DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, SECRETARY
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

GEOLOGIC ATLAS
OF THE
UNITED STATES

ELKTON-WILMINGTON FOLIO

MARYLAND-DELAWARE-NEW JERSEY-PENNSYLVANIA

BY

F. BASCOM AND B. L. MILLER

SURVEYED IN COOPERATION WITH
THE STATE OF MARYLAND

WASHINGTON, D. C.
ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY
GEORGE W. STOSE, EDITOR OF GEOLOGIC MAPS   S. J. KUBEL, CHIEF ENGRAVER
1920

GEOLOGIC ATLAS OF THE UNITED STATES.

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

THE TOPOGRAPHIC MAP.

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

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

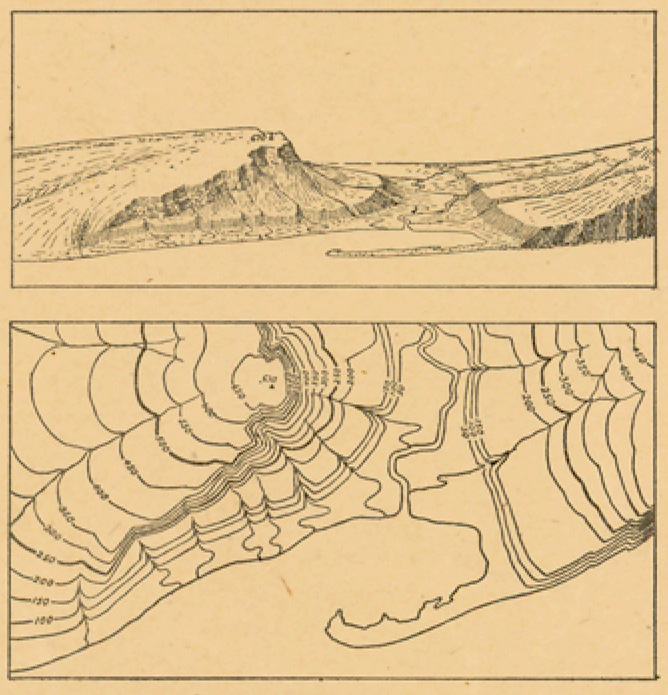


FIGURE 1.—Ideal view and corresponding contour map.

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

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

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

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

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

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

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

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

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

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

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

THE GEOLOGIC MAPS.

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

KINDS OF ROCKS.

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

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

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

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

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

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

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

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

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

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

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

FORMATIONS.

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

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

AGES OF ROCKS.

Geologic time.—The time during which rocks were made is divided into *periods*. Smaller time divisions are called *epochs*,

DESCRIPTION OF THE ELKTON AND WILMINGTON QUADRANGLES.[1]

By F. Bascom and B. L. Miller.

INTRODUCTION.

GEOGRAPHY OF THE ELKTON AND WILMINGTON QUADRANGLES.

By F. Bascom.

LOCATION AND AREA.

The Elkton and Wilmington quadrangles, described in this folio, lie between parallels 39° 30′ and 39° 45′ and meridians 75° 30′ and 76°. They therefore include one-eighth of a square degree, which in this latitude is about 460 square miles. (See fig. 1.) The area lies in Cecil County, Md., New Castle

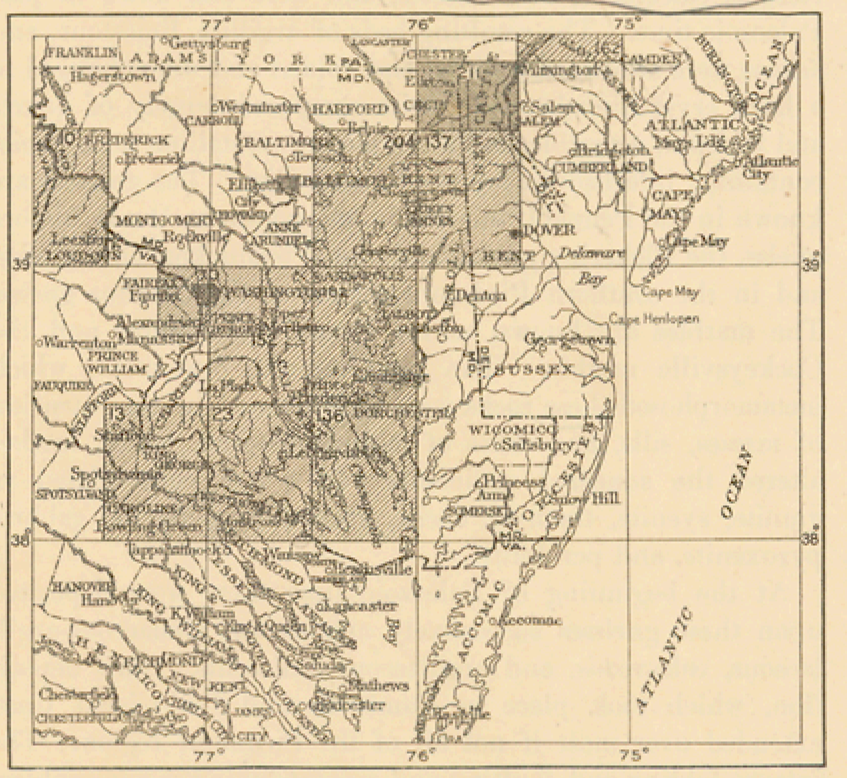


FIGURE 1.—Index map of Delaware and parts of adjacent States.

The location of the Elkton and Wilmington quadrangles is shown by the darker ruling (No. 211). Published folios describing other quadrangles, indicated by lighter ruling, include Nos. 10, Harpers Ferry; 13, Fredericksburg; 23, Nomini; 70, Washington; 136, St. Marys; 137, Dover; 152, Patuxent; 162, Philadelphia; 182, Choptank; 204, Tolchester.

County, Del., Chester County, Pa., and Salem County, N. J., thus including parts of four States. It contains a population of about 150,000. The city of Wilmington, which is 26 miles southwest of Philadelphia, is in the extreme northeast corner of the Wilmington quadrangle, and Delaware River, which is navigable by ocean steamers, crosses the east side of that quadrangle.

CLIMATE, VEGETATION, AND CULTURE.

The physical features of the Elkton and Wilmington quadrangles are not such as to produce great local differences in climate; on the contrary, the climate throughout the area is uniform. Observations made at Wilmington and Newark, Del., in the Wilmington quadrangle, and at Woodlawn, Md., 4½ miles west of the Elkton quadrangle, indicate the normal weather in these quadrangles. Some of the results of these observations are given below.

The mean annual temperature at Wilmington from 1913 to 1915, a period of 3 years, was 56.5° F. The maximum monthly mean during that period was 78.6°, in July, 1913, and the minimum monthly mean was 30.4°, in February, 1914. The average temperature in February was 34.9°; the average in July was 77.4°; and the difference between the coldest and the warmest months during these years was 42.5°. The difference in seasonal temperature is not so great as it is farther inland.

The mean annual temperature at Newark during a period of 13 years was 52.4°. The lowest monthly mean in that period was 28.5°, in February, and the highest monthly mean was 75.1°, in July, the average seasonal difference thus being 46.6°. The highest temperature recorded in 12 years at Newark was 100°, in July, and the lowest temperature recorded in the same period was —12°, in February.

The mean annual temperature at Woodlawn for 11 years was 51.9°, the mean temperature in January was 29.8°, and the mean temperature in July was 75.8°, the seasonal difference thus being 46°. The highest temperature recorded in this period was 100°, in July, and the lowest temperature was —10°, in January.

[1] The part of this area that lies in Maryland was surveyed in cooperation with the Maryland Geological Survey.

The first killing frost is likely to occur in this region just after the middle of October (October 17) and the last killing frost just after the middle of April (April 17), leaving a period of six months for safe plant growth.

Precipitation in the Elkton and Wilmington quadrangles is abundant and normally is equably distributed through the year. The mean annual precipitation at Wilmington for 20 years was 42.61 inches. The mean annual precipitation at Newark for 14 years was 43.40 inches. The mean annual precipitation at Woodlawn for 11 years was 47.96 inches. The months of greatest precipitation are June, July, and August, when thunder showers are of frequent occurrence. Precipitation tables for this region show that rainfall is likely to be abundant in all months of the year, and that, though the variability is greatest during the crop season, no month is without rainfall. The season of snowfall extends from November to April, and the average annual fall is 31.7 inches. The prevailing winds are from the northwest and the southwest.

Climate and soil are favorable to the vigorous growth of many kinds of forest trees, both northern and southern types. At one time the fertile uplands were covered with splendid forests of oak, chestnut, and beech, and the streams were fringed with the tulip tree, black walnut, and hickory, but the best soils have been cleared for agriculture, and the abuse and neglect of the remaining forests have reduced them to mere remnants, made up of young or defective trees growing on barren soil or along streams. Even such timber as survives on barren soil is being depleted by the charcoal burner and destroyed by fires started through carelessness. The timber that fringes the cultivated lands, most of it growing on good soil but in places too wet or too steep for cultivation, is utilized as firewood and for other domestic purposes.

Among the trees and shrubs that are native to the Elkton and Wilmington quadrangles are pitch, scrub, and short-leaf pine, red cedar, butternut, black walnut, hickory, willow, poplar, birch, beech, chestnut, oak (13 species), elm, tulip tree, pawpaw, mulberry, sycamore, sweet gum, locust, maple, black gum, black cherry, redbud, dogwood, laurel, box elder, holly, sumach, and witch hazel.

The Baltimore & Ohio Railroad, several branch lines of the Pennsylvania system, and the Philadelphia & Reading Railroad traverse the quadrangles, connecting the cities of the Atlantic seaboard with one another and with through western and southern routes.

Electric lines connect Delaware City and New Castle with Wilmington and Wilmington with Kennett Square and West Chester, to the north.

Delaware River is a thoroughfare for ocean and coastwise steamers and is connected with Elk River by the Chesapeake & Delaware Canal, which extends from Delaware City to Chesapeake City. Northeast and Elk rivers are navigable by coastwise craft below Northeast and Elkton. The quadrangles are traversed by a network of highroads, which are in fair condition for horse-drawn vehicles. A cement automobile road that connects Wilmington with Baltimore passes through Newark, Elkton, and Northeast.

Wilmington (population 110,168), the county seat of New Castle County, Del., is the commercial and manufacturing center of Delaware. Its factories include shipyards, iron and steel works, manufactories of carriages, railway cars and wheels, boilers, bridges, paper-making machinery, paper, leather, fiber, cotton, and flour. At Newport there are glue and paint works. Newark has machine shops and fiber mills and is the seat of Delaware State College, Delaware College for Women, and the Delaware Agricultural Experiment Station.

Elkton, the county seat of Cecil County, Md., contains cotton mills, canneries, iron foundries, and boat yards. Northeast manufactures clay products and flour.

PHYSIOGRAPHIC DIVISIONS OF THE REGION.

The Elkton and Wilmington quadrangles lie in two unlike geographic divisions—the Appalachian Highlands and the Atlantic Plain; the northwestern third of the area is included in the Appalachian Highlands and the southeastern two-thirds in the Atlantic Plain. (See fig. 2.) It is desirable to consider the geographic and geologic character of these divisions in order to comprehend the history of the Elkton-Wilmington area.

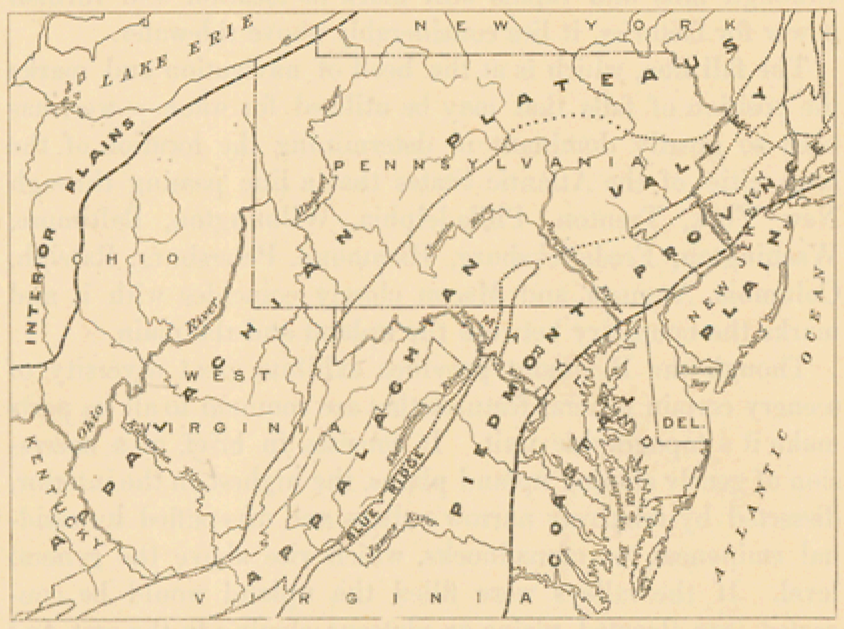


FIGURE 2.—Map of the Middle Atlantic States showing physiographic divisions.

