DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS

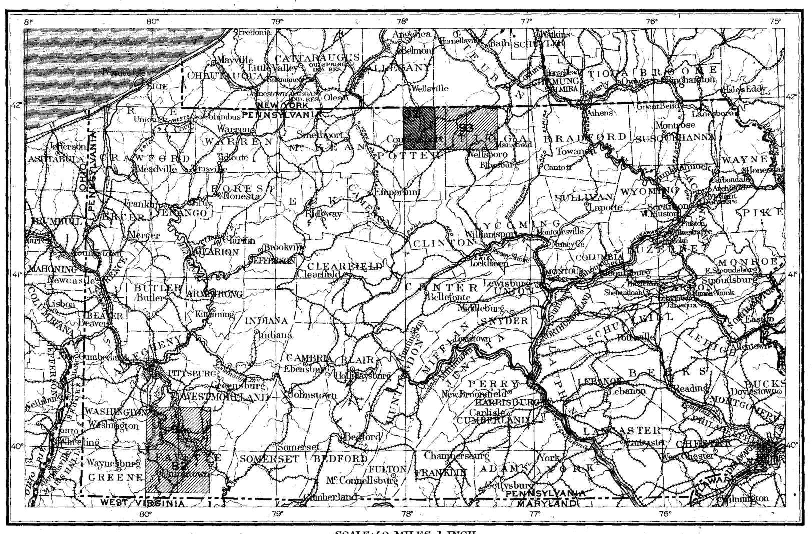
OF THE

UNITED STATES

GAINES FOLIO

PENNSYLVANIA - NEW YORK

INDEX MAP



SCALE: 40 MILES-1 INCH

AREA OF THE GAINES FOLIO

AREA OF OTHER PUBLISHED FOLIOS

CONTENTS

LIBRARY EDITION

GAINES FOLIO
NO. 92

WASHINGTON, D. C.
ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY
GEORGE W. STOSE, EDITOR OF GEOLOGIC MAPS   S. J. KUBEL, CHIEF ENGRAVER
1903

EXPLANATION.

The Geological Survey is making a geologic map of the United States, which necessitates the preparation of a topographic base map. The two are being issued together in the form of an atlas, the parts of which are called folios. Each folio consists of a topographic base map and geologic maps of a small area of country, together with explanatory and descriptive texts.

THE TOPOGRAPHIC MAP.

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

Relief.—All elevations are measured from mean sea level. The heights of many points are accurately determined, and those which are most important are given on the map in figures. It is desirable, however, to give the elevation of all parts of the area mapped, to delineate the horizontal outline, or contour, of all slopes, and to indicate their grade or degree of steepness. This is done by lines connecting points of equal elevation above mean sea level, the lines being drawn at regular vertical intervals. These lines are called *contours*, and the uniform vertical space between each two contours is called the *contour interval*. Contours and elevations are printed in brown.

The manner in which contours express elevation, form, and grade is shown in the following sketch and corresponding contour map:

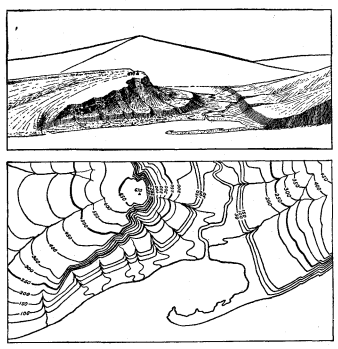


Fig. 1.—Ideal sketch and corresponding contour map.

The sketch represents a river valley between two hills. In the foreground is the sea, with a bay which is partly closed by a hooked sand bar. On each side of the valley is a terrace. From the terrace on the right a hill rises gradually, while from that on the left the ground ascends steeply in a precipice. Contrasted with this precipice is the gentle descent of the slope at the left. In the map each of these features is indicated, directly beneath its position in the sketch, by contours. The following explanation may make clearer the manner in which contours delineate elevation, form, and grade:

1. A contour indicates approximately a certain height above sea level. In this illustration the contour interval is 50 feet; therefore the contours are drawn at 50, 100, 150, 200 feet, and so on, above sea level. Along the contour at 250 feet lie all points of the surface 250 feet above sea; and similarly with any other contour. In the space between any two contours are found all elevations above the lower and below the higher contour. Thus the contour at 150 feet falls just below the edge of the terrace, while that at 200 feet lies above the terrace; therefore all points on the terrace are shown to be more than 150 but less than 200 feet above sea. The summit of the higher hill is stated to be 670 feet above sea; accordingly the contour at 650 feet surrounds it. In this illustration nearly all the contours are numbered. Where this is not possible, certain contours—say every fifth one—are accentuated and numbered; the heights of others may then be ascertained by counting up or down from a numbered contour.

2. Contours define the forms of slopes. Since contours are continuous horizontal lines conforming to the surface of the ground, they wind smoothly about smooth surfaces, recede into all reentrant angles of ravines, and project in passing about prominences. The relations of contour curves and angles to forms of the landscape can be traced in the map and sketch.

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

For a flat or gently undulating country a small contour interval is used; for a steep or mountainous country a large interval is necessary. The smallest interval used on the atlas sheets of the Geological Survey is 5 feet. This is used for regions like the Mississippi delta and the Dismal Swamp. In mapping great mountain masses, like those in Colorado, the interval may be 250 feet. For intermediate relief contour intervals of 10, 20, 25, 50, and 100 feet are used.

Drainage.—Water courses are indicated by blue lines. If the streams flow the year round the line is drawn unbroken, but if the channel is dry a part of the year the line is broken or dotted. Where a stream sinks and reappears at the surface, the supposed underground course is shown by a broken blue line. Lakes, marshes, and other bodies of water are also shown in blue, by appropriate conventional signs.

Culture.—The works of man, such as roads, railroads, and towns, together with boundaries of townships, counties, and States, and artificial details, are printed in black.

Scales.—The area of the United States (excluding Alaska) is about 3,025,000 square miles. On a map with the scale of 1 mile to the inch this would cover 3,025,000 square inches, and to accommodate it the paper dimensions would need to be about 240 by 180 feet. Each square mile of ground surface would be represented by a square inch of map surface, and one linear mile on the ground would be represented by a linear inch on the map. This relation between distance in nature and corresponding distance on the map is called the scale of the map. In this case it is "1 mile to an inch." The scale may be expressed also by a fraction, of which the numerator is a length on the map and the denominator the corresponding length in nature expressed in the same unit. Thus, as there are 63,360 inches in a mile, the scale of "1 mile to an inch" is expressed by $\frac{1}{63,360}$. Both of these methods are used on the maps of the Geological Survey.

Three scales are used on the atlas sheets of the Geological Survey; the smallest is $\frac{1}{250,000}$, the intermediate $\frac{1}{125,000}$, and the largest $\frac{1}{62,500}$. These correspond approximately to 4 miles, 2 miles, and 1 mile on the ground to an inch on the map. On the scale $\frac{1}{62,500}$ a square inch of map surface represents and corresponds nearly to 1 square mile; on the scale $\frac{1}{125,000}$ to about 4 square miles; and on the scale $\frac{1}{250,000}$ to about 16 square miles. At the bottom of each atlas sheet the scale is expressed in three different ways, one being a graduated line representing miles and parts of miles in English inches, another indicating distance in the metric system, and a third giving the fractional scale.

Atlas sheets and quadrangles.—The map is being published in atlas sheets of convenient size, which are bounded by parallels and meridians. The corresponding four-cornered portions of territory are called *quadrangles*. Each sheet on the scale of $\frac{1}{250,000}$ contains one square degree, i. e., a degree of latitude by a degree of longitude; each sheet on the scale of $\frac{1}{125,000}$ contains one-quarter of a square degree; each sheet on a scale of $\frac{1}{62,500}$ contains one-sixteenth of a square degree. The areas of the corresponding quadrangles are about 4000, 1000, and 250 square miles, respectively.

The atlas sheets, being only parts of one map of the United States, are laid out without regard to the boundary lines of the States, counties, or townships. To each sheet, and to the quadrangle it represents, is given the name of some well-known town or natural feature within its limits, and at the sides and corners of each sheet the names of adjacent sheets, if published, are printed.

Uses of the topographic sheet.—Within the limits of scale the topographic sheet is an accurate and characteristic delineation of the relief, drainage, and culture of the district represented. Viewing the landscape, map in hand, every characteristic feature of sufficient magnitude should be recognizable. It should guide the traveler; serve the investor or owner who desires to ascertain the position and surroundings of property to be bought or sold; save the engineer preliminary surveys in locating roads, railways, and irrigation ditches; provide educational material for schools and homes; and serve many of the purposes of a map for local reference.

THE GEOLOGIC MAP.

The maps representing areal geology show by colors and conventional signs, on the topographic base map, the distribution of rock formations on the surface of the earth, and the structure-section map shows their underground relations, as far as known and in such detail as the scale permits.

KINDS OF ROCKS.

Rocks are of many kinds. The original crust of the earth was probably composed of *igneous rocks*, and all other rocks have been derived from them in one way or another.

Atmospheric agencies gradually break up igneous rocks, forming superficial, or *surficial*, deposits of clay, sand, and gravel. Deposits of this class have been formed on land surfaces since the earliest geologic time. Through the transporting agencies of streams the surficial materials of all ages and origins are carried to the sea, where, along with material derived from the land by the action of the waves on the coast, they form *sedimentary rocks*. These are usually hardened into conglomerate, sandstone, shale, and limestone, but they may remain unconsolidated and still be called "rocks" by the geologist, though popularly known as gravel, sand, and clay.

From time to time in geologic history igneous and sedimentary rocks have been deeply buried, consolidated, and raised again above the surface of the water. In these processes, through the agencies of pressure, movement, and chemical action, they are often greatly altered, and in this condition they are called *metamorphic rocks*.

Igneous rocks.—These are rocks which have cooled and consolidated from a liquid state. As has been explained, sedimentary rocks were deposited on the original igneous rocks. Through the igneous and sedimentary rocks of all ages molten material has from time to time been forced upward to or near the surface, and there consolidated. When the channels or vents into which this molten material is forced do not reach the surface, it may consolidate in cracks or fissures crossing the bedding planes, thus forming dikes, or spread out between the strata in large bodies, called sheets or laccoliths, or form large irregular cross-cutting masses, called stocks. Such rocks are called *intrusive*. Within their rock inclosures they cool slowly, and hence are generally of crystalline texture. When the channels reach the surface the lavas often flow out and build up volcanoes. These lavas cool rapidly in the air, acquiring a glassy or, more often, a partially crystalline condition. They are usually more or less porous. The igneous rocks thus formed upon the surface are called *extrusive*. Explosive action often accompanies volcanic eruptions, causing ejections of dust or ash and larger fragments. These materials when consolidated constitute breccias, agglomerates, and tuffs. The ash when carried into lakes or seas may become stratified, so as to have the structure of sedimentary rocks.

The age of an igneous rock is often difficult or impossible to determine. When it cuts across a sedimentary rock it is younger than that rock, and when a sedimentary rock is deposited over it the igneous rock is the older.

Under the influence of dynamic and chemical forces an igneous rock may be metamorphosed. The alteration may involve only a rearrangement of its minute particles or it may be accompanied by a change in chemical and mineralogic composition. Further, the structure of the rock may be changed by the development of planes of division, so that it splits in one direction more easily than in others. Thus a granite may pass into a gneiss, and from that into a mica-schist.

Sedimentary rocks.—These comprise all rocks which have been deposited under water, whether in sea, lake, or stream. They form a very large part of the dry land.

When the materials of which sedimentary rocks are composed are carried as solid particles by water and deposited as gravel, sand, or mud, the deposit is called a mechanical sediment. These may become hardened into conglomerate, sandstone, or shale. When the material is carried in solution by the water and is deposited without the aid of life, it is called a chemical sediment; if deposited with the aid of life, it is called an organic sediment. The more important rocks formed from chemical and organic deposits are limestone, chert, gypsum, salt, iron ore, peat, lignite, and coal. Any one of the above sedimentary deposits may be separately formed, or the different materials may be intermingled in many ways, producing a great variety of rocks.

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

The surface of the earth is not fixed, as it seems to be; it very slowly rises or sinks over wide expanses, and as it rises or subsides the shore lines of the ocean are changed: areas of deposition may rise above the water and become land areas, and land areas may sink below the water and become areas of deposition. If North America were gradually to sink a thousand feet the sea would flow over the Atlantic coast and the Mississippi and Ohio valleys from the Gulf of Mexico to the Great Lakes; the Appalachian Mountains would become an archipelago, and the ocean's shore would traverse Wisconsin, Iowa, and Kansas, and extend thence to Texas. More extensive changes than this have repeatedly occurred in the past.

The character of the original sediments may be changed by chemical and dynamic action so as to produce metamorphic rocks. In the metamorphism of a sedimentary rock, just as in the metamorphism of an igneous rock, the substances of which it is composed may enter into new combinations, or new substances may be added. When these processes are complete the sedimentary rock becomes crystalline. Such changes transform sandstone to quartzite, limestone to marble, and modify other rocks according to their composition. A system of parallel division planes is often produced, which may cross the original beds or strata at any angle. Rocks divided by such planes are called slates or schists.

Rocks of any period of the earth's history may be more or less altered, but the younger formations have generally escaped marked metamorphism, and the oldest sediments known, though generally the most altered, in some localities remain essentially unchanged.

Surficial rocks.—These embrace the soils, clays, sands, gravels, and bowlders that cover the surface, whether derived from the breaking up or disintegration of the underlying rocks by atmospheric agencies or from glacial action. Surficial rocks that are due to disintegration are produced chiefly by the action of air, water, frost, animals, and plants. They consist mainly of the least soluble parts of the rocks, which remain after the more soluble parts have been leached out, and hence are known as residual products. Soils and subsoils are the most important. Residual accumulations are often washed or blown into valleys or other depressions, where they lodge and form deposits that grade into the sedimentary class. Surficial rocks that are due to glacial action are formed of the products of disintegration, together with bowlders and fragments of rock rubbed from the surface and ground together. These are spread irregularly over the territory occupied by the ice, and form a mixture of clay, pebbles, and bowlders which is known as till. It may occur as a sheet or be bunched into hills and ridges, forming moraines, drumlins, and other special forms. Much of this mixed material was washed away from the ice, assorted by water, and redeposited as beds or trains of sand and clay, thus forming another gradation into sedimentary deposits. Some of this glacial wash was deposited in tunnels and channels in the ice, and forms characteristic ridges and mounds of sand and gravel, known as osars, or eskers, and kames. The material deposited by the ice is called glacial drift; that washed from the ice onto the adjacent land is called modified drift. It is usual also to class as surficial rocks the deposits of the sea and of lakes and rivers that were made at the same time as the ice deposit.

AGES OF ROCKS.

Rocks are further distinguished according to their relative ages, for they were not formed all at one time, but from age to age in the earth's history. Classification by age is independent of origin; igneous, sedimentary, and surficial rocks may be of the same age.

When the predominant material of a rock mass is essentially the same, and it is bounded by rocks of different materials, it is convenient to call the mass throughout its extent a *formation*, and such a formation is the unit of geologic mapping.

Several formations considered together are designated a *system*. The time taken for the deposition of a formation is called an *epoch*, and the time taken for that of a system, or some larger fraction of a system, a *period*. The rocks are mapped by formations, and the formations are classified into systems. The rocks composing a system and the time taken for its deposition are given the same name, as, for instance, Cambrian system, Cambrian period.

As sedimentary deposits or strata accumulate the younger rest on those that are older, and the relative ages of the deposits may be discovered by observing their relative positions. This relationship holds except in regions of intense disturbance; sometimes in such regions the disturbance of the beds has been so great that their position is reversed, and it is often difficult to determine the relative ages of the beds from their positions; then *fossils*, or the remains of plants and animals, are guides to show which of two or more formations is the oldest.

Strata often contain the remains of plants and animals which lived in the sea or were washed from the land into lakes or seas or were buried in surficial deposits on the land. Rocks that contain the remains of life are called fossiliferous. By studying these remains, or fossils, it has been found that the species of each period of the earth's history have to a great extent differed from those of other periods. Only the simpler kinds of marine life existed when the oldest fossiliferous rocks were deposited. From time to time more complex kinds developed, and as the simpler ones lived on in modified forms life became more varied. But during each period there lived peculiar forms, which did not exist in earlier times and have not existed since; these are characteristic types, and they define the age of any bed of rock in which they are found. Other types passed on from period to period, and thus linked the systems together, forming a chain of life from the time of the oldest fossiliferous rocks to the present.

When two formations are remote one from the other and it is impossible to observe their relative positions, the characteristic fossil types found in them may determine which was deposited first.

Fossil remains found in the rocks of different areas, provinces, and continents afford the most important means for combining local histories into a general earth history.

Colors and patterns.—To show the relative ages of strata, the history of the sedimentary rocks is divided into periods. The names of the periods in proper order (from new to old), with the colors and symbol assigned to each, are given in the table in the next column. The names of certain subdivisions and groups of the periods, frequently used in geologic writings, are bracketed against the appropriate period names.

To distinguish the sedimentary formations of any one period from those of another the patterns for the formations of each period are printed in the appropriate period-color, with the exception of the one at the top of the column (Pleistocene) and the one at the bottom (Archean). The sedimentary formations of any one period, excepting the Pleistocene and the Archean, are distinguished from one another by different patterns, made of parallel straight lines. Two tints of the period-color are used: a pale tint is printed evenly over the whole surface representing the period; a dark tint brings out the different patterns representing formations. Each formation is furthermore given

Period.		Symbol.	Color.
Cenozoic	Pleistocene	P	Any colors.
	Neocene { Pliocene, Miocene }	N	Buffs.
	Eocene, including Oligocene	E	Olive-browns.
Mesozoic	Cretaceous	K	Olive-greens.
	Juratrias { Jurassic, Triassic }	J	Blue-greens.
Paleozoic	Carboniferous, including Permian	C	Blues.
	Devonian	D	Blue-purples.
	Silurian, including Ordovician	S	Red-purples.
	Cambrian	Є	Pinks.
	Algonkian	A	Orange-browns.
	Archean	Æ	Any colors.

a letter-symbol composed of the period letter combined with small letters standing for the formation name. In the case of a sedimentary formation of uncertain age the pattern is printed on white ground in the color of the period to which the formation is supposed to belong, the letter-symbol of the period being omitted.

The number and extent of surficial formations, chiefly Pleistocene, render them so important that, to distinguish them from those of other periods and from the igneous rocks, patterns of dots and circles, printed in any colors, are used.

The origin of the Archean rocks is not fully settled. Many of them are certainly igneous. Whether sedimentary rocks are also included is not determined. The Archean rocks, and all metamorphic rocks of unknown origin, of whatever age, are represented on the maps by patterns consisting of short dashes irregularly placed. These are printed in any color, and may be darker or lighter than the background. If the rock is a schist the dashes or hachures may be arranged in wavy parallel lines. If the metamorphic rock is known to be of sedimentary origin the hachure patterns may be combined with the parallel-line patterns of sedimentary formations. If the rock is recognized as having been originally igneous, the hachures may be combined with the igneous pattern.

Known igneous formations are represented by patterns of triangles or rhombs printed in any brilliant color. If the formation is of known age the letter-symbol of the formation is preceded by the capital letter-symbol of the proper period. If the age of the formation is unknown the letter-symbol consists of small letters which suggest the name of the rocks.

THE VARIOUS GEOLOGIC SHEETS.

Areal geology sheet.—This sheet shows the areas occupied by the various formations. On the margin is a *legend*, which is the key to the map. To ascertain the meaning of any particular colored pattern and its letter-symbol on the map the reader should look for that color, pattern, and symbol in the legend, where he will find the name and description of the formation. If it is desired to find any given formation, its name should be sought in the legend and its color and pattern noted, when the areas on the map corresponding in color and pattern may be traced out.

The legend is also a partial statement of the geologic history. In it the symbols and names are arranged, in columnar form, according to the origin of the formations—surficial, sedimentary, and igneous—and within each group they are placed in the order of age, so far as known, the youngest at the top.

