHIAN PLATEAU.

The section of the plateau lying north and west of the Ohio Valley is smaller and drains into that river by way of Scioto, Muskingum, and Allegheny rivers and numerous smaller streams. These streams have both minor and major irregularities through none of them are very indirect. They differ somewhat from the southern tributaries because they drain a lower district and all of them have to carry glacial waters and glacial debris. In eastern and southern Ohio the general slope of the surface is to the northeast, away from Ohio River, and hence the streams there are not so active as those coming into the river from the southeast. But in preglacial times all the streams north of central Kentucky probably flowed northeastward and discharged their waters through the St. Lawrence system. (See fig. 8.) The encroachment of one of the earlier of the great ice sheets closed this northern outlet and established new drainage lines across old divides, so that the upper Ohio and its principal tributaries have been forced into their present courses by glaciation. Indeed, in preglacial times there was no upper Ohio; the valley through which the upper river now flows is in part new and in part made up of sections of several preglacial valleys. As the Foxburg and Clarion quadrangles lie within the area of modified drainage, this feature will be described in detail under the heading "Drainage," on page 3.

The southern boundary of the quadrangles, which is the one-sixteenth parallel of latitude, extends from the Atlantic Coastal Plain on the east to the Allegheny Plateaus, but more recently, by the United States Geological Survey. The elevations in the Foxburg area seem to vary from 42 to 80 feet in the northern part of the State to about 2600 at the southern boundary. Apparently this plateau continues to rise as far as central West Virginia, where it reaches its culmination of 6000 feet. In the northern part of the plateau the drainage of the Potomac drainage basin is but a small stream, but in the southern part, where the rocks are soft, the plateau character has not disappeared. Throughout most of the present plateau here are ridges that rise to a greater height than the surface of this plateau.

The remnants of the higher peneplains slope toward the west, but are separated from the next lower plateau by an escarpment. In Pennsylvania this lower plateau is called the Harrisburg peneplain, because of its development in the vicinity of Harrisburg. It seems to correspond with the Highland plateau of Tennessee and the Lexington Plain of Kentucky. In Tennessee the divided escarpment has a height of 1000 feet, but it is not pronounced in Pennsylvania except along Chestnut Ridge, and there the surface of the upper plateau is so greatly dissected that it can be recognized only with difficulty. In the central part of the State the plateau surface approaches such a state and the escarpment narrows into a mass of hills. The lower plateau seems to rise from an altitude of 700 or 800 feet in Indiana to 1000 feet in Ohio, 1200 to 1300 feet in southwestern Pennsylvania, and 1500 to 2100 feet throughs Pennsylvania and southern New York. The Foxburg and Clarion quadrangles lie in a region in which the lower plateau was widely developed, but the irregularity in the altitude of the hills makes it doubtful whether more than a vestige of the old surface remains. However, its effect on the topography of those quadrangles becomes evident when it is noted how constantly the higher hills rise to nearly the same elevation, and it is visible to the eye in the level skyline seen from any of the higher hills. Although this lower plateau is much dissected in Pennsylvania, it is less so than the upper one, and in Kentucky and parts of Tennessee it is a nearly featureless plain.

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

High terraces and abandoned valleys.—Many of the larger valleys of the province, particularly those tributary to the Ohio, have broad high terraces ranging up to 300 feet above the present stream channel, and lying 300 feet or more below the general upland surface. The terraces, which are all rock shelves covered with gravel, have been described in many of the Survey's bulletins on that region, and have been discussed in numerous other publications. Some of them bear glacial outwash gravel and sands, and have been covered with natural land formations, but all are only slightly related, from which the terraces are to be treated together. The gravel seems to be stream-deposited and commonly attains a thickness of 100 feet. The
It will be seen from the foregoing that on the large streams the upper limit of gravel is commonly a little over 100 feet above the rock floor; that on the smaller streams the deposit is thin and lies at less elevation above the stream, and that on such streams as carry no glacial material, particularly on the Clarion, the deposit is thinner upstream.

The strata of the Appalachian Plateau belong to the Carboniferous system, which is divided into three series, the Mississippian, the Pennsylvanian, and the Permian, the Pennsylvanian series containing most of the coal measures, or "Coal Measures," which make up the largest portion of the Appalachian coal field. The subdivisions of the Mississippian series that are represented in Pennsylvania are the Pococnus group and the Mounts Group formation. The term Pococnus has been used in other fields in a formation sense, but, as will be explained below, it has been found desirable to subdivide the rocks in northwestern Pennsylvania and treat them as a group rather than a formation. The Pennsylvanian series includes the Pottsville, Allegheny, Conemaugh, and Monongahela formations.

The most pronounced fold is a low, broad arch, known as the Cincinnati anticline. The main axis of this fold enters the page 2

<table>
<thead>
<tr>
<th>Formation</th>
<th>Upper Pennsylvania</th>
<th>Lower Pennsylvania</th>
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<tbody>
<tr>
<td>Allegheny</td>
<td>1,015</td>
<td>975</td>
</tr>
<tr>
<td>Conemaugh</td>
<td>1,025</td>
<td>942</td>
</tr>
<tr>
<td>Monongahela</td>
<td>1,035</td>
<td>1,025</td>
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<tr>
<td>Pottsville</td>
<td>1,045</td>
<td>1,035</td>
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<table>
<thead>
<tr>
<th>Place</th>
<th>Miles</th>
<th>Feet per mile</th>
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</thead>
<tbody>
<tr>
<td>Allegheny River</td>
<td>102</td>
<td>80+</td>
</tr>
<tr>
<td>Clarion River, lower 14 miles</td>
<td>11</td>
<td>810</td>
</tr>
<tr>
<td>Conemaugh Creek, next 10 miles</td>
<td>10</td>
<td>725</td>
</tr>
<tr>
<td>Conemaugh River, next 10 miles</td>
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<td>625</td>
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<tr>
<td>Conemaugh River, next 55 miles</td>
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<td>160</td>
</tr>
<tr>
<td>Conemaugh River, next 65 miles</td>
<td>3</td>
<td>725</td>
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</tbody>
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From the above table, and also by reference to the topographic map, it will be seen that every drainage tributary that stems into the Allegheny has a higher gradient near its mouth than it has further back in its course. The topographic map shows also that the lower valleys of these tributaries are gullied and gorges, which widen upstream; and many of the small streams have fixed points near their source. These features are a direct result of a rejuvenation which the Allegheny has undergone in Quaternary time.

The region about Foxburg and Clarion is very well drained, and the hills have rounded tops and gently sloping sides. Surface features of another group consist of stream-cut terraces and abandoned channels, which are well developed along the lower part of the Clarion, and continue down along the Allegheny below the mouth of the Clarion. They are also developed to some extent along Redbank Creek.

The strata of the Appalachian Plateau belong to the Carboniferous and Mississippian systems. The Carboniferous system is divided into three series, the Mississippian, the Pennsylvanian, and the Permian, the Pennsylvanian series containing most of the coal measures, or "Coal Measures," which make up the largest portion of the Appalachian coal field. The subdivisions of the Mississippian series that are represented in Pennsylvania are the Pococnus group and the Mounts Group formation. The term Pococnus has been used in other fields in a formation sense, but, as will be explained below, it has been found desirable to subdivide the rocks in northwestern Pennsylvania and treat them as a group rather than a formation. The Pennsylvanian series includes the Pottsville, Allegheny, Conemaugh, and Monongahela formations.