The boundary between the Coastal Plain and the Piedmont province marks the "fall line."

THE APPALACHIAN HIGHLANDS.

By F. Bascom.

SUBDIVISIONS.

The Appalachian Highlands extend from the Interior Plains on the west to the Atlantic Plain on the east and from Canada on the north to central Georgia and Alabama on the south. In the latitude of the Elkton and Wilmington quadrangles they are composed of four well-defined provinces, the Appalachian Plateaus, the Appalachian Valley, the Blue Ridge, and the Piedmont province, which extend from northeast to southwest and within each of which the rocks, the rock structure, and the surface features present a general similarity. The Appalachian Plateaus, consisting of the dissected Allegheny Plateau, the Cumberland Plateau, and several lower plateaus, which descend from an eastward-facing escarpment, the Allegheny Front, westward to the Interior Plains, form the westernmost of these provinces. The great Appalachian Valley, comprising in Pennsylvania and Maryland a series of valleys and intervening narrow ridges, constitutes the central province. It lies between the Allegheny Front and the Blue Ridge or, where that is absent, the western escarpment of the Piedmont province. The Blue Ridge stands at the eastern border of the Appalachian Valley, separating it from a group of plateaus which stretch away eastward and merge into the Atlantic Plain. This group of plateaus constitutes a vast upland known as the Piedmont province. A small part of the Piedmont province of the Appalachian Highlands lies within the Elkton-Wilmington district, constituting its northwestern third.

THE PIEDMONT PROVINCE.

GEOGRAPHY.

The Piedmont province, embracing the Piedmont Upland and the Triassic Lowland, owes its name to its location at the foot of the Blue Ridge. It extends northeastward along the eastern foot of the mountains until it merges into the New England province and southwestward until it merges into the eastern Gulf Coastal Plain, in a curve parallel to the Atlantic coast. Its mean width is 60 miles, and its maximum width, in its middle part, is 120 miles.

Between the Piedmont province and the submerged eastern margin of the continental shelf lies the Atlantic Plain, which is about 250 miles wide. From the Massachusetts coast northward the entire Atlantic Plain is submerged, forming the continental shelf, and the eastern border of the New England upland coincides with the coast line. From Massachusetts southward the Atlantic Plain is only in part submerged, and the upland is separated from the coast line by the Coastal Plain, which is of varying width. This plain dips gently eastward to the sea and increases in width toward the south.

The boundary between upland and plain is nearly everywhere defined by a well-marked change in geographic features and geologic formations. Topographically the change consists in places of an abrupt transition from a diversified upland to a relatively simple lowland. Geologically it is marked by a change from older hard crystalline rock to younger unconsolidated clay, sand, and gravel. The formations of the Coastal Plain everywhere overlap the eastern border of the upland and in some districts are found even far inland, where they obscure somewhat the passage from upland to plain. The margin of the upland is indicated, however, by an abrupt decrease in the velocity of the streams that pass from the upland to the plain, and so generally do falls or rapids mark this margin that it has been called the "fall line," a term that describes it imperfectly, for it is actually not a line but a zone of considerable width. North of Cape Lookout the eastern border of the Coastal Plain is deeply indented by estuaries that are the submerged lower courses of streams which are navigable to the fall line but which above the fall line occupy narrow rocky channels and are not navigable. South of Cape Lookout the eastern border of the Coastal Plain shows only shallow embayments, and the fall line gradually rises until, in the Carolinas and in Georgia, although falls and rapids still mark its location and furnish power for factories, it lies considerably above tidewater.

The fall line, which is at the head of navigation and marks the position of falls that may be utilized for water power, has been so greatly dominant in determining the location of the large cities of the Atlantic States that a line passing through New York, Trenton, Philadelphia, Wilmington, Baltimore, Washington, Fredericksburg, Richmond, Petersburg, Raleigh, Columbia, Augusta, and Macon closely coincides with it and marks the boundary between the upland and the plain.

Though the Piedmont province exhibits great diversity of scenery certain general features that are common to all its parts make it a topographic unit. It consists, in brief, of a succession of gently sloping upland plains, the highest in the interior, dissected by relatively narrow valleys and diversified by residual eminences, or monadnocks, which rise above the general level. If the valleys were filled the upland would be converted into elevated plains or plateaus sloping to the east and southeast toward the Atlantic or to the south toward the Gulf of Mexico.

In the northern part of the Appalachians these plateaus may be resolved into five incomplete upland plains, which represent old peneplains, whose history and origin are given in detail under the heading "Geologic history." After a highland area is reduced by erosion to a relatively smooth plain—that is, to a peneplain—and then uplifted by earth movement erosion will deepen and widen the valleys on it until eventually a new plain is cut into the surface of the older, remnants of which, consisting of the more resistant rocks, may be preserved on the divides. Successive movements of uplift separated by long periods of stability and erosion will develop a series of partial peneplains, the oldest of which will have been most completely removed and will be represented by remnants found only on the highest levels, and the youngest will appear on the lowest levels and will be the least developed. Intermediate peneplains will be formed at intermediate levels and will remain in different stages of preservation.

Such a series of peneplains was long ago developed in the northern part of the Appalachian Highlands. Remnants of the oldest and now the highest peneplain are preserved in the highest divides of the Appalachian Valley province. The resistant sandstone and conglomerate of Kittatinny Mountain conspicuously maintain remnants of this surface at an altitude of 1,600 feet, and this peneplain has therefore been named the Kittatinny. The Kittatinny peneplain crosses the Blue Ridge province, where its remnants stand at altitudes of 1,900 feet in southern Pennsylvania and 1,200 and 1,100 feet about Reading. Whether the Kittatinny peneplain is anywhere preserved in the Piedmont province is questionable. Reduced remnants of it may appear on Welsh Mountain, in eastern Pennsylvania. Near the fall line, where the lowest and oldest deposits (Patuxent formation) of the Coastal Plain overlap the Piedmont Upland, the surface on which they lie probably represents the Kittatinny peneplain, a fossil peneplain buried beneath these deposits. Wherever the overlying deposits have been removed by erosion the surface of the peneplain has been exposed and cut away, so that the old surface does not appear except in the immediate vicinity of these overlying deposits. In this latitude the newly exposed surface of this peneplain stands at an altitude of about 120 feet, but farther southwest it rises to an altitude of 350 feet.

The next older peneplain, named the Schooley peneplain, from a notable remnant preserved in Schooley Mountain, in the northern Piedmont Upland, at altitudes between 1,200 and 1,300 feet, maintains about the same altitudes in the Blue Ridge region, to the southwest, and descends in the central Piedmont region to 800 feet. If the Schooley peneplain is still preserved near the fall line it will be found on the border of and beneath certain older deposits (probably the Patapsco formation) of the Coastal Plain at altitudes of 100 to 300 feet, rising toward the southwest.

A third peneplain, which is here named the Honeybrook, from remnants of it that are preserved on granite gneiss in the neighborhood of Honeybrook, Pa., about 15 miles south of Reading, stands in that region at altitudes ranging from 700 to 800 feet. The Honeybrook peneplain is preserved in this latitude in the Appalachian Valley at altitudes between 700 and 800 feet, in the Blue Ridge province at 800 feet, and in the Piedmont province at 700 feet. The Honeybrook peneplain appears again southeast of the fall line, where it is preserved by Upper Cretaceous deposits that are believed to have been laid down upon its surface and where it is now exposed at places from which these deposits have been removed by erosion. The Honeybrook peneplain has not been traced north or south of eastern Pennsylvania and may not have been of wide extent.

A fourth upland plain is found at altitudes ranging from 560 to 600 feet. This plain, which is well preserved on the shale northeast of Harrisburg, is known as the Harrisburg peneplain. The Harrisburg peneplain, which stands at an altitude of 600 feet in that part of the Appalachian Valley and the Blue Ridge, is widespread at about the same elevation in the central Piedmont province, but on the eastern border of the upland it descends to 500 feet. It does not appear in the fall-line zone but is believed to descend below sea level beneath Tertiary deposits that lie far out on the Atlantic Plain.

A fifth and widely preserved upland plain in the Pennsylvania Piedmont region, ranging in height from 400 to 500 feet, is called the early Brandywine, from deposits of the Brandywine formation (formerly called the "Lafayette formation") found on its border. The early Brandywine peneplain has an elevation of 500 feet near Harrisburg, where it is developed on a shale formation in the Great Valley (the most easterly valley of the Appalachian Valley province) below the Harrisburg peneplain, which is preserved on the same shale in that vicinity. It crosses the Blue Ridge at the same level, and in the Piedmont Upland it is the most extensively preserved of the peneplains. It passes under early Brandywine deposits at an altitude of 400 feet in the fall-line zone north of Wilmington.

This surface is everywhere dissected by wide U-shaped valleys and is intersected on the southeast by slopes that face Delaware River and the Coastal Plain. The slopes of the valleys extend from interstream areas having an altitude of 400 feet or more to an altitude of about 200 feet, where they abruptly end at the brink of the inner stream gorges. The slopes facing the Coastal Plain likewise decline from about 400 feet to about 200 feet, where they terminate in a feebly developed scarp.

Upon this sloping surface lies in some places the lower-level or late Brandywine gravel, and the surface is therefore provisionally called the late Brandywine. It was developed during a period of erosion which succeeded early Brandywine time and brought about the submature dissection of the early Brandywine peneplain but did not produce a new peneplain. Below the southeastward-facing scarp at the extreme eastern border of the Piedmont Upland, there are two and in some places three narrow terraces. These terraces, named in order from the highest to the lowest, are called the Sunderland, the Wicomico, and the Talbot in Maryland, where they are most strongly developed, and the Bridgeton, Pensauken, and Cape May in New Jersey, where they are less terrace-like. They are clearly seen in the Piedmont Upland of Pennsylvania bordering the lower course of Delaware River. They are described under the heading "The Coastal Plain" (p. 4).

The five upland plains thus described constitute most of the surface of the Piedmont province and slope gradually from their western to their eastern border, their slope being independent of the attitude or the hardness of the underlying rock beds, which are so greatly folded and faulted as to be highly complex in structure. The master streams of the upland plains maintain courses that are also quite independent of the constitution of the rock floor. The courses of the tributary streams, on the other hand, are in a large measure adjusted to the unequally resistant rock layers that form the floor upon which the streams flow, and the valleys produced by them, together with the intervening ridges left between the valleys, begin to show marked conformity to the geologic structure. The general trend of the Appalachian Highlands, which is northeastward, in harmony with the strike of the beds, therefore is in accord not with the courses of the main (antecedent) drainageways of the Piedmont Upland but with the courses of the tributary (subsequent) streams. The master streams of the Piedmont Upland—the Delaware, Susquehanna, and Potomac—rise on the western border of the Appalachian Highland and pursue southerly courses across the Appalachian Valley, the Blue Ridge, and the Piedmont provinces. At the border of the Triassic Lowland these streams turn southeastward and flow in that direction until they reach the fall line, where, swerving at a right angle, they pursue southwesterly and southerly courses to the sea. This remarkable change of direction at the fall line will be explained under the heading "The Coastal Plain" (p. 4).

In the region south of a line drawn from east to west north of New Brunswick, N. J., the interstream areas are covered with a mantle of residual soil and there are no rock ledges. In the region north of this line the surface is mantled with glacial drift, the depth of which differs from place to place, reaching a maximum of 200 feet. Rock ledges become increasingly numerous and prominent toward the north, and the contour of the surface has been formed not only by the work of streams but by glacial erosion and glacial deposition.

The discordance of structure of the underlying rock beds with the gently sloping surfaces of the Piedmont Upland, the presence of residual eminences, the narrow gorges, the non-adjustment of the master streams to the rock formations, the deep mantle of soil and the absence of rock ledges furnish the data upon which is based the history of the region, which is outlined under the heading "Geologic history" (p. 15).

GEOLOGY.

The rocks of the Piedmont province include highly metamorphosed crystalline formations, unmetamorphosed consolidated fragmental material, and unconsolidated fragmental material.

The oldest formation of the Pennsylvania Piedmont region is of igneous origin—that is, the rock crystallized from a molten solution. Since its consolidation it has been subjected to pressure, which has altered it and produced in it a more or less marked lamination. Quartz, feldspar, and pyroxene are the chief minerals in this rock, which is a granite gneiss.

Most of the later formations are of sedimentary origin and include some of the oldest material known to have been laid down in the sea and some of the most recently deposited.

The first sediments deposited in this Atlantic belt were argillaceous, calcareous, and arkosic, and were laid down in pre-Paleozoic time. The resulting beds of argillite, limestone, and arkose were afterward uplifted and folded and were changed to a hard crystalline banded gneiss composed largely of quartz and feldspar, a marble, and a completely crystalline mica gneiss containing interbedded layers of mica schist. The gneisses are known in the Pennsylvania Piedmont region as the Baltimore gneiss, the Pickering gneiss, and the Wissahickon mica gneiss, and in the southern Piedmont region as the Carolina gneiss. The marbles are known as the Franklin limestone and the Cockeysville marble. The pre-Cambrian movements which metamorphosed these rocks were accompanied by the intrusion of masses, sills, and dikes of molten material, which further altered the squeezed sediments and which consolidated as granite, syenite, trachyte, dacite, granodiorite, diorite, gabbro, pyroxenite, and peridotite.