Economic geology sheet.—This sheet represents the distribution of useful minerals, the occurrence of artesian water, or other facts of economic interest, showing their relations to the features of topography and to the geologic formations. All the formations which appear on the historical geology sheet are shown on this sheet by fainter color patterns. The areal geology, thus printed, affords a subdued background upon which the areas of productive formations may be emphasized by strong colors. A symbol for mines is introduced at each occurrence, accompanied by the name of the principal mineral mined or of the stone quarried.

Structure-section sheet.—This sheet exhibits the relations of the formations beneath the surface.

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

The geologist is not limited, however, to the natural and artificial cuttings for his information concerning the earth's structure. Knowing the manner of the formation of rocks, and having traced out the relations among beds on the surface, he can infer their relative positions after they pass beneath the surface, draw sections which represent the structure of the earth to a considerable depth, and construct a diagram exhibiting what would be seen in the side of a cutting many miles long and several thousand feet deep. This is illustrated in the following figure:

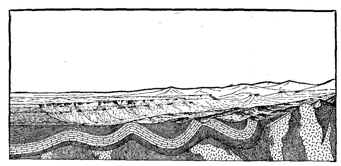


Fig. 2.—Sketch showing a vertical section in the front of the picture, with a landscape beyond.

The figure represents a landscape which is cut off sharply in the foreground by a vertical plane, so as to show the underground relations of the rocks.

The kinds of rock are indicated in the section by appropriate symbols of lines, dots, and dashes. These symbols admit of much variation, but the following are generally used in sections to represent the commoner kinds of rock:

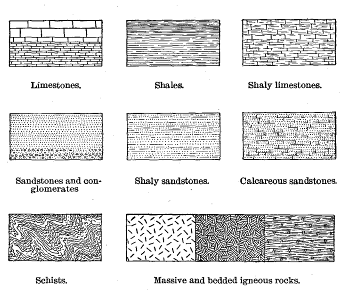


Fig. 3.—Symbols used to represent different kinds of rock.

The plateau in fig. 2 presents toward the lower land an escarpment, or front, which is made up of sandstones, forming the cliffs, and shales, constituting the slopes, as shown at the extreme left of the section.

The broad belt of lower land is traversed by several ridges, which are seen in the section to correspond to beds of sandstone that rise to the surface. The upturned edges of these beds form the ridges, and the intermediate valleys follow the outcrops of limestone and calcareous shales.

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

When strata which are thus inclined are traced underground in mining, or by inference, it is frequently observed that they form troughs or arches, such as the section shows. The arches are called *anticlines* and the troughs *synclines*. But the sandstones, shales, and limestones were deposited beneath the sea in nearly flat sheets. That they are now bent and folded is regarded as proof that forces exist which have from time to time caused the earth's surface to wrinkle along certain zones. In places the strata are broken across and the parts slipped past one another. Such breaks are termed *faults*.

On the right of the sketch the section is composed of schists which are traversed by masses of igneous rock. The schists are much contorted and their arrangement underground can not be inferred. Hence that portion of the section delineates what is probably true but is not known by observation or well-founded inference.

In fig. 2 there are three sets of formations, distinguished by their underground relations. The first of these, seen at the left of the section, is the set of sandstones and shales, which lie in a horizontal position. These sedimentary strata are now high above the sea, forming a plateau, and their change of elevation shows that a portion of the earth's mass has swelled upward from a lower to a higher level. The strata of this set are parallel, a relation which is called *conformable*.

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

The horizontal strata of the plateau rest upon the upturned, eroded edges of the beds of the second set at the left of the section. The overlying deposits are, from their positions, evidently younger than the underlying formations, and the bending and degradation of the older strata must have occurred between the deposition of the older beds and the accumulation of the younger. When younger strata thus rest upon an eroded surface of older strata the relation between the two is an *unconformable* one, and their surface of contact is an *unconformity*.

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

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

Columnar section sheet.—This sheet contains a concise description of the rock formations which occur in the quadrangle. It presents a summary of the facts relating to the character of the rocks, the thicknesses of the formations, and the order of accumulation of successive deposits.

The rocks are described under the corresponding heading, and their characters are indicated in the columnar diagrams by appropriate symbols. The thicknesses of formations are given in figures which state the least and greatest measurements. The average thickness of each formation is shown in the column, which is drawn to a scale—usually 1000 feet to 1 inch. The order of accumulation of the sediments is shown in the columnar arrangement: the oldest formation is placed at the bottom of the column, the youngest at the top, and igneous rocks or surficial deposits, when present, are indicated in their proper relations.

The formations are combined into systems which correspond with the periods of geologic history. Thus the ages of the rocks are shown, and also the total thickness of each system.

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

CHARLES D. WALCOTT,
Director.

Revised January, 1902.

DESCRIPTION OF THE GAINES QUADRANGLE.

General Geology by Myron L. Fuller. Pleistocene Geology by William C. Alden and Myron L. Fuller.

GENERAL RELATIONS.

Location and area.—The Gaines quadrangle is situated in northern Pennsylvania, immediately south of its northern boundary and about midway between the eastern and western limits of the State. It embraces the area between latitude 41° 45′ on the south and 42° on the north, and between longitude 77° 30′ on the east and 77° 45′ on the west, and includes one-sixteenth of a square degree of surface. Its north-south length is about 17.2 miles, its breadth about 13 miles, and its area 222.5 square miles. It includes portions of Potter and Tioga counties, and is named for the town of Gaines, situated on Pine Creek, in the southeast portion of the area, and the center of operations for the small oil field of the same name lying just outside of the quadrangle on the south.

Relations to the Appalachian province.—The Appalachian province, which extends from New York on the north to central Alabama on the south, and from the Atlantic Coastal Plain on the east to the lowlands of the Mississippi Basin on the west, has been subdivided into three divisions. The eastern division is marked by the more or less rounded soil-covered ridges of altered sedimentary or igneous rocks of the Appalachian Mountains proper; the central division, known as the Appalachian Valley, by the long, straight, or gently curved ridges produced by the erosion of strongly folded and faulted sedimentary rocks; and the western division, known as the Allegheny Plateau, by the deeply trenched plateau-like uplands existing over the region of gently folded rocks lying north and northwest of the central division. It is to this region of gentle folds and plateau-like topography that the Gaines quadrangle belongs, the southeast corner as measured across the strike of the folds to the south being about 40 miles from the Allegheny Front, which constitutes the western margin of the Appalachian Valley. (See fig. 7, Illustration sheet.)

TOPOGRAPHY.

Drainage.—The quadrangle is drained by two principal streams—Cowanesque River and Pine Creek, which flow eastward, parallel to the trend of the rock folds—and by a considerable number of streams tributary to them, flowing transverse to the trend of the folds. Cowanesque River joins Tioga River near the New York State line, the latter stream flowing northward and joining Chemung River near Corning, whence the waters are carried back southward and added to those of the North Branch of the Susquehanna, in the northern part of Bradford County, Pennsylvania. Thence they flow in a somewhat devious course across the Appalachian ridges, and eventually empty into Chesapeake Bay.

Pine Creek originally joined Tioga River and followed the same course; but later, through the indirect agency of the ice sheet that covered the region in early Pleistocene time, it was turned from that course into a new and much shorter channel, which led its waters southward to the West Branch of the Susquehanna, near Jersey Shore. From here the waters flow eastward and southward until they unite with the North Branch near Sunbury, and continue to Chesapeake Bay, as before.

A noticeable feature of the region is the greater average length of the southward-flowing streams as compared with that of those flowing northward. The quadrangle is too small to exhibit this to good advantage, but reference to fig. 6 will show that it is a conspicuous feature, not only of the tributaries of Cowanesque River and Pine Creek, but of other streams of the region as well. On an average the lengths of the southward-flowing streams are at least a third or a half greater than those of the northward-flowing streams.

Of the two principal streams of the area, Pine Creek is the larger, and notwithstanding the fact that the greater portion of its course lies outside the limits of the quadrangle, it drains somewhat more than half of the area.

The western border of the quadrangle lies along the divide which separates the waters flowing to the Susquehanna from those flowing northward, by Genesee River, to Lake Ontario and the St. Lawrence. No streams of considerable size belonging to the latter drainage system are found within the limits of the quadrangle, but a few small runs head near the western border of the area in Ulysses and Bingham townships.

The development of the drainage system will be considered under the head of Physiography.

Relief.—Briefly stated, the topography or relief of the quadrangle is that of a dissected plateau, or, in other words, a plateau that has been cut by streams until the valley bottoms lie far below the general level of the uplands. The general level of the plateau is indicated by the flat tops of the mountainous belts of the quadrangle, the elevations of which vary from 2220 to 2610 feet. Two of these belts enter the quadrangle from the east, the northernmost, or the Cowanesque mountain belt, entering near Westfield, and the southernmost, or the Pine Creek mountain belt, entering near Gurnee, in the northern portion of Gaines Township.

North of the Cowanesque mountain belt, and also between it and the Pine Creek mountain belt, there are broad, belt-like areas of rounded hills standing at distinctly lower levels. Within these areas the hills, although showing almost nothing of the plateau character, appear to rise to a somewhat uniform elevation of from 2000 to 2100 feet. Relatively speaking, therefore, these areas may be termed lowlands. They are most noticeable in the eastern and northern portions of the quadrangle, and are due to the presence of softer and more readily eroded rocks, which have been brought to the surface by anticlinal folds or arches. In the northwestern and western portions of the area the lowland belts have disappeared, and the uplands extend over most of the surface. This is largely due to the fact that the anticlinal arches were not sufficiently pronounced to bring the softer beds to the surface, where they could be attacked by the streams. The distance of portions of the area from prominent streams is also a retarding factor in the erosion.

The contrast between the steep sides and the flat tops of the prominences of the mountain belts is one of the most marked features of the topography of the quadangle. For instance, along Pine Creek, Long and Phoenix runs, and Genesee Forks, the land in some places rises from 800 to 1000 feet in less than a mile; but when the crest is once attained the country often presents a broad, flat surface which may extend for a mile, or even two miles, with a change of elevation of only 20 to 60 feet. This evenness of level is strikingly shown in the views presented from the tops of these flat-topped crests. Everywhere along the mountain belts the crests appear to reach the same general level, and their irregularities, which when seen close at hand sometimes seem to be important, appear in their true nature when viewed from a distance—as simply slight undulations in the upland surface. When thus viewed, all except the nearest of the valleys, though perhaps a thousand feet deep, disappear from sight, and one apparently looks out over a very gently undulating, almost featureless plain covered with forests—a close reproduction, doubtless, of the appearance of the original plain before the erosive action of the streams had begun to cut into it and to wear it down until only the flat-topped ridges and mountains remain to show the position of the old land surface. A level or very gently undulating surface, such as this must once have been, is known as a peneplain.

The origin of this peneplain, as well as that of the present mountainous surface, was due to erosion, which, took place however, under widely different conditions in the two cases. Both will be considered under the heading "Physiography."

Though, as has been stated, the hardness of the rocks has been the most important factor governing the production of the broader features of the present topography, yet the character of the streams has been the controlling factor in the production of the minor features. The large streams, especially those which have been at work for long periods, have eroded wider and flatter-bottomed valleys than the smaller and younger streams. Thus the smaller streams, such as Shin Hollow, Johnson Brook, Meeker Hollow, and the tributaries of Long and Phoenix runs and of Genesee Forks, etc., flow in sharp, V-shaped valleys, while Cowanesque River, Pine Creek, Long Run, Genesee and North forks, Mill Creek, etc., flow in whole or in part upon flat-bottomed valleys, and are bordered by more or less well-defined flood plains. There is also a tendency to a more rounded topography in the vicinity of the larger streams, though this is not often conspicuous, because of the greater hardness of the rocks near the principal streams.

DESCRIPTIVE GEOLOGY.

Formations represented.—The rocks exposed at the surface in the Gaines quadrangle are of two types. They include not only firm, hard beds which everyone at once recognizes as rocks, but also loose, unconsolidated deposits of silt, sand, gravel, glacial till, etc., which are likewise considered by geologists as rock, and which occur as fillings in the valleys, or as a thin mantle over the general surface of the area.

The materials of these unconsolidated or surficial rocks were derived mainly from the underlying hard rocks, or from closely adjacent rocks to the north. A small percentage, however, came from greater distances, some even being brought from sources as distant as Canada. In part these materials were laid down in streams, and in part by the direct action of an ice sheet similar to that now covering the surface of Greenland, which, starting in the far north during the early part of the present geologic period, spread out over nearly the whole of the northeastern portion of North America. The entire quadrangle, with the exception of a small portion of the extreme southwest corner, was covered by this sheet. Neither the materials deposited by the ice nor those deposited by the streams leading away from it reach any considerable thickness at any point within the quadrangle, and the deposits laid down since the retreat of the ice are of even less geologic importance, being confined to a thin coating of silt forming the surface of the flood plains along the larger streams and to a few small torrent and marsh deposits.

The materials of which the consolidated sedimentary rocks are composed were originally derived, in the form of gravel, sand, and mud, from the wearing away of an old land mass, under the action of streams or waves, the resulting waste being carried to the margin of the seas then existing, and there deposited as stratified or sedimentary beds. As time has elapsed, these beds have been gradually consolidated by the deposition of chemical matter about the grains of which they are composed, the material thus deposited acting as a cement to bind the grains together into a solid mass.

In northern Pennsylvania and southern New York these sedimentary rocks reach a thickness of many thousand feet, and although only a small part of the whole can be seen at any one point, or even within a single quadrangle, the deep cutting of the streams, taken in connection with the moderate tilting of the beds, has been sufficient to expose, in the area under discussion, a thickness of nearly 2500 feet of rocks of Devonian and Carboniferous age. These exhibit many alternations of sandstone, shale, impure limestone, etc., but they may be so grouped by their lithologic features as to form six formations, each marked by its own characteristic and distinctive features. In ascending order, these lithologic divisions are the Chemung, Cattaraugus, Oswayo, Mauch Chunk, and Pottsville formations. The first two are of Devonian age, the third is in part Devonian and in part Carboniferous, and the remainder are Carboniferous. Their general characters and relative thicknesses are shown graphically in the geologic column at the end of the folio, and are described in detail in the following paragraphs.

DEVONIAN FORMATIONS.

Chemung formation.—The name Chemung is here applied to a lithologic division, which includes the alternating shales, sandstones, and thin limestones, having as its base (not exposed in the Gaines quadrangle) the bluish shales of the Portage formation, and at the top the red shales or the red or green sandstones of the Cattaraugus formation. It should be clearly distinguished from the paleontologic division called Chemung, which includes both the marine fauna of the lithologic Chemung and the fresh- or brackish-water fauna of the overlying Cattaraugus and the lower portion of the Oswayo formation.

The Chemung is the lowest of the formations encountered at the surface in the Gaines quadrangle, and is made up largely of a series of calcareous and shaly sandstones, alternating with thick beds of soft shale and thin seams of impure limestone. Gray, greenish-gray, and buff are ordinarily the predominating colors of both the sandstones and the shales. The calcareous sandstone is of the type which has come to be considered especially characteristic of the Chemung, namely, a somewhat coarse, friable sandstone crowded with open cavities left by the solution of the fossil shells it originally contained.

Where the Chemung is exposed at the surface, the sandstones sometimes appear to constitute the predominating rock; but this is probably due largely to the fact that they are more resistant to disintegration than the soft and finely laminated shales which, as the records of the wells that have been drilled for oil in the quadrangle show, constitute the larger portion of the formation. The calcareous sandstones grade on the one hand into typical gray and somewhat flaggy sandstone, and on the other into more or less impure limestone.

The limestones are of two distinct types. The first, and most common, is a dark bluish-gray, sometimes almost black, argillaceous limestone, rich in brachiopod fossils, and occurring in beds usually only a few inches but sometimes several feet in thickness. The second type may be of gray, bluish-gray, or pinkish color, and is composed almost entirely of the fragments of small crinoids, in some instances exhibiting in their arrangement a typical cross-bedded structure. This limestone is finely exposed to a thickness of several feet in the west bank of Elk Run, about 1½ miles southwest of Gaines, but has been recognized only by fragments within the area of the quadrangle itself. It occurs in the upper portion of the Chemung, near its junction with the overlying Cattaraugus formation.

The general character of the Chemung sediments appears to be fairly uniform throughout. Beds of sufficiently distinct lithologic character to permit tracing, if they were continuous, are known, as for example, the limestone just described; but no beds have been seen which could be recognized at widely separated points. This absence of traceable beds adds greatly to the difficulty of working out the geologic structure of the region.

The general character and rapid alternations of sandstones and shales in the upper portion of the

Chemung formation, and also in the lower portion of the overlying Cattaraugus formation, are well brought out in the following record of a well drilled for oil near the present upper railroad station at Gaines:

Record of Billings well No. 1, Gaines, Pa., 1884,[1]

	Thickness in feet.	Depth in feet.
Cattaraugus formation, including Chemung-Cattaraugus transition beds:		
Conductor	13	13
Sandstone, hard, blue	1	14
Shale, blue	4	18
Red rock	20	38
Slate	23	61
Red rock	48	109
Shale, blue	20	129
Red rock	40	169
Sandstone, gray	2	171
Red rock	22	193
Slate	24	217
Red rock	23	240
Slate and shells	15	255
Sandstone, gray	10	265
Red rock	20	285
Slate and shells	17	302
Slate, gray (salt water)	18	320
Red rock, dark	30	350
Chemung formation:		
Sandstone, gray	10	360
Shells and slate	3	363
Sandstone, hard, gray (casing to 371 feet)	8	371
Sandstone, hard	2	373
Slate, black	15	388
Sandstone, hard, dark gray	9	397
Slate and shells	20	417
Slate and dark, hard shells	35	452
Sandstone, hard, gray	26	478
Slate and shells	40	518
Sandstone, dark, reddish	45	563
Slate and shells	30	593
Slate	22	615
Slate and shells	30	645
Sandstone, gray	10	655
Slate, soft	18	673
Slate and hard shells	7	680
Slate and shells	40	720
Slate	25	745
Hard shells	5	750
Sandstone, gray	30	780
Slate	20	800
Shells and sand	15	815
Sandstone	31	846
Slate and shells	43	889
Shells, hard	12	901
Slate	29	930
Sandstone, gray	50	980
Sandstone, gray, hard	20	1000
Slate	60	1060
Slate and shells	20	1080
Slate	20	1100
Sandstone, dark gray	135	1235
Sandstone, dark (oil show, and some gas)	5	1240
Sandstone, dark gray	26	1266
Sandstone, gray	19	1285
Sandstone (gray), slate, and shells	60	1345

The upper limit of the Chemung formation is ill defined, as the change from the conditions of the Chemung epoch to those of the Cattaraugus was not abrupt. This is indicated by the fact that beds of the Chemung type, carrying the same fossils, occur everywhere above the lowest of the red beds of the Cattaraugus, the interval varying from 50 to 200 feet, or even more. In mapping, however, it has been necessary to select some line to mark the upper limit of the formation, and the horizon or level of the bottom of the lowest red bed is the one chosen. Beds of the same lithologic type and the same fauna as the Chemung which occur above the lowest red bed and below the heavy red beds of the Cattaraugus formation are regarded and mapped as transition beds, partaking of the natures of both the underlying and the overlying formations. On the map the Cattaraugus is not represented as beginning until the red beds occur in considerable strength, a phase which is accompanied by a general change from the marine fauna characteristic of the Chemung to the fresh- or brackish-water fauna characteristic of the Cattaraugus. Marine forms may occur, though very sparingly, in the grayish shales and sandstones at considerably higher horizons.

In regard to the distribution of the rocks of the Chemung formation, little need be said beyond the fact that they are brought to the surface by the anticlinal folds as two well-marked belts, one entering the quadrangle in the eastern portion of the northern boundary, and the other entering the eastern border about midway its length. Both cross the quadrangle in a southeast direction, and both decrease in breadth and in the thickness of the rocks exposed as the distance to the west increases. This is especially noticeable in the case of the southern belt, the rocks of which are exposed over an area from 5 to 6 miles in width, and to a depth of about 600 feet in the eastern portion of the quadrangle, but which in the western portion are represented by only an isolated patch $2\frac{1}{2}$ miles in width and of slight thickness, occurring at the bottom of the valley of Genesee Forks.