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runs and several unnamed brooks; and the Clarion from Cherry Run and Licking Creek. A few small streams in the southeasterly quadrangle discharge into Redbank Creek. About twelveth of the Clarion quadrangle drains into Clarion River and one-twelfth into Redbank Creek. Clarion River crosses the northwest corner of the quadrangle in a southwesterly direction. North of the northwest corner of the quadrangle is Mill Creek, which drains the northwest corner, and Piney Creek, which drains the central portion of this quadrangle. Redbank Creek crosses the southwestern corner of the quadrangle from Mayport to New Bethlehem and then, except for one or two northeastern branches, remains south of the quadrangle. The principal streams that flow into the Redbank are, from west to east, Wildcat Run, Leatherwood Run, Leisure Run, and Town Run. The divide between Clarion River and Redbank Creek extends northward from Emsenham station, between Findley, Tamms, and Armstrong townships, and thence southward to its junction with the Monongahela at Pittsburgh. The river is about 325 miles long and its drainage basin has an area of 11,000 square miles. The peculiar course of the river and the arrangement of its tributaries has been generally explained by the cutting away of forest cover from the drainage basins of Clarion River and Redbank Creek.

**RELATION OF PRESENT TO FORMER DRAINAGE.**

In order to set forth clearly the meaning of certain drainage features of the Foxburg and Clarion quadrangles, it will be necessary to make some general reference to Allegheny River. It rises in northern Potter County in passes about 2500 feet above sea level, and flows through McKean County in a northerly direction into New York. The sources of area of its tributaries are within 7 miles of Lake Erie. After flowing some 300 miles through a series of passes in southwestern Pennsylvania it joins the Allegheny at the northeast corner of Warren County, and passes in a southeasterly and southeastern direction through Washington, Fayette, and Armstrong counties, and thence southward to its junction with the Monongahela at Pittsburgh. The river is about 325 miles long and its drainage basin has an area of 11,000 square miles. The peculiar course of the river and the arrangement of its tributaries has been generally explained by the cutting away of forest cover from the drainage basins of Clarion River and Redbank Creek.

Although the entire area is hilly and appears at first sight wholly irregular, there is more or less uniformity in the attitude of the hills. This becomes evident when the elevations are compared with the altitudes of the hilltops. This becomes evident when the surface of the old peneplain is compared with the altitudes of the hilltops. This becomes evident when the surface of the old peneplain is compared with the altitudes of the hilltops.

In a bulletin of the U. S. Geol. Survey 4, the elevations of the older formations at places where they are exposed in the pipes are plotted to scale and the record of this well is plotted to scale on the columnar sheet at places where they are exposed in the pipes. A notable exception is the Cretaceous series of the Carboniferous system. This road is standard gauge as far as Foxburg and thence is a branch of the Baltimore & Ohio Railroad. This is equivalent to saying that the process known as denudation or erosion has been done, and it is only at high water that any boats enter the river. The longest and most formidable river is the Allegheny, which forms an outlet for the product of several coal mines. The making of Allegheny River navigable is a project which, although it has been recognized a hundred feet or so below the Harrisburg and Clarion quadrangles indicates that the present position of the old peneplain surface here is approximately 1500 feet above sea level. The valley of Redbank Creek is, however, used by the Louisville and St. Louis and Southern Railroad. The map published in a bulletin of the U. S. Geol. Survey 4, the elevations of the older formations at places where they are exposed in the pipes are plotted to scale and the record of this well is plotted to scale on the columnar sheet at places where they are exposed in the pipes.

In the region around Pittsburgh the Allegheny is not navigable, and it is only at high water that any boats enter the river. The longest and most formidable river is the Allegheny, which forms an outlet for the product of several coal mines. The making of Allegheny River navigable is a project which, although it has been recognized a hundred feet or so below the Harrisburg and Clarion quadrangles indicates that the present position of the old peneplain surface here is approximately 1500 feet above sea level. The valley of Redbank Creek is, however, used by the Louisville and St. Louis and Southern Railroad. The map published in a bulletin of the U. S. Geol. Survey 4, the elevations of the older formations at places where they are exposed in the pipes are plotted to scale and the record of this well is plotted to scale on the columnar sheet at places where they are exposed in the pipes.

ingly white or gray in color. Rarely the Third sand and some number and prominence of sands found in each well. The bottom of the Fourth is from 30 to 100 feet above correlation of the sands has been discussed more fully in the general settled the stratigraphic position of the more prominent wango formation of the Warren quadrangle.

It is thought that the deposits here doubtfully assigned to the Catskill formation. In the light of later it is believed to represent the Catskill (?) formation.

are there discussed.

In the Foxburg and Clarion quadrangles the Pocono group consists of about 200 feet of gray sandstone and shale extending from the base of the Hundred-foot sand to an unconformity at the top of the Burgoo sandstone (known to the drillers as the Big Injun or Mountain sand).

The Hundred-foot sand has been fairly conclusively shown to be the basal member of this group and to be equivalent to the Beem sandstone of northeastern Ohio and the Venango First and Butler Second sands of Pennsylvania. This bed is one of the great sands of the Appalachian province and underlies thousands of square miles in Ohio, Pennsylvania, and West Virginia. The Hundred-foot sand has a total thickness of about 25 to 100 feet, averaging about 100 feet, and is made up of two or three sandstone layers separated by irregular shale divisions. This is exclusive of the Murrysville or Butler glacial sand, which is about what is generally considered to be the Hundred-foot sand and separated from it by 10 to 60 feet or more of gray or red shale. The Murrysville sand is the uppermost bed of a nearly solid mass of sediments at the base of the Pocono group which in the Foxburg and Clarion quadrangles has an average thickness of about 300 feet. Above this sandstone is soft sandy gray sand having a total thickness of 400 to 500 feet, which is thought to represent the Cuyahoga formation. This sandstone lies above the middle firmer part of the sands amounting to 80 feet in thickness, which is regarded as the lower part of the Sharonville sandstone number of the Cuyahoga formation in Crawford County. It is called First sand by the drillers. The shale above the sandstone is darker and more wet in character and is generally chalky. It is conceded that the shale was laid down in shallow water. Some marine fossils were collected from the shale and have been identified by George H. Girty. They are: Chonetes illoinosis, Rhipidolepis immorfica, and Pterodactylus sp., Pterodactylus indet. On the basis of these fossils and the stratigraphic position and biologic character of the rock, it is believed that this shale belongs to the Meadville shale member of the Cuyahoga formation as developed in northeastern Pennsylvania.

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

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

The Burgoo sandstone, named from Burgoo Creek, in Grant County, West Virginia, is a prominent formation in most of its characters but consists principally of sandstone, though considerable amounts of shale also are included. The formation as mapped, to the drillers, is known as the Burgoo sand and is to be represented in the Foxburg and Clarion quadrangles, which should not be confused with the true red beds, which are marked by any stratum which is always recognizable. Several features are commonly considered in locating the base of the Burgoo sandstone, but the only layer previously referred to is, where present, about 15 feet below the
It is found along the lower 3 miles of Mill Creek and the lower three miles of White and Beaver Creeks, which is the lowest member of the Pottsville formation. Although the Mauch Chunk formation has been eroded from this area, the Pottsville is the youngest and newest formation. The Pottsville is a very resistant layer of rock, similar to the upper portion of the Burgoon sandstone. It has received the name Mercer shale member, because in thickness from 6 to 10 inches. The thickness of the Mercer sandstone varies from 6 inches to 40 feet or more. In the westernmost part of the Foxburg quadrangle the member seems to be represented by only 6 inches to 2 feet of sandy shale. Fossils of the Mercer consist almost entirely of plant remains and are comparatively rare. They are very distinctive. In other shales equivalent to the Mercer are much thicker than in Pennsylvania, and the fish of the member is not different from that of strata above and below, but the member itself may be separated into two or more parts on fossil evidence. The best Mercer exposure in the Clarion quadrangle is in the railroad cut one-half mile west of Mayport, where the section shows 20 feet of shale, in which are two thin beds of coal.