At the beginning of Paleozoic time there were deposited upon these gneisses successively arenaceous, arenaceous-argillaceous, calcareous, and argillaceous sediments. This deposition, which took place in Cambrian and Ordovician time, extended over most if not all of the Piedmont region. The intense folding and faulting and accompanying metamorphism to which they have since been subjected have converted the arenaceous material into quartzite, the arenaceous-argillaceous sediments into mixed quartzite and mica schists, the calcareous material into marble and calcareous schist, and the argillaceous material into slates and mica schists.

These formations are widespread though not continuous throughout the Piedmont Upland, and the portions of them that lie in that region in Pennsylvania are called the Chickies quartzite, Shenandoah limestone, and Octoraro schist. These crystallized sediments and the associated igneous intrusive rocks form the foundation of the Piedmont Upland, though they appear at the surface only in detached belts that trend northeastward. They have been folded in great depressed or uplifted masses made up of compressed synclines and anticlines with dominant southeasterly dips, with a steep southeasterly cleavage, and with thrust faulting. These geologic formations and structural features are not confined to the Piedmont province but appear also in the Blue Ridge province, into which the Piedmont Upland merges on the west without geologic change, forming with the Blue Ridge a geologic unit.

Upon the eroded crystalline floor formed by these beds in the central and northeastern parts of the Piedmont province there were deposited, in a shallow inland basin, coarse and fine grained ripple-marked sands, sandy mud, and mud. These sediments show sun cracks and the tracks of animals and in some places are rich in vegetable matter. Contemporaneously with this deposition, which took place in Triassic time, igneous material was intruded between the beds of sediment, or traversed them as dikes, or was poured out in lava flows, metamorphosing the adjacent sediments. These Triassic beds were afterward consolidated and uplifted without further metamorphism. The uplift was accompanied by faulting and by tilting sufficient to produce gentle dips to the west and northwest. The Triassic formations, wherever they occur in the Piedmont province, possess a very persistent threefold character, and the portions of them that were laid down in Pennsylvania and New Jersey, where they cover a large part of the province known as the Triassic Lowland, are called the Stockton formation (conglomerate and sandstone), the Lockatong formation (shale and sandstone), and the Brunswick shale. The contemporaneous igneous materials are basalt and diabase, occurring as sills, dikes, or lava flows. These rocks strongly resist erosion and therefore form bold ridges whose level tops preserve the older peneplains or whose summits rise as monadnocks above later peneplains.

Such eminences are the Palisades in New York and New Jersey, First and Second Mountains and Sourland Mountain in New Jersey, Haycock Mountain, Rock Hill, Mount Monocacy, Gibraltar Hill, and many other lesser hills in Pennsylvania.

On the extreme eastern border of the Piedmont province and in scattered outlying areas within that border the old crystalline rocks are concealed beneath unconsolidated beds of gravel, sand, and clay, which were deposited in an estuary and along a former coast line during Cretaceous time. These beds are the Patuxent and Patapsco formations (Lower Cretaceous), and the Raritan, Magothy, Matawan, Monmouth, and Rancocas formations (Upper Cretaceous). These formations are at many places overlapped or overlain by sand and gravel laid down in the Tertiary and Quaternary periods, showing that the eastern border of the Piedmont Upland was intermittently submerged beneath estuarine waters during these periods. These beds of sand and gravel are the Choptank and Brandywine formations (Tertiary) and the Sunderland, Wicomico, and Talbot (Bridgeton, Pensauken, and Cape May) formations (Quaternary).

THE ATLANTIC PLAIN.

By Benjamin L. Miller.

In its physiographic and geologic relations the greater part of these quadrangles is included in the Atlantic Plain, the physiographic province which forms the entire eastern border of the North American continent and which in its essential features is strikingly different from the Piedmont province on the west and the main bed of the Atlantic Ocean on the east. The eastern limit of the Atlantic Plain is marked by the edge of the well-defined escarpment bounding the continental shelf on its seaward side. This edge lies at a general depth of 450 to 500 feet below sea level, but the 100-fathom line is conventionally regarded as the boundary of the continental shelf. The descent of 5,000 to 10,000 feet or more from that line to the greater ocean depths is abrupt, amounting at Cape Hatteras to 9,000 feet in 13 miles, a grade as steep as many found on the flanks of the greater mountain systems. In striking contrast to this declivity is the comparatively flat ocean bed that stretches eastward away from it. If it could be seen from its base the escarpment would present the appearance of a high mountain range having a very even sky line. Here and there would be seen notches, probably produced by streams that once flowed across the continental shelf, but there would be no peaks and no serrated ridges.

On the west and northwest the Atlantic Plain is bounded by the Piedmont province, already described. The boundary between these two provinces is marked, as has been stated, by the fall line, southeast of which the streams show a marked decrease in velocity.

The Atlantic Plain is divided by the present shore line into two parts—a submerged part, known as the continental shelf or continental platform, and an emerged part, commonly called the Coastal Plain. At some places the line separating the two parts is marked by a sea cliff of moderate height, but commonly they grade into each other with scarcely perceptible change, the only mark of separation being the shore line. The areas of the two parts have changed frequently during geologic time, owing to the shifting of the shore line eastward or westward by local or general uplifts or depressions, and such movements may be in progress even now. Deep channels, which were probably old river valleys, the continuations of the valleys of existing streams, have been traced entirely across the continental shelf, at the margin of which they appear as deep gorges. The channel opposite the mouth of Hudson River is particularly well marked and extends almost uninterruptedly to the edge of the shelf, over 100 miles southeast of the present mouth of the river. A similar channel lies opposite the mouth of Chesapeake Bay. The combined width of the continental shelf and the Coastal Plain is fairly uniform along the eastern border of the continent and measures approximately 250 miles. In Florida and Georgia the Coastal Plain is more than 150 miles wide, whereas the continental shelf is narrow, in places, as along the eastern shore of the Florida peninsula, only a few miles wide. Toward the north the width of the continental shelf gradually increases and that of the Coastal Plain decreases. Except in the region near Cape Hatteras, where the continental shelf becomes narrower and the Coastal Plain becomes correspondingly wider, this gradual change continues as far north as southeastern Massachusetts, beyond which the Coastal Plain disappears altogether through submergence. Off Newfoundland the continental shelf is about 300 miles wide.

From the fall line the Coastal Plain has a gentle slope to the southeast, generally not exceeding 5 feet to the mile except in the vicinity of the Piedmont Upland, where the slope is in places as great as 10 to 15 feet to the mile or even more. The continental shelf is monotonously flat, as deposition has filled up most of the irregularities produced by erosion when this portion formed a part of the land area. The slight elevation of the Coastal Plain, which at few places reaches an altitude of 400 feet and is for the most part less than half that amount, has prevented the streams from cutting valleys of more than moderate depth. Throughout the greater part of the area the relief is slight and the streams flow in open valleys but little lower than the broad, flat divides. In certain regions the relief along the stream courses is greater, but it nowhere exceeds a few hundred feet.

The land or Coastal Plain portion of the Atlantic Plain is incised by many bays and estuaries which occupy submerged valleys carved when the land stood higher than it does now. Delaware Bay, which covers part of the former extended valley of Delaware River, and Chesapeake Bay, which occupies the old lower valley of Susquehanna River, together with such tributaries as Patuxent, Potomac, York, and James rivers, are such bays and estuaries, and there are many smaller ones. On reaching the Coastal Plain several streams that flow from the Piedmont province turn in a direction roughly parallel to the old coast line.

The materials of which the Coastal Plain is composed comprise boulders, pebbles, sand, clay, and marl, mostly loose, though locally indurated. In age the formations range from Cretaceous to Recent. Since the oldest formations of the province were laid down there have been many periods of deposition and of erosion. The sea advanced and retreated to different lines in different parts of the region, so that few of the formations can now be traced by outcropping beds throughout the Coastal Plain. Different conditions thus prevailed during each period, producing great variety in the deposits.

The structure of the Coastal Plain is extremely simple, the overlapping beds having almost everywhere a southeasterly dip. The oldest strata dip 50 to 60 feet to the mile in some places, but the succeeding beds are progressively less steeply inclined, and in the youngest deposits a dip of more than 10 feet to the mile is uncommon.

SURFACE FEATURES OF THE ELKTON AND WILMINGTON QUADRANGLES.

THE PIEDMONT UPLAND.

By F. Bascom.

RELIEF.

The northwestern third of the Elkton-Wilmington district lies in the Piedmont province and the remainder of it in the Coastal Plain. The Baltimore & Ohio Railroad skirts the southeastern border of the Piedmont Upland, and the Pennsylvania Railroad the northwestern border of the Coastal Plain. The area between these railroads is a zone in which the formations of the Coastal Plain thinly overlap the Piedmont Upland and in which the streams that cut through these formations expose the underlying crystalline rocks. Chestnut Hill, Iron Hill, and Grays Hill, which are composed of very resistant rocks, are outliers of the Piedmont Upland in the Coastal Plain. They were monadnocks on the Kittatinny, Schooley, and Honeybrook peneplains and were high islands in the Cretaceous sea in which sediments were deposited on the Coastal Plain. (See fig. 3.) There are also outliers of sediments well up on the Piedmont Upland, so that this zone of overlap has a width of nearly 5 miles.

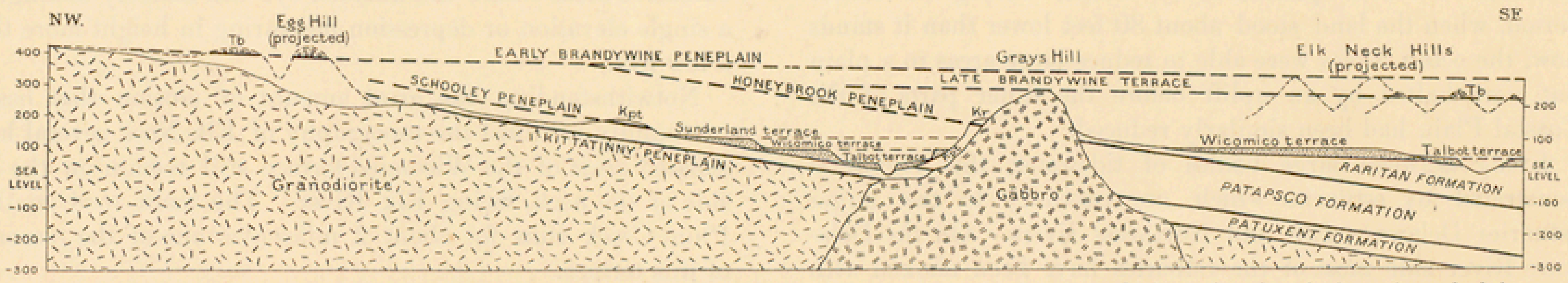


Figure 3.—Ideal section across the Coastal Plain and fall line belt in the Elkton quadrangle, showing relations of surface features to underlying formations.

The relations of the Brandywine formation (Tb) on Egg Hill and Elk Neck Hills to the early Brandywine peneplain and the late Brandywine terrace are shown, as are also the relations of the Sunderland, Wicomico, and Talbot formations to their respective terraces. Although the Raritan formation (Kr) is shown as deposited on the Honeybrook peneplain, the Patapsco formation (Kpt) on the Schooley peneplain, and the Patuxent formation on the Kittatinny peneplain, these correlations are not fully established.

The highest altitude of the Piedmont Upland in these quadrangles is 510 feet, an altitude that is reached in the extreme northwest corner of the Elkton quadrangle, about 9 miles northwest of the border of the upland, and that represents the maximum relief in the Elkton and Wilmington quadrangles; the lowest altitude on the Coastal Plain is at sea level.

The Kittatinny, Schooley, and Honeybrook peneplains probably have been completely removed from the upland of the Elkton and Wilmington quadrangles and in the Coastal Plain area are buried under the Patuxent, the Patapsco, and the Raritan formations, respectively.

The surfaces at an altitude of 500 feet at Chrome, a mile northwest of Chrome, and half a mile northeast of Chrome, in East Nottingham, are probably remnants of the Harrisburg peneplain. With the exception of these remnants the surface of the Harrisburg peneplain has been completely removed from the Elkton and Wilmington quadrangles and may be found again only to the south of these quadrangles, where it is buried beneath Tertiary formations.