[1]Authority, D. A. Paddock, Second Geological Survey of Pennsylvania, Rept. I^5, pp. 147-148.

DEVONO-CARBONIFEROUS FORMATIONS.

CATSKILL-POCONO GROUP.

Commencing with the beds of red shale which have been taken as marking the beginning of the formation succeeding the Chemung, and continuing upward to the Mauch Chunk formation, or, in its absence, to the Sharon conglomerate, there is, in the Gaines region, a great sequence of rapidly alternating shales and sandstones which are referred to in the reports of the Pennsylvania geological survey as the Catskill and the Pocono formations. Bright-red shales predominate in the lower portion of the series, and green or greenish-gray sandstones in the upper portion; and although the two are separated by no sharp break, either in their lithologic or paleontologic characters, but rather by a gradual transition, the physical characters of the two divisions are in so marked contrast that the series has been separated into two formations.

The terms "Catskill" and "Pocono" as used in their typical localities are based on distinctions which do not hold in the Gaines region, and new names have, therefore, been applied. The names here used are Cattaraugus and Oswayo, the former embracing the lower, or red, shale division and the latter the upper greenish-gray sandstone division. The Cattaraugus formation is named from Cattaraugus County, N. Y., and the Oswayo formation after Oswayo Creek, which empties into the Allegheny River in the southeastern corner of the same county. The rocks of both divisions are well represented at many points in the southeastern portion of the county.

Cattaraugus formation.—The Cattaraugus formation proper is considered as beginning at the first considerable red bed above the Chemung, or, as has been stated, at an interval of from 50 to 200 feet above the lowest red bed. The point is marked by a general change from an abundant marine fauna, consisting mainly of brachiopods, to a much less abundant fauna, mainly of fresh and brackish water, consisting largely of fish remains, ferns, etc. Occasional layers of the formation, however, carry a few salt-water lamellibranchs. In age the whole of the formation is believed to belong to the Devonian.

The upper limit of the Cattaraugus is placed at the top of the uppermost of the prominent and persistent red beds. The actual point at which this transition occurs is variable and does not admit of direct tracing. In general, however, it may be said that all of the larger and more important red beds occur within an interval of 500 feet above the top of the Chemung, while above that interval only occasional thin beds of relatively restricted area are found. On the map the top of the formation is drawn arbitrarily at the top of this interval of 500 feet.

The rocks of the Cattaraugus formation consist of a practically unfossiliferous succession of red shale and red and brown sandstone interspersed at intervals with gray and greenish shales and sandstones. If the formation is made to include the interval from the lowest to the highest of the persistent red beds, it is probable that the actual thickness of the red material will not greatly exceed one-half of the whole thickness, the remainder being taken up by the green and gray shales and sandstones. The red beds, nevertheless, are the most characteristic and distinctive feature of the formation, and in places may constitute as high as 75 per cent of its material.

Of the gray and green shales and sandstones, the green sandstone is the most conspicuous. This is largely because of its hard and siliceous composition, which causes it to resist erosion and to stand out more conspicuously than the softer portions of the formation. When fresh, it is of a distinct greenish color on exposed surfaces. It is almost invariably cross-bedded, the laminæ of both the sloping and the horizontal layers being unusually thin and perfect. Of the gray and green shales, the former predominate and form an important part of the formation. Some of the lighter beds carry ferns and other plant remains. The character of the Cattaraugus formation, and especially the relative amounts of the red and gray materials, etc., is well shown in the record of the Billings well, given in connection with the Chemung formation, and also in the Wattles Run section[1] given below.

Wattles Run section.

	Thickness in feet.	Depth in feet.
Cattaraugus formation, including Chemung-Cattaraugus transition beds:		
Shelly gray sandstone and shale	18	18
Red and green shale	5	23
Red shale	5	28
Green shale	4	32
Green sandstone	1	33
Greenish shale	4	37
Shelly gray sandstone, shale, and covered	20	57
Gray shale and thin-bedded sandstone	25	82
Covered	5	87
Gray shale	10	97
Greenish-gray thin-bedded sandstone	10	107
Red shale	3	110
Greenish-gray and red thin-bedded sandstone	10	120
Red shale	10	130
Greenish shale	15	145
Covered	24	169
Gray thin-bedded sandstone	12	181
Red shale and shelly sandstone	10	191
Shelly green sandstone	3	194
Greenish thin-bedded sandstone and covered	100	294
Red sandstone	1	295
Red shale	8	303
Chemung formation:		
Gray to greenish shale	16	319
Mostly covered	50	369
Gray shale and sandstone	17	386
Covered	30	416
Gray shale and thin-bedded sandstone	18	434
Thin-bedded gray sandstone and covered	53	487
Thin-bedded gray sandstone	10	497
Covered	10	507
Gray fossiliferous sandstone	5	512
Concealed	20	532
Thin-bedded gray sandstone full of fossils	4	536
Irregularly-bedded gray sandstone	7	543

The rocks of the Cattaraugus formation are most widely distributed in the northern half of the quadrangle, where they occur not only on the flanks of the anticlinal folds, but also in the center of the shallow syncline along Cowanesque River. Farther south they are found on both sides of the anticline in Clymer, Hector, and Jackson townships; also along Pine Creek near the southern edge of the quadrangle. The best exposures of the red rocks in the area are on Wattles Run and along Pine Creek.

Oswayo formation.—The Oswayo formation includes the thick series of gray and green sandstones and shales, with occasional thin beds or lenses of red shales, lying above the uppermost of the stronger red beds and below the Mauch Chunk formation or the Sharon conglomerate. The total thickness is not far from a thousand feet. In the Gaines quadrangle its age is supposed to be in part Devonian and in part Carboniferous.

The green or greenish-gray sandstones predominate, and because of their siliceous character they frequently stand out on the hill and mountain sides as distinct shelves and tables. On the exposed surface the sandstones are generally of a pronounced greenish-gray color. Internally, however, they are of a dirty buff or brown color, distinctly argillaceous, and frequently specked with limonitic spots, probably due to the decomposition of minute crystals of pyrite. On continued exposure to the weather the sandstones seem to lose their greenish tinge, becoming light-gray in color, presumably because of the washing away of the finer products of disintegration and decay, leaving only the insoluble quartz showing upon the surface. Like those of the Cattaraugus formation, the Oswayo sandstones are almost invariably cross bedded and are characterized by the frequent occurrence of minute plates of mica along the lamination planes. In fact, the greenish sandstones of the two formations are so similar that it is impossible to distinguish them by lithologic characters.

In the upper portion of the Oswayo formation as mapped in this folio, there sometimes appears to be a thickness of perhaps 100 feet or more of sandstones, etc., which seem to be of a lighter, more gray or buff color than the greenish sandstones forming the mass of the formation. Whether this is due to an actual difference in composition, or simply to the bleaching action of the weather, is not clearly established.

[1]By Dr. E. M. Kindle.

The rocks of the Oswayo formation constitute the upper portion of the hills along both sides of Pine Creek in the southern portion of the quadrangle, though the rocks of the immediate crests of the hills belong to a higher formation. Another broad belt of the rocks of the Oswayo formation is found in Hector and Ulysses townships. They are also found in the crests along both sides of Cowanesque River.

CARBONIFEROUS FORMATIONS.

Mauch Chunk shales.—About $1\frac{1}{2}$ miles south of Gurnee, on the road to Manhattan, there are exposures indicating an aggregate thickness of perhaps 40 feet or less of red clay lying immediately below the Sharon conglomerate member, which here forms the base of the Pottsville formation. This clay, which occasionally contains small fragments of red and green shale, without doubt resulted from the decomposition of beds of shale of those colors. Although it is recognized that the outcrop may be only an especially pronounced example of the lenses of red shales which are occasionally found in the Oswayo formation, its occurrence in the proper position of the Mauch Chunk shales points strongly to the probability of its belonging to that formation, and it has been so mapped.

Besides the locality south of Gurnee, the red shales have been recognized at the bottom of the Sharon conglomerate at only one other place in the Gaines quadrangle, namely, near the crest of the highlands northeast of the railroad between Galeton and West Pike. The thickness in neither case could be more than 60 or 80 feet. At other points the lowest of the Pottsville rocks apparently rest directly upon sandstones of the Oswayo type, in one case at least the two being well exposed within a vertical interval of a few feet of each other.

Pottsville formation.—The Pottsville is the uppermost of the formations exposed in the Gaines quadrangle. In this region it may be separated into two main divisions, the lower consisting of the well-known Sharon conglomerate member, and the upper of a sequence of sandstones and shales, with one or more coal seams, which overlies the conglomerate and which is identifiable by its fossils as of Pottsville age.

The Sharon conglomerate member, which varies in thickness from 60 to 100 feet, is composed almost entirely of quartz, and is frequently a coarse sandstone rather than a conglomerate. The character of the sand grains and pebbles, both of which are usually of pure white quartz, ordinarily gives the rock a bright, almost white appearance, quite different from other rocks with which it is associated. Though sometimes thin bedded, it is commonly massive in character, and gives rise to somewhat conspicuous cliff-like outcrops. This cliff-forming character, however, is not nearly so prominent in the Gaines quadrangle as at many other points in the State, and is apparently confined to certain of the more massive layers, which do not necessarily occur at exactly the same horizons in different localities.

The bed of conglomerate, though extremely resistant to the action of weathering and erosion, is nevertheless much broken in places. This is probably due in large measure to the weathering out and removal of the softer and more easily eroded beds underlying the conglomerate, which is thus left unsupported. Large bowlders, and even flat masses of great size, are frequently broken off and slide downward, burying the slopes with accumulations of débris.

The conglomerate occurs on each of the hills of the mountain belt along the southern edge of the quadrangle, on the crest between California Creek and Genesee Forks, and again on the crest west of Cushing Hollow.

The upper portion of the Pottsville, which is more sandy and shaly than the lower portion, is less widely distributed than the Sharon conglomerate member, but is exposed on the hill near Gurnee, on the ridge between Long and Phoenix runs, and on the crest west of the point at which Pine Creek leaves the quadrangle. In the vicinity of Gurnee nearly 200 feet of strata occur above the conglomerate. Because of their soft nature the members are nowhere well exposed, but the following section, based largely on superficial indications, will give a good general idea of the character and succession of the beds. The section is from the top down.

Section near Gurnee.

	Thickness in feet.	Depth in feet.
Buff laminated sandstone	25	25
Black shale	5	30
Coal ($1\frac{1}{2}$ to 4 feet)	3	33
Fire clay	2	35
Gray and ferruginous laminated sandstones	10	45
Black shale	15	60
Fire clay	5	65
Buff sandstone, in part shaly	30	95
Black shale	15	110
Fire clay with coal streak	5	115
Greenish and gray argillaceous sandstone, weathering yellow	60	175
Black shale with 3 inches of coal	5	180
Greenish shaly sandstone	15	195

The fossil plants associated with the coal indicate, according to identification by David White, that it is to be correlated with the Mercer horizon of the Pottsville. The 25-foot bed of shaly sandstone over the coal and its shale has as yet yielded no fossils, but is almost certainly a part of the Pottsville.

PLEISTOCENE FORMATIONS.

The Pleistocene deposits in the Gaines region are of two classes, (1) those which were laid down either directly or indirectly through the agency of the great ice sheet which covered the region in the earlier portion of the period, and (2) those which have been deposited by streams or other agencies since the final disappearance of the ice sheet. The former are known as Glacial deposits and the latter as post-Glacial or Recent deposits.

GLACIAL DEPOSITS.

The glacial deposits consist of materials which were picked up or dragged along in the bottom of the ice sheet during its southward movement, or which were transported by its associated streams. The material has all been moved from its original position, and is therefore known as *drift*. This drift was frequently deposited directly by the ice, being either set free by the melting of the portion in which it had been frozen, or simply dropped and left behind as a sheet beneath the ice, as the friction between the drift in the bottom of the moving ice and the overridden surfaces became so great as to cause lagging and lodgment. The drift liberated by either of these methods usually consists of a heterogeneous mixture, including all grades of material, from clay to large bowlders, and is known as *till*. Drift which was not deposited directly from the ice, but which was taken up and transported by glacial streams before it was finally deposited in more or less distinctly stratified masses, is known as *stratified* or *modified drift*. Each class is further subdivided into several types, depending upon minor features of origin. Of the till deposits two types, the terminal moraine and the ground moraine, have been recognized in the Gaines quadrangle, while the stratified glacial deposits of the area include the morainal and other glacial terraces, the glacial stream and lake deposits, and the kame and other isolated gravels.

Till sheet or ground moraine.—By far the most abundant of the deposits laid down by the direct action of the ice are those which belong to the class of till known as till sheet or ground moraine, and which were deposited beneath the ice sheet, as has been stated, by the melting of the basal débris-laden layer, or by the lodgment of the débris.

The till thus deposited consists of a matrix of fine material which has been derived partly from the old soil and partly from the grinding and pulverizing of rock fragments, and in which are embedded angular and slightly worn fragments of rock varying from mere chips or pebbles to bowlders several feet in diameter. In places the fine material is more or less clayey, but since it is very largely derived from the underlying rocks it is in the Gaines region generally quite sandy in character. Not infrequently there occur rock fragments which show smoothing, polishing, and striations like those which have been noted on certain exposed rock surfaces, and which have resulted from the grinding action of the rock material carried or dragged along at the bottom of the ice sheet. Such erosion phenomena are characteristic of glaciation as distinguished from water erosion or weathering.

One of the striking features of the till of this area, however, is the small amount of wear to which the greater part of the stony material has been subjected. The till is full of fragments of rock as fresh and angular as if but recently broken. Almost everywhere in the cultivated portions of the area are to be seen piles and fence walls composed of flat fragments of rock, only a small part of which gives evidence of having been ground beneath the glacier. This angularity is undoubtedly very largely due to the brittle, thin-bedded character of most of the rock of the region, in consequence of which the bowlders, instead of becoming smoother and striated, as would a limestone of ordinary bedding and texture, split up into a series of thin plates and are broken to pieces. Certain layers of the Chemung formation are of a type of impure limestone which gives somewhat thicker bowlders, sometimes beautifully polished and striated.

Sections giving accurate measurements of the thickness of the drift are infrequent, and because of their slight depth are of little value except as indicating the minimum amounts of filling. However, the frequent outcropping of the underlying rock strata indicate that the average depth must be very moderate, this being particularly true of the mountain belts where prominent ledges are often exposed. In other parts of the area the lack of these jutting ledges, together with the beautifully rounded contours typical of a well-glaciated region, give the impression that the drift mantle is of considerable thickness, yet even here road cuttings but a few feet deep are very likely to expose the soft, shaly beds of the Chemung formation, showing that the forms of the hills are due rather to erosion than to the accumulation of drift upon their surface.

Since more or less water was continually being released by the melting of the ice, a part of the drift was stratified. The greater part of this stratified or modified drift is naturally found in the valleys where the glacial waters were concentrated, but limited deposits may occur at any place. Not all the drift in the valley is stratified. On the contrary, in nearly all the valleys excepting those of Cowanesque River and Pine Creek the till deposits seem to predominate over the assorted clays, sands, and gravels.

When these deposits of till occur in the valleys, especially in the deeper cut valleys of the mountain belts the slopes do not extend regularly from top to bottom, but part way up the declivity become less steep, forming somewhat indefinite sloping shelves, above which the slopes again rise steeply. The shelves probably represent in many instances the original level of the drift filling, into which the sharp, steep-sided channels of the lower portions of the valleys have subsequently been cut. In other cases the shelves may have been the result of irregularities of deposition. The V-shaped valleys are especially characteristic of the tributaries of Pine Creek.

In the lower part of some of the other valleys, such as Mill Creek and Potter Brook in Westfield Township, and Purple Brook in Brookfield, the filling is so disposed as to give broad valley bottoms sloping gently to the streams. In each of them the stream has been crowded close against one side of the valley and has there cut its channel in drift and rock. Mill Creek in Westfield Township and Long Run in Gaines have eroded channels with narrow flood plains.

The amount of valley filling is not readily estimated. The streams frequently cut into or expose the underlying rock beds, but this usually occurs where the creek is crowded against one side of the valley. The sinking of water wells, however, shows that at many points the drift is 30, 50, or even 75 feet deep in the middle of the valleys. This filling, it should be remembered, is not all till but consists in part of stratified drift, which in cases may even form a considerable portion of the deposit.

A feature which attracts the attention of one passing through this area is the almost universal abundance of loose stone in the soil and on the surface, much of which has been collected in piles and stone walls. By far the larger part of these fragments are of the same character as the underlying rock, but a few are of rock from contiguous formations occurring a few miles away, while a still smaller percentage are from regions as far away as Canada or the Adirondack Mountains. To one familiar with the glacial deposits of the Mississippi Valley the most striking feature of the surficial deposit is the extremely local character of the rock fragments. In certain parts of the northern interior of the United States 80 to 90 per cent of the stony material of the body of the drift is of local origin, while only 10 to 20 per cent was derived from crystalline rocks found several hundred miles farther north in Canada. Of the surface bowlders of that region, however, frequently as high as 95 per cent came from beyond the Great Lakes. In marked contrast to this is the drift of the Gaines quadrangle. Here not only the body of the drift is formed of material of local derivation, but practically all of the surface bowlders are of the same origin. In fact, only a few dozen foreign bowlders were noted in the quadrangle, and these were of small size and widely distributed.

Morainal deposits.—Besides the ground moraine or till sheet which accumulated beneath the ice in the manner already explained, there is another class of drift, deposited in direct connection with the ice, which, though perhaps of no more importance, is often more conspicuous than the former. This is the class of deposits known as moraines, the materials of which have accumulated along the margin of the ice sheet at various periods of its history. The deposits sometimes occur in the form of ridges, but more frequently consist of linear strips of more or less isolated deposits, or of irregular ridge-like belts.

Morainal deposits are of two classes, the first including those occurring at the outer limit reached by the Wisconsin ice sheet and known as terminal moraines, and the second embracing scattered patches accumulated during temporary halts or re-advances during the general retreat of the ice sheet mentioned, and known as retreatal moraines. The materials in both consist of intermixtures of unassorted drift or till and of assorted or stratified drift. In the first the material has been set free at the front of the glacier by the melting of the ice, and in the second it has been deposited by streams or rivulets issuing from the margin.

Terminal moraine.—In the Gaines quadrangle the more conspicuous morainal deposits are those of the terminal moraine. As indicated in fig. 2 and on the Surficial Geology map they are found only in the extreme southwestern corner of the area. The deposits do not here form a connected series, but consist of more or less detached patches near West Pike at the mouth of Genesee Forks. A considerable part of the material is stratified and a large percentage of the stony material is rounded. On the slope west and northwest of this village the morainal gravels are found up to elevations of 1700 or 1750 feet, or about 300 feet above the river.

Retreatal moraines.—Much drift of a morainal character is found along the valley of Genesee Forks north of the deposits of the terminal moraine near West Pike. Although intimately connected with the latter deposits the accumulation probably did not take place until the beginning of the retreat of the ice, hence the deposits are to be classed with the retreatal type of moraines. At the junction of Cushing Hollow and Genesee Forks the deposits rise to an elevation of 200 feet above the valley on the slope of the spur between the two streams. They consist mainly of gravel and are marked by shallow kettles in the lower portions.

Other than the deposits just mentioned there are no very conspicuous retreatal accumulations in the quadrangle. On Phoenix Run, about a mile below the mouth of Little Phoenix Run, the valley is constricted by a hill projecting from the east side which seems to be composed of drift and has the appearance of once having formed a morainal dam across the valley. Somewhat similar accumulations also occur a little farther down the same valley. Southeast of Potter Brook village and also between California and Purple brooks, in the northern portion of the area, there are deposits whose uneven surfaces suggest a morainal origin. This suggestion is borne out to some extent in the case of the latter by the occurrence of morainal deposits along the same line just outside the quadrangle.

