DESCRIPTION OF THE PHILADELPHIA DISTRICT.

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INTRODUCTION.

LOCATION AND AREA.

The area herein referred to as the Philadelphia district lies between 39° 45′ and 40° 15′ north latitude and 75° and 75° 30′ west longitude. It covers one-quarter of a square degree, which is equivalent in this latitude to 915.25 square miles, or about 34.50 miles from north to south and 26.53 miles from east to west.

The district consists of four quadrangles—the Germantown, Norristown, Philadelphia, and Chester—each of which measures fifteen minutes of latitude and fifteen minutes of longitude. It lies in three States—Pennsylvania, New Jersey, and Delaware—and embraces in whole or in part ten counties, namely: Bucks, Montgomery, Philadelphia, Delaware, and Chester counties in Pennsylvania; Burlington, Camden, Gloucester, and Salem counties in New Jersey; and Newcastle County in Delaware. Within these limits there is a population of more than a million and a half.

OUTLINE OF GEOGRAPHY AND GEOLOGY OF ATLANTIC BORDER REGION.

The Atlantic border region, of which the Philadelphia district is a part, is divisible into two distinct geologic provinces—the Appalachian and the Coastal. The Philadelphia district comprises portions of both provinces, each of which is characterized by special topographic features which record its geologic and physiographic history.

The Appalachian Province is composed of three well-defined geographic districts, which extend throughout its length. The Allegheny and Cumberland plateaus form the most western of these divisions; the Greater Appalachian Valley, comprising in Pennsylvania a group of valleys and a succession of narrow ridges, constitutes the central district, while the eastern division of the province embraces the Appalachian Mountains, which border the Greater Valley, and the group of plateaus which, stretching away to the east, constitute a vast upland known as the Piedmont Plateau.

Of the three divisions of the Appalachian Province, only a part of the eastern, or Piedmont Plateau, is embraced within the district described in this folio.

PIEDMONT PLATEAU.

By F. Bascom.

GEOGRAPHY.

The Piedmont Plateau lies at the southeastern foot of the Appalachian Mountains, and owes its name to this location. It extends northeastward until it merges into the New England Plateau and southwestward as far as Alabama, curving parallel to the Atlantic coast line. Its mean width is 60 miles, and it has a maximum width, in the central portion, of 120 miles.

The Appalachian Mountains, which form its northwest border, while more or less distinct topographically, are united with the Piedmont Plateau in one physiographic division because the mountains and the plateau express essentially one and the same geologic and physiographic history. South of Pennsylvania these highlands are chiefly represented by the Cohutta Mountains of Georgia, the Great Smoky Mountains of Tennessee and North Carolina, and the Blue Ridge of North Carolina, Virginia, and Maryland. In Pennsylvania, the continuation of the Blue Ridge in South, Neversink, Lehigh, and Musconetcong mountains limits the Plateau on the west. North of Pennsylvania the Highlands of New Jersey and New York form its western margin.

Physiographically this boundary between the Appalachian Mountains and the Piedmont Plateau is not sharply defined but is crossed by features possessing similar and contemporaneous origins. Geologically there is no destinction, the same geologic formations and structures appearing in mountains and plateau. Topographically there is usually a more or less abrupt passage from a trenched upland to level-topped mountains and ridges.

On the east the plateau is separated from the seaward margin of the continental shelf by a belt of coastal province 250 miles in width. The greater part of this is under water in this latitude; the land portion is called the Coastal Plain. This dips gently eastward under the sea and increases greatly in width toward the south. The boundary between plateau and plain is usually defined by a well-marked change in the topographic features and geologic formations. Topographically the change consists generally of an abrupt transition from a diversified upland to a relatively undiversified lowland. Geologically there is a transition from consolidated and for the most part crystalline rocks to unconsolidated clays, sands, and gravels of more recent age. These Coastal Plain formations always overlap the eastern border of the plateau, and in some districts are found far inland and somewhat obscure the passage from plateau to plain.

The margin of the plateau is always indicated, however, by a change in the character of the streams which pass from plateau to plain. An abrupt decrease in stream velocity characterizes this passage, and so frequently do falls or rapids mark the margin of the plateau that this boundary has been called the "fall line." This term is imperfectly descriptive of the boundary, which is actually a zone of appreciable width. East of this zone navigable streams leading to tidal estuaries afford good shipping facilities; west of it the streams cease to be navigable and occupy narrow turbulent channels. In the southern extension of the plateau the "fall line" gradually rises until in the Carolinas and Georgia, although falls and rapids still mark its location and furnish power for factories, it lies considerably above the tidal limit.

The position of this "fall line," at the head of navigation and at the source of water power, has been a dominant factor in determining the location of the large cities of the Atlantic States. A line passing through New York, Trenton, Philadelphia, Wilmington, Baltimore, Washington, Fredericksburg, Richmond, Petersburg, Raleigh, Columbia, Augusta, and Macon will therefore mark in a general way the passage from plateau to plain.

While the plateau exhibits diversity of scenery, there are certain general features common to the entire region which make it a topographic unit. The province is, in brief, a sloping upland of moderate elevation dissected by rather shallow open valleys, which become usually more rugged and narrower on the eastern border, and diversified by isolated eminences rising above the general level of the upland. These valleys have been formed by recent stream cutting since the plateau surface was carved. If they were filled in, the uplands would be converted into an elevated plain, or plateau, sloping eastward and southeastward toward the Atlantic or south to the Gulf of Mexico.

Above the surface of this sloping upland rise isolated eminences, left unreduced by the erosion which produced the peneplain, now an upland.

On the New England Plateau, Mount Monadnock, a typical residual prominence, has furnished to physiographic literature the term "monadnock," by which similar residual hills are designated.

In New Jersey the upland has a relief on its western edge of about 800 feet, while a few monadnocks rise a little above that height, and the eastern margin ranges from near sea level to an altitude of about 60 feet.

The Pennsylvania upland descends from an altitude of 900 feet to an average elevation of 200 feet in the neighborhood of Philadelphia. The monadnocks, Long Hill, Gibraltar Hill, and other similar prominences rise 100 to 200 feet above the upland.

In Maryland the western edge of the upland reaches an altitude of 700 feet, and slopes to an eastern margin in the vicinity of Baltimore, 300 feet above tide level. Rocky Ridge and State Ridge are monadnocks on this upland.

In Virginia, North Carolina, South Carolina, and Georgia the plateau slopes southeastward and southward. Its summits range from 500 to 1500 feet in height along its western border, and its eastern margin has an altitude of 300 to 500 feet. Southwest Mountains, Brushy Mountains, South Mountain, and many others are residual masses on this plateau.

The plane surface which, sloping gradually from western border to eastern margin, forms the plateau, does not owe its even contour to the underlying rock formations, for they possess highly complex structures. The larger streams, which have cut into the plateau, converting it into a diversified upland, maintain courses which are quite independent of the structure and character of the rock floor. The tributary or subsequent streams, on the other hand, show adjustment to the constitution of the rock floor; and by means of them the heterogeneity of rock character and the complexity of rock structure are finding expression. The general trend of the highlands, which is northeast-southwest, in harmony with the strike of the underlying rocks, does not accord with the main drainage lines of the plateau but with the courses of the secondary streams. The main streams of the plateau, rising either in the Appalachian Mountains or on the inland border of the Piedmont, pursue courses consequent upon the slope of the upland—i. e., to the east, southeast, and south, and either empty into estuaries heading at the eastern margin of the Plateau or, crossing the Coastal Plain, empty directly into the Atlantic or into the Gulf of Mexico. The Delaware, Susquehanna, and Potomac are such master streams which have cut into the plateau rugged valleys transverse to the strike of the rock formation.

South of an east-west line drawn just north of New Brunswick, N. J., the interstream areas are covered by a mantle of residual soil and are characterized by absence of rock ledges. North of this line the rock mantle is glacial drift, the depth of which varies from zero to 200 feet. Rock ledges become an increasingly prominent feature toward the north, and contours are controlled, not by streamwork alone, but by ice erosion and deposition.

The discordance of underground structure with the level contour of the plateau, the presence of residual eminences, the V-shaped valleys within broad U-shaped valleys, the nonadjustment of the master streams to rock formations, the deep rock mantle and the absence of rock ledges, all have their explanation in the history of the plateau, which will be outlined under the heading "Physiographic record." (See p. 18.)

GEOLOGY.

The rocks of the Piedmont Plateau include both highly metamorphosed crystalline material and unmetamorphosed fragmental material. The oldest formation of the Pennsylvania Piedmont is presumably of igneous origin—i. e., the material consolidated from a molten condition. Since consolidation it has been subjected to pressure and metamorphism, which have produced an obscurely banded structure. Such rocks are largely composed of quartz and feldspar and are known as gneisses. In the Pennsylvania Piedmont they form a part of a composite formation known as the Baltimore gneiss.

The later formations are chiefly of sedimentary origin—i. e., the materials of which they are composed were accumulated beneath the sea, consolidated by pressure and cementing materials, and subsequently uplifted with more or less folding. These facts are indicated by their constitution, their structure, and their mutual relations. They include some of the oldest materials known to have thus accumulated and some of the most recent.

The first sediments that were deposited in this Atlantic belt were of arkosic and argillaceous character, and their deposition took place in pre-Paleozoic time. The subsequent compression and folding to which the arkose and argillites were subjected have developed from them a hard, crystalline, finely banded gneiss, composed largely of quartz and feldspar, and a mica gneiss with interbedded mica schist facies. These gneisses have been differently named in different portions of the plateau. In the Pennsylvania Piedmont the finely banded quartz-feldspar gneiss is intimately associated with the more massive gneiss and forms with it the composite Baltimore gneiss, while the mica gneiss is known as the Wissahickon mica gneiss.

The pre-Cambrian movements which metamorphosed these formations were accompanied by the intrusion of bosses, irregular masses, sills, and dikes of molten material which further altered the squeezed sediments and which consolidated as granite, gabbro, pyroxenite, and peridotite.

With the opening of Paleozoic time there were deposited upon these gneisses successively arenaceous, arenaceous-argillaceous, calcareous, and argillaceous sediments. This deposition, taking place in Cambrian and Ordovician time, extended over a considerable portion of the Piedmont region, but not throughout the region. The intense folding, faulting, and accompanying metamorphism to which they were subjected by the close of Paleozoic time converted the arenaceous materials into quartzite, the arenaceous-argillaceous sediments into interbedded quartzites and mica schists, the calcareous material into marble and calc schists, and the argillaceous deposits into slates or micaceous schists.

These formations, which are widespread though not continuous throughout the Piedmont belt, are respectively designated in the Pennsylvania Piedmont the Chickies quartzite, the Shenandoah limestone, and the Octoraro schist.

These crystallized sediments and igneous intrusions constitute the foundation of the Pennsylvania Piedmont Plateau, but are uncovered only in detached belts trending northeast and southwest. They have been folded in synclinoria and anticlinoria made up of compressed anticlines and synclines with dominant isoclinal southeast dips and steep southeast cleavage dips, and have further suffered thrust faulting.

These geologic formations and structures are not confined to the plateau but appear also in the Appalachian Mountains, into which the plateau merges on the west without geologic change, forming with the Appalachian Mountains a geologic unit.

Upon the central and northeastern portions of this eroded crystalline floor there accumulated in a shallow inland estuary both coarse and fine ripple-marked sands and sun-cracked mud which in places bears the tracks of animals or is locally rich in vegetable matter. Contemporaneously with this deposition, which took place in the Triassic period, igneous material was intruded between the beds of sediment, or traversed them in the form of dikes, or was poured out in lava flows. The consolidation and uplifting of these sediments took place without metamorphism. The uplift was accompanied by abundant normal faulting and tilting, sufficient only to produce gentle west and northwest dips. These formations, wherever they occur on the Piedmont Plateau, possess a very uniform constitution and character, and are known in Pennsylvania and New Jersey, where they cover a large part of the plateau, as the Stockton and Lockatong formations and the Brunswick shale. The contemporaneous igneous material, occurring in the form of lava flows, sills, and dikes, is diabase and basalt. The latter rocks resist erosion and form bold ridges whose level tops are a part of the Piedmont slope or whose summits rise as monadnocks above the plain. Such eminences are the Palisades in New York and New Jersey, First and Second Watchung mountains and Sourland Mountain in New Jersey, Haycock Mountain, Rock Hill, Long Hill, Gibraltar Hill, and many other lesser hills in Pennsylvania.

On the extreme eastern border of the Piedmont Plateau and in adjacent outlying areas the crystalline floor is concealed beneath unconsolidated gravel, sand, and clay, which were deposited in a marine estuary and along a former coast line during Cretaceous time. These are the Patapsco and Raritan formations of the Lower Cretaceous and the Magothy formation and Matawan, Monmouth, and Rancocas groups of the Upper Cretaceous. Overlapping these formations and left by erosion in scattered areas is a thin covering of sand and gravel belonging to the Tertiary and Quaternary periods. They show that the eastern border of the plateau was intermittently submerged beneath estuarine waters during these periods. They are the Cohansey and Lafayette formations of the Tertiary period and the Bridgeton, Pensauken, and Cape May formations of the Quaternary.

COASTAL PROVINCE.

By F. Bascom and B. L. Miller.

GEOGRAPHY.

The Coastal Province forms the eastern margin of the North American continental plateau, and is in geologic and geographic features essentially unlike the Piedmont Plateau. Its western limit coincides with the eastern boundary of the Piedmont Plateau and has already been characterized as the "fall line." Its eastern limits are defined by the steep slopes of the continental shelf, which vary in height from 5000 to 10,000 or more feet. This declivity generally begins at a depth of 450 to 500 feet below sea level, and the descent from this level to greater ocean depths is steep. Off Cape Hatteras there is an increase in depth of 9000 feet within 13 miles, a grade as steep as that found on the flanks of the greater mountain systems. In striking contrast to this declivity is the comparatively flat ocean bottom stretching away to the east with but few and slight irregularities.

Seen from its base the abrupt slope leading up to the continental shelf would have the appearance of a high mountain range with an even sky line, broken here and there by notches produced by streams which flowed across the shelf when it was a coastal plain.

The Atlantic Coastal Province is divided into two parts by the present shore line—a submarine portion, known as the continental shelf, and a subaerial portion, known as the Coastal Plain. In some cases the dividing line is marked by a low sea cliff, but more often the two portions grade into each other without perceptible topographic change, separated only by the shore line. Their relative areas have frequently altered in geologic time because of a shifting of the shore line eastward or westward, due to local or general depressions or uplifts. Such changes are in progress also at the present time.

That at some period the entire width of the continental shelf was above water is shown by the fact that old river valleys—the continuation of valleys of existing streams—have been traced entirely across the shelf, in which they have cut deep gorges. The channel of Hudson River is well defined, extending uninterruptedly to the edge of the shelf, more than 100 miles east of the present mouth of the river. The same facts have been observed for Chesapeake Bay, the continuation of the Susquehanna channel.

The combined width of the submarine and subaerial portions of the Coastal Province is uniform along the entire eastern border of the continent, being approximately 250 miles. In the south the subaerial portion expands to 150 miles, while the submarine portion dwindles in width and along the eastern shore of Florida almost disappears. Northward the submarine portion increases in width, while the subaerial portion diminishes, disappearing altogether north of Massachusetts through the submergence of the entire Coastal Province. Off Newfoundland this province is about 300 miles in width.

From the "fall line" the Coastal Plain, or subaerial portion, has a gentle slope to the southeast, seldom exceeding 5 feet to the mile, except in the vicinity of the Piedmont Plateau, where the slope is occasionally as great as 10 to 15 feet to the mile. The submarine portion, or continental shelf, is even more monotonously flat, as marine erosion and submarine deposition have smoothed out the irregularities due to earlier subaerial erosion. The continental shelf bears the sandbars which fringe the Atlantic coast and the sand flats and marshes which almost unite the bars to the Coastal Plain.

The moderate elevation of the Coastal Plain, which seldom reaches 400 feet and is for the most part less than half that amount, has prevented the streams from cutting valleys of any considerable depth. Throughout the greater portion of the plain, therefore, the relief is inconsiderable, the streams flowing in open valleys which lie at only slightly lower levels than the broad, flat divides. The drainage is largely simple, most of the streams being consequent upon the uplift of the plain from the sea and lying wholly within the Coastal Plain. The master rivers are the extension of streams that rise in the Piedmont or Appalachian districts and are therefore complex.

Conspicuous features of the plain are the marshes bordering the stream courses, and the numerous bays and estuaries, which are due to the submergence of valleys carved during a time when the province stood at a higher level than the present. Chesapeake Bay (the old valley of the Susquehanna) and Delaware Bay (the extended valley of the Delaware) together with such tributary streams as Patuxent, Potomac, York, and James rivers, are chief among such bays and estuaries. The streams which have their sources in the Appalachian province are sometimes turned at the "fall line" in a direction roughly parallel to the strike of the formation, or the old coast line. Otherwise the structure of the geologic formations and the character of the materials have had but slight effect upon stream development, except locally.

GEOLOGY.

The structure of the Coastal Plain is extremely simple. Upon a floor of crystalline and indurated fragmental rocks, the submerged border of the Piedmont Plateau, rest overlapping beds of unconsolidated sediments having a southeast dip of a few feet to the mile, uniform with the slope of the rock floor. The materials of these beds are bowlders, pebbles, sand, clay, and marl. Their total thickness varies from a maximum of 50 feet in the neighborhood of the "fall line" to 2250 feet near the coast line.

In age the formations range from Jurassic to Recent. Since the deposit of the oldest formation there have been many periods of deposition alternating with erosion intervals. The sea advanced and retreated differently in different parts of the province, and therefore few formations can be continuously traced throughout the entire Coastal Plain. Unlike conditions thus prevailed synchronously in distinct portions of the district and produced great diversity in the character and thickness of deposits of a single period. A full representation of the successive stages can be found within the Coastal Plain, but can not be seen in any one section. Their general character and the distinctive terms applied to them are given in the description of the geology of the Piedmont Plateau. (See pp. 3–8.)

TOPOGRAPHY.

By F. Bascom.

RELIEF.

About three-fourths of the Philadelphia district is within the Piedmont Plateau and about one-fourth is within the Coastal Plain. Delaware River marks the boundary between the two provinces.

The Piedmont Plateau portion of the Philadelphia district is more or less conspicuously divisible into northern and southern parts. These parts, which are of nearly equal area, are distinguished by unlike topographies: The topography of the southern part is largely controlled by Quaternary and pre-Triassic formations, while in the northern part the topography is controlled by Triassic formations.

From the flood plains of Delaware River the southern part rises by an abrupt wave-cut escarpment. This escarpment, beginning at the 20-foot contour line and 40 feet in height, is separated by a faint and narrow terrace from a second escarpment, which rises to the altitude of 80 feet. The combined escarpments form a well-marked topographic feature which in the neighborhood of Philadelphia is some 5 miles from the river. To the extreme north and south of the city it lies close to the west bank of the Delaware. From the top of this escarpment, represented by the 80-foot contour line, the upland terrace gradually rises, reaching at a height of 160 to 180 feet the base of a third well-defined escarpment. This escarpment, the crest of which is marked by the 180- and 200-foot contour lines, extends from Somerton on the northeast southwestward to Gordon Heights, where the three escarpments merge. Fox Chase, Summit, the Queen Lane reservoir, the Swarthmore College buildings, and the Chester reservoir are located on its crest, from which the relatively flat slope to the Delaware can be surveyed.

Northwest of the escarpment a more rugged topography prevails. The upland rises more rapidly, and 10 to 14 miles northwest of the Delaware elevations of 400, 460, and 500 feet are reached. These elevations mark the level tops of hills which trend northeast-southwest and which constitute a more or less well-defined topographic feature known as Buck Ridge.

In the western part of the Philadelphia district, in the southwestern portion of the Norristown quadrangle, Buck Ridge is separated by a shallow valley, known as Cream Valley, from conspicuous hills rising at Paoli and Devon to a height of 520 feet. These hills are known as the South Valley Hills. North of them lie Chester Valley and the North Valley Hills, also trending northeast and southwest and rising to a height of 600 feet. The shapes of these hills and of Chester Valley are due to the character of the rock floor. Hard quartzite and quartzose mica schist appear in the hills, while the valley is underlain by relatively easily weathered limestone. Toward the north this rock floor slopes northwest and passes under a cover of Triassic formations, and the topography alters in character. In the eastern half of the Philadelphia district, in the Germantown quadrangle, the South Valley Hills disappear and Buck Ridge becomes the southern boundary of Chester Valley. This valley diminishes in width and depth toward the east and then likewise disappears, and Buck Ridge and the North Valley Hills merge in a broad highland extending to the northeast and passing on the northwest under the Triassic cover.

The northern part of the Philadelphia Piedmont, underlain by flat-lying sandstone and shale, is less than half as large as the southern part, which is characterized by well-defined ridges and valleys. The range of elevation is not great; the average height of land is from 380 to 400 feet, while the greatest altitude reached is only 480 feet, in the neighborhood of Fairview village. This elevation marks the top of a relatively low and vaguely defined highland trending northeast and southwest. The more open, level character of the territory underlain by Triassic formations, contrasted with the rougher topography of the southern part of the Piedmont, in which the crystalline rocks are uncovered, is very apparent from the summits of the North Valley Hills, which separate the two parts and command them both.

That limited portion of the Coastal Plain which is included in the Philadelphia district lies wholly within the Delaware watershed. The original slopes of this portion of the plain were toward the Delaware basin, and erosion has not materially modified them. Its greatest altitude, which is in the extreme southeast corner of the district, is only 180 feet above sea level, while in the neighborhood of the Delaware the plain lies approximately at sea level. This surface of low relief and gentle slopes yet shows traces of two escarpments which separate areas with somewhat contrasting topography. These two escarpments correspond to the first two escarpments on the west side of the Delaware, but are less pronounced. The first escarpment southeast of the Delaware occurs at an elevation between 45 and 58 feet above sea level. At Morris the escarpment borders the marshes of Delaware River; at Fish House it is half a mile from the river. As it extends southwest it retreats eastward, reaching in the vicinity of Bridgeport a distance of 5 to 6 miles southeast of the Delaware. The area between the river and this escarpment is characterized by exceedingly low relief, extremely gentle slopes, and correspondingly sluggish streams bordered by marsh land. Eastward the land gradually rises, over the divides, to a height of nearly 100 feet. At this height occur the second escarpment and terrace. This terrace is not so flat as the low-lying one, and the streams which have cut through it have a higher gradient; consequently the marsh land diminishes and the valleys become more pronounced. From this second escarpment to the southeastern border of the Philadelphia district the country is rolling, and in the region of Turnersville the surface is even hilly. In the vicinity of Barnsboro, Wenonah, Good Intent, and Laurel Springs the valleys are relatively deep and the stream gradients are sufficient for mill ponds. A more or less conspicuous feature of the valleys of the Coastal Plain is the fact that the northeast slopes are steeper than the southwest. This is particularly striking in the valleys cut by Pensauken Creek, the branches of Mantua Creek, Edwards Run, etc., and is thought to be due to the fact that weathering is stimulated on the southwest slopes, which are exposed to the sun, more than on the northeast slopes. The rapid melting of frost and snow and alternate freezing and thawing which take place on this slope wear down the easily eroded Cretaceous materials more rapidly on the right bank than on the left, where the materials may remain continuously frozen during the larger part of the winter season.

This differential weathering would be most effective on such easily transported materials as the unconsolidated sands of the Cretaceous, and would not be so effective on the crystalline formations of the Piedmont Plateau, where, therefore, a similar difference of valley slopes is not found.

DRAINAGE.

Delaware River, which flows parallel to the trend of the geologic formations and topographic features, and Schuylkill River, tributary to the Delaware and flowing transverse to the geologic and topographic conformations, are the chief drainage basins of the Philadelphia district.

Of the total length of Delaware River (410 miles) only 35 miles are included in the Philadelphia district. It is navigable by ocean steamers to Philadelphia, 100 miles from the Delaware capes, and with a low-water depth of 5 feet to Trenton, 30 miles northeast of Philadelphia. It is tidal to this point, 130 miles above the capes. Like all the streams of the district which are without natural storage reservoirs the Delaware is subject to considerable seasonal fluctuation in volume. The conditions favorable to floods are those common to the district—heavy rainfall on frozen ground, or rainfall in excess of what the ground is able to absorb.

Somewhat less than one-third of the total length of Schuylkill River, or 30 miles, lies within the Philadelphia district. Its drainage area comprises 1915 square miles. With headwaters in the anthracite coal regions of Schuylkill County, the Schuylkill flows across the Triassic formations and the Paleozoic crystallines of the Piedmont Plateau, emptying into the Delaware at Philadelphia. From source to mouth the Schuylkill has a fall of about 800 feet, or an average grade of 8 feet to the mile. Most of this fall is above Reading. From Reading to Norristown, a distance of 41 miles, the river descends 141 feet, or $3\frac{1}{2}$ feet to the mile. From Norristown to the Delaware, a distance of 18 miles, the river descends 60 feet, or $3\frac{1}{3}$ feet to the mile.

The divide between the Schuylkill and the Delaware basins on the southwest is followed by the tracks of the western division of the Pennsylvania Railroad Company. The Delaware watershed is drained by Cobbs, Darby, Crum, Ridley, and Chester creeks, simple consequent streams. Rising in the South Valley Hills, they pursue courses which are, in general, transverse to the strike of the underlying rock formations and in the direction of the prevailing dip. Having an average fall of 480 feet in distances of 16 to 20 miles, they have cut rocky channels 200 feet below the level of the Plateau. These four creeks pursue roughly parallel courses through a fertile and cultivated country. They possess drainage basins of approximately the same area, averaging in round numbers 30 square miles.

The streams north of the divide—Valley, Trout, Gulf, and Mill creeks, lesser tributaries of the Schuylkill, which enter it on the right bank—having a higher gradient and flowing against the prevalent dip, are contesting the divide vigorously with the four southern creeks.

On the northeast the location of Germantown and Chestnut Hill marks the divide between Schuylkill and Delaware rivers. The Delaware watershed is drained by Pennypack and Tacony creeks. The Pennypack rises on the Triassic formations and flows across the ancient crystalline rocks, and is therefore a composite stream. The Tacony is confined to the Paleozoic area. Like the streams on the southwest, their courses are transverse to the trend of the rocks and in the direction of the prevalent dip. Their valleys do not exceed 100 feet in depth.

The chief tributaries of the Schuylkill are the Perkiomen and the Wissahickon. The former is confined to the Triassic rocks and has cut a valley 270 feet deep. The latter flows on both the Triassic cover and the uncovered crystallines, and has cut a gorge 160 feet deep.

Perkiomen Creek, only the last 10 miles of which is included in the Philadelphia district, has its source in the Blackhead Hills, which border on the east the Greater Valley. Its watershed comprises an area of 447.59 square miles. The Perkiomen falls, from its source to the entrance of Northeast Branch, about 800 feet in 24 miles, and 40 feet from this point to its mouth, a distance of 11 miles.

The watershed of Wissahickon Creek separates that of the Perkiomen from that of the Little Neshaminy. The Wissahickon rises near Montgomeryville, at the extreme northern limit of the Philadelphia district, and pursues a southerly course for 20 miles, emptying into Schuylkill River at Fairmont Park. It is the most important of the creeks entirely within the Philadelphia district. Its watershed is 646 square miles in area and is underlain partly by Triassic shales and partly by crystalline rocks. The creek has a fall of 420 feet from source to mouth, or an average gradient of 21 feet to the mile. The upper courses of the Wissahickon north of Chestnut Hill are in an open, shallow valley, which is part of an agricultural country. The percentage of woodland is small. From Chestnut Hill to its mouth, a distance of 6 miles, the stream has cut a rocky channel which lies about 200 feet below the general level of the country and has steep, well-wooded slopes.

The streams of that portion of the Coastal Plain which is within the Philadelphia district are all subsequent and tributary to the Delaware. Pensauken, Cooper, Big Timber, Woodbury, Mantua, Raccoon, and Oldmans creeks are simple streams, having their sources in the Upper Cretaceous marls or on the border of the Miocene sands, and pursuing northwest courses, against the gentle southeastward dip of the marls, clay marls, and plastic clays of the Cretaceous, into the Delaware. Flowing on unconsolidated materials with an average fall of only 8 feet to the mile, their valleys are shallow, even in the upper courses, while in their lower courses they are flat and marshy and their channels are meandering.

These streams range in length between 10 and 16 miles, and are tidal for about half their total lengths. Owing to this fact they have little importance as sources of water supply and water power.

DESCRIPTIVE GEOLOGY.

PIEDMONT PLATEAU AREA.

PRE-TRIASSIC METAMORPHIC ROCKS.

By F. Bascom.

GENERAL STATEMENT.

The old crystalline rock formations of the Philadelphia district, which are covered in the Coastal Plain by gravels, sands, clays, and marls, and in the northwestern portion of the Piedmont Plateau by shales and sandstones, are uncovered, save for a few scattered outliers of these younger formations, throughout a broad central belt. This belt, trending northeast and southwest, traverses the Philadelphia district obliquely. It has a width of 12 to 20 miles, widening southwestward, and constitutes nearly one-half of the whole district.

The belt is a complex of highly metamorphosed sedimentary and igneous materials, and is an important part of a broad belt of similar material which extends from Newfoundland to Alabama and forms an important part of the Continental Shelf east of the Appalachian region. The Philadelphia belt passes under a cover of Triassic sediments at Trenton, and emerges at the surface in southeastern New York and in New England.

In southwestern New England and in New York, the following successions of formations have been determined:

New England:

Ordovician	Berkshire schist.
Cambro-Ordovician	Stockbridge limestone.
Cambrian	Cheshire quartzite.
Pre-Cambrian	Stamford, Becket, and other gneisses.

New York:

Ordovician	Hudson schist.
Cambro Ordovician	Stockbridge limestone or dolomite.
Cambrian	Poughquag quartzite.
Pre-Cambrian	Fordham gneiss.

The belt extends southward through the eastern half of the Piedmont Plateau of Maryland and into Virginia and the District of Columbia. In Maryland the following succession has been provisionally determined:

Ordovician	Peach Bottom slate.
	Cardiff quartz conglomerate.
	Mica schist or phyllite.
Cambro-Ordovician	Cockeysville marble.
Cambrian	Setters quartzite.
Pre-Cambian	Baltimore gneiss.

Farther south similar pre-Cambrian mica schist, and mica gneisses have been described by Keith under the term Carolina gneiss.

In Pennsylvania the belt shows a basement of igneous rock, a sedimentary series of arkosic, argillaceous, arenaceous, and calcareous character, and intrusive igneous material both basic and acidic in character. The sedimentary rocks have been completely crystallized and indurated. The argillaceous and arkosic sediments have been converted into gneisses and schists, the arenaceous sediments into quartzites and quartz schists, and the calcareous material into crystalline limestone and marble. Both the sedimentary and the igneous formations have been subjected to tangential thrust from the southeast, which has produced longitudinal folds overturned to the northwest and trending northeast, cleavage normal to the compressive force, and fissibility both normal and diagonal to the force. In the argillaceous material and in some of the arenaceous, mica has been abundantly developed with its longest axis and cleavage plane normal to the compressive force, thus producing either a schistose structure or a gneissic banding. Which of these two secondary structures is produced is determined by the character of the other constituents and the amount of mica developed.

The sedimentary rocks of the Plateau fall into four divisions:

Ordovician	Octoraro schist.
Cambro-Ordovician	Shenandoah limestone.
Cambrian	Chickies quartzite.
Pre-Cambrian	Wissahickon mica gneiss.
	Baltimore gneiss.

Into the pre-Cambrian formations there have been intruded great masses, sheets, and smaller bodies of igneous material—granite, gabbro, pyroxenite, peridotite, and diabase. The sedimentary formations lie in belts traversing the district from the southwest to the northeast. The igneous rocks cut across these belts more or less irregularly, but with a general northeast and southwest trend.

SEDIMENTARY ROCKS.

PRE-CAMBRIAN ROCKS.

BALTIMORE GNEISS.

Distribution.—The Baltimore gneiss appears in the middle portion of the district and traverses it obliquely to the northeast. It is very thoroughly injected by a gabbro gneiss, which, with the Baltimore gneiss, constitutes the flat-topped highland known as Buck Ridge. Northwest of Chestnut Hill the gneiss belt is very narrow, although still persistent, while to the southwest and to the northeast it rapidly expands in broad uplands. In the southwest it is bounded on both sides by faults, and on one side only in the northeast. The formation is best exposed on the east bank of Schuylkill River between Lafayette and Spring Mill.

Character and stratigraphic relations.—The Baltimore gneiss is a medium-grained, thoroughly crystalline aggregate of quartz, feldspar, hornblende, and biotite. The gneiss shows two facies: It may be either quite massive and granitic; or it may be characterized by a more pronounced banding which is usually fine and intensely plicated—the gneissic facies. The former type has wide distribution in the areas northwest of the Philadelphia district, while the more gneissic rock is relatively more important within the district.

The granitic facies varies from a light-colored, almost pure quartz-feldspar rock to a dark-gray rock in which garnets may be developed in profusion, together with hornblende, biotite, and more rarely augite. The feldspars are orthoclase, albite, and oligoclase (Ab_2An_1). The following analysis of the igneous facies of the Baltimore gneiss was made by W. F. Hillebrand from a composite sample collected from six localities:

Analysis of Baltimore gneiss.

SiO_2	70.21	ZrO_2	Trace.
Al_2O_3	13.95	P_2O_5	.10
Fe_2O_3	1.03	Cl	Not estimated.
FeO	3.08	F	Not estimated.
MgO	1.20	S	.09
CaO	3.10	NiO	Faint trace.
Na_2O	3.27	MnO	.11
K_2O	2.69	BaO	.09
H_2O+	.48	SrO	Trace.
H_2O-	.19	Li_2O	None.
CO_2	.11		100.30
TiO_2	.52		

The norm may be calculated as follows:

Quartz	30.06
Orthoclase	16.68
Albite	27.77
Anorthite	15.01
Diopside	.22
Hypersthene	6.99
Magnetite	1.39
Ilmenite	.91
Pyrite	.18
Apatite	.34
H_2O	.67
Co_2	.11
	100.33

Under the quantitative system of classification the rock falls into Class I, order 4, rang 3, and subrang 4—a persalane, quardofelic, alkalicalcic, dosodic yellowstonose, which means that the rock is extremely rich in salic constituents, i. e., quartz and feldspars, that of these minerals the feldspars are dominant, that of the feldspars the orthoclase and albite molecules do not greatly exceed the anorthite molecules, and finally that of the alkaline feldspars albite is more abundant than orthoclase.

The structure of the rock is hypautomorphic, and biotite and hornblende are abnormative minerals. Recognizing these facts in the name it becomes a biotitic hornblende granoyellowstonose.

The gneissic facies of the Baltimore gneiss is characterized by a gritty feel and a pseudoporphyritic texture. To the alteration of layers of biotite with quartz layers or quartz-feldspar layers is due the finely gneissic character of the rock. Biotite occurs in minute plates, but is never developed in such dimensions or in such excess as to render the rock schistose. Associated with the biotitic layers are hornblende, epidote, titanite, garnets, and more rarely staurolite or augite. Hornblende is sometimes as prominent a constituent as biotite, and, like it, is arranged in layers. The feldspar, like that of the massive type, is orthoclase and acidic plagioclase of about the composition of oligoclase; in addition considerable microcline is present. The apparently porphyritic texture is due to lenses of quartz and of feldspar irregularly interspersed along layers. These lenticular areas are without crystal boundaries, are rounded and pebble-like, and sometimes obviously suggest that the rock is a metamorphosed conglomerate. The micaceous layers bend about them. Rounded apatites are also present in the gneiss.

The fresh character of the crystallization and the absence of pressure effects in the crystals, indicating that strain was relieved by recrystallization, the rounded apatite, quartz, and feldspar grains, and the sorting of the mineral constituents are microscopic evidences of a sedimentary origin. In the field the gneiss has the appearance of a stratified rock.

Both east and west of the Philadelphia district the Baltimore gneiss contains considerable graphite, which is disseminated in flakes in presumably pegmatitic injections.

The Schuylkill River section exposes both types of the Baltimore gneiss. The formation shows anticlinal folding; steep dips prevail on the periphery (see fig. 10, illustration sheet), while in the center the folds are gentle and open and the rock is more massive. The major folding is from southeast to northwest, and the minor folding from northeast to southwest.

The clastic, finely banded gneiss lies on the flanks of the massive gneiss, from which its constituents are considered to be derived by subaerial disintegration, and subsequently to be covered by the deposits of an encroaching sea, with little reworking by water. The alternation of mineral constituents and the other evidences of sedimentary origin seem to preclude the possibility of its being a flow gneiss peripheral to a massive central core.

There is no means of estimating the thickness of this formation, which is the floor upon which the other sediments were laid down.

Correlation and name.—The Baltimore gneiss underlies material known to be of Georgian ("Lower Cambrian") age. It is therefore pre-Cambrian and is correlated approximately with the pre-Cambrian Stamford gneiss of western New England, the Fordham gneiss of New York, the Baltimore gneiss of Maryland, and the Carolina gneiss of the District of Columbia and Virginia. While the Baltimore gneiss of Pennsylvania is not stratigraphically continuous with the Baltimore gneiss of Maryland, similar stratigraphic relations, like lithologic character, and proximity of the two formations have found recognition in a common name. The pre-Cambrian gneiss of Maryland has been called the Baltimore gneiss because of a fine exposure of it at Jones Falls Creek in the city of Baltimore.

The Baltimore gneiss includes H. D. Rogers's Primal lower slate and a part of his northern or third gneiss belt. The major part of the "third gneiss belt" is gabbro. Both the Baltimore gneiss and the gabbro are included by the Second Geological Survey of Pennsylvania under the term Laurentian gneiss.

WISSAHICKON MICA GNEISS.

Distribution.—The Wissahickon mica gneiss extends from Buck Ridge to the Delaware River valley, where it passes under Cretaceous and Quaternary materials. It is also found in a narrow belt on the northwest side of Buck Ridge in the southwestern portion of the Norristown quadrangle. This belt rapidly expands west of the Philadelphia district and eventually becomes continuous with the mica gneiss of the southeast slope of Buck Ridge. Both areas are intruded by large bodies of granitic, gabbroitic, pyroxenitic, and peridotitic material.

Character.—The Wissahickon mica gneiss is manifestly a stratigraphic unit, although possessing an extremely heterogeneous character. This heterogeneity, which is both local and regional, together with the intimate association of an intrusive granite gneiss, has led to its separation by former surveys into three belts—the "Chestnut Hill," "Manayunk" (chiefly an intrusive granite gneiss), and "Philadelphia" gneiss belts. With variations which are indicated later, the formation as a whole may be described as a medium- to coarse-grained banded rock characterized by an excess of mica. The chief constituents of the formation are quartz, feldspar, both orthoclase and plagioclase, green or brown biotite, and muscovite. Magnetite, apatite, zircon, tourmaline, garnets, andalusite, sillimanite, and zoisite are accessory constituents. The more gneissic beds contain abundant orthoclase and plagioclase, which whenever tested prove to be an acidic variety between oligoclase and andesine (Ab_3An_1). The rock is perfectly crystalline and the constituents possess clear-cut boundaries. The freshness of the crystallization and the absence of pressure effects upon the constituents indicate a recrystallized sediment.

The belt passing through Chestnut Hill and Bryn Mawr is composed of beds which are alternately micaceous and quartzose. Cleavage and jointing are conspicuous features of this belt, and on weathering the rock readily splits up into pencil fragments aptly likened by Rogers to "half-rotted fibrous wood." A yellow color, with brownish-black stains on the joint planes, such as partly decayed wood exhibits, adds to the resemblance. The formation is also very garnetiferous, especially in the neighborhood of the peridotite intrusives, and for this reason has been known as the "garnetiferous mica schist."

Even in this excessively micaceous belt the formation is not free from feldspar, and in the direction of Manayunk and Philadelphia massive gneissic strata interbedded with micaceous and quartzose layers become increasingly prominent and garnets are replaced by andalusite and sillimanite.

Within the contact zone of the most northerly of the serpentine dikes on the south flank of Buck Ridge the mica gneiss has locally been altered to a muscovite schist. It contains large lustrous areas of muscovite which have won for it the designation "spangled mica schist." It is siliceous, light colored, coarsely crystalline, and splits readily.