**Pottsville formation**

Although the Mauch Chunk formation has been eroded from this area, and the Pottsville rocks lie unconformably on the Burgoon sandstone, the line of separation is not lithologically clear and fossils are very scarce. In many places thick-bedded sandstones are found both at the top of the Burgoon and at the bottom of the Pottsville. Such sandstones are very similar in all characters, the grains of sand being of approximately the same size, and about equally rounded. The only viable difference is that the sandstones of the Pottsville formation are, as a whole, somewhat thicker bedded, slightly coarser, and approach more closely to pure siliceous sandstones. The similarity of the sandstones, taken in connection with the fact that in the northern part of the State the Burgoon was derived by erosion from the Burgoon sandstone. By reference to figure 4 it will be seen that as far south as Tidioute the top of the Burgoon was entirely removed by the erosion that preceded Pottsville time, and that the shore of the Pottsville was derived by erosion from the Burgoon sandstone. By reference to figure 4 it will be seen that as far south as Tidioute the Pottsville formation comprises the greatest area of any other in the region. The best Mercer exposure in the Clarion quadrangle is in the railroad cut one-half mile west of Mayport, where the section shows 20 feet of shale, in which are two thin beds of coal.

**Allegheny formation**

The Allegheny formation is composed of sandstone and shale, interbedded with coal, clay, and limestone. It is very thick and is the most important formation containing coal. It is divided into three parts: the lowermost part is the Bedroom, the middle part is the Homewood, and the uppermost part is the Olean. The Bedroom is a coarse-grained, massive sandstone, consisting of quartz grains sizes ranging from 0.2 to 2 millimeters. It is a resistant layer of rock, similar to the upper portion of the Burgoon sandstone. It has received the name Mercer shale member, because in Pennsylvania, and the fish of the member is not different from that of strata above and below, but the member itself may be separated into two or more parts on fossil evidence. The best Mercer exposure in the Clarion quadrangle is in the railroad cut one-half mile west of Mayport, where the section shows 20 feet of shale, in which are two thin beds of coal.

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

**Brookville coal.**—Lying above the Pattonville formation and separated from it by a few feet of clay, clay shale, or siltaceous sandstone known as the Brookville clay, is the Brookville coal. This bed is generally too thin to be workable, but in the northeastern part of the area described it reaches a thickness of 45 feet. In the Clarion quadrangle it varies from bituminous shale to shaly coal and hard siltaceous sandstone containing thick partings of shale and pyrite. In the Foxburg quadrangle it is found in shale of sub-bituminous rank, and the bed is of workable thickness only at the southern end of the Foxburg quadrangle, and is the thickest coal below the Vanport limestone. It is nowhere free from iron pyrites or bedded. A jink to 2-inch bolder near the middle of the bed, however, is entirely bright coal. This coal is generally thin, with several feet of white plastic clay beneath.

In the southern part of the Clarion quadrangle, the Lower Clarion coal is too thin to be workable, but in nearly all of the northern part of the territory it ranges from 2 to 4 feet in thickness.

**Upper Clarion coal.**—In the upper division of the Clarion coal is separated from the lower by a body of shale from 3 to 5 inches to 25 feet thick, and a similar body of shale separates it from the Vanport limestone above. In most sections there is no under clay, but the coal rests directly upon a hard, black, non-plastic middle shale. Except in a few places where there is a layer of sandstone, the strata between the Clarion coal consists of a group of dark-gray shales, which on weathering turn black.

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

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

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

In quality the Vanport limestone is very pure, an analysis showing about 95 per cent calcium carbonate, with little magnesium. The rock is dark grey and faintly birefringent. Brachiopods and fragments of crinoid stems and corals, pelecypods, and gastropods are common. All of these fossils indicate that the rock is of oceanic origin. The average thickness of the limestone in the Clarion quadrangle is about 7 feet. Drills report 30 feet of limestone in places, but none of the sections noted in quarters exceeded 8 feet. In the Foxburg quadrangle the average thickness of the Vanport is about 10 feet, and this increases to 30 feet south of Colfleburg. Figure 5 is a typical section of the Vanport limestone.

None of the limestones occurs as a solid unbroken mass. It is broken both horizontally and vertically by joints, which under light cover or in the limestone quarries into large boulders. Near or at the top of the limestone there is com-
monly a bed of chert about a foot thick. This chert, because of its resistance to weathering, indicates the presence of the Vanport at many places where the limestones themselves are not seen.

Immediately above the limestones is a layer of iron ore in the form of siderite or limonite. The cherty layer usually found locally in the vicinity of Squirrel Hill.

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

The evidence in favor of the assumption that the limestones never existed in the areas where they now are absent is given below:

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

**Second:** Near the boundary of such limestone areas the strata below seem to thicken at the expense of the limestones and to occupy its position. For example, 2½ miles south of West Freedom and 1 mile north of Concord Church a coarse sandstone seems to thicken and take the place of the limestone.

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

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

**Fifth:** The Lower Kittanning coal is about midway between the Upper Clarion and the Lower Kittanning coal. Whether this bed should be considered a lower bench of the Lower Kittanning or a separate formation is not clear, but the intervals suggest that the Lower Kittanning splits near Sligo, and that the two benches diverge to the northeast and north throughout the area in which the Middle coal occurs. It is probable that these irregularities in deposition lasted long enough to effect uniformly the formation of the Lower Kittanning coal. The coal thins northwestward, and is very thin or almost absent in a large district containing Edinboro, Foxburg, and Parkers Landing, extending eastward to Knox.

In the northern part of the Clarion quadrangle a coal bed about 15 inches thick lies below the main Lower Kittanning and is separated from it by a 20 to 30 feet of clay and sandstone. In the northeastern part of the Clarion quadrangle also there is a coal bed about midway between the Upper Clarion and the Lower Kittanning. Whether this bed should be considered a lower bench of the Lower Kittanning or a separate formation is not clear, but the intervals suggest that the Lower Kittanning splits near Sligo, and that the two benches diverge to the northeast and north throughout the area in which the Middle coal occurs. It is probable that these irregularities in deposition lasted long enough to effect uniformly the formation of the Lower Kittanning coal. The coal thins northwestward, and is very thin or almost absent in a large district containing Edinboro, Foxburg, and Parkers Landing, extending eastward to Knox.

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

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extends from the top of the Upper Freeport coal to the base of the Pittsburg coal. It is, like the Allegheny basin, very large in size, and the surface is generally above sea level. The proportionate amount of sandstone and shale is less in the Allegheny, but there is relatively less limestone and more coal.

The entire thickness of the Conemaugh is over 300 feet in the central part of the State. Of this, 200 feet, or nearly one-half, is exposed in the Foxburg quadrangle, the highest rocks being found 2 miles southeast of Petersville. The formation capping the highest hills is its ancient glacial bedrock, which contains much fine-grained sandstone, and the second, composed of pebbles of local origin. The thickness of the late glacial drift was deposited by streams which flowed over this ancient glacial bedrock. The cause of their deposition was the great increase of ice which was delivered to the streams by the melting ice. Glacial of the second class was deposited by streams which never carried glacial gravel, and whose load probably did not increase. Their deposition was due to changes of gradient rather than to greater load. Since it is not certain that the two classes of deposits were developed at exactly the same time, and since they differ in origin and probably in other features, they have been given different names. The first class is spoken of as the early glacial gravel, and the second has been called Carmichaeles formation, from its excellent development near the town of that name, which is thought to be older than Kansan gravel because of glacially ground fresh rock of all kinds and hence coarse.