The surfaces which stand at altitudes of 400 to 410 feet in the interstream areas in the western part of the upland of the Elkton quadrangle, and which at Egg Hill, on the divides three-fourths of a mile west of Egg Hill, and on the hills at the western border of the Elkton quadrangle carry early Brandywine gravel, are remnants of the early Brandywine peneplain. Outlying remnants of this peneplain are Iron Hill and several hills over 300 feet in altitude on Elk Neck, such as Black Hill, Bull Mountain, and the western and southern knobs of Hog Hills. This peneplain was once a continuous surface. The lowlands that now interrupt it were at the time of its formation filled to the tops of these hills with Cretaceous rocks. Other hills on Elk Neck that are capped with late Brandywine gravel stand at a somewhat lower level, the base of the gravel lying on an old surface at an altitude of about 220 feet. This surface, which is also preserved on many hills that are not capped with gravel, is of late Brandywine age and represents the late Brandywine erosion surface. In places the upland slopes southward and southeastward from the remnants of the early Brandywine peneplain to an altitude of about 200 feet, where it is terminated by an escarpment. This gentle slope also represents the late Brandywine erosion surface, which embraces all the upland portion of the Wilmington quadrangle and which is perhaps at some places where the Patuxent has been recently removed nearly coincident with the oldest peneplain of the Piedmont province, the Kittatinny. The erosion that cut this late Brandywine surface has partly removed the Cretaceous formation, uncovering and at the same time cutting into the old buried Kittatinny peneplain.

The three terraces that lie below the late Brandywine surface and that are conspicuously developed in the Chester quadrangle parallel to Delaware River are less sharply defined in the Wilmington quadrangle, and the demarcation between them is still less sharp in the Elkton quadrangle, where the lower terraces cover considerable areas. The Sunderland scarp and terrace may be found on the northern border of the Wilmington quadrangle between altitudes 180 and 100 feet, but in the Elkton quadrangle the Sunderland loses its terrace-like character.

In the Wilmington quadrangle the upland passes more or less abruptly into the Coastal Plain at about the 100-foot contour line with some appearance of an escarpment. In the Elkton quadrangle, west of Elk River, where the surface of the Coastal Plain is abnormally high and rolling, the transition from upland to plain is less sharp. The 100-foot contour marks the escarpment above the Wicomico terrace and the 45-foot contour the escarpment above the Talbot terrace. These terraces are described on page 4, under the heading "The Coastal Plain."

DRAINAGE.

The streams of the small part of the upland that is embraced in the Elkton and Wilmington quadrangles are not large nor are they navigable. They are tributary to Delaware River and to Chesapeake Bay and, named in order from east to west, are Brandywine, Red Clay, Mill, Pike, White Clay, Christiana, Big Elk, Little Elk, Little Northeast, and Northeast creeks. These streams have certain features in common—(1) they cross the upland from northwest to southeast in courses that are not confined to one kind of rock but are transverse to the general strike of the rock formations, passing indifferently from one formation to another, cutting serpentine, gabbro, gneiss, and granite; (2) although they flow on a slope sufficiently steep to cause them to cut down vertically, they have meandering channels; and (3) they occupy rather deep rocky gorges sunk in gently sloping open valleys, a feature that is conspicuous in proportion to the capacity of the stream. Big Elk Creek illustrates this feature, its gorge being 120 to 140 feet deep and the divides rising with gentle slopes 100 feet above this gorge to the surface of the early Brandywine peneplain, the summit of the interstream areas. The headwaters of these creeks and of their tributaries flow in open upland valleys.

These three features of the drainage lines—the courses transverse to the strike of the formations, the meandering channels, and the gently sloping terraced valleys—indicate that the region was reduced to a peneplain and that sediments were deposited on its depressed border before the streams were established in their present courses. The uplift that followed this sedimentation raised a new land surface above the sea, a low, nearly featureless plain sloping slightly toward the south and southeast. The sluggish streams that then meandered across this plain formed channels whose courses were directly dependent on the gentle slope and on the local features of the relief of the surface and were not affected by the character of the underlying rock formations. These meandering streams, however, after their courses had been well established, cut down to the crystalline rocks, reaching them too late to be turned aside by variations in the hardness of those rocks. Thus wide, shallow valleys were slowly formed, and the cover of sediments was almost wholly eroded, even from the crests of the divides. Then followed a second uplift of a few hundred feet, in consequence of which the streams cut down more vigorously and formed rock-bound gorges within their wide, shallow valleys. The meandering gorges now cut in the hard rocks are thus the incised meanders of streams formed on a gentle slope when these rocks were concealed under a thin cover of sediment. The stronger the stream the more clearly are these events recorded. Young headwater and tributary streams whose courses were formed after the second uplift flow in valleys that are not cut within outer, wider valleys.

THE COASTAL PLAIN.

By Benjamin L. Miller.

RELIEF.

GENERAL FEATURES.

The altitude of the Coastal Plain portion of the quadrangles ranges from sea level to 442 feet above sea level. The highest point where Coastal Plain sediments are found is on the top of Egg Hill (altitude 442 feet), which forms an outlier of Coastal Plain deposits resting upon and surrounded by crystalline rocks of the Piedmont Upland. On Elk Neck, the peninsula between Northeast and Elk rivers, there are several hills that have an elevation exceeding 300 feet.

The topography of the Coastal Plain in these quadrangles presents two distinct types, which are separated by Elk River. In the area northwest of Elk River the topography is very irregular, rugged hills from 200 to 300 feet high are common, and the surface slopes steeply to the large estuaries that form the head of Chesapeake Bay. In the area southeast of Elk River the contrast is striking; broad plains form the river divides, most of the streams are bordered by gently sloping land, and there are few elevations exceeding 100 feet above sea level. This distinction is not local but applies to the land on both sides of Chesapeake Bay, which extends for a distance of about 200 miles. The topography of Elk Neck and of the region about Charlestown is like that of the western shore of Chesapeake Bay; the topography of the remaining area is like that of the peninsula between Chesapeake Bay on the west and Delaware River, Delaware Bay, and the Atlantic Ocean on the east, the region that constitutes the greater portion of Delaware and all of the Eastern Shore of Maryland and Virginia. The striking differences in the topography of the two parts of the province would suggest different kinds of underlying rocks. This, however, is not the explanation of the differences, for the same formations are found on both sides of Elk River and on both sides of Chesapeake Bay. The differences are due, instead, to marine planation, by which, during an earlier period, when the land stood about 80 feet lower than it stands now, the ocean waves were able to reduce large areas to a plain but were halted by an uplift before the inner parts of the Coastal Plain had been similarly reduced.

Lying between large bodies of tidewater, this region is penetrated by estuaries which are tributary to the larger estuaries Delaware, Elk, and Northeast rivers. On the Delaware River side most of the estuaries have been choked with silt and vegetation and converted into swamps; on the other side many of the estuaries of Elk and Northeast rivers are still open for a distance of several miles from their mouths. Back Creek is the most notable of these estuaries because of its size and also because it forms one link of the water connection between Chesapeake and Delaware bays by way of the canal between Chesapeake City and Delaware City.

With the exception of Elk Neck the coast is low and of rather irregular outline. The estuaries are bordered by marshes or low-lying terraces, which pass beneath the water with no definite topographic break except, in places, a low cliff cut by the waves during storms or high tides.

TOPOGRAPHIC DIVISIONS.

Those parts of the Elkton and Wilmington quadrangles that lie within the Coastal Plain exhibit six topographic divisions, which are generally distinct. Three of them are unusually well marked; the others are so fragmentary that they might be overlooked were it not for their relation to similar but larger areas in adjoining regions. These divisions differ greatly in area but most noticeably in elevation. Named in order of elevation they are the tidal marshes, the Talbot terrace, the Wicomico terrace, the Sunderland terrace, the late Brandywine terrace, and the early Brandywine peneplain.

Tidal marshes.—The lowest of these topographic divisions consists of the tidal marshes in the valleys of most of the larger estuaries. These extend over a number of square miles and lie so low that the tides frequently submerge them in part. Artificial embankments have been built at many places along both sides of Delaware River to prevent flooding of these areas during high tides and heavy storms. Many of these marshes that are so protected have been drained by an elaborate system of ditches, as indicated on the topographic map.

The small streams that flow into many of the estuaries meander through these marshes, which are rapidly encroaching on them. The marshes are formed by growth of sedges and other marsh plants, which aid in filling the depressions by obstructing the passage of mud carried in by streams and by furnishing a perennial accumulation of vegetable débris.

Talbot terrace.—The term terrace is used in this folio in a somewhat specialized sense to include not only the true plains in the areas between the streams but also the extensions of the plains into the terraces along the stream valleys.

The Talbot terrace borders the tidal marshes and ranges in altitude from sea level to about 45 feet above it. This terrace extends along the larger streams of both quadrangles, and it and the tidal marshes embrace all that part of New Jersey which lies within the Wilmington quadrangle. On the west side of Delaware River it forms a border, from 1 to 2 miles wide, throughout the length of the quadrangle and extends several miles farther up Christiana, Red Lion, Dragon, and St. Georges creeks.

In the Elkton quadrangle the Talbot terrace is less continuous but is well developed along Elk River and Back Creek and forms an extensive flat plain, on which the town of Elkton has been built. Along Northeast River the terrace is represented by several detached areas. The town of Northeast and the greater part of Charlestown have been built on two remnants of this terrace, which was probably at one time continuous on both sides of Northeast River, just as it is now continuous along Delaware River.

Wicomico terrace.—The Wicomico terrace lies at a higher level than the Talbot and at many places is separated from it by a low bluff or escarpment, which ranges in height from a few feet to 15 or 20 feet. At some places this escarpment is absent, so that there seems to be a gradual passage from the Talbot terrace to the Wicomico. The abrupt change of slope can be observed, however, at so many places that the line of separation between the two terraces can be determined with little difficulty. The base of the low bluff lies at an elevation of about 40 feet. The Wicomico plain ranges in height from 40 to about 100 feet and is in turn separated by another abrupt change of slope from the next higher terrace.

The Wicomico terrace is the most pronounced topographic feature of the Elkton and Wilmington quadrangles and covers about one-third the entire area. It forms the main divide between Delaware and Elk rivers and the divides between most of the creeks. The Wicomico terrace is older than the Talbot and has undergone greater erosion. The streams have cut into it, making its boundary very irregular and modifying its plainlike character in their proximity, but over the larger divides it still presents a flat, featureless surface. In the region immediately east of the Delaware-Maryland line there are extensive areas where the unaided eye can scarcely distinguish a single elevation or depression measuring in height more than a few feet.

Notwithstanding the great amount of erosion that has so profoundly modified the topography of Elk Neck several large isolated areas of the Wicomico terrace still remain on the east side of the neck, facing Elk River. The main road south of Plum Creek runs for about 2 miles over one of the remnants of this terrace.

The Wicomico terrace surrounds Grays Hill, Iron Hill, and Chestnut Hill, a fact which indicates that they existed as rocky islands near the margin of the ocean when the Wicomico terrace was formed.

Along Delaware River the line of demarcation between the Talbot and Wicomico terraces is not very prominent, owing either to the inability of the Talbot waves to cut a bluff in the Wicomico materials or to the destruction by erosion of the escarpment common to the two terraces. In the vicinity of Elk River the line is marked by a low bluff. A part of this bluff stands about half a mile northwest of Elkton and can be plainly seen from passing trains.

Sunderland terrace.—The Sunderland terrace is higher than the Wicomico and extends from about 100 feet to about 180 feet above sea level. In this area it is at many places separated from the Wicomico terrace by a low bluff, and at some places farther southwest it is separated from the next higher terrace—the late Brandywine—by a marked escarpment. In these quadrangles the Sunderland and late Brandywine terraces are not sharply separated.

In the region northeast of the Wilmington quadrangle a pronounced escarpment is cut in the crystalline rocks at the inner margin of the Sunderland plain at an elevation of about 180 feet above sea level. Indications of a similar escarpment, which, however, is less distinctly developed, can be seen at several places within a few miles of Brandywine Springs. The Sunderland deposits only here and there extend to the foot of the escarpment.

Although the Sunderland terrace was no doubt at one time extensive in the Elkton and Wilmington quadrangles, it is now represented only by small detached remnants. The largest of these remnants lie in the west part of Wilmington and in the region immediately north of Elsmere, and smaller parts of it are seen in a series of flat-topped hills northwest and west of Marshallton. A few remnants are also still preserved north of Elkton and on the eastern slopes of Elk Neck. The Sunderland terrace, as described in the folios on areas in southern Maryland, is not recognizable in these quadrangles.

Late Brandywine surface.—In the Piedmont Upland the continuation of the floor on which late Brandywine sediments were deposited is known as the late Brandywine surface. This surface is older and lies at a higher level than the terraces which have been described above and has consequently been longer subjected to erosion. Remnants of it are now found near the small village of Elk Neck, where they are preserved under late Brandywine gravels at an elevation of 220 feet.

Early Brandywine peneplain.—The early Brandywine peneplain, which once extended far to the west on the Piedmont Upland and covered the greater part of the portions of the Elkton and Wilmington quadrangles that lie within the Coastal Plain, is now preserved only on a few high hills in the area. It forms the flat summits of the highest hills on Elk Neck and underlies early Brandywine gravel which caps Egg Hill and other high hills on the western border of the Elkton quadrangle, where it has an elevation of 380 feet.

DRAINAGE.