The mica gneiss on the northwest flank of Buck Ridge is adjacent to the Octoraro schist, from which it is distinguished with great difficulty. It becomes increasingly like the mica schist in the neighborhood of that formation, losing completely the gneissic character which characterizes the rock elsewhere.

On the whole, the gneiss is separated from the schist by the possession of a coarser crystallization. The muscovite of the gneiss occurs in patches of relatively considerable size, which gives to the rock a spangled appearance not possessed by the finer grained smooth fissile mica schist. Elsewhere in this northwest area, removed from the vicinity of the mica schist and near igneous intrusives, garnets, staurolite, and tourmaline are developed; these minerals, together with large muscovite crystals, make a rock type easily recognized.

As shown by analysis the rock has a chemical composition which, while it resembles that of a shale, is not of a decisive character. The high alumina and low alkali percentages and the preponderance of magnesia over lime, shown by the analyses, are characters common to siliceous argillites, while in feldspar-bearing rocks of igneous origin, on the other hand, lime dominates the magnesia. The analyses permit, however, the calculation of norms, and fall into line with the quantitative system of classification of igneous rocks.

Analyses of Wissahickon mica gneiss.

	1.	2.	3.
SiO_2	56.40	66.13	73.68
Al_2O_3	19.76	15.11	12.49
Fe_2O_3	4.35	2.52	2.10
FeO	4.40	3.19	2.22
MgO	3.11	2.42	2.04
CaO	.09	1.87	.56
Na_2O	5.82	2.71	2.97
K_2O	1.27	2.86	2.91
H_2O+	3.37 (with H_2O-)	1.55	1.34 (with H_2O-)
H_2O-		.24	
CO_2		None.	
TiO_2	1.05	.82	.81
ZrO_2		Not est.	
P_2O_5	.37	.22	.12
Cl		Not est.	
F		Not est.	
S		.03	
Cr_2O_3		None.	
NO	Trace.	Trace.	
MnO		.20	.18
BaO		Trace.	
SrO		Trace.	
Li_2O	Trace.	None.	
	99.99	99.87	101.42

1. Mica gneiss, Neshaminy Creek.
2. Mica gneiss, analysis made from composite sample collected from four localities.
3. Mica gneiss, Neshaminy Creek, below 1.

Analyses 1 and 3 made by F. A. Genth, jr., Second Geol. Survey Pennsylvania, vol. C 6, pp. 108, 109.

Analysis 2 made by W. F. Hillebrand, of the United States Geological Survey.

Cleavage and fissility are always features of the mica gneiss and are most marked where the formation is least feldspathic and most micaceous. The foliæ are usually wavy and seldom as smooth as those of the Octoraro schist. Stratification is often obscure in the material poor in feldspar, but where fresh rock is exposed this structure can usually be discerned even in such material.

The beds show minute crumpling and both gentle (see fig. 2) and steep folding. In the latter case, cleavage, fissility, and bedding are parallel structures, inclined 60° to 70° SE. The strike is N. 60° to 80° E., with a pitch of 5° to 25° NE.

Thickness.—It is not possible to determine with any exactness the thickness of the mica gneiss. The isoclinal folding and constant variation in beds give a false idea of its thickness, which probably is between 1000 and 2000 feet.

Name and correlation. — Wissahickon Creek affords an excellent section across the strike of the formation, and because of its fine exposure in the gorge of that stream it is called the Wissahickon mica gneiss.

The mica gneiss contains within itself no clue to its age, which must be determined wholly on the stratigraphic relations that the formation appears to sustain with sediments that are correlated with fossil-bearing material.

In northern Delaware and in the southwestern part of Chester County, Pa., the formation is found in association with crystalline limestone and quartzite. While most of this limestone lies southeast of the main mass of Shenandoah limestone of Chester Valley, the rock perfectly resembles that formation and a series of the exposures is in line with the strike of those in Chester Valley. There is also a quartzite associated with the limestone which resembles the thin-bedded sandy material of the Chickies and, like it, contains broken tourmaline crystals. No fossils have been found in either formation, but because of their lithologic resemblance to recognized Paleozoic rocks and their similar stratigraphic relations they are held to represent Cambrian and Cambro-Ordovician sediments.

In all of the exposures of mica gneiss and limestone the gneiss overlies the limestone. It is sometimes separated from the latter formation by thin beds of quartzite, but frequently is found in immediate contact with the limestone. If the obvious stratigraphic relations of gneiss and limestone were the true relations, the Wissahickon mica gneiss would be Ordovician in age. That, however, the superposition of the gneiss is only apparent, while its actual stratigraphic relation is that of an underlying formation, is presumed to be the case on the following field evidence:

1. Within and west of the Philadelphia district Wissahickon gneiss is adjacent for 50 miles to recognized Ordovician mica schist. While in proximity to the latter formation, the mica gneiss shows a very close resemblance to the mica schist, making it difficult to separate the two formations, yet a separation can be made, and is made, on the basis of the greater metamorphism of the mica gneiss as exhibited in a more coarsely crystalline texture. It is true that crystallinity increases eastward in all the formations, but this change in grain or crystallization seems sufficiently abrupt to indicate a different and older or pre-Ordovician formation.

2. The structure of the limestone exposures permits the interpretation that they are overturned synclines, or in some cases fan-shaped synclines, in the troughs of which limestone is left by erosion. This structure puts the gneiss below the limestone.

3. The presence of tourmaline-bearing quartzite between the limestone and the Wissahickon gneiss is normal if the succession is an inverted one.

4. The occurrence in the gneiss of lenticular areas of quartzite altogether similar to the Chickies quartzite also suggests a reversed sequence.

5. That a garnetiferous mica gneiss is interbedded with recognized Cambrian material is seen to be the case in a section through Cambrian sediments made by the Pennsylvania Railroad near Atglen, Pa. Here a mica gneiss is exposed between the quartzite and limestone and also interbedded with the quartzite.

6. No formation resembling the Wissahickon gneiss has been found associated with the Paleozoics to the northwest of the Baltimore gneiss axis.

7. Intrusive igneous material occurs abundantly in the Wissahickon gneiss and in the Baltimore gneiss, but, with exceptions to be mentioned, it is significantly absent from recognized Paleozoic rocks. The exceptions are a single occurrence of serpentine surrounded by the Ordovician mica schist and the indiscriminate passage of pegmatites from the Wissahickon gneiss to later Paleozoic formations.

In the case of the first of these apparent exceptions it might be stated that the serpentine exposure shows no contact relations with the mica schist and that the serpentine may be older than the latter formation.

In regard to the pegmatites it may be stated that pegmatization does not represent vigorous igneous activity, but is rather the result of expiring igneous force. The igneous activity whose vigorous action resulted in the basic intrusions, which are seemingly confined to pre-Cambrian time, may have expressed its expiring force in pegmatization, which continued through Cambrian and Ordovician time. It is also conceivable that pegmatization may have occurred in connection with the intrusions of Devonian and Carboniferous granites which are found in the Appalachian Mountains far to the south.

These stratigraphic relations and igneous associations indicate that the Wissahickon gneiss is, in part at least, older than the Chickies quartzite, and that to the southeast it often supplants the Chickies quartzite. There was some micaceous-argillaceous sedimentation during Cambrian time, as shown in the Atglen section, in the gradation of mica gneiss into quartzite elsewhere, and in the passage of quartzite into mica gneiss parallel to the strike in still other localities. Yet both north and south of Pennsylvania, sedimentation in earlier Cambrian time was dominantly arenaceous. In consideration of this fact, the Wissahickon gneiss, probably representing originally many thousand feet of scantily arenaceous sedimentation, is assigned to pre-Cambrian time. Subærial erosion of the mica gneiss subsequent to the deposit of sand in an encroaching sea will explain the apparent gradations of the mica gneiss into the quartzite, while the thin and lenticular character of lower Cambrian sediments to the east will explain the apparent passage of quartzite into gneiss along the strike.

As has been indicated, the Wissahickon gneiss occurs in extensive areas southeast of the Buck Ridge axis, and toward the south, overlapping this highland, is found immediately in contact with outlying Paleozoic rocks; but northwest of Buck Ridge the Wissahickon is missing and the Paleozoic formations immediately overlie the Baltimore gneiss.

This peculiar distribution compels one of two assumptions: Either there was land area during Wissahickon time in the west while the Wissahickon was accumulating in an eastern sea, or there was a subsequent abruptly defined uplift in the west which permitted pre-Cambrian erosion to cut deeply into the mica gneiss, removing it completely on the northwest, so that when subsidence initiating Paleozoic sedimentation occurred Cambrian sand was laid down first directly upon the Baltimore gneiss and later, as the sea encroached on the land, upon superficially decayed Wissahickon gneiss. This deposition to the east may have taken place in bays or estuaries, and later in enlarging bays or estuaries where the Cambro-Ordovician limestone accumulated. This material, both pre-Cambrian and later sediments, was subsequently folded, metamorphosed, faulted, and thrust upon the western Paleozoics. In the Philadelphia district the Cambro-Ordovician material which presumably once overlay the Wissahickon gneiss, has been completely removed by erosion. The folded, metamorphosed, and faulted Wissahickon gneiss alone remains.

The relation of the Wissahickon gneiss to the Baltimore gneiss is not perfectly clear. On the southeast flank of Buck Ridge the two formations are adjacent for several miles, but are always separated topographically by a line of depression and for the most part structurally by a thrust fault which is the plane of contact between the two formations.

On the northwest flank of Buck Ridge the Wissahickon gneiss lies conformably against the Baltimore gneiss. The mica gneiss is cut out almost immediately by the Cream Valley fault, but so far as this exposure is concerned the Baltimore gneiss grades vertically upward into the Wissahickon gneiss.

The Wissahickon gneiss, together with intrusive granite gneiss, comprise H. D. Rogers's first and second gneiss belts and the "Chestnut Hill," "Manayunk," and "Philadelphia" mica schist and gneisses, considered by the Second Geological Survey of Pennsylvania to be pre-Cambrian in age.

CAMBRIAN SYSTEM.

The Cambrian system is represented in the Philadelphia district by arenaceous and calcareous sediments which are completely metamorphosed and now appear as quartzite and marble or crystalline limestone.

These formations are devoid of igneous intrusions and represent continuous deposition during early, middle, and late Cambrian time. They form a syncline 2 or 3 miles in width, striking to the northeast across the central portion of the Piedmont division.

CHICKIES QUARTZITE.

Distribution. — The hard, resistant formation known as the Chickies quartzite constitutes the North Valley Hills, the highlands at Hickorytown and Coldpoint, the hills west of Whitemarsh, Fort Hill, Camp Hill, the highland about Willow Grove, and the long ridge known as Edge Hill and Lafayette Hill, also the hill that bounds the northwest side of Huntington Valley.

Character. — The Chickies quartzite usually shows a conglomeratic lower member, which is largely composed of elongated pebbles of the blue quartz that characterizes the pegmatites and some facies of the Baltimore gneiss. This lower member of the quartzite is not often exposed. One mile south of Morganville and an equal distance east of Willow Grove it is brought to the surface in the end of a pitching syncline. It is also exposed at the base of the North Valley Hills near the dam at Valley Forge, where it is brought up on the limb of an anticline. The conglomerate passes upward into a gray, compact, crystalline quartzite, which, in turn, grades into a siliceous slate or a sericitic quartz schist, or is altogether supplanted by the quartz schist.

The sericitic quartz schist, or so-called itacolumite, is typically exposed in quarries half a mile northeast of Somerton station and in the Edge Hill quarries. Here it is thin bedded. Bedding and schistosity coincide and dip steeply southeast. The quartz schist is of a light buff to white color and always contains feldspar. The feldspar is for the most part orthoclase, more rarely microcline, and is usually more or less kaolinized. Tourmaline, apatite, zircon, magnetite, and staurolite are accessory constituents. "Stretched" or broken tourmaline is so constant and characteristic a constituent of the Cambrian quartzite, not only in the Philadelphia district but throughout the Piedmont Plateau that it is a guide in the identification of the formation. The schist readily splits into flattened rhombohedrons whose faces are parallel to planes of schistosity and fissility. Locally the quartzite may contain many geodes lined with quartz crystals. Quartzite of this character occurs at a locality known as Diamond Rock, on the southwest flank of the North Valley Hills.

Thirty miles west of the Philadelphia district a section through the Chickies quartzite shows a considerable thickness of micaceous feldspathic material interbedded with the quartzite. Such beds occur as the uppermost member of the series, separating typical quartzite from the overlying limestone, and also as a lower member. Toward the east these micaceous beds become very thin and are altogether absent from the Philadelphia district.

A chemical analysis shows the rock to be highly siliceous, with sufficient alumina and potassa for sericite and orthoclase.

Chemical analyses of the Chickies quartzite.

	1.	2.	3.
SiO_2	87.87	58.97	56.35
Al_2O_3	6.61	22.61	22.28
Fe_2O_3	2.39	5.67	3.21
MgO	Trace.	.25	1.40
CaO	.24	.08	.19
Na_2O	.19	.32	.38
K_2O	1.73	7.34	12.63
Ignition	1.20	3.73	2.89
TiO_2	.38	1.11	.82
P_2O_5	.06	.07	.16
MnO	.13		Trace.
Li_2O			Strong reaction.
	100.80	100.15	100.31

1. Sericitic quartzite; one-half mile southeast of Vanartsdalen's, near Neshaminy Creek.
2. Sericitic quartzite; quarry northeast of Somerton.
3. Sericitic quartzite; one-half mile south of Willow Grove station.

Analyses by F. A. Genth, jr., Second Geol. Survey Pennsylvania, vol. C 6, pp. 116, 117, 121.

Thickness.—The thickness of the formation varies; it never exceeds and is often less than 1300 feet, although the isoclinal folding in some localities gives the appearance of greater thickness. An overturned synclinorium with stratification and cleavage dips to the southeast is the prevailing structure. The average strike is N. 50° to 70° E., and the dip 45° to 80° SE. Faulting explains the disappearance of the quartzite on the south limb of the anticline.

Stratigraphic relations, and correlation.—The name of the formation is taken from the locality of its finest exposure and greatest thickness, on Susquehanna River north of Columbia. At this locality the quartzite shows abundant traces of *Scolithus linearis*, as is the case also in the North Valley Hills, and underlies quartzite in which *Olenellus* fragments have been found by Walcott, thus establishing its age as Georgian ("Lower Cambrian"). The quartzite of the Philadelphia district deposited farther to the east than this typical exposure of Georgian quartzite on Susquehanna River may have been laid down in an encroaching sea and thus belong to a later stage in the Cambrian than the Georgian. No forms of life save *Scolithus linearis* have been found in it, hence it can not positively be stated to be of Georgian age. It can, however, be safely affirmed to be Cambrian and is to be correlated with the Cheshire quartzite of New England, the Poughquag quartzite of New York, the Hardyston quartzite of New Jersey and provisionally with the Setters quartzite of Maryland. It is the Primal sandstone of H. D. Rogers and the Formation No. 1, Chickies sandstone of the Second Geological Survey of Pennsylvania.

CAMBRO-ORDOVICIAN ROCKS.

SHENANDOAH LIMESTONE.

Distribution.—The Shenandoah ("Chester Valley") limestone is a heavily bedded, crystalline, white or blue magnesian limestone. Its surface exposure in the Philadelphia district is confined, with a few scattered outcrops along the Huntingdon and Cream Valley faults, to Chester Valley, where it covers an area 20 miles long and 2 to 2½ miles wide. The presence of limestone in Huntington Valley along the course of Meadow Brook is indicated by the character of the well water. The rock actually outcrops only in the cellar of a wagon house one-fourth of a mile northeast of Meadow Brook station. In Cream Valley, which lies on the west side of the Schuylkill and follows the southeast flank of the South Valley Hills, there are three exposures of the limestone—in several localities in West Conshohocken, at the head of Gulf ravine, and in the bed of Gulf Creek 1½ miles southwest. A series of sink holes in line with the strike of these outcrops attests the presence of the limestone near the surface. This line of outcrops is continued southwest of the Philadelphia district.

Character and stratigraphic relations.—The limestone is highly siliceous and magnesian. The analyses show great variation in the percentages of SiO_2 and MgO, but no analysis gives a sufficiently high content of MgO to warrant calling the formation a dolomite. It is everywhere crystalline, and increasingly so from west to east. Associated with increasing crystallinity is a lighter color, though blue and white limestone may occur in the same quarry.

It is in places quite micaceous, and always so in the neighborhood of the overlying mica schist. The beds immediately underlying the mica schist are siliceous, micaceous, and schistose, and are to be characterized as calcareous schist. The limestone is abundantly traversed by calcite and quartz veins. Quartz, feldspar, phlogopite, graphite, pyrite, and siderite are accessory constituents, disseminated in minute grains and crystals. Limonitic iron ore occurs in pockets in the limestone.

Intercalated with the limestone are beds of siliceous or micaceous schists. These intercalations, which are lenticular in character, are conspicuous in the limestone west of the Philadelphia district, but occur infrequently in that portion of the limestone confined to Chester Valley. Near Pomeroy, 25 miles west of the Philadelphia district, an intraformational calcareous conglomerate shows near the top of the formation.

The following analysis shows the siliceous and magnesian character of the formation.

The limestone lies above the Cambrian quartzite in an unsymmetrical syncline. The prevailing strike is N. 60° to 90° E., and the dips vary from 35° to 85° SE., with a gradual change in this average strike and dip around the end of the synclinal trough in the northeastern end of Chester Valley. As in the case of the quartzite, on the limbs of the overturned isoclinal folds stratification and cleavage dip are coincident when the stratification dip is to the southeast. The prevailing structure is isoclinal.

Analysis of Shenandoah limestone.

SiO_2	24.23
Al_2O_3	1.12
Fe_2O_3	1.06
MgO	.11
CaO	.55
Alkalies	1.42
$CaCO_3$	40.27
$MgCO_3$	31.24
	100.00

Limestone from West Conshohocken, Montgomery County, Pa. Analysis by F. A. Genth, jr., Second Geol. Survey Pennsylvania, vol. C 6, pp. 126, 127.

In an abandoned quarry at Rennyson, 1½ miles northwest of Berwyn, a compressed overturned syncline may be seen, with cleavage and bedding coincident and dipping steeply southeast on the limb of the syncline, and cleavage transverse to the bedding in the trough of the syncline. An overturned isoclinal anticline is exposed in a rock cut on the north bank of Valley Creek one-half mile north of Howellville. (See fig. 13 on the illustration sheet.) A similar overturned anticline is to be seen in the cut made by the Washington branch of the Pennsylvania Railroad near Arlingham, 1½ miles southeast of Fort Washington. These secondary folds illustrate the character of the primary folding of the limestone. The limestone of Cream Valley is brought to the surface on the crest of a low anticline.

Thickness.—If the interpretation of the structure given above is correct the thickness of the formation must be much less than the width of its outcrop. It is not determinable exactly, but probably is not greater than 1000 feet.

Correlation and name.—Fossils of Chazy, Beekmantown, and Trenton ages have been found in the limestone occurring to the west of Chester Valley and stratigraphically continuous with the limestone of Chester Valley. Fossils have also been found in Chester Valley in somewhat ambiguous material. This material is a drusy, geodiferous rock which seems to have originated through the replacement of calcareous material by silica. A mass of the rock is exposed just south of Bridgeport, near the Trenton branch of the Philadelphia Railroad. Elsewhere it is found only in scattered fragments which rest on the limestone and accompany more or less persistently the contact of limestone and Octoraro schist. It thus seems to mark a definite horizon whose persistence between the schist and the limestone precludes the possibility of a faulted or an unconformable contact.

The material has not proved fossiliferous except at one locality, near Henderson station, where fragments resting on the surface of the ground have been found to contain gasteropod and cephalopod forms.

The following determinations were made by E. O. Ulrich, of the United States Geological Survey: *Raphistoma*, two species, *Maclurea*, *Lituites*, *Cyrtoceras*. These are Ordovician forms and indicate a horizon in the lower half, probably Beekmantown. The limestone overlies conformably Georgian ("Lower Cambrian") quartzite and is therefore Cambro-Ordovician in age. It is correlated with the Stockbridge limestone of New England and New York, doubtfully with the Cockeysville marble of Maryland, and with the Shenandoah limestone of Virginia. It is the most easterly representative of the great belt of limestone, the Auroral limestone of H. D. Rogers and Formation No. II of the Second Geological Survey of Pennsylvania. Aside from a few scattered and very minor exposures, the limestone of the Philadelphia district is confined to, and controls the form of, Chester Valley, a conspicuous topographic feature of the district. For this reason it has long been locally known as the "Chester Valley limestone." It is here called the Shenandoah because it has the same limits and stratigraphic associations as the extensive and well-known limestone of that name.

ORDOVICIAN SYSTEM.

That calcareous sedimentation, which began in Cambrian time, continued into Ordovician time is shown by the presence of Lower Ordovician fossils in an upper member of the Shenandoah limestone.

Further sedimentation in Ordovician time is represented by the Octoraro. This is the last known Paleozoic deposit in this region, and, like the preceding Paleozoic sediments, is dynamically metamorphosed and free from igneous intrusions.

OCTORARO SCHIST.

Distribution.—The Octoraro schist is largely confined to the South Valley Hills, pinching out to the northeast and expanding to the southwest. Outliers of the mica schist occur north of Berwyn and of Paoli and on Henderson and Bridgeport hills. The Henderson and Bridgeport outliers, while lithologically similar to the main mass of mica schist, can not be positively correlated with the formation. Their relation to limestone of Chazy age, as seen in the Schuylkill River cut is such as to admit interpretation either as an interbedded structure or as the overlying synclinal structure which the Octoraro schist must possess.

Character and stratigraphic relations.—The mica schist is characterized by a pronounced lamination of a slaty rather than a schistose type. The laminæ exhibit lustrous silvery surfaces and a blue-gray or green-gray color, which under the action of weathering alters to reddish yellow.

The chief constituents of this mica schist are quartz, muscovite, orthoclase, and chlorite. Quartz occurs in interlocking grains which show undulatory extinction and other pressure effects in their form and arrangement. Orthoclase occurs sporadically in considerable areas, but it is not an important or characteristic constituent. Chlorite is uniformly distributed through the rock, interspersed with wavy lamellæ of muscovite. Plagioclase, biotite, magnetite, ilmenite, tourmaline, apatite, and pyrite are accessory constituents.

The constituents of the schist do not possess clearly defined outlines and the crystalline texture is neither so coarse nor so sharply defined as in the Wissahickon gneiss.

In the hand specimen quartz is completely overlain by minute plates of mica, which alone show on the cleavage surface, while eyelets of quartz may show on the edges of the laminæ. Cubes of pyrite more or less altered to limonite are characteristic. Considerable oxide of iron is present in this formation, which is evidently the source of the limonite ore that occurs sporadically in pockets between the limestone and the schist.

The analyses of the mica schist, with the relatively high alumina and low silica and absence of lime, fairly indicate a sedimentary origin for the formation.

Analyses of Octoraro schist.

	1.	2.	3.
SiO_2	43.81	43.10	39.35
Al_2O_3	27.52	30.86	31.92
Fe_2O_3	7.30	7.28	2.19
FeO	Trace.		9.00
MgO	1.77	1.80	3.08
CaO	.19		
Na_2O	.56	.66	1.98
K_2O	8.81	6.87	5.26
H_2O+, H_2O-	7.52	5.91	6.06
CO_2	3.78	3.28	1.20
P_2O_5	.13	Trace.	.49
Li_2O	Trace.		
	101.39	99.76	100.58

1. Mica schist; between Gulf Mills and Hitner's marble quarry.
2. Mica schist; between Gulf Mills and King of Prussia.
3. Mica schist; 1200 feet from "Bird in Hand" tavern, on road from Gulf Mills to Bryn Mawr.

Analyses made by F. A. Genth, jr., Second Geol. Survey Pennsylvania, vol. C 6, pp. 132, 133.

The lower beds of this formation are more calcareous, more siliceous, finer, and darker colored than the upper beds. The outlying areas at Bridgeport and Henderson are of this character. In some places there appears interbedded with the mica schist a quartz schist or a quartzite similar to the Cambrian quartzite. Fragments of such a quartz schist show 1 mile north of Paoli on the northwestern boundary of the mica schist, and 2 miles north of Wayne such a siliceous member furnishes sand for local use.

The mica schist of the South Valley Hills appears to overlie the Shenandoah limestone without faulting or unconformity. This is indicated by the lithologic gradation between the limestone and schist which may be seen at the northwest base of the South Valley Hills and by the persistence of the same geodiferous quartzose beds along the contact of the two formations, and is confirmed by the fact that the outcrops show that deformation was by folding and flowage and not by faulting.

The structure of the hills is evidently synclinal, though cleavage and fissility are so pronounced as to obscure the stratification. On the limbs of the syncline cleavage and bedding are approximately parallel, while cross structures prevail in the trough of the syncline.

The mica schist is well exposed in a ravine cut through the South Valley Hills by Gulf Creek. Where the rock overhangs the road, midway in the ravine, it shows vertical cleavage and vertical fissility, also fissility in two directions at an angle of 45°. Stratification is obliterated at this exposure, though it may be found at the entrance of the ravine.

Thickness.—The structure of the formation in the South Valley Hills indicates a thickness probably not exceeding 1000 feet. It is not known, however, whether the full thickness of the formation is present here.

Name and correlation.—The name of this formation is taken from Octoraro Creek, which, cutting through the mica schist south of Atglen, has laid bare a fine series of exposures for 10 miles.

The formation is held to be Ordovician in age on the ground of its normal stratigraphic position on the Cambro-Ordovician limestone. It is correlated with the Berkshire schist of the New England section, the Hudson schist of New York, and doubtfully with the phyllites of Maryland. It is the Primal upper slate of the First Geological Survey of Pennsylvania, and the Cambrian phyllite of the Second Geological Survey.

IGNEOUS ROCKS.

The igneous rocks of the district are all intrusive. They may be classed lithologically as granitic, including several distinct masses; and as gabbroitic, including the gabbro, hypersthene gabbro, norite, pyroxenite, peridotite, metagabbro, metapyroxenite, and metaperidotite; and diabase.

The application to them of the quantitative system of classification brings out the fact that they are all rich in lime, even the granite being alkalicalcic and the others docalcic or percalcic. While differentiation has developed representatives of different classes, the various species show magmatic relationship—i. e., they form part of a zone of lime-rich rocks, which, as has been elsewhere pointed out, lies parallel to the Atlantic coast and west of a zone of igneous rocks rich in soda.

These intrusions, with the exception of the diabase, are confined to pre-Paleozoic formations and are therefore probably pre-Paleozoic in age. As the diabase is associated with Triassic formations and belongs to that period, it is described under the heading "Triassic rocks."

GRANITE GNEISS.

Distribution.—An igneous intrusive of granitic character is well exposed on the west side of the Schuylkill. It disappears somewhat abruptly on the east bank of the river, at the Falls of Schuylkill, but expands southwestward toward Delaware River, where it disappears as a surface formation beneath a cover of gravel. Its presence beneath the gravel is attested by numerous large quarries in the formation on Crum and Ridley creeks (see fig. 11, illustration sheet) in the neighborhood of Delaware River. West of this body of granite gneiss a similar rock occurs southeast of Lima and can be traced to Glen Riddle.

East of the main body granite gneiss emerges from a cover of mica gneiss, and is exposed on Pennypack Creek near Verreeville and at Holmesburg, where it has long been quarried.

A granite gneiss also occurs in West Philadelphia and Fairmount Park. It was temporarily exposed in the neighborhood of Powelton avenue station when that station was removed and the railroad cut widened. The general lithologic similarity of these isolated outcrops of granite gneiss suggests a common magmatic origin.

Character.—The rock of the main mass of granite is medium to coarse grained, typically gneissoid, though much of it is massive away from the periphery. It is characteristically porphyritic. The phenocrysts, or porphyritic crystals, are light flesh-colored orthoclases which show an orientation of their longest axes parallel to the strike of the rock. The phenocrysts range from one-half inch to $1\frac{1}{4}$ inches in length. The chief constituents of the rock are quartz, feldspar, biotite, and hornblende. Muscovite may also be present, but is not as characteristic a constituent as is biotite. The feldspar is chiefly orthoclase and microcline and subordinately oligoclase (Ab_6An_1). Accessory constituents are titanite, apatite, epidote, and actinolite. The rock shows the result of pressure by the presence of microcline structure, by the granulation of the feldspar, by the granulation of quartz, and by the orientation of the constituents. Along the contacts with the bounding rock (mica gneiss), an injection gneiss has been produced by the penetration of the acidic magma parallel to planes of fissility in the mica gneiss.

In the Pennsylvania Railroad cut $1\frac{1}{2}$ miles southeast of Overbrook station a contact facies of the granite gneiss is exposed. The porphyritic granite passes abruptly into a close-grained, aphanitic, tough, light-gray rock which breaks with a conchoidal fracture. Quartz, feldspar (bytownite Ab_1An_5), colorless augite, and titanite are the chief constituents. The texture is microgranulitic. The exposure is about 500 feet in width; no other exposure of this type has been found. This may be a dike; if, on the other hand, it represents a contact zone, the more rapid cooling and earlier crystallization which would characterize the periphery of the intruding granite may explain the finer grain and more basic character of the contact zone.

Along the lower courses of Ridley and Crum creeks the rock is nonporphyritic, of an even medium grain, light colored, and is characterized by the presence of both micas.

This granite gneiss has not been separated by the previous surveys from the "Manayunk" and "Philadelphia" gneisses.

The following two analyses have been made of the granite at Port Deposit, Md., where there is a southwestward extension of this intrusive body.

Analyses of granite from Port Deposit, Md.[a]

	1.	2.
SiO_2	73.69	66.68
Al_2O_3	12.89	14.93
Fe_2O_3	1.02	1.58
FeO	2.58	3.23
MgO	.50	2.19
CaO	3.74	4.89
Na_2O	2.81	2.65
K_2O	1.48	2.05
H_2O+	} 1.06	1.09
H_2O-		.16
TiO_2	----------	.50
P_2O_5	----------	.10
MnO	----------	.10
BaO	----------	.08
SrO	----------	Trace.
Li_2O	----------	Trace.
	99.77	100.23

[a] Grimsley, G. P. Jour. Cincinnati Soc. Nat. His., vol. 17, 1894, pp. 88, 89.

1. Biotite granite or quartz monzonite. Analysis by William Brownell, Johns Hopkins University.

2. Hornblende-biotite granite or quartz monzonite. Analysis by W. F. Hillebrand, United States Geological Survey.

These analyses give the following norms:

	1.	2.
Quartz	41.28	27.84
Orthoclase	8.90	12.23
Albite	23.58	23.06
Anorthite	18.07	22.24
Diopside	.25	1.30
Hypersthene	5.13	8.80
Magnetite	1.39	2.32
Ilmenite	----------	.91
Apatite	----------	.34
H_2O	1.06	1.25
	99.76	100.45

These norms show that the more acidic facies of the granite from Port Deposit is a biotite granosusquehannose (Class I, order 3, rang 3, subrang 4). This means that the salic or quartz-feldspar constituents preponderate; that quartz and feldspar are present in nearly equal amounts; that of the feldspars the alkali molecules are equal to the lime molecules; that of the alkalies soda is dominant; and finally that the texture is megascopically hypautomorphic granular, and that the only abnormative mineral present in the rock is biotite.

The more basic facies falls in Class II, order 1, rang 3, subrang 4. Like the susquehannose it is dosodic and alkalicalcic, but differs from the other facies in the fact that the salic minerals are merely dominant, not preponderating, and that feldspar is dominant over quartz.

The texture of the rock is hypautomorphic granular; biotite is the only abnormative mineral present and is a critical mineral. According to the quantitative classification the rock is therefore a biotite granotonalose.

Age.—Because of the relation which the granite sustains to gabbro and to serpentine, an alteration product of a basic intrusive, the granite is held to be the oldest of the pre-Paleozoic intrusives.

North and west of Lansdowne considerable masses of gabbro have invaded the granite and altered it along contact zones.

Between Glen Riddle and Lenni Mills the Wilmington and Baltimore Central divisions of the Pennsylvania Railroad afford a section through granite and serpentine. Both rocks are greatly decomposed, but the facts indicated by the section seem to be that the granite is the older intrusive and that the serpentine cuts through the granite and lies on top of it as a sheet. The relation of the outcrop of granite and serpentine to the topography also indicates that the latter rock overlies the granite.

HORNBLENDE GNEISS.

In the eastern part of the Philadelphia district there is a large body of hornblende gneiss whose areal distribution is concealed by a covering of younger materials. Quarries on the outskirts of Frankford near Chelten avenue, Germantown, and an exposure on Pennypack Creek north of Holmesburg, reveal the character of the material. It is also penetrated by the shafts and tunnel of the Torresdale filtration plant. The contact of the hornblende gneiss and the Wissahickon mica gneiss was seen in this tunnel. The hornblende gneiss cuts across the structure planes of the mica gneiss and sends apophyses into the mica gneiss. The character of this contact and the constitution of the rock, indicate an intrusive igneous origin. The rock is medium grained and dark colored, owing to the prevalence of hornblende. This constituent is dark green and is arranged with the longest axes parallel, thus producing the gneissoid structure. The other constituents are quartz, orthoclase, microcline, oligoclase, biotite, titanite, and apatite. The structure is granulitic and gneissoid. Owing to the excess of hornblende the rock is darker colored than the granitic intrusive on the west side of Schuylkill River. It is otherwise not unlike it and may be genetically related to the granite. The stone, which is extensively quarried at Frankford, has been used for building purposes and for bridge abutments.

GABBRO AND ALLIED ROCKS.

Distribution.—A formation including gabbro, hypersthene gabbro, and norite constitutes a great igneous body which intrudes itself into the crystalline rocks of the Atlantic border from Virginia to New York. It is an important formation in Maryland, Delaware, and southeastern Pennsylvania. It invades alike pre-Cambrian Baltimore gneiss and Wissahickon mica gneiss. In the Philadelphia district its maximum development is in the southwest. From this section it extends northeast, forming the main mass of Buck Ridge, where it shows itself at the surface in exceedingly irregular areas. It is intimately associated with the Baltimore gneiss and has so affected this gneiss along contacts as to produce an appearance of gradation from banded gneiss to massive gabbro. Many instructive exposures of gabbro and Baltimore gneiss show the intercalation, along the periphery of the gabbro mass, of the gabbro between the folded beds of the gneiss. The penetration of the gneiss by the gabbro is irregular, thin sheets swelling into larger masses which weather into rounded bowlders on exposure.

Because of this peculiar injection of the gneiss by the gabbro, gabbro bowlders may appear sporadically in areas where gneiss is the prevailing formation at the surface, and vice versa.

At Glen Mills, a few rods south of a large quarry in gabbro, an abandoned quarry shows a composite of gneiss and gabbro, yet the gneiss does not appear as a surface formation. It is therefore impossible, in drawing the boundaries of these two formations, not to include some gneiss within the gabbro area, while gabbro may be seen within the gneiss areas in rock cuts, though not prevailing at the surface. This is particularly true of the areas northwest of Media. The two formations have not before been separated. They alike give rise to a relatively elevated rolling country with irregular rounded eminences. Dark-colored bowlders of disintegration with rusty exteriors strew the fields and afford almost the only indication of the underlying rock. The gabbro bowlders are extremely tough, except along contacts with the gneiss, where the development of hornblende and mica renders the rock more schistose and more easily attacked mechanically.

Character.—The gabbro is a medium-grained massive rock, possessing a bronzy gray or a greenish gray color, the shade depending on the freshness of the ferromagnesian constituents. Quartz, pyroxene, and feldspar may be determined in the hand specimen. Further study shows the gabbro to be typically a hypersthene-augite-plagioclase rock with accessory quartz, biotite, hornblende, magnetite, apatite, titanite, pyrite, pyrrhotite, garnet, and orthoclase. Decomposition products are actinolite, chlorite, and serpentine. Quartz is an extremely variable constituent, ranging, where present, from a trace to 30 per cent. The pyroxenic constituent may be exclusively or chiefly hypersthene, when the rock becomes a norite, or less frequently chiefly augite (hypersthene gabbro) or exclusively augite or diallage, when the rock is a typical gabbro. The pyroxene constitutes from 10 to 40 per cent of the rock.

The feldspathic constituent is labradorite or labradorite-bytownite, and varies in amount from 5 to 60 per cent of the rock. Between the pyroxene, whether hypersthene or augite, and the labradorite there occur reactionary peripheral zones of garnets. On the inner margins of the garnet rims there may be a narrow zone of quartz and hornblende. These garnet rims are a persistent and striking petrographic feature of the gabbro. (See figs. 18, 19, illustration sheet.) Wherever the gabbro has been subjected to pressure, as along the periphery of the intrusive mass, pyroxene has been replaced chiefly by green hornblende and subordinately by biotite and quartz. (See fig. 20.) A more or less schistose structure was produced by the development of these two minerals. In the intruded rock (Baltimore gneiss), hornblende is also developed along the intrusive contacts and accompanies biotite as a constituent of the gneiss. This contact phenomenon increases the difficulty of separating the gabbro and the gneiss. The gabbro is associated with, and through decrease in feldspar grades into, pyroxenite, or with the addition of olivine into peridotite.

An analysis of the gabbro, made by W. F. Hillebrand, from a composite specimen representing three localities, gives the following oxide percentages:

Gabbro from the neighborhood of Radnor and of Bryn Mawr.

SiO_2	54.03	ZrO_2	Not estimated.
Al_2O_3	16.71	P_2O_5	0.13
Fe_2O_3	1.37	Cl	Not estimated.
FeO	7.70	F	Not estimated.
MgO	5.66	S	.09
CaO	8.84	Cr_2O_3	Trace.
Na_2O	2.99	NiO	Trace.
K_2O	.67	MnO	.13
H_2O+	.53	BaO	Trace.
H_2O-	.14	SrO	Trace (?).
TiO_2	.84	Li_2O	Trace.
CO_2	.40		100.23

The norm according to the quantitative classification would be as follows:

Quartz	4.56
Orthoclase	3.89
Albite	25.68
Anorthite	30.30
Hypersthene	20.67
Diopside	10.52
Apatite	.34
Ilmenite	1.52
Magnetite	2.09
Pyrite	.24
H_2O	.67
CO_2	.40
	100.88

The rock therefore falls into Class II, order 5, rang 4, subrang 3, and is a hessose. This means that the salic, or in this case the quartz-feldspar, constituents are dominant and the femic or ferromagnesian constituents subordinate. Of the salic constituents feldspar predominates to an extreme degree and lime-soda feldspar with dominant lime is the prevailing feldspar. Augite is the only abnormative mineral among the essential constituents of the rock, and it usually plays the role of a critical mineral. The texture of the rock is hypautomorphic, granular; it may therefore be designated an augitic granohessose.

Age.—The youngest material into which the gabbro has been found to intrude is the pre-Cambrian Wissahickon gneiss. The gabbro is, therefore, pre-Cambrian in age. Its relations to the granite indicate that the granite is the earlier intrusive. By the previous surveys the gabbro has not been separated from the Baltimore gneiss and has been included in the "Third gneiss belt" or the "Laurentian gneiss."

Metagabbro dikes.—Penetrating the Baltimore gneiss and the Wissahickon gneiss are numerous basic dikes which have been altered to hornblende schists. Many of them are distinctly connected with the great gabbro intrusive, and presumably there is connection when it is not obvious.

Such dikes occur $1\frac{1}{2}$ miles south of Ithan on Ithan Creek, one-half mile north of Ithan, one-half mile southeast of Villa Nova, in the Schuylkill section near Spring Mill, one-half mile north of Bryn Mawr station, on Crum Creek in Willistown Township, parallel to Crum Creek in the neighborhood of Swarthmore, on Chester Creek near Ridgewater, on Rocky Run in Middletown Township at Edgemont in Edgemont Township, at Valley Falls station on Pennypack Creek, near Verreeville on the same creek, at Ogontz, and at other localities.

These dykes vary in width from 1 to 100 feet. While the larger dikes are more or less massive, the narrow ones are thoroughly schistose, and in all of them hornblende is the prevailing constituent.

Feldspar, chiefly plagioclase, and quartz, scanty and in part secondary, are the other essential constituents. Apatite, titanite, biotite, magnetite, abundant garnets, and pyrite are accessory constituents. Secondary constituents, in addition to quartz and hornblende, are actinolite, anthophyllite, zoisite, epidote, chlorite, and muscovite.