In the Kittanning folio, which treats of an adjoining area on the Allegheny and Clarion rivers, it is inferred that they are synchronous. However, the Carmichaeles formation contains no glacial gravel and therefore was not deposited by a stream overloaded with waste from the great ice sheet. In all probability the unconsolidated pebbles above mentioned have not traveled far. The quartz pebbles were found in a conglomerate (the Black conglomerate) which outcrops in the Clarion basin in Cameron, Elk, and Forest counties. Such pebbles were well rounded in the conglomerate, and the stream which picked them up. The origin of the high terrace gravel will be more fully discussed under the heading "Geologic history."

**QUATERNARY SYSTEM.**

After the deposition of the Carboniferous rocks just described sediments continued to accumulate for an unknown length of time, but before the end of the Carboniferous period the region was uplifted and has remained a land area until the present time. During this long period the surface has been subjected to erosion, and although the streams have carried away much material, they have also made local deposits. Of these deposits practically none remain except those made in Quaternary time. Those consist of alluvial and eolian deposits, of which the former are composed of drifted sand and gravel, and the latter of sand and gravel, and coarse, well-rounded pebbles, mostly under 3 inches in diameter, and in some sections a bed of glacial-fluvial sediments. The thickness of the Wisconsin gravel is as great as 40 feet above the valley bottoms and was laid down at about the time of the last ice age, or very early in the Quaternary period. Similar gravel is found in the lower portions of the Western Pennsylvania formations, and in the upper portions of the Allegheny River in the northern part of the state. Here it is composed of mixed material, which contains much fine-grained sandstone, and the second, composed of pebbles of local origin. The thickness of the late glacial drift was deposited by streams which flowed over this ancient glacial bedrock. The cause of their deposition was the great increase of ice which was delivered to the streams by the melting ice. Glacial of the second class was deposited by streams which never carried glacial gravel, and whose load probably did not increase. Their deposition was due to changes of gradient rather than to greater load. Since it is not certain that the two classes of deposits were developed at exactly the same time, and since they differ in origin and probably in other features, they have been given different names. The first class is spoken of as the early glacial gravel, and the second has been called Carmichaeles formation, from its excellent development near the town of that name, which is thought to be older than Kansan gravel because of glacially ground fresh rock of all kinds and hence coarse.

**CARMICHAELS FORMATION.**

**Extent and composition.**—The principal development of the Carmichaeles formation is in the lower part of the valley of Clarion River. Here it occupies terraces, many of them a mile or more in extent and a few hundred feet above the present streams. The formation consists of unconsolidated gravel, sand, clay, and silt, in which are embedded well-rounded pebbles of quartz and sandstone and a few unrounded pebbles of sandstone. At different places along the valley side these beds are laid down at the mouth of the old Allegheny Valley from Foxburg to and beyond Pittsburg. This deposit was made over 100 feet thick, possibly 200 feet thick, and is overlain by 70 feet of uniform olive shale, with traces of sandstone. The overlying conglomerate which is thought to be older than Kansan gravel, because of glacially ground fresh rock of all kinds and hence coarse.

**RECENT ALLUVIUM.**

The principal development of the recent alluvium is in the lower part of the valley of Clarion River. Here it occupies terraces, many of them a mile or more in extent and a few hundred feet above the present streams. The formation consists of unconsolidated gravel, sand, clay, and silt, in which are embedded well-rounded pebbles of quartz and sandstone and a few unrounded pebbles of sandstone. At different places along the valley side these beds are laid down at the mouth of the old Allegheny Valley from Foxburg to and beyond Pittsburg. This deposit was made over 100 feet thick, possibly 200 feet thick, and is overlain by 70 feet of uniform olive shale, with traces of sandstone. The overlying conglomerate which is thought to be older than Kansan gravel, because of glacially ground fresh rock of all kinds and hence coarse.

**SYNOPSIS OF GEOLOGIC DATA.**

Below the high terraces and above the outwash of the last or Wisconsin glacier, there are at many places small deposits of gravel, particularly on long, sloping promontories on the inner side of the river bends. In some places, as at Clarion Mills, they lie on a rock floor; elsewhere, as at the great bend above Dotter, they are, simply, built terraces. There is less sand, and, as at the great bend above Dotter, there are others, 30, 80, and 120 feet above the water. These terrace deposits may have been produced by intermittent streams, but this seems quite possible, in view of their slight and irregular development, that they are normal stream deposits, which have not been ended away in the course of the stream's downstream and lateral cutting. Their preservation is probably due to the presence of their outcrops being on the inner side of bends of the river, where the stream has swung laterally away from them, and consequently the attack of erosion has not been severe. Similar deposits are found on the Clarion, at Martin's Mill, Stover's Mill, and Callensburg. They are the remaining part of deposits made at various stages of the stream's downstream cutting.
Since the rock strata are approximately parallel and the average to dip away from the outcrop. The expense for draining and knowledge is well brought out by the hundreds of coal prospecting from the elevation of the reference stratum, as indicated by the strike and dip of the beds. The importance of this is well brought out by the beds of the pro-

The altitude, amount, and direction of slope of its surface are such a region are scarcely perceptible in a cross section, so that there is little or no faulting, for the structural features in

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

West of the Fairmount syncline is the Kellersburg anticline. It crosses the area in approximately the course assigned to Brady's Bend anticline in the Pennsylvania reports, but it is a continuation of the Kellersburg anticline, as traced through the Kinnsman and Rural Valley folios. The axis of the anticline enters the quadrangle about midway between Lashwood Station and New Bethelham, follows a slightly serpentine course which passes about one-half mile west of Fronen, and then out through the west boundary of the quadrangle west of Day. The southeast flank of this anticline dips 75 to 175 feet per mile; the northwest flank dips 30 to 125 feet per mile.

West of the Kellersburg anticline there is a broad, shallow depression, the main axis of which extends from Westminster School through Baldi and through Lashwood Station, just west of the Clarion and Rannels quadrangles shown by contours on the Vanport limestone.

The structure of the oil sands, which lie from about 1000 to 1500 feet below the Vanport limestone, is highly complicated. The remaining structural features are the product of (1) irregularities of the surface upon which each layer was deposited; (2) differential settling; (3) warping at various times since deposit. The general dip is probably the result of deformation since the rocks were laid down, but the irregularities of the northern part of the area are somewhat similar to those represented on contour sheets of such regions as that off Cape Henry or the central part of Chesapeake Bay, where there are broad, low swells and shallow depressions of irregular shape and arrangement. It is therefore considered probable that the irregularities of structure are due in part to the slope of the floor upon which each successive stratum was laid down.

The structure of the oil sands, which lie from about 1000 to 1500 feet below the Vanport limestone, which the contours of figure 7 are drawn, is very similar to that of the surface beds, notwithstanding the fact that the two horizons are sepa-

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

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CARBONIFEROUS PERIOD

The Carboniferous period is significant for the formation of coal and the diversification of land plants. It is classified into three stages: the Famennian, the Viséan, and the Frasnian. The strata of this period are known for their rich coal seams and abundant marine fossils. The period spans from about 360 million to 289 million years ago, marking a crucial transition from the oceans to land. The climate was generally warm and humid, providing ideal conditions for plant growth and coal formation.

Throughout the Carboniferous period, the land plants flourished, particularly the seed ferns, which were the dominant vegetation. The carboniferous sea, which covered much of the world, retreated, and the landmasses that would form the continents began to take shape. The Appalachian region was a part of a larger landmass that stretched from western Europe to eastern North America. The geological history of the Appalachian region during the Carboniferous period is characterized by the deposition of sedimentary rocks and the formation of coal deposits.