General conditions.—The drainage of those parts of the Elkton and Wilmington quadrangles that lie within the Coastal Plain is comparatively simple, its simplicity being a result of the relative uniformity with which the several formations of the Coastal Plain have been eroded and the proximity of the region to tidewater. With the exception of the tidal marshes, which are drained by ditches, most of the land in the quadrangles is drained naturally. Some of the flatter parts of the Wicomico terrace are drained underground. A layer of gravel that lies beneath the surface loam and sand facilitates underground drainage and obviates the necessity of artificial drainage in regions that are too level to permit water to flow freely at the surface.

Estuaries.—The larger streams of the region are estuaries formed by submergence, as a result of which parts of their former valleys are occupied by tidewater. The region is so greatly dissected by the estuaries of Delaware, Elk, and Northeast rivers that practically all the parts of these quadrangles that are included in the Coastal Plain lie within 6 miles of tidewater.

The courses of the larger streams in the Piedmont province have already been described, and it remains to describe and explain their courses in the Coastal Plain. Perhaps their most striking feature is their change of direction at or near the fall line. This change is well shown in Delaware, Susquehanna, and Potomac rivers. Delaware River changes its southeasterly course at Trenton and flows southwestward to Wilmington and thence southward to southeastward to the ocean. Susquehanna River flows southeastward, and Chesapeake Bay, the continuation of the Susquehanna, has a southwesterly course from its head to the mouth of Patapsco River, and thence a southerly to southeasterly course to the ocean. Potomac River has a southeasterly course at the fall line, from which it flows southward to southwestward to the mouth of Aquia Creek and thence southeastward to the ocean. In all these streams the change to the southwesterly direction takes place as they cross the fall line, and for considerable distances their courses follow or lie parallel to that line. The Delaware follows the fall line for 60 miles. Chesapeake Bay lies parallel to and a short distance east of the fall line for 35 miles, and Potomac River flows parallel and close to the fall line for 36 miles.

The changes in the courses of these streams may be explained as follows: The streams assumed their present courses at the beginning of the uplift that terminated Brandywine deposition, and the conditions then prevailing must have determined those courses. Before the uplift the coast line was presumably fringed with sand bars, as it is now from Sandy Hook to Cape Lookout. These sand bars, which were formed by southwestward-moving shore currents and therefore grew toward the southwest, had pushed the stream outlets or tidal inlets farther and farther southwestward. When the ocean retreated the streams maintained the courses thus established in lagoons parallel to the coast line but extended their courses across the newly formed Coastal Plain in a southeasterly direction, consequent upon the slope of the plain.

Minor streams.—The estuaries that form so prominent a feature in these quadrangles receive the waters of numerous minor streams. At the head of each estuary there are one or more small streams, which seem insignificant in comparison with the bodies of water into which they flow. Thus there are Little Elk and Big Elk creeks, which flow into Elk River, and

Northeast and Little Northeast creeks, which flow into the head of Northeast River. Most of the streams that flow into the sides of the estuaries are small, and some are sluggish, meandering streams, such as Christiana Creek, which flows for miles through a broad, flat-bottomed valley. The streams on Elk Neck, however, are swifter and straighter, occupy narrow, steep-sided valleys, and are still cutting down their beds. At their junction with the larger bodies nearly all the minor streams are bordered by swamps, which indicate that the estuaries that formerly occupied their lower courses have been filled up by wash from the surrounding uplands.

and petrographic resemblances, some of the extremely metamorphosed gneisses, limestones, and schists have been correlated with Paleozoic and others with pre-Cambrian rocks. The discrimination between Paleozoic and pre-Cambrian formations that lie adjacent to one another and have been subjected to dynamic metamorphism of the same kind and degree must depend on evidence that has not yet been obtained.

The accompanying table shows the names, character, and succession of these formations in Maryland, Pennsylvania, and New York, the conclusions that have been reached as to their age, and the questions that are still open.

Pre Cambrian, Cambrian, and Ordovician sedimentary formations of the Piedmont Plateau in Maryland, Pennsylvania, and New York.

Age.	Maryland.	Pennsylvania.	Southeastern New York.	New York City (Geologic Folio 83, 1902).
Ordovician.	Peach Bottom slate, Cardiff quartzite, and (in part) phyllite. The phyllite consists of fine-grained fissile schists composed of quartz, sericite, and chlorite.	Martinsburg shale and Octoraro schist. The schist is the more highly metamorphosed equivalent of the shale; it occupies a similar stratigraphic position and occurs southeast of the shale in direction of increasing metamorphism.	"Hudson River slates."	Hudson schist. Mica schist consisting of biotite and quartz, accompanied by garnet, staurolite, fibrolite, and cyanite. Some authors now regard the schist in the New York City area as pre-Cambrian, and apply to it the local name Manhattan schist.
Cambrian and Ordovician.	Shenandoah limestone and Cockeysville marble. The marble is coarse grained, granular, and magnesian and contains numerous flakes of mica. Relations unknown. It is tentatively placed with the Shenandoah limestone but may be older.	Shenandoah limestone. Medium to fine grained white and blue limestone, becoming increasingly crystalline toward the southeast.	"Wappinger limestone." Dark-gray fine-grained crystalline limestone.	Stockbridge dolomite. Coarsely crystalline dolomite, in places containing diopside and tremolite. Some writers now regard the dolomite in the New York City area as of pre-Cambrian age, and apply to it the local name Inwood limestone.
Cambrian.	Setters quartzite. Thin-bedded tourmaline-bearing and massive, heavy bedded white quartzite. Contains no fossils but is probably of Cambrian age. It is not equivalent to the Chickies quartzite but may represent a part of it.	Chickies quartzite. Thin-bedded tourmaline-bearing silicified sandstone—quartzite. Contains Lower Cambrian fossils.	Cheshire ("Poughquag") quartzite. Silicified sandstone.	Poughquag quartzite. Thin-bedded white to brownish quartzite. Some writers now regard the quartzite in the New York City area as of pre-Cambrian age and apply to it the local name Lowerre quartzite.
Pre-Cambrian.	Phyllite (in part). Fissile schists composed of quartz, sericite, and chlorite; consists in part of altered volcanic rocks.			
	Wissahickon mica gneiss. Coarse-grained micaceous schist and gneiss, generally finely crinkled. Tentatively regarded as pre-Cambrian but may be early Paleozoic.	Wissahickon mica gneiss. Thoroughly crystalline quartz-mica-feldspar gneiss and mica schist; possibly Cambrian or possibly post-Cambrian and the equivalent of the Octoraro schist.	Manhattan schist. Thoroughly crystalline sediment, formerly supposed to be the equivalent of the "Hudson River slates," but of different physical and petrographic character. By some authors now regarded as pre-Cambrian. Called Hudson schist in New York City folio.	
		Limestone. Coarsely crystalline, associated as lentils with gneiss and penetrated by pegmatites. Possibly equivalent to Inwood limestone.	Inwood limestone. A magnesian crystalline limestone formerly believed to be the equivalent of the Stockbridge but by some authors now regarded as pre-Cambrian.	
		Quartzite. Occupies only small areas. Possibly equivalent to Lowerre quartzite.	Lowerre quartzite. Occupies only small areas. Formerly believed to be same as Poughquag quartzite but by some authors now regarded as pre-Cambrian.	Rare.
	Limestone. White, medium to coarsely crystalline; interbedded in Baltimore gneiss.	Franklin limestone. Coarsely crystalline white limestone containing graphite and numerous silicate minerals.	Crystalline and very impure limestone; tremolitic; interbedded in Fordham gneiss.	
	Baltimore gneiss. Medium-grained quartzose gneiss; altered sedimentary rock; feldspathic gneiss; altered granite.	Baltimore gneiss. Sedimentary and igneous medium grained, banded quartz-feldspar-mica rock and granitic gneisses, with igneous intrusives.	Fordham gneiss. Chiefly sedimentary, granitic and quartzose banded gneisses and schist, with igneous intrusives.	Fordham gneiss. Gray banded gneiss composed of orthoclase, quartz, and biotite.

GEOLOGY OF THE ELKTON AND WILMINGTON QUADRANGLES.

STRATIGRAPHY OF THE PIEDMONT UPLAND.

By F. Bascom.

SEDIMENTARY ROCKS.

GENERAL SUCCESSION OF FORMATIONS.

The formations of the southeastern Piedmont Upland, except the unconsolidated sediments that overlap its border and that are described under the heading "Coastal Plain" (p. 4), are crystalline rocks of pre-Cambrian and Paleozoic age. They are gneisses, limestones, and schists of sedimentary origin, and intrusive granite, dacite, granodiorite, quartz diorite, diorite, gabbro, pyroxenite, and peridotite of igneous origin. All the formations lie in a zone that trends northeast. The sedimentary rocks of the upland fall into six divisions, shown below.

System or period.	Formation.
Ordovician	Octoraro schist.
Cambrian and Ordovician	Shenandoah limestone.
Cambrian	Chickies quartzite.
Pre-Cambrian	Wissahickon mica gneiss.
	Franklin limestone.
	Baltimore gneiss.

Rocks of similar lithology and age appear in the New England States and in New York. In these States and in the Piedmont Upland there is serious difficulty in discriminating between pre-Cambrian limestone and highly metamorphosed Cambrian and Ordovician limestone, and between pre-Cambrian mica schist or gneiss and metamorphosed Ordovician mica schist. In these States and in the Piedmont Upland there are relatively unmetamorphosed Cambrian and Ordovician limestones and Ordovician slate as well as more highly metamorphosed Paleozoic limestones and schists and extremely metamorphosed pre-Cambrian gneisses, limestones, and schists. Finally, in addition to these relatively unmetamorphosed, more highly metamorphosed, and extremely metamorphosed formations of known age, there are extremely metamorphosed gneisses, limestones, and schists whose age is still in question. The known Paleozoic rocks have not been found in undoubted stratigraphic continuity with these extremely metamorphosed gneisses, limestones, and schists of questionable age, yet, because of similar field relations

The sedimentary rocks of the Piedmont Upland area in the Elkton and Wilmington quadrangles are highly metamorphosed. They consist of a biotitic gneiss, a lenticular crystalline limestone or marble, and a crumpled muscovite schist.

The gneiss and schist in the Piedmont Upland of Pennsylvania are nearly everywhere separated from Cambrian quartzite by an igneous unconformity — that is, the gneiss and schist areas are marked by granitic and gabbroitic intrusive bodies that are not found in known Cambrian rocks. Some Cambrian gneiss may be included in these areas, but where structural relations do not connect such gneiss with recognized Cambrian quartzite it has not been feasible to separate questionable Cambrian gneiss from pre-Cambrian gneiss.

PRE-CAMBRIAN ROCKS.

BALTIMORE GNEISS.

Distribution.—Biotitic gneiss is found in the north-central part of the Elkton-Wilmington district, where it underlies about 36 square miles of open, arable country. This gneiss extends northward beyond the Elkton and Wilmington quadrangles, where it is a part of the widespread Baltimore gneiss of the West Chester quadrangle, and on the east, south, and west it is cut off by granite and gabbro, which are intrusive in it. The rock is seen in a small quarry a mile northwest of Calvert, in natural exposures on Big Elk, White Clay, and Mill creeks, and at the Choate quarry, 3 miles northeast of Newark. In general the gneissic banding strikes northeast and dips southeast.

Character.—The gneiss is a completely crystalline, medium-grained granular or banded rock. Normally its constituent minerals are distributed rather evenly through it or, exceptionally, quartz-feldspar layers alternate with more strongly micaceous layers and with brownish-black plates of biotite, some of which are 0.5 centimeter long and have cleavage surfaces parallel to the banding. Quartz, feldspar, and biotite are its primary constituents, and magnetite, apatite, garnet, zircon, staurolite, sillimanite, allanite, and pyrite are accessory constituents. Kaolin, cordierite, chlorite, epidote, hematite, limonite, and a zeolite, possibly scolecite, are secondary constituents. The feldspar is chiefly orthoclase and albite but includes some microcline, oligoclase, and a sodic labradorite. The percentages of the three primary constituents vary greatly. Biotite is in places abundant but nowhere exceeds the sum of the quartz and feldspar, and these two occur in about equal amounts.

On Mill Creek, near the contact of gabbro and gneiss, the gneiss, which is garnetiferous, contains almond-shaped nodules 3 to 4 centimeters long, brought out in relief by weathering. These nodules are composed of cordierite and sillimanite.

Thickness.—The thickness of the Baltimore gneiss can not be determined. It is the oldest formation of the Piedmont province, the floor upon which the other formations were laid down, and its lower limit is nowhere visible. In some places where it is associated with intrusive granite or gabbro the gneiss appears to be very thin, and it is impossible to say whether more deeply seated gneiss has been completely displaced by intrusive bodies.

Correlation and name.—The age of the formation has been determined from its relations to Cambrian material and to the intrusive rocks of the Piedmont Upland. In the Germantown quadrangle, northeast of the Elkton and Wilmington quadrangles, the gneiss is exposed at the upper end of a pitching syncline, where it dips under a Lower Cambrian pebbly quartzite or conglomerate. Most of the pebbles of this conglomerate are composed of blue quartz that forms abundant and characteristic veins in the Baltimore gneiss. The gneiss in that area at least must be regarded as pre-Cambrian.