That hornblende, which usually occurs in fresh green blades with a parallel arrangement of the longer axes, is an alteration product from pyroxene is proved by the presence in some cases of an unaltered augitic core surrounded by hornblende. The feldspars are twinned, granulated, or altered to zoisite, epidote, muscovite, and chlorite.

An analysis, made by W. F. Hillebrand, of a specimen from a dike of metagabbro occurring 1 mile north of Bryn Mawr station, is as follows:

Analysis of metagabbro dike, Roberts road, Bryn Mawr.

SiO_2	48.68	P_2O_5	0.29
Al_2O_3	14.39	Cl	Not estimated.
Fe_2O_3	4.00	T·	Not estimated.
FeO	10.09	S	Trace.
MgO	6.32	Cr_2O_3	None.
CaO	9.23	NiO	Trace.
Na_2O	2.31	MnO	.22
K_2O	.47	BaO	Faint trace.
H_2O+	2.03	SrO	None.
H_2O-	.46	Li_2O	Trace (?).
TiO_2	1.69		
ZrO_2	Not estimated.		100.18
CO_2	None.		

The norm is given below:

Quartz	2.82
Orthoclase	2.78
Albite	19.39
Anorthite	27.52
Hypersthene	21.78
Diopside	13.67
Apatite	.67
Magnetite	5.80
Ilmenite	3.19
H_2O	2.49
	100.11

The rock falls into Class III, order 5, rang 4, subrang 3—i. e., it is an auvergnose. Like the gabbro mass to which it is probably genetically related, it is perfelic, docalcic, and presodic, though it is slightly more basic, the femic constituents being equal to the salic. This is the chemical relation which dikes often bear to larger intrusive bodies from the same parent magma. The dikes, representing later intrusions, are, because of differentiation, either more acidic or more basic than the earlier intrusives.

METAPYROXENITE, METAPERIDOTITE, AND RELATED ROCKS.

Distribution.—More or less intimately associated with the Atlantic belt of gabbro are altered pyroxenites and peridotites, or metapyroxenites and metaperidotites. These are the serpentines and allied rocks. Serpentines of such origin are found in the Piedmont belt of North Carolina, Virginia, Maryland, Delaware, Pennsylvania, New York and the New England States.

In the Philadelphia district there are four belts of interrupted lenticular exposures of serpentine and closely related rock types, trending northeast and southwest. Two of these belts are on the southeast flank of the gabbro; one belt lies within the gabbro area, and the fourth belt lies on the northwest flank of the gabbro. All of these belts continue southwestward into Delaware and Maryland.

The areas that have been mapped under this heading are by no means underlain by serpentine exclusively, nor even by rocks in which serpentine is the predominating constituent. In some localities the serpentine has been completely removed and only siliceous ironstone or "honeycomb rock" remains. In other localities serpentine is scarcely developed and pyroxenite or peridotite is the underlying material. In still other localities talc, anthophyllite, or chlorite is the prevailing alteration product producing a soapstone, an anthophyllite rock, or a chlorite schist. The occurrence on the tributary to Green Creek 1¼ miles southwest of Chelsea is a pure anthophyllite-steatite rock, in which the former mineral occurs in larger radiating crystals. A great variety of minerals, in addition to or replacing serpentine, may develop from the alteration of the basic igneous rocks.

Talc, asbestos, anthophyllite, tremolite, hornblende, actinolite, epidote, chlorite, clinochlore, vermiculite, pectolite, magnetite, hematite, limonite, calcite, breunnerite, magnesite, quartz, (especially drusy quartz), chalcedony, opal, chromite, and corundum have been found associated with the serpentine of the Philadelphia district.

Topography and soil.—Serpentine country, even though so limited in area as in the Philadelphia district, has certain marked and characteristic features. The areas underlain by serpentine stand out in relief as low ridges. The rock, though very soft, is exceedingly stable chemically under atmospheric conditions, hence weathering leaves it in relief. For the same reason the rock mantle, the product of weathering, is scant or absent, and rock lies close to the surface and crops out in many places. In areas of the less-altered peridotite, the material weathers in huge bowlders, which strew the ground. Where the peridotite has been completely altered to serpentine the surface of the ground is covered with flat fragments broken along joint planes. The thin soil is of a light-green color, like the rock. On relatively low land, where the soil possesses greater depth, it is of a deep-red color due to the oxidation of the iron silicate.

Serpentine soil, because of its thinness and because of the magnesia which it contains, is not a fertile soil, and vegetation on serpentine areas is therefore scanty and of a peculiar character. The moss pink (*Phlox subulata*) covers the ground in such profusion as locally to give the name Pink Hill to some of the serpentine ridges. Cedars, scrub oak, and cat brier are very characteristic of the serpentine country, which usually presents a wild and barren aspect.

Character.—Of the four belts or dikes the most southeasterly, which extends from Bryn Mawr to Chestnut Hill, lies wholly in the Wissahickon gneiss, but is presumably an offset from the main mass. Both the field and the petrographic characters of the rock are those of an igneous intrusive. The interrupted character of the exposures, the variation in width of the belt, the massive nature of the rock, the contact phenomena, and the displacement of the mica gneiss which have accompanied its intrusion are field evidences of an intrusive origin. Petrographically the rock shows its alteration from the igneous type, peridotite, an olivine-pyroxene rock. It is in general characterized by the remains of olivine crystals, by serpentine, which is often the chief constituent of the rock, by steatite which is an alteration product both of the original pyroxenite constituent and of the serpentine and may be developed in crystalline form (talc) or as a massive constituent, and by calcite, quartz, and the iron oxides. The last three constituents not only occur in subordinate amount to the serpentine as by-products of serpentinization, but as the final products of alteration they may constitute the entire rock mass. Breunnerite is also sometimes present as a by-product.

Locally the rock varies greatly. In some localities, notably near Lafayette on both sides of the Schuylkill, it is a fairly pure, gray-green steatite (soapstone); in others (near Mill Creek) it is a massive blue-green serpentine or a reddish-yellow siliceous rock; in still others (Black Rock quarry) the original rock type can still be traced. In this case dark-green serpentinized olivine crystals mottle the light-gray steatite which forms the body of the rock. Penetration twins of olivine, producing cross and stellate forms, have been found in this belt. (See fig. 21, illustration sheet.) The formation is penetrated by a network of joints and on the joint planes a blue-green opaline serpentine is sometimes deposited.

The second dike upon the southeast flank of the gabbro mass extends from the east bank of the Schuylkill to 2 miles southwest of Chester Creek. It widens southward, reaching a maximum width of 1⅝ miles. There are numerous scattered outcrops southeast of the main areas.

As in the case of the first dike, contact metamorphism has affected the surrounding rock. The Wissahickon gneiss has been altered to an actinolite schist or to a spangled muscovite schist or has become excessively garnetiferous. Petrographically the rock shows alteration from an original type which differed from that of the first dike in the possession of a larger amount of pyroxene and a smaller amount of olivine. This original rock type seems to have been a pyroxenite in which enstatite was the prevailing pyroxene. Associated with the serpentine are enstatite, tremolite, and anthophyllite in abundant development. The usual accessory constituents are present.

The third dike has few exposures. The most conspicuous of them is located southeast of Edgemont. Here the rock lies piled up in picturesque masses which have won for the locality the name Castle Rock. (See fig. 6, illustration sheet.) Serpentinization and steatization are not far advanced in the main mass of Castle Rock, which still shows the character of the original rock, an augite-enstatite rock or pyroxenite. Associated with this pyroxenite is a pure green serpentine.

The serpentine of the fourth or most northwesterly intrusive extends with disconnected outcrops from "the Gulf" southwestward. South of Paoli it expands into a considerable area, which is continuous to West Chester and has a sporadic extension into Maryland. The State line follows for several miles one of the more considerable outcrops; for this reason the belt of rocks has been commonly known as the State Line serpentines. The rock of this dike is chiefly a massive dark-green or a light-green granular serpentine. Fibrous serpentine is associated with it, also talc, quartz, magnetite, and limonite. The microscopic texture of the serpentine indicates that the original rock type was olivinitic—i. e., a peridotite.

The genetic relationship of the metapyroxenite and metaperidotite to the gabbro is to be seen (1) in the petrographic character of the original types and (2) in the field relations which the serpentine sustains to the gabbro. The petrographic character shows it to be a differentiation product of the gabbro magma; the field relations show it to be either peripheral in character or a subsequent intrusive in spaces left by the contraction of the cooling gabbro.

Age.—The limitation of the serpentine dikes to pre-Cambrian material, the field relations of the serpentine and the granite elsewhere described, and the genetic associations of serpentine and gabbro show that the serpentine is pre-Cambrian, younger than the granite and contemporaneous with or somewhat subsequent to the gabbro.

TRIASSIC ROCKS.

GENERAL STATEMENT.

By N. H. Darton.

Extent.—The Triassic rocks described in this folio are a representative portion of an occurrence of the Newark group which extends from Hudson River southward through New Jersey, Pennsylvania, and Maryland into Virginia. Other detached areas are found in Nova Scotia, Connecticut, Massachusetts, Virginia, and North Carolina. The belt of occurrences is thus more than 1000 miles long, but the areas are now widely separated and may never have been directly connected.

Constitution and structure.—The Newark rocks in general are remarkably uniform in character. They comprise great thicknesses of alternating sandstones and shales, in larger part of reddish-brown color, in which are intercalated sheets and dikes of igneous rocks. Many of the sheets are intrusive, but others, in New Jersey and in the Connecticut Valley, are unmistakably contemporaneous lava flows. The structure of the strata is monoclinal over wide areas, with faults having the upthrow mainly on the side toward which the strata dip. From New Jersey southward this monocline in greater part slopes westward at angles of 10° to 15°, while in New England and Nova Scotia, and at some of the easternmost outcrops in Virginia and North Carolina, the inclination is in the opposite direction. The thickness of the sediments is great, but as yet has been determined only approximately, and only in portions of the belt. The great width of territory in which there are monoclinal dips would indicate a vast succession of sediments, but longitudinal faults cause frequent repetition of the outcrops of the series.

Age.—The Newark group is believed to be of later Triassic age and possibly it includes the earlier Jurassic, but its precise equivalency is not established. Fossil plants, crustaceans, and vertebrates have been collected and compared with similar forms from European deposits of those ages, and they correspond within general limits, but correlation of exact horizons is not practicable. The Newark rocks did not share in the folding which occurred at the close of the Carboniferous period, and therefore must be of later date, and they are clearly older than the earliest Cretaceous formations, which overlap them unconformably in Maryland and southward. They are thus separated from earlier and later deposits by intervals of upheaval and erosion of unknown but great duration, and their position in geologic history can not be determined more closely than by the general correlation of fossils above indicated.

NEWARK GROUP.

By N. H. Darton.

DISTRIBUTION AND SUBDIVISION IN SOUTHEASTERN PENNSYLVANIA.

The Newark group in Pennsylvania occupies a broad belt extending across the southeastern portion of the State from Delaware River to the Maryland line south of Gettysburg. It is 32 miles wide on the Delaware, 12 miles on the Susquehanna, 4 miles in northern Lancaster County, and 14 miles at the Maryland line. It is bounded by shales, limestones, sandstones, quartzites, mica schists, gneisses, and granites, varying in age from Ordovician to pre-Paleozoic, which it overlaps along irregular boundary lines. In some portions of the area its margin is determined by faults, but these marginal faults appear not to be extensive either in throw or in length. Over wide areas the dips are to the north and northwest, but in some districts there are flexures of moderate amount and extent. The group is traversed by numerous normal faults, mostly extending northeast-southwest and with downthrow on the east side of the fault plane. One of these extending through Bucks and Montgomery counties has a vertical displacement of several thousand feet.

In the rocks of the Newark group in southeastern Pennsylvania, as in other regions, the typical red-brown sandstone and shale predominate, and there are igneous rocks in intrusive sheets and dikes. The classification which has been established in New Jersey is applicable here, and comprises three formations—the Stockton, Lockatong, and Brunswick, the last named being the youngest. A series of names proposed by the Pennsylvania Geological Survey has not been found acceptable because of their indefinite application.

The Stockton formation comprises gray to buff arkosic sandstone, red-brown sandstone, and numerous masses of red shale, in no regular succession and presenting many local variations in stratigraphy. It lies on gneiss, schist, quartzite, and limestone, in Montgomery, Bucks, and northern Chester counties. Many of the sandstones are cross-bedded, and the finer grained rocks exhibit ripple marks, mud cracks, and raindrop impressions, which indicate shallow-water conditions during deposition. The lower beds usually are arkose—a sandstone containing more or less feldspar and kaolin derived from the gneiss. The Lockatong formation consists mostly of dark-colored, hard, compact, fine-grained rocks originally composed of a mixture of clay and fine sand in variable proportions. Some beds are moderately massive, others vary from shaly to flaggy, and many of them exhibit mud cracks and other evidences of shallow-water deposition. Some of the beds contain carbonaceous material. The Brunswick shale consists mainly of a great thickness of soft, red shale with some thin sandstone layers.

These three formations are not sharply separated by abrupt changes of materials, but usually merge through beds of passage which appear to vary somewhat in thickness and possibly also in stratigraphic position in different areas.

RELATIONS IN PHILADELPHIA DISTRICT.

GENERAL OUTLINE.

The rocks of the Newark group occupy an area of about 230 square miles extending across the northern portion of the Philadelphia district. Most of the rocks of the group in this region are comparatively soft sandstones and shales, forming valleys and rolling hills varying in altitude from about 70 to 485 feet. The most prominent topographic feature is a ridge which rises about 200 feet above the lower hills north of Norristown and which is due to the increased resistance to erosion offered by the hard beds of the Lockatong formation. At the southern margin of the group the older rocks rise along a line which, in general, trends east-west but presents considerable sinuosity. Southwest of Norristown there are two small outliers of the Stockton formation lying on the limestone. This irregularity of margin is due in part to unequal erosion and in part to undulations in the floor of older rocks. South of Norristown it is evident that there were low hills and shallow valleys in the pre-Newark land surface. Originally the Newark sediments extended farther toward the south, but they have been removed by erosion, except the two outliers southwest of Norristown. There is no special topographic evidence as to the original limits, and the line of steep slopes extending along the south side of the limestone valley westward from Conshohocken, is due to a fault. The thickness of the Newark group in this district is very difficult to estimate, for, although the altitude of the beds is relatively uniform, probably there are so many faults that thicknesses calculated from dip and breadth of outcrop are unreliable. The section from Valley Forge northward up Perkiomen Creek to the northern margin of the district indicates a thickness of more than 13,000 feet as calculated from the dips, but numerous small faults were observed which, with others not detected, should reduce this estimate. Normal faults are seen in every extensive exposure of the rocks, but their total number and amount of displacement could not be ascertained.

The rocks of the Newark group have yielded but very few traces of life in the Philadelphia district. In the dark shale of the Lockatong formation, in tunnels near Phoenixville and Gwynedd, a number of fish scales and reptilian remains were found by Lea and Leidy. Numerous remains of *Cypris* were found in the Gwynedd tunnel, and Lea has reported fish scales and caudal rays in red shale near Yerkes station which resemble *Radiolepis elegans* Emm. of the "Chatham series" of North Carolina. Plant impressions are reported from the middle beds of the Stockton formation at Fort Washington and below Norristown, and carbonized plant fragments are noticeable at many points. Dinosaurian tracks have been found in ripple-marked shale of the Brunswick on Landis Brook, 1¼ miles northwest of Graters Ford. Two species are represented. Silicified wood collected by E. T. Wherry from Stockton beds in railroad cuts north of Morganville and a mile northeast of Churchville proves to be a new species of *Dadoxylon* (*Araucarioxylon*).

STOCKTON FORMATION.

General character.—The rocks of the Stockton formation are partly coarse sandstone and partly red shale, the two alternating in bodies so irregular that the stratigraphy is extremely variable. At many horizons in the formation occur bodies of sandstone alternating with masses of bright red-brown shale. Some of these sandstones are moderately hard and regular in texture and are used for building stone, especially for rough work.

Lower and middle beds.—Sandstones are of general occurrence along the southern margin of the formation, and lie on the older rocks. They are usually arkosic, consisting of coarse quartz sand, which in many places includes numerous quartz or quartzite pebbles and fragments of more or less decomposed feldspar. Mica and other minerals are present in small proportion, as well as variable amounts of clay of white to red color. Some of the rock is a sandy conglomerate, and the coarser constituents comprise many fragments of the underlying older rock, the beds along the quartzite contact containing numerous quartzite pebbles and fragments. Cross-bedding is rather general and the layers are thick and irregular. The colors are mostly gray, but buff, purplish, and reddish tints are frequent. Many of the rocks are loosely consolidated and crumble quickly when exposed to the weather. Exposures of these basal beds are numerous all along the southern margin of the formation, but one of special clearness is in the Trenton cut-off of the Pennsylvania Railroad 1½ miles southeast of Fort Washington. Long railroad cuts and old quarries along the north side of Schuylkill River west of Norristown afford good exposures of some of the middle and lower beds of the formation. There are extensive exposures about Morganville.

Upper sandstones.—Sandstone beds occurring toward the top of the formation present the most uniform grain, even texture, and regular bedding and have been the source of supply for much building stone for local use and in some cases for shipment. One of the freshest exposures of sandstone high in the formation is in the quarry on the opposite side of the Little Neshaminy from Grenoble station. The upper limit of the Stockton formation appears not to be clearly defined, as the next succeeding formation begins by a gradual change in character of the sediments, probably not everywhere at the same horizon.

Well sections.—A boring 102 feet deep near Stony Creek in Norristown, passed through the following beds of the Stockton formation:

Record of well boring near Stony Creek in Norristown, Pa.

	Thickness.	Depth.
	Feet.	*Feet.*
Made ground	15	15
Sandstone, light colored, coarse grained, containing fragments of orthoclase feldspar	23	38
Sandstone, dull red, fine grained, with specks of muscovite; color due to iron oxide	33	71
Sandstone, light pink (produced by pink orthoclase), fine grained; quartz grains transparent; fine specks of muscovite mica	31	102

Another well at Norristown passed through the following beds:

Record of well boring at Norristown, Pa.

	Thickness.	Depth.
	Feet.	*Feet.*
Cased at 28 feet with 6-inch pipe.		
Sandstone, very white and fine grained, containing a little pink orthoclase	30	30
Sandstone, white, containing coarse fragments of orthoclase	5	35
Shale, dark red	6	41
Sandstone, white, containing muscovite	14	55
Sandstone, lighter color, more feldspathic	10	65
Sandstone, very white, fine grained	3	68
Sandstone, dark red, coarse, containing much iron oxide and a little mica	6	74
Shale, red	4	78
Sandstone, red, fine, micaceous	18	96
Shale, red	4	100

A well drilled on top of Sandy Hill, Norristown, which passed through Stockton beds, is reported as follows:

Record of well boring on Sandy Hill, Norristown, Pa.

	Thickness.	Depth.
	Feet.	*Feet.*
Sandstone	56	56
Dark-red shale	6	62
Red shale, micaceous	6	68
Sandstone, light-colored transparent quartz, abundance of silvery muscovite	2	70
Red shale	5	75
White sandstone, muscovite, quartz, and pink orthoclase	7	82
Pink sandstone, more pink orthoclase	2	84
White sandstone, finer grained	2	86
White sandstone, orthoclase, quartz, very little mica	5	91
Red shale, no mica	4	95
Red shale, slightly micaceous	5	100
Red sandstone, fine grained	2	102
Gray sandstone, little mica	2	104
Light-red sandstone, orthoclase, quartz, and muscovite	8	112
White sandstone, feldspathic	2	114
Red shale	2	116
Red sandstone, feldspathic	9	125
White sandstone, very fine grained, little mica, feldspar absent	5	130
Dark-red sandstone, micaceous	5	135
Dark-red sandstone, slightly micaceous	5	140
White sandstone like that at 130 feet; resembles sea sand	5	145
White sandstone, very fine grained, only little feldspar	5	150
Pink and white sandstone, orthoclase, and muscovite	10	160
Pink and white sandstone, muscovite, and more orthoclase	9	169

LOCKATONG FORMATION.

General character.—The second member of the Newark group consists of fine-grained deposits, mostly of dark color and considerable hardness. Much of the rock, in its unweathered condition, is a very compact fine-grained sandstone of dark bluish-gray color, in beds from 1 inch to 6 inches thick. The original material was a sandy clay. Some of the beds are of lighter color, or become so on weathering. Many layers of dark shale occur, and at some localities, especially in the upper portion of the formation, there are bodies of light-gray, brown, and red shales. A short distance south of North Wales 200 feet or more of red shale and sandstone appear to be included near the top of the formation, a feature which continues for some distance to the east and west. A similar body of red shale is also seen at Doe Run. Usually when red shales are included in the formation they are of slightly darker color and of harder texture than those in the adjoining formations.

Distribution and thickness.—The Lockatong formation extends across the Philadelphia district in a belt which averages about 3 miles in width north of Norristown and east of North Wales, but narrows locally on Wissahickon Creek and diminishes gradually toward the west, being only about a mile wide north of Port Providence. These lesser widths are due partly to increase of dip and partly to decrease in thickness. East of Perkiomen Creek the apparent thickness is somewhat over 3000 feet, without making allowance for faults.

Topography.—Owing to the fact that the Lockatong formation is much harder than the adjoining sediments, it gives rise to a ridge of some prominence and the larger valleys are constricted into canyons in crossing it.

Local features.—There are extensive exposures along Perkiomen Creek, and the formation is exhibited in nearly complete cross section in the deep cuts and tunnel of the Philadelphia and Reading Railroad between North Wales and Hoyt stations. In the principal excavation along this railroad west of Gwynedd more than a thousand feet of beds are exposed, consisting mainly of dark-gray to dark-buff fine-grained sandstone with shale layers. Several masses of dark-red sandstone and shale are intercalated, as are numerous layers of dark-reddish fine-grained sandstone. Some of the shale layers contain considerable carbonaceous material. In these cuts the beds are traversed by numerous faults, which are described under "Structural geology" (p. 17).

A cut in the southern portion of the village of North Wales exhibits 100 feet or more of fine-grained buff to brown and gray sandstone and gray, buff, and dark greenish-gray shale. These appear to be underlain by several hundred feet of red sandstones and shales exposed in the next cut south, but it could not be ascertained whether these beds are in regular succession in the formation or whether the dark beds north are brought up from the main mass of Lockatong sediments by a fault. In most portions of the district the summit of the Lockatong formation is clearly defined by an abrupt change from dark fine-grained sandstones or shales to the red shale of the next succeeding formation. It is possible, however, that this change does not take place at the same horizon throughout.

Quarries.—The Lockatong beds have been quarried to some extent, mainly for road metal, for which they are admirably suited. The largest quarry is a mile and a quarter southeast of Montgomery Square, where a steam crusher has been established. Another quarry in the upper beds of the formation is half a mile northeast of Montgomery Square. The beds have a slabby character, which weathering brings out, and afford useful material for underpinning and fences, for which the rock is extensively employed.

Equivalency.—The Lockatong formation is nearly equivalent to the Gwynedd shales of B. S. Lyman, of the Second Geological Survey of Pennsylvania. Apparently, however, the term Gwynedd has been applied to a considerable but variable thickness of beds of passage in the adjoining formations; at least it is so mapped as to include portions of them.

BRUNSWICK SHALE.

The name Brunswick has been employed in New Jersey for the entire upper portion of the Newark sediments. A part of this formation extends across the northwest corner of the Philadelphia district. It consists of several thousand feet of red shale containing here and there beds of reddish-brown sandstone. Some of the shales contain considerable sand admixture, and there are also included some inconspicuous thin local deposits of gray, brownish, and greenish shales. In the railroad cut at Yerkes station concretions of the size of a hickory nut and smaller are rather abundant in the Brunswick shale. The rocks are soft and the region which they underlie is a general valley with hills having low slopes. The rocks are frequently exposed in road cuts and low bluffs along the streams, but there are many areas in which the soil covers the underlying material. The region is a fertile one, and nearly all of it is occupied by productive farms.

IGNEOUS ROCKS.

By F. Bascom.

DIABASE.

The intrusion of igneous material which characterized the Triassic period and which manifests itself to the north in the great diabase masses of Mount Holyoke, Mount Tom, and the Palisades of New York and New Jersey shows itself in this district in a few dikes not exceeding 60 feet in width.

One of these dikes has been known as the Conshohocken dike, because of a prominent outcrop of it in that town This exposure is pictured in fig. 12. The dike has been traced continuously from Lafayette Hill to "the Gulf" and thence intermittently into Maryland. It has a width of about 30 feet. The rock exhibits a very uniform character, weathering in bowlders which are readily recognized by a rusty-yellow oxidized coat and a greenish-gray color and conchoidal fracture on fresh surfaces. The rock is a comparatively fresh, medium-grained, typical diabase. Plagioclase and pyroxene in about equal amounts are its primary essential constituents, and ilmenite, quartz, and apatite are accessory. The secondary minerals are chlorite, scanty biotite, calcite, and epidote. The plagioclase, which is labradorite-bytownite, forms a network of automorphic lath-shaped crystals. The pyroxene, which is the aluminous monoclinic variety augite, is xenomorphic and fills the interstices of the feldspar network.

Another diabase dike extends northeast and southwest in the neighborhood of Dreshertown, Jarrettown, and Warminster. It is exposed in a cut on the Pennsylvania Railroad north of Camp Hill, where its width is 55 feet. It cuts across the beds of the arkosic sandstone on a plane dipping about 70° W. Here it does not seem to have appreciably affected the sandstones, but shale traversed by it exhibits for several feet a darker color and increased hardness.

Some stray bowlders of the rock appear on Camp Hill, and although the dike can not be traced continuously in the Paleozoic area, it is probably the continuation of the Conshohocken dike.

Toward the north it cuts diagonally across the entire area of the Stockton formation, trending due northeast to a short distance beyond the Bucks-Montgomery county line and thence nearly north to its end, just north of the northern margin of the district. Throughout its course it crosses the strike of the Stockton formation. Its width probably is variable and at some points it may possibly be discontinuous for a short distances. Its course is marked by rounded masses of diabase lying on the surface of the ground. These masses vary in size from less than an inch to 2 feet in diameter and are ordinarily of an ocherous-yellow color on the surface. This color, which is due to iron oxide, is limited to a thin layer of soft, decomposed material under which there is extremely hard, dark-gray, fine-grained rock. Many of these bowlders have been collected by farmers and used for fences, road metal, and other purposes, which in some areas has given them a wide distribution along the roads. Locally they are found a mile distant from the dike, but in all such places they appear to have been carried from their original position.

The rock of this dike is of the same petrographic type as that of the Conshohocken dike and exhibits like constituents and texture.

An analysis of the rock of the Conshohocken dike, made by F. A. Genth, jr. (Second Geol. Survey Pennsylvania, Report C 6, p. 134), is as follows:

Analysis of rock of Conshohocken dike.

SiO_2	51.56
Al_2O_3	17.38
Fe_2O_3	6.57
FeO	3.85
MgO	3.42
CaO	10.19
Na_2O	2.19
K_2O	1.46
Loss	2.15
TiO_2	1.63
PO_4	.13
Li_2O	Trace.
	100.53

This analysis gives the following norm:

Quartz	13.44
Orthoclase	8.90
Albite	12.56
Anorthite	36.42
Enstatite	8.50
Wollastonite	5.57
Apatite	.34
Ilmenite	3.04
Hematite	7.89
H_2O	2.15
	99.93

The rock therefore falls into Class II, order 4, rang 4, subrang 3—i. e., it is a dosalane bandose. This indicates close similarity to gabbro, differing chiefly in the relation of the feldspar to the other salic constituents. Feldspar is dominant over quartz, but not to an extreme degree.

COASTAL PLAIN AREA.

By W. B. Clark, H. B. Kümmel, and B. L. Miller.

GENERAL STATEMENT.

The geologic formations of the Atlantic Coastal Plain represent a nearly complete sequence of deposits from later Jurassic or early Cretaceous to Recent. They form a series of thin sheets which are inclined slightly to the southeast, so that successively later formations are generally encountered in crossing the Plain from its inland border to the coast. (See fig. 9, p. 17.) Variations in the angle and direction of tilting, as well as later denudation, have occasioned in some places marked divergences from these normal conditions. These variations, however, are most pronounced along the western margin of the belt, where, as the result of transgression, it is not uncommon to find one or more formations lacking in a given district. As a result of denudation detached outcrops likewise appear along the western margin of the several formations, some of them far removed from the main body of the deposits. These various factors must of course be worked out for each individual district, and their relations in the Philadelphia district will be discussed on subsequent pages.

CRETACEOUS SYSTEM.

The Cretaceous deposits of the Philadelphia district represent portions of both the Lower and the Upper Cretaceous. Still older Cretaceous deposits have been recognized beyond this district to the south in Maryland and Virginia, and still younger Cretaceous deposits to the north in Burlington and Monmouth counties, N. J. In general the Upper Cretaceous formations are best developed in New Jersey and the Lower Cretaceous in Maryland and Virginia.

The Lower Cretaceous deposits of estuarine origin were described by McGee as the Potomac formation, although they are now known to represent several stratigraphic units. As the type of deposition was much the same through the entire series of formations, the name Potomac group is retained to designate them as a whole. Of the four formations into which the Potomac group is divided only two, the Patapsco and the Raritan, are known with certainty to occur in the Philadelphia district. Overlying the Raritan formation are transitional beds that, from their fossil remains at more northern localities, have been referred to the base of the Upper Cretaceous. The deposits themselves contain materials that ally them in part with the overlying and in part with the underlying formations. They were evidently marine in the vicinity of Raritan Bay, but no marine fossils have been observed to the south of Burlington County, and it is evident that they were estuarine from that region southward into Maryland. They have been designated the Magothy formation.

The Upper Cretaceous deposits of strictly marine origin were referred to by the older writers as the "Clay marls" and the "Greensand marls," the mineral glauconite occurring in greater or less amounts in all of the formations. The lithologic features of each formation are in general sufficiently distinctive and persistent, however, to render the determination of the several horizons, even in the absence of fossils, a relatively easy task. Three groups of formations, the Matawan, the Monmouth, and the Rancocas, are recognized in the Philadelphia district. They will receive further consideration on later pages.

LOWER CRETACEOUS DEPOSITS.

POTOMAC GROUP.

The Potomac group of the Coastal Plain consists of highly colored gravels, sands, and clays which outcrop along a sinuous line that extends from New York to Richmond, passing near the cities of Philadelphia, Wilmington, Baltimore, and Washington. In Maryland, where the Potomac deposits are best developed four formations have been differentiated—from below upward, the Patuxent, the Arundel, the Patapsco, and the Raritan. The two older formations, of questionable Jurassic affinities, are not known to occur in the Philadelphia district.

PATAPSCO FORMATION.

Areal distribution.—The Patapsco formation in the Philadelphia district has been recognized only in Pennsylvania, where it is represented by outliers in the vicinity of Conshohocken, to the north and northeast of that place in the valley of Plymouth Creek, and to the northwest in small patches extending nearly to Valley Forge. With the exception of one or two isolated localities still farther north these are the last occurrences of the Patapsco formation in the North Atlantic region. Toward the south the deposits become more frequent until they finally merge into the main body of the formation in Maryland and Virginia.

It is quite probable, however, that the Patapsco formation underlies the Raritan near the southwestern border of the quadrangle, where it is concealed beneath the Quaternary cover, as an extensive outcrop occurs a few miles farther to the south, near Wilmington, Del. Some of the well borings in the vicinity of Philadelphia, notably those at League Island, also penetrate beds apparently of Patapsco age, and in a few instances even reach strata that possess many of the characteristics of the underlying Patuxent formation. The very deep depression at League Island, which is perhaps the extension of the ancient Schuylkill channel, furnishes an unusual section of pre-Raritan deposits that can with difficulty be referred in their entirety to the Patapsco formation.

Lithologic character. — The materials consist mainly of the highly colored clay so characteristic of the Patapsco formation farther south. This is ferruginous and plastic to a marked degree and commonly rests on a basal bed of yellow sand which may possibly represent the Patuxent formation, although in the absence of more conclusive evidence such reference would be unwise. No outcrops of this sand have been found, but highly arkosic beds occur with the clay at Henderson. These arkose deposits are also like the Patuxent formation, though their relations to the clay are such as seemingly to preclude such a correlation.

Paleontologic character.—The organic remains of the Patapsco are neither plentiful nor varied. The only remains of animals thus far discovered are a single dinosaurian bone, found on the west side of Chesapeake Bay, probably redeposited from the Arundel formation, and a few molluscan shells. The vegetable remains are more numerous and have been found at many localities. The forms identified belong to the ferns, cycads, conifers, monocotyledons, and dicotyledons. Of the last a few only have been found as compared with the number collected from the next younger formation.

Thickness.—The thickness of the small outliers often exceeds 40 feet, but at no point can an adequate idea of the full thickness of the formation be gained, as the deposits are not overlain at any point by the next younger or Raritan formation, except in the deep-well borings, where the limits of the formation can not be satisfactorily determined.

Name and correlation.—The Patapsco formation receives its name from Patapsco River, Maryland, in the valley of which stream it is typically developed. The name was proposed in 1897 (Jour. Geology, vol 5, pp. 479–506), after careful stratigraphic work had shown that the deposits formerly included in the Potomac formation were readily separable, on the basis of unconformities and fossil contents, into four distinct formations. The remains of dicotyledonous plants not known positively to exist in beds earlier than those of the Cretaceous, and the similarity of other Patapsco organic forms to well-known types of Lower Cretaceous age in European horizons, have caused the reference of the Patapsco formation to the Lower Cretaceous. It probably represents a part of the Neocomian-Albian series of European geologists.

Stratigraphic relations.—The Patapsco outcrops previously mentioned, although numerous throughout the district of their occurrence, are discontinuous and small. They occupy depressions, probably holes of solution, in the crystalline limestones. This relation is well shown in a large limestone quarry about 1¼ miles northeast of Conshohocken. As previously stated, in some places in this region the lowermost beds of Potomac materials may represent the Patuxent formation, but the data are insufficient to determine this point.

Within the region under discussion Quaternary strata only are seen to overlie the Patapsco beds, but many well records about Philadelphia indicate the presence of the Patapsco beneath the Raritan, a relation which is well exhibited in places in Maryland. So far as observations have been made, unconformities separate the Patapsco from all the formations, both below and above, with which it comes in contact.

RARITAN FORMATION.

Areal distribution. — The Raritan formation occupies a belt along the valley of Delaware River, but for the most part it underlies the river or is covered by Quaternary deposits on the New Jersey side of that stream. The best exposures are those at the base of the sand pits north of Morris station. A single outlier occurs at Media, in the hill containing the reservoir, near the northern limits of that town, where a deep pit has furnished an excellent section.

The Raritan formation continues beyond the limits of the quadrangle along the valley of Delaware River to the region of Trenton and thence across New Jersey to Raritan River and beyond. To the south it extends across Delaware to the headwaters of Chesapeake Bay in Maryland and thence southward to the valley of Potomac River, where it finally disappears beneath the cover of later deposits. The outcrops are more extensive in New Jersey than toward the south and the late Cretaceous and Eocene deposits gradually transgress until they come in turn to rest directly upon the Patapsco formation in southern Maryland and Virginia.

Lithologic character. — The character of the Raritan materials is somewhat variable, consisting chiefly of light-colored sands and clays, the former in places so highly ferruginous that they form a firm ironstone. In general the deposits are not highly colored or variegated like those of the Patapsco formation.

They are commonly very variable in composition, the sandy layers being often replaced within short distances by beds of clay. Cross-bedding is frequent in the sands and no section can be considered as typical except within very narrow limits. In the vicinity of Raritan River, where the most complete section of the beds has been found, there is an evident preponderance of clays in the lower and of sands in the upper half of the formation.

Paleontologic character. — The fossils of the Raritan formation consist largely of plant remains which have been recognized in many different localities in New Jersey. The known flora of the formation includes about 170 species, including one thallophyte, ten ferns, six cycads, eighteen conifers, and one monocotyledon, the remainder being dicotyledons distributed among many genera, some of which still exist. Within the area of the Philadelphia quadrangle fossil plants have been found in the upper part of this formation at the extreme base of the section at Hylton's pit, from which Berry has identified the following species: *Andromeda parlatorii, Aralia quinquepartita, Aralia rotundiloba, Cinnamomum intermedium, Eucalyptus attenuata, Ficus woolsoni, Laurus plutonia, Liriodendropsis simplex, Sequoia heterophylla,* and *Widdringtonites reichii.* The known fauna is very limited, consisting of a few Mollusca, a plesiosaurian bone, and possibly an insect.

Thickness.—The thickness of the deposits is somewhat variable, on account of the irregular surface upon which they were laid down. At the outcrop the thickness it is evidently from 200 to 300 feet, but this increases toward the southeast beneath the later formations, and in places has been penetrated in well borings to a depth of more than 500 feet, although part of the latter may represent the Patapsco and possibly even the Patuxent formation. Owing to the cover of Quaternary materials, only a small part of the Raritan is represented by outcropping strata in the Philadelphia district.

Name and correlation.—The Raritan formation was named by Clark from the typical development of the deposits in the valley of Raritan River. As first used the term included the beds now classified as Magothy. The flora of the Raritan is highly characteristic, with its large proportion of dicotyledonous forms, and affords the basis for a correlation of the deposits on paleontologic grounds. Prof. L. F. Ward is of the opinion that the Raritan flora represents for the most part the late Lower Cretaceous and is therefore approximately equivalent to the Gault of England. E. W. Berry, on the other hand, suggests the possibility that the flora is Cenomanian, and thus, perhaps, Upper Cretaceous.

Stratigraphic relations.—The Raritan formation rests unconformably either on the floor of crystalline rocks or on the Patapsco deposits. This contact has been reached in numerous well borings along the western margin of the formation.

The Raritan is unconformably overlain by the Magothy formation, and where outcrops at the contact are found the line is for the most part sharply defined, although an exception to this appears when dark-colored carbonaceous beds occur at the top of the Raritan.

In the Philadelphia district the Raritan formation lies for the most part at low levels along the valley of the Delaware, where it has been covered by Quaternary deposits, which have obscured over wide areas its contact with the crystalline rocks and other formations below and above. This is particularly true of its basal contact along the western bank of the Delaware, where, for much of the distance, the presence of the Raritan can be determined only from well borings.

The deposits strike northeast and southwest and have a dip of about 40 feet in the mile to the southeast.

UPPER CRETACEOUS DEPOSITS.

MAGOTHY FORMATION.

Areal distribution.—The Magothy formation occurs as a narrow belt to the east of the Raritan formation but does not outcrop continuously in the Philadelphia district. It overlies the Raritan clays in Hylton's pits on Pensauken Creek, New Jersey, and in several of the streams that reach Delaware River from the New Jersey bank. The best exposures are in Hylton's sand pits and at Red Bank on Delaware River.

The Magothy formation extends as an almost continuous belt from Raritan Bay to the District of Columbia, where it disappears beneath the cover of later deposits.

Lithologic character.—The Magothy deposits are highly variable, consisting of alternating beds of dark clays and light sands, the latter in places reddish or brownish. The clay beds are commonly lignitic, and near Raritan Bay, where they carry a large marine fauna, some of them are slightly glauconitic. The carbonaceous clays are in many localities filled with minute fragments of lignite which give the materials a somewhat spotted appearance. The clays are locally micaceous and not unlike some of the overlying Matawan materials.

Segregation of the ferruginous matter, usually somewhat evenly distributed through the sand, has occurred in several places, producing irregular iron crusts, with many fantastic shapes. These are well shown near the east end of Hylton's pits and at Red Bank.

Paleontologic character.—In this district the only organic remains thus far recognized in the Magothy are leaf impressions in the drab clays that occur in thin laminæ alternating with layers of sand. These are mostly fragmentary, but careful search would doubtless reveal the presence of identifiable forms.