The Carboniferous period is also known for the emergence of the first land animals, including insects and small amphibians. The evolution of these early terrestrial life forms laid the groundwork for the complex ecosystem that would develop in subsequent periods.

The end of the Carboniferous period marked a significant geological event, the widespread formation of coal deposits in the western United States and Europe. These coal deposits are a testament to the rich vegetation that flourished during this time and the ancient landscapes that have long since vanished.

The Carboniferous period is a time of great geological change, with significant implications for the development of the modern world. The formation of the coal deposits during this period provided a crucial energy source for the industrial revolution and continues to shape the global economy today.
With the completion of the deposits of sandstone, shale, and clay just described, land had taken the place of sea and conditions had become favorable for extensive coal making. This period is marked by the formation of the Lower Kittanning coal, one of the most persistent and uniform beds in western Pennsylvania. The subsidence that caused the burial of the Kittanning sandstone was followed by a number of comparatively frequent changes, which resulted in a series of shales and shaly sandstones interbedded with small coals. Further deposition of shale and sandstone laid the foundation for the Lower Freeport coal, which in turn was buried by silt and sand and was succeeded at the close of the epoch by the formation of the Upper Freeport coal. Conditions during the Conemaugh epoch were less favorable to coal forming than those of the Allegheny, as that, although the period was of long duration, much less coal was formed. The epoch commenced with a subsidence which allowed sand and mud to accumulate to a depth of 90 to 120 feet. This accumulation of shale and sandstone laid the foundation for the Mahoning sandstone member, which was succeeded by a number of beds of shale and sandstone that were later firmed into the Mahoning coal. The Lower Kittanning coal was followed by a number of comparatively uniform beds of coal, which were often highly indurated and consequently resistant. The Upper Kittanning coal developed, probably in local basins. But after the formation of the Kittanning coal was deposited sandstone alternating with shale. Although it is probable that all of these sediments were deposited in the Foxburg and Clarion quadrangles, a large part, probably 90 per cent, has been removed by later erosion. In the northern part of the area the formation is entirely absent, but in the southwestern part, near Petrolia, many hills, one of which extends 200 feet above the Upper Freeport coal, are capped by the Conemaugh. Conditions during the Lower Kittanning coal were more favorable to coal formation than those of the Allegheny, as that, although the period was of long duration, much less coal was formed. The epoch commenced with a subsidence which allowed sand and mud to accumulate to a depth of 90 to 120 feet. This accumulation of shale and sandstone laid the foundation for the Mahoning sandstone member, which was succeeded by a number of beds of shale and sandstone that were later firmed into the Mahoning coal. The Lower Kittanning coal was followed by a number of comparatively uniform beds of coal, which were often highly indurated and consequently resistant. The Upper Kittanning coal developed, probably in local basins. But after the formation of the Kittanning coal was deposited sandstone alternating with shale. Although it is probable that all of these sediments were deposited in the Foxburg and Clarion quadrangles, a large part, probably 90 per cent, has been removed by later erosion. In the northern part of the area the formation is entirely absent, but in the southwestern part, near Petrolia, many hills, one of which extends 200 feet above the Upper Freeport coal, are capped by the Conemaugh.
Numerous small streams were probably involved and possibly several other divisions were entered, but these were the main changes.

KANSAN (5) Epoch

The high stream terraces described above are the remnants of the floors of ancient valleys which had steep sides but broad, flat bottoms. The term Parker strath has been applied to the rock floor under the stream deposits, though the valley bottom represented by the upper surface of the terraces was ever more stream-like. The stream channel was filled at that time with sand and gravel. The evidence that the valley train did not dam itself indicates that at least the upper part of the deposit was laid down by the stream. As the new stream and its tributaries reached approximate equilibrium, the volume of material brought to the Lower Allegheny diminished until the river was no longer able to carry its load, but began to carry away part of the gravel which it had dropped. For a time it considered about in its former deposits and formed the benches lower than the upper limit of gravel, one of the best of which is on the west side of the river 2 miles north of Parker’s Landing and about 80 feet below the highest gravel flood. Then followed the downcutting which produced the present gorge. The Allegheny may have aggraded during this period, perhaps at one time, but no record of such aggradation is preserved except that of the Wisconsin stages. There were three positions several kilometers below the Kansan, and there are deposits of gravel high of about 40 feet above the river which are supposed to be a part of the flood which formed in association with the Wisconsin glaciation. The watercontent characteristic of the quartz pebbles in Cambrian formations does not of itself prove that they were brought from a great distance, for they might have been derived from an existing conglomerate of well-rounded pebbles, but no such cause as this is seen in the Clarion and Foxburg quadrangles, and probably not within 50 miles of them.

The mingling of the gravels of the Clarion and Allegheny rivers at the confluence of the two streams and the concomitance of their upper elevations at that place indicates that they were developed at the same time. It is thought, however, that they are not due to the same cause, but that the gravel terraces on the Clarion were due to the building up of the stream into which it discharged. The mixture of pebbles showing varying degrees of wear—of angular boulders with well-rounded pebbles from a distance—serves to distinguish this deposit from ordinary fluvial gravels in which the pebbles show an approximately uniform degree of rounding. There are many boulderized deposits that have been modified by the stream and which probably lie near their parent beds in the valley wall. As the top of the glacial valley train along the main stream near the deposit on the Clarion grew thicker and lengthened upstream. This process continued until the Allegheny ceased to build up. The evidence that the valley train did not dam the Clarion and produce a lake in the fact that the coarse material is found throughout the valley, especially near the end of the east end of the river. The coarse gravel seen was at the upper end of the terraces at Koonsville. The fact that the upper part of the river was at the same elevation as the other part of the deposit was laid down by the stream.
If the terraces of the Clarion were above the Kansan material, their growth with width, as compared with that of the Allegheny, might be explained by assuming a seaward tilting of the earth's surface in this region, decreasing the gradient of the southward-flowing Allegheny, but there should be other evidence of such a tilt, and such evidence seems to be lacking. Moreover, the close connection of these terraces with the stream and the terraces at many different elevations show that the stream has had much lateral swelling, and it may be that much lateral corrasion took place while the Clarion was waiting for the Allegheny to carry out its load and resume the work of deepened cutting.

The part which requiring hardest work has played in the development of the Clarion Valley has probably been considerable. The rock floor of most of the terraces is sandstone (Pocono or Pottsville), where the sides of the valley above the terraces are composed largely of shale. South of Fort Pittsburg a heavy sandstone lies above the terrace level, and here the valley is so much constricted that for a mile terraces are lacking. However, the terrace surface of the Allegheny has not been accounted for by a difference in underlying rock, for the rocks are practically the same along both rivers.

Some lower terraces, such as the one 60 feet above the river southeast of Caledonia, may also have been cut at a time when the Allegheny was overdeepened with lateral glacial debris, perhaps Illinois. However, it may be that the overdeepening of the Allegheny in early glacial times must have lasted longer than in any later epoch, for the higher terraces are much the wider.

The cause of the abandonment of the channel just southeast of Caledonia is not evident. It is fully 100 feet below the high terrace deposits and only 65 feet above the stream. The present gully through which the river flows appears to have been cut through the narrow head of the river below the terrace, but the neck is short. No evidence was found at this place either of an old channel or of cutting up and superposition.