Morainal and frontal terraces.—Closely related to the moraines are the morainal terraces. These are formed, as are true moraines, in direct contact with the ice margin, but differ in that water has been the controlling feature of the deposition. This deposition sometimes took place in the form of broad, flat, alluvial fans spread out between the ice margin and the valley walls and again as nearly flat-topped deltas or as terraces in bodies of water ponded between the ice and the adjacent hills. From the fact that in either case the ice formed one of the boundaries of the deposit it is commonly found that more or less morainic till is present, especially along the margin. The marginal or ice contact topography which resulted from the final melting back of the ice from the deposits has often a decided morainic aspect, and, taken in connection with the presence of the associated till and bowlders, has given to this class of deposits the appropriate name of morainal terrace.

Deposits of this type occur along the south bank of Pine Creek just east of Shin Hollow and again near Westfield, and at the junction of Cronce Brook and Cowanesque River.

For three-quarters of a mile east of Westfield there are remnants of a delta deposit, now considerably modified by erosion, which is associated with stony drift and which is marked by gravel knolls rising from its surface. The deposit on either side of Cronce Brook is of the nature of a delta, but slight sags indent its surface and knolls of gravel lie above it. Sections of the gravelly knolls show that the material is largely fine, but that it includes stones ranging in size from 3 inches to a foot in diameter. The bedding dips strongly to the south or away from the ice which probably filled the remainder of the valley at that time. Both the Westfield and Cronce Brook deposits belong to the class of frontal terraces, and probably also to the morainal group.

Glacial stream and lake deposits.—It has already been stated, in the discussion of the till sheet, that there are often considerable amounts of stratified drift in the valleys, especially in those of the larger streams, such as Cowanesque River and Pine Creek. The sedimentary deposits consist of sand and gravel, and are composed mainly of materials which were set free by the melting of the débris-laden portion of the ice and which were taken up, transported, and finally deposited by the streams originating in the melting ice sheet and leading away from its margin. The total thickness of these valley fillings, consisting in part of the gravels just mentioned and in part of unstratified drift, is difficult to determine, but the information afforded by occasional water wells shows that it is considerable. Thus at the village of North Fork, in northeastern Harrison Township, several flowing wells are said to draw water from the gravels immediately overlying the rock at depths of 50 or 60 feet. In the same valley near the south line of Brookfield Township, E. M. Gardner's well showed the presence of 75 feet of filling over the rock bottom. Again, in Mill Creek Valley, about three-quarters of a mile south of the main street of Westfield, a well did not reach rock in 30 feet. The drift in the main Cowanesque Valley is probably 75 to 100 feet or more in thickness.

A portion of the stratified drift was deposited in the beds of the glacial streams, but in the valley of Cowanesque River and in the lower portion of the tributary valleys entering it in Westfield and Harrison townships much of the material appears to have been deposited in a temporary lake that had formed in front of the northeastwardly retreating ice margin, which lay across the course of the Cowanesque Valley at a point outside the limits of the quadrangle to the east. The outlets were across the divide between Mill Creek and Long Run south of Sabinsville and between Jemason and Crooked creeks in Chatham Township, about 4 miles east of Sabinsville and outside the limits of the area under consideration.

The deposits laid down in this temporary lake were probably relatively unimportant and can not now be separated from contemporaneous or subsequent stream deposits. The clays occurring at the brick yards of J. W. Seaman & Son, near the fair grounds at Westfield, and elsewhere are probably the only deposits that were certainly formed in this lake. They are covered in part by stony drift subsequently deposited by streams leading from the glacier.

Kames and isolated gravel deposits.—The kames and isolated gravel deposits of the Gaines quadrangle consist of more or less irregular heaps of confusedly stratified sands, gravels, etc., which were probably deposited in tunnels or other cavities beneath the ice, or in channels near the margin into which flowed the waters resulting from the melting of the basal portion of the ice sheet. In some respects they resemble morainal deposits, but in the area under discussion they appear to have no specific connection with them. The only deposits in the quadrangle classed as kames are the stratified beds upon which the cemetery is located at Brookfield and the small gravel knoll with kettle-like depressions a half mile farther south.

Gravel fans or deltas.—As the ice front melted back the valleys tributary to Pine Creek, and later those entering Cowanesque River, were successively opened and became lines of discharge of the glacial waters until the ice front had retreated beyond the limits of their drainage areas. When these streams left the narrow tributary valleys and emerged upon the broad, flat bottoms of the main valleys the larger portion of the material brought from the ice front or eroded from the older valley filling was deposited in broad, low, flat alluvial fans or deltas.

At the mouth of Phoenix Run, about a mile south of the limits of the quadrangle, there is a delta with an elevation of 1310 feet in its highest point, whence it declines gently to the sharply cut channel of Pine Creek. At the mouth of Elk Run, also just outside the southern limits of the quadrangle, there is another delta. The portion on the south side of Pine Creek has been largely cut away by the present stream, but its extension on the north side of the creek is the site of the village of Watrous.

The structure of the delta on which stands the village of Gaines is exposed in the railway cut just east of the South Gaines station. Cattaraugus sandstones and shales are exposed up to an elevation of 1250 feet, or about 30 feet above the stream, above which are about 45 feet of coarse, poorly assorted cobblestone gravel with considerable clayey material. The level of the delta at the edge of the bluff facing the river is 1290 feet, but half a mile to the north, where it heads in Long Run, it has risen to 1320 feet. The present brook has cut a channel in the deposit over three-quarters of a mile long above its mouth near Manhattan, at which point the gravels have thinned to 5 feet.

Coarse gravels form a considerable deposit between the mouths of Lick Run and Shin Hollow about a mile southeast of Gaines and just outside the quadrangle. Three-eighths of a mile east of Shin Hollow, Pine Creek swings to the north side of the valley, leaving a broad gravel plain on the south side, which gradually rises to the east from an elevation of 1230 to an elevation of 1240 feet near the eastern limit of Gaines Township. This was probably an overwash delta from the ice at a period when the margin rested near the morainal deposits just beyond the southeast corner of the quadrangle.

The majority of the gravel fans occur, as has been stated, at the mouths of the streams flowing south or away from the ice. There are many instances in adjoining areas, however, in which they also occur in northward-flowing streams. In such instances the materials have evidently been derived from the valley deposits left by the glacier on its retreat, the latter deposits being cut into and partially removed by the action of the present streams. Even in many of the deltas of the southward-flowing streams this post-Glacial erosion and deposition may have been an important factor in the formation of the fans.

POST-GLACIAL DEPOSITS.

Alluvium.—Besides the gravel fans which, though in the main of glacial origin, are frequently in part of post-Glacial age, the only deposits marking the period since the final disappearance of the ice are the relatively thin sheet of flood-plain alluvium and a few minor swamp or marsh deposits. The flood-plain alluvium, though having an important agricultural significance, usually consists of only a few feet of silts, as is attested by the sections afforded by the banks of the shallow channels of the streams. These deposits are limited mainly to the valleys of Pine Creek and Cowanesque River, though some of the larger tributary streams have imperfect flood plains in the lower portions of their courses. Among these may be mentioned Potter Brook, Mill Creek, Genesee Forks, and Long Run.

Marsh deposits.—The marsh deposits of the quadrangle are usually confined to the vicinity of springs issuing from the hillsides and are in general of too limited area to be mapped. The most extensive marsh in the area is that at the head of Johnson Brook in Pike Township, and is the result of an artificial dam.

GEOLOGIC STRUCTURE.

The Gaines quadrangle, as has been stated under the heading "General relations," belongs to the moderately folded western division of the Appalachian province or that part of it that lies west and northwest of the Allegheny Front, which is the westernmost of the prominent ridges of the Appalachian Valley. Northwest of the Allegheny Front the folding gradually becomes less pronounced, and finally subsides into the very gently undulating, or almost flat structure of northwestern Pennsylvania and southern New York.

The Gaines quadrangle is situated about 40 miles from the Allegheny Front, and is characterized by gentle though distinct folding. The dips throughout the greater part of the area are very gentle, being as a rule hardly appreciable to the eye in the ordinary small exposures. In larger exposures, however, the rocks are seen to possess slight inclinations, usually from 2° to 4°, but in a few instances dips as high as 9° or 10° were noted. These dips, slight as they are, are sufficient, nevertheless, to make a difference of about 2000 feet between the altitude at which beds occur at the bottoms of the deeper synclines and that at which they occur at the crest of the higher anticlines.

The quadrangle is crossed by 2 anticlines and 2 synclines, which, beginning at the north, may be designated as the Harrison anticline, the Cowanesque syncline, the Sabinsville anticline and the Pine Creek syncline. The structure of the folds and the relations they bear to one another are shown in fig. 1 by means of contour lines which give at 100-foot intervals the elevation above sea of the upper surface of the Chemung formation. Where the top of the Chemung has been eroded in the anticlinal areas the elevations are those which the surface would possess if no erosion had taken place. Occasional reference to the above figure, in connection with the following descriptions, will serve more clearly to bring out the points described. Fig. 6, on page 8, shows the extension of the folds in northern Pennsylvania and indicates more plainly the relations of the structure of the Gaines quadrangle to that of the adjacent portions of the Allegheny Plateau.

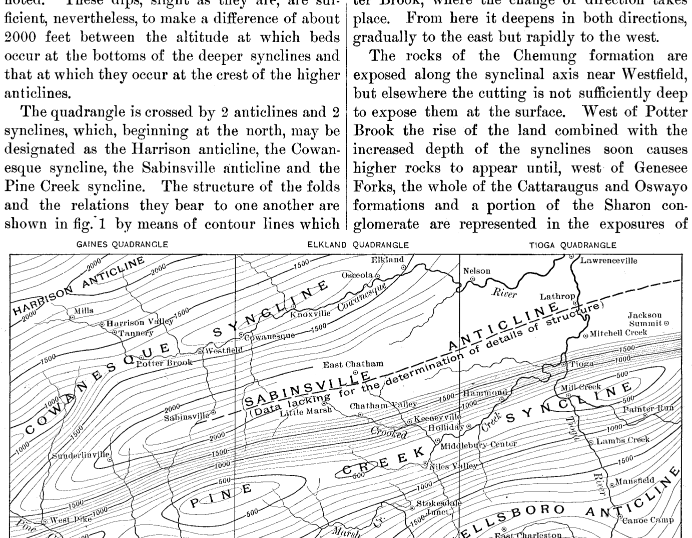


FIG. 1.—Sketch map of Gaines, Elkland, and Tioga quadrangles, showing by contours the structure of the upper surface of the Chemung formation.
Contour interval, 100 feet. Datum is mean sea level.

Harrison anticline.—This anticline receives its name from Harrison Township, within the limits of which the larger portion of that part of the fold included in the quadrangle occurs. Its axis enters the northern border of the area about 1½ miles east of the Tioga–Potter county line, passes, with a course about S. 70° W., through the village of Brookfield and across the northern portion of Harrison Township, and finally leaves the quadrangle at a point about 3½ miles south of its northeast corner. The axis as it enters this area has a gentle westward pitch of about 50 feet or less to a mile. This continues to a point about 2 miles northwest of the village of Mills, where the axis apparently becomes first horizontal and then rises again to the west. In reality, the structure near the point at which the Harrison anticline leaves the area may be more complicated than has here been stated. This is owing to irregularities attendant on the separation of the anticline into two anticlines separated by a syncline, which takes place a short distance west of the limits of the quadrangle. The exposures are insufficient, however, to give anything but a general idea of the structure.

Where the anticline enters the northern edge of the area the Chemung rocks are everywhere exposed except on the highest knobs, but as the anticline subsides to the west, the rocks of the Cattaraugus formation form the upper portion of the hills and the Chemung is confined mainly to the valleys. The dips both to the north and south are very gentle, averaging only about 150 feet to a mile.

Cowanesque syncline.—The Cowanesque syncline takes its name from Cowanesque River, which flows near the axis of the fold from Potter Brook to the vicinity of Elkland, about 16 miles to the east. The axis enters the quadrangle from the east near the Westfield–Brookfield town line and follows a course of S. 70° W. to the vicinity of Potter Brook, beyond which it swings rapidly to the south, and, with a course of S. 53° W., passes out of the quadrangle at a point about 2 miles north of the south line of Ulysses Township. The syncline is shallowest in the vicinity of Potter Brook, where the change of direction takes place. From here it deepens in both directions, gradually to the east but rapidly to the west.

The rocks of the Chemung formation are exposed along the synclinal axis near Westfield, but elsewhere the cutting is not sufficiently deep to expose them at the surface. West of Potter Brook the rise of the land combined with the increased depth of the synclines soon causes higher rocks to appear until, west of Genesee Forks, the whole of the Cattaraugus and Oswayo formations and a portion of the Sharon conglomerate are represented in the exposures of the mountain ridges. The ridge between the headwaters of Genesee Forks and California Creek is capped near its southern end by the Sharon conglomerate. On the next crest, which lies between California Creek and Cushing Hollow and is of practically the same elevation as the preceding, there is no trace of the conglomerate. The conglomerate appears again, however, on the crest southwest of Cushing Hollow at nearly the same elevation as upon the first ridge. The occurrence is of interest as showing a slight local rise of the bottom of the syncline in the vicinity of the middle crest, on each side of which are basins of greater depth.

The dips toward the axis of the syncline are gentle, amounting to about 250 feet per mile on the north side and about 400 feet per mile on the south side.

Sabinsville anticline.—This anticline is so called from the village of Sabinsville, which is situated in the northern portion of Clymer Township and a little to the north of the summit of the anticline. The axis enters the quadrangle 1½ miles east and one-half mile south of the village and extends with a course of about S. 70° W. to Mixtown. Here it swings a little to the south and with a course of S. 30° W. passes through Sunderlinville, and finally leaves the area at the point at which Cushing Creek enters it from the west. The anticline is highest at the point where it enters the area from the east. From there to Mixtown it has a slight westerly pitch, but beyond this town the pitch increases to about 100 feet per mile. This rate is maintained beyond the limits of the quadrangle. This rapid subsidence of the anticline is of significance as presaging its disappearance as a prominent structural feature, which occurs just west of the limits of the quadrangle, where the Cowanesque and Pine Creek synclines unite into a single broad trough with only a gentle swell marking the continuation of the previously pronounced anticline.

Chemung rocks are exposed in the eastern portion of the area over a belt 5 or 6 miles wide, and marked by long tongues of Chemung extending down the northward-draining valleys. The thickness exposed is 700 feet or more. In the western portion of the area the anticline is so reduced in size that the Chemung is represented by a single, small, isolated patch of slight thickness occurring at the bottom of the valley of Genesee Forks, 2 miles north of West Pike.

The dips toward the Cowanesque syncline on the north vary from 200 feet per mile in the eastern portion of the quadrangle to 300 or 400 feet per mile in the western portion. The southerly dips, or those toward the Pine Creek syncline, range from 500 feet per mile in the vicinity of West Pike to 800 feet per mile in the region east of Long Run.

Pine Creek syncline.—The Pine Creek syncline is named from Pine Creek, one of the most prominent streams of the region, which flows eastward for a considerable distance along the southern flanks of the synclinal mountain before it finally turns southward at Ansonia, about 8 miles east of Gaines, and cuts across the folds of the Appalachian Plateau on its way to the West Branch of the Susquehanna near Jersey Shore.

The axis of the syncline enters the area a little south of Gurnee, crosses it with a course, at first, of S. 73° W., then S. 65° W., and finally leaves its southern limits near Cushing Creek. The syncline reaches its greatest depth near Gurnee, the exact center, as shown by the coal workings, being 300 feet east of the road opposite the main dump. Here, not only the whole of the Sharon conglomerate is exposed, but also about 200 feet of the overlying shales and sandstones, forming the upper portion of the Pottsville formation. Between Long and Phoenix runs the syncline becomes shallower and only a few feet of the rocks above the conglomerate are exposed on the crest at that point. West of Phoenix Run it becomes still shallower, nothing above the conglomerate being shown, but beyond Pine Creek the syncline deepens again and the measures above the conglomerate appear on the hilltops in the southwest corner of the quadrangle, but only a slight thickness is present in the area shown on the map.

The rise of the beds is rapid on the north of the synclinal axis, varying from 500 to 800 feet per mile, but it is relatively gentle to the south, being only 200 to 300 feet per mile. The southward rise continues for a distance of 2 or 3 miles beyond the southern limit of the quadrangle, where it culminates in a low anticline known as the Marshfield anticline. (See fig. 6.)

Structure sections.—The sections on the Structure Section sheet supplement the foregoing description by exhibiting in a graphic manner the probable underground extensions of the beds recognized at the surface. They show the relative positions of the beds and the folds into which they have been compressed, as they would be exhibited if cut transversely by a deep valley or trench located along the line at the upper edge of the blank space above the section on the map. The horizontal and vertical scales are the same, hence the hills, the thickness and dips of the beds, and the breadth and character of the folds are shown in the same proportion as they actually occur. In the absence of deep wells or other sources of information as to the structure beneath the ground the general features of the underground structure have been calculated from what it was possible to observe on the surface.

GEOLOGIC HISTORY.

ACCUMULATION OF THE LOCAL SEDIMENTS.

DEVONIAN PERIOD.

Chemung deposition.—The earliest deposits that appear at the surface in the Gaines quadrangle are the fossiliferous sandstones, shales, and thin limestones of the Chemung formation. At the time these beds were deposited, namely, toward the close of the Devonian period, nearly the whole of the southern half of the interior portion of what is now the North American Continent was covered by the waters of a great interior sea. It was in the great northeastern bay of this sea, which extended across western and central Pennsylvania and southern New York, that the deposits of the Chemung were laid down. The land from which the sediments were derived was situated to the east of the present Appalachian Mountains, probably having the form of highlands lying not far from the present coast line of the Atlantic. To the south the Devonian land is known to have been low and flat and it seems likely that in the north the relief was likewise moderate.

The waters of the bay in which the deposition took place were comparatively shallow, as is attested by the somewhat sandy character of the sediments and the presence of ripple marks and cross bedding resulting from the action of currents. That the water in the Pennsylvania and New York region was clear and salt, and not fresh or brackish, or surcharged with silt, as was the case during the same period farther south, and also in the north during the deposition of a considerable portion of the overlying Cattaraugus and Oswayo formations, is attested by the presence of an especially abundant marine fauna.

A characteristic feature of the Chemung formation is the great number of alternations of material which it exhibits, and while it is true that there are no indications of marked or extensive changes of condition, the rapid alternations of thin beds of shales and sandstones with occasional thin limestones are indicative of fluctuating conditions of sufficient magnitude to affect deposition, though probably the changes were mainly of a local nature. The conditions in the north were in this respect also at variance with the conditions existing farther south, where they were fairly constant during the corresponding period of time.

DEVONO-CARBONIFEROUS TRANSITION.

CATSKILL-POCONO EPOCH.

Cattaraugus and Oswayo deposition.—The deposition of the Cattaraugus beds was preceded or accompanied by a somewhat marked change of physical conditions. The salt-water deposits of the Chemung gave place, as is attested by ferns, fresh-water fishes, etc., to the fresh- or brackish-water deposits of the Cattaraugus formation. The waters at the same time doubtless became much shallower, as is indicated by the greatly increased frequency of cross bedding, ripple marks, rain prints, and other shore features, apparently indicating a more or less complete separation of the embayment from the open interior sea.

Whether this change was brought about by a cessation or a temporary reversal of the movement of subsidence which had been going on during the deposition of the Chemung and earlier sediments, or whether the rapid accumulation of the sediments themselves, resulting from a supposed acceleration of erosion due to the increase in the elevation of the land area, is not fully understood. It is known, however, that the time at which the deposition representing the advent of what is usually known as Catskill conditions took place was not the same throughout the areal extent of the formation, but was earliest in the eastern portion of the embayment and became progressively later as the distance from the eastern margin increased. In eastern New York the deposition of the peculiar deposits began soon after the close of the Hamilton, and as time elapsed and the conditions became favorable, the Cattaraugus beds were deposited farther and farther west. It was probably not until near, or possibly after the close of the Devonian, however, that conditions favorable to the deposition of red beds came into existence in western New York. In the Gaines region the Catskill conditions were not inaugurated until after a great but unknown thickness of Portage and 2000 feet or more of Chemung sediments had been deposited and those conditions continued at least to the close of the Devonian, and probably well into the Carboniferous period.