At Cliffwood Point, on the south side of Raritan Bay, New Jersey, beds of this formation have yielded a considerable flora and a marine fauna. The animal remains described by Weller[a] were found mainly in smooth concretionary nodules in a clay bed or lying loose on the beach, where they were left by the erosion of the clay beds that originally contained them. The fauna is characterized by the presence of great numbers of crustacean remains. In almost every instance some portion of a crab seems to have been the nucleus about which the nodule was formed. Pelecypods, gasteropods, and cephalopods also occur. The most abundant forms are the pelecypods *Trigonarca triquetra, Leda cliffwoodensis, Pteria petrosa, Nucula percrassa, Yoldia cliffwoodensies, Isocardia cliffwoodensis, Cymbophora lintea, Corbula bisulcata,* and among the Crustacea *Tetracarcinus subquadratus.* These are of considerable importance for they are the earliest marine fossils found in the deposit of the Atlantic Coastal Plain. Weller states that the assemblage of forms constitutes a distinct faunule of 43 species, of which 14 do not occur in other formations in New Jersey. Of the remaining 29 forms which have a wider range, a larger number occur in the Woodbury and Wenonah formations than in the Merchantville, which immediately overlies the Magothy.

The flora of the beds at Cliffwood Point[b] is notably varied, more than 80 species having been described by Berry. Many of the species occur also in the Raritan formation, but most of them are new or are characteristic of later formations elsewhere. The most common fossil plants of that locality are the imperfectly petrified cones of *Sequoia gracillima.* Other common species are *Cunninghamites squamosus, Dammara cliffwoodensis,* and *Sequoia reichenbachi.* Berry and Hollick state that the flora of the beds at Cliffwood Point show Cenomanian characteristics, while Weller has pointed out that the fauna is more like that of the Senonian.

Thickness.—The thickness of the Magothy formation is about 40 feet, but it increases toward the north, reaching about 80 feet on the shores of Raritan Bay. Farther southward it thins and in southern Maryland is not more than 20 to 30 feet in thickness.

Name and correlation.—The Magothy formation, so called by Darton in 1893 from the typical development of the deposits in the valley of Magothy River, Maryland, can be traced almost continuously, except for the cover of Quaternary materials, from the valley of Raritan River southward to the western shore of Chesapeake Bay. It changes somewhat in character toward the south, and the marine fossils of the north have not thus far been observed south of Burlington County, N. J., although the alternating clay and sand with their lignitic beds persist. A more or less constant characteristic of the clays is the presence of iron nodules, many of which are fossiliferous.

The flora of the Magothy presents a much more recent aspect than that of the Raritan. Only 37 per cent of Raritan forms have been described from the Magothy formation, and these are not of the oldest and most characteristic type. Many later forms appear and the flora as a whole is regarded by paleobotanists who have examined and described the specimens collected as showing Cenomanian affinities.

The fauna consists mainly of marine molluscan shells, crab claws, and shark teeth. It is the lowest appearance of a fauna which recurs in the Woodbury, Wenonah, and Redbank. Weller considers that it possesses close affinities to that of the Ripley formation of the South, and that it is thus allied to the Senonian of Europe.

Stratigraphic relation.—The Magothy formation overlies the Raritan formation unconformably, although the contact is not commonly observed on account of the extensive cover of Quaternary materials along the western margin of the Coastal Plain. To the south the Matawan transgresses the Magothy and rests upon the Raritan, but in New Jersey local sections show no evidence of any break in sedimentation, and there is no distinct indication of any overlap.

The deposits generally strike northeast and southwest and have a dip to the southeast of about 40 feet in the mile.

[a] Geol. Survey New Jersey, Paleontology, vol. 4, pp. 33-42.
[b] Bull. New York Bot. Gard., vol. 3, No. 9, pp. 45-103; Bull. Torrey Bot. Club, vol. 31, pp. 67-82; vol. 32, pp. 43-48.

MATAWAN GROUP.

The strata included in the Matawan group have been regarded by Clark as constituting a single formation, composed of two members, the Crosswicks clays and Hazlet sands. To this formation Clark gave the name Matawan because of the typical deposits of this age along Matawan Creek in Monmouth County, N. J., but the geologists of the New Jersey State Survey have subdivided it into five parts, which are regarded as distinct formations for this district. The fifth formation, the Wenonah, though paleontologically distinct from the overlying Mount Laurel, is not sharply distinguished from it lithologically, and is therefore combined with that formation in the Philadelphia district for mapping purposes and will be discussed in connection with the Monmouth group. Farther south, in Delaware and Maryland these distinctions gradually disappear and the Matawan strata finally constitute a single unit of very constant lithologic character.

The five formations in New Jersey which are believed to be the correlative of the single Matawan formation of Maryland are the Merchantville, and Woodbury clays, the Englishtown sand, the Marshalltown formation, and the Wenonah sand, all of which outcrop in the Philadelphia district, the first four being separately represented on the accompanying maps.

MERCHANTVILLE CLAY.

Areal distribution.—In the Philadelphia district the Merchantville clay occupies a narrow belt in New Jersey roughly parallel to Delaware River and diagonally crossing the Philadelphia and Chester quadrangles. It has not been recognized in Pennsylvania, unless some beds penetrated in a well on Gordon Heights be referred to this formation. It is principally covered by later deposits over the divides, but outcrops along many of the tributaries of Delaware River. In the area under discussion the best exposures are along the railroad east of Merchantville and in the clay pits near City Line station, Camden. Exposures also occur in the banks or bed of most of the creeks from Pensauken Creek to Raccoon Creek.

Lithologic character.—The Merchantville clay, the lowest member of the Matawan group, is black, glauconitic, and micaceous. It is usually greasy in appearance, and commonly massive in texture, particularly in the lower portion, while the upper part is more sandy and is sometimes distinctly laminated. The upper and basal portions of this bed are commonly much more glauconitic than the middle part, and have, at times, been dug for marl, although their use for this purpose has not been extensive. The glauconite is unevenly distributed, occurring commonly in patches rather than as disseminated grains. It is entirely absent at some horizons. Locally, small pebbles occur very sparingly in the basal portion.

The weathered portions of this formation are very characteristic. Where marly they form an indurated, cinnamon-brown earth, in which the small black unweathered grains of marl are conspicuous. Where more sandy the weathered portion has a peculiar pepper and salt aspect. The weathered part of the nonmarly portion is less characteristic and is sometimes a light chocolate-colored clay, resembling the weathered part of the next higher formation.

Paleontologic character.—The Merchantville fauna is a large and varied one (102 species), and is characterized by the abundance of *Axinea subaustralis, Cucullæa antrosa, Cardium tenuistriatum, Turritella merchantvillensis*, and *Panopea decisa*, species which are conspicuous for their absence or great rarity in both the underlying Magothy and the Woodbury clay above, but which recur more or less frequently in the Marshalltown and Navesink formations.

Thickness.—The greatest thickness of the Merchantville formation is about 60 feet.

Name and correlation.—The formation receives its name from the small town of Merchantville, in Camden County, N. J., which is underlain by beds of this age. It represents the lower part of the "Crosswicks clays" (lower Matawan), described by Clark in the reports of the New Jersey Geological Survey, and forms the base of the Clay-marl series of Cook.

Stratigraphic relations.—The Merchantville clay rests upon the Magothy and is overlain by the Woodbury clay, with which it is conformable.

The base of the Merchantville clay is a sharply marked stratigraphic line, readily recognized wherever exposed and easily traceable throughout the entire area in which it outcrops. The underlying Magothy strata consist of loose, coarse lignite-bearing sands or finely interlaminated sands and clays, with the upper sandy layers not infrequently cemented to form an ironstone. The contrast between those materials and the overlying Merchantville black marly clay or its weathered equivalent is striking. The contact of the Merchantville and Magothy formations is exposed on Pensauken Creek a mile north of Maple Shade station, and at the clay pits near City Line station, Camden. The upper contact of the Merchantville clay is much less distinct, but the transition to the overlying Woodbury strata is generally accomplished within 1 to 3 feet, and where exposures are fresh there is rarely any question as to where the division between the two should be made.

In much of the region of its outcrop the Merchantville is unconformably overlain by deposits of Quaternary age.

WOODBURY CLAY.

Areal distribution.—The Woodbury clay outcrops in a narrow belt lying just southeast of the Merchantville line of outcrop. The upper part is exposed in the railroad cut 1 mile north of Haddonfield, where a few feet of the overlying Englishtown sand is also shown. The clay pits southwest of Cuthbert afford a good section of the lower portion of the formation. There are good exposures along the banks of Woodbury Creek and its branches west of Woodbury, and also on Raccoon Creek west of Swedesboro. Southeast of Merchantville it is but slightly concealed by wash from later deposits over a considerable area.

Lithologic character.—The Woodbury is composed primarily of a thick bed of clay. It is somewhat micaceous, black, not sandy in the lower portion but slightly so in the upper, where it is distinctly laminated. It does not contain glauconite except, perhaps, at the very base and locally to a slight amount in the extreme upper portion. In this respect it is to be distinguished from the Merchantville clay. It weathers to a light-chocolate color, and when dry breaks into innumerable blocks, large and small, frequently with a conchoidal fracture. In its lower portion it is penetrated by numerous joints, which in some localities, as in the clay pits at West Collingswood, are smoothed and polished. Many of the joints are filled with crusts of limonite, which sometimes form large honeycomb masses many feet in diameter and tons in weight. In fact, all gradations between films of limonite coating joints faces and these large masses can be found.

Lithologically the Woodbury is readily differentiated from the Merchantville by its light-brown color where weathered, its usual lack of glauconite, and its numerous joints. The change to the overlying Englishtown sand is comparatively abrupt, the transition beds rarely exceeding 2 or 3 feet in thickness.

Paleontologic character.—The Woodbury clay contains an abundant fauna, 95 species having been recognized. *Lingula subspatulata, Yoldia longifrons, Lucina cretacea*, and *Cyprimeria cretacea* are the most characteristic forms. The fact that not one of these forms has been seen in the Merchantville clay and that the several abundant forms of the Merchantville are exceedingly rare in the Woodbury shows a faunal as well as a lithologic difference between the two formations. The Woodbury fauna has more in common with that of the Magothy and Wenonah than it has with the Merchantville below or the Marshalltown above.

Thickness.—The thickness of the Woodbury clay is about 50 feet.

Name and correlation.—The formation receives its name from the town of Woodbury, in Gloucester County, N. J. It was so designated because of the good sections formerly exposed in the railroad cut at that place. It represents the upper part of the "Crosswicks clays" (lower Matawan), described by Clark in the reports of the New Jersey Geological Survey, and forms part of the Clay-marl series of Cook.

Stratigraphic relations.—The Woodbury formation rests upon the Merchantville and is overlain by the Englishtown, with both of which it is conformable. Like the other Cretaceous formations of the district, the Woodbury in the region of its outcrop is in many places unconformably overlain by Quaternary deposits.

ENGLISHTOWN SAND.

Areal distribution.—The Englishtown sand in the Philadelphia district appears as a series of outcrops extending from Ellisburg to Swedesboro. In its wider distribution it has been recognized from the Atlantic Highlands to Salem County, N. J. Owing to the generally loose, incoherent character of the materials composing the formation, fresh exposures are speedily washed down and obscured. It outcrops on the banks of Cooper Creek at Haddonfield and along Beaver Brook near Bellmawr, and forms the surface over considerable areas southwest of Woodbury.

Lithologic character.—This member of the Matawan group is a conspicuous bed of white or yellow quartz sand, slightly micaceous and with minute amounts of glauconite. It is in some places marked by delicate lines of red, giving it a highly variegated appearance, while locally the percentage of iron present is much greater and the sands have been cemented into rather massive beds of sandstone. Although for the most part the formation is composed of loose quartz sand, often closely resembling the sand of the present beaches, not infrequently it contains thin laminæ of fine brittle clay, which stand in sharp contrast to the adjoining sands, without any gradation between them. Toward the upper portion of the formation there is a horizon at which a bed of clay a few feet in thickness occurs locally. It is apparently not continuous, although it has been seen at a number of widely separated points.

Paleontologic character.—So far as known the Englishtown sand contains no fossils.

Thickness.—Its thickness ranges from 20 feet near Swedesboro to nearly 50 feet on Crosswicks Creek (a few miles northeast of the Philadelphia district) and to about 100 feet still farther north in Monmouth County.

Name and correlation.—The formation receives its name from Englishtown, Monmouth County, where it is well developed. It represents the lower part of the Hazlet sands (upper Matawan) of Clark and forms a part of Cook's Clay-marl series. It is the formation formerly called Columbus sand in reports of the New Jersey State Survey, but that name was abandoned because preoccupied by a Devonian formation in Ohio.

Stratigraphic relations.—The formation is conformable with the underlying Woodbury clay and the overlying Marshalltown formation. Throughout considerable areas the Englishtown sand is covered by unconformable Quaternary strata.

MARSHALLTOWN FORMATION.

Areal distribution.—The outcrops of the Marshalltown formation border those of the Englishtown sand on the southeast and form a belt extending diagonally across the southeastern portion of the district in a northeast-southwest direction from Haddonfield to Swedesboro. Small but good exposures of the strata occur on Tindale Run southeast of Haddonfield, along Otter and Beaver brooks, near Woodbury Heights, along Mantua Creek and its tributaries, and along the creeks between Mickleton and Swedesboro.

Lithologic character.—The formation ranges from a black sandy clay to an argillaceous marl. In the area under discussion the latter phase is the most common one, but farther northeast it is chiefly a black, laminated, micaceous clay with thin seams of sand. Locally glauconite forms so large a constituent of the mass that the bed has been exploited as a "marl bed," and, indeed, by earlier geologists was correlated with the "Lower marl" (Navesink) of Monmouth County.

Paleontologic character.—The Marshalltown clay in its southern extent (within the limits of the Philadelphia district and farther southwest) is abundantly fossiliferous (43 species). Near Swedesboro, in particular, just beyond the southern limit of the district, the fossils occur in a remarkably perfect state of preservation and in great numbers. *Cucullæa tippana, Neithea quinquecostata*, and *Cardium tenuistriatum* are prominent species which are recurrent from the Merchantville; the most conspicuous characteristic fossils, however, constitute a new element, which persists in the recurrent fauna of the Mount Laurel and Navesink. Weller, in Paleontology of New Jersey, volume 4, 1907, page 88, says:

> This element is represented most conspicuously by the ponderous species *Exogyra* and *Gryphæa*, by the little oyster *O. falcata*, which is of the type of *O. larva*, and by *Gryphæostrea vomer*. Besides these oyster-like forms which so strongly characterize the Marshalltown and the Navesink, some other species should probably be included in the same faunal element, among which are the following species which are as yet known only from these two faunas: *Plagiostoma erecta, Unicardium umbonatum*, and *Odontofusus medians*. To these should also be added, in all probability, *Tigonia thoracica*, which has been recognized in both the faunas and also in the intermediate Wenonah, where, however, only a single occurrence of a single individual has been observed.

Thickness.—Along its outcrop the thickness of the Marshalltown formation is about 30 to 35 feet, but this increases toward the southeast to at least 50 feet, as shown by a well boring at Grenloch.

Name and correlation.—Marshalltown, Salem County, N. J. near which strata belonging to this division were once extensively worked for marl, has furnished the name for the formation. In Monmouth County these beds are a part of the "Laminated sands" which formed the upper portion of the Clay-marl series of Cook, but in their extension in the Philadelphia district and southwest they were correlated and mapped by him as Lower marl (Navesink). They were included in the Hazlet sands (upper Matawan) of Clark.

Stratigraphic relations.—No unconformities have been observed between the Marshalltown and the underlying Woodbury, nor between the Marshalltown and the overlying Wenonah strata. Locally the Marshalltown formation is overlain unconformably by later deposits of the Quaternary.

MONMOUTH GROUP.

The deposits in New Jersey which are here placed in the Monmouth group consist of the Mount Laurel sand, the Navesink marl, and the Redbank sand. The first two only are represented in the Philadelphia district; and in Maryland no differentiation of the Monmouth into parts is possible, the deposits being known as the Monmouth formation. The Wenonah sand, although included in the group of formations held to be correlatives of the Matawan of Maryland, has not been mapped separately from the Mount Laurel in this district and is therefore discussed in connection with that formation. Similarly the absence of the Redbank sand in this district brings the Navesink marl into immediate contact with the overlying Hornerstown marl of the Rancocas group, from which lithologically it cannot be readily distinguished. Paleontologically the two are readily separable, but as fossils are in many places absent, separation of the Navesink and Hornerstown is rather difficult. Consequently, for the cartographic purposes of this folio, the Navesink of the Monmouth is combined with the Hornerstown of the Rancocas, just as the Wenonah of the Matawan group is combined with the Mount Laurel of the Monmouth group, and to avoid confusion these same groupings are followed in the descriptions.

WENONAH AND MOUNT LAUREL SANDS.

There has been some difference of opinion regarding the classification and nomenclature of these sands. The terms Mount Laurel and Wenonah have both been used for them in part. There are somewhat definite lithologic differences between them, although not always to the same degree, thus rendering it difficult to separate them in many places. Paleontologically they are distinct, however, the lower portion containing a fauna with many species recurrent from the Woodbury, while a much less number is common either to the Marshalltown immediately below or to the Mount Laurel and Navesink above. This fauna is furthermore closely allied to that of the Redbank. The fauna of the upper portion (Mount Laurel), on the contrary, is identical with that of the Navesink marl, and is closely allied with that of the Marshalltown on the one hand and of the Tinton (uppermost sand member of the Redbank) on the other. It therefore seems best to recognize both subdivisions in the stratigraphic column, restricting the term Wenonah to the lower and Mount Laurel to the upper subdivision. For representation on the map of the Philadelphia district, where the Wenonah sand is thin and with difficulty separated from the overlying Mount Laurel, it seems best to combine them as a single formation.

Areal distribution.—These formations outcrop along a comparatively high belt, 2 to 3 miles in width, from Haddonfield to Swedesboro. At the east end of the deep railroad cut 2 miles east of Haddonfield, just beyond the eastern limit of the Philadelphia district, are shown 25 feet of coarse, reddish, iron-cemented sand (Mount Laurel) underlain by a 6-foot exposure of fine, more or less micaceous sand which is somewhat clayey (Wenonah). The Wenonah is also exposed, 15 feet thick in a deep road cut a mile south of Haddonfield. A mile northeast of Runnemede there are exposures showing 25 feet of fine micaceous mottled sand with thin seams and small pellets of clay (Wenonah), grading upward into a coarse reddish-yellow sand (Mount Laurel). Along the ravines north and west of Wenonah there are exposures of an argillaceous, micaceous sand (Wenonah), probably 20 to 25 feet thick, above the Marshalltown, while in the railroad cut and south and east of the town there are thick exposures of the Mount Laurel.

Lithologic character.—Northeast of the Philadelphia quadrangle, in Monmouth County, the deposits at this horizon consist mainly of a fine micaceous sand with some clay laminæ, overlain by a coarse quartz sand and containing considerable glauconite, the grains of quartz being one-eighth to one-quarter of an inch in diameter. Southwest of the Philadelphia and Chester quadrangles, in Salem County, the deposits consist essentially of the upper, coarse reddish quartz sand type, with glauconite throughout. This deposit is strongly impregnated with iron, which forms crusts of all imaginable shapes and locally has cemented the sand into firm beds of sandstone. In the Philadelphia district both types of sand have been recognized, although the coarser phase has the greater development, and the lithologic differences are not so marked as farther to the northeast, owing to a gradual change in the lower member.

Paleontologic character.—Though the Wenonah fauna (80 species) contains an equal number of Merchantville and Woodbury species, characteristic forms of the Merchantville are absent or very rare, while its affiliations with the Woodbury fauna are close. The ponderous *Gryphæa* and *Exogyra* of the Marshalltown fauna are absent in the Wenonah, but *Ostrea plumosa* is in places a very common species. The fauna of the Mount Laurel sand is marked by the introduction of a new factor entirely foreign to the earlier faunas of the region, the most characteristic species of this new element being the cephalopod *Belemnitella americana* and the brachiopod *Terebratella plicata*, both of which are also especially abundant and characteristic of the overlying Navesink marl. The paleontologic data indicate that the line between the Mount Laurel and Wenonah sands marked by the introduction of the *Belemnitella* fauna is of greater significance than the relatively slight difference in the character of the sediments would imply.

Thickness.—The combined thickness of the Wenonah and Mount Laurel strata ranges from 40 to 80 feet.

Name and correlation.—The town of Wenonah, in Gloucester County, N. J., and the hill known as Mount Laurel in Camden County, furnish the names to these formations. As already stated, the Wenonah constitutes the uppermost division of the Matawan group and the Mount Laurel is the basal division of the Monmouth group.

Stratigraphic relations.—Beneath the Wenonah lies the Marshalltown formation, with no stratigraphic unconformity separating them, and the same condition holds true regarding the Mount Laurel and the overlying Navesink marl.

RANCOCAS GROUP.

The formations composing the Rancocas group are two in number and were earlier described by Clark as the Sewell marls and the Vincentown lime sands. He later applied the name Hornerstown to the "Sewell marls," the latter name having been elsewhere employed. They were first classed as members of a single formation, to which the name Rancocas was applied because of the typical development of strata of this age in the valley of Rancocas Creek, Burlington County, N. J. More recent studies by members of the New Jersey State Survey indicate that there are good paleontologic reasons for uniting not only the Hornerstown and Vincentown, but also the Manasquan in a single group, although their lithologic likeness to one another is no greater than to the subjacent formations of the Upper Cretaceous. As stated in a preceding paragraph, the Navesink marl in the Philadelphia district is in immediate contact with the Hornerstown marl, the Redbank sand which separates them in Monmouth County, N. J., being absent in this region. Lithologically they can not be readily separated, and so it seems best to map them for the Philadelphia folio as a single unit. The paleontologic studies indicate greater faunal changes between the Navesink and Hornerstown than between the Navesink and any earlier formation. The greatest faunal break in the Upper Cretaceous of New Jersey occurs at the base of the Hornerstown, the fauna of which is closely allied to that of the Vincentown and overlying Manasquan.

NAVESINK AND HORNERSTOWN MARLS.

Areal distribution.—The Navesink and Hornerstown marls outcrop in this district in a belt extending in a southwest direction from Ashland nearly to the southwest corner of the Philadelphia quadrangle. They are not found in the Chester quadrangle. Many very excellent exposures occur along the streams in the vicinity of Sewell and at Mullica Hill, a short distance south of the borders of the district.

Lithologic character. — The Navesink and Hornerstown strata are composed chiefly of glauconite, with 10 to 20 per cent of clay and a small amount of quartz sand, which commonly increases in amount toward the lower and upper portions of the marl bed. The basal portion of the Navesink grades downward into the Mount Laurel, the transition beds being sometimes referred to as "sand marl," which in many places contains numerous fossils. This shell bed is well exposed at Mullica Hill and at a number of points along the tributaries of Edwards Run, 2 miles southwest of Mantua.

The top of the Hornerstown marl is also marked in many places by another shell bed locally 5 feet thick and made up almost exclusively of shells of two or three species. These two shell beds furnish definite horizon lines which, where present, can be readily recognized and mapped.

Paleontologic character.—The Navesink marl (with the Mount Laurel sand) has yielded a large fauna of 121 species of which *Belemnitella americana* and *Terebratella plicata* are the most characteristic element, neither of them occurring in any other formation. A second conspicuous element is the *Exogyra* and *Gryphæa* group of forms, which recur from in the Marshalltown formation, *E. ponderosa* being succeeded by *E. costata*. A third conspicuous element, distinct from the European *Belemnitella* element and from the southern *Exogyra* element, is the *Cucullæa* fauna recurrent from the Merchantville and Marshalltown, among which are *Axinea subaustralis* and *Cucullæa antrosa*, while there is an entire absence of the characteristic members of the *Lucina cretacea* fauna of the Woodbury clay.

The fauna of the Hornerstown marl is small and, apart from the shell bed at the top of the formation, has not yielded many fossils, but it is totally different in essential characteristics from the faunas of all the underlying formations. *Terebratula harlani*, *Cucullæa vulgaris*, and *Gryphæa sewellensis* are characteristic forms. The shell bed at the top of the marl contains a fauna so closely allied to that of the Vincentown sand that it is a question whether it ought not to be regarded as the base of that formation rather than as the top of the marl.

Thickness.—The thickness of the Navesink and Hornerstown marls, as shown by the record from numerous artesian wells, is from 40 to 45 feet. Northeast of the Philadelphia district the Navesink marl extends several feet below the shell bed which in this region marks its base, and in Monmouth County, N. J., shows a thickness of 40 feet. This increased thickness to the northeast, which is coincident with a decrease in the thickness of the Mount Laurel sand, the changed position of the base of the marl in reference to the shell bed, and the beginning of the *Belemnitella* fauna, suggests very strongly that the upper part of what is classed as Mount Laurel sand in the region near Philadelphia becomes a nearly pure glauconite in Monmouth County, thus reducing the Mount Laurel sand in the section at Atlantic Highlands to a thin bed scarcely more than 4 or 5 feet thick.

Name and correlation. — Navesink River, in Monmouth County, N. J., has furnished the name for the Navesink marl, and the village of Hornerstown, in Burlington County, near which are extensive marl pits, has supplied the name for the Hornerstown marl. The Navesink has about the same limits as the Lower marl of Cook; the Hornerstown and Vincentown together constitute Cook's Middle marl.

Stratigraphic relations. — The Navesink and Hornerstown marls are conformably underlain in the Philadelphia district by the Mount Laurel sand, while overlying them, also conformably, is the Vincentown sand, or unconformably the Miocene sands and clays. The outcrops of the Navsink and Hornerstown are in many places concealed from view by the unconformable deposits of the Quaternary.

VINCENTOWN SAND.

Areal distribution.—The outcrops of the Vincentown sand in this district are confined entirely to the Philadelphia quadrangle and occur in a narrow belt extending from Laurel Springs southwestward to the vicinity of Jefferson. There are good exposures showing induration of the materials at Laurel Springs, where the nodular limestone was formerly dug in a line of pits along Timber Creek; along the creek below Grenloch; and on Mantua Creek southwest of Hurffville.

Lithologic character.—The Vincentown sand, where most typically developed, consists of a mass of broken bryozoan, echinoid, coral, and other calcareous remains, with some quartz sand and glauconite. The more calcareous layers frequently form beds of limestone intercalated with softer layers, which are sometimes a lime sand, but more commonly a glauconitic quartz sand. The alternating hard and soft layers range from 4 inches to 2 feet in thickness, the indurated beds being, on an average, only about half as thick as the incoherent layers, so that at the best the larger part of the formation is a glauconitic quartz sand. Traced northeast beyond the limits of the Philadelphia quadrangle, the lime-sand phase becomes less marked, particularly in the upper portion, until in Monmouth County the whole formation is essentially a yellow quartz sand carrying varying amounts of glauconite with some broken shells, which was described by Cook as the "yellow sand."

Paleontologic character.—The calcareous phase of the Vincentown is almost entirely made up of the remains of bryozoans, while Foraminifera and echinoids are very abundant, forming a fauna quite different in these respects from that occurring in the Hornerstown marl. But where the "yellow sand" phase is developed *Terebratula harlani*, a *Gryphæa*, and other pelecypods belonging to the same genera as the forms occurring in the shell bed at the top of the Hornerstown are found in association with forms characteristic of the calcareous phase of the formation, thus furnishing a sufficient reason for placing the Hornerstown and Vincentown in one paleontologic group, in which may also be included the overlying Manasquan, although this formation does not occur in the Philadelphia district.

Thickness.—The thickness of the Vincentown along the line of its outcrop in the Philadelphia quadrangle is rarely more than 25 feet, but from well borings it is known to attain a thickness of more than 100 feet a few miles to the southeast.

Name and correlation.—The Vincentown sand received its name from Vincentown, N. J., near which the calcareous phase is typically developed. It was included by Cook as a part of the "Middle marl."

Stratigraphic relations.—In the Philadelphia district the Vincentown along its outcrop is overlain unconformably by Quaternary beds or by the Kirkwood formation of the Miocene. Northeast of this district other Cretaceous and Eocene beds intervene and there the Manasquan formation conformably overlies the Vincentown, as is also the case in this district a short distance down the dip. The Vincentown rests conformably upon the Hornerstown formation.

TERTIARY SYSTEM.

The Tertiary deposits of the Philadelphia district represent both the Miocene and the Pliocene; the Eocene deposits do not occur in this district, though shown in different facies both to the north and to the south.

The Miocene deposits of the Philadelphia district comprise a part only of the extensive series of beds so characteristically developed along Chesapeake Bay and its tributaries and known by the name of the Chesapeake group. In that region they are divided into three formations, which are, from below upward, the Calvert formation, the Choptank formation, and the St. Marys formation. Within the Philadelphia district two divisions have been made of the Tertiary beds—the Kirkwood and the Cohansey, the former corresponding in part at least, to the Calvert formation of Maryland and Virginia. The Cohansey is unconformable to the Kirkwood and may represent a horizon higher than the St. Marys, since beds of similar lithologic character are found farther east above strata carrying fossils recognized only in beds of St. Marys age farther south. In Maryland the Choptank formation presents lithologic characters not unlike those of the Cohansey and rests unconformably on the Calvert, but in the absence of fossils it is impossible to establish a satisfactory correlation between them.

The deposits of supposed Pliocene age (unless the Cohansey sand is Pliocene) are confined to the few worn remnants of the great mantle of coarse gravels and sands that closed the series of Tertiary sediments along the Atlantic and Gulf borders and known as the Lafayette formation. They cover only a small area within the Philadelphia district and are confined to the Pennsylvania side of Delaware River. They reach their first important development in southern Maryland, from which point southward they are a significant part of the surficial deposits.

KIRKWOOD FORMATION.

Areal distribution.—The Kirkwood formation in this district is confined to the southeast corner of the Philadelphia quadrangle, lying southeast of the Navesink and Hornerstown marls. The extreme width of outcrop is about 5 miles, not including one or two small outliers that occur along its western margin. These outliers are exposed in the 120-foot and 140-foot hills south of Woodbury, in the 140-foot hill (Irish Hill) west of Magnolia, and in the hill just north of Mechanicsville.

Lithologic character.—The Kirkwood of the Philadelphia district is principally a very fine, flourlike sand, usually delicately banded in shades of salmon-pink and yellow. The lower portion often contains some glauconite, and scattered pebbles up to half an inch in thickness are found in this portion, although not abundantly. Locally, thin beds of coarse sand or even fine gravel occur immediately at the base. In very many places the lower few feet are composed of black beds made up of thin clay and sand laminæ, as is well shown in the marl pits at Sewell, where a bed of sandy clay 6 feet thick rests upon the Hornerstown marl. Less commonly, the lower sands have been converted to nodular masses of quartzite by the infiltration of silica, and a silicified log was found in this formation at Lindenwold. The "bull's-head" bowlders of quartzite which occur commonly on the surface from which the Kirkwood has been eroded are believed to have been derived from this formation.

Northeast of the Philadelphia quadrangle the formation is predominantly a fine, fluffy sand, with black lignitic clays at or near the base and some similar clayey layers at other horizons. Southwest of this quadrangle the Kirkwood changes considerably in character. Near the base occurs a fine, loose, somewhat glauconitic sand, above which are several feet of very soft, micaceous sand and clay that has a soapy, talclike feel and is snow-white where pure, but is not uncommonly stained with iron. Above this sand is a thick (80- to 90-foot) bed of clay, chocolate to drab in color, and locally black. It is in many places cut by joint planes into small cubes, many of the joint faces being covered with thin crusts of iron oxide. Borings show logs of lignite, leaf beds, and considerable lenses of sand occurring within the clay, although no sand layers are recognized in its area of outcrop. Locally it is fossiliferous, but fossils are not common.

Above this clay is a bed of brown clay and fine clayey gray sand, containing great numbers of shells. It is known only from openings along the headwaters of Stowe Creek and its tributaries and has been often described by earlier writers as the Shiloh marl. It forms the upper bed of the Kirkwood in the region in which it occurs.

Paleontologic character.—Along its outcrop the Kirkwood formation is not markedly fossiliferous, except that part known as the Shiloh marl, from which a large fauna, more than a hundred species, has been described (Whitfield, Mon. U. S. Geol. Survey, vol. 24). It contains the characteristic fauna of the Calvert formation of Maryland and Virginia.

Thickness. — The thickness of the Kirkwood formation in the Philadelphia district is probably about 90 feet. To the southwest the thick clay bed about Woodstown and Alloway is known to have a thickness of at least 80 feet, while locally the Shiloh marl bed has been penetrated for 30 feet, and the talclike sand sometimes reaches 10 feet. Toward the southeast these members increase greatly in thickness by the intercalation of beds at the top and the base, so that at Atlantic City strata carrying a Miocene fauna range from 390 to 1220 feet below mean tide and comprise beds representing the entire Miocene series found farther south.

Name and correlation.—The name Kirkwood is taken from the small village of Kirkwood, Camden County. The formation is to be correlated, in part at least, with the Calvert formation of Maryland, the fauna of the Shiloh marl member being closely related to that of the Plum Point marl member, and the lower fine micaceous sand probably corresponding closely to the Fairhaven diatomaceous earth member, although no diatoms have yet been found in it.

Stratigraphic relations.—The Kirkwood formation in the Philadelphia district overlies unconformably the various Cretaceous strata (chiefly the Vincentown and Hornerstown), but some of the outliers rest on even lower formations, and in the adjoining districts the Manasquan (a higher formation) is locally exposed along stream banks in small outcrops beneath the Kirkwood.

The relation of the Kirkwood to the Cohansey is not positively known. There is no definite evidence of a break in sedimentation, and within the area under discussion they seem to be conformable, but in their wider extent there is good reason for believing that the Cohansey overlaps the Kirkwood. Well borings farther southeast indicate the presence beneath the Cohansey of beds that are much younger than the Kirkwood at its outcrop.

COHANSEY SAND.

Areal distribution.—The Cohansey sand appears only in the southeast corner of the Philadelphia quadrangle, where it is for the most part thinly covered by a discontinuous mantle of unclassified Quaternary materials. It occurs at higher elevations than any of the other Cretaceous or Tertiary formations, near the headwaters of the northwest-ward-flowing tributaries of Delaware River.

Lithologic character.—The Cohansey is primarily a sand formation, but it contains some gravel and locally considerable beds of clay, none of the latter, however, occurring within this area. The sand is predominantly coarser than that of the Kirkwood, and the grains are often coated with clay, so that when moist it readily compacts. The fine micaceous, mealy sand with its delicate pink and buff mottlings characteristic of the Kirkwood does not occur in the Cohansey. The gravel of the Cohansey consists of pebbles of quartz, chert, and quartzose sandstone, ranging in size from one-quarter inch to $1\frac{1}{2}$ inches in diameter and having angular to subangular forms.

Paleontologic character.— No fossils have been found in these beds in the Philadelphia quadrangle, but Hollick (New Jersey Geol. Survey, vol. 6, pp. 138–139) reports fifty species of plant remains in collections made near Bridgeton, in beds that may prove to be of the same age and that contain a flora comparable with that of certain European upper Miocene localities, and he regards the sands as either late Miocene or Pliocene. Obscure casts of molluscan shells have been found in it near Millville.

Thickness.—At its outcrop in the Philadelphia quadrangle, the Cohansey has a thickness of 40 to 50 feet, but this is only a portion of its entire thickness, since it had been much eroded before the deposition of the Pleistocene Bridgeton formation, by which it is unconformably overlain. Its maximum thickness is not definitely known, but it unquestionably exceeds 200 feet.

Name and correlation.—This formation takes its name from Cohansey Creek, Cumberland County, N. J., along which it is well developed. It corresponds to the sand member of the Beacon Hill formation as formerly described in the New Jersey reports (Salisbury, 1901). Data regarding its age are indefinite and in a measure contradictory. Paleobotanic evidence favors its reference to late Miocene or Pliocene, while the scanty paleozoologic data are indecisive. At its outcrop it rests on the Kirkwood without apparent unconformity, but farther southeast beds of similar lithologic character overlie strata bearing a St. Marys fauna, and it is therefore apparently unconformable to the Kirkwood.

Stratigraphic relations.—The Cohansey is overlain unconformably by the Quaternary formations, while its relation to the Kirkwood is indefinite, as above indicated. Its dip is fairly regular to the southeast, its base declining from 100 feet above sea level at Grenloch to about 390 feet below at Atlantic City—a descent of 490 feet in 45 miles, or 11 feet to the mile.

The strike of the beds is northeast and southwest, conforming in a general way to that of the underlying Cretaceous formations, although northeastward across New Jersey the higher members of the Cretaceous and finally the Eocene beds appear from beneath the Kirkwood, showing that the strike of the Tertiary formations is a little more to the east than that of the Cretaceous beds.

LAFAYETTE FORMATION.

Areal distribution.—The Lafayette formation is entirely confined to the higher lands lying north and west of Philadelphia, where it occurs as irregular outliers. The Lafayette formation has not been recognized at any point in the New Jersey portion of the district, and the outliers in Pennsylvania represent apparently the most northerly deposits of this formation. They become gradually more numerous southward, but do not constitute any important part of the Coastal Plain series of formations until they extend as a broad mantle down the backbone of the southern Maryland peninsula. The best exposure of Lafayette materials in this district occurs near the reservoir in Media.

Lithologic character.—The deposits of the Lafayette formation consist of gravels, gravelly loams, sands, and sandy loams, locally firmly indurated. The coarser materials are much decayed, and the whole deposit gives an indication of age which is lacking in the Quaternary formations. The northern deposits are in the main less highly colored than those farther south, where they have a characteristic orange color.

Paleontologic character.—No fossils have been found in the Lafayette beds of the North Atlantic Coastal Plain, the materials being wholly unadapted to their preservation.

Thickness.—The thickness of the Lafayette formation is variable in the Philadelphia district. The outliers have probably been much reduced by erosion and no longer represent the full thickness of the deposits. The beds at no place apparently exceed 20 feet in thickness.

Name and correlation.—The name Lafayette was early used by Hilgard to designate deposits of this age in the central Gulf region. The correlation and wider extension of the term were made by McGee, and although some questions regarding the equivalency of the deposits still remain unsolved, geologists have in recent years generally followed McGee in the use of the name. The deposits here referred to the Lafayette were earlier described under the name "Bryn Mawr gravels." From their location, relations, and lithologic features there can be no question that they are part of the dissected mantle of the late Tertiary deposits that are so well developed farther south in Maryland and Virginia.

Stratigraphic relations.—The Lafayette rests, for the most part, in the several outliers within the Philadelphia district, on crystalline rocks, though, as has already been stated, a small outcrop of Raritan materials shows beneath the cover of the Lafayette at Media, Pa.

The Lafayette formation is found at considerably higher levels than the later Quaternary deposits, so that its relations to them in this district can not be definitely determined. Farther south the oldest of the Quaternary formations often rests unconformably upon the Lafayette.

Nothing definite can be determined regarding the strike and dip of the beds from the small outliers in the Philadelphia district. The main body of the formation farther south shows that the strata have the usual northeast-southwest strike, conforming to the continent margin, and that the dip of the beds is in general that of the other late Tertiary formations, being southeastward and about 10 feet to the mile.

QUATERNARY SYSTEM.

EAST OF DELAWARE RIVER.

By R. D. Salisbury and G. N. Knapp.

RELATIONS AND ORIGIN OF THE FORMATIONS.

In that part of this district which lies east of Delaware River there are several Quaternary formations, whose relations are somewhat complex. Unlike the older formations beneath, they do not lie in regular beds with fairly constant dip in a uniform direction. Each formation, as now seen, consists of a series of patches of gravel, sand, loam, etc., at somewhat various levels, but yet standing in rather definite relations both to the relief and to the drainage of the region. Much difference of opinion has arisen concerning the interpretation of these formations, a difference which still exists.

Principal formations.—There are three principal Quaternary formations in the area east of the Delaware, according to the interpretation here stated. These are, in order of age, the Bridgeton, the Pensauken, and the Cape May. Minor variations being disregarded, these formations may be said to lie at different levels along any line drawn at right angles to the Delaware. The Bridgeton formation occurs in small remnants only in the southeastern part of the Philadelphia quadrangle. The altitude of its base at the extreme southeast ranges from about 175 feet to about 110 feet, but in most places the range is from 125 to 140 feet. The Pensauken formation occurs in larger areas at lower levels, and its altitude becomes lower to the south and west. The larger patches of this formation near Delaware River are believed to be remnants of a once continuous formation deposited in the main valley, while the patches more remote from the Delaware are believed to consist chiefly of materials brought down at about the same time by tributary streams descending from the east and southeast. The extreme range of the base of the formation is from sea level, or even below, as at some points near Camden, to about 120 feet in the southeastern part of the Philadelphia quadrangle. The Cape May formation, which appears chiefly along the streams, occurs at various altitudes from tide level, along the Delaware and the lower ends of its tributaries, up to the level of the Pensauken, or at the southeast corner of the Philadelphia quadrangle well up toward the base of the Bridgeton formation.