There are but few terraces on the already above the mouth of the Clarion. The gorge is very narrow, and its narrowness is due principally to its decomposing valley, but the valley may be narrower than it would have been if the rock strata along its walls had been more resistant than the underlying rock near Parkers Landing. Probably the most resistant rocks in the Foxburg quadrangle are the sandstones of the Pottsville and the Poceno in the vicinity of Elizabeth, at Foxburg these sandstones are thinly cross-bedded and much less coherent, while at Parkers Landing both the Pottsville and Poceno are primarily shale. Not only do these formations become more resistant to the north, but they are found a higher elevation. At Parkers Landing the top of the Pottsville is 100 feet higher than the Parker sands, and it is 140 feet higher still at Elizabeth.

The features of the high terraces and abandoned channels of the Foxburg quadrangle may be summarized as follows: we have no evidence of faulting or earth dunes and no evidence of a general peeling off; on the other hand, no features were observed which could not be satisfactorily accounted for in the development of the ordinary work of streams.

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The general ponding of waters; on the other hand, no features were observed which could not be satisfactorily accounted for in the development of the ordinary work of streams. A bulletin on the coal, oil, gas of the Foxburg quadrangle is in press and on this account the present discussion will not be extended as might otherwise be warranted.

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LATE GLACIAL AND RECENT EVENTS

Since the high terraces were formed on extensive deposits have accumulated in the Foxburg and Clarion quadrangles, and the erosion which has taken place is shown clearly in the depths of the river valleys below the high terraces. The earth's surface in this region does not seem to have been deformed at all in Recent times, except possibly, by a general uplift. The rock strata have never been greatly faulted or folded and the old stream deposits have a uniform slope. The deep river gorges indicate regional elevation, but the elevation may have taken place before or during the development of the high terraces.

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

Some of the older channels have been taken in place since early glacial time. One small ditch 60 feet wide at Turnipole is two small streams, the seared palisades of a larger one which since flowed near Clarion River and paralleled the river valley widened as it deepened, and the river itself swung slightly in this direction, which was flowing in a shallow valley because it was unable to cut down as rapidly as the large stream. A gully or wash cut across the narrow divide which separated them and the small stream was abandon.

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

Steel another change involved Mill Creek, in the southeastern part of the Clarion quadrangle. This stream formerly descended into the river at Detter station, having its course parallel to the river, similar to the stream near Turnipole. Here the river swung laterally, captured the small stream, and gave it an outlet 15 miles above its old one. The river absorbed about a mile of Mill Creek valley and is now unusually wide at this place, while immediately above Detter its high isolated hill separates the old valley of the tributary from the present river valley.

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

MINERAL RESOURCES.

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

COAL.

Mines have been opened on no less than eleven different beds of coal, four of which, the Lower Clarion, Kiskiaville, Lower Freeport, and Upper Freeport, are known to be of workable thickness throughout considerable areas. Openings have also been made on the Mercer, Brookville, Foxburg, Clarion, Upper Clarion, Middle and Upper Kiskiaville, and Malachite coals. Figures 11, 12, 13, 14, 15 have shown representative sections of the more valuable beds.

1. Lower Freeport coal, 2 miles southwest of Petrolia.
2. Lower Clarion coal, 3 miles southwest of Petrolia.
3. Upper Freeport coal, 2 miles northwest of Petrolia.
4. Mercer coal, 1 mile northeast of Mercy Mount.
5. Kiskiaville coal, 1 mile northeast of Clarion Junction.
6. Kiskiaville coal, 1 mile southwest of Cranberry.
7. Upper Freeport coal, 2 miles northwest of Sissonville.

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

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

LOWER KISKIAVILLE COAL.

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

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

Wherever seen, the bed has a shale roof and clay floor. Analysis of the coal generally show it to be high in sulphur and moderately high in ash, but it contains less sulphur and is more valuable than the Clarion coal. In the vicinity of Waueling's Corners it is usually free from sulphur and has been used as a blacksmith coal.

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

An attempt under the heading "Geology," there is an area several miles wide between Latherwood and Flemington where
there are no openings on the Lower Kittanning, and in this region the coal is probably not thick enough to be mined profitably. On the other hand, 3 miles south of Clarion, an opening has been made on a coal which appears to be the lower of the two beds assigned to the Lower Kittanning horizon in the geologic sections.

From Sligo northward to Clarion River there appears to be no opening but rather a thin seam in the northern corner of the Foxburg quadrangle. There are two coal beds separated by shale and sandstone near the position of the Lower Kittanning. The upper one is the more valuable and shows very unusual local dips. Near Westlingtowns Corners there is said to be a drop of 30 feet in a distance of 40 rods.

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

**Mingo Townships Coal.**

As already stated, there are in the Clarion quadrangle two coal zones, the Lower and the Upper Kittanning, and a few local mines are opened on each of them. In these mines the coal is from 2 feet to 4 feet 4 inches in thickness, except in a bench on the upper part about 1 mile north of New Bethlehem, where it is 4 feet thick and of excellent quality. In the central and southwestern part of the Foxburg quadrangle the Middle Kittanning is 12 to 20 inches thick, averaging about 16 inches. It is commonly held as a reserve supply for furnaces when they sell the Lower Kittanning. There are several small country banks on this coal.

**Upper Kittanning Coal.**

The Upper Kittanning coal is variable in thickness and quality and is separated by the same "Pit vein," by which it is also known. Except for one or two banks this coal is found only in the southern half of the quadrangle. In most, if not all, of the openings it is thin and dirty, but in a bank 2 miles north of New Bethlehem it is 3 feet thick. Near Petrolia also it is valuable, but in several places its thickness decreases in 200 yards from 5 feet 6 inches to 7 inches.

**Lower Freeport Coal.**

The lower Freeport coal has been worked commercially only in the vicinity of New Bethlehem and has been opened in a number of country banks and small local mines. This coal is above large areas and where present it is generally too thin to be mined. In the New Bethlehem region the coal ranges in thickness from 3 to 7 feet and is of good quality, but it is rarely worked out. Along the railroad southeast of West Freedom the Lower Freeport coal is known as the "Willowton vein." It is mined here in several country banks and its quality is, as usual, very good, but a part of the 2 feet thick seam separates the coal into two benches, each about 2 feet thick.

**Upper Freeport Coal.**

Next to the Lower Kittanning and Clarion coals the Upper Freeport is the most valuable in the Foxburg quadrangle. It is persistent and is of minable thickness in perhaps half of the area in which it occurs. There are no shipping mines on this coal, but in the vicinity of New Bethlehem, just south of the area, it has been mined extensively for the last fifty years, and much of it has been coked. The coke was of superior quality but was unsuited for iron making. The Upper Freeport is found near the tops of the hills; consequently it occurs in many isolated areas and its outcrop is long and irregular. It is extensively worked in the vicinity of Rimsville and northward beyond.

In the Clarion quadrangle the Upper Freeport coal, besides being worked in approximately the same area as the lower, is also opened in the hill 2 mile north by east from Traftonburg, in the ridge 2 miles west of this town; on the Clarion-Redbank divide, 1½ miles south of Smo Gap; and in Myers Hill, 2½ miles south by east from Sligo. All the openings are on small bodies of coal, near the hilltops. The thickness ranges from 3 to 5 feet.