Fluctuations of the conditions of deposition were probably less frequent but possibly of longer duration during the deposition of the Catskill–Pocono group than in the Chemung. This is apparently attested by the less frequent changes in lithologic character but greater thickness of the component strata of the former. The greater thickness, however, may have been due entirely to the greater rapidity of the deposition of the Catskill–Pocono group, due to the accumulation having taken place close to the shores of the lands from which the materials were derived. The supply of material was also probably greater because of an acceleration of erosion due to the slight uplift of the land surface which appears to have accompanied the inauguration of Catskill conditions.

The red Cattaraugus shales, which are the earliest of the deposits accompanying the introduction of Catskill conditions, gradually disappear, the sandstones at the same time rapidly increasing in importance and constituting the thick sandy formation known as the Oswayo. The change from one to another, however, takes place without recognizable break, indicating the absence of any abrupt change of conditions at the opening of the Carboniferous period.

CARBONIFEROUS PERIOD.

Mauch Chunk deposition. — Following the deposition of the Oswayo sandstones, which carry relatively little shale, there appears to have been a return to conditions similar to those existing during the accumulation of the deposits of the Catskill type. As in the case of the Catskill deposits the sediments were thickest in the east, and decreased gradually from a maximum of about 3000 feet in the region of the anthracite coal fields of Pennsylvania to nothing in the northwestern portion of the State. At the east the sediments were evidently deposited not far from shore, and though prevailingly of red and green shale, also include considerable thicknesses of gray, greenish, buff, and even carbonaceous sandstones. At the west the series is less sandy and the shales become distinctly calcareous and include thin beds of impure limestone, apparently indicating the existence of deeper water. In the Gaines region, the red and green shales corresponding in position to the Mauch Chunk are not over 40 feet in thickness at the most, and may be considerably less.

Pre-Pottsville deformation and erosion.—The deposition of the Mauch Chunk shales appears to have been followed by a period in which deposition ceased and the clays just laid down were more or less extensively eroded. In the Gaines region the Mauch Chunk beds have been recognized only in occasional patches, and the entire lower and middle portions of the Pottsville formations are missing, the Sharon conglomerate, constituting the lowermost member of the upper division of the Pottsville, resting either on the Mauch Chunk shales or on the Oswayo sandstone.

Two hypotheses have been advanced to account for the absence of the lower and middle Pottsville deposits and the erosion of the Mauch Chunk shales. The first postulates strong currents sweeping around the borders of the embayment from the southwest and receiving and partially distributing sediments from the land on the southeast and east. No sediments are supposed to have been received from the north, the action of the currents on this side of the embayment being almost entirely one of scour. The second hypothesis postulates an uplift of the region which brought all but the southern and eastern portions of the floor of the former embayment above the level of the waters, where it was subjected to erosion by streams or waves.

The uplift, which is here accepted as the most probable cause leading to the Mauch Chunk–Pottsville unconformity, is generally supposed to have taken place without noticeable folding. In the Gaines quadrangle, however, there are evidences which appear to indicate that this supposition is not entirely true. Thus, in the region about Gaines and Gurnee it is found that the dip of the Pottsville conglomerate is only from a third to half as great as the calculated dip of the Chemung and the conformable Cattaraugus and Oswayo beds. On account of the limited extent of the Pottsville beds and the lack of exposure at critical points, the existence of structural unconformity can not be said to have been fully established, yet the above and similar discrepancies in the dips at other localities seem to bear out the natural inference that the Appalachian folding had begun in this region before the deposition of the Sharon conglomerate member of the Pottsville formation. The amount of erosion is unknown, but is believed to have been considerable, being probably sufficient in the western and thinner portions of the series to entirely remove the Mauch Chunk sediments, except for occasional patches over considerable areas.

Pottsville deposition.—While the erosion just described was going on in the west, there was a subsidence near the former Mauch Chunk shore to the east, and the lowest of the Pottsville beds, consisting of materials derived from the adjoining Archean lands, were laid down. It was considerably later when the subsidence, which once more carried the eroded surface of the Mauch Chunk beds below the level of the sea, extended to the western portion of the State. The deposition of the Sharon conglomerate member, constituting in the Gaines region the lowest of the Pottsville beds, and known from the paleobotanic evidence of the associated sandstones to belong to the upper division of the Pottsville, did not begin to be deposited until after many hundred feet of Pottsville sediments had been laid down in eastern Pennsylvania.

After the deposition of the Sharon conglomerate member the conditions during the deposition of the remainder of the Pottsville sediments were somewhat unsettled. Periods of submergence, marked by the deposition of sandstones, alternated with periods of slight uplift during which considerable areas were cut off from the sea and fresh-water vegetation, now marked by black shale and coal beds, flourished upon their surfaces. These alternating conditions continued throughout the Pottsville, and in fact, throughout the remainder of the Carboniferous period, during which many hundred feet of sandstones, shales, limestones, etc., were laid down.

UPLIFT AND FOLDING.

Appalachian revolution.—The deposition of the thick sediments of the Carboniferous was accompanied by a gradual subsidence of the sea bottom, a process which is essential to the accumulation of great thicknesses of strata, for otherwise the sea level would soon be reached and deposition practically cease.

The depression thus inaugurated constituted a zone of weakness, and under the application of lateral pressure its beds were compressed into broad, and often steep, folds and broken by the great fractures or faults which are so characteristic of the Appalachian province. If the interpretation of the conditions of unconformity near Gaines is correct, the folding began as early as the close of the deposition of the Mauch Chunk beds, but did not attain its maximum until near the close of the Carboniferous period.

The extent and complexity of the folding and faulting was greatest in the east, or near the coast line of the interior sea. It was here, in close proximity to the shore, that the sediments accumulated in greatest thickness, where the subsidence and weakening of the crust was greatest, and where, consequently, the effect of lateral or tangential pressure of the earth's crust met the least resistance. In this portion of the Appalachian province the difference in elevation of the crests and troughs of the folds is often several thousand feet and the faults are of great length and magnitude. To the west the folding gradually became less severe and complex. The sharp folds gradually gave place to the open folds and gentle undulations of the western portion of the province, faulting became at the same time less frequent and finally ceased almost entirely. It is in this gently folded region that the Gaines quadrangle lies.

Accompanying the upheaval of the folds of the Appalachian region, constituting what is known as the Appalachian revolution, there was a general bodily uplift of the whole interior of the continent, the result of which was to raise its surface above the water and to bring to a close the history of this great interior sea. At the same time it is believed that there was a sinking of the eastern land mass from which the sediments had been derived, until finally most of it disappeared beneath the waters of what is now the Atlantic Ocean.

Later deformations.—The subsequent movements of the earth's crust, of which there were several, though properly coming under the head of uplift and folding, are known to us rather by topographic features than by rock structures, and for that reason will be considered under the heading "Physiography."

PHYSIOGRAPHY.

Cretaceous peneplain.—As soon as the folds of the Appalachian region began to appear above the surface of the interior sea, erosion began its work of reducing them and of carrying back the materials to the sea. It seems likely that in the Appalachian Mountains erosion did not keep pace with the uplifting of the folds but that more or less pronounced elevations soon began to appear and to increase in prominence as long as folding continued. After the cessation of the folding the land is believed to have remained fairly constant in elevation during the remainder of Carboniferous and early Triassic times. In this interval erosion progressed rapidly, though to exactly what extent is not established. It is known, however, that the Newark beds of later Triassic times, which occur at intervals along the Atlantic border, rest upon rocks reduced by erosion to a flat or gently rolling surface such as is known to geologists as a peneplain.

The uplift accompanied by the tilting and faulting of the Newark beds in late Triassic or early Jurassic times partly neutralized the effect of previous erosion. Erosion in the new cycle proceeded vigorously, with the result that the continental border had been so reduced in late Jurassic or early Cretaceous times that a slight subsidence allowed the sea to advance and cover with deposits of Cretaceous age the wide flat or undulating lowlands reaching to the base of the highlands then existing near the present limits of the Coastal Plain. Erosion, however, continued its attack on the remaining highlands with undiminished energy until in late Cretaceous times they had been reduced to a peneplain—the Cretaceous peneplain—on which the folds of the Appalachian region were represented, if at all, only by broad, low, flat hills, the component strata, both hard and soft and of all ages, being alike cut down to the peneplain level. The highest point of this peneplain, in the north at least, as is apparently indicated by the surviving drainage, is supposed to have been in northern Pennsylvania or southern New York, from which region it probably sloped away in all directions. In the Gaines region its position is indicated by the flat-topped mountain crests, which simply are remnants of the old surface not yet reduced by erosion.

The general crest lines of the mountain belts are not level, however, but rise gently to the west. From an elevation of about 2300 feet in the central portion of the quadrangle the crests of the Cowanesque mountain belt increase in elevation to 2500 or 2600 feet at the western limits, while the Pine Creek Mountain belt, starting in the east at an elevation of 2280 feet, increases to 2400 at the southwest corner of the area, and from 2400 to 2500 feet as it becomes merged with the Cowanesque belt to the northwest.

Over the Chemung and Catskill anticlinal areas between the Cowanesque and Pine Creek mountain belts and to the north of the former there are probably no remnants of this peneplain surface, the higher knobs reaching only to about 2200 feet.

Early Tertiary peneplain.—In the Elkland and Tioga quadrangles, lying east of the Gaines quadrangle, there are evidences of plateau-like surfaces of two distinct elevations, the first corresponding to the plateau surface of the Gaines quadrangle and the second apparently standing from 300 to 500 feet lower. It was at first thought that the differences in altitude simply marked variations of a single surface which had been locally, but not entirely, reduced to a peneplain. Recent studies of Mr. M. R. Campbell, however, make it seem probable that the lower plateau surface is to be correlated with a similar surface in the regions to the north, south, and southwest, which seems to represent an early Tertiary, possibly Eocene, period of peneplanation. A further objection urged against the reference of the general uplift of the region to the Cretaceous age is the comparatively youthful character of its drainage development as compared with the mature development and dissection of the known Cretaceous peneplain along the western flanks of the Appalachian mountain system toward the south.

In the Gaines quadrangle the only areas which can be referred to the later reduction are the small anticlinal areas of relatively soft rocks, and it seems doubtful whether the land of these areas was reduced to the level of the Tertiary peneplain, although it probably stood well below the Cretaceous peneplain.

The vertical interval between the upper and lower peneplains varies from an average of about 400 feet in the area just east of the Gaines quadrangle to 1100 feet in the vicinity of Harrisburg, Pa., and probably about 1200 feet in the southwestern portion of the State. This would indicate that previous to the last prominent uplift the remnants of the Cretaceous peneplain stood at an altitude of about 1100 feet above the later plain in southeastern Pennsylvania, but not more than 400 feet above it in the Gaines region. What the altitude may have been relative to sea level can not be told, but it is probable that it was not much in excess of the figures indicated. The uplift following the development of the Tertiary peneplain, as indicated by the present altitude of its remnants, reached its maximum in the north instead of in the south, as was the case of the early uplift, and resulted in a partial or, as in certain regions in central Pennsylvania, nearly complete restoration of the Cretaceous peneplain to a horizontal position.

Development of drainage in the Gaines area.—The slopes bordering the streams in the synclinal areas of relatively resistant rocks rise abruptly and without break nearly to the level of the plateau-like remnants of the Cretaceous peneplain. A moderate broadening may apparently be detected, however, about 100 feet below the highest level of the older peneplain, and is probably to be regarded as marking the position of the valleys during the period of the development of the later peneplain. The feature is confined to the vicinity of the present valleys, indicating that the major drainage lines of the present time agree essentially in location to those of the Cretaceous and Tertiary peneplains.

It is thought that the agreement of the present with the early drainage is probably a general feature throughout this portion of northern Pennsylvania. If so, it would indicate that in the development of the Cretaceous peneplain the larger streams, though exhibiting a general tendency to follow strike lines, did not occupy either the synclinal troughs, as the original consequent streams of the newly folded regions must have done, nor the soft and easily eroded anticlinal areas of Chemung rocks, as would have been the case with a completely adjusted system, but usually took an intermediate position at one side of the hard rocks occupying the center of the syncline, though in some instances, as in the cases of Cowanesque River and the stream draining the Blossburg syncline (fig. 6), the streams appear to have followed for considerable distances along the very center of the synclines.

To what extent the courses of the transverse streams have been influenced by the outcrops of the folded beds is not apparent, though it seems probable that in the Gaines region the influence was very slight. In fact, although in its broader relations the development of the present drainage appears to have been dependent to a considerable extent upon the geologic structure, its minor features show very little relation to it.

The present drainage lines, coinciding as they do with the location of the drainage lines existing on the surface of the older peneplain, may be said to have been inherited from that surface. Further back than that, little is known beyond the fact of the existence of the general relationship of the drainage to structure.

Uplift and erosion of the later peneplain.—After the development of the lower and younger of the peneplains, the completion of which is assigned provisionally to early Tertiary time, possibly Eocene, occurred an uplift which was accompanied by a tilting and slight warping, and which elevated the surface to a position not far from that which its uneroded remnants still possess. The result was an increased activity of the streams, which began cutting deep and canyon-like gorges, first in their lower courses and later about their headwaters. This erosion, though probably affected by a number of oscillations of level in late Tertiary and in Pleistocene times, has continued until the present, and has resulted in the formation of the topography as it now exists. The uplift that inaugurated this period of erosion appears to have culminated at a point some distance west of the Gaines area. Within the quadrangle the slope is toward the southeast.

The tilting seems to have been sufficient to change the general slope of the peneplain from a northeastward direction, as indicated by its main drainage lines, to a southeastward direction, but the uplift was not sufficiently rapid to reverse the drainage. In fact, the effect of the southward slope is shown chiefly in the greater activity of the southward-flowing streams as recorded by their greater length and their greater erosive effects. Thus while the larger of the northward-flowing streams, such as Potter and Cronce Brooks, Mill Creek, and the various tributaries entering Pine Creek from the south, were cutting back a distance of 4 to 7 miles, the southward flowing streams, such as the North Fork, Long and Phoenix runs, Genesee Forks, etc., had cut back a distance of from 8 to 10 miles. The difference is even more conspicuous at many points in the surrounding regions. (See fig. 6.)

While the relative differences between the lengths of the northward- and the southward-flowing tributaries of Cowanesque River and Pine Creek are the same, the actual lengths of the tributaries of the latter stream are considerably greater. This is evidently because of the greater drainage area of Pine Creek, the larger supply of water more than counterbalancing the more circuitous course of the creek and the greater hardness of the rocks over which it flowed.

Late Tertiary events.—It has been generally conceded among geologists that the advent of the earliest Pleistocene ice sheet was preceded by a general uplift of the northern portion of the continent affecting the surface throughout the northern part of the United States. In western Pennsylvania there is evidence that the uplift recorded by the gorges of the Monongahela and Allegheny rivers did not occur until after the first ice invasion. The uplift recorded along the Susquehanna in the eastern portion of the State is of unknown date. It is almost certainly not younger and may be older than that which brought about the formation of the Monongahela and Allegheny gorges. In the Gaines region there is a slight notching in the bottoms of the old valley of Pine Creek, but this was not produced until after the southward deflection of the lower portion of this creek through the gorge at Ansonia, which is described in the following paragraph. There is, therefore, no evidence in the quadrangle to substantiate the supposed late Tertiary or early Pleistocene uplift.

In the description of the drainage (page 1) mention was made of the diversion of the water of Pine Creek from its old channel leading from Ansonia to Middlebury Center and thence to Tioga River at Tioga, which it followed previous to the glacial invasion. Through the influence of the tilting accompanying the uplift of the early Tertiary peneplain and the consequent impetus to the southward-flowing streams, in virtue of which they rapidly cut back their valleys to the north, and with the further aid of the stream cutting attendant on the uplift preceding the first ice invasion, if such uplift occurred, the divides between the northward- and southward-flowing drainage systems were so reduced that when the ice sheet advanced from the northeast and obstructed the established northward drainage of the Tioga River, the ponded waters found a relatively low outlet provided for their escape to the south.

GLACIAL HISTORY.

From the phenomena of erosion, transportation, and deposition of a character known to be associated with glacial action it has been established that most of the northern half of North America has been covered in comparatively recent (Pleistocene) geologic time by great ice sheets similar to those covering the greater part of Greenland.

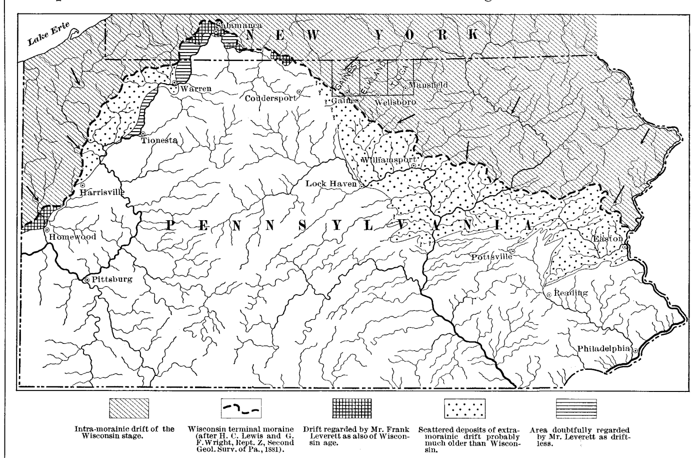


FIG. 2.—Sketch map showing the distribution of the glacial deposits of Pennsylvania and adjoining portion of New York. Compiled by Wm. C. Alden, 1901.

Arrows indicate direction of glacial striæ.

The limit of the extra-morainic deposits west of Coudersport is by Mr. Leverett; that east of Coudersport is by Prof. Edward H. Williams, jr., who regards this drift as of comparatively recent age (Am. Jour. Sci., vol. 149, 1895, pp. 174-185, and personal communication).

The phenomena associated with the ice invasion consist of certain peculiar surficial deposits of clay, sand, gravel, and bowlders known as *drift*, and certain scourings and groovings of the surface of the underlying rocks, evidently due to some agent like a glacier, furnished with rock fragments which were pushed or dragged along over the surface upon which it rested. The examination of these deposits over the vast area covered by the ice leaves no reasonable doubt that this is their general mode of origin, though parts of the material, it is equally clear, were deposited through the agency of glacial waters. The two types unite to form a nearly continuous mantle overlying indiscriminately rock formations of all characters and ages.

Glacial stages.—A detailed examination of the structure of the drift and of its general distribution and associations shows that instead of constituting a single sheet formed by one ice advance, it is composed in reality of several distinct drift sheets, each of which represents a separate ice advance.

The intervals of deglaciation or disappearance of ice between these ice advances are made apparent by the presence of soils and beds of peat and muck and other effects of life, and also by the weathering of certain zones now buried in the midst of drift deposits; while the sheets themselves differ markedly in extent and often in color, composition, and other physical properties. These differences, together with the morainal ridges marking the various positions of the ice margins, form a basis for the subdivision of the Glacial epoch in North America into nine divisions, as follows beginning with the earliest:

Outline of glacial stages.

1. Pre-Kansan or sub-Aftonian glaciation.
2. Aftonian deglaciation.
3. Kansan glaciation.
4. Yarmouth deglaciation.
5. Illinoian glaciation.
6. Sangamon deglaciation.
7. Iowan glaciation.
8. Peorian deglaciation.
9. Wisconsin glaciation.

Of the drift sheets of the various stages only two have been recognized in Pennsylvania and of these only one can be assigned with certainty to a definite stage. This is the main drift sheet covering the northern part of the State and including the Gaines quadrangle. It is assigned to the Wisconsin stage. The other recognized drift consists of scattered fragments or a thin sheet deposited by ice and its associated drainage beyond the moraine marking the southern limits of the Wisconsin drift. From its associations further west it is believed to belong to the Kansan or pre-Kansan stage. The distribution of both is shown in fig. 2.