Criteria for separation.—The differentiation of the formations is based on their topographic relations, constitution, and relations to drainage lines.

Looked at in a large way, the three formations are topographically distinct, and this distinction holds over a much larger area than that considered in this folio. This general statement does not lose sight of the fact that the range of level of the Cape May formation is from sea level up nearly to the base of the Bridgeton in this district, and notably higher at a few points elsewhere; but for any given region the topographic distinction of the several formations is reasonably sharp. Exceptions to this general rule are not wanting.

The three formations are characterized by certain differences in constitution, though they are not so distinct that any one of them could be certainly identified from a single exposure on the basis of its constitution alone. In spite of all confusing gradations, there are certain broad distinctions which persist, not only in this area, but throughout the State.

Another distinction between the formations is found in their relation to drainage lines. This applies particularly to the Pensauken and Cape May formations.

The separation of the formations as here defined is not on the basis of any one of these three criteria, but on all three, and especially on their relations to one another.

Origin.—The study of the Quaternary formations of this and adjacent regions has led to the conclusion that streams played an important part in their deposition. The Pensauken and Cape May formations, so far as they occur in this district, are interpreted as deposits made chiefly by surface drainage; but this statement is not to be interpreted to mean that there was no submergence of any part of the area where these formations occur during the Quaternary period. The reasons for assigning to rivers an important part in the origin of these formations will appear when the constitution of the formations has been considered.

The alternative conclusion to which some students of these and equivalent formations in adjacent regions have been led is that the formations are primarily of marine origin.

BRIDGETON FORMATION.

Distribution. — The Bridgeton formation, the oldest of the Quaternary formations of this region, has but slight representation in this district. East of the Delaware it appears only in the southeastern part of the Philadelphia quadrangle, and there in small areas only. Southeast of this quadrangle the formation occurs in much larger areas, and the patches which appear in the Philadelphia quadrangle are to be looked on as outliers. (See figs. 1 and 2.) They are larger and less widely separated to the southeast, and smaller and more widely separated to the northwest. The most northwesterly outliers are a few small areas arranged in a

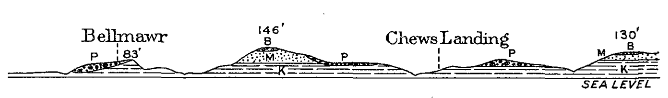

Fig. 1.—Section through hill east of Runnemede and hill east of Mechanicsville, N. J., showing the relations of the Bridgeton and Pensauken formations.

K, Cretaceous; M, Miocene; B, Bridgeton; P, Pensauken.

northeast-southwest line extending from a point a mile or so south of Clarksboro on the southwest to a point near Haddonfield on the northeast. In these areas remnants of the Bridgeton formation cap four somewhat conspicuous hills, which rise to altitudes of 133, 144, 146, and 140 feet. The base of the Bridgeton formation in these four hills

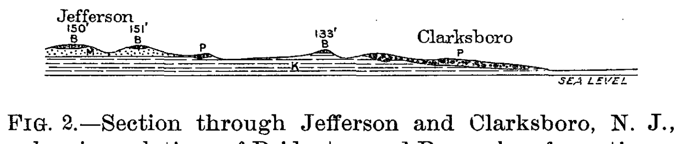

Fig. 2.—Section through Jefferson and Clarksboro, N. J., showing relations of Bridgeton and Pensauken formations.

K, Cretaceous; M, Miocene; B, Bridgeton; P, Pensauken.

has elevations ranging from about 125 to 135 feet. These heights give some indication of the position of the surface along this line when the Bridgeton formation was deposited. Two other remnants of doubtful Bridgeton gravel appear about 2 miles south of Woodbury.

The bases of the remnants of this formation lying farther southeast, about Jefferson, Barnsboro, Fairview, Blackwood, and Turnersville, have elevations ranging from about 110 to 130 feet, while at the extreme southeast corner of the quadrangle the base of the formation is at a distinctly higher level, about 170 feet.

Phenomena of adjacent areas beyond these quadrangles are of similar import, and make it appear that at the time of the deposition of the Bridgeton formation there was a broad tract of low land adjacent to Delaware River, the surface of which stood at a level which is now 110 to 135 feet above sea level, and that this lowland was bordered on the southeast by land some 50 feet higher. The strike of the slope between these two tracts had a northeast-southwest direction, passing through the southeast corner of the Philadelphia quadrangle. The Bridgeton formation was deposited chiefly on the lowland to the northwest. Where the scarp to the southeast was low the lowland appears to have been aggraded to its top; where it was higher the Bridgeton formation appears to have failed to reach its top, but to have been banked against it on the northwest side.

Constitution.—The Bridgeton formation is made up primarily of sand and gravel, the former predominating. The sand is largely, but not altogether, coarse and angular, and is generally more or less arkose. The material of the gravel has notable lithologic range. It includes quartz, sandstone of various sorts, quartzite, chert, trap, granite, gneiss, schist, and shale. While stones of these sorts of rocks rarely exceed a few inches in diameter, they sometimes attain the size of bowlders and some of them give evidence of but little wear. The gravel is distributed more or less generally through the sand, often in thin seams, but sometimes irregularly. (See fig. 14 on illustration sheet.) A thin layer (1 or 2 feet) of coarse gravel is especially likely to occur at the very base of the formation. Those varieties of rock which are subject to decay are generally thoroughly softened. This is true, for example, of most of the crystalline rock, of the shale, and of the sandstones which are not composed almost wholly of quartz. More or less earthy matter is mingled with the sand and gravel, giving the whole a compactness not characteristic of common sand and gravel. In most places, indeed, compactness is one of its distinguishing characteristics. As a result, the gravel often stands with vertical faces year after year, in the pits where it is dug for road material.

Lithologically the material of the Bridgeton formation could not be distinguished with certainty from much of that of the Pensauken formation, though certain minor differences may often be detected. In many places it contains more loose sand than that phase of the Pensauken which it most resembles, probably because sand from the Kirkwood and Cohansey formations of the vicinity entered more largely into its make-up.

Exposures.—The Bridgeton formation is well exposed in Irish Hill 1½ miles southeast of Bellmawr, in the hill at Woodbury Heights, a little to the northeast of Jefferson, half a mile north of Barnsboro, a mile southeast of Fairview, 2 miles west of Turnersville, and a mile north-northeast of Blackwood. It is, indeed, exposed fairly well on most of the hills which it caps.

Difficulties of correlation.—It is possible that some of the gravel classed as Bridgeton on the geologic maps and lying at the lower levels has crept or slumped down somewhat from its original position. It is possible too that some of it has been shifted somewhat and redeposited, retaining essentially its original composition. Material which has had this history is really younger than the Bridgeton proper, but its association with that formation may yet be closer than that with the next younger formation which is definitely recognized. It should be distinctly borne in mind that in a series such as that of which the Bridgeton formation is a member deposits of all ages, from the oldest to the youngest, are possible, or even probable.

The difficulties of correlation are greatest at the southeast, for here the base of the Bridgeton is nearly as low as the uppermost part of the Pensauken. Where the topographic distinction between the two formations fails their separation is based chiefly on their constitution. The younger formation (Pensauken) is made up in part of material derived from the older (Bridgeton), but in its shifting and redeposition the softer constituents, such as the decayed crystalline rock, the shale, etc., largely disappeared. Another of the marks of the reworked material of the later formation is the presence in it of worn pieces of iron-cemented parts of the Bridgeton. It is true, however, that after all considerations bearing on the question of correlation for a given area have been weighed reasonable doubt may remain. This is true, for example, in the case of some portions of areas mapped as unclassified sands and gravels.

EROSION INTERVAL BETWEEN BRIDGETON AND PENSAUKEN.

After the deposition of the Bridgeton formation a period of erosion followed, during which much of the formation within this district was removed. The evidence of this erosion is found chiefly in the configuration of the surface on which the next succeeding formation, the Pensauken, was deposited. This has a very considerable relief. Near the Delaware the altitude of the base of the Pensauken formation generally ranges from about 40 feet at the southwest to 80 to 90 feet at the northeast, with a tendency to sink to lower levels toward the Delaware and near tributary streams. Along the Delaware, indeed, the formation probably runs down to mean tide level locally, and near Camden material that has the composition of the Pensauken has been thrown out of excavations 20 feet below tide. It is inferred, therefore, that the Delaware Valley was a little deeper than now when the deposition of the Pensauken formation began, and that tributary streams had valleys at harmonious levels. The deeper parts of these valleys appear to have been narrow. Farther from the Delaware the base of the Pensauken is somewhat higher.

The configuration of the surface beneath the Pensauken formation indicates that above the somewhat narrow and deep valley of the Delaware there was a broad plain along the Delaware after this interval of erosion, and that the level of this plain now ranges from about 50 feet above sea level near Swedesboro to 60 feet at Woodbury and to 70 feet or a little more at Haddonfield. This valley plain sloped gently toward the Delaware below Camden, while farther north it maintained its high level nearly to the stream, and then dropped off abruptly to the valley along the line where the large areas of Pensauken now approach that stream. This valley plain was affected by low swells on the one hand and by shallow valleys on the other.

This plain along the Delaware is believed to have been terminated eastward by a slope or low scarp some 50 feet in height, which ran from Swedesboro on the southwest through Woodbury to Haddonfield. Its position was determined primarily by the outcrop of certain relatively resistant beds of the Cretaceous (Wenonah and Mount Laurel sands to the southwest, Englishtown sand to the northeast). At the time of the deposition of the Pensauken formation this scarp was much interrupted by the valleys tributary to the Delaware. It has since been largely destroyed by erosion. The higher surface southeast of the scarp had been somewhat maturely dissected by streams which led to the Delaware along courses essentially the same as those of the present streams, before the Pensauken formation was deposited.

Since the surface on which the Pensauken formation was deposited is believed to have been developed by subaerial erosion after the deposition of the Bridgeton beds, the interval between these formations must have been somewhat long. While erosion seems to have been the dominant process of this interval in this region, there was doubtless some deposition on the lower slopes and valley plains.

PENSAUKEN FORMATION.

Distribution. — After the development of the topography just sketched the valleys of the Delaware and its tributaries became the sites of deposition, and the deposits made constitute the Pensauken formation. Proceeding from the Delaware, deposition spread laterally over the valley plain, aggrading it to a level which approached, but did not generally reach, the top of the Swedesboro-Haddonfield scarp to the southeast. As its composition shows, much of the material deposited on the plain east of the Delaware was brought in from the north, while some of it was brought in from the southeast by the tributaries of the Delaware.

Deposition in the main valley caused the tributaries to aggrade their valleys. The formations on which they worked ranged from the Cretaceous to the Bridgeton—formations which were, on the whole, unlike those from which the Delaware and the Schuylkill derived their sediments. The result was that the deposits in the tributary valleys, made contemporaneously with the deposits in the main valley, are of somewhat different constitution. Materials from the tributaries entered into the deposits along the main valley to some extent, but material brought down by the main stream did not enter into the deposits of the valleys of the tributaries. While, therefore, the Pensauken formation is not uniform lithologically, its variations are somewhat definitely related to the several contributing drainage basins. The distinction here made is recognized on the map. In New Jersey, within this district, the one phase of the formation is found northwest and the other southeast of a line running from Ellisburg, near the eastern margin, to Swedesboro, at the southern margin. That phase of the formation which lies in the main valley, nearer the Delaware, is called the Delaware River phase, while the phase which lies to the southeast is called the tributary-valley phase. The patches of the former are parts of a once continuous formation; those of the latter were, perhaps, never continuous.

DELAWARE RIVER PHASE.

Composition. — The Pensauken formation is composed primarily of sand and gravel, but locally, as at Fish House, it includes beds or bodies of clay. The gravel beds carry occasional bowlders which, in exceptional cases, are 4 and even 6 feet in diameter. At Fish House the clay constitutes a bed 20 to 25 feet thick. In general, coarse and more or less angular sand predominates, while the gravel generally appears either in thin beds or seams in the sand or at its base. Locally, however, gravel predominates, but even in such cases stones larger than cobbles are rarely abundant. The sand and gravel are usually accompanied by a little loam, more or less generally distributed through the coarser materials, but more abundant in the upper part than in the lower. The materials are commonly somewhat highly colored, generally with iron oxide. Toward the top the color is in places orange-brown. In some places the ferrugination has gone so far that the material is firmly cemented into conglomerate, but more commonly the iron oxide has only made the gravel and sand somewhat coherent. (See figs. 16 and 17, illustration sheet.)

The coarse materials consist of quartz, quartzite, sandstone of various sorts, chert, shale, gneiss, schist, granite, gabbro, basalt, and iron-cemented sandstone and conglomerate. Much more commonly than otherwise these materials are well worn. (See fig. 16.) The proportions of these several constituents vary greatly, but in the area under consideration quartzose materials (quartz, quartzite, quartzose sandstone, chert, etc.) predominate greatly. Granites, gneisses, etc., rarely make so much as 10 per cent of the stones large enough to be readily identified, and shale and arkose sandstone even less. Locally the waterworn pieces of ironstone are more abundant than any of the other constituents, but in the Delaware River phase of the formation they are, as a rule, distinctly subordinate. The sand consists primarily of quartz, but it locally contains more or less decomposed feldspar (kaolin), glauconite, and grains of iron oxide.

This phase of the formation varies somewhat, both physically and lithologically, from the northwest to the southeast. The materials, which are coarse near the Delaware, become finer with increasing distance from the river, and at the same time the various sorts of crystalline rock, the shale, and some varieties of sandstone decrease in abundance and the sand becomes less arkose. On the other hand, fragments of ironstone are more abundant and coarser toward the southeast. These variations appear to mean that the materials which were contributed by streams from the north are scarcer toward the southeast, while the materials contributed by the streams from the southeast increase in abundance in that direction. The northwesterly derived materials do not, as a rule, extend southeast of the scarp referred to. The materials from the southeast extend northwest of this scarp to a much greater extent than the northerly materials extend southeast of it. These general statements are perhaps less true of the area southwest of Woodbury than of the area farther north.

Sources of the material.—It is not generally possible to identify the precise localities whence the materials of the Pensauken came, but the northern origin of most of its coarse materials is certain. Thus certain types of the sandstone which it contains appear to correspond with the sandstone of the Newark at various points up the Delaware, as at Stockton and Milford. Red shale from the Newark group is also a constituent of the Pensauken, though some of the red shale probably comes from the Paleozoic formations of Pennsylvania. The occasional pieces of diabase are also doubtless from the Newark. Much of the gneiss and schist may be confidently referred to the gneiss of the Philadelphia region, but it is not possible to identify the precise localities whence they came. The source of the granite and gabbro, both of which are extremely rare south of Camden, is not known. The ironstone came from the Cretaceous and later formations. The quartz and chert pebbles, which are generally prominent constituents, were probably derived chiefly from the Bridgeton and older formations to the southeast. The glauconitic sand is evidently from the Cretaceous southeast of the Delaware.

Structure.—The upper part of the formation does not usually appear to be distinctly stratified. This is often the case to a depth of 8 to 10 feet. If the formation attains greater thickness, and in places where it does not, stratification may be distinct in the lower part. Cross-bedding is conspicuous (fig. 15 on illustration sheet). The materials are, on the whole, not well assorted, and the details of the sections vary notably not only from pit to pit but often in the faces of the same pit.

The formation is, on the whole, rather compact, a characteristic which is often conspicuous in the pits that have been opened in it. The compactness is due to (1) incipient cementation of the material by iron oxide; (2) the presence of clay, loam, etc., which fill the interstices between the grains; or (3) most commonly to both. The formation is extensively worked for road material, its value depending on the presence of the loam and clay, the iron oxide, and the decayed condition of many of the coarser materials, which crush readily and pack well in the road bed.

Thickness.—The formation appears to have been thickest near the Delaware, but in many places its present thickness depends on subsequent erosion, so that existing remnants are thin near the Delaware as well as far from it. Within this area the formation is at few places more than 30 feet thick and its average thickness is probably less than half that amount. In the city of Philadelphia it has a known thickness of 50 feet.

Originally the upper surface of the Delaware River phase of the Pensauken probably extended from an elevation of about 120 feet in the vicinity of Haddington (West Philadelphia), to about the same elevation at Haddonfield, N. J. (See fig. 3.) If so, approximately 80 feet of the formation must have been removed from the vicinity of the city hall in Philadelphia, where its original thickness must have been about 120 feet. This probably represents about the maximum original thickness of the formation. The area was narrow where the thickness was so great.

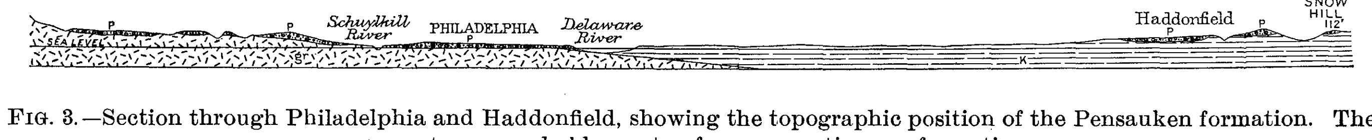

FIG. 3.—Section through Philadelphia and Haddonfield, showing the topographic position of the Pensauken formation. The remants are probably parts of a once continuous formation.
gr, granitic rocks; K, Cretaceous; P, Pensauken.

Local details.—The type locality of the Pensauken formation is at the northern border of the Philadelphia quadrangle, at the mouth of Pensauken Creek. The best exposures are south of the creek, south of Palmyra and east of Morris. The thickness of the formation here ranges from 8 to 30 feet, and its base is from 30 to 60 feet above sea level.

The general character of the formation is shown by fig. 9. The extensive sections exposed vary so much from point to point that the range of the formation for this region may be seen at this locality. At one point the section is as follows:

Section of Pensauken formation near mouth of Pensauken Creek, New Jersey.

	Feet.
Brown sand and gravel	4
Brownish-yellow sand, somewhat arkose	20
Gravel and cobbles	½
Cretaceous clay.	

A few rods distant the section is as follows:

	Feet.
Coarse, compact gravel and brown sand	8
Coarse, brown, arkose sand	16
Coarse gravel and cobbles	½
Cretaceous clay and sand.	

As the Cretaceous beneath contains gravel at some points, it is locally difficult to determine the exact line of junction of the Pensauken and the Cretaceous.

In the gravel of the above sections cobbles and pebbles of crystalline material, such as granite, gneiss, and schist, are abundant and are for the most part thoroughly decomposed. Shale and basaltic rocks, probably of Triassic origin, are perhaps equally abundant. Most of the coarse materials are distinctly waterworn, but angular pieces are not wanting. Other exposures of the same sort occur at various points for a mile southeast of the principal pits.

East of Palmyra the formation in some places contains a considerable amount of dark clay, associated with the sand and gravel. The sections showing the clay are 30 to 40 feet above sea level and suggest that during the early stages of Pensauken deposition slack-water conditions obtained, at least locally.

The most exceptional section of the Pensauken occurs at Fish House, where it contains 20 to 25 feet of dark clay. The clay rests on Cretaceous clay at some points and on Pensauken gravel at others. The latter contact has not been seen in section, but material thrown out from holes sunk below the floor of the clay pit for drainage purposes has the distinctive characteristics of Pensauken gravel. It contains numerous bits of shale, granite, etc., apparently identical in kind with materials seen in section at corresponding levels at other points in the valley, especially in Philadelphia, where a layer of clay 4 feet thick, like that at Fish House except in color, has been seen in the Pensauken formation. The general relations of the clay at Fish House are shown in

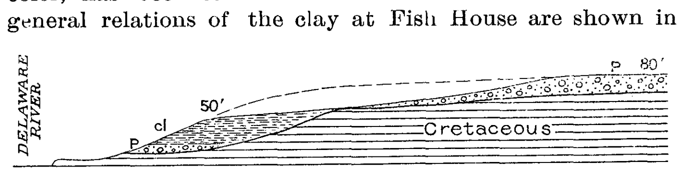

FIG. 4.—Section showing the relationship of the clay (cl) to the gravel of the Pensauken formation (p) at Fish House. Dashed line above the section marks the former extension of the Pensauken.

fig. 4. It has been seen to grade laterally into sand. At one stage the face of the pit here showed a bed of black clay 8 feet thick, with no trace of sand, grading into sand with no clay, the transition being accomplished in a distance of 60 feet.

The clay at Fish House contains abundant fresh-water fossils (*Unio*), one species being still represented in the Delaware of the immediate vicinity (Woolman).

In the area about Haddonfield the surface of the Pensauken attains the maximum altitude for this region, 120 feet. The base of the Pensauken is here uneven, being higher to the southeast. As the base rises the constitution of the formation changes; it becomes less and less arkose, and carries less and less shale and other material to which a northerly origin can be confidently assigned. The formation thins to the southeast as its surface rises, and pinches out against the slope of the underlying Cretaceous, the top of which, about the 140-foot hill, has an elevation of about 100 feet. The Pensauken material about the 140-foot hill (with cap of Bridgeton) is more or less generally cemented by iron oxide. Good exposures occur in the pits a mile southwest of Haddonfield.

Near Audubon, at an elevation of about 70 feet, the section of the Pensauken is as follows:

Section of Pensauken formation near Audubon.

	Feet.
Sandy loam with small pebbles	2
Brown arkose sand, very compact, with bands of pebbles	4 to 6
Gravel and cobbles, many of granite and shale	½
Yellowish arkose sand	1 to 3

Near Mount Ephraim, on the Haddonfield road, in the southwest bank of the creek, 10 feet of Pensauken sand and gravel are exposed, with the base about 20 feet above sea level. The gravel is in thin sheets in the sand, and the sand is coarse, angular, and arkose. Many of the cobbles and pebbles are of decomposed granite and shale.

Half a mile north of Barrington, at an elevation of about 90 feet, the irregularity of the base of the Pensauken is shown in the railway cut. Its relations are suggested by fig. 3. The irregularity of its base is shown again in the vicinity of Bellmawr, where it ranges from 80 feet or so down to 20 feet. Exposures showing the contact of the Pensauken and Cretaceous have been well seen just west of the Bellmawr station, where its altitude is about 50 feet, and half a mile to the north, on the east side of the Bellmawr-Mount Ephraim wagon road, in the south bank of the creek, where its altitude is but 20 feet. The Pensauken sand here is distinguished from the Cretaceous sand beneath only by careful observation. The former is somewhat arkosic, and has a few pebbles, whereas the latter has neither of these features. The contact of the two formations, including part of each, is often cemented (see fig. 6).

The Pensauken is well exposed in pits about North Woodbury, where there is great variation in its constitution.

About Clarksboro there is a large irregular area of Pensauken, composed chiefly of the usual arkose sand, with fragments of shale and crystalline rock in the gravel. The nature of the material here is well seen only in cuts, since the surface is covered with younger loam. At the northwest its base has an elevation of 30 to 50 feet; to the southeast it rises to nearly 100 feet.

About Asbury and Rulons is a very considerable area of Pensauken which locally attains a thickness of 30 feet. It is made up chiefly of arkose sand, locally cemented by iron oxide. At the northwest its base has an elevation of 20 to 50 feet; at the southeast, 50 to 90 feet. At this level, which appears to represent nearly its original maximum elevation here, it terminates against the old Cretaceous scarp, remnants of which appear in the hills, rising to elevations of 114 to 122 feet. The basal part (one-half to two-thirds) is of arkose sand, while the upper part (one-third to one-half) contains gravel. The higher remnants of gravel to the east belong to the other phase of the formation.

TRIBUTARY-VALLEY PHASE.

The second phase of the Pensauken formation differs notably from the first. Its areas are, on the whole, smaller and less well defined. The material is, in general, not arkose; and in few places is there anything which can be referred definitely to a northwestern source. Such sand and gravel as might have come from the Cretaceous and from the Kirkwood, Cohansey, and Bridgeton formations to the east predominate; crystalline rock, shale, etc., are essentially lacking; and, locally at least, ironstone is very abundant. As a whole, therefore, the material packs less readily and is less useful for road material than that of the Delaware phase. It nowhere occurs in such thick beds as the Delaware River phase of the formation, thicknesses of more than 10 to 15 feet being rare. On the whole, the base of this phase of the formation is slightly higher than the base of the other phase, and it rises toward the heads of the valleys, locally approaching or perhaps even reaching the level of the Bridgeton.

As already indicated, this phase of the formation is regarded as the sedimentary matter deposited chiefly by tributary drainage during the deposition of the Delaware River phase of the Pensauken; but some of the gravel and sand mapped as Pensauken may have been deposited prior to the deposition of the Delaware River phase and some afterward. The material was originally deposited chiefly in the tributary valleys and on the gentle slopes above them, and the scattered patches of the present time are not believed ever to have been united into a continuous stratum. Since this phase of the formation was deposited the streams have shifted their courses down the dip of the underlying beds, and some of the old valley accumulations have thus been left well back from the present streams. Some of them, indeed, now constitute low divides.

Local details.—Northeast of Swedesboro in the southeast corner of the Chester quadrangle there is a series of patches of gravel capping hills which range from 90 to 115 feet in elevation. These gravel caps are mere remnants. The slopes below the hilltops and above the main body of the Pensauken (Delaware River phase) to the west are nearly bare Cretaceous. These caps of gravel are essentially without arkose sand, crystalline rock, and shale. They are probably not strictly contemporaneous with the Delaware River phase of the Pensauken, but were probably deposited in the pre-Pensauken-post-Bridgeton interval of erosion. The sand and gravel are more or less cemented by iron oxide (see fig. 17, illustration sheet). West of some of these hills, which have steep slopes, the arkose sand of the Delaware River phase of the Pensauken comes in about where the angle of slope changes. Similar remnants occur at various points northeastward to Wenonah, where there are larger areas of this phase of the Pensauken.

A section along the railway south of Wenonah, in the south bank of Mantua Creek, is as follows:

Section south of Wenonah, in bank of Mantua Creek.

	Feet.
Reddish-brown clay loam	3
Gravel with sand and loam interstratified	8
Loam and sand	4
Gravelly sand, with glauconite and green clay	3
Conglomerate with ferruginous cement	1
Cretaceous sand.	

Waterworn bits and small slabs of ironstone are common in the gravel, also cobbles of quartzose material. The material is strikingly like that now being deposited in the stream beds of the region. The general relations of this material are shown in fig. 5. This material is regarded as sediment

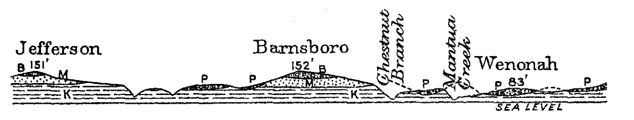

FIG. 5.—Section through Jefferson, Barnsboro, and Wenonah. The Pensauken on the divide to the right of Chestnut Branch was probably deposited by that stream, which has since shifted its bed toward the west. The Pensauken at Wenonah was probably deposited by Mantua Creek, which has since shifted its position likewise toward the west.
K, Cretaceous; M, Miocene; B, Bridgeton; P, Pensauken.

accumulated in a valley at about the time that the Delaware River phase of the formation was being deposited farther west. The material was probably deposited by Chestnut Branch, rather than by Mantua Creek. The dotted line of fig. 5 suggests the topography at the time of its deposition, since which Chestnut Branch has shifted toward the west to its present position. Mantua Creek has probably shifted its position comparably, and remnants of the deposits which it is thought to have made in the Pensauken epoch appear north of Salina.

From 1½ to 2 miles southeast of Woodbury there are some thin beds of gravel capping knolls which have an elevation of about 100 feet. In general the gravel caps are very thin—2 feet or less. A mile east of Woodbury Heights, where there is fully 6 feet of gravel, is some material of northwestern origin. It is possible that these materials, exceptional for this region, were derived from the Bridgeton to the east, though all the soft materials, such as the shale, decayed granite, etc., generally disappeared when the Bridgeton material was reworked. It is more likely that the area where these materials occur was once connected with the Delaware River phase of the formation, though now isolated by erosion. Bits of gneiss are also found in the Pensauken remnant 2 miles east of Woodbury. This remnant was probably once connected with the larger areas to the west, and represents about the summit level of the Delaware River phase of the formation.

Between Chews Landing and Turnersville there are numerous patches of surface material mapped as Pensauken, but their deposition may have taken place at any time after the degradation of the Bridgeton surface was well advanced. They are made up of materials derived from the Bridgeton and lower formations to the east.

The correlation of the remnants of this region is more or less uncertain, for between the Bridgeton and the Pensauken there seem to be all possible gradations, and it is sometimes impracticable to distinguish between portions of the Bridgeton which were deposited at lower levels than usual at the outset and portions which have been redeposited with little transportation and wear, and so remain much like the original in constitution. An instance of such uncertainty appears in the little hill just north of Turnersville, where the gravel is cemented so as to be quarried for stone. The quarrying takes place just above the 100-foot level. The material, which was originally cross-bedded sand with cobbles, is fairly characteristic of the Bridgeton, including shale, sandstone, quartzite, etc. Over the cemented portion lies sand, which appears to have been a derivative from the Miocene. This is one of the cases where it is impossible to say whether the material is Bridgeton in its original position or whether it should be classed with the Pensauken.

Southeast of Barrington (2 miles southwest of Haddonfield) the base on which the Pensauken rests is irregular and the gravel is without the distinctive constituents which point to a northwesterly origin. (See fig. 6.) The Pensauken of this

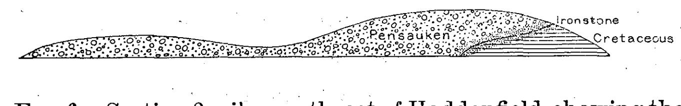

FIG. 6.—Section 2 miles southeast of Haddonfield, showing the irregular base of the Pensauken formation. The sand and clay at the contact of the Pensauken and Cretaceous, are more or less cemented into ironstone.

locality is somewhat cemented and is sometimes covered with dune sand. Several small areas of the same sort of material occur about Snow Hill, 2 miles south of Haddonfield. The gravel here is thin, and consists almost wholly of quartz. Locally greenish or brownish clay is associated with the gravel. The material may have been derived from the Cretaceous of the vicinity.

About Ashland, exposures show 6 feet of gravel, sand, and loam, containing none of the materials which indicate a northwesterly origin. Ironstone, quartz, quartzite, sandstone, and chert appear, but no granite or shale. Similar gravels occur about Greenland, Somerdale, and Kirkwood, at elevations ranging from 95 to 115 feet. These gravels may have accumulated during the degradation which followed the deposition of the Bridgeton, and preceded the deposition of the main part of the Pensauken. In many places there is not more gravel in these localities than might have been left on the surface during its reduction from the Bridgeton to the Pensauken level.

The geologic map includes under the heading Pensauken formation certain areas of gravel and sand which are regarded as of somewhere near Pensauken age. These beds may include material which is older than the Pensauken but younger than the Bridgeton, and some which is younger than the Pensauken but not so young as the Cape May. Inasmuch as deposits of slight extent at least appear to have been made at all stages since the deposition of the Bridgeton beds, a complete and decisive classification into formations representing definite periods of sedimentation is not possible. Some of the areas of doubtful Pensauken may possibly be the equivalent of some of the areas mapped as Bridgeton. Where there is no topographic basis for the separation of these two classes of areas their differentiation, as mapped, is based on the lithologic constitution of the deposits. It should be clear from what has been said above that all gradations between these formations may exist and that the separation of the deposits into Bridgeton and Pensauken must in some cases be arbitrary.

ORIGIN OF THE PENSAUKEN.

The Delaware River phase of the Pensauken is composed of débris which is believed to have been brought down by streams from the north during one of the early glacial epochs, an epoch which antedated the last glacial epoch by a very long period of time. The streams, such as the Delaware, leading out from the ice sheet and laden with débris which the ice had prepared, aggraded their valleys, and the ice floating down the streams helped them to transport the large pieces of rock, occasionally of bowlder size, which occur in the formation of this region. The same agency—floating ice—helps to account for the unworn character of some of the coarse material of the formation, and at the same time affords a rational explanation of the presence so far from its source of such soft materials as the friable Newark shale and sandstone. It is not believed that rivers, unaided by floating ice, could have carried them so far, and it is still more incredible that they could have been transported from their original position by waves. Furthermore, a single well-glaciated stone has been found in the Pensauken at Falsington, Pa., a few miles north of this district. Material much like the Pensauken occurs up the Delaware, as at Raven Rock, at much higher levels (200 feet), seeming to point to the direction whence the material came. At least one distinctly glaciated bowlder has been found at Raven Rock. As already indicated, the material of the tributary valley phase of the formation had a different and more local source.

There may be some question as to whether the material of the Delaware River phase of the Pensauken formation of this region, brought from the north by streams, was deposited by them directly, or whether the area of deposition was depressed sufficiently to be submerged beneath the sea or a bay. It seems clear that the material of the formation was essentially river borne, not wave derived. This is shown by its constitution, for it was derived from very different levels, some of them levels which no moderate submergence would have made accessible to the waves. It is shown also by the relation of the constitution of the formation to the rock terranes along its borders. If it were a marine deposit, or at any rate if its materials were in any considerable part wave derived, they should change from point to point, as the shore formations change. Their failure to change in this way is a strong argument against the wave origin of the material, if not against its deposition in the sea. Again, no distinctive mark of a marine formation has been recognized in the Pensauken formation. Its only known fossils are fresh-water and land species. No sea cliff, nor any shore line, definitely identified as such, is found. Various lines of cliffs at one point and another have been interpreted as sea cliffs, but it does not appear that they are not equally well interpreted as the bluffs of river valleys. So far as New Jersey is concerned, indeed, this seems the better interpretation.

On the other hand, it should be said that the physical condition of the formation is such that, even if it once contained abundant marine shells, they would probably have disappeared except from the clayey parts, for the formation now contains practically nothing which is not nearly insoluble under normal conditions. A bit of limestone, for example, has never been found in the formation, and the condition of the sand and gravel is such as to lead almost inevitably to the conclusion that if limestone pebbles had ever been present they would have been leached out long ago. The absence of marine fossils, therefore, can hardly be considered conclusive evidence against the marine origin of the formation.

The structure of the formation has been referred to. The extensive cross-bedding is consistent with a fluviatile origin, and perhaps not inconsistent with deposition in standing water. The formation has nowhere been seen to possess structural features different from those which affect the deposits of glacio-fluvial waters. The ill assortment of the gravels, sands, and loams is a feature of stream deposits, rather than of ocean deposits.

Another point which seems to favor the interpretation of the Pensauken formation as a land rather than a marine deposit is found in the chemical constitution of the material. It is usually as thoroughly decayed at the bottom as at the top. While this is by no means a conclusive line of evidence, it is a condition rather characteristic of river deposits, which are made slowly and under conditions favoring decay, and it is less characteristic of marine formations.

On the whole, therefore, if the formation can not be said to possess characteristics which demonstrate its fluviatile origin, it is yet true that such an origin seems, all things considered, to accord best with the facts, as now understood.

While the Pensauken appears to be chiefly a fluviatile formation, there is some reason to think that subsidence affected the region while the Pensauken formation was being deposited. If so, some of the materials of this formation may be marine or estuarine. There is evidence in the clay beds of the formation that deposition took place locally in standing rather than running water. Standing water, of course, does not necessarily imply submergence beneath the sea, and it is significant that the only fossils found in that part of the formation which surely implies standing water are all fresh-water shells and the bones of land animals. In some other parts of New Jersey, however (near Tuckerton, for example), marine shells, which are perhaps to be referred to this epoch, are found at elevations somewhat above the present level of the sea; but since the age of these shells is not certainly known, great weight should not be attached to them in this connection. While, therefore, the Delaware River phase of the Pensauken is regarded as primarily a river deposit, the hypothesis is entertained that when the material was deposited the region where it was deposited may have been somewhat depressed, thus facilitating the deposition by the streams.

DISTINCTION OF PENSAUKEN FROM BRIDGETON.

It has been seen that the constitution of the Delaware River phase of the Pensauken formation is essentially the same as that of the Bridgeton, while the composition of the tributary-valley phase of the Pensauken differs in that its distinctive constituents came from the southeast. The Delaware River phase of the Pensauken is much like the Bridgeton lithologically, but distinct from it topographically. The tributary-valley phase of the Pensauken is unlike the Bridgeton lithologically, but is not always distinct from it topographically. The tributary-valley phase of the Pensauken is unlike

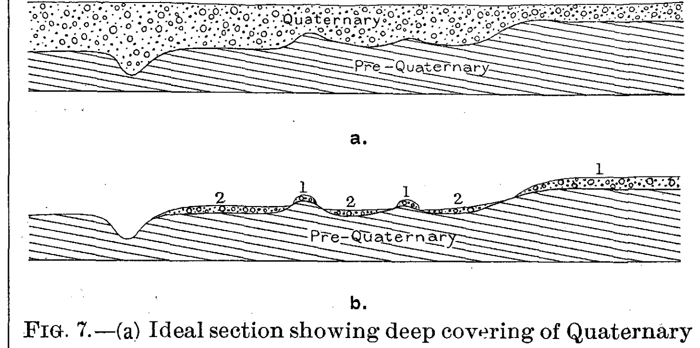

FIG. 7.—(a) Ideal section showing deep covering of Quaternary sediments over an irregular surface. (b) Same section after erosion. The remnants of surficial deposits are so distributed as to give the appearance of constituting two separate formations, 1 and 2.

the Bridgeton lithologically, but is not everywhere distinct from it topographically. The general conception of its historical relations is indicated by fig. 7.

The outliers of Bridgeton well away from the highlands at the southeast, as near Jefferson, Barnsboro, and Bellmawr, are much more readily distinguished from the Pensauken than the areas to the southeast, as about Turnersville, where the Pensauken is higher and rather less unlike the Bridgeton in constitution. In spite of the fact that the two formations seem to grade into each other in some places, the balance of evidence seems to be in favor of their separation by a long period of erosion.

CAPE MAY FORMATION.

Distribution.—The Cape May formation is the youngest formation of the region, if wind-blown sand, modern alluvium, and swamp accumulations of vegetable matter be left out of consideration. The largest areas of the formation in New Jersey, within the limits of this district, occur along Delaware River, especially in the Chester quadrangle, and about Camden in the Philadelphia quadrangle. The significant feature of its distribution is that it occurs chiefly along the streams. It is indeed primarily a valley deposit, but at the lower levels some of its material was probably deposited in standing water, though brought to its position by streams; elsewhere it is strictly fluviatile.

Being essentially a stream deposit, the formation is not limited by contour lines, but its variations of level are systematic, increasing in altitude up the streams. Along the Delaware the formation ranges up to 30 feet in altitude in this district, but toward the heads of the larger streams tributary to the Delaware from the east it rises to the level of the tributary-valley phase of the Pensauken formation, and in such situations it is sometimes difficult to distinguish the two, topographically as well as lithologically. Locally, as east of Mantua, the Cape May formation rests on the Pensauken; in other places it lies against that formation (see fig. 8), so

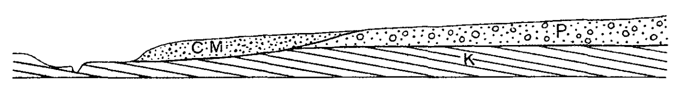

FIG. 8.—Section illustrating a common relation of the Cape May formation in the tributary valleys.

K, Cretaceous; P, Pensauken; CM, Cape May.

that while the streamward edge of the terrace is Cape May, the inner edge is Pensauken. As both formations are often covered with loam sufficiently deep to conceal the more characteristic materials beneath, absolute lines can not always be drawn between them. In still other cases the Cape May formation appears at low levels along the streams, while the Pensauken caps the divides; and over the slopes, above the upper edge of the Cape May, there is detritus washed down from the Pensauken above, which grades into the Cape May below. These relations make it difficult to separate the formations in some places.

The Cape May formation occurs locally in the form of terraces along the streams, but many of the terraces are ill defined. It is, on the whole, more extensively developed on the right sides of the streams than on the left, probably because of the monoclinal shifting which the streams suffered before the Cape May epoch, giving them gentler slopes on the right and steeper slopes on the left.