Near Westgrove and Avondale,[1] in the Coatesville quadrangle, north of the Elkton quadrangle, similar gneiss passes without a conglomeratic facies into quartzose gneiss which is presumably Cambrian and which dips under presumably Cambrian limestone. The gneiss in those areas may be Cambrian.

In general the biotitic gneiss is separated from Paleozoic rocks by an igneous unconformity, and for this reason and because it is not practicable, either by lithology or structure, to divide it into a Cambrian and a pre-Cambrian gneiss, it is referred to the pre-Cambrian and is identified with the Fordham gneiss of New York State and the Baltimore gneiss of Pennsylvania and Maryland. Though the pre-Cambrian gneiss of the Piedmont Upland of Pennsylvania and Maryland is not stratigraphically continuous, the same name has been applied to the formation in these States because it shows similar stratigraphic relations and lithologic character.

PRE-CAMBRIAN LIMESTONE.

Distribution.—Pre-Cambrian limestone is exposed only in three adjacent abandoned quarries half a mile east of Pleasant Hill, in the northwest corner of the Wilmington quadrangle, but presumably it underlies a narrow belt of lowland extending about a mile to the northeast. These quarries are known as the Eastburne quarries and were operated many years ago, when the stone was burned for lime.

Character and thickness.—The structure in the quarries is anticlinal; the strike is N. 20°–80° E.; the dip on the southeast side of the most southerly of the three quarries is 35° SE. and that on the northeast side is 55° NW. The limestone appears to be interbedded with the Baltimore gneiss, which in part overlies it and which strikes and dips with it. The limestone is white and is medium to coarsely crystalline, the crystals ranging in diameter from 0.4 to 0.7 centimeter. It is penetrated by a pegmatite dike. The base of the limestone is not exposed, so that the thickness of the formation can not be determined. In the absence of any evidence to the contrary the limestone is regarded as a lens in the Baltimore gneiss.

Correlation.—In color and in perfection of crystallization, as well as in its association with gneiss and pegmatitic material, the limestone resembles the pre-Cambrian Franklin limestone found in New Jersey in the Franklin Furnace district. Lenses of a similar highly crystalline limestone are found associated with pre-Cambrian Pickering gneiss, and with igneous intrusives and pegmatites in areas in the Burlington and Phoenixville quadrangles, northeast and north of the Elkton-Wilmington district. The limestone of these areas is quite unassociated with any Paleozoic material and contains graphite and numerous silicate minerals—features that are characteristic of pre-Cambrian limestone. There seems to be no reason to question the pre-Cambrian age of these lenses of limestone.

The age of the limestone in the Elkton-Wilmington district is not so clearly evident, for it also resembles some highly crystalline limestones found on Doe Run, in the Coatesville and West Chester quadrangles, which are adjacent on the north to the Elkton and Wilmington quadrangles. These limestones on Doe Run are associated with Paleozoic rocks as well as with gneiss, and they have been regarded as Paleozoic. The limestone of this area, however, unlike the limestones of Doe Run, is not in the line of strike with recognized Paleozoic limestone, and because of its associations and lithologic character it is correlated with pre-Cambrian limestones and herein classified as pre-Cambrian.

[1] The section at Avondale may be interpreted as follows:

Limestone	Cambrian.
Gneiss (quartzose)	Probably Cambrian, or possibly pre-Cambrian.
Wissahickon mica gneiss, including mica schist and limestone lenses	

Such an interpretation will include within the Wissahickon formation the mica schist of the Wissahickon, the gneiss mapped as Baltimore in the Elkton-Wilmington area, and the limestone lens exposed at the Eastburne quarries.

WISSAHICKON MICA GNEISS.

Distribution.—The Wissahickon mica gneiss is found only in the northwestern part of the Piedmont area of the Elkton quadrangle, where it lies above the Baltimore gneiss. In areas farther north it is widely extended and lies in contact with Ordovician Octoraro schist.

Character.—The Wissahickon formation in this area is typically a schist rather than a gneiss, for it contains a small amount of feldspar and a large amount of mica (muscovite) and is conspicuously foliated. It may be distinguished from the Baltimore gneiss by its large content of muscovite, by its almost complete lack of biotite, by its schistosity, and by its fluting and folding. The muscovite, which occurs in glistening scales, gives the rock its peculiarly lustrous or spangled aspect. The amount of quartz and feldspar it contains differs greatly from place to place, but neither is anywhere absent. The quartz is fine grained; the feldspar (orthoclase and plagioclase) occurs in large areas of the rock but is nowhere so abundant as it is in the Baltimore gneiss. Chlorite is a secondary constituent. Within the Elkton and Wilmington quadrangles the petrography of the schist is very simple and the accessory constituents are not abundant. In this district the schist is intruded by great masses of serpentine.

Thickness.—The Wissahickon mica gneiss is a widespread and important formation in areas north and northeast of the Elkton and Wilmington quadrangles, where it must be very thick, but variations in the thickness and character of the beds without recognizable recurrence, as well as isoclinal folding, make a close estimate of its thickness impossible. A rough estimate makes it 1,000 to 2,000 feet. In the Elkton and Wilmington quadrangles the formation has been reduced by erosion to a thin cover, and in the more deeply eroded parts of the upland it has been altogether removed.

Correlation and name.—The Wissahickon mica gneiss is probably pre-Cambrian, but it may be in part Cambrian or it may be even post-Cambrian and equivalent to the Ordovician Octoraro schist. The only clues to its age lie in its relations to other sedimentary formations and to igneous rocks, and in the degree of its metamorphism. These clues are rendered less reliable by its apparent sedimentary contact with the Ordovician schist, although it lies across the strike of the schist, and by an increase in the metamorphism of the Ordovician formation from the northwest to the southeast. The Ordovician schist, which is a slate in areas to the northwest, is a mica schist in areas farther southeast, and in areas still farther southeast might be as coarsely crystalline as the Wissahickon mica gneiss in the Elkton quadrangle.

The Wissahickon is provisionally classed as pre-Cambrian because it is faulted in relation to the Paleozoic rocks, because in some localities it shows lithologic transition into the Baltimore gneiss, because it is everywhere associated with igneous intrusions, and because it is highly metamorphosed—a fact shown in both the character and the size of its minerals. No one of these features is found in known Ordovician formations. The name Wissahickon is derived from that of a tributary of Schuylkill River that has cut into the mica gneiss and that displays it in good exposures. These exposures are not in every place typical of the Wissahickon gneiss owing to the saturation of the gneiss by pegmatitic injections.

IGNEOUS ROCKS.

DISTRIBUTION.

The igneous rocks of the Elkton and Wilmington quadrangles are batholiths and dikes of granodiorite, dacite, quartz diorite, gabbro, pyroxenite, and peridotite.

Of the igneous origin of these rocks there can be no reasonable doubt. Chemically, mineralogically, and texturally they are ordinary batholithic and dike rocks, departing from the normal types only in exhibiting a texture that is more or less foliated. This texture is limited mainly to small intrusive masses that have been greatly compressed or to parts of larger masses which have been subjected to parallel injection. The rocks of the great mass of the batholiths are granular and have the textures and constituents of unaltered plutonic rocks.

Similar plutonic intrusives are associated with pre-Cambrian gneisses throughout the Atlantic province. They form a large part of the pre-Cambrian complex of the Adirondacks; they appear in the Highlands of New Jersey as the Byram gneiss, Losee gneiss, and Pochuck gneiss; they continue through Pennsylvania and Maryland; and they occur in Tennessee and North Carolina as the Cranberry granite and Roan gneiss.

PLUTONIC ROCKS.

GRANODIORITE.

Distribution.—Granodiorite is the most widely distributed igneous rock in the Elkton-Wilmington district. It is exposed in a large area in the central part of the Elkton quadrangle, and extends southward beneath Cretaceous and later sediments; here it is exposed wherever the streams have cut deep enough into these sediments to reach the rock floor. In the Wilmington quadrangle the granodiorite is cut out by intrusions of gabbro, but it reappears to the northeast in the adjacent Chester quadrangle and in the Philadelphia district.

Character.—The granodiorite group contains many rocks that are usually known as granites but that differ from true granites in containing a larger amount of soda-lime feldspar, or plagioclase, than of potash feldspar, or orthoclase. The dominant feldspar in true granite is orthoclase; that in quartz diorite is plagioclase (oligoclase-andesine); quartz monzonite contains equal or nearly equal amounts of orthoclase and plagioclase; granodiorite is intermediate in mineral composition between quartz monzonite and quartz diorite.

Two types of granodiorite, differing in silicity, are found in the Elkton and Wilmington quadrangles. The more silicic type is the prevailing granodiorite, which is finely exposed in quarries at Port Deposit and Frenchtown, on Susquehanna River, west of the Elkton quadrangle. This rock is medium grained, grayish white to gray, and is mottled with overlapping scales of biotite arranged in more or less discontinuous bands, producing a distinctly gneissoid texture. The essential constituents of the rock are quartz, feldspar, and biotite, and the accessory constituents are hornblende, apatite, zircon, titanite, allanite, garnet, tourmaline, and magnetite. Muscovite, epidote, chlorite, and calcite are products of the decomposition of the feldspar and biotite. The quartz is granulated, and the feldspar, which is orthoclase, microcline, and plagioclase of the oligoclase-andesine-labradorite series (Ab_2An_1 to Ab_1An_1), is partly altered, the orthoclase having been altered to muscovite, which occurs in minute scales, and the plagioclase to epidote. The rock is less distinctly porphyritic than the granodiorite of the Philadelphia district, but the crystals of feldspar are notably idiomorphic; the plagioclase shows zonal growth, which, however, is obscured by the products of alteration. The biotite scales lie in more or less parallel bands and are in part altered to chlorite or to muscovite. Quartz constitutes about 40 per cent of the rock, feldspar 30 per cent, and the ferromagnesian minerals also about 30 per cent.

Both to the north and to the south the granodiorite becomes darker colored and less gneissoid and contains a larger percentage of hornblende. This less silicic type of granodiorite is exposed on the lower courses of Big Elk and Little Elk creeks. Feldspar, quartz, hornblende, and biotite are its essential constituents; magnetite, apatite, zircon, titanite, and garnet are accessory constituents; and epidote, chlorite, calcite, and muscovite are secondary constituents.

The quartz constitutes about 30 per cent of the rock. The feldspar, which is orthoclase and andesine-labradorite (Ab_1An_1), varies in abundance, ranging from a subordinate amount to 50 per cent of the rock. The plagioclase, which is about twice as abundant as the orthoclase and tends to be idiomorphic, is crowded with anhedral grains of epidote. The biotite contains numerous inclusions of zircon, titanite, and epidote. A green hornblende partly replaces the biotite or occurs in about the same amount. The ferromagnesian constituents average about 20 per cent of the rock. The dominant alteration product is epidote. In some places the rock grades into a quartz diorite.

The following analyses have been made of these two types of the granodiorite, and from the analyses the norms have been calculated as shown:

Analyses and norms of granodiorite, Cecil County, Md.

Analysis.	1	2	Norm.	1a	2a
SiO_2	73.69	66.68	Quartz	41.22	28.14
Al_2O_3	12.89	14.93	Orthoclase	8.90	12.23
Fe_2O_3	1.02	1.58	Albite	23.58	22.53
FeO	2.58	3.32	Anorthite	18.07	22.52
MgO	.50	2.19	Diopside	.48	.89
CaO	3.74	4.89	Hypersthene	5.02	9.16
Na_2O	2.81	2.65	Magnetite	1.39	2.32
K_2O	1.48	2.05	Ilmenite	------	.91
H_2O+	1.06	1.09	Apatite	------	.34
H_2O-	------	.16	Water	1.06	1.25
TiO_2	------	.50		99.72	100.29
P_2O_5	------	.10	Symbol	I''.3.3.4.	(I)II.''4.3''4.
MnO	------	.10			
BaO	------	.08			
SrO	------	Trace.			
Li_2O	------	Trace.			
	99.77	100.32			

1. "Biotite granite," Port Deposit, Md. Analysis made by William Brommell in the chemical laboratory of Johns Hopkins University. Grimsley, G. P., The granites of Cecil County, in northeastern Maryland: Cincinnati Soc. Nat. Hist. Jour., vol. 17, p. 96, 1894.

2. "Hornblende-biotite granite," Rowlandsville, Md. Analysis by W. F. Hillebrand, U. S. Geol. Survey. Grimsley, G. P., op. cit., p. 88.

1a. Norm of "biotite granite," Port Deposit, Md.

2a. Norm of "hornblende-biotite granite," Rowlandsville, Md.

The more silicic granodiorite is persalic, quarfelic, alkalicalcic, and dosodic—that is, the quartz and feldspar are about equally abundant and together greatly exceed all the other constituents. The alkalies and the feldspathic lime are about equal, and of the alkalies soda is dominant. The less silicic granodiorite is dosalic, quardofelic, alkalicalcic, and dosodic—that is, the quartz and feldspar are the dominant constituents, though they do not so much exceed the ferromagnesian constituents as do the quartz and feldspar of the biotite granite. Quartz is less abundant than feldspar, the alkalies and feldspathic lime are about equal in amount, and of the alkalies soda is dominant. The two magmas show consanguinity in that they are alkalicalcic and dosodic, and they show incipient differentiation in that they are respectively persalic-quarfelic and dosalic-quardofelic. The more silicic type is a biotite grano-susquehannose, and the more basic type is a biotite grano-harzose-tonalose. Both are members of a continuous series that shows progressive differentiation of an alkalicalcic magma, a fact that will appear in the discussion of the other igneous rocks.