KANSAN OR PRE-KANSAN INVASION.

Advance of the ice.—The cause of the accumulation of the glacial ice and its spread over so large a part of the northern portion of the continent is not well understood, but is generally believed to be due to a somewhat pronounced uplift of the land and an increase of snowfall, aided perhaps by a relative lack of carbonic acid gas in the atmosphere and by certain favorable astronomical conditions. The eastern portion of the great ice sheet had its origin, perhaps, in the coalescence of local ice sheets, such as might have been formed in the Adirondack region of New York or in the highlands of northeastern Canada. After their incorporation into a single ice sheet the borders of the latter continued to spread outward, the ice advancing, as has been seen, into the latitude of northern Pennsylvania. (See fig. 2.)

Obstruction and deflection of drainage.—When the ice margin advancing from the northeast reached the lower portion of the Tioga River near Corning, New York, the natural outlet for the waters of that river and its tributaries, draining the Gaines area and the whole of the northern and eastern portions of Tioga County, was obstructed and a series of long, narrow lakes similar to the Finger Lakes of New York, but more crooked, came into existence in the valleys of the Tioga and its larger tributaries. The water in this branching lake must have continued to rise until it finally overflowed at the lowest divide and passed off southward to the Susquehanna. The lowest divide appears to have been about 8 miles east of Gaines, at a point about 2 miles south of Ansonia. Its elevation can not now be determined, but it had probably undergone great reduction by the backward cutting of the headwaters of the southward-leading stream in consequence of the uplift and tilting of the early Tertiary peneplain.

When, on the continued advance of the ice, the margin reached the lower portion of Cowanesque River the arm of the early lake occupying its valley became a separate lake, which continued to rise until it found a divide at the head of Jemason Creek about 3 or 4 miles east of the limits of the Gaines quadrangle. The elevation appears to have been originally 1600 or 1700 feet, but it was gradually reduced as the waters continued to pour over its crest. On the closing of this outlet by the advancing ice a new one was opened at an elevation of probably 1800 feet or more, over the divide between Mill Creek and Long Run, southwest of Sabinsville. This in turn was gradually reduced in height by the escaping waters until the advancing ice covered the region and brought the first chapter of the history of the lakes to an end.

Drift deposits.—So scanty are the remnants of the early drift sheet in the Pennsylvania region that within the area covered by the later advance of the ice it has almost entirely escaped observation. Nowhere in the Gaines area has it been distinguished from the later drift, and even beyond the limit of the later drift sheet, in the area of extra-morainic drift shown in fig. 2, the deposits are so attenuated that it is very difficult if not impossible to determine the exact limits of the earlier ice invasion. The area south of Pine Creek, in the southwestern corner of the quadrangle, has been mapped as driftless because no drift was found on the mountain at that point, yet from the more detailed studies of others in the region farther south it appears possible that the early ice advance may have extended southwestward some distance beyond the limits of the Gaines quadrangle. (See fig. 2.)

INTERVAL OF DEGLACIATION.

With the cessation of the conditions favorable to its existence, the ice sheet drew back to the north and possibly entirely disappeared from the continent. During this retreat it is probable that there occurred a series of events similar in character but in reversed sequence to those occurring during the advance. It seems likely that the lakes were of shorter duration than the earlier, and that the divides over which the waters escaped suffered relatively little reduction. The reduction of the divide south of Ansonia appears to have been completed, so that it afforded, even at the disappearance of the first ice sheet, the easiest outlet for the waters of the upper Pine Creek. Following the disappearance of the ice, the streams and the atmosphere began their work upon the glacial deposits, with the result that considerable portions of the drift were doubtless washed away, and in some parts of Pennsylvania, at least, the underlying rocks were strongly trenched by the streams. Such drift as remains is deeply weathered and oxidized, the crystalline rock fragments being largely in an advanced state of disintegration. The calcareous elements of the drift are almost entirely leached out. These evidences of long exposure to the weather as compared with the fresh, almost unchanged Wisconsin drift, taken in connection with the extensive erosion which in many places in the country is known to have occurred since the earlier drift was deposited, has led to the belief that the time interval between it and the Wisconsin drift is many times as long as the period which has elapsed since the latter was laid down. This long intervening period was marked in other regions by stages of glaciation, during which the ice readvanced over the soils, vegetation, and older drift deposits, and by stages of deglaciation, when the ice retreated far to the north or completely disappeared. None of these advances are known to have invaded the Pennsylvania region.

WISCONSIN INVASION.

Advance of the ice.—The recurring conditions favorable to glaciation at length produced an ice sheet during the Wisconsin stage which reached southward into Pennsylvania. As in the earlier invasion, it seems probable that the Wisconsin ice sheet was first represented, at least in the eastern portion of the continent, by a series of local glaciers in the Adirondacks and other mountains and highlands of northeastern United States and eastern Canada. These local glaciers are supposed to have coalesced into a single sheet, which continued to advance until the whole of northeastern Pennsylvania was covered. The limits of the invasion in this State are shown in fig. 2.

Direction of ice movement.—As in the earlier invasion, the general movement was from the northeast to the southwest. (See fig. 2.) The local movement, however, was probably more or less dependent on the configuration of the surface over which the ice passed, and varied through wide angles. Striæ were observed at only two points in the Gaines quadrangle, the locations of which are shown on the Surficial Geology map. One of these, in northern Brookfield Township, has a bearing of 45° W., which is probably about the normal direction of movement. Of the striæ observed at the locality in northwestern Clymer Township, those bearing from S. 80° W. to due west are the most pronounced. At the same point, however, there are other striæ, having the abnormal bearing of S. 55° E. (or N. 55° W.)

During the maximum development of the ice sheet the movement was essentially independent of all but the broader features of the topography and was normally S. 40° W. to S. 50° W. The divergent character and abnormal direction of the striæ in question would appear to indicate that they were not formed under such conditions, but were probably produced during the closing stages of the Wisconsin invasion by the agency of constantly shifting ice currents controlled by the underlying or adjacent topography. Diverging striæ of the nature indicated may, however, result from the irregular movement of loose fragments carried along at the bottom of the ice sheet or set free by basal melting during the closing stages of glacial activity.

Deflection of drainage.—When the ice margin, advancing from the northeast, obstructed the lower portion of the Tioga River near Corning, New York, the drainage was again gathered into long narrow lakes which overflowed through the abandoned valley between Middlebury Center and Ansonia, formerly occupied by Pine Creek, into the new channel which this creek had established for itself at the time of the previous invasion. As the ice continued to advance and obstructed the waters of Cowanesque River a separate lake was formed in its valley which, as in the earlier invasion, found outlets first across the divide at the head of Jemason Creek and later over the divide southeast of Sabinsville.

Work of the glacier.—The work of the glacier consisted of the erosion of the rock surface over which it moved, the transportation of the débris thus obtained to greater or less distances from the places of derivation, and the deposition of this débris, both directly by the melting of the ice and indirectly by the waters flowing beneath the glacier or issuing from its front. The amount and character of the work accomplished by the ice in a given locality depends largely upon the thickness of the ice, the rapidity of its movement, the amount of abrasive materials it carried, and the character of the rock over which it moved.

In the Gaines area all of the general topographic features are clearly the work of streams, though the ice was possibly a factor of some importance in forming the beautifully flowing contours of the broad areas of Chemung rocks. That the action of erosion was not powerful, however, is apparent to one passing from these areas into the areas of the harder Cattaraugus and Oswayo formations, where the slopes are steep, the crests imperfectly rounded and nearly free from glacial deposits, and projecting ledges abundant. An examination of the rounded Chemung hills shows that a very slight cutting usually serves to expose the underlying rock, indicating that relatively little of the rounding is due to coatings of glacial materials. In fact the general topography is everywhere manifestly the result of stream erosion. Although in general the glacial action was not such as would produce an important modification of the topography, there were local conditions, especially in certain parts of the valleys, which favored the accumulation of considerable amounts of glacial drift. On entering the deep narrow valleys lying transverse to the direction of glacial movement the heavily drift-laden basal layers of the ice sheet became lodged, or at least greatly retarded, and on melting deposited, either directly or through the agency of the glacial waters that were concentrated in the valleys, the considerable quantities of drift found in such positions.

The most conspicuous deposits of the glacier, however, are those which accumulated at the immediate margin of the ice, in the manner previously described, and which are known as moraines. Such moraines were probably formed during every important halt in the ice advance or in its retreat.

The outermost or terminal moraine is of special interest as marking, in this region at least, the limits of the ice advance of the Wisconsin stage. The belt enters Tioga County from the southeast and crosses Pine Creek at the mouth of Babbs Creek in Morris Township. From here it extends northwestward across the southwestern part of Morris and Elk townships, passes a little south of Marshfield, and then crosses Pine Creek a second time just west of the Potter County line. Traversing Pike Township its line crosses Genesee Forks north of West Pike and continues northwestward through Jackson, Ulysses, Allegheny, Genesee, Oswayo, and Sharon townships in Potter County, finally passing into New York just west of Honeoye Creek. (See figs. 2 and 6.)

Within the area of the Gaines quadrangle there are no continuous or well-defined morainal deposits, but deposits probably marking the limits of the glacial ice are found at a number of points along Genesee Forks from West Pike northward to Loucks Mills. These have been described on page 3.

Similar deposits have been noted in the valley of Pine Creek between Johnson Brook and Phoenix Run, but there is no indication of the position of the ice front as it lay across the mountains between these points.

Considerable deposits of gravel occur in the valley of Pine Creek in Pike and eastern Jackson townships and also for some distance above the morainal deposits between Phoenix Run and Johnson Brook, the deposition of which is probably to be correlated with that of the terminal moraine. At the mouths of the ravines in the northeast slopes of the valley of Pine Creek in this region there are considerable delta deposits of waterworn gravels. These are spread out along the valley bottom and have crowded the creek against the opposite slope. Instead of receiving additions these deltas are now being eroded, hence it appears probable that they were formed by the glacial waters issuing from the ice front on the mountain to the northeast and flowing down the ravines and probably into a lake ponded in front of the ice margin which at this time appears to have laid across Pine Creek at a point a number of miles to the east.

Retreat of the ice.—The peculiar climatic conditions which led to the inauguration, development, and maintenance of the ice sheet finally gave way to a more temperate climate, with the result that the ice sheet gradually contracted and finally disappeared. It appears probable that the ice in the Gaines region did not respond quickly to this climatic change, and that instead of a gradual retreat of the ice front, the whole marginal portion of the sheet for some miles from its edge became essentially stagnant. It is unlikely, however, that it was at any time stagnant over the whole of the quadrangle, the motion probably continuing in the north long after it had ceased in the region to the south, or even after the ice had completely disappeared in some of those areas. The deposits of morainic character described as occurring at a number of points in the quadrangle probably mark halts or possible readvances of the ice, during which the movement again became active to the very front.

Finally, with the retreat of the ice to the north, a number of long, narrow glacial lakes came successively into existence in the valleys of Pine Creek and Cowanesque River. The lake occupying the valley of Pine Creek was the first to disappear. As the ice receded the lake became extended to the east, and on the disappearance of the ice from the region of the outlet south of Ansonia, the waters were drawn off into the valley leading southward to the Susquehanna. Pine Creek did not return to its original valley even after the final disappearance of the ice, but persisted in the newer channel which it had acquired at the time of the first invasion. The waters entering the abandoned portion of the valley of Pine Creek in part followed their original course eastward to Tioga River and in part flowed in a reversed direction to the new Pine Creek at Ansonia.

The Cowanesque lake did not come into existence until after the Pine Creek lake had been drained, but it continued to exist for a longer period, completely disappearing only after the ice had melted back beyond the site of Corning, N. Y.

POST-GLACIAL HISTORY.

As the valleys were successively opened up by the retreat of the ice front the streams of the steeper ones entered actively upon the work of removing the glacial deposits from their bottoms and of returning to their former condition. The deposits thus removed from the smaller and steeper valleys have been carried to the broad, open valleys of gentle slope, where they have been incorporated in the general filling on which the present flood plain deposits rest, or left in the form of broad, low gravel fans at the mouths of the streams. The valley fillings are probably composed mainly of glacial materials, but the filling of the inequalities and the building of the upper portion of the deposits is doubtless to be assigned to post-Glacial deposition of the nature mentioned.

The only other deposits which are assigned to post-Glacial time are the poorly assorted gravels of certain of the torrential streams, the marsh deposits occurring in poorly drained portions of the flood plains and in drift-obstructed valleys or in drift depressions, and the thin coating of flood-plain silts along the rivers.

The small amount of erosion and the correspondingly limited deposition, together with the slight leaching and oxidation of the drift, seem to indicate a post-Glacial time which in length is but a small fraction of that which elapsed between the earliest and the latest invasion of the ice in this region.

ECONOMIC GEOLOGY.

PETROLEUM.

Oil has not yet been found in paying quantities at any point within the Gaines quadrangle, but the northern edge of the Gaines oil field is within one-eighth of a mile of the southern edge of the quadrangle and the whole field falls within a strip a mile wide, adjoining the quadrangle on the south. The center of operation for the field is at Gaines, from which town the quadrangle, as well as this oil field, takes its name. Because of the intimate relation of the oil field to the Gaines quadrangle it has appeared desirable to consider the occurrence of the oil at some length.

Discovery and development of the Gaines oil field.—Wells were sunk in search of oil in the vicinity of Gaines as early as 1884, but although some slight shows were obtained, nothing of value was found, and after the drilling of a few more scattered wells along Pine Creek from Galeton to Ansonia in 1885 and 1886, the search for oil was abandoned until 1897–8. At this time a well was put down at Galeton which gave a sufficient show to encourage further drilling in the region and which led to the sinking of a well at Gaines by Woodward & Co., of Wellsville, N. Y. This well gave salt water and a good show of oil, and in turn led to the sinking of a well by E. M. Atwell on his own estate. This well, known as Atwell No. 1, produced about 10 barrels a day at the start from a fine-grained sandstone lying at a depth of about 790 feet. The appearance of the sand under the microscope is shown in fig. 8 of the Illustration sheet.

Following the Atwell No. 1, other wells were sunk in rapid succession, most of which had an initial production of 10 to 20 barrels, though a few went as high as 30 to 40 barrels a day. As the drilling proceeded, however, it soon became evident that the pool was of very limited area, and as finally outlined by the wells was found to cover only a narrow belt, less than one-quarter of a mile wide, and about 2 miles long, extending from near Gaines to about a mile west of Watrous.

(See fig. 3.) In this belt there were about 60 producing wells, nearly all of which were yielding oil (in 1901), after from 1 to 3 years of pumping, though in most of the wells the daily yield was less than 5 barrels.

While the original sand, called the Atwell sand in honor of the owner of the first producing well, was being developed, a new oil horizon was found a short distance southwest of Manhattan, at a depth of from 500 to 550 feet or more below the level of Pine Creek. (See fig. 10, Illustration sheet.) The oil did not generally appear to occur in sandstone, as in the wells about Watrous, but along more or less open bedding and joint planes, or "fissures," from which the oil was given up with great rapidity. The wells were "gushers" in nearly every case, but were short-lived, and in 1901 hardly any were producing. There were about 30 producing wells, all told, the production at the start varying from a few barrels up to 2100 barrels a day, this being the product of Blossburg well No. 4. The location of the wells is indicated in fig. 3. The zone in which the oil occurred consisted of an alternating series of shaly sandstones, shales, shaly limestones, and thin limestones, and is known to the drillers as the Blossburg formation. The appearance of one of the shaly sandstones under the microscope is shown in fig. 9.

A list of the producing wells which have been sunk at various times, together with statistics as to depths, casing, production, etc., are given for both portions of the Gaines field in the following tables.

Production of wells of the Gaines oil field, as reported by the individual operators.

Wells.	No. of well, fig. 3.	Production at start.
		Barrels per diem.
South Penn Oil Co. (wells in Atwell sand):		
Atwell No. 1	53	10
Atwell No, 2	49	20
Atwell No. 3	47	10
Atwell No. 4	50	35
Atwell No. 5.	52	35
Atwell No. 6	51	15
Atwell No. 7	48	25
Atwell No. 8	55	25
Atwell No. 10	57	40
Atwell No. 11	56	25
Atwell No. 13	54	20
Dimmick No. 1	46	50
Dimmick No. 3	34	30
Dimmick No. 4	37	30
Dimmick No. 5	41	35
Dimmick No. 6	33	20
Dimmick No. 8	38	35
Dimmick No. 9	28	8
Dimmick No. 10	....	8
Dimmick No. 11	....	25
Legal No. 1	30	15
Legal No. 2	35	30
Legal No. 3	31	20
Legal No. 4	36	15
Legal No. 5	29	10
Legal No. 6	27	25
Legal No. 7	26	11
Knoxville Oil and Gas Co. (wells in Atwell sand):		
Knoxville No. 1	58	55
Knoxville No. 4.	59	35
Maxwell Oil Co. (wells in Atwell sand):		
Maxwell No. 2	22	20
Maxwell No. 3	19	75
Mæxwell No. 4	24	25
Maxwell No. 5	21	30
Maxwell No. 6	20	15
Maxwell No. 7	16	40
Maxwell No. 8	....	3
Maxwell No. 9	18	50
Maxwell No. 10	15	6
Blossburg and Gaines Oil and Gas Co. (wells in Blossburg formation):		
Blossburg No. 2	....	6
Blossbürg No. 3	73	500
Blossburg No. 4	74	2,100
Blossburg No. 5	75	230
Blossburg No. 6	76	200
Blossburg No. 7	77	100
Blossburg No. 8	78	100
Blossburg No. 9	84	30
Blossburg No. 10	83	100
Blossburg No. 11	82	60
Blossburg No. 12	81	60
Wellsboro Oil and Gas Co. (wells in Blossburg formation):		
Wellsboro No. 1	63	56
Wellsboro No. 2	64	22

Production of wells of the Gaines oil field, as reported by the individual operators—Continued.

Wells.	No. of well, fig. 3.	Production at start.
Wellsboro No. 3	65	25
Wellsboro No. 4	66	30
Wellsboro No. 5	67	5
Wellsboro No. 6	68	15
Wellsboro No. 7	69	150
Wellsboro No. 8	70	200
Wellsboro No. 9	71	250
Wellsboro No. 10	....	100
Billings Oil and Gas Co. (wells in Blossburg formation):		
Billings No. 1	88	140
Billings No. 2.	87	500
Billings No. 3	86	60
Billings No. 4	90	20
		Production at end of ten days.
Scott & Fay (wells in Atwell sand):		
W. H. Watrous No. 1	11	10
W. H. Watrous No. 2	13	10
W. H. Watrous No. 3	....	10
W. H. Watrous No. 4	10	5
W. H. Watrous No. 5	14	2
W. H. Watrous No. 6	7	5
W. H. Watrous No. 7	12	3
W. H. Watrous No. 8	8	6
W. H. Watrous No. 9	....	2
W. H. Watrous No. 10	....	4
W. H. Watrous No. 11	9	10
C. H. Watrous No. 1	....	1
C. H. Watrous No. 2	5	4
C. H. Watrous No. 5	1	2
C. H. Watrous No. 6	4	2
C. H. Watrous No. 7	3	2
C. H. Watrous No. 8	2	2

Summary of production at start, as reported by individual operators.

Company.	Producing sand.	Number of wells reporting.	Production at start. Max.	Min.	Av.
			Barrels per diem.	*Barrels per diem.*	*Barrels per diem.*
South Penn Oil Co.:					
"Legal" purchase	Atwell	6	30	10	19
Atwell lease	do	11	40	10	24
Dimmick lease	do	9	50	8	27
Knoxville Oil and Gas Co.	do	5	55	?	30
Maxwell Oil Co	do	9	75	3	27
Scott & Fay (estimated)	do	14	20	2	10
Blossburg and Gaines Oil and Gas Co	Blossburg.	11	2,100	6	317
Wellsboro Oil and Gas Co	do	10	250	5	85
Billings Oil and Gas Co	do	4	500	20	180

Geology of the oil field.—The records of the wells show that the Atwell sand probably occurs at a depth of about 700 feet below the lowest red bed which has been taken as marking the bottom of the Cattaraugus formation. It is thus seen to be well down in the Chemung. The horizon of the Blossburg formation, though rather indefinite, may be placed at an interval of about 200 feet above the horizon of the Atwell sand.