Composition.—The formation is for the most part a mixture of sand and gravel; but locally loam and even clay are among its constituents. These materials, especially the sand and gravel, are as a rule distinctly stratified, and the character of the stratification is not unlike that of the Pensauken formation. Cross-bedding is common, and the sand and gravel are often not well separated. The formation is distinguished from the Delaware River phase of the Pensauken in that it is not arkose and does not contain the pieces of crystalline rock, shale, soft sandstone, or soft chert characteristic of that formation, and in that it contains many more fragments of iron-cemented sandstone. It is less compact than the Pensauken, contains notably less iron oxide, and less loam in the form of coatings over the grains and pebbles. The formation has but slight thickness, often less than 5 feet and rarely so much as 15 feet.

Origin.—The Cape May formation is of late glacial age. This is shown by the fact that, traced up the valley of the Delaware, it is continuous with the gravels of late glacial age that are well developed about Trenton and at various points between Trenton and Philadelphia, especially on the west side of the river. The aggradation of the Delaware Valley had the effect of ponding its tributaries. Their currents, thus checked, dropped the coarser parts of their loads, though some of their fine sand and silt doubtless reached the Delaware Valley and helped to silt it up. Under these conditions, material derived from the Paleozoic rocks to the north appear in the Cape May formation of the main valley, especially to the north, while the equivalent deposits in the tributary valleys are made up of such materials as the tributary streams could get from the Cretaceous, Miocene, Bridgeton, and Pensauken formations.

In the reworking of the arkose sands of the older Quaternary formations the kaolin was separated from the coarser materials, and the decayed pieces of crystalline rock, the soft shales and sandstones, and the decayed cherts were destroyed. The more resistant quartzose materials of these formations, however, entered into the new Cape May formation. Fragments of iron-cemented sandstone and conglomerate from these formations, and the iron-cemented sandstone from the Cretaceous, Miocene, and Pliocene also entered into the sediments deposited in the valleys and were mingled with the finer sediments.

There are reasons for thinking that the surface of the land may have stood somewhat lower than now when the formation was deposited, or at some stage during its deposition. One reason is found in the nature of the deposits along the Delaware itself. The sand and gravel which are characteristic of this formation to the north essentially fail below Philadelphia. Again, marine diatoms have been abundantly identified in the loam of the Cape May formation in Philadelphia up to levels of 40 feet or a little more. While it is of course recognized that diatom tests might be blown about, it would appear that if this were their origin they should not be restricted to rather definite levels, as is said to be the case. On the other hand, it is to be remembered that marine diatoms, often in secondary positions, have been found in the glacial drift of the Great Plains and about the head of Lake Michigan (Dawson, Jour. Geology, vol. 5, p. 257), where the deposits in which they occur can hardly be supposed to be of a marine origin. At other points in the State, too, especially on the south coast, marine shells of various sorts have been found in this formation a few feet above tide.

Delaware River.—In the Chester quadrangle the Cretaceous near the Delaware is covered with but a thin mantle of loam and sand, which in places is gravelly near the streams. It is rarely more than 5 or 6 feet in depth, but locally thickens as it becomes coarser. Here and there this surface mantle is so thin and discontinuous that the Cretaceous appears in patches at the surface, as at Billingsport and Gibbstown, at very low levels. It is possible that the surface of this lowland has been degraded since the Cape May formation was deposited, but it is regarded as more probable that the amount of Cape May material deposited here at the outset was slight.

The topography of the lowland along the Delaware in the Chester quadrangle is not in strict accord with the drainage. Though drainage features predominate, they are somewhat masked by the surface loam, which, in its deposition, seems to have developed undulations of a feeble sort. The topography is such as might be developed if an old plain of but few feet relief were submerged and a few feet of loose material deposited on it. On the other hand, there are occasional traces of wind-blown sand, and at least many of the undulations may be explained in this way.

The formation appears to a greater or less extent along every tributary to the Delaware within this region, and to a greater extent in the larger valleys than in the smaller ones. About Camden the wide area of the Cape May formation seems to be connected in origin with Cooper Creek, rather than with the Delaware.

Pensauken Creek.—The Cape May formation appears up both branches of Pensauken Creek, but more on the right side than on the left, as is the case generally throughout the region. The first well-defined terrace appears about Parry, but the formation appears in more considerable thickness between the two principal branches of the stream, just above their junction. The material is here loose sand and gravel, and its surface has an elevation of 20 to 25 feet. The Cape May terraces, or terraces covered with Cape May material, appear at other points up the South Branch, as west of Maple Shade, and again near the east edge of the district, where they have an elevation of 30 to 40 feet. At this point, as at many others, the streamward edge of the terrace is flat, while the inner edge is undulatory and slightly lower.

Cooper Creek.—The upper edge of the Cape May formation is ill-defined in many places along Cooper Creek. The formation is often easily recognized near the streams, where it may have a depth of 10 to 20 feet, but back from the streams it thins out, usually with no well-defined topographic limit. Where as much as 10 to 20 feet thick, it consists of well-stratified gravel and sand, generally free from loam; but as it thins out it takes on loam akin to that of the slope above, so that there is often between the Cape May below and the Pensauken above an uncertain belt. Cooper Creek heads back in the Miocene area, and the peculiar sand of the Miocene influenced the character of the Cape May deposits below.

Terraces appear on Cooper Creek 3 miles from the Delaware, at an elevation of about 20 feet. They are often affected by wind-blown sand, which sometimes occurs in low ridges, 2 to 4 feet high. The terraces rise upstream slowly. Five miles from the Delaware they are a little higher, and the material is more than 20 feet deep on the right bank of the stream, with the streamward edge of the terrace flat and the from-stream edge undulatory. At Ellisburg the corresponding terraces have an elevation of about 30 feet. Farther up the valley the formation rises to an elevation of 60 feet or more within the Philadelphia quadrangle. It is, however, not everywhere disposed in the form of distinct terraces.

Newton Creek.—The formation is widespread in the basin of Newton Creek, but its thickness rarely exceeds 8 to 10 feet. The top part is usually loam, below which there are 2 to 8 feet of sand and gravel. The gravel is fine, and thins out back from the streams, where in many places loam is all that appears over the older formations. Shallow valleys appear to have been filled up with the sand and gravel, and the loam then spread over all. The surface is undulatory, especially marked by shallow basins at some points, as south and southeast of Mount Ephraim station and on the north slope of Little Timber Creek. It is not possible to say how far these undulations of surface are due to the deposition of the Cape May formation and how far they are the result of movement of the underlying Cretaceous beds.

Big Timber Creek.—The Cape May formation is more extensively developed along Big Timber Creek than along most others. It is well shown on the Delaware at Westville and for 1½ miles up the creek. Here it is fully 20 feet thick, is composed of sand and gravel, and its base is at least as low as tide level. The formation is also well shown on the narrow belt between Big Timber and Beaver creeks, and again between Big Timber and Almonesson creeks, just above their junction. Up Almonesson Creek there are deposits of the same age, but they do not constitute well-defined terraces. Along the main creek the formation extends to the edge of the district. It is well exposed a mile northeast of Almonesson, where it is 15 to 20 feet thick and where it runs up the slope to an elevation of about 50 feet. The material consists of clean, incoherent, well-stratified sand and fine gravel, very like that at Westville. At Mechanicsville it attains an elevation of 50 feet and is at least 20 feet thick. At Blackwood it has risen to the Pensauken level and is not readily distinguished from that formation.

On the north branch of the creek, a little above the junction, there is 10 feet of the Cape May formation on the Cretaceous, the top being at an elevation of about 50 feet. Loam of uncertain age occurs on the slope above. A mile east of Chews Landing the formation has a thickness of 20 feet or so, but thins up the stream, where it rises to the Pensauken level, 60 to 75 feet, and the separation of the two becomes confusing.

During the deposition of the Cape May formation the valley of Big Timber Creek seems to have been filled up to a level of 20 feet or a little more at Westville and to 40 feet at Glendora, the South Branch to 60 feet at Blackwood and 70 feet at Turnersville, and the North Branch to 60 feet or more at Laurel Springs.

The surface loam is less conspicuous in the Big Timber Creek basin than in most other parts of the region. It is not, however, absent, for the ridge between Big Timber Creek and Almonessen Creek is loam covered. This loam may be eolian so far as known.

Woodbury Creek.—There are terraces of Cape May material on Woodbury Creek below Mathews Brook, at an elevation of 20 feet, on the south side of the main stream. The formation here departs from its usual habit in that it contains some silt and clay along with the sand and gravel. The same phenomenon recurs at Swedesboro.

Near the junction of Mathews Brook the Cape May terraces approach a level of 30 feet, the formation having a thickness of about 10 feet. Distinct benches occur just west of Woodbury at 10 to 20 feet, but they are probably degradational. Loam often covers the terraces, concealing the sand and gravel below.

Mantua Creek.—Along the lower course of Mantua Creek there are 20 to 30 feet of sand and gravel, filling old valleys in the Cretaceous plain. The surface is loamy or sandy, as about Thorofare, or clayey, as east of Paradise. At Berkeley gravel and sand make a terrace 20 to 25 feet high on the left bank of the stream. The material is mainly well-stratified sand with a little fine gravel. Between Mantua Creek and Edwards Run, and just above their junction, there is perhaps 40 feet of Cape May material; that is, the formation at this point appears to go down to tide level. The surface is more or less affected by wind-blown sand.

Half a mile west of Mantua the terrace level is about 40 feet, 10 feet of sand and gravel overlying the Cretaceous. The formation is well exposed both north and south of the little creek tributary from the south, west of Mantua. On the right bank of the Mantua above Wenonah the Cape May formation appears at an elevation of 60 feet, having a thickness of 20 feet. It was formerly well exposed in the railroad cut between Mantua and Monongahela creeks.

Raccoon Creek.—Three miles from the Delaware 20-foot terraces appear along the left bank of this stream, the material being sand and fine gravel, and its surface affected by eolian sand. About 4½ miles from the Delaware, on the right bank, the terrace level is about 30 feet, though the mantle of Cape May material is thin. Half a mile west of Swedesboro the terrace has an elevation of about 35 feet, with 20 feet of Cape May sand so clean that it is dug for mason's sand. At some points along the lower course of the Raccoon there is a little clay in the lower part of the Cape May formation.

UNCLASSIFIED DEPOSITS.

In the Philadelphia district considerable areas are covered by a thin and discontinuous mantle of surface material, the age of which is, in many places, not determinable. In other places, as at the level of the Cape May formation, its age may not be open to great doubt, but its amount is so meager that the underlying beds are but poorly masked and the surface material is chiefly derived from them. It has seemed best to put such areas together on the map. The material of this mantle is of various ages. In many places it lies on slopes or areas intermediate between the Pensauken above and the Cape May below. In such situations it is probably made up largely of material which lodged on flats or gentle slopes below the Pensauken in post-Pensauken time. Some of it came to its present position, probably, before the Cape May epoch, some of it during that epoch, and some of it afterward. In many places the line separating the Pensauken from the undifferentiated material below can not be drawn accurately, for in the absence of exposures it is not always, and perhaps not generally, possible to determine the exact limit of the Pensauken as originally deposited. This would be simple if its base were everywhere at the same level, or at the same level everywhere in a given region, but it is not.

A lesser amount of the undifferentiated material lies on slopes between the Bridgeton and the Pensauken. Such areas are less extensive than the others. In a few places the undifferentiated material lies on slopes between the Bridgeton above and the Cape May below, where the Pensauken formation, if once present, has been removed. When the material is in such situations its age can only be said to be post-Bridgeton.

Slope wash and lodgment, slumping, the creep of material down the slopes, and the wind, all have contributed to the development of this class of undifferentiated material. It is not unlike the other phases of the Quaternary deposits, except in its thinness and in the fact that its age can not always be determined.

Where the undifferentiated material is but slightly below the formations from which it is derived it may closely resemble them in constitution. Where it has been transported farther its composition has been more altered, particularly by the elimination of the readily destructible materials, such as kaolin, soft shale, decayed granite, etc., which often exist in some of the older and higher members of the Quaternary.

WIND-BLOWN SAND, LOAM, AND ALLUVIUM.

Eolian sand is widespread within the district, but it is rarely in such quantity as to merit separate mapping. A few areas of dune sand are shown.

A thin mantle of loam, of uncertain origin is also widespread. A part of it may be eolian, and parts may have originated in other ways. Quantitatively it is of little importance, except that it is in many places just thick enough to cover up the material beneath, so that the various features of the underlying formations are obscured at the surface. The data on which the mapping of the underlying formation is based include hundreds of borings a few feet in depth, penetrating the masking and deceptive mantle of loam. These borings have often led to a mapping which would hardly have been justified on the basis of the natural surface.

Alluvium occurs in the marshes bordering the Delaware and the flood plains near the mouths of its tributaries.

WEST OF DELAWARE RIVER.

By F. BASCOM.

The Quaternary deposits on the west side of Delaware River in this area form a narrow band from 1 to 5 miles in width, extending entirely across the Germantown, Philadelphia, and Chester quadrangles. The inner border of the oldest deposits is marked by a distinct escarpment that passes near Somerton, Fox Chase, Cheltonham, Wayne Junction, Falls of the Schuylkill, Fairmount Park (Philadelphia), Lansdowne, Swarthmore, Boothwyn, and Gordon Heights. More faintly defined escarpments mark the inner border of each of the two later divisions of the Quaternary deposits. A few of the deposits over part of the region lying to the southeast of these escarpments are so thin that they have not been represented on the map. The Quaternary deposits have been cut through by the tributary streams of Delaware River that have their sources in the Piedmont crystalline rocks. Thus in many places the crystalline rocks are exposed along the valleys, while the Quaternary deposits cap the stream divides. The deposits are usually thin, except in the immediate vicinity of the Delaware, where they have a very considerable thickness, as is shown by well borings in the city of Philadelphia. In physical and lithologic characters they are similar to the corresponding deposits on the east side of Delaware River elsewhere described in detail.

Besides the Quaternary sediments within the Delaware Valley, there are isolated areas covered with rather thin deposits of Quaternary materials in Chester Valley. Few of these deposits are more than 10 feet in thickness, and many of them consist of mere films of surface waterworn gravels. The latter are not shown on the map, though they are present in a number of places. One of the thickest deposits is situated in Chester Valley, about 2 miles southeast of Valley Forge, and consists of loose gravels and sands that have been dug for road-building purposes. Other deposits of similar materials occur in the vicinity of Swedeland; in the vicinity of the old iron-ore mines about 1½ miles north of Conshohocken, in the Norristown quadrangle; and in the vicinity of Flourtown and Oreland, in the Germantown quadrangle. These isolated patches of sands and gravels are so far removed from the Quaternary deposits bordering the Delaware and differ so much in their position and lithologic characteristics that it is not possible to establish any definite correlation. Provisionally, however, they are correlated with the older gravels of the Delaware River area. They represent deposits of stream-borne materials laid down when the streams that now cross the valley were flooded or when the region stood at a lower level than at present. These gravels now lie in the interstream areas at a considerable elevation above the channels of the present streams.

STRUCTURAL GEOLOGY.

PIEDMONT PLATEAU AREA.

By F. Bascom.

GENERAL STATEMENT.

The prevailing structural features of the Piedmont Plateau are major folding of the Appalachian type, forming anticlinoria and synclinoria, which extend for long distances northeast and southwest and are roughly parallel; gentle minor folding at right angles to the major folds; normal and thrust faulting of varying magnitude; a very complete metamorphism of the formations, extensively producing schists and gneisses which show cleavage and fissility. A small portion of the Plateau is covered with Triassic sediments and outliers of the Coastal Plain deposits, whose freedom from metamorphism and structural simplicity are in striking contrast to the complexity of the crystalline floor upon which they lie.

The structures of the crystalline formations are due to compressive force acting in a northwest-southeast direction, normal to the strike of the major folds. A minor force acted at right angles to this major force and to it is due the gentle transverse folding. While much remains to be accomplished in the mapping of these major anticlines and synclines in their extension throughout the Piedmont Plateau, some well-defined folds have been recognized.

Such an anticline extends from the neighborhood of Cabin John, Md., where it has been traced by Keith, northeastward through Maryland, where it has been mapped by Mathews, and into Pennsylvania, where it shows itself in the Buck Ridge anticline. To the east of this anticline two synclines and an anticline have been partly traced in Maryland and the District of Columbia. They are not well defined in the Philadelphia district. West of the Cabin John–Buck Ridge anticline is a synclinal basin which is clearly marked in Pennsylvania and Maryland. In Pennsylvania it is the Chester Valley syncline. It passes through Maryland in the neighborhood of Cardiff and is recognized by Keith in the Washington area just west of Great Falls. Such is the succession of anticline and syncline of the first order from east to west in the Piedmont area east of the Triassic cover. The Cambro-Ordovician sediments of the whole width of the Piedmont Plateau, ignoring the Triassic formations which conceal a broad central area, apparently form an anticlinorium, which has brought to the surface pre-Cambrian gneiss along a central axis flanked by Cambrian quartzite, Cambro-Ordovician limestone, and Ordovician mica schist. The surface outcrop of these formations is interrupted parallel to the strike and controlled in width by the minor folding, which, alternately bending the axis of the anticlinorium in a low trough or raising it in a low arch, brings to the surface successively younger or successively older formations. There is, then, an anticlinorium compounded of anticlines and synclines of the first order, which are in turn composed of secondary and tertiary anticlines and synclines.

The secondary folds in the limestone and quartzite of the eastern portion of the Plateau are isoclinal in character and are uniformly overturned to the northwest, while in the gneisses and schists they are more varied, ranging from open and nearly symmetrical to inclined, overturned, or isoclinal folds. The unsymmetrical folds are uniformly inclined to the northwest.

Normal and thrust faults are both found in the Piedmont district. The Triassic sediments, which were uplifted with little or no folding or with a very gentle northwest tilt, show scarcely any but normal faults. These faults are so numerous that they may be seen in every extensive exposure of the Newark rocks. It is impossible to ascertain their total number or amount of displacement, which is often exceedingly slight. They were developed in connection with the crustal movement which resulted in the uplift of the Triassic sediments, and presumably are not confined to the present Triassic cover but occur also in the adjacent crystallines. It is very difficult to trace such faults in the crystallines, where there is an absence of well-defined beds. Several small, nearly vertical faults can be seen in the railroad cut just east of Overbrook station, and similar faults show in the Schuylkill River section.

Thrust faulting is the rule in the Appalachian structure, and many important faults of the Piedmont Plateau are of that nature. Those that have been traced in the southern Piedmont area lie nearly parallel to the planes of schistosity of the formations—i. e., they dip at a high angle. Adjustment, by means of innumerable microscopic dislocations, has also taken place along planes of schistosity, which have thus become planes of fissility.

LOCAL STRUCTURES.

Structure sections.—The structure of the formations of the Philadelphia district is shown in the sections on the structure-section sheets and in fig. 9. On the structure-section sheet the vertical and horizontal scales of the sections are the same and the actual dips of the strata, as they appear at the surface, are incorporated in the sections. Of course, on the scale of the sections the smaller structures can not be shown, and all folds of tertiary order are omitted. Faults are represented on the map by heavy solid or broken lines, and in the sections by a solid line whose inclination shows the probable dip of the fault. The relative direction of the movement of the strata on either side of the fault plane is indicated by arrows.

Folds and faults.—The formations in this part of the Piedmont Plateau illustrate very perfectly the structures which have just been mentioned. The northwestern portion of the crystallines is concealed beneath the Triassic cover, which has the gentle northwest dip and normal faulting common to all the Triassic rocks of the Piedmont Plateau.

The crystalline foundation emerges from beneath the Triassic to form the Chester Valley syncline. The limbs of the syncline, separating it from the adjacent anticlines, are formed by the Chickies quartzite. This formation, resisting erosion more successfully than the limestone, gives rise to the hills which border Chester Valley on the north, and in the eastern half of the valley forms also the southern hills. These hills are thus monoclinal in structure. To the southwest the southeastern limb is progressively faulted out (Cream Valley fault) near Conshohocken and along the South Valley Hills. This shearing action is combined with a cross or minor fold which produces a general southwest pitch of the syncline. It is this southwest pitch of the syncline that brings the older beds to the surface in succession at the northeast end of Chester Valley, and causes the expansion northeastward of the oldest formation, the Baltimore gneiss, and the expansion southwestward of the youngest formation, the Octoraro schist.

The character of the secondary synclines and anticlines which compose the main fold is inferred from that of the tertiary folding on their limbs. These tertiary folds (see fig. 13) in the Shenandoah limestone are isoclinal in character, the dips varying from 45° to 80° SE.

The Chester Valley syncline is paralleled on the southeast by the Buck Ridge anticline, which brings to the surface the Baltimore gneiss. In the east the adjacent syncline is faulted on the southeast flank of this anticline, and to the west the complementary syncline is faulted. These two faults, called respectively the Huntington Valley and the Cream Valley faults, from the valleys to which they have given rise, are possibly continuous over the crest of the anticline north of Chestnut Hill.

The Cream Valley fault splits into two faults about 3 miles west of the Schuylkill. The more northern branch is the plane of contact between the Wissahickon gneiss and the Octoraro schist, and continues for many miles to the west. The southern fault causes the almost complete disappearance of the limestone and quartzite of the northwest limb of the anticline.

Limestone appears in Mechanicsville, west of the Schuylkill, on the crest of a subordinate anticline bounded on the southeast by the Cream Valley thrust fault, which first brings the Shenandoah limestone and the Baltimore gneiss in contact and thence southwestward brings in contact the Wissahickon gneiss and the Octoraro schist. Within the Philadelphia district the quartzite of the northwest limb of the primary syncline appears at only two points west of the Schuylkill. The first outcrop, one-quarter of a mile southeast of Gulf Ravine, on the flank of Buck Ridge, is probably due to an infolding of the quartzite in the gneiss. In the other exposure, between St. Davids and Strafford stations, the quartzite is brought to the level of the Wissahickon gneiss by the Cream Valley thrust fault.

The anticlinal character of the fold in the Baltimore gneiss is shown in the Schuylkill River section. The secondary folding is close on either limb of the anticline and open in the center. The dips vary from vertical to a steep southeast dip on the northwest limb, and are predominantly northwest on the southeast limb, thus showing a divergence of foliation. There is a very gentle northeast pitch, indicating a subordinate minor fold. The only other locality where the structure of the Baltimore gneiss can be seen is in a cut of the Cresheim branch of the Pennsylvania Railroad near Laverock. Here the gneiss is vertical to 60° SE. Elsewhere the gneiss when exposed is either so decayed or so thoroughly penetrated by the gabbro as to obscure structural planes and the record of the folding to which it has been subjected.

The Huntington Valley fault, on the southeast flank of the Buck Ridge anticline, dips to the southeast, and by means of it the Wissahickon gneiss was thrust upon the pre-Cambrian and Paleozoic materials. The mica gneiss, susceptible to crumpling, shows much secondary folding. This fact, together with the absence of recognizable beds, obscures the primary folding, and while there are evidences of two synclines and one anticline southeast of the Huntington Valley fault line, they can not be distinctly traced in the Philadelphia district. The presence of intrusives and the cover of Quaternary materials further obscure the structure of the mica gneiss. Along the Wissahickon, where the gneiss is well exposed, the dips are often very gentle and predominantly northwest. The cleavage dip remains constant to the southeast.

METAMORPHISM.

Every process of metamorphism has been concerned in the transformation of the simple sediments of the Philadelphia district to crystalline schists and gneisses; a more limited number of processes is concerned in the metamorphism of the igneous material. Chief of such processes are: (1) Induration, a mass movement of mineral particles in response to pressure, by means of which the mineral constituents of a rock are brought closer together and hardened; (2) crystallization, a molecular movement in response to pressure, by means of which, in association with induration, an interlocking crystalline texture may be formed; (3) impregnation, the penetration of a rock along planes of parting (which may be either bedding, joint, or fissility planes) by vein material—i. e., by material precipitated from solutions; (4) injection, the penetration of a rock along planes of parting by molten material in relatively thin layers; (5) metasomatism, a process whereby the original mineral constituents of a rock are altered to, or replaced by, other minerals; (6) granulation, or the crushing of mineral particles under compression, which, together with differential movements along parallel planes and recrystallization, results in the deformation of the rock.

Two or more of these processes have usually combined in the metamorphism of a single formation, though in different formations one process may be dominant. The processes called into play and the results produced will be dependent on the original constitution of the rocks.

Crystallization and metasomatism have been the dominant processes concerned in the production of the Octoraro schist and the pre-Cambrian gneisses from shale and arkose. The Octoraro schist and the Wissahickon gneiss were both developed from argillaceous material—the former from a more completely weathered product than the latter. This fact may go far to explain the present differences and resemblances between the two formations.

The Octoraro schist was presumably developed from a fine clay containing muscovite in minute scales and possibly some undecomposed orthoclase. From the kaolin and the orthoclase muscovite and quartz may develop, with a loss of water, and a mica schist be produced.

In the case of the Wissahickon gneiss the original deposit was more feldspathic and therefore presumably coarser grained. The resulting rock is both more feldspathic and more coarsely crystalline than the mica schist.

In the production of the pre-Cambrian gneisses injection and impregnation have also been active. The Baltimore gneiss is in some places thoroughly injected with pegmatitic bands, and much of the Wissahickon mica gneiss owes its pronounced gneissic character to injection and impregnation.

The fact that the new minerals which have crystallized out from the impurities of the sediments are all minerals which, by a parallel orientation of their longer axes normal to the direction of compression, enable the rock to occupy less horizontal space than before crystallization, shows that their development, like the folding, was in response to pressure and was a means of relieving strain. The intensity of the pressure is further indicated by the fact that muscovite and biotite are developed in excess of hornblende and chlorite.

Locally, in the pre-Cambrian gneisses, the action of the processes of crystallization and metasomatism has been intensified by the intrusion of large bodies of igneous material. In this case pressure has been relatively a less active agent, and the crystallization has therefore been of a more granular character. Under these conditions garnet, tourmaline, staurolite, andalusite, hornblende, and chlorite have developed, and have reached a size which render them conspicuous to the naked eye. The development of garnet, tourmaline, staurolite, and andalusite is not confined, however, to contact zones. They occur very generally in the mica gneiss and show that the formation has been in that deep-seated zone of metamorphism where minerals of high specific gravity are developed.

In the Chickies quartzite induration and crystallization have been the processes at work and have converted the relatively pure beach sand into a quartzite made up of interlocking crystals of quartz.

Where the sand was originally impure—i. e., feldspathic or argillaceous—metasomatism has also taken place and brought about the development of muscovite and sericite. Such crystallization taking place under pressure results in an arrangement of the cleavage planes of the mica normal to the compressive force; in this way is produced a rock cleavage parallel to the mineral cleavage, and the rock becomes quartz schist. Sometimes infiltration material has caused an enlargement of both quartz and feldspar, if the latter mineral is present, and has produced a rock which is much like gneiss.

In the Shenandoah limestone, crystallization has been the process chiefly active in converting calcareous sediments into crystalline limestone or marble. Amorphous calcium carbonate has crystallized and sometimes partly interchanged with magnesium carbonate, and the amorphous impurities have crystallized into silicates such as phlogopite (chiefly), tremolite, and diopside, and thus a dolomitic marble, or in some places a dolomite, has been developed, and all evidence of the organisms which may have assisted in the original formation of the rock is lost. Not only have new minerals been developed in the sediments, but new structures have been produced, namely, schistosity and gneissic banding. These structures were the result of deformation due to compression and were brought about by the flattening through granulation and recrystallization, and the rotation of the original minerals of the sediments, such as quartz or feldspar, and by the parallel orientation, described above, of the new minerals, which combined to produce a parallel arrangement of the constituents. This parallel arrangement gives rise to rock cleavage or to actual fracture, called fissility.

This ease of fracture along approximately parallel but usually wavy planes, combined with actual fracture or fissility, produces a structure which is known as schistosity. The deformation which results in schistosity is microscopic as well as macroscopic. A strained molecular condition which shows itself in undulatory extinction, granulation confined to the periphery of the mineral, complete granulation, and granulation with rotation of the grain were stages in the process. Granulation is not a marked feature of the Piedmont sedimentary formations. The presence of water, included with them as sediments, was favorable to crystallization rather than to granulation, and less energy was consumed in this process than in granulation and rotation. The intensity of the pressure also favored crystallization rather than granulation.

Where feldspar was a more or less abundant constituent, giving a granular character to the rock, and where alternating layers of the rock varied somewhat in mineral constitution, owing either to an original difference in the beds or to the injection or impregnation of new material, gneissic banding rather than schistosity was produced by the reorientation of the constituents.

The minerals which have developed near the contacts of the igneous bodies do not, however, take part in this parallel orientation. Their longer axes or their prominent cleavages may be transverse to the schistosity of the containing rock. This fact, the relatively large dimensions of the crystals, and their granular form give them a porphyritic character and show that their formation must have been subsequent to the period of greatest pressure.

The results of the processes of metamorphism in the igneous rocks of the Piedmont area are not less characteristic than are the results of these processes in the sediments. Unlike the sediments, the igneous rocks, already possessing an interlocking crystalline texture and little if any included water, responded to pressure by such strain effects as undulatory extinction, granulation, and a partial mineral alteration. Instead, therefore, of the fresh crystallization of the metamorphosed sediments, the igneous rocks exhibit strained or granulated quartzes, zoisitized feldspars and pyroxenes partly or completely altered to hornblende.

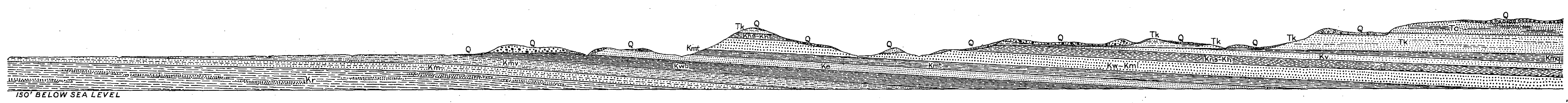

Fig. 9.—Section along line A-A on Philadelphia geologic map, showing sequence, relation, and structure of Cretaceous and Tertiary strata. (Vertical scale five times the horizontal.)

Kr, Raritan formation; Km, Magothy formation; Kmv, Merchantville clay; Kwb, Woodbury clay; Ke, Englishtown sand; Kmt, Marshalltown formation; Kw-Kml, Wenonah and Mount Laurel sands; Kns-Kh, Navesink and Hornerstown marls; Kv, Vincentown sand; Kmq, Manasquan formation; Tk, Kirkwood formation; Tc, Cohansey sand; Q, Quaternary deposits.

NEWARK GROUP.

By N. H. Darton.

General relations.—The Newark rocks in the Philadelphia district constitute the southern portion of an extensive monocline in which the strata dip north or west of north at angles of 12° to 20°. Owing to this structure the formations outcrop in regular succession from older to younger from southeast to northwest. The dip is due to tilting of the strata, and not to inclined deposition, for the bedding planes of the shales, with ripple marks, rain-drop impressions, and footprints, are all tilted. Cross-bedded sandstones often exhibit dips of deposition, but the layers incline in various directions. The monocline is not traversed by folds in this district, as it is in some other portions of the Newark area.

Local dips.—The direction of dip in this region is from 18° to 20° west of north through the center of the area, and varies from due north to 10° west of north toward the northeast corner and along Perkiomen Creek. Local variations of small amount are numerous, but the general dip is remarkably uniform in direction. The amount of inclination varies irregularly from 12° to 20° in greater part, mostly ranging from 14° to 16° in the western portion of the area and from 12° to 15° in the eastern portion. There appear to be no large areas of exceptional dips nor any regular regional variation, except a general diminution northeastward from Fort Washington into Bucks County, which widens the outcrop area of the Stockton formation.

Faults.—There are evidences of faults at many localities, but the only exposures in which their relations are exhibited are in the long, deep railroad cuts between North Wales and Hoyt station. Here the Lockatong strata are broken by a succession of faults trending with the strike of the rocks and dipping approximately at right angles to the dip of the beds. At least ten of these faults are visible within a distance of a mile. One, a short distance north of the tunnel, appears to have a throw of only 6 feet, with the drop on the south side. Some of the others may be of much greater throw than this, for they have considerable breccia along the plane of movement. These faults, however, are very small in comparison with the great displacements in adjoining regions in New Jersey, some of which amount to several thousand feet. It is believed that the deformation of the Newark beds is probably due to vertical movements in the floor of crystalline rocks upon which they lie. W. M. Davis has suggested that these movements were the result of tangential compression in the inclined granites and schists, which caused unequal tilting and faulting of the overlying sedimentary rocks.

COASTAL PLAIN AREA.

By W. B. Clark.

The Coastal Plain has not the simple structure which was earlier assigned to it. From the beginning of Cretaceous time onward the angle and direction of tilting constantly changed, and although the angle of dip is to-day slight and its direction is prevailingly eastward or southeastward it differs in nearly all the formations. As a result of uplifts and depressions the landward margins of the formations particularly show much complexity, with a marked change in the sequence of deposits from point to point. At times transgression has buried the landward outcrop over wide areas, although the formation may be found in sections farther east. These differential movements have in portions of the Coastal Plain even brought about the total disappearance above sea level of entire groups of formations, although they may at times be found far from the region of surface outcrops in deep-well borings.

The older formations of the Potomac group exposed in Delaware and Maryland have been in this way gradually transgressed toward the north in New Jersey and Pennsylvania by the Raritan formation, while toward the south the Raritan is itself gradually transgressed by the Upper Cretaceous formations until it finally disappears in southern Maryland, the Matawan deposits resting directly upon the Patapsco.

The Upper Cretaceous formations from the Magothy to the Manasquan, as well as the Eocene Shark River marl, are similarly transgressed from New Jersey southward by the Aquia formation, of later Eocene age, although the probable northward extension of the latter is again buried by transgressions of Miocene strata, with the result that the Shark River and Aquia formations nowhere come into actual contact so far as known. Although the lowest beds of the Matawan group still outcrop as far southward as southern Maryland, they disappear in Virginia below the Aquia formation, being represented in that State only in deep-well borings near the seaward margin of the Coastal Plain.

Transgression likewise occurs within the series of the Miocene formations, the Choptank formation of Maryland gradually overlapping the older Miocene beds toward the north.

The marked changes in the sequence of strata from one part of the Coastal Plain to the other produced by these transgressions are reflected in the angle and direction of dip of the beds. In general the dip is slight, ranging from 40 to 50 feet to the mile in the earlier Cretaceous formations to 10 to 15 feet to the mile in the later Tertiary deposits. The direction of the dip, although in general easterly, is somewhat more northerly in the Lower Cretaceous formations than in the Upper Cretaceous and Eocene formations, which become progressively more southerly. In the Miocene beds, however, the direction of dip swings gradually back toward the north and reaches its climax in this direction again in the upper Miocene. From the gradual disappearance northward of the marine Pliocene beds of the Carolinas the dip evidently changes again to the south before the close of the Tertiary.

The mantle of Quaternary formations slopes gradually either seaward or locally toward the channels of the various estuaries. These formations occur as a veneer over the older deposits.

In the Philadelphia district, as elsewhere in the Coastal Plain, the Lower Cretaceous formations dip eastward at a higher angle than any of the other Coastal Plain formations—about 40 to 50 feet to the mile—while the unconformably overlying Upper Cretaceous formations have a slightly lower dip—about 35 feet to the mile—but in a more southerly direction. The Miocene formations, which unconformably overlie the Upper Cretaceous deposits in this area (see fig. 9), the Eocene formations being absent, dip at a still less angle—about 15 feet to the mile—but in a more northerly direction, the dip becoming progressively more marked in the higher beds, as shown by the general overlap of the lower Miocene beds by the higher toward the north. The overlying mantle of Quaternary formations has in general the same characteristics as in adjacent areas, and has already been described for the whole Coastal Plain district.

Numerous unconformities appear in the series of Coastal Plain formations. Omitting from consideration the formations not represented in this district, the first occurs between the Patapsco and the Raritan. No satisfactory contact between these formations has been observed in the Philadelphia district, but their relationship is probably the same here as elsewhere. A marked unconformity, however, appears between the Raritan and the Magothy formations, and the same probably occurs between the Magothy formation and the Matawan group. The later Upper Cretaceous formations are evidently conformable to the Matawan, but a pronounced unconformity occurs between them and the overlying Miocene Kirkwood formation. (See fig. 9.) The latter is again overlain unconformably by the Cohansey, of later Miocene age, while the Quaternary formations rest everywhere unconformably upon the underlying deposits.

An epitome of the oscillations of the Coastal Plain in this district is as follows:

Subsidence and deposition of the Patapsco formation.
Uplift and erosion.
Subsidence and deposition of the Raritan formation, with northerly tilting.
Uplift and erosion.
Subsidence and deposition of the Magothy formation, with southerly tilting.
Uplift and erosion.
Subsidence and deposition of the conformable sequence of Matawan, Monmouth, and Rancocas groups, with southerly tilting.
Uplift and erosion.
Subsidence and deposition of the Kirkwood formation, with northerly tilting, accompanied by extensive transgression over the latest Cretaceous and Eocene formations.
Uplift and erosion.
Subsidence and deposition of the Cohansey formation, with northerly tilting.
Uplift and erosion.
Subsidence and deposition of the Lafayette formation, accompanied by an extensive transgression.
Uplift and erosion, producing main drainage lines.
Subsidence and deposition of the Pleistocene formations at different levels during successive oscillations.

HISTORICAL GEOLOGY.

PIEDMONT PLATEAU AREA.

By F. Bascom.

SEDIMENTARY AND IGNEOUS RECORD.

The Atlantic Ocean basin and the North American continental plateau are very ancient. The North American continent in its present form, however, is much younger. At the time geologic history opens along the Atlantic border the present continent had not come into existence and only isolated and limited portions of the continental plateau were above the sea. Here was situated a comparatively limited land mass, which has been called "Appalachia." Appalachia extended east of the present shore line, but probably not beyond the present continental plateau. West of it was the Appalachian sea, in which sediments were accumulating. The western border of Appalachia was brought under water during the early history of this region by a submergence taking place in time known as pre-Paleozoic. Pre-Paleozoic submergence is recorded by a shallow-water deposit of granitic sand and, with denudation of the land and deepening of the sea, by a fine argillaceous deposit. These sediments accumulated upon an uneven floor of granitic rocks and in an encroaching sea which permitted the argillaceous material to collect to the east of the earlier arkosic deposits,

In this way the arkosic sand was both overlain by argillaceous mud and altogether supplanted by this material on the east.

In the north mechanical sedimentation was succeeded by organic and chemical deposits of calcareous material. These sediments grew to a thickness undetermined and in a period not definitely known, but presumably long enough before Cambrian time to permit not only their accumulation but also their consolidation, partial metamorphism, and uplift to a land surface. This uplift was accompanied by the intrusion of great igneous masses which consolidated into granite, gabbro, pyroxenite, and peridotite.

During Cambrian time the sea again encroached on the land and gradually deepened. At first a pebbly beach deposit was formed, the material of which was derived from pre-Cambrian granite, gneiss, and mica gneiss of Appalachia. The gravel was succeeded by a clean beach sand deposit. With deepening sea, clay was mixed with the sand, followed by calcareous mud and, with a clearing of the sea, by calcareous sediments. This continued into Ordovician time, when the sea shallowed again, the land rose, and a clay deposit followed over a wide area.

In this district there is no record of further sedimentation during Paleozoic time. It is not probable, however, that the subsequent movements of uplift immediately followed the deposition of sandy clay and that sedimentation on this border of Appalachia ceased. The amount of material deposited in Paleozoic time which has disappeared through subsequent erosion is not known, but was presumably considerable.

On the New Jersey Piedmont Plateau there is a partial record of overlapping sedimentation during Silurian and Devonian time, followed by an uplift with open folding, faulting, and slight metamorphism.

Beginning perhaps at the close of Devonian time and continuing until the close of Paleozoic time, there were earth movements along the Atlantic border which resulted in the uplifting, folding, and recrystallization of these sediments. The eroded pre-Cambrian crystalline rocks were further deformed and faulted; the Cambrian beach deposits were altered to quartz conglomerate, quartzite, and quartz schist; the calcareous sediments were metamorphosed into calcareous schist and crystalline limestone, and the sandy clay deposits were consolidated and crystallized into a schist.

The uplifting of the sediments above the sea was probably not a continuous process, but intermittent, and while erosion did not keep pace with the upward movement, Paleozoic topography undoubtedly never exhibited a constructional form—i. e., the arches and troughs of the folded crystallines never existed unmodified by erosion. Before the beginning of the next period of sedimentation of which there is a record they had been eroded to a relatively even surface.