**Kittanning Coal.**

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

**Analyses of coal samples from Clarion quadrangle, Pennsylvania.**

<table>
<thead>
<tr>
<th>Analyses</th>
<th>Upper Freeport</th>
<th>Lower Kittanning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 1</td>
<td>55.79</td>
<td>84.41</td>
</tr>
<tr>
<td>Sample 2</td>
<td>6.19</td>
<td>7.25</td>
</tr>
<tr>
<td>Sample 3</td>
<td>1.53</td>
<td>2.30</td>
</tr>
<tr>
<td>Sample 4</td>
<td>8.81</td>
<td>7.05</td>
</tr>
<tr>
<td>Sample 5</td>
<td>2.35</td>
<td>4.09</td>
</tr>
</tbody>
</table>

**Petroleum and Natural Gas.**

The Clarion and Foxburg quadrangles lie within the great petroleum and natural gas region of western Pennsylvania, and from this area enormous quantities of both of these products have been obtained. Drilling has been begun here as early as 1865, when a well was sunk on Clarion River at the mouth of Deer Creek, in which oil was found. Between 1865 and 1870 a number of oil wells were drilled at that point, some of which flowed oil in small quantities. Several hundred barrels of this oil were shipped to Pittsburgh. The wells were not closed up and much trouble was experienced with salt water; the wells produced only for a short time, until the gas pressure was relieved, and then ceased altogether. The development of the larger pools began at Foxburg in 1869, when the first well in the great Petroleum-Elk City field was completed. Soon after this well was brought in another was drilled at the head of Armstrong Run, in Ferry Township, Armstrong County, which began to produce 22 barrels of oil per day. These wells initiated one of the great oil excitements, which have frequently occurred in Pennsylvania since Drake's discovery of oil at Oil Creek, 1859. The general work was so rapid that as early as 1875 the great Petroleum-Elk City and the Cona Belt fields were fairly well outlined, and more than 1700 wells had been drilled having a total daily production of more than 20,000 barrels. Since then thousands of new wells have been sunk in these quadrangles, both in search of new pools and in restating areas partly depleted during the early oil excitement. This drilling has thoroughly tested most of this territory, though there still remains a number of small isolated areas which may be the bone of some pools of considerable value.

The oil and gas field is found in greater or less quantities in nearly all of the sandstone beds from the base of the Doughton down to and including the oil sands at the top of the Permain formation, which are believed to represent the Freeport sands.

Practically all of the oil and most of the gas found in commercial quantities occur, however, in the Vandalusia oil sands of the Cretaceous (Cockell) formation and the lower Pocono. Named in the northern part of the quadrangles are the Third, Fourth, Fifth, and Sixth sandstone beds, though it is highly probable that several other small pools have been overlooked in areas where better pools occur in other sands. Gas is found in small quantities in the Fifth sand at several points, but the total production from this source is small.
POOLS IN THE THIRD SAND

The sand generally called by drillers the Third sand has been the source of an enormous supply of oil within these quadrangles. This sand has been found to be oil-bearing in a belt from 1 to 3 miles wide extending from Petrolia in the northwest part of the Clarion quadrangle to Elk City in the southeast corner of the Emlenton-Richey Run field. This sand is shown on figures 9 and 10.

In the Foxburg quadrangle the oil in the Third sand is produced primarily from the Hundred-foot sand, and secondly in the Clarion quadrangle from the Murrysville sand. The South Clarion pool, which lies about 200 feet below the Third sand, is developed in the southeast half of the Clarion quadrangle. In the northwestern part of the Clarion quadrangle the oil in the Third sand is associated with salt water and a large high pressure pipe line. So far as known to the writer, however, this water has in no case been drilled for.

POOLS IN THE HUNDRED-FOOT AND THE MURRYSVILLE SANDS

The top of the Hundred-foot sand in the Clarion quadrangle is about 150 feet above the Third sand. This sand has an average thickness of about 100 feet and is divided into two parts. In the Clarion quadrangle no pools are known in this sand and the production of gas is of little importance, being confined to a few scattered wells.

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POOLS IN THE RANDOLPH AND THE HUNDRED-FOOT SANDS

The oil in the Third sand has an average thickness of about 65 feet. Small gas pools have been found in this sand in both quadrangles and in occasional small pools throughout most of that field. This sand is especially productive in the vicinity of Mariaville and in the northwestern part of the Clarion quadrangle. Gas is also found in both of these sands at many places in the northwestern half of the Foxburg quadrangle, but the pools are generally small. In the Clarion quadrangle no oil pools are known in these sands and the production of gas is of little importance, being confined to a few scattered wells.

POOLS IN THE BOWLDOR SAND

The top of the Bowlder sand is about 350 feet above the Third sand. This sand is part of what the drillers call the Second sand, and is assigned by producers.

The Bowlder sand is an example where the oil occurs with salt water almost immediately. In this sand the oil and salt water are produced together in the same well, and the oil is separated from the salt water by a thin layer of water. In the Clarion quadrangle, however, there are several small gas pools and a few scattered wells.

In the Foxburg quadrangle the Bowlder sand is not being developed to any great extent and is grouped by drillers as the Second sand. In so grouping this sandstone phase of the lower Pocono rocks some of the drillers confuse the lower part of the Bowlder sand with the Nineteenth Thirty-foot sand, or, less frequently, with the Bowlder sand. In a few instances the same Red Valley sand has also been applied to what seems to be the lower member of the Hundred-foot sand, but this may be more easily equivalent to the upper member. What many drillers call the Second sand may be more nearly comparable to the Murrysville sand than to the upper member of the Hundred-foot sand.

In both quadrangles the Bowlder sand has little or no commercial value.

FIGURE 15. Structure of the oil-bearing sands and of the rocks at the surface of the Foxburg and Clarion quadrangles. Contour interval 25 ft.

Salt water is present with the oil in the Rosewiner field, and according to the generally accepted antithetical theory of accumulation, the oil, under such conditions, should be found on the side or crest of a anticline. This is true of the Rosewiner pool, but this rule does not hold good for other pools in what is called by drillers the Second sand within the quadrangle.

in other thin sandstones that are thought to belong to the Clarion formation and in the Big Injun sand, but in sufficient quantity to justify exploitation for commercial purposes.

The oil shows of the Foxburg and Clarion quadrangles show no marked relation to the structure of the rocks. Individual pools appear to be somewhat affected by the structure, but these instances of apparent contiguity are so rare and insignifi- cant in comparison to the total productive territory in the quadrangles that in such cases the position and extent of the pools is probably only slightly, if at all, the result of struc- tural influence. The structure of the oil-bearing rocks is shown by contours in figure 12, which also shows, for comparison, the structure in the surface rocks.
The difficulty of explaining the Third sand pools of these quadrangles by the antilithized theory, is made greater by the fact that the data in hand indicate that the Third sand is composed of impure sand and water from a source except in the vicinity of Elk City and outcropping to the Clarion and fossil pools, where sand and plastic varieties, but neither is used extensively.

Shale—The only shale that is being developed commercially at present is the one below the horizons of the Clarion coal. The Clarion, Tilt & Hollow Brick Co. has a pit on this shale about three-quarters of a mile west of New Bethlehem and uses it in construction of hollow building blocks and dense tile. A section of the pit is as follows:

- **Shale, slate, beds, firm, very firm**
- **Carbonaceous layer (Clarion and?)**
- **Shale, slate, firm**
- **Shale, clay, slaty**
- **Shale, clay, slaty, sandy**
- **Shale, slate, very firm**
- **Claystone**

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

**CLAY**

*Clay in Mercer shale member.—In some parts of western Pennsylvania the Mercer shale member contains valuable clay which is presumably equivalent to the Mount Savage clay of Maryland, but in the Foxburg and Clarion quadrangles there is very little clay in this member. There is, however, much clay in the Foxburg clay, and a small deposit has been worked. The member outcrops along the gorges of Clarion and Allegheny Rivers, where it forms a more or less linear system. In the northeastern part of the area is very thin.*

There is no good exposure of thin clay in the Mercer member in the Foxburg and Clarion quadrangles, but small outcrops of thin clay which are probably examples of the Mercer silt bed and the Clarion in the southeastern part of the area are thin.