The granodiorite has a schistosity in planes that strike N. 60° E. and dip about 30° SE., and exhibits four joint systems, striking N. 69° W., N. 35° W., N. 25° E., and horizontal or nearly so.

METADACITE.

Distribution.—The granodiorite is intruded by a fine-grained silicic igneous rock, a metadacite, which is found in the Elkton quadrangle in a wedge-shaped area that extends northeastward and southeastward from Bayview. The rock is nearly everywhere concealed beneath a cover of gravel, but it is exposed at the junction of the two branches of Stony Run and on Northeast and Little Northeast creeks. A narrow dike of the rock is exposed at Mechanic Valley, near Little Northeast Creek, and a similar dike, which may be a continuation of the other, is exposed northeast of Mechanic Valley, near Leeds.

Half a mile east of BayviewNortheast Creek dashes between and over huge boulders of the metadacite in a series of cascades that give a pleasant wildness and charm to the locality, which is known as Gilpin Rocks and is utilized as a picnic ground. The metadacite is penetrated by narrow fine-grained aplitic dikes.

Character.—The rock is fine grained and is prevailingly green, though in some fresh exposures it is light gray. The fresh material is hard, compact, and aphanitic and contains inconspicuous phenocrysts of quartz and feldspar. The green material owes its color, its somewhat fibrous texture, and its greater softness to hornblende, chlorite, and epidote, the formation of which has quite obscured the original character of the rock.

The essential constituents of the metadacite are quartz, feldspar, and scanty biotite; the accessory constituents are magnetite, apatite, titanite, garnet, and pyrite or pyrrhotite; the secondary constituents are hornblende, epidote, chlorite, and muscovite. A microscopic mosaic of granular quartz and feldspar containing scattered phenocrysts of quartz and feldspar and blades of biotite or green hornblende make up the fresher material. Quartz constitutes about 40 per cent of the rock, feldspar 45 per cent, and all other constituents 15 per cent. The feldspar, so far as the few minute and imperfect phenocrysts admit of determination, is orthoclase, albite, and oligoclase (Ab_2An_1), the plagioclase exceeding the orthoclase by about ten to one. The amount of biotite decreases with the development of nearly colorless to green hornblende, which increases rapidly in amount toward the border of the intrusive, the metadacite finally becoming a hornblende-epidote rock with interstitial granular quartz and feldspar and a little chlorite.

The original texture and constituents of the rock are those of a dacite, and the extreme alteration that the rock has undergone are recognized in the designation metadacite.

Analysis and norm of metadacite, Cecil County, Md.

[W. F. Hillebrand, analyst.]

	Analysis.		Norm.
SiO_2	75.67	Quartz	43.98
Al_2O_3	12.28	Orthoclase	4.45
Fe_2O_3	.85	Albite	30.39
FeO	2.59	Anorthite	13.07
MgO	.37	Corundum	.82
CaO	2.65	Hypersthene	4.73
Na_2O	3.63	Ilmenite	.61
K_2O	.78	Magnetite	1.16
H_2O+	.29	Pyrite	.12
H_2O-	.12	Water	.41
TiO_2	.29	Miscellaneous	.12
ZrO_2	None.		99.86
CO_2	Trace.	Symbol, I''.3.''3.(4)5.	
P_2O_5	.05		
S	.11		
MnO	.18		
BaO	.07		
SrO	Trace.		
Li_2O	None.		
	99.93		

According to the quantitative classification the rock is persalic, quarfelic, alkalicalcic, and persodic—that is, the quartz and feldspar are much more abundant than the ferromagnesian minerals and are about equal in amount, the sum of the alkalies about equals the lime, and of the alkalies soda is dominant. As the rock is transitional between subrangs 4 and 5, its magmatic name is susquehannose-vulcanose. Biotite is an abnormative constituent, and its texture is aphanitic, hence the rock name is biotitic felsi-susquehannose-vulcanose. The metadacite represents a magma somewhat more differentiated than the granodiorite and therefore more silicic and sodic.

GABBRO.

The granodiorite is intruded and is cut out to the northeast by masses of dark feldspathic rocks ranging from quartz diorite to peridotite and including quartz diorite, quartz gabbro, augite gabbro, hypersthene gabbro, hornblende gabbro, pyroxenite, olivine gabbro, peridotite, and serpentine. These are apparently differentiations of the same magma and are mapped as gabbro. Hypersthene gabbro, pyroxenite, olivine gabbro, and peridotite are found west of Elk Mills and in Grays, Chestnut, and Iron hills. Hornblende gabbro occurs chiefly as intrusive dikes and along the western border of the Wilmington area of gabbro, where it is exposed in the New Castle County Almshouse quarry on Red Clay Creek. Quartz diorite, augite gabbro, and hypersthene gabbro (norite) facies are found in the northeastern part of the Wilmington quadrangle and are finely exposed in quarries on Brandywine Creek in Wilmington. The Delaware Granite & Mining Co., whose quarry is on Brandywine Creek about three-fourths of a mile north of the Pennsylvania Railroad, is quarrying typical pyroxene gabbro, which by the company is called "pyroxene quartzite."

The rock of the Elkton-Wilmington gabbro area is made up of so many transitional types that the formation as a whole can not be easily characterized. The rock is darker colored than the granodiorite and is more massive. Biotite, the prominent ferromagnesian constituent of the granodiorite, is not an essential constituent of this rock, and the dominant feldspars are gray calcic plagioclases.

The rock here mapped as gabbro includes the types described below.

Quartz Diorite.

Distribution.—In areas north of the Elkton and Wilmington quadrangles quartz diorite is widely distributed and is a well-recognized differentiate of gabbro. In this area it occurs sparingly as a silicic facies of the gabbro. It is an integral part of the gabbro intrusion, and as it grades imperceptibly into the main body of gabbro of which it is only an insignificant part it has not been separated from that rock in the mapping of the Wilmington quadrangle.

The quarries of the Stewart & Donahue Co., on the northern outskirts of Wilmington and north of the Wilmington quadrangle, expose a quartz diorite that is known commercially as "Brandywine granite."

Character.—This most silicic facies of the gabbro mass is of lighter color than the normal gabbro. One of its striking features is its content of blue quartz, which not only is an abundant essential constituent of the rock but occurs in veins and segregations through it. The rock is medium to coarse grained and contains about 30 per cent of primary quartz, 60 per cent of feldspar, and not more than 10 per cent of pyroxene. The feldspar is chiefly andesine of approximately the composition Ab_2An_1, as is indicated by its optical properties, its specific gravity, and chemical analysis. The rock contains also orthoclase and a more calcic feldspar.

Pyroxene Gabbro.

The dominant type of rock in this intrusive area in the Wilmington quadrangle is a normal pyroxene gabbro in which the pyroxene is augite or hypersthene. This gabbro, of which quartz may or may not be a constituent, passes northward into a quartz diorite, westward into a hornblende gabbro, and southward into an olivine gabbro. It is a dark-gray medium-grained to fine-grained rock composed essentially of feldspar and pyroxene. Blue quartz veins traverse the rock, but quartz appears only sparingly as a regular constituent. The pyroxene, which is diopside and hypersthene, forms with magnetite about 55 per cent of the rock, and feldspar (dominantly labradorite and labradorite-bytownite), accessory quartz, and apatite form about 45 per cent. The rock is fresh and massive and shows hypidiomorphic, inequigranular texture. The feldspar of the normal gabbro from the Brandywine quarries was isolated by the specific-gravity method and analyzed in the laboratory of the United States Geological Survey with the following results:[1]

Analysis and recalculation of feldspar from Brandywine quarries, Wilmington, Del., showing a feldspar having approximately the composition Ab_1An_2.

	1	2		1a	2a
SiO_2	51.44	51.7	Orthoclase	1.11	------
Al_2O_3	30.05	30.9	Albite	34.06	33.33
CaO	13.19	13.4	Anorthite	63.06	66.67
Na_2O	4.07	4.0	CaO	.45	------
K_2O	.21	------	Fe_2O_3	.96	------
Fe_2O_3[a]	.96	------	Ignition	.35	------
MgO[a]	Trace.	------		99.99	100.00
Ignition	.35	------			
	100.27	100.00			
Specific gravity	2.689	2.710			

[a] Inclusions.

1. Feldspar of gabbro from the Brandywine quarries. Separation made by J. S. Diller; analysis made by R. B. Riggs.
2. Calculated oxide percentages of Ab_1An_2.
1a. Calculation of feldspar molecules from analysis 1.
2a. Calculation of feldspar molecules from analysis 2.

The analysis corresponds very closely to the calculated analysis of a feldspar of the composition Ab_1An_2, which belongs to the calcic end of the labradorite series. The feldspars vary considerably, however, with variations in the silicity of the rock, and more than one species of feldspar may be present even in a single exposure. Accessory constituents of the gabbro, which occur in very minor amount, are apatite, zircon, sphene, and garnet.

Typical hypersthene gabbro is found in the exposures about Mermaid, where the rock is somewhat darker than the normal gabbro and of a bronzy gray color. Hypersthene, showing some slight alteration to hornblende, is the dominant pyroxene, but either augite or diopside is also present. The feldspar (labradorite-bytownite) constitutes from 50 to 55 per cent of the rock and the pyroxene and magnetite from 50 to 45 per cent. The texture is hypidiomorphic and inequigranular, and the poikilitic fabric is characteristic, hypersthene being the inclosing mineral and diverse prismoid feldspar the inclosed mineral.

Olivine Gabbro.

The gabbro of Grays Hill (locally known as Red Hill), Chestnut Hill, and Iron Hill, northeast of Elkton, represents the most basic type of this rock, which presumably passes by gradation into the gabbro of the northern area, though the exposures are separated by a cover of Pleistocene sediments. Normally it is a dark, purplish to greenish gray, medium-grained to coarse-grained massive rock, composed essentially of pyroxene, the crystals of which may reach a length of 2 centimeters, and calcic feldspar, with or without olivine and without primary quartz. The coarse-grained varieties show conspicuous poikilitic fabric. This normal type is intimately associated with pyroxenic and peridotitic types in which feldspar is absent. In the meadows west of Iron Hill the rock weathers into small spheres not more than 3 to 5 inches in diameter.

The feldspar, which is bytownite-anorthite, was separated from the Iron Hill rock and analyzed with the following results:[2]

Analysis and recalculation of feldspar from gabbro of Iron Hill, New Castle County, Del., showing a feldspar having approximately the composition Ab_1An_{12}.

	1	2		1a	2a
Specific gravity	2.592-2.749	2.74-2.76	Orthoclase	1.11	------
SiO_2	44.09	45.18	Albite	8.38	7.85
Al_2O_3	35.41	35.34	Anorthite	87.01	92.15
CaO	18.47	18.56	SiO_2	.06	------
Na_2O	.99	.92	Al_2O_3	1.63	------
K_2O	.19	------	Fe_2O_3	.51	------
Fe_2O_3[a]	.51	------	CaO	.95	------
MnO[a]	Trace.	------	Ignition	.35	------
Ignition	.35	------		100.00	100.00
	100.01	100.00			

[a] Inclusions.

1. Analysis of the feldspar. Separation made by J. S. Diller; analysis by R. B. Riggs, in laboratory of U. S. Geological Survey.
2. Calculated percentages of the oxides in the formula Ab_1An_{12}.
This analysis indicates a feldspar of nearly the composition Ab_1An_{12}—that is, a member of the anorthite series.
1a. Calculation of feldspar molecules from analysis 1.
2a. Calculation of feldspar molecules from analysis 2.

The ferromagnesian constituents—hypersthene, augite, and olivine—constitute 50 to 99 per cent of the rock. The pyroxene, which is hypersthene and augite, diopside, or enstatite in about equal amounts or with hypersthene dominant, is almost universally altered to green hornblende. This alteration is partial or complete, and it occurs directly or through the intervention of a colorless tremolite. The alteration of augite or diopside to hornblende is usually direct, beginning at the outside of the crystal and growing toward its center. The early stage of the alteration shows an aggregate of hornblende crystals; the later stages show compact green hornblende. Where hypersthene is altered a colorless border of fibers of tremolite is formed between the original pyroxene and the green hornblende. The development of these amphibole minerals from hypersthene involves also the feldspar, which supplies the lime and alumina. Therefore, where the alteration is complete, not only has the pyroxene disappeared but also most of the feldspar, and the rock is an amphibolite.