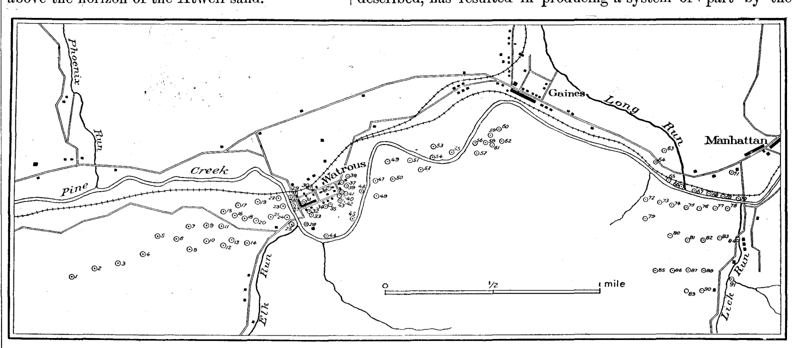


FIG. 3.—Sketch map showing location of the wells of the Gaines oil field. A list of the wells is given on this page.

The dip of the beds is brought out by the well records. In direction it is a little west of north, and in amount about 3°. The position of the pool is 2.7 miles south of the axis of the Pine Creek syncline and a little less than this north of the axis of the Marshfield anticline. (See fig. 6.)

The structural features which may be of significance in regard to the occurrence of oil at this point are as follows: (1) A change from steep to flat dips near the northern margin of the field, (2) a shallowing of that portion of the syncline immediately north of the field, and (3) a simultaneous change in the direction of the axial trend of the syncline.

The dips brought out by the well records are very slight, only about 3°, while in the bend of Pine Creek near Gaines, just north of the productive area, dips as high as 10° are to be seen. If the change of dip observed at the surface holds at the depth of the oil sand, the conditions will be somewhat as represented in fig. 4, in which it will be noticed that the oil is found in the sand just beyond the point marked *a*, at which the

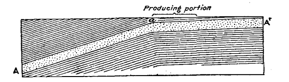


FIG 4.—Ideal section showing relation of Gaines oil pool to supposed change of dip of the strata.

A–A', Oil sand; *a*, brink of terrace where oil is supposed to have accumulated.

flattening takes place, or at the brink of the terrace thus formed. In general, therefore, it may be said that the occurrence of the oil roughly accords with the anticlinal theory, for although not at the crest of an anticline it seems to have risen until the dips were so slight as to prevent, for the time at least, its further upward passage. This is possibly the most important factor governing the location of the oil at the precise spot at which it is found.

The shallowing of the Pine Creek syncline at a point opposite the oil field (fig. 1) has given rise to somewhat flatter dips than ordinarily exist along the south side of the syncline in adjacent regions, which is a feature favorable to the retention of the oil in the rock.

The slight swing of the syncline to the south, taken in connection with the shallowness just described, has resulted in producing a system of diverging dips, or converging upward slopes (fig. 5), which, theoretically, would tend to bring about a concentration of any oil passing upward through the rocks. The position of the Gaines field is in accordance with theoretical results of such a structure and the accumulation may have been, in fact, in some measure dependent upon it.

Prospects.—Practically none of the wells of the Blossburg formation were producing in 1901, though most of those in the Atwell sand were

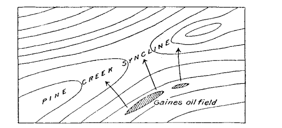


FIG. 5.—Sketch showing relation of Gaines oil field to Pine Creek syncline. The structure is shown by sketch contours, and the arrows show dips which converge upward to the oil field.

still yielding small amounts. The limits of the field have been well defined by drilling and are not likely to be extended. The few wells that have been sunk to the rocks below the Atwell sand have also failed to discover further oil. In fact, it seems almost certain that no further development is to be expected in the field itself unless at depths greater than those yet penetrated by the drill, and even if oil were to be found it seems unlikely that the amounts would compensate for the cost of drilling.

It is probable that there are numerous other points in Tioga and Potter counties where the geologic conditions for the occurrence of oil are as favorable as at Gaines, but although considerable "wild-cat" drilling has been done, it has as yet met no success. It should be remembered, however, that fields of the width of Gaines field—less than one-quarter of a mile wide—might exist at a number of points and yet escape discovery even in a region well tested by "wild-cat" wells, while in a region which, like the Gaines area, has been tested only by occasional holes, the chances for striking such fields would be very small.

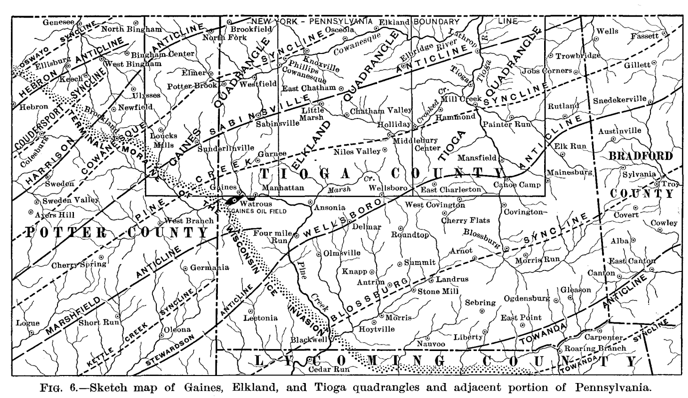


FIG. 6.—Sketch map of Gaines, Elkland, and Tioga quadrangles and adjacent portion of Pennsylvania. Showing position of the terminal moraine and approximate location of anticlinal and synclinal axes. The Gaines oil field is shown at the southern border of the Gaines quadrangle.

Fig. 6 shows with approximate correctness the locations of the anticlinal and synclinal axes in the surrounding region as determined by the Second Geological Survey of Pennsylvania and in part by the United States Geological Survey. From it the localities corresponding to that of the Gaines oil field in position and structure can be roughly determined.

In drilling for oil in this region, it should be borne in mind that the Gaines field occurs in more strongly folded rocks than any other oil field in Pennsylvania, and that while it can not be said that oil will not be found in the more strongly folded region between Gaines and the Allegheny Front near Williamsport, the chances for finding it in paying quantities are probably better in the less strongly folded region to the north of Gaines.

NATURAL GAS.

Gas as well as oil is found in many of the wells drawing their supplies of oil from the Atwell sand. The amounts are hardly sufficient to run the boilers used in pumping and almost none is used about the town. The wells of the Blossburg formation have given little gas except that which came off with the oil when the wells were drilled, and which unavoidably escaped. Gas has been found in a number of "wild-cat" wells, sometimes under heavy pressure, but the pockets have been very small, and no economic use has so far been made of it.

COAL.

Although rocks of the age of the coal-bearing formations of central and southern Pennsylvania occur at three points along the Pine Creek mountain belt within the quadrangle, no coal has been found except near Gurnee, on the crest of the mountain northeast of Gaines. This coal occurs about 160 feet above the Sharon conglomerate member, and as only a thin cropping of the measures above the comglomerate occur on the other two crests mentioned, the corresponding coal is not to be looked for.

The coal is located geologically in the center of an elongated trough-shaped depression from which the rocks rise in all directions; steeply to the north and south, gently to the east and west. This depression is known as the Gaines coal basin, and is really a simple local deepening of the greater Pine Creek syncline. (See fig. 1.)

Coal has been known to occur in the Gaines basin for half a century or more and was actively exploited about twenty-five years ago. At that time careful examinations were undertaken and openings on coal were made at many points, on the basis of which a minutely detailed geologic section showing the presence of 11 coals, 4 of which were reported to be 3 feet or more in thickness, was made out. On the basis of this section and the accompanying report a company was organized, a railroad built up the side of the mountain from Lansing, 700 feet below, and a mine opened on the most promising vein, then known as the Knox and Billings coal. This coal proved to be of good quality and to possess a fairly persistent thickness of about 3 feet, and was actively mined for a number of years. The mining developments, however, brought to light unexpected dips, and the coal, instead of underlying the whole of the broad flats of the mountain top, was found to underlie an area of less than a square mile. It also gradually became certain that the many openings, supposedly on different coals, were in reality on a single bed, with the exception of a 3-inch seam occurring 15 or 20 feet above the top of the conglomerate. The area was long ago exhausted of all the coal that could profitably be mined by the larger company, and the mines were practically abandoned, though they have since been reopened and are still worked on a small scale by Mr. P. Smith, who was foreman of the company.

The coal is cuboidal and on a fresh surface is seen to consist of deep black, shiny layers alternating with duller partings of amorphous carbon. It is rather soft and friable and carries considerable sulphur. Its coke is also friable but meets the requirements of good blacksmiths coal, for which use it is in considerable demand. It is popular in the surrounding country for general heating purposes, and at the present time is also in demand as a fuel in the nearby oil field.

An analysis made and published by the Second Geological Survey of Pennsylvania (Rept. C, p. 221) is as follows:

Analysis of coal from the Gaines basin.

Water (mainly absorbed moisture)	3.260
Volatile matter	27.860
Fixed carbon	60.421
Sulphur	.804
Ash	7.655
	100.000

Coke, per cent, 68.88.
Color of ash, reddish gray.

BUILDING STONE.

There is very little good building stone within the area under consideration, the rocks being as a rule too thin-bedded and shaly to afford blocks or slabs of desirable thickness. The Chemung formation is largely shaly, and the sandstones that do occur are generally too calcareous and friable to furnish desirable building material. A gritty sandstone of this age, which might afford small amounts of building stone, has, however, been reported as occurring in the banks of the Cowanesque about a mile below Harrison Valley.

The Catskill–Pocono rocks, like those of the Chemung, are usually too thin bedded to furnish any but the thinnest of slabs. An exception, however, occurs in the quarry on the hillside north of Cowanesque River near Westfield, where a handsome, pale-green, even-grained sandstone is obtained in blocks up to about 2 feet in thickness. It is used to a considerable extent about Westfield and vicinity and is an effective building stone.

The only other formation which furnishes stone of economic value is the Sharon conglomerate, but as it occurs only on a few of the highest and most inaccessible hilltops, is very difficult to split into desirable shapes, and has a strong tendency to disintegrate into sand, it is not likely to prove to be of great value. The smaller blocks which have slid down the hillsides to the valleys below are, nevertheless, often collected and used for rough work, and at one locality on the north side of Pine Creek, near the point where it leaves the quadrangle, a quarry employing a considerable number of men is reported to have been opened on an immense block of the conglomerate which has slid down the hillside several hundred feet from its outcrop.

IRON ORES.

The amount of iron in the form of hematite or red oxide in certain of the red shales near the base of the Catskill formation is sometimes sufficient to appreciably affect the weight of the material, constituting, in fact, a low grade of iron ore. Fragments of ore picked up at Wattles Run, Clymer Township, were analyzed by the Second Geological Survey of Pennsylvania, but showed only a little over 18 per cent of iron. A 16-inch bed of ore is also said to occur in a hill above Long Run, in the southern part of the same township. No beds of economic value have been found, though in the vicinity of Mansfield, about 20 miles farther east, beds of ore of similar character and of the same geologic position were found in sufficient thickness to admit of working during the period preceding the development of the Lake Superior ores.

LIMESTONE.

No pure limestones of any considerable thickness have been noted within the quadrangle, though in a few instances the impure, sandy, or argillaceous limestones of the Chemung formation have been burned in a small way for fertilizing material.

Drive pipe, casing, and nitroglycerin required in the sinking and shooting of the wells of the Gaines oil field.

Group of wells.	Producing sand.	Number of wells.	Drive pipe.			Casing.			Nitroglycerin.		
			Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Av.
South Penn Oil Company:			Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Qts.	Qts.	Qts.
Atwell lease	Atwell	13	42	12	25	456	273	355	100	20	72
Dimmick lease	do	12	42	15	26	443	344	385	100	20	49
Legal Oil Company purchase	do	7	37	12	27	443	411	425	(?)	(?)	(?)
Scott & Fay	do	19	138	52	112	723	372	434	90	40	61
Maxwell Oil Company	do	11	35	17	23	663	367	457	60	40	50
Knoxville Oil and Gas Company	do	5	123	74	97	334	321	329	(?)	(?)	(?)
Blossburg and Gaines Oil and Gas Company	Blossburg	12	84	22	54	......	......	......	Usually not shot.		
Wellsboro Oil and Gas Company	do	10	48	20	32	440	328	565	Usually not shot.		
Billings Oil and Gas Company	do	5	95	43	67	......	......	......	Usually not shot.		

GRAVELS.

Gravels occur in abundance at many points, especially along the larger streams and in the moraines, terraces, gravel fans, etc., which are shown on the Surficial Geology map. The material is little used except as road metal on those roads built upon the soft, loamy top of flood plains adjoining the river.

MINERAL WATER.

A well put down in search for oil near Harrison Valley in 1900 obtained a flow of 2880 barrels of water a day from a depth of only 100 feet. The water possessed a recognizable taste, and on analysis showed the presence of calcium sulphate, calcium carbonate, magnesian carbonate, potassium sulphate, iron carbonate, and some alumina, silica, salt, and natural gas. A company was organized and the water was placed on the market as a mineral water of valuable medicinal properties.

CLAY.

The glacial clays have been opened at the brick yard of J. M. Seaman just west of the Westfield fairgrounds. The principal bed consists of a red laminated clay from 4 to 18 feet thick, resting on a gravel seam 4 or 5 inches in thickness, below which, again, is a bluish-clay. Similar clays probably occur at other points along the valley of Cowanesque River, but have not yet been anywhere developed.

SOILS.

The soils of the Gaines area are of two types, glacial and alluvial. True sedentary soils, or those formed in the exact spot where they are found and composed of the insoluble sandy and clayey products of decay of the immediately underlying rock, occur only over a small area southwest of Pine Creek, in the extreme southwestern corner of the quadrangle.

The glacial soils of the region, however, are fundamentally of sedentary derivation, the glacier having merely taken up the soil it found covering the surface on its advance, transported it a short distance and then, as the ice melted, deposited it. The soils thus formed consist of heterogeneous aggregates of materials ranging in size from clay to large fragments, the finer portions of which are thoroughly decayed. Most of the soils of this type, like the true sedentary soils, agree in composition with the underlying rock, hence the geological map showing the distribution of the rocks will also show, in a general way, the distribution of the soils. The best farming land appears to be in those locations where the soil most nearly approaches the character of a true sedentary soil.

Of the formations represented on the maps the Chemung gives the most regular and gentle slopes and soils most nearly resembling those of sedentary origin. It underlies the broad belt of low hills lying between the Cowanesque and Pine Creek Mountain belt and also the low belt north of the former. It includes all the valuable farming land except that along the alluvial flood plains of the larger streams, and yields excellent crops of wheat, oats, corn, etc.

Next to the Chemung the Cattaraugus formation affords the most valuable soil, but because of the presence of heavy beds of flaggy sandstones and its association with the relatively massive Oswayo formation, the areas are usually steep and rough and are not well adapted to cultivation. Buckwheat is the principal crop.

The Oswayo formation gives extremely steep slopes and soils composed almost entirely of a mass of sandstone fragments. Its areas are mostly forested and have in the past yielded quantities of timber and of hemlock tan bark. Occasional small clearings have been made and small amounts of buckwheat and other grains are raised.

The outcrops of the Mauch Chunk shales and of the Sharon conglomerate are of very limited extent and the resulting soils are so slight as to be negligible.

The alluvial soils are partly the result of deposition by glacial streams and partly the result of the deposition of fine sediments on the flood plains of the larger streams in recent times. The glacial alluvium is irregular in its distribution, covers but a small area, and is unimportant as a soil. The flood plain alluvium, however, furnishes the richest soil of the region and gives fine crops of superior tobacco.

June, 1902.

U.S.GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

STATE OF PENNSYLVANIA
GEORGE W. MC NEES, SIMON HARROLD,
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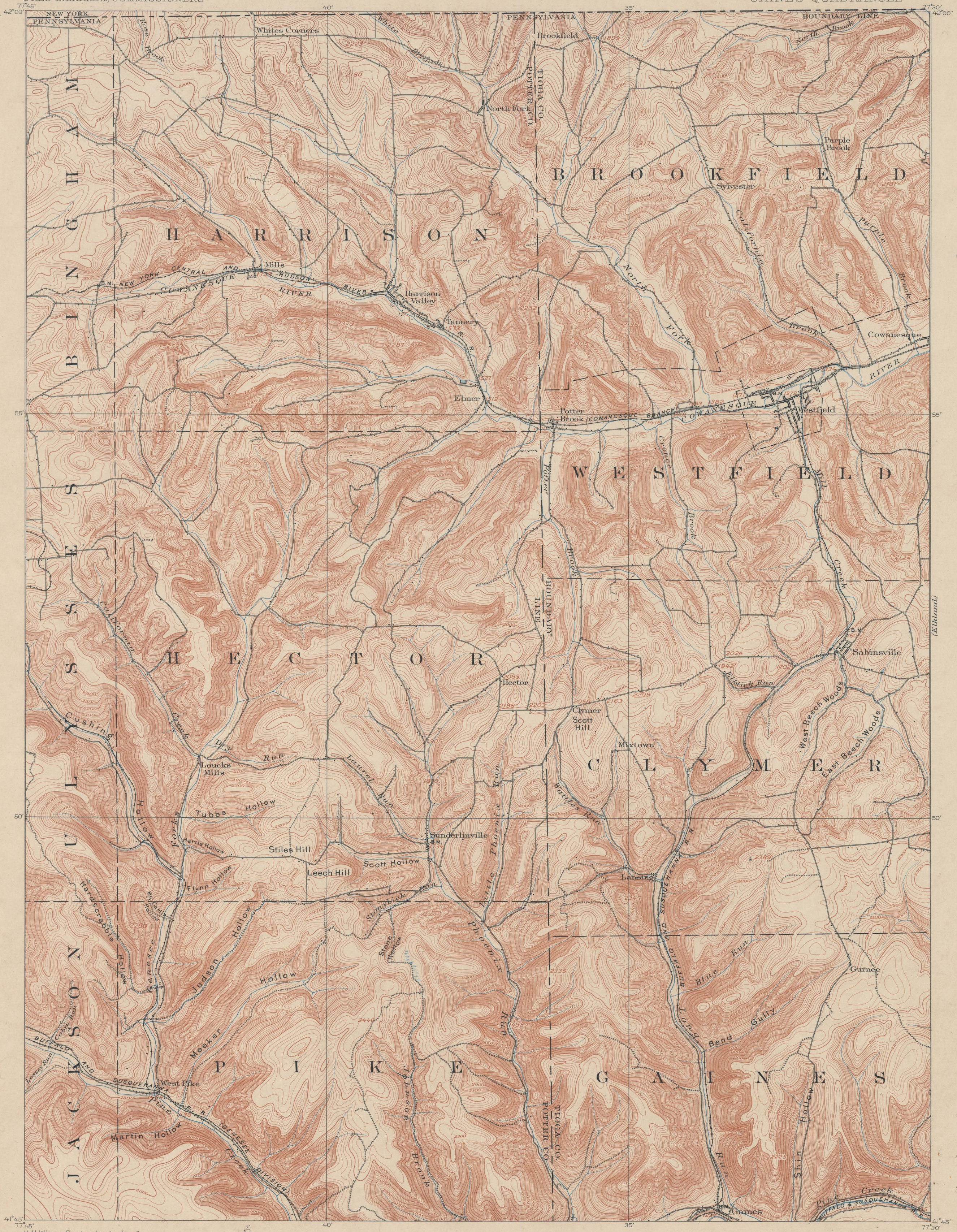
TOPOGRAPHY

PENNSYLVANIA–NEW YORK
GAINES QUADRANGLE



LEGEND

RELIEF
(printed in brown)

2152 — Figures *(showing heights above mean sea level instrumentally determined)*

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

DRAINAGE
(printed in blue)

Streams

Marshes

CULTURE
(printed in black)

Roads and buildings

Private and secondary roads

Railroads

Reservoir

State lines

County lines

Township lines

Village lines

B.M. × — Bench marks

△ — Triangulation stations

H.M.Wilson, Geographer in charge.
Control by S.S.Gannett, Oscar Jones, and J.H.Wheat.
Topography by J.H.Jennings and J.W.Thom.
Surveyed in 1899 in cooperation with the State of Pennsylvania.