This period, known as the Triassic, is separated by a long interval of time from Paleozoic sedimentation. There was time enough during this interval for the formation by uplift and the removal by erosion of mountain ranges, and finally the development of great tidal estuaries or inland basins embracing all the areas now covered by Triassic formations.

These basins were long, narrow troughs roughly parallel to the coast and extending from Hudson River through New Jersey and Pennsylvania into Virginia and North Carolina. They were probably due, not to erosion, but to warping or faulting, and early in their history possessed shores steep enough on the west at least to supply to the basins quartzose gravel and calcareous cliff débris. A quartzose conglomerate and a limestone breccia which has considerable local development on the western border are evidences of this earlier configuration of the land. Huge reptiles, now extinct, and smaller vertebrate animals wandered over these sand flats, and their tracks imprinted on the soft mud are now preserved in the indurated mud stone or shale.

Before the close of the period of Triassic sedimentation igneous material was intruded between the beds, or traversed them in the form of dikes, or flowed out at the surface. Following the consolidation and accompanying the uplifting and gentle tipping of these sediments there occured seismic movements which dislocated the sandstones and shales and the associated igneous rocks. These formations were ruptured and displaced by slipping along the planes of rupture.

There is little, if any, record in the Philadelphia district of events which took place in the following period, the Jurassic. Erosion rather than sedimentation marks this period. Toward the close of Jurassic time, however, and at the opening of the succeeding period, the Cretaceous, estuarine conditions are known to have prevailed.

The basin of the most inland estuary was located along the eastern edge of the old Triassic estuary. This is inferred from the fact that in the Philadelphia district deposits of the Cretaceous estuary lie immediately upon a deeply eroded crystalline floor, from only a part of which a Triassic cover has been removed, and also from the fact that they gained some of their material from Triassic formations to the west. These deposits are now found in outlying areas on the Piedmont Plateau, left in scattered pockets by subsequent erosion; they occur also as a continuous deposit in the basin of the Delaware, where a second estuary was located. They are still mainly unconsolidated.

About the middle of Cretaceous time the barrier between the Delaware estuary and the sea disappeared and the Paleozoic crystallines bearing a cover of early Cretaceous deposits were submerged beneath the Atlantic. This submergence, scarcely reaching west of the Delaware, was gradual, as the character of the deposits of this period indicates, and was accompanied by seaward tilting and landward uplift. Erosion of the Plateau was renewed and furnished material for thick beds of clay and sand. While, on the whole, during later Cretaceous time depression of the sea floor increased at the same time that erosion, lowering the surface of the land, decreased the activity of the streams, which consequently supplied a diminished amount of mechanical sediments, there must also have been oscillation of the level of sea floor and land surface, accompanied by variations in the angle and direction of the tilting. The interbedding of sand, gravel, and clay which characterizes the deposits of this period indicates temporary increased activity of the streams, while the change in direction and amount of dip of these formations indicates a warping of the sea floor. The deposits of Upper Cretaceous time have suffered little, if any, alteration since their deposition.

The periods following the Cretaceous, the Tertiary and Quaternary, were marked by a changing shore line, by renewed uplift of the Appalachians, by the doming of the Piedmont Plateau, and by the glaciation of northern North America. The accelerated rivers, supplied from the ice sheet and the Plateau, furnished abundant sand and gravel for the thick deposits of these periods. These deposits, while in the main spread upon the Coastal Plain, also accumulated in estuarine waters bordering the Piedmont Plateau, and extended during Tertiary time 10 miles west of Delaware River. In early Pleistocene time an inland basin occupied part of Chester Valley, while estuarine deposits were accumulating on the border of the Plateau. Later the inland basin disappeared, the Delaware estuary narrowed, and the later Pleistocene deposits are to be found in the Philadelphia Piedmont only on the margin of the Plateau. At the close of Pleistocene time estuaries disappeared, the coast line assumed its present position, and the physical geography of the district approached that of the present day.

PHYSIOGRAPHIC RECORD.

It was stated in the "Introduction" that the present form of the Piedmont Plateau is not a constructional form, and that the rock structure is discordant with the surface.

If the comparatively slight depressions made by the present streams were filled in, a perfectly level plain would result, sloping seaward. If, on the other hand, the arches and troughs of the original anticlines and synclines of the underlying rock were restored, a region of lofty mountains and deep valleys would be developed. These two strikingly unlike topographies are separated by a long and more or less complex erosion history. It is to be doubted whether the perfect constructional form ever existed, but a greater height of land than exists at the present time must have characterized this region during some portion of Paleozoic time. This height of land was so far reduced at the opening of Triassic time that it was upon a comparatively level and deeply eroded floor that the materials of the Triassic were laid down.

The later sediments of the Paleozoic series of the Appalachian region must, in large measure, represent material removed from this belt of high land when the main drainage basin discharged in a western sea. During Triassic time the portion of the Plateau east of the Triassic estuary drained northwestward into this estuary and furnished materials to the sediments accumulating there.

The reduction of the surface of the Philadelphia district must have continued during Jurassic and early Cretaceous time. It was during this time that a nearly featureless plain sloping seaward was formed. Such a plain, carved by subærial erosion, the work of the atmosphere and of running water, is called a peneplain. Only peneplanation can explain the even skylines of the ridges and hills, and the discordance between surface configuration and underground structure. The time of the peneplanation is established by the age of the deposits borne upon its surface. A peneplain of so vast a scope as that of which the Philadelphia district is an insignificant part is necessarily not of the same age throughout its extent. Peneplanation, begins along the main drainage lines, but spreads with incredible slowness away from these lines. Thus the eastern border of the Piedmont region may have been reduced to a peneplain and even submerged while erosion was still progressing on the western margin.

The oldest deposits on this border are the Patapsco and Raritan formations, belonging indisputably to Lower Cretaceous time; the peneplain also carried Upper Cretaceous, Tertiary, and Quaternary deposits. The presence of these deposits and their character indicate that in this region submergence terminated Jurassic peneplanation and that this submergence was not due to a single crustal movement but to an interrupted and complex series of movements.

First there was subsidence with tilting, which produced estuaries bordering the sea and extending inland roughly parallel to the present sea border. In these estuaries were deposited the clay and gravel of the Patapsco formation. An uplift followed which brought the Piedmont district above the sea. The erosion which succeeded this uplift removed the Patapsco deposits, except from the deepest portion of the inland estuary.

Following upon the erosion interval was a second subsidence and the renewal of estuaries in which Raritan deposits were laid down. The uplift that followed was more marked than the preceding and the district remained above water a long time, during which extensive erosion took place. The third subsidence, which followed this erosion interval, lasted during all Upper Cretaceous time, was more extended than any of the preceding, and was oscillatory in character. The adjoining land must have been low, so that the streams furnished only fine sand deposits. Following Cretaceous time was an uplift and an erosion interval of long duration. During this period portions of the Coastal Plain were intermittently beneath and above water, but the Piedmont region remained above water continuously until Lafayette time, when all the Coastal Plain and part of the Piedmont Plateau were brought beneath the sea by tilting which raised the northern half of the plateau. Stream velocity was accelerated so that the streams were able to carry to the sea coarse as well as fine gravel. This was true for the first time since early Cretaceous time. The uplift which followed this tilting, and which brought the continental shelf as well as the Coastal Plain above water, inaugurated a drainage which could not have been very unlike that of the present. The lower courses of the Schuylkill and the Delaware became established along the present lines and the development of the present topography began. The gorges carved in the continental shelf, mentioned in the "Introduction," date from this erosion interval.

Following this time of active erosion there was a subsidence of the eastern portion of the Piedmont district, sufficient to admit the entrance of estuarine waters upon the margin of the Plateau. A stationary position of the shore line is indicated by the escarpment crossing the Plateau diagonally from southwest to northeast, described in the Introduction. The 180-foot contour approximately outlines the escarpment, which extends from Gordon Heights northeastward to Somerton. It can be easily located by the present boundaries of the earliest Pleistocene deposits, though erosion has removed this material for the most part from the immediate neighborhood of the former shore line. In the vicinity of Somerton it is a well-defined escarpment, from which the plain of estuarine erosion to the south may be overlooked. This escarpment is the western wave-cut shore of the broad estuary whose eastern shore is located on the Coastal Plain to the east of the Philadelphia district and whose waters found access to the open sea to the southwest, following the submerged channel of the post-Lafayette and pre-Pleistocene Delaware River.

The uplift which interrupted the deposition of early Pleistocene materials in these waters reduced the limits of the estuary, and in middle Pleistocene time a second stationary position of the shore line is marked by the 60 to 80-foot escarpment on the Plateau and the 100-foot escarpment on the Coastal Plain. The final position of the shore line before the contraction of the estuarine waters to the present channel of the Delaware is preserved in the first escarpments on either side of Delaware River, the 20- to 60-foot scarp on the west and the 45- to 58-foot scarp on the east. The late Pleistocene shore line is more strongly marked on the Plateau than on the Plain. An unequal tilting gave an opportunity to cut into and expose the crystallines of the Plateau.

Since Pleistocene time both Piedmont Plateau and Coastal Plain have been continuously above water, and the drainage of the Plateau has assumed its present form. The pre-Cretaceous peneplain now stands at a height sufficient for the establishment of a drainage actively eroding its surface. The cover of Cretaceous, Tertiary, and Quaternary formations has been so far removed as to lay bare large areas of the crystalline peneplaned floor. The streams have not only eroded the cover, but have cut into the crystalline rocks. The peneplain which thus by uplift became a plateau has by the renewal of erosion become a dissected plateau.

Post-Jurassic peneplanation on the western margin of the Piedmont Plateau is recorded in traces of three peneplains, which, on the eastern margin, embracing the Philadelphia district, can not be discriminated from the older peneplain.

It was stated in the "Introduction" that the larger streams maintain courses which are independent of the lithologic character and structure of the underlying rock. An explanation of this fact is found in the presence of the cover of Cretaceous, Tertiary, or Quaternary materials which, existing at the time of the development of the drainage, masked the pre-Paleozoic and Paleozoic formations beneath it. The drainage, superimposed upon this cover, became too well established in courses consequent on the slope of the Plateau and independent of the concealed rock floor to alter these courses when subsequently the rock floor was uncovered.

Drainage may in like manner be superimposed by peneplanation. The streams which cross Chester Valley are superimposed by the peneplanation subsequent to which the valley developed.

Chester Valley is exactly confined to the outcrop of the Shenandoah limestone and is not now occupied by a stream, nor does it show evidences of such occupation at any time; but, on the other hand, it is crossed in the Philadelphia district by tributaries of the Schuylkill and west of this district by tributaries of the Delaware. The limestone yields to weathering much more readily than does the quartzite or the schist adjacent to it, but does not show the same difference in resistance to mechanical corrasion. Chester Valley must have developed since the peneplanation and presumably by means of differential weathering.

The Wissahickon and the Schuylkill, crossing the limestone valley and cutting gorges in hard gneisses, are examples of superimposed streams—superimposed by peneplanation and by sedimentation. The peculiar courses of Gulf and Valley creeks, both of which have cut through divides composed of relatively hard materials, are due to superimposition. The secondary tributaries do not show the characters of superimposed streams, but are adjusted to the constitution of their rock bed. This fact and differential weathering explain the diversities of topography which have been noted in that portion of the Plateau in which the Paleozoic and pre-Paleozoic rocks are uncovered.

COASTAL PLAIN AREA.

By W. B. Clark.

GENERAL STATEMENT.

The later geologic formations along the Atlantic border form a low plain of varying width that extends from the New England coast to the Gulf. The deposits consist of a succession of gravels, sands, clays, and marls, with a gentle dip toward the southeast. Representatives of nearly every epoch from the Upper Jurassic or the Lower Cretaceous to the Recent are recognized, the oldest formations in general being found along the western side of the Coastal Plain and the younger formations successively farther east.

A detailed study of the character and distribution of the several formations shows that the angle and direction of the tilting were not constant from Cretaceous time onward. The oscillations resulted in transgressions of the waters with their accompanying sediments, which at several periods entirely overlapped locally the earlier formations, burying from view their landward exposures and bringing about at times the deposition of some of the later formations far to the westward of any outcrops of the earlier deposits.

Denudation at various periods down to the present has left remnants of all formations scattered as outliers along the western margin of the main bodies of the deposits. With the exception of the Pliocene and Pleistocene formations, however, the chief outcrops of the several formations in the Philadelphia district are successively encountered in crossing the Coastal Plain from northwest to southeast. Farther toward the south also the normal succession of most of these formations is shown, although the relations of the Pleistocene deposits to the other members of the series are complicated because of the extensive erosion that took place at the close of the Tertiary period and the consequent submergence of the valleys throughout the coastal area.

POTOMAC HISTORY.

A great variety of conditions characterize the deposition of the Coastal Plain sediments. During the earlier periods of this history estuarine conditions prevailed throughout the region. A great estuary, the extent of which can be no longer determined, occupied a depression in the Piedmont surface and followed in general the main structure lines of the Appalachian uplift. Just when this later estuary was formed can not be definitely determined, but the dinosaurs which have been found in one of the lower formations have led some eminent vertebrate paleontologists to regard the age as late Jurassic. The plant forms found in these earlier beds likewise show certain Jurassic affinities, but primitive dicotyledonous types also occur, which on the whole have led paleobotanists to regard even the oldest beds as early Cretaceous.

Uplifts and depressions took place during the time of formation of these estuarine deposits, which are collectively known as the Potomac group, and which have been divided in Maryland, where the most complete sequence occurs, into the Patuxent, the Arundel, the Patapsco, and the Raritan formations. Of these, the two lower have been doubtfully referred to the Jurassic because of the vertebrate remains, as above mentioned, in the Arundel beds. So far as known, neither of these formations appears at the surface within the Philadelphia district, the earliest of the Potomac beds being referable to the Patapsco, of whose Cretaceous affinities there can be no doubt. Land conditions existed at the close of Arundel time, as shown both by a marked unconformity between the Arundel and Patapsco formations and by the existence in the strata of certain lignitic deposits, the tree stumps of which are to-day found in an upright position. With the advent of Patapsco time a considerable widening of the estuary took place, and it is possible that the Philadelphia district was then for the first time submerged. Potomac time closed with the deposition of the Raritan formation, the most extensive of the early Cretaceous formations represented in the Philadelphia district and neighboring areas. Deposits coarser than the preceding Patapsco characterize the Raritan, and it would seem that considerable deformation of the shores of the ancient estuary must have been in progress, later culminating in the breaking down of the eastern barrier and the entrance of the open waters of the Atlantic.

MAGOTHY HISTORY.

The date of the change just mentioned was evidently not earlier than the close of the Lower Cretaceous. At first the marine faunas, which apparently entered the basin of deposition in the Raritan Bay region, did not extend far southward, for the Magothy deposits in the Philadelphia district and toward the south have not as yet afforded marine fossils. It seems probable that the encroaching sea merged into an extensive estuary that extended southward along the old line of Potomac sedimentation across Delaware to the western shore of Chesapeake Bay. The same is probably true in a measure northward, although the exact limits of the so-called "Island series," on which this generalization must be based, are not fully comprehended. The flora of the Magothy strata suggests that this change was not consummated until late Cenomanian time, and the fauna points even to the Senonian. Magothy time apparently represents a transitional period between the estuarine conditions of Potomac time and the distinctly marine conditions that characterize the remainder of the Cretaceous.

MATAWAN HISTORY.

The materials composing the marine sediments are mainly sand and clay, which from the base of the group upward contain greater or less amounts of glauconite, showing that during much of the time land-derived materials must have reached the area of deposition in small amounts. It is probable that the region was not far removed from the shore line of the period, and that the land had been gradually reduced until a great peneplain had been developed, extending westward at least into the Appalachian district. The evidence for this is found not only in the glauconitic character of the sediments throughout late Cretaceous and early Tertiary time but also in the even-topped ridges throughout the Atlantic border district as far back as the Allegheny Plateau. A marked similarity in composition characterizes these late Cretaceous sediments, from the Matawan to the Manasquan, as a whole, although they vary sufficiently over considerable areas to make it possible to separate them on lithologic grounds into several formations. Glauconite in greater or less amounts appears, as above stated, at nearly all horizons, in places constituting the main body of the deposits, while in other places it is sparsely distributed and may be limited to definite beds or may occur as small lenses or patches inclosed in other materials. In general the beds become gradually more glauconitic in passing upward in the series, the highest beds consisting in places almost entirely of glauconite.

The opening period of this later division of the Cretaceous, known as the Matawan, was marked at the outset by extensive deposits of clays and sands. The sea encroached over a more or less even floor, producing sediments that had their origin in the still unconsolidated materials of the earlier Cretaceous as well as in the older rocks to the west. Marine life was abundant and varied, an extensive fauna of cephalopods, gasteropods, and pelecypods characterizing the period. The conditions of sedimentation changed during this time, especially in the north, where a clearly defined differentiation in the materials occurs. Southward this feature is less pronounced and the deposits gradually become more homogeneous, the distinctions being entirely lost in Maryland.

MONMOUTH HISTORY.

The advent of Monmouth time was not marked by any pronounced change, sedimentation having continued without interruption. As the period advanced, however, thick-bedded glauconitic deposits were laid down, and the greensand of the Monmouth is very unlike anything which had preceded it. The middle formation of the Monmouth, known as the Navesink marl, is a characteristic greensand marl, and in its numerous fossils shows the extensive marine fauna that existed at this period. Many of the species are different from those of earlier time, although many fossils are found common to one of the zones of the earlier Matawan and to the later Redbank. The red sands found both above and below the greensand marl are quite unknown at later horizons, except in the northern phase of the later Rancocas. Locally the beds are highly calcareous on account of the great number of molluscan remains entombed in the deposits.

RANCOCAS HISTORY.

With the close of Monmouth sedimentation came a time of pronounced glauconitic accumulation. The greensands of the Hornerstown constitute the most significant beds of glauconitic materials in the entire Cretaceous system. They represent quiet seas, in which the accumulation of materials must have been extremely slow. The land area to the west by this time had become reduced to a featureless peneplain, while the sea floor itself may have been still further depressed, carrying the area of sedimentation farther landward. Conditions must in any event have persisted through a considerable period, for the thick deposits of nearly homogeneous greensand extend throughout the district from Raritan River southward to the point of their final disappearance near the Maryland border. The Rancocas closed with an extensive accumulation of quartz deposits, known as the Vincentown sand, which are in places largely made up of the remains of Bryozoa and Foraminifera, forming a lime sand, and are at other places decidedly glauconitic. These deposits where calcareous are among the most striking in the entire Cretaceous system of the north Atlantic Coastal Plain, and indicate a great profusion of life in the seas of the time.

LATE CRETACEOUS AND EOCENE HISTORY.

A long period of time passed after the close of Rancocas deposition before the next younger sediments of the Philadelphia district were deposited. The record of these times is represented in the Manasquan formation, of late Cretaceous time, and the Shark River marl, of early Eocene time, developed mainly toward the north, and in the Aquia and Nanjemoy formations, of middle Eocene time, developed mainly toward the south in Delaware and Maryland.

MIOCENE HISTORY.

Evidently much the same conditions as hitherto prevailed along the Atlantic border, as far as can be judged from the deposits farther south, until Miocene time. The deposits of the earliest period are for the most part clays and fine sands, although in the extreme southern part of New Jersey occur marl beds which by their numerous fossils show the existence of an extensive molluscan fauna. To the south, however, extensive diatomaceous beds give evidence of the existence of vast numbers of diatoms in the seas of early Miocene time.

Unlike the early Miocene sediments of this district, the later deposits consist of coarser sands and fine gravels, which show that the land areas toward the west had become extensively elevated as the Tertiary period advanced, causing the streams to transport large amounts of coarser materials down their courses to the sea. A great thickness of highly characteristic sandy deposits was laid down, which farther off shore or in regions remote from the mouths of streams became finer, with beds of clay bearing an extensive molluscan fauna. Toward the south in Maryland, where these deposits are most characteristically developed, a great number of species have been recognized.

The latest portion of Miocene time is represented east of the Philadelphia district, by deposits of sand and clay which are now buried beneath a cover of Pleistocene materials. In the deeper well borings along the coast and toward the south in Maryland these deposits afford sands and clays that lithologically are not unlike those of the earliest period in many respects, although generally finer, indicating in all probability the lessening volume of sedimentation.

PLIOCENE HISTORY.

The close of the Tertiary along the Atlantic and Gulf borders is marked by the deposition of a cover of gravels and sands. This was brought about by landward uplift accompanied by a depression of the shore line, since the deposits of the Lafayette formation, which has been thought to represent the Pliocene, are found distributed widely above the Miocene strata as well as those of earlier time, reaching to the crystalline rocks of the Piedmont area. Within the Philadelphia district these deposits are to-day limited to the Piedmont Plateau, lying to the west of Philadelphia, so that their relations to the other Tertiary formations must be sought in Maryland and Virginia, where they are more fully developed. The period of time represented by the Lafayette must have been short, and was terminated by extensive uplift of the sea floor, during which time the present drainage lines of the Coastal Plain were largely developed.

PLEISTOCENE HISTORY.

In these ancient channels and on the adjoining lowlands the deposits of the Pleistocene epoch were laid down. The materials consist of gravels, sands, and clays that were to a considerable extent derived from the earlier Coastal Plain strata, although the streams flowing from the Piedmont Plateau added their quota to the materials deposited. The life of the Pleistocene approached more nearly that of the Recent, although relatively few localities are known in the north Atlantic coastal region in which any considerable assemblage of Pleistocene species occurs.

The blocking of the minor post-Lafayette channels in later Pleistocene time produced ponded areas in which were laid down the thick deposits of black clay so typically developed at Fish House and at numerous other points toward the south, through New Jersey, Delaware, and Maryland.

ECONOMIC GEOLOGY.

MINERAL RESOURCES.

PIEDMONT PLATEAU AREA.

By F. Bascom.

In the Piedmont Plateau area the chief natural products of economic importance are building stone and road metal. The former product is supplied to a greater or less degree by all the formations of the Plateau, and the latter in large amount by several of the formations.

BUILDING STONE.

Baltimore gneiss.—The Baltimore gneiss, of which the character and distribution have been discussed, does not furnish a large amount of building stone in the Philadelphia district. The granitic facies supplies a better stone than the sedimentary facies, whose serviceableness for building purposes is reduced by its finely banded character. Between Bethayres and Paper Mills, on Pennypack Creek, there are large quarries in the massive phase of the gneiss, from which fair building stone has been taken, as well as a large amount of road metal. The rock possesses a nearly vertical jointing, is light colored with gray bands, and is medium to coarse grained. It resembles in appearance the granite gneiss at Port Deposit, to which in hardness, strength, and durability it is probably not inferior. The quarries are conveniently located for transportation.

Wissahickon gneiss.—The Wissahickon gneiss furnishes a very acceptable building stone, which is accessible, easily quarried, and readily dressed. The joints and bedding planes are such as to permit blocks to be quarried of sufficient size for ordinary building purposes. The color of the stone is a warm gray, the grain medium. In hardness and durability the stone is somewhat variable; although it disintegrates readily when exposed at the surface of the ground, experience has shown that it wears very well if properly laid in a building and that pleasing effects may be obtained with it.

Near Walnut Lane station, on the Philadelphia and Reading Railroad, a quarry owned by Glassy & Fowler has furnished stone for Blair Hall, Princeton University; for Memorial Chapel, Williams College; and for the library at Vassar College. At Mermaid a quarry owned by Jerry O'Neil has furnished stone for Rockefeller Hall and the library at Bryn Mawr College. The gymnasium, Dalton, Denbigh, and Pembroke halls of Bryn Mawr College are built of stone furnished by Hayden's and Foulton's quarries, on the west side of the Schuylkill. Many private houses in Germantown and throughout the suburban districts are built of this stone.

Chickies quartzite.—There are large quarries in the Chickies quartzite at Edge Hill and between Edge Hill and Abington. Quarries have also been worked in the quartzite of Huntington Valley and in the neighborhood of Chestnut Hill. The material is quarried in thin slabs cut parallel to the steeply dipping cleavage and bedding planes, and is used for cellar walls, furnace linings, and, in a limited way, for building purposes.

The quartzite of the North Valley Hills is quarried extensively. The material is transported to Valley Forge, where it is crushed and shipped to iron works throughout the Schuylkill Valley and used for bottoms in heating furnaces and steel works. Twenty-five to 50 tons are shipped daily.

Shenandoah limestone.—The Shenandoah limestone is always crystalline and much of it is a white or blue marble of medium grain. The stone is fairly accessible throughout Chester Valley and can be quarried parallel to the bedding and joint planes, yielding blocks which range from 5.94 by 5.90 by 5.92 feet in the vicinity of Conshohocken, where the formation is somewhat thinly bedded, to 6.50 by 6.05 by 6.03 feet in the open valley. The average crushing strength of the stone per square inch, calculated from eight samples, is 12,075 pounds.

There are now more abandoned than active quarries in the Shenandoah limestone, notably at Five Points, Plymouth Meeting, Marble Hall, Port Kennedy, New Centerville, and Rennyson. In the early history of Philadelphia, marble from Chester Valley was in great demand for house trimmings, doorsteps, and for more elaborate architectural purposes. The sarcophagi at Mount Vernon, Va., and the marble blocks contributed by the State of Pennsylvania to the Washington Monument were quarried in Chester Valley, which has also furnished stone for Girard College, the United States custom-house at Philadelphia, and many other noted buildings. Within the last fifty years Vermont marble, owing to its greater beauty, its freedom from iron pyrites, and the cheaper methods of quarrying it, has gradually replaced the Chester Valley stone. At present the Shenandoah limestone is more frequently quarried for use as lime and road metal than to furnish building stone. Large quarries are being operated at Williams station, at Plymouth Meeting, and, intermittently, at Mogee, the stone from which is burnt for lime. At two localities—one-half mile west of Plymouth Meeting and a mile west of Port Kennedy—the limestone is utilized for the manufacture of magnesium carbonate by the American Magnesia and Covering Company, and the Ehret Magnesia Manufacturing Company, respectively. The product is used for magnesia steam-pipe and boiler coverings and locomotive lagging.

Three-fourths of a mile southeast of King of Prussia a quarry in the limestone yields both light-colored and dark-blue marble. This stone is used for monuments and other ornamental purposes. At Howellville a large quarry is successfully operated. The stone is used for concrete, ballast, macadam, and building purposes, and is shipped by railroad to points within a radius of 50 miles.

For a distance of five-eighths of a mile northwest of West Conshohocken, on both sides of Schuylkill River, the limestone contains so low a percentage of lime as to unfit it for burning into lime. There are three quarries in this lime-poor rock of calcareous schist on the west side of the river, operated by the West Conshohocken Stone Company, and a like number on the east side, controlled by the Schuylkill Stone Company and the Philadelphia and Conshohocken Stone Quarry Company. This stone is used for constructing railway bridges and in foundations for heavy buildings and for wall work requiring a nice face. These quarries also furnish standard foundation material.

Octoraro schist.—The mica schist is an inferior stone for economic use of any sort. In a very small way it has been quarried at numerous localities, where the material taken out has been used for cellar walls. One of the larger quarries is at Bridgeport Hill, where the siliceous character of the rock renders it fairly serviceable for foundations. Sand for local use has been obtained from a pit opened in the disintegrated quartzose member of the mica schist, three-eighths of a mile west of Radnor and 2 miles north of Wayne, on the road to King of Prussia and near the northern base of the South Valley Hills. This pit is operated by James Fletcher of Mount Pleasant, Wayne.

Gabbro, diabase, serpentine, and soapstone.—Gabbro has been used somewhat as a building stone. It is very tough for quarrying, but on the other hand can be worked in blocks of any size desired and is a permanent stone with a crushing strength twice that of limestone. It is, however, too dark colored to be popular as a building stone, but is suitable for curbing and for Belgian blocks.

Diabase, which has been used in ornamental stone walls and in the construction of stables, is, like the gabbro, too dark colored for general use in dwelling houses.

Serpentine usually occurs badly jointed, but notwithstanding this feature, the stone has had a wide use for building purposes because of its softness and consequent ease of quarrying and dressing, its remarkable durability, and its soft green color. Many dwelling houses, churches, and the older buildings of the University of Pennsylvania and of the Academy of Sciences at Philadelphia are built of this material. There are no quarries now in active operation in the serpentine of the Philadelphia district, and much of the serpentine used in Philadelphia has been obtained from Brinton's quarry, 3 miles southwest of West Chester, west of this district.

The rare combination of softness and indestructibility offered by soapstone renders it, when pure, suitable for a considerable range of application. Soapstone has but a scanty distribution in the Philadelphia district. It is confined to the most southerly of the serpentine dikes and to the neighborhood of Schuylkill River. Even here it is only locally quite pure (steatite) and free from serpentine or serpentinized olivines. These constituents are much harder than steatite and cause the soapstone to wear unevenly. The Philadelphia stone was once in demand for door sills. Such old door sills now show the serpentine knots projecting above the soapstone like "hobnails in a plank."

Soapstone has been much more extensively quarried in the past than it is at present. A quarry (Prince's) on the east bank of the Schuylkill near Lafayette station, opened more than a hundred years ago to furnish door sills for the old State House and for a long time operated, is now closed and is partly buried by a landslide. An old quarry (Rose quarry) on the west bank of the Schuylkill in the same formation has been recently reopened and, like Prince's quarry, furnishes material of good quality, which is used for stove and furnace linings, as a filler in the manufacture of paint and paper, and as a lubricant.

Granite gneiss.—One of the best building stones of the district is furnished by the granite gneiss, whose distribution and character have been discussed: There are large quarries in this formation at Holmesburg, at the Falls of Schuylkill on the west bank of the river, at Overbrook (southeast of the station), south of Overbrook on Indian Creek, at Kellyville, and on the lower courses of Crum and Chester creeks. Here are the Avondale, Ward's, Deshony's, and Leiperville quarries. Some of these quarries have been operated almost continuously for more than a century. Bridges, curbing, dwelling houses, churches, public buildings, and monuments have been made from the stone. It has horizontal and vertical partings, which enable it to be quarried in cubical blocks, and is strong, durable, and attractive. Tests of the crushing strength of granite gneiss from Holmesburg made in 1902 by Lathbury and Spockman gave the following results: Crushing strength per square inch on edge, 24,034 pounds; crushing strength per square inch on bed, 26,254 pounds.

Hornblende gneiss.—The hornblende gneiss is quarried at Frankford and Queen Lane. Stone from Frankford is used for cellar walls and for dwellings. Stone from McKinney's quarry, Queen Lane, is used for Belgian blocks, for bridge building, and for schoolhouses.

Sandstones in the Newark.—The sandstones of the Stockton, Lockatong, and Brunswick formations have been quarried to some extent to supply building stone for local use. The sandstone of the Stockton is of gray to buff color and much is of sufficient hardness and homogeneity to be of considerable value. The most extensive quarries are in the bluffs on the north bank of Schuylkill River 3 to 5 miles above Norristown and at Grenoble, but they are only worked occasionally to supply some transient demand for stone. There are small quarries half a mile north of Fort Washington, in the eastern part of Norristown, at Warrington, and half a mile north of Horsham.

The hard, dark-colored, slabby sandstones of the Lockatong formation are extensively utilized for underpinning and are crushed in large amounts for road metal. The principal quarries are on the main road halfway between Spring House and Montgomery Square and a half mile northeast of the latter place. Many small openings have been made at other localities.

The brownish-red sandstones of the Brunswick formation are as a rule too soft to be of use for building, but they serve to some extent for local use. A small quarry on the east side of Perkiomen Creek 1½ miles above Graters Ford has been worked at intervals for many years and yields a rock of hardness unusual for that formation.

ROAD METAL.

Road metal is abundantly provided by the formations of the Piedmont Plateau. The Baltimore gneiss, the Shenandoah limestone, the gabbro, and the diabase are utilized for this purpose. Yeakle's quarry, one-half mile west of Glenside, and the lower quarries on Pennypack Creek in the Baltimore gneiss are provided with stone crushers and furnish road metal. Limestone has been extensively used in road construction. The cementing quality of the limestone is excellent and its wearing qualities are improved by the siliceous character of the rock. In durability, however, it is inferior to the gabbro, and roads macadamized with limestone soon present a dusty white surface which may be avoided by the use of gabbro. Some of the quarries now operated in the limestone furnish stone solely for road metal. Such a quarry is situated one-half mile southwest of Oreland.

The hard sandy shales of the Lockatong formation have been used to a considerable extent in the northern part of the Philadelphia district for road metal.

Of the rocks of the Plateau that are abundant and available the best road metal is furnished by the gabbro. Diabase affords equally good or even better material, but is too meager in occurrence to be of economic importance in the Philadelphia district. Gabbro owes its superiority to limestone or gneiss as road material to its greater toughness, hardness, and consequent wearing quality. In binding power it is inferior to these stones.

Large quarries in the gabbro at Wayne, at Glen Mills, and at Locksley furnish to this district an inexhaustible supply of crushed stone. A smaller quarry for the same purpose has been opened on Little Darby Creek. Gabbro is widely used in road construction in the Philadelphia district, which is justly famous for good roads. Crushed rock from the Glen Mills quarry has been used in making artificial stone for building purposes.

In the table given below, percentage of wear represents the amount of material under 0.16 centimeter in diameter lost by abrasion from a weighed quantity of rock fragments of definite size; toughness is the power possessed by a material to resist fracture by impact; hardness is the resistance which a material offers to the displacement of its particles by friction; cementing value is the power possessed by a rock powder to bind the coarser fragments.

Physical properties of road metal.

[Edwin C. E. Lord, Bull. No. 31, U. S. Dept. of Agr., 1907.]

Metal.	Percentage of wear.	Toughness.	Hardness.	Cementing value.	Specific gravity.
Biotite granite	4.4	10	16.8	17	2.64
Gabbro	2.8	16	17.9	29	3.00
Fresh diabase	2.0	30	18.2	49	3.00
Altered diabase	2.5	24	17.5	156	2.95
Limestone	5.6	10	12.7	60	2.70

IRON ORE.

In the pockets here and there throughout Chester Valley is found a limonitic iron ore. In places it is accompanied by hematite. Its presence is due to the segregation of the iron oxide upon the limestone by leaching from the mica schist. This must have taken place subsequent to the folding of limestone and schist, and has been deposited in disregard of stratification. These iron-ore pockets were at one time mined, as the numerous pits distributed throughout the limestone area testify, but of late years the iron interests have been diverted to other and more profitable districts.

FELDSPAR.

Penetrating the gneisses, particularly in the southwestern part of the Philadelphia district, are pegmatitic masses or dikes which in a few instances furnish feldspar of a marketable character. The dikes are usually composed of a coarsely crystalline aggregate of microcline, albite, quartz, and muscovite. In many of the granite quarries in the neighborhood of Chester such pegmatitic masses have been exposed.

The Chester Heights Feldspar Company, located at Chester Heights, about 6 miles southwest of Media, furnishes feldspar both for dental purposes and for pottery. One mile east of Glen Mills, on the Sharpless estate, there is an abandoned feldspar and mica quarry. About 1½ miles south of Chelsea a potash feldspar has been quarried. On the east bank of the Schuylkill River, in the Baltimore gneiss, a mass of acidic feldspar was for a short time quarried. The amount of feldspar in the Philadelphia district is limited, but west of the Philadelphia region feldspar and the kaolin derived from it support an important industry.

COAL.

Some very thin beds of coal occur in the dark shales of the Lockatong formation, but most of the coal is very impure. Several attempts have been made to develop coal mines, notably at a locality on Perkiomen Creek near Arcola station, where it is claimed that a bed 26 inches thick was found. A thin coal bed is reported in wells bored at North Wales and Lansdale. It is improbable that any deposit of value exists at this place or elsewhere in the formation.

LEAD AND COPPER.

Traces of lead and copper materials (galenite, copper pyrites, and the carbonates of copper) occur in many places in rocks of the Newark group, and in a single locality in the Baltimore gneiss of the Philadelphia district, but not in sufficient amount to give the least promise of value. Such traces are to be found in the gneiss 1½ miles west by south of Valley Forge. A pit known as the "Perkiomen mine" was opened half a century ago in the Stockton formation and was worked at intervals, but was finally abandoned. It is in the valley of Mine Run, north by west of Shannonville; the rock is light-brown sandstone containing small amounts of copper pyrites and malachite. At the Acton mine one-half mile west of Shannonville, small traces of copper pyrites, blende, and galenite appear in the excavated material, which is mostly a brownish sandstone with sandy shale.

SOILS.

The soils of the Piedmont Plateau of Pennsylvania are residual and are derived from the rocks which immediately underlie them. They are, with one exception, productive soils. From Delaware River to Buck Ridge the soil is chiefly a brownish-buff micaceous clay loam derived from the decay of the Wissahickon mica gneiss. This is exclusive of an alluvial soil confined to the lowlands in the immediate vicinity of the Delaware and limited areas of a loose sandy soil; these soils are described later among the Coastal Plain products, the former as the Meadow and the latter as the Norfolk sand. The clay loam is characterized by the presence of abundant fragments of mica, of gneiss, and of vein quartz. It is a mellow, fertile soil and grades imperceptibly into solid rock through a considerable depth of decayed rock. It corresponds to soil which, in adjacent regions in Maryland, has been designated by the Bureau of Soils, Department of Agriculture, the Cecil mica loam. The names of soils used in this folio are those adopted by the Bureau of Soils, Department of Agriculture, and are not in any sense of the term geologic names.

The decay of the granite gneiss forms a very similar soil, which often is scarcely to be distinguished from the mica loam. It is a clay loam showing fewer fragments of mica. It is not confined exclusively to the areas underlain by granite, but is a residual product of the less micaceous gneiss. This soil has been designated the Cecil loam.

The gabbro which constitutes the greater part of Buck Ridge disintegrates into red clay soil thickly set with tough bowlders of gabbro. The soil is not as deep as on the mica gneiss and gives place somewhat abruptly to solid rock. This soil characterizes the broken hilly country. It corresponds to the Cecil clay of the Bureau of Soils. The Baltimore gneiss supplies a sandy clay soil like the Cecil clay, free from mica scales, but possessing a yellow rather than a red color, and containing flat fragments of the gneiss. This sandy clay soil and the Cecil clay clothe Buck Ridge.

The mica schist of the South Valley Hills forms a yellow micaceous sandy soil, differing from the mica loam, chiefly in a larger content of sand, in freedom from mica plates, and in containing many small fragments of mica schist. The limestone valley beyond is characterized by the reddish clayey soil which normally results from the decay of limestone. It is free from stones, is deep, and is very productive. Some of the best farms of the plateau are located on this soil. It corresponds to the Conestoga loam of the Bureau of Soils.

The quartz schist of the North Valley Hills, Camp Hill, Edge Hill, and other highlands gives rise to a sandy soil which contains also both mica and clay. It is less productive than the other soils because less tillable, being thickly studded with quartzite fragments and characterized by a rugged topography. There is no distinction between soil and subsoil and it does not exceed 2 feet in depth. This corresponds to the Edgemont stony loam mapped by the Bureau of Soils in Lancaster County, Pa.

The serpentine areas are marked by a thin, light greenish yellow soil. This soil may be only a few inches deep or merely lodged in pockets on the otherwise bare rock. When the serpentine soil is deeper it usually has a reddish color. Its thinness and consequent incapacity to hold water is a sufficient reason for its unproductiveness. Chemically it differs from the other soils in the presence of a large percentage of magnesia and the absence (or the presence of only an excessively low percentage) of lime and potassa and other nutrient materials. Where the serpentine soil is deep enough to hold moisture and has been treated with the usual fertilizers it does not differ from other soils in productiveness. It has been called the Conowingo barrens.

The soil derived from the disintegration of the Triassic sandstones and shales covers a larger area than any other single type of soil in the Philadelphia district. It is a sandy clay loam characterized by an Indian red or brownish-red color. Confined as it is to gently rolling country and being comparatively free from stones, it is tillable and productive. This is the Penn loam of the Bureau of Soils.

With the exception of the Conowingo barrens, which support a scanty and characteristic vegetation, the soils of the Piedmont area are not dissimilar in productiveness. A great variety of forest trees of fine proportions characterize the plateau. Among them are several varieties of the oak, beech, chestnut, tulip tree, sycamore, basswood, hickory, butternut, soft maple, locust, gum, sassafras, dogwood, and cedar.