*Roopville clay.—The Roopville clay is underlain by a bed of clay 1 to 10 feet thick, and the clay is present in many places where the coal is absent. It is generally very sandy and contains a small amount of shale.*

*Clarion clay.—One of the most conspicuous clay beds in the western part of the area is found below the Lower Clarion coal. It is plastic and generally white in weathered outcrop. The thickness ranges between 3 and 10 feet. In some districts the Upper Clarion coal is underlain by clay. A section on the run near the schoolhouse about 2 miles southwest of Pinsey shows 5 feet or more of clay, below which the Clarion coal is present. The clay in the Foxburg and Clarion quadrangles has not been used, so little is known of the clay. It has a thickness of a quarter mile west of New Bethlehem and uses it in construction of hollow building blocks and dense tile. The Brookville coal is underlain by a bed of clay 1 to 10 feet thick, and the clay is present in many places where the coal is absent. It is generally very sandy and contains a small amount of shale.*

*Kittanning clay.—In some locations there are at least four Kittanning coal, each underlain by clay beds. The upper clay beds are usually a bed of clay, the lower are a bed of silt, and the middle a bed of silt. The thickness of the clay beds is less than 100 feet. The clay beds are underlain by a bed of sand and gravel, which is usually 1 to 2 feet thick.*

*Clay and shale.—Clay and shale are exposed in both the Foxburg and the Clarion quadrangles. The clay includes both the float and plastic varieties, although not used extensively.*
from 1 to 2 miles on each side of Clarion River, except north of the town of Clarion. Owing to the height of the clay in the hills, however, only a small portion of the area is actually utilizable by it. The clay is persistent in its occurrence but has a wide range in quality. The best clay is light yellowish brown, fine grained, and moderately hard. Weathered pieces are bluish gray on exposed surfaces and are easily broken.

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

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

<table>
<thead>
<tr>
<th>Analysis of a drift sample of clay from the C. B. McQuon farm.</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultimate analysis:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silica (SiO₂)</td>
<td>65.90</td>
<td>64.60</td>
</tr>
<tr>
<td>Alumina (Al₂O₃)</td>
<td>15.99</td>
<td>15.99</td>
</tr>
<tr>
<td>Potash (K₂O)</td>
<td>9.90</td>
<td>9.90</td>
</tr>
<tr>
<td>Water at 100° C</td>
<td>9.90</td>
<td>10.84</td>
</tr>
<tr>
<td>Total iron oxide (Fe₂O₃)</td>
<td>1.89</td>
<td>1.89</td>
</tr>
<tr>
<td>Magnesia (MgO)</td>
<td>0.37</td>
<td>0.37</td>
</tr>
<tr>
<td>Total base</td>
<td>25.80</td>
<td>25.80</td>
</tr>
<tr>
<td>Total base as oxides</td>
<td>26.10</td>
<td>26.10</td>
</tr>
<tr>
<td>Total oxides</td>
<td>95.20</td>
<td>95.20</td>
</tr>
</tbody>
</table>

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

Footnote—Both of the Freeport coals are usually underlain with clay, but the area of their occurrence in those quadrangles is small and the clay is not valuable. Flint clay is found below the Lower Freeport coal 1 mile west of Pickett and on the ridge 2 miles southeast of Shapathy Church.

It is also locally developed below the Upper Freeport and may be seen near the top of the hill one-fourth mile northwest of Blumberg station. This flint clay occurs in quantities so small that it is not commercially important in the Foxburg and Clarion quadrangles.

**IRON ORE.**

Immediately above the Vaught ("Periferous") limestone member, and coextensive with it, occurs a bed of iron ore sometimes termed "burnstone ore" because of the chert associated with it. The ore is idarite except near the outcrop, where it is altered to limonite. Chance reports that the usual thickness of the ore is from 6 to 14 inches, averaging 10 inches, and that exceptionally the bed is 2, 3, 4, or even 6 feet thick. A partial analysis of ore from a point near Sligo is as follows.

<table>
<thead>
<tr>
<th>Analysis of iron ore near Sligo.</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Metallic iron</td>
<td>36.30</td>
<td>35.00</td>
</tr>
<tr>
<td>Metallic manganese</td>
<td>0.30</td>
<td>0.30</td>
</tr>
<tr>
<td>Siderite</td>
<td>17.50</td>
<td>17.50</td>
</tr>
<tr>
<td>Magnesia</td>
<td>0.20</td>
<td>0.20</td>
</tr>
</tbody>
</table>

The average content of metallic iron is 35 per cent. The ore was obtained in considerable quantity by stripping, and more readily by drifting. The waste from the old workings is in evidence at a great many localities and well marks the ore stratum. The industry died out when the more economically handled and higher grade Lake Superior ores were opened up. With the exhaustion of the latter the deposit in Pennsylvania may again become valuable.

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

Iron ore was mined in eastern Pennsylvania principally between 1830 and 1890. It was smelted in charcoal furnaces of which a few picturesque remains are still evident. The extensive forests of those days were used in making the charcoal, by piling up 20 to 40 cords of wood, covering it with soil, and burning it. About 30 pounds of charcoal were obtained from each 100 pounds of wood, and about 200 bushels of charcoal ore required for each ton of iron.

**LIMESTONE.**

**VARPORT LIMESTONE MEMBER.**

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

<table>
<thead>
<tr>
<th>Analysis of Vaught limestone member.</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium carbonate</td>
<td>95.20</td>
<td>95.20</td>
</tr>
<tr>
<td>Oxide of iron and alumina</td>
<td>1.30</td>
<td>1.30</td>
</tr>
<tr>
<td>Magnesian carbonate</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>Magnesian carbonate</td>
<td>0.30</td>
<td>0.30</td>
</tr>
<tr>
<td>Total carbonates</td>
<td>96.50</td>
<td>96.50</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Analysis of limestone near Foxburg.</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium carbonate</td>
<td>95.20</td>
<td>95.20</td>
</tr>
<tr>
<td>Magnesia</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>Total carbonates</td>
<td>96.90</td>
<td>96.90</td>
</tr>
</tbody>
</table>

Where the limestone is removed from drifts this cherty layer which is usually about 1 foot thick and separated by a parting from the strata below, makes an excellent roof. Formerly the limestone was used in the old iron furnaces as a flux. Very little of it has been used for building, but just now thousands of tons are being used in the construction of the macadamized road from Foxburg to Alum Rock. An analysis of a sample of the limestone by McGeough follows.

<table>
<thead>
<tr>
<th>Analysis of limestone from Vanport member.</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium carbonate</td>
<td>95.20</td>
<td>95.20</td>
</tr>
<tr>
<td>Magnesia</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>Total carbonates</td>
<td>96.60</td>
<td>96.60</td>
</tr>
</tbody>
</table>

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

**FREEPORT LIMESTONE MEMBER.**

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

**SANDSTONE.**

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

The Kittanning sandstone has been used to some extent for building stone. The rock is medium coarse grained, and much of it when freshly cut has a pleasing pinkish color. It weathered, however, a dull gray. There is a quarry about 2 miles south of Strattonville at which this sandstone is cut into cinders. An abundant supply of desirable sandstone for making concrete, for road foundations, bridge abutments, etc., is found throughout the area. A new macadamized road is being built from Foxburg to Alum Rock, and the road bed is first covered with a thick layer of Burgess sandstone, taken from nearby residual bedlows. There seems to be a little rock in these quadrangles which is suitable for dimension stone.

**May, 1910.**