7° TRUE NORTH MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1902.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 20 feet.

Datum is mean sea level.

Edition of Mar. 1903.

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CHARLES D. WALCOTT, DIRECTOR

STATE OF PENNSYLVANIA
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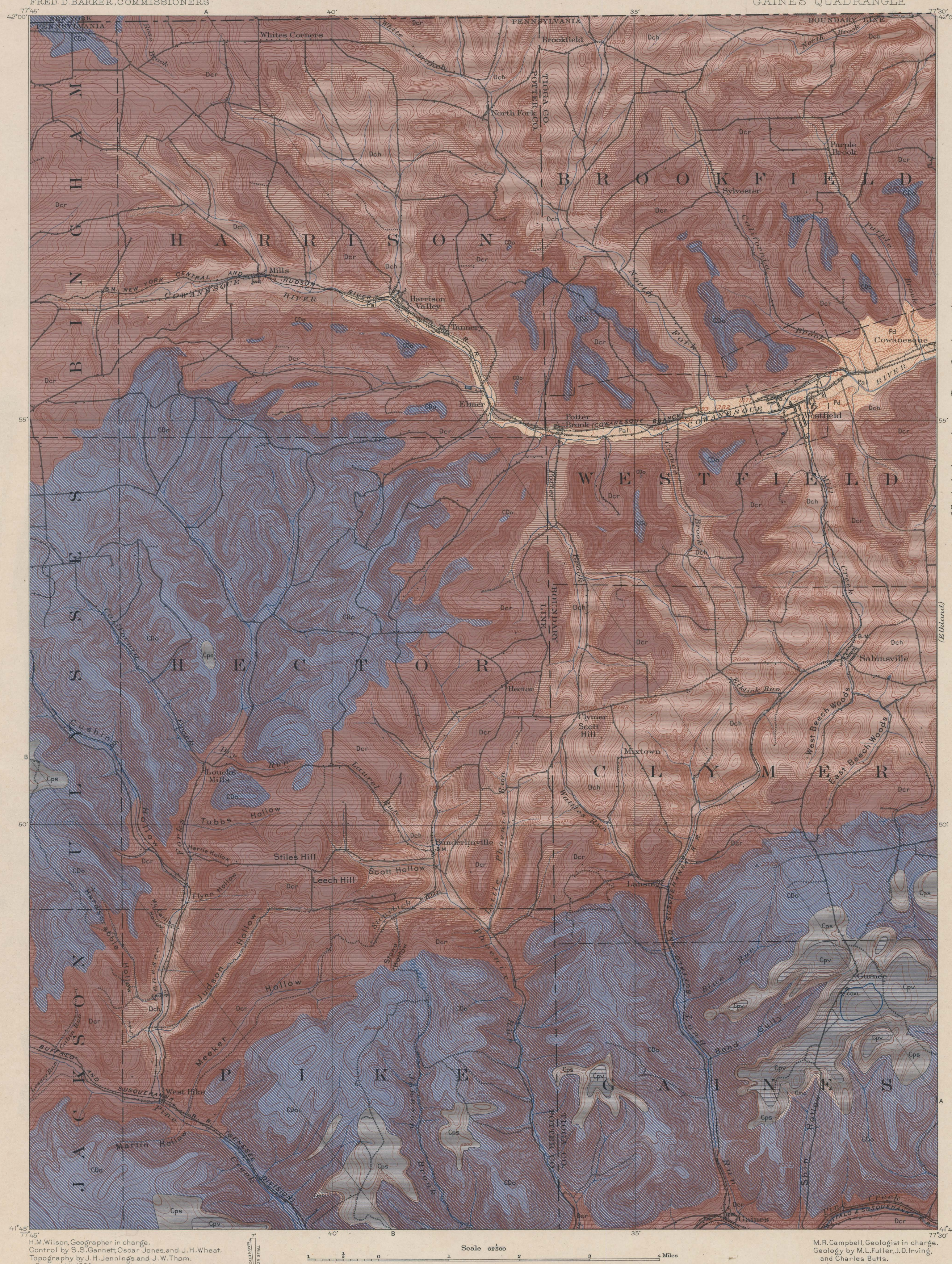
AREAL GEOLOGY

PENNSYLVANIA-NEW YORK
GAINES QUADRANGLE



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Surveyed in 1899 in cooperation with the State of Pennsylvania.

APPROXIMATE MEAN DECLINATION 1902.

Scale $\frac{1}{62500}$

Contour interval 20 feet.
Datum is mean sea level.
Edition of May 1903.

M.R.Campbell, Geologist in charge.
Geology by M.L.Fuller, J.D.Irving, and Charles Butts.
Surveyed in 1900.

LEGEND

SURFICIAL ROCKS
(Areas of Surficial rocks are shown by patterns of dots and circles.)

PLEISTOCENE

- Pal — Valley alluvium *(gravels, sands, and silts in the larger valleys)*
- Pd — Deposits other than alluvium *(shown only where deeply covering the boundaries between underlying formations)*

SEDIMENTARY ROCKS
(Areas of Sedimentary rocks are shown by patterns of parallel lines.)

CARBONIFEROUS

Pennsylvanian series

- Cpv — Pottsville formation exclusive of Sharon conglomerate *(buff sandstone and gray to black shale)*
- Cps — Sharon conglomerate member of Pottsville formation *(white quartz conglomerate at the base of the formation)*

UNCONFORMITY

Mississippian series

- Cmc — Mauch Chunk shale *(red shale.)*

Catskill-Pocono group

- CDo — Oswayo formation *(green sandstone and shale)*

DEVONIAN

- Dcr — Cattaraugus formation *(red shale and sandstone)*
- Dch — Chemung formation *(buff and gray shale, sandstone, and impure limestone)*

Coal mines

Sections

Known productive formations

Coal outcrop *(workable bed in Pottsville formation)*

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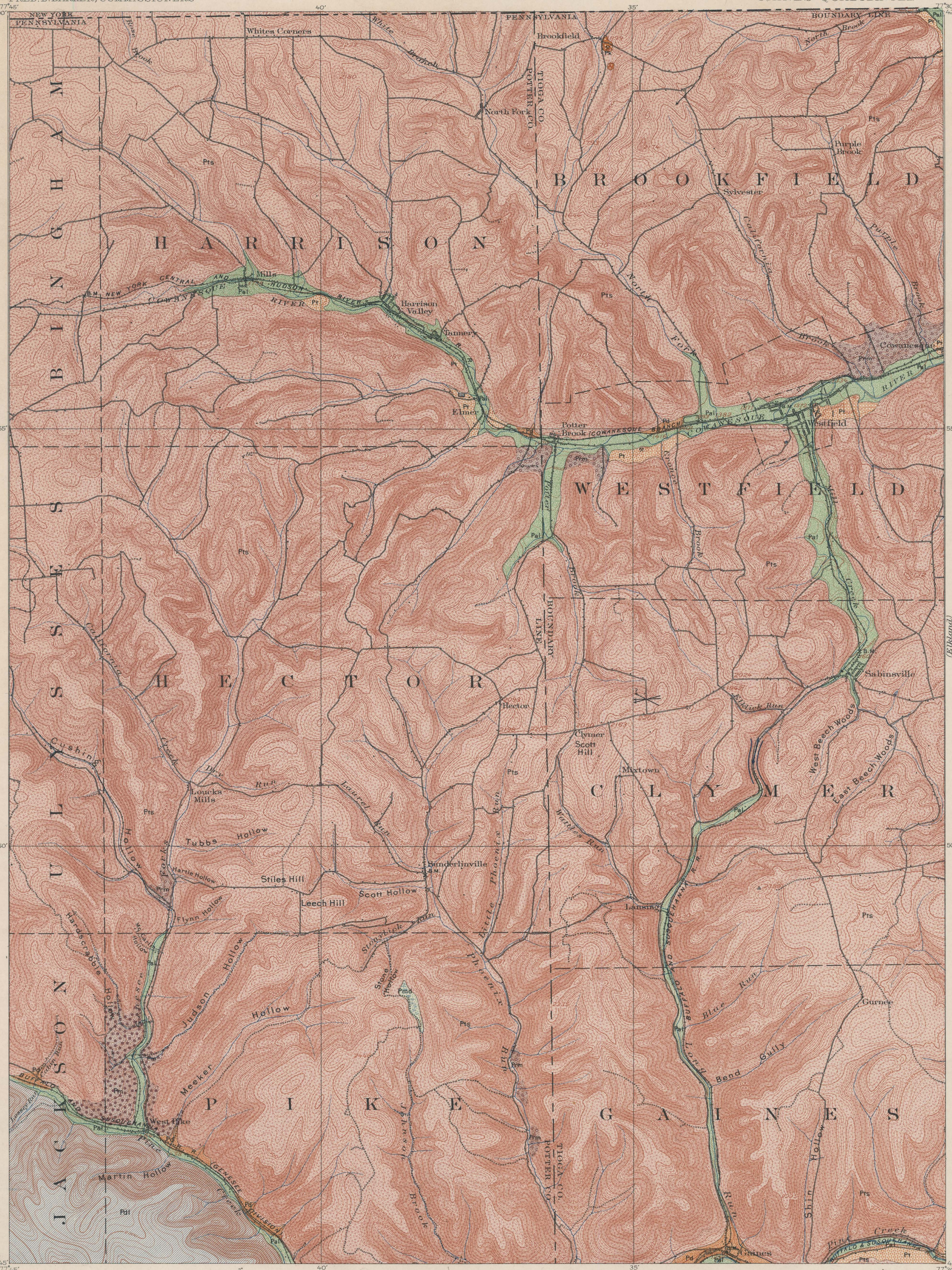
SURFICIAL GEOLOGY

PENNSYLVANIA-NEW YORK
GAINES QUADRANGLE



77°45′ 42°00′ — 40′ — 35′ — 77°30′ 42°00′
55′ — 50′
41°45′ 77°45′ — 40′ — 35′ — 77°30′ 41°45′

LEGEND

SURFICIAL ROCKS

(Areas of Surficial rocks are shown by patterns of dots and circles.)

PLEISTOCENE

Post-Glacial

- Pal — Alluvium *(flood plain silts underlain by stratified drift)*
- Pmd — Marsh deposits *(peat and muck)*

Wisconsin Glacial Invasion

- Pd — Gravel fans or deltas
- Pt — Morainal and frontal terraces
- Pk — Kames *(including isolated gravel deposits)*
- Prm — Retreatal moraines
- Pm — Terminal moraine
- Pts — Till sheet
- Pdl — Apparently driftless area *(surface covered with sedentary soil and talus)*

Glacial spillways *(direction of current indicated by arrow)*

Glacial striae
Gravel pits

(Elkland)

H.M. Wilson, Geographer in charge.
Control by S.S. Gannett, Oscar Jones, and J.H. Wheat.
Topography by J.H. Jennings and J.W. Thom.
Surveyed in 1899 in cooperation with the State of Pennsylvania.

7° TRUE NORTH MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1902.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 20 feet.
Datum is mean sea level.
Edition of April 1903.

T.C. Chamberlin, Geologist in charge.
Geology by William C. Alden.
Surveyed in 1900.

U.S.GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

STATE OF PENNSYLVANIA
GEORGE W. MC NEES, SIMON HARROLD,
FRED D. BARKER, COMMISSIONERS

STRUCTURE SECTIONS

PENNSYLVANIA–NEW YORK
GAINES QUADRANGLE

LEGEND

SURFICIAL ROCKS

PLEISTOCENE
- Pal — Valley alluvium (gravels, sands, and silts in the larger valleys)
- Pd — Deposits other than alluvium (shown only where deeply covering the boundaries between underlying formations)

SEDIMENTARY ROCKS

CARBONIFEROUS — Pennsylvanian series
- Cpv — Pottsville formation exclusive of Sharon conglomerate (buff sandstone and gray to black shale)
- Cps — Sharon conglomerate member of Pottsville formation (white quartz conglomerate at the base of the formation)

UNCONFORMITY

Mississippian series
- Cmc — Manch Chunk shale (red shale)

DEVONIAN — Catskill-Pocono group
- CDo — Oswayo formation (green sandstone and shale)
- Dcr — Cattaraugus formation (red shale and sandstone)
- Dch — Chemung formation (buff and gray shale, sandstone, and impure limestone)

H.M.Wilson, Geographer in charge.
Control by S.S.Gannett, Oscar Jones, and J.H.Wheat.
Topography by J.H.Jennings and J.W.Thom.
Surveyed in 1899 in cooperation with the State of Pennsylvania.

APPROXIMATE MEAN DECLINATION 1902.

Scale 1/62500

1 ½ 0 1 2 3 4 Miles

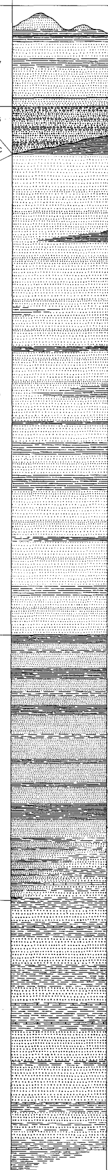
1 ½ 0 1 2 3 4 5 Kilometers

M.R.Campbell, Geologist in charge.
Geology by M.L.Fuller, J.D.Irving, and Charles Butts.
Surveyed in 1900.

Edition of June 1903.

COLUMNAR SECTION

GENERALIZED SECTION OF THE SEDIMENTARY ROCKS OF THE GAINES QUADRANGLE.
SCALE: 1 INCH=200 FEET.



System.		Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography and Soil.
CARBONIFEROUS	PENNSYLVANIAN	Pottsville formation.	Cpv		200	Sandstone, black shale, and fire clay, with a 3-foot coal bed in the upper part.	Gently undulating or flat cappings to the plateau remnants. Soil sandy and rather barren. Inaccessible for cultivation.
		Sharon conglomerate member.	Cps		60 - 100	White quartz conglomerate and sandstone.	Cappings to or rims about the plateau remnants, frequently forming cliffs. Soil highly siliceous sand of very limited distribution.
		UNCONFORMITY.					
	MISSISSIPPIAN	Mauch Chunk shale.	Cmc		0 - 40 ?	Red shale.	No appreciable effect on topography. Clayey soil, covered by talus from overlying beds.
?		Oswayo formation.	CDo		1000±	Heavy beds of green and gray flaggy sandstones with some green and gray shales and local beds of red shale. Thin-bedded gray or buff sandstone appears to predominate in the upper 200 feet of the formation.	Steep hillsides with frequent projecting ledges. Slopes generally covered with talus of sandstone plates. Soil stony and barren.
DEVONIAN		Cattaraugus formation.	Dcr		500±	Persistent red shales, alternating with red, brown, and green sandstones and gray and green shales.	The lower, moderately steep slopes of hillsides, frequently covered with talus of sandstone from its own beds or from the overlying Oswayo formation. Soil generally sandy and stony. Poorly situated for farming.
		Chemung formation.	Dch		600+	Relatively thin fossiliferous beds of gray and buff sandstones, calcareous sandstone and shale, argillaceous shale, and thin beds and streaks of limestone in rapid alternation.	The lower slopes of steep hillsides and well-rounded hills of moderate slope and height, free from talus. Soil yellowish and of good quality. Contains many platy fragments of shale and shaly limestone.

MYRON L. FULLER,
Geologist.

ILLUSTRATION SHEET

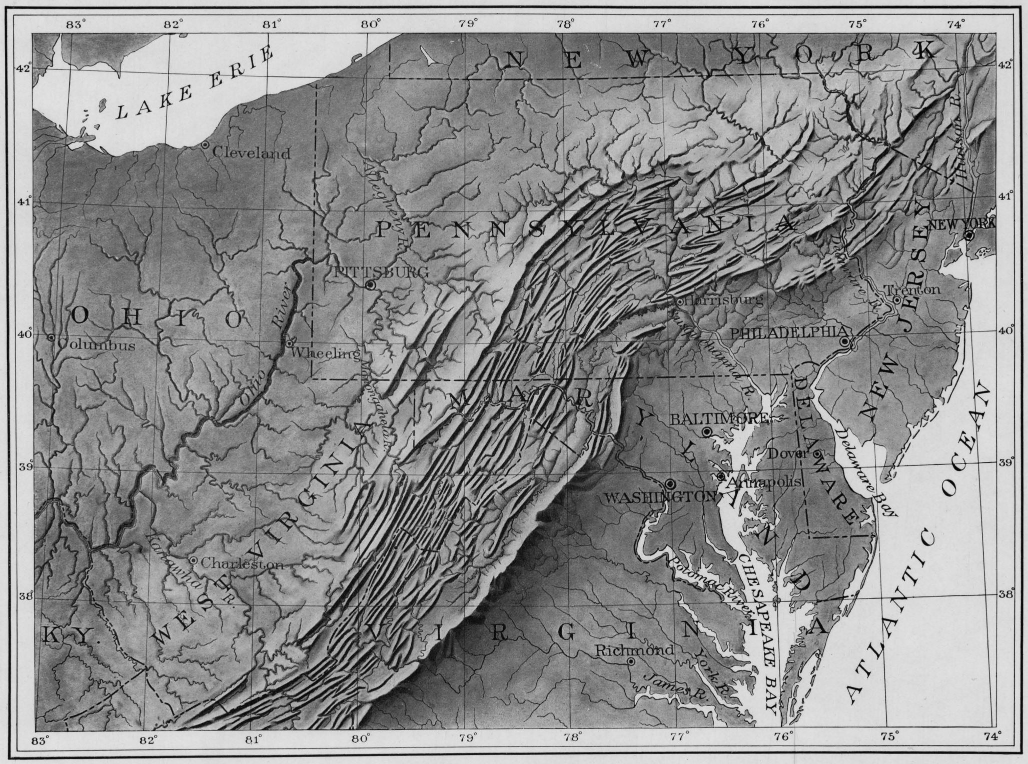


Fig. 7.—RELIEF MAP OF THE NORTHERN APPALACHIAN MOUNTAINS.

The Gaines quadrangle is situated in northern Pennsylvania, in the plateau belt north of the high valley ridges. It lies between meridians 77° and 78°, and its northern border approximately coincides with the New York–Pennsylvania State line.

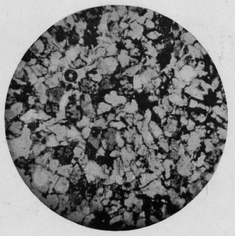


Fig. 8.—MICROSCOPIC SECTION OF ATWELL SAND.

The light-colored angular grains are of quartz. The irregular dark patches are solid hydrocarbons deposited from the oil while it occupied the pores of the sandstone. Enlarged about 25 diameters

Fig. 10.—OIL WELLS ALONG PINE CREEK, WEST OF MANHATTAN.

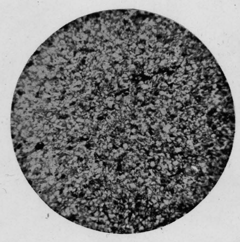


Fig. 9.—MICROSCOPIC SECTION OF ONE OF THE SANDS OF THE BLOSSBURG FORMATION.

Sample taken rom the level of highest production (660 feet from surface) in well No. 4 of Blossburg and Gaines Oil and Gas Company. The well produced 2,100 barrels a day from this level. The white and light-colored grains are of finely divided and highly angular quartz. The dark patches are solid hydrocarbons occupying the pores of the sandstone Enlarged about 25 diameters.

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