COASTAL PLAIN AREA.

By W. B. Clark and B. L. Miller.

The mineral resources of the Coastal Plain area consist of gravel, sand, clay, marl, and soils. No one of them can be regarded as of great economic significance except the soils, although industries of importance have been established in connection with the sand, the clay, and the marl.

GRAVEL.

The gravels wherever found have been employed to a greater or less extent for road building, the most important of these materials coming from the Magothy, Lafayette, and Quaternary formations. The Lafayette gravel, as earlier described, is confined to the elevated areas west of Philadelphia, where its loamy and ferruginous character has led to its extensive use on the local highways. The gravel and coarse sand of the Magothy are confined to the New Jersey area bordering Delaware River. They are likewise highly ferruginous and well adapted for road building, although they have not been employed to any great extent. The most widely used gravels are those of the Quaternary formations, which cap the higher levels on both sides of Delaware River and are particularly important throughout the New Jersey district as road-building materials. They will doubtless be much more extensively employed in the future than they have been in the past.

SAND.

Sands of various kinds, both coarse and fine, occur at several horizons. Those which have hitherto been economically employed are for the most part confined to the Magothy, Kirkwood, and Cohansey formations. Immense pits have been opened in the Magothy along the south bank of Pensauken Creek and the materials have been shipped in great quantities to Philadelphia and elsewhere for general building and other purposes. The Magothy sand used in this locality consists of white quartz grains remarkably free from impurities and varying in size from fine to coarse, while the grains themselves are angular. The sands that are profitable occur in pockets or lenses which may have a thickness of only a few feet and a horizontal extent of a few rods or in lenses 15 to 20 feet and an areal extent of several acres. The even-grained character of these sands has led to their extensive adoption as filter materials. They have also been employed in the manufacture of fire brick because of their infusibility, caused by the absence of fluxible substances, while some of the sands have sufficient bonding power to render them valuable for molding purposes.

The Kirkwood sand is much finer than the Magothy or the Cohansey sands, and considerable quantities have been shipped from pits to the north of Mechanicsville as molding materials. The sands in this small outlier evidently occupy a deep depression in the underlying Cretaceous beds, so that the amount of material at this point is quite out of proportion to its areal extent.

The Cohansey sand is not being commercially employed at present within the limits of the Philadelphia district, but is extensively dug as glass sand beyond the district toward the southeast.

Sands are also found at other horizons, particularly at the base of the Patapsco formation in the vicinity of Conshohocken, this material being employed for architectural purposes and for electric cars and locomotives. Sand for local uses has been taken from the Pleistocene deposits in many places.

CLAY.

A great variety of clay occurs among the Coastal Plain deposits, the most important formations that furnish it belonging to the Potomac, Matawan, and Quaternary formations.

POTOMAC CLAYS.

The clays of the Potomac group are contained in the Patapsco and Raritan formations, the only two formations of the group represented in the Philadelphia district.

Patapsco clay.—The Patapsco clay is of high grade and is worked at various points in the Conshohocken region, especially near Harmansville and Spring Mill. The clay occurs in deep depressions in the surface of the limestone that are generally of small areal extent. The clay is interbedded with sand and gravel lenses of variable character. In some places the clay is as much as 25 feet in thickness, but elsewhere it is only a few feet thick or is entirely wanting. The clay is of variable color drab, red, black, and mottled being most common. It is exceedingly tough, so that the deposits are worked with difficulty. The overburden is also heavy in some of the pockets, rendering the working of the deposits unprofitable.

The Patapsco clay is the most valuable clay of the Philadelphia district, although at present not worked as extensively as are some of the Upper Cretaceous clay deposits on the east side of Delaware River. It is used in the manufacture of fire brick, terra cotta, pottery, furnace linings, etc.

Raritan clay.—The Raritan formation throughout New Jersey is the most valuable clay formation of the State and yields a great variety of clays suitable for many purposes. In the Philadelphia district the Raritan has a very scanty exposure and very little clay has been utilized from deposits of this age. On the south side of Pensauken Creek near its junction with Delaware River white and mottled clays have been dug to a limited extent. The clays are of good quality and are suitable for fire brick, saggers, tile, and some grades of pottery. A few years ago a somewhat similar deposit of white clay of Raritan age was exposed in the vicinity of the clay pits at Fish House, but it is not worked at the present time.

MATAWAN CLAYS.

The Matawan clays are contained in the Merchantville, Woodbury, and Englishtown formations and are the most extensive clay deposits of the district.

Merchantville clay.—Clay belonging to the Merchantville formation is worked at Budd Brothers' brick-yard in the southeastern part of Camden, near City Line station. The clay bed is from 14 to 16 feet in thickness; it rests upon coarse white sand of the Magothy and is in turn overlain by a few feet of Pleistocene gravelly loam. In color the clay is black to greenish black, the green color being due to the presence of considerable glauconite, which is in small pockets or evenly distributed throughout the clay. Mica flakes of small size are also numerous. The clay is easily obtained, as the thin bed of overlying Pleistocene is mixed with the Matawan clay without any injurious effects. The presence of coarse sand beneath the clay is also of considerable importance, as it facilitates easy drainage of the pit. All that is necessary to rid the pit of water is to dig a few small holes into the Magothy sand; into these the water drains and finds its way to the river by underground channels. The clay fuses rather easily and makes a good building brick.

Similar clay is worked for the manufacture of brick a short distance east of Maple Shade, just beyond the border of the Philadelphia district. It also outcrops in a railroad cut near Merchantville, though it has not been worked there.

Woodbury clay.—Within the boundaries of the Philadelphia district the Woodbury clay is worked at only one place, about a mile south of Collinswood, where it is dug for the manufacture of brick. In this pit the clay is from 12 to 15 feet in thickness and is easily obtained. When fresh the clay is black, but on weathering it changes in color to light chocolate-brown. It contains some small flakes of mica and is somewhat sandy in certain places. The clay is considerably jointed. The bricks made from this clay burn to a good red color, are dense, and possess high tensile strength, as shown by tests made by the New Jersey Geological Survey.

Englishtown clay.—A thin layer of clay in the Englishtown sand has been worked about three-fourths of a mile south of Woodbury for the manufacture of brick. The clay is rather sandy and is mixed with surface loam. It makes a grade of brick that is suitable for foundation purposes. The deposits are shallow and not continuous, so that the clay is of no especial significance.

QUATERNARY CLAYS.

Clays of Quaternary age have been extensively worked on both sides of Delaware River in the Philadelphia district. On the Pennsylvania side these clays have been used at numerous places in the suburbs of Philadelphia in the manufacture of common building brick. In places the clay has been removed over large areas which have later been built upon, and it is now being worked in the vicinity of Frankford, Nicetown, Point Breeze, and between Angora and Haddington. The material is a rather tough reddish-brown clay loam and has been formed mainly from the decomposed products of the crystalline rocks of the near-by region. The clay occurs at the surface, so that little or no stripping is required. Where worked the clay loam is from 5 to 18 feet in thickness.

On the New Jersey side of Delaware River the most extensive deposit of Pleistocene clay occurs at Fish House. At this place there is a deposit of plastic black clay varying in thickness from 20 to 30 feet and extending over an area about two-thirds of a mile long and one-third of a mile wide. This clay has been worked for a great many years and is by far the largest single clay pit in the Philadelphia district. The clay has attracted much attention because of the presence of a great many *Unio* casts. It also contains considerable lignitic matter in places. The clay rests on coarse sand and gravel of the same age and is overlain by a few feet of surface loam. It has been mainly used in the manufacture of building brick, though some has been utilized for stoneware.

Some of the Quaternary clay near the mouth of Woodbury Creek has been used by the Camden Iron Works.

GLAUCONITE MARL.

The formations of the Monmouth and Rancocas groups are rich in deposits of glauconitic marls, which are of value as fertilizers. From New Jersey to North Carolina such deposits have been worked spasmodically since the early part of the last century, when their value was first determined, yet their importance in enriching the soil has never been generally recognized. They consist of quartz sand with an admixture of many grains of glauconite, a soft green mineral, which is essentially a hydrous silicate of iron and potassium. On account of the glauconite, the marls are green in color and are commonly known as "greensand marls." They are rich in calcium carbonate, derived from the shells which are abundant in the deposits, and chemical analyses usually show the presence of small amounts of mineral phosphate. The marls thus contain three important plant foods—potash, lime, and phosphates. Altogether these constitute only a small percentage of the entire content of the deposits, yet whenever the marls can be obtained at low cost they furnish economical means for increasing soil fertility. Where the glauconite marls have been used it is claimed that their beneficial effect is much much more lasting than that obtained by means of artificial fertilizers.

The marls of the Rancocas group have been extensively worked for many years in the vicinity of Sewell, where a large plant is at the present time in full operation. The material is dried and shipped to fertilizer works as the base for commercial fertilizers. Considerable marl of the same horizon has also been dug a short distance north of Kirkwood for the same purpose. At present no marl is used in the natural condition, largely because its value as a fertilizer has been underestimated, but also because of the scarcity of labor.

SOIL.

The soils of the Coastal Plain are for the most part directly derived from the Quaternary formations, since most of the underlying Cretaceous and Tertiary deposits are buried beneath a cover of later origin. The underlying sands, clays, and marls, have, however, exerted an important influence on the Quaternary materials of the several areas, these later formations having been often largely derived from the immediately underlying beds. In certain localities, for example, they consist largely of reworked marls which partake of the character of the marl bed below.

The overlying Quaternary is in places spread in so thin a mantle that the basal formations constitute the subsoil, and along the slopes may even be the source of the soil itself. In a few restricted areas the cover of Quaternary is entirely lacking.

The United States Department of Agriculture, in its report on the Salem area in "Field Operations of the Bureau of Soils, 1901" describes the soil types for a considerable part of the Philadelphia Coastal Plain area, under the following names: Sassafras loam, Quinton sandy loam, Elsinboro fine sand, Elkton clay, Alloway clay, Norfolk sand, Westphalia sand, Collington sandy loam, Windsor sand, Sassafras gravelly loam, and Meadow. By far the greater part of the Coastal Plain of the Philadelphia district is composed of Norfolk sand, Meadow, Sassafras gravelly loam, and Quinton sandy loam, here named in the order of importance.

The Norfolk sand consists of a loose sand of medium to coarse texture containing a small percentage of silt and clay. It is derived from the several Quaternary formations and is found at all elevations from sea level to the highest portions of the upland. This soil, which covers a larger area than any of the others, is particularly well adapted for truck farming.

The next most important soil is the Meadow, which occupies the low areas along Delaware River and its tributaries. In the main this land is so low and wet as to be unfitted for agricultural purposes until drained. These meadows supply herd's grass in large amount for rough forage, and they also furnish pasturage for cattle. Vegetables are also raised on some of the higher portions, but in general the region is still largely forested, black and sweet gum, willow oak, white oak, magnolias, and two or three varieties of cedar being the trees most commonly found.

The Sassafras gravelly loam, as well as the other types referred to, occupy much more restricted areas than the Norfolk sand and the Meadow. The Sassafras gravelly loam occupies the upland areas, being mainly derived from the higher-lying Quaternary formations. The soil consists of a brown sandy loam mixed with gravel and is especially well adapted to fruit culture, particularly that of peaches, pears, plums, and cherries. Corn is also raised. A forest growth of oak and pine also covers some parts of the region.

The Quinton sandy loam is largely derived from the Cohansey sand or its reworked materials. It consists primarily of a loamy sand and is largely adapted to the production of corn as well as of clover.

The other soil types referred to are developed only in very small areas in that portion of the Salem region which falls within the Philadelphia district, and as the remainder of this district maintains much the same soil conditions as far as the eastern border, these less important soil types will not be described in detail. Enough has been said to show that the Coastal Plain portion of the Philadelphia district possesses a considerable variety of soil conditions in which important truck-soil areas predominate, although fruit, corn, and wheat lands also occur. The soils are generally well drained, except along the main stream courses, and important crops are raised throughout the region.

WATER RESOURCES.

By F. Bascom.

SURFACE WATER.

PIEDMONT PLATEAU.

The tributaries of the Delaware which traverse the Piedmont Plateau of the Philadelphia district are Pennypack and Tacony creeks, Schuylkill River, and Cobbs, Darby, Crum, Ridley, and Chester creeks.

Pennypack and Tacony creeks.—These creeks have drainage basins of approximately 63 and 45 square miles respectively. They drain a cultivated and populated district, in which woodland has been sacrificed to culture and is found now only on the steep hillsides and bottom lands bordering the creeks. There are no natural storage basins along their courses and the tributaries are fed by surface springs and rainfall; under these surface conditions rainfall is not detained by ground storage. The run-off is proportionately great and carries with it large quantities of surface soil to the tributaries. The main streams become torrential and turbid and transport a heavy load of fine sediment. The same conditions which diminish ground storage increase evaporation during the summer months, hence there is a marked seasonal fluctuation in the stream flow. The exposed soil is parched and cracked in summer by evaporation. The level of ground water falls below the surface springs and upper courses of the tributaries; the springs, therefore, dry up and the streams are reduced. Thus January, February, March, and sometimes April are months usually of large stream flow, while August, September, and October are usually months of least stream flow. The water power of these streams is only partly utilized. They are not a source of water supply, with the exception of Sandy Run, a tributary to the Pennypack.

Schuylkill River.—The Schuylkill, with its chief tributaries, the Wissahickon, the Perkiomen, and the Pickering, is an important source both of water power and of water supply. Observations of the daily stream flow of the Schuylkill made by the Philadelphia Bureau of Water show that the months of maximum stream flow are December to April, and that the months of minimum stream flow are June to September. The maximum daily average stream flow in 1902 occurred during March and was 5,840,530,000 gallons.[a] The minimum stream flow was in June and was 594,430,000 gallons.

Norristown and Philadelphia take their water supply chiefly from the Schuylkill. From Norristown to Philadelphia all the sewage and industrial refuse of the towns along the Schuylkill drains into that river and render the unfiltered water entirely unfit for domestic purposes. This has made necessary an efficient system of filtration such as is now operated at Roxboro and Belmont.

Perkiomen Creek.—The Perkiomen drains a region of which 20 per cent is woodland, 77.5 per cent cultivated land, 0.5 per cent flats, and 2 per cent roads. Like the other streams of the district, the Perkiomen shows a maximum stream flow in January, February, and March, and a minimum stream flow in August, September and October. The maximum observed flow for one day in February, 1902, in round numbers was 27,300,000 gallons per day per square mile of area drained above the gaging station, an area of 152 square miles. The minimum observed flow for one day was in September, 1885, and was only 21,700 gallons per day per square mile. The average daily flow of the Perkiomen is found to be 177,900,000 gallons per day above the gaging station.

Comparison of run-off, in inches, of Perkiomen Creek and Schuylkill River from January to December.

Year.	Perkiomen Creek.	Schuylkill River.
1898	21.50	24.39
1899	24.66	22.29
1900	15.21	18.23
1901	17.55	17.80
1902	29.01	29.02

Pickering Creek.—This stream appears on the western edge of the Norristown quadrangle, but most of its drainage area lies outside the Philadelphia district. It has a drainage basin of 65.88 square miles. This basin lies, for the most part, on pre-Cambrian gneiss, but the last 3 miles of the creek's course are on the Triassic formations. Its minimum annual flow has been estimated at 4,000,000 gallons, and its maximum flow at 4,000,000,000 gallons.

Cobbs, Darby, Crum, Ridley, and Chester creeks.—These creeks flow in roughly parallel courses and possess drainage basins of approximately the same area. For Crum and Ridley creeks the stream flow has been recorded; the amount can not be very different for Darby and Chester creeks.

Crum Creek has a drainage area of 29.47 square miles, of which about 40 per cent is wooded. Its minimum average monthly flow from 1892 to 1901 was 5,220,000 gallons in twenty-four hours (September, 1901); its maximum flow was 138,000,000 gallons in twenty-four hours (May, 1894).

Ridley Creek possesses a drainage basin of 33.6 square miles. Its minimum computed flow between 1892 and 1901 was 5,940,000 gallons in twenty-four hours (September, 1895). Its maximum observed flow was 157,500,000 gallons in twenty-four hours (May, 1894). Its minimum flow occurs in August, September, and October, at the close of the growing period and the opening of the replenishing period. At this time stream flow has not begun to show the effects of the season of replenishing, and the ground water, at the close of a period of maximum vegetable growth and maximum evaporation, is at its lowest level. The maximum flow occurs in March, April, or May, at the close of the storage period, when evaporation and plant absorption are at a minimum and ground and surficial storage at a maximum.

[a] 1,000,000 gallons a day=1.55 second-feet.

From Ridley Creek 1,500,000 gallons every twenty-four hours are taken by the water department of the borough of Media. From Crum Creek 2,000,000 gallons are taken by the Springfield Water Company and distributed to the suburban towns. It has been asserted that a draft of 1,000,000 gallons per day per square mile of watershed could be made upon the tributaries of the Delaware.

The average rainfall, 1884 to 1897, at 22 stations where observations were made by the Philadelphia water bureau was about 48.5 inches. Of this average rainfall nearly 50 per cent, or 24.1 inches, was found in the stream flow.

Delaware River.—As a source of water supply and water power the Delaware is extremely important. It has been utilized for this purpose to a large degree, but the increasing impurity of its water, like that of the water of the Schuylkill, necessitates an elaborate system of filtration, such as is now being established at Torresdale by the city of Philadelphia. With adequate filtration the Delaware can supply the increasing population on its banks with abundant water. It now supplies in New Jersey 142,636 inhabitants with 17,010,464 gallons of water daily. The estimated supply for Trenton without storage is 601,600,000 gallons. The analysis of the water of Delaware River at Trenton shows that above the city the river is polluted with sewage and industrial refuse to a dangerous degree.

The water power of the Delaware has been largely left unutilized, probably because of the difficulty of building dams and the comparative cheapness of fuel. The number of mills on the Delaware above Trenton is only 186, with a net horsepower of 6658. The New Jersey Survey estimates that 50.7 horsepower per foot at Trenton is unused.

Ponds.—The Philadelphia district, lying south of the limit of glacial deposits, is quite without natural ponds. The ponds that exist are insignificant and occupy artificial basins. The streams thus lack storage basins.

COASTAL PLAIN.

The streams of the Coastal Plain of the Philadelphia district are without exception tributary to the Delaware. They are tidal for half or more than half their lengths, and flow for a considerable fraction of their courses upon marls. These features greatly impair the availability of the streams for water supply or water power. The water supply of the district, therefore, is not taken from the streams, except in the cases of Haddonfield and Woodbury, where headwaters unaffected by marls are available. The area of the drainage basins of the chief streams and their daily average flow are given in the following table:

Area of drainage basins and daily average flow of chief streams.

Creek.	Drainage basin.	Average daily flow at mouth.	Average daily flow of driest month at mouth.
	Sq. miles.	*Gallons.*	*Gallons.*
Pensauken	35.4	39,900,000	5,900,000
Coopers	40.5	40,000,000	6,800,900
Big Timber	59.3	55,400,000	9,980,000
Woodbury[a]	------	------	------
Mantua, above Hurffville	51.2	------	2,180,000
Raccoon[b]	44.4	------	------
Oldmans	44.4	------	1,680,000

[a] Tidal for more than half its length of 7 miles.
[b] Tidal for more than half its length.

UNDERGROUND WATER.

PIEDMONT PLATEAU.

Erosion of the heterogeneous, dipping strata of the Piedmont Plateau produces favorable conditions for the emergence of underground water in the form of springs. Between the Newark group and the Paleozoic rocks, brought to the surface by folding and erosion, springs emerge on all the hillsides. The small creeks are fed by springs and every farmhouse is supplied with spring water. A remarkably copious spring in the Paleozoic belt issues from the base of the limestone at Spring Mill.

Deep wells in the Wissahickon gneiss.

Location.	Depth (feet).	Diameter (inches).	Water supply (gallons per minute).
Barrett Ice Plant, Bryn Mawr, 600 feet west of Bryn Mawr avenue, on the county line road; 2 wells	752 475	------ ------	10 60
Bryn Mawr Hospital	135	------	[a] 5
Bryn Mawr Hotel	350	10	50
Springfield Water Company station at Bryn Mawr; 2 wells	560	6	83⅓
Overbrook, 2 wells (F. P. Hayes)	150 240	6	500 10
Jenkintown	349	6	75
Jenkintown station	324 150	------ ------	75 ------
Wyncote:[b]			
A	154	------	97
B	205	------	60
C	212	------	76
D	188	------	70
E	147	------	78
F	235	------	30
G	175	------	50
H	200	------	[c] 28
Cheltenham Academy	352	------	12
Chelten Hill station	118	------	3
Oak Lane; 2 wells	125 340	------ 8	1 208
Noble station	163	1	16

[a] Without head.
[b] Eight wells less than 100 feet apart. These wells furnish water to those parts of Jenkintown not supplied by the North Springfield Water Company.
[c] The best flow is at a depth of 100 feet. The flow increases with use.

Successful artesian wells have been bored in the pre-Paleozoic and Paleozoic formations. The more important wells are as follows: In the pre-Cambrian Baltimore gneiss and gabbro complex there is a well at Wayne 150 feet deep, yielding about 200 gallons per minute; at Radnor station there is a well on the property of the Pennsylvania Railroad Company which furnishes water for locomotives. The well is 12 inches in diameter and 1000 feet deep, but it is worked only to a depth of 120 feet, yielding at this depth by the pneumatic system of pumping 60 gallons per minute. At Newtown Square a well in the Baltimore gneiss 300 feet deep and 8 inches in diameter yields 60 gallons of water per minute.

There are between 40 and 50 artesian wells in and near Philadelphia which have passed through the Raritan formation and which gain their water supply from the pre-Paleozoic crystalline rocks. Data concerning these wells are given below.

In the Chickies quartzite wells have been successfully bored as follows:

Wells in Chickies quartzite.

Locality.	Depth (feet).	Water supply (gallons per minute).
Near Fort Washington (J. Conrad)	64	10
Tyson's, Edge Hill	150	------
Waverly Heights, Edge Hill (Winthrop Smith)	570 500	No water.
Near Williams station	132	5
Willow Grove	780	100

In the Shenandoah limestone there are wells as follows:

Wells in Shenandoah limestone.

Locality.	Depth (feet).	Water supply (gallons per minute).
Near Flourtown (Kunkle's farm)	60	83⅓
Near Lancasterville (H. F. Hallman)	98	10
Near King of Prussia (William Thomas)	90	------
Near Williams station (Thomas Phipps)	43	[a] 900
Near Plymouth station (Hovenden)	90	40

[a] Highly magnesian.

On the southern slope of the South Valley Hills numerous wells have been bored for private individuals. Those wells of which record has been obtained have penetrated the Octoraro schist of these hills. They vary in depth from 60 to 80

Deep wells reaching the pre-Paleozoic crystalline rocks.

Location.	Depth (feet).	Diameter (inches).	Water supply (gallons per minute).	Depth to rock (feet).
Navy-yard, League Island	906	------	------	[a] 260
Do	600	------	------	[b] 270
Near Grays Ferry	232	------	------	137
Hog Island, Delaware River	456	------	------	208
Delair	188	------	------	168
Cramer Hill Ferry	126	------	------	115
Camden, near Front and Elm street	115⅙	------	------	95
Fairmount Co. Ice Works, 2401 Green street	300	8	120	------
Schemm's brewery, Twentieth and Poplar streets	252	8	[c] 60	------
Bower & Co.'s packing house, Twenty-fourth and Brown streets	495	6	60	------
Thirteenth and Mount Vernon streets	2,031	8	[d] 50	------
Brewery, 1708 North Twelfth street.	350	8	100	------
Seventh and Callowhill streets	452	8	150	------
Brewery, 1729 Mervine street	340	8	75	------
Prospect brewery, Eleventh and Oxford streets	350	8	[c] 75	------
Crown and Willow streets	1,000	10	100	------
Ice works, 23 North Eleventh street	250	8	300	------
Wall-paper factory, 2228 North Tenth street	210	8	100	------
Fifteenth and Market streets	500	8	100	------
Woolen mills, Ninth and Dauphin streets	272	6	30	------
Carpet works, Eleventh and Cambria streets	200	6	50	------
Dye works, 4520 Worth street, Frankford	335	6	250	------
Continental Hotel, Ninth and Chestnut streets	240	8	40	------
Hotel, Eleventh and Pine streets	576	5	[e] 40	------
Hotel, 108 South Broad street	484	8	60	------
Hotel, Broad street below Locust	525	8	70	------
Turkish bath, 1104 Walnut street	265	8	110	------
Machine shop, Fifty-second street and Lancaster avenue	100	6	200	------
Morocco works, Frankford and Junction streets	500	6	500	------
Do	322	6	500	------
Do	252	6	500	------
Children's Home, west of Georges Hill	364	8	[c] 60	------
Angora Cotton factory	252	8	60	------
Vicker residence, Clifton Heights	30	5	100	------
G. Taylor, southeastern part of city	670	12	250	------
Morris and Otsego streets	140	------	------	------
Laurel and Beech streets	308	------	------	------
The Charles E. Hines Co., Broad street above Race	2,000	------	------	------
Jacob Hornung, 3125 Clearfield street	525	8	------	20
National Biscuit Co., Broad and Cambria streets	125	------	------	60
Franklinville dye works, 3961 North Fifth street	314	6	40	------
Berg Company, Richmond and Ontario streets	400	8	100	125
Bedford Company, Frankford	1,021	8	60	20
Methers, Fifty-third and Baltimore avenue	114	------	40	15
Beekman, Sixty-ninth and Haverford avenue	64	8	60	25
Mitchell & Pearson, Schuylkill avenue and Reed street	320	8	150	18
Millbourne Mills Co., Sixty-third and Market streets	600	------	50	20
John Wyeth & Bro., Eleventh street and Washington avenue	93	8	30	90
Quaker City Chocolate Co., 2140 Germantown avenue	480	8	40	60
Camden Brewing Co., South Camden	------	8	------	240

[a] Water at 536 feet. [b] Water at 572 feet. [c] Flowing wells.
[d] Water not good in boilers. [e] Lime and iron water.

feet and supply abundant water. In the shallow wells the water is soft. From the deeper wells it is reported to be hard. The thickness of the mica schist is not great on the slope of the hill and probably the hard water has its source in a limestone horizon.

The gently northwestward-dipping sandstones interbedded in shales belonging to the Newark group, which occupy the northern third of the Philadelphia district, afford favorable conditions for bored wells, and the water supply of that area is largely furnished by such wells. The following are the deep wells of which reports could be obtained:

Deep wells in the rocks of the Newark group.

Locality.	Depth (feet).	Depth in feet below surface to which water rises.	Geologic horizon.	Water supply (gallons per hour).
Norristown, Sandy Hill	169	74	Sandstone bed in Stockton formation	900
Norristown, near Stony Creek	102		do	1,003
Norristown	100	16	do	3,000
Between Norristown and Jeffersonville (West End Land Co.).	75		do	1,500
Jeffersonville (F. A. Potts)	$92\frac{1}{2}$		Two sandstone horizons in Stockton formation: 35-40, 86-$92\frac{1}{2}$.	(est.) 1,200
Hickorytown	70	45	Sandstone bed in Stockton formation	600
Bridgeport (Chas. Meyers)	65		do	600
Sandy Hill schoolhouse, Whiteplain Township	60	28	do	120
Washington Square	35	11	do	1,500
Washington Square schoolhouse	$38\frac{1}{2}$	14	do	600
Belfrey station, Stony Creek R. R.[a]	37	15	do	30
Ambler (3)	275		Cambro-Ordovician limestone	2,100
Shady Grove schoolhouse	45	19	Probably sandstone of Lockatong formation.	900
Morris road and Skippack pike, North Wales[b]			Sandstone of Lockatong formation	
Lansdale	159		Sandstone horizons of Brunswick formation.	
Do	376		do	
Do	611	140	do	
Lansdale, southwest of	65	15	do	

[a] Abandoned. [b] Water very hard.

COASTAL PLAIN.

The chief water-bearing formations of the Coastal Plain are Cretaceous. The earlier discussions of the geology of the Cretaceous have shown that conditions are favorable for artesian wells in these rocks. Permeable sandy or gravelly beds are interstratified with impermeable clay beds. At the outcrops of the more porous beds water is absorbed and, there being no outlet to the east, these beds become saturated by water which is under considerable pressure. When wells penetrate such beds the water rises, and if the mouth of the well is lower than the outcrop where the water enters, the well overflows. The principal water horizons within the Coastal Plain of the Philadelphia district are as follows:

(1) The pre-Paleozoic crystalline formations which underlie the Cretaceous, Tertiary, and Quaternary deposits. This floor is reached by wells in the Delaware Valley at a depth of 95 to 270 feet, and at varying depths below its upper surface yields a large supply of excellent water. Such wells have been sunk in Camden, Philadelphia, Delair, at Cramer Hill Ferry, near Grays Ferry, and on League Island. A list of these wells is given above.

(2) The basal Raritan beds. These are heavy yellowish-white gravel and cobble strata near the base of the Raritan or plastic clays. They are reached by wells in Camden (Esterbrook Pen Company, American Nickel Works, power house of Camden Railroad Company, city hall, United States Chemical Works, county prison, Reeves Oilcloth Works, foot of Penn street, Cooper Hospital well, pumping station wells), Philadelphia (Little Dock street and Moore street wharf), Gloucester, National Park below Redbank, Washington Park, Stockton, Pavonia, Delair, Riverton, and Maple Shade. The supply of water from this horizon is fair. The depth of the wells varies from 70 feet in Camden to 375 feet in Maple Shade.

(3) Beds in the Raritan above the basal beds. Interstratified with the clays and fine sands of the Raritan occur local beds of coarse sand or gravel. These beds are water bearing. Water has been obtained in them at Camden, Gloucester, Paulsboro, Pavonia, Stockton, Collingswood, Delair, Palmyra, Morris, Riverton, Pedricktown, Billingsport, Magnolia, Westville, and Maple Shade. The depth at which water is reached varies from 67 feet in Camden to 260 feet in Maple Shade. The supply is excellent.

(4) At the top of the Raritan there are bluish-white gravel beds which furnish an abundant supply of fine water. Wells have been sunk to this horizon south and east of Camden, and they vary in depth from 46 feet in Cinnaminson to 117 feet in Woodbury. The following are localities where water from this horizon has been obtained: Cinnaminson, Collingwood, Gloucester, Westville, Woodbury, Wenonah, Sewell, Maple Shade, Thorofare, Mount Ephraim, Washington Park, Clarksboro, Mickleton, and Swedesboro.

(5) In the Matawan above the basal beds are sandy beds from which many wells derive their water supply, although it is generally not very abundant. Their depth at Maple Shade is from 63 to 97 feet, increasing to the south. Wells in these beds are located at Newbold, South Westville, Woodbury, Wenonah, Sewell, Maple Shade, Merchantville, Kirkwood, Laurel Springs, Blackwood, Thorofare, Clarksboro, and Mickleton.

(6) The Mount Laurel sand at the base of the Monmouth group affords a water supply. Many of the best wells in southern New Jersey, outside of the Philadelphia district, obtain their supply from this horizon. There are such wells at Laurel Springs, Blackwood, and Sewell, which vary in depth from 70 to 100 feet.

(7) The Vincentown sand, which constitutes the upper portion of the Rancocas group, is a highly calcareous green sand composed chiefly of bryozoan earth, and constitutes a water-bearing horizon. Wells at Laurel Springs gain their supply from this horizon at a depth of 45 to 50 feet.

(8) The basal member of the Miocene is a water-bearing formation. No wells have been reported to tap this formation in the Philadelphia district, though it is an exceedingly important source of water supply in southeastern New Jersey.

WATER SUPPLY TO PHILADELPHIA AND SUBURBAN TOWNS.

Philadelphia Bureau of Water.—Philadelphia, Falls of Schuylkill, Manayunk, Roxboro, Chestnut Hill (in part), Mount Airy, Germantown, Frankford, Bridesburg, Wissinoming, and the intervening areas are supplied with water through the Bureau of Water of Philadelphia.

The water is pumped from the Schuylkill at five stations—(1) Roxboro or Shawmont, (2) Queen Lane, (3) Belmont, (4) Spring Garden, (5) Fairmount. Water is also pumped from the Delaware at the Frankford station, one-half mile northeast of the mouth of Wissinoming Creek. From these stations it is pumped to reservoirs at Roxboro, Queen Lane, Fairmount Park, and Frankford, whence it has been distributed without filtration. The increasing impurity of the Schuylkill and Delaware waters, contaminated by the sewage of the numerous manufacturing towns along their courses, has rendered them utterly unfit for household use without being filtered.

A new and comprehensive system of plain sand filters is now being introduced. There are three plants, located at Roxboro, Bala (Belmont and City Line avenues), and Torresdale. At Torresdale water is taken from the Delaware, and after being passed through sand filters is carried in a rock tunnel to Robbins street, Tacony, whence it is to be distributed to the Philadelphia district, which includes the Queen Lane district (the Falls of Schuylkill and Germantown, in part), East Philadelphia, and the towns lying between Philadelphia and Torresdale, with the exception of Tacony and Holmesburg. Overbrook and West Philadelphia are to be supplied from the Belmont plant. The Roxboro district, comprising Roxboro, Manayunk, Chestnut Hill, Mount Airy, and Germantown (in part), are now supplied from the Roxboro filter plant, which is completed and in operation.

The combined capacity of the filters is about 320,000,000 gallons, or 30,000,000 gallons more than the capacity of the Croton Aqueduct. At present New York uses 120 gallons per capita daily, whereas Philadelphia uses 229 gallons.

Springfield water companies.—The Springfield Water Company and the North Springfield Water Company, under the control of the American Pipe Manufacturing Company, supply with water most of the suburban districts of Philadelphia. All towns situated on the north bank of the Delaware between Cobbs and Crum creeks, and Eddystone, west of Crum Creek, are supplied by the Springfield Water Company. The towns along the Pennsylvania Railroad main line as far as Glenlock, 25.3 miles from Philadelphia, are supplied by the Springfield and North Springfield water companies, also the towns east of the main line, Conshohocken, Chestnut Hill (in part), Oreland, Glenside, Jenkintown (in part), Oak Lane, and the intervening towns. Chester, Media, Norristown, Lansdale, Tacony, and Holmesburg are the only considerable towns in the Philadelphia district not supplied by the Philadelphia Bureau of Water or the Springfield water companies.

The Springfield Water Company takes its water from Crum Creek at a point $1\frac{1}{2}$ miles northeast of Media, in the township of Springfield. The water is first coagulated with sulphate of alumina and passed into a 10,000,000-gallon sedimentation basin. Thence it passes into a suction well, from which it is pumped through six pressure filters of 500,000 gallons capacity each, which are thoroughly washed and rinsed daily.

The North Springfield Water Company takes its water from Pickering Creek near its mouth. Here are located a pumping station, a sedimentation basin, and filters. There are three filters—one slow sand filter covering one-half acre, with a capacity of 1,500,000 gallons, and two gravity mechanical filters with a combined capacity of 2,500,000 gallons. The water is first pumped to a 10,000,000-gallon sedimentation reservoir located close to the pumping station, but on the opposite side of Pickering Creek. From the sedimentation basin the water gravitates through a filter plant to a 1,500,000-gallon clear-water basin, and thence the water is pumped to the distributing reservoirs by means of the two high-duty fly-wheel pumping engines.

There are under the control of the North Springfield Water Company three artesian wells, which act as a reserve supply—one at Bryn Mawr, 560 feet deep, good for 120,000 gallons in twenty-four hours, and two at Oak Lane, 340 feet deep, good for 300,000 gallons in twenty-four hours. The hardness of the water of the Bryn Mawr well is 5.5 degrees in 100,000, and that of the Oak Lane wells 5.29.

Analysis of the filtered water of Pickering Creek gives the following results:

Analysis of filtered water of Pickering Creek.

	Parts per million.
Free ammonia	0.08
Nitrogen as nitrates	1.33
Chlorine	5.0
Alkalinity, in terms of carbonate of lime	37.0
Hardness, in terms of carbonate of lime	42.0
Number of bacteria exceedingly low.	

Analyses of Crum Creek water taken from the spigots are even more favorable, showing the water to be excellent in quality for domestic and manufacturing uses.

Tacony, Holmesburg, and Torresdale.—These towns, in the thirty-fifth and forty-first wards of the city of Philadelphia, are supplied with water by the Disston Water Company, which leases and operates the plant of the Holmesburg Water Company, in Holmesburg at the mouth of Sandy Run. This little stream rises near Fox Chase and pursues a winding course over a rock and gravel bottom to Pennypack Creek, into which it empties at a point about $2\frac{1}{2}$ miles above the Delaware. It is fed by springs all along its course. A mechanical system of filtration, installed by the New York Continental Jewell Filtration Company, with a capacity of 2,000,000 gallons per day, is in use.

Chester.—The water supply for the city of Chester is taken from Delaware River. It is pumped a distance of 4 miles from Chester, where it is deposited in two 8,000,000-gallon reservoirs. After it has passed through a process of sedimentation it is put through mechanical filters and thence goes to a clear-water basin.

Media.—The water department of the borough of Media obtains its water supply from Ridley Creek. The water is pumped through sand filters to a reservoir and standpipe.

Norristown.—The city of Norristown is supplied with water by the Norristown Water Company, which obtains its water supply from the Schuylkill. The water pipes are laid under the river and draw their supply from the channel to the southwest of the island opposite Norristown. Thus is avoided contamination from Stony Creek, which carries the drainage of the State Insane Asylum.

The water is first pumped into a small sedimentation basin, where it is coagulated by means of sulphate of alumina. It then filters by gravity through a 5,000,000-gallon filter plant and passes into a clear-water basin, from which it is pumped to the distributing reservoir located on the hill to the north of Norristown. This reservoir has a capacity of 11,000,000 gallons.

Lansdale.—The water supply of Lansdale is furnished by the Lansdale Water Company, which owns two artesian wells and a standpipe with a capacity of 38,000 gallons.

Ambler.—The Ambler Spring Water Company, which supplies Ambler, obtains very pure water from a large number of springs issuing from a sandstone bed of the Stockton formation. These springs furnish about 2,000,000 gallons daily. In addition, a large spring in a quarry in the Stockton formation is used, which yields about 15,000 gallons per hour.

WATER SUPPLY TO CAMDEN AND SUBURBAN TOWNS.

Camden.—For many years (since about 1853) the city of Camden had taken its water supply from Delaware River southeast of Petty Island. The pumping station was located at Pavonia, northeast of the mouth of Cooper Creek. Because of the increasing impurity of the water the supply became very unsatisfactory, and in 1897 and 1898 there were sunk near Morris station more than a hundred artesian wells. These wells gain their water from two horizons within the Raritan. The deeper wells probably reach the base of the Raritan. All the wells are furnished with bottom strainers and supply an abundance of pure water. A pumping station has been established at this point and more than 20,000,000 gallons of water can be obtained every twenty-four hours.

Riverton and Palmyra.—The Riverton and Palmyra Water Company, which supplies these two towns, obtains its water from a dug well, 15 feet deep, near Delaware River. The well is sunk in gravel and intercepts the water on its way to the river. From 300,000 to 500,000 gallons of water per day are pumped from this well, and it is estimated to have a capacity of 1,000,000 gallons per day.

Gloucester.—This town obtains its water from open wells which supply 1,000,000 gallons of water per day.

Newbold and Westville.—These towns are supplied by the Westville-Newbold Water Company, which obtains water from three artesian wells 160 feet deep.

Woodbury.—This town is supplied from the headwaters of Mantua Creek. The water is used without filtration. The larger portion of Mantua Creek lies upon the marls and is therefore unfit for a water supply.

Redbank and Paulsboro.—Redbank is supplied from both open and tube wells. Paulsboro obtains its water supply from wells 65 feet deep, from which 350 gallons per minute are pumped. No filter plant is required. The water is clear, colorless, and odorless, and analysis shows it to be remarkably pure.

Haddonfield.—The water supply of Haddonfield is taken from a tributary to North Branch of Coopers Creek. This stream is fed by springs and furnishes about 5,000,000 gallons per day. It is collected in a reservoir which is protected from surface water. There is no filtration plant.

Wenonah and Merchantville.—These towns are supplied from springs.

March, 1908.