The olivine shows the characteristic alteration to serpentine, and associated with the olivine gabbro and peridotite are serpentines which must have originated from the olivinitic rocks, although transitional types have not been found. Such serpentines occur in the railway cut southwest of Iron Hill station on the Philadelphia, Baltimore & Washington Railroad. The rock which underlies the Patapsco formation is a grayish-green serpentine that crumbles in the fingers and is evidently metamorphosed from a coarse-grained peridotite. Associated with the crumbling boulders of serpentine is an olivine gabbro containing about 45 per cent of feldspar and a hornblende gabbro in which all the original pyroxene has altered to hornblende. Also associated with these serpentines as a final product of alteration is a siliceous "honeycomb" ironstone, containing cellular cavities the walls of which are coated with yellow chalcedony.

Hornblende Gabbro or Metagabbro.

As has been already stated, the western border of the gabbro area near Wilmington and the gabbro intrusives and dikes of the Elkton quadrangle that lie north of and penetrate the granite are dominantly hornblende-bearing rocks. Rock of this type, which is known as metagabbro, because the hornblende is secondary, is quarried $2\frac{1}{2}$ miles west of Elsmere, at the New Castle County Almshouse quarry. It is also exposed a mile south of that quarry, on Red Clay Creek, at Marshallton; on Pike Creek at Choate; and on the southeast slope of Iron Hill, all localities in the Wilmington quadrangle. It is the prevailing type in the Elkton quadrangle.

The metagabbro is a medium-grained dark-green rock containing an excess of hornblende or of epidote. Its texture is generally more schistose than granular. The crystals of hornblende have in some places attained a length of a centimeter or more. Feldspar is invariably present, though in some places it has been largely replaced by epidote as well as by hornblende.

The hornblende, which occurs in fibrous green crystals or in compact blades having a more or less parallel arrangement, is believed to be secondary to a pyroxene that is presumably augite. Though no pyroxene is found in these rocks, all stages of the change of augite to hornblende have been observed in the gabbro at Wilmington. The hornblende constitutes 45 to 55 per cent of the rock. The epidote is secondary both to hornblende and to feldspar; secondary quartz is present and primary quartz may or may not be present.

The feldspar is normally labradorite; the accessory constituents are biotite, magnetite, apatite, and pyrite.

Analyses of Gabbro.

The following analyses have been made of the gabbro from the district adjacent to the Elkton quadrangle on the west.[3] 1 and 2 represent the silicic type of gabbro, 4 the less silicic type, and 3 a pyroxenite. The pyroxenite contains a higher percentage of silica than the hypersthene gabbro, but it is quartz free and perfemic, a fact clearly brought out by the quantitative system of classification, which places the rock in Class V.

Analyses and norms of gabbros from Cecil County, Md.

[W. F. Hillebrand, analyst.]

ANALYSES.

	1	2	3	4
SiO_2	58.57	55.16	53.21	48.02
Al_2O_3	16.10	17.51	1.94	20.01
Fe_2O_3	2.89	2.62	1.44	1.13
FeO	6.12	5.83	7.92	7.29
MgO	2.33	4.35	20.78	10.05
CaO	7.39	8.50	13.12	11.42
Na_2O	2.11	1.83	.11	.51
K_2O	1.01	1.08	.07	.05
H_2O+	1.27	2.01	.87	.57
H_2O-	.21	.18	.14	.10
TiO_2	1.41	.64	.26	.23
ZrO_2	.09	.02	Trace.	None.
CO_2	None.	None.	.10	.25
P_2O_5	.37	.21	Trace.	Trace.
FeS_2	Trace.	.03	.03	.11
Cr_2O_3	None.	Trace.	.20	.03 (.027)
V_2O_3	.02 (.018)	.04 (.036)	.03 (.034)	.02 (.019)
NiO	None.	.01	.03	.01
MnO	.18	.15	.22	.18
BaO	Trace.	Trace.	None.	None.
SrO	Trace.	Trace.	None.	None.
Li_2O	Trace.	Trace.	Trace.	None.
	100.07	100.17	100.47	99.98
Specific gravity	2.890	2.902	------	------

NORMS.

	1a	2a	3a	4a
Quartz	21.60	13.80	------	0.60
Orthoclase	6.12	6.12	0.56	.56
Albite	17.82	15.20	1.05	4.19
Anorthite	31.41	36.70	4.45	51.99
Diopside	2.32	3.86	48.21	3.83
Hypersthene	11.50	16.80	42.08	35.65
Olivine	------	------	.14	------
Magnetite	4.18	3.71	2.09	1.62
Ilmenite	2.74	1.22	.46	.46
Apatite	1.01	.34	------	------
Chromite	------	------	.22	------
Pyrite	------	.03	.03	.11
Water	1.48	2.19	1.01	.67
Miscellaneous	.11	.07	.16	.31
	100.29	100.04	100.46	100.09

1. "Quartz-biotite metagabbro," foundry on Stone Run, Cecil County, Md.
2. "Quartz-biotite metagabbro," Porters Bridge, Octoraro Creek, Cecil County, Md.
3. Pyroxenite (websterite), Oakwood, Cecil County, Md.
4. Hypersthene gabbro (norite), McKinsey's Mill, Cecil County, Md.
1a. Norm of 1. Biotitic hornblende-grano-bandose, II.4.4.4.
2a. Norm of 2. Biotitic hornblende-grano-bandose, II.4.4.4.
3a. Norm of 3. Augite-grano-cecilose, V.1.1.2.'2.
4a. Norm of 4. Grano-kedabekase, "III.5.5.0 (I.1.1.2).

[1] Chester, F. D., The gabbros and associated rocks in Delaware: U. S. Geol. Survey Bull. 59, p. 12, 1890.

[2] Chester, F. D., op. cit., p. 28.

[3] Leonard, A. G., Basic rocks of northeastern Maryland: Am. Geologist, vol. 28, pp. 146, 151-152, 159, 1901.

The biotitic-hornblende-grano-bandose, Nos. 1 and 2, represents the more silicic type of the gabbro. The feldspar is labradorite of about the composition Ab_1An_2, and the rock is therefore a true gabbro and not a diorite, as it was at one time called because of the presence in it of hornblende, a constituent which is secondary to the original pyroxene. The magma is dosalic, quardofelic, docalcic, and dosodic—that is, quartz and feldspar are the dominant constituents, the feldspar is dominant over the quartz, the lime utilized in the feldspar is dominant over the alkalies, and of the alkalies soda is the more abundant. Biotite is a varietal abnormative constituent and hornblende a critical abnormative constituent, and the texture is hypidiomorphic granular, hence the name biotitic hornblende-grano-bandose.

The grano-kedabekase represents the hypersthene gabbro, the less silicic type. The feldspar belongs to the anorthite series; there are no abnormative minerals. The rock is salfemic, perfelic, percalcic—that is, the quartz and feldspar are about equal to the ferromagnesian constituents, the feldspar is more abundant than the quartz, and the feldspathic lime exceeds the sum of the alkalies. The petrographic description and the analysis of this hypersthene-bytownite type of gabbro, though made from a sample collected about 25 miles west of the area of gabbro in the Wilmington quadrangle, agrees very closely with the hypersthene gabbro of this district.

The augite-grano-cecilose is a coarse-grained aggregate of hypersthene and augite with a little almost pure anorthite feldspar and resembles the pyroxenite of Iron Hill. The analysis and norm show that it is perfemic, perpolic, permirlic, domiric, and domagnesic, which means that the ferromagnesian minerals are the dominant constituents of the rock, that the ferromagnesian silicates greatly preponderate over the oxides, that the magnesia and ferrous oxide are dominant over the lime, and finally that the magnesia is dominant over the ferrous oxide.

SERPENTINE, STEATITE, AND ASSOCIATED ALTERATION PRODUCTS (METAPYROXENITE AND METAPERIDOTITE).

Distribution.—With the serpentine have been mapped certain dark rocks which are intimately associated with it and which, like it, are products of the alteration of pyroxenite or peridotite. Such rocks are hornblende, actinolite, anthophyllite, tremolite, or chlorite schists, enstatite-serpentine rocks, asbestos, and steatite schists. They are found in large irregular oval areas near Chrome, in the northwest corner of the Elkton quadrangle. Some of these areas are crossed by the Pennsylvania-Maryland State line, and the rocks are therefore known as the "State-line serpentines." These rocks are noted for their associated minerals. There are seven of these State-line areas, in which the prevailing rock is pure serpentine. Serpentine occurs also as the product of the alteration of the gabbro of Flint Hill, Chestnut Hill, and Iron Hill. The prevailing rock at Chestnut Hill and Iron Hill is gabbro in which serpentine is only one of the secondary constituents and is therefore not mapped separately.

Character.—Although serpentine is one of the most readily recognized of rocks it shows the greatest variation in color and general appearance. In color it ranges from buff or even white to a deep emerald green or from light-yellowish green to dark blue-green, with which are associated shades of reddish brown. Light colors generally accompany an earthy texture and dark colors a compact stony texture; grayish-green shades are associated with a fibrous texture, which is due to the development of talc, asbestos, or tremolite. The rock has many irregular and interrupted joint planes, whose surfaces are commonly slickensided. A final product of the alteration of the serpentine is a rusty yellow siliceous rock, consisting of crystalline quartz or jasper or chalcedony or opal colored by limonite and having a cellular or honeycomb texture due to the removal of the magnesian silicate, illustrated by the quartz-strewn surface of Flint Hill, 2 miles north of Elkton. Besides the associated minerals already mentioned the rock contains many accessory and secondary minerals, the most common of which are chromic iron, magnetite, calcite, quartz, and talc (steatite).

Chrome ore was mined in the "State-line serpentines," west of the Elkton district, as early as 1828. Some of these chrome ore mines, notably Wood's mine, have been well-known collecting grounds for the rarer minerals that are associated with serpentine, such as brucite, clinochlore, deweylite, zaratite, picrolite, magnesite, hydromagnesite, and williamsite or precious serpentine.

The following analysis of serpentine rock from Mineral Hill, Middletown, Delaware County, Pa., was made by F. A. Genth:

Analysis of serpentine from Mineral Hill, Delaware County, Pa., compared with composition of pure serpentine and other serpentine.

	1	2	3
SiO_2	44.18	43.49	43.13
Al_2O_3	Trace.		
FeO	1.64		1.76
MgO	39.37	43.47	42.17
H_2O+	12.78	13.04	12.94
H_2O-	2.10		
	100.07	100.00	100.00

1. Serpentine from Mineral Hill, Middletown, Delaware County, Pa. Pennsylvania Second Geol. Survey Rept. C5, pt. 1, p. 120, 1885.
2. Theoretical composition of the mineral serpentine.
3. Composition of serpentine in which some of the magnesia is replaced by ferrous oxide.

Derivation.—The derivation of serpentine from pyroxenite (nonfeldspathic pyroxene-bearing rock) and from peridotite (nonfeldspathic olivine-pyroxene rock) is well recognized. Serpentine that is derived from pyroxenite is likely to be somewhat fibrous and to be associated with tremolite, anthophyllite, smaragdite, or actinolite—minerals that represent intermediate stages in the passage of pyroxene to serpentine. Serpentine that is derived from a peridotite is more massive and shows under the microscope a grating fabric due to the development of the serpentine along a network of cracks in the olivine. Olivine cores still remain in serpentine in which the alteration is incomplete.

Topographic form.—The soil derived from serpentine, as well as the general aspect of the country underlain by serpentine, is distinctive. The sterility of "honeycomb rock" soil, which is well known among farmers, is due as much to its thinness and its inability to hold water as it is to its chemical composition. Because serpentine weathers less readily than other rocks on account of its chemical stability, and possibly because of vertical expansion due to hydration, it forms low hills and ridges in which the rock outcrops or is covered with but a scanty yellowish-green soil. The "State-line serpentines" give rise to hills that are locally known as "the barrens," and that in general present a striking contrast to the surrounding country. A serpentine hill that stands in the midst of a cultivated agricultural country but that is left uncultivated because of the character of its soil may remain relatively wild and desolate, supporting a scanty vegetation of ground pink (*Phlox subulata*), cat briar, cedars, and stunted pines. Flint Hill, 2 miles north of Elkton, is a good example of a quartz-strewn serpentine hill.

The application of the quantitative system of classification to the igneous rocks of the Elkton and Wilmington quadrangles shows that they are calcic rather than alkalic. This statement can be extended to the pre-Cambrian igneous rocks of the whole Pennsylvania Piedmont region. Analyses of 16 different igneous rocks found in eastern Pennsylvania and adjacent areas in Maryland show that all except two are alkalicalcic (5), docalcic (8), or percalcic (1); that all are presodic—that is, sodipotassic (3) or dosodic (7) or persodic (6); and that they form a continuous series ranging from a persalic type, in which quartz and feldspar dominate, to a perfemic type, in which the ferromagnesian constituents dominate. The fact that rocks which vary widely in silicity are constantly calcic and presodic indicates that they are magmatically consanguineous, and that the continuous variation in silica with the maintenance of nearly constant ratios between the lime and the alkalies and between the alkalies can be due only to magmatic differentiation by fractional crystallization.

DIABASE AND PEGMATITE DIKES.

The granodiorite, the Wissahickon mica gneiss, and the Baltimore gneiss are penetrated by numerous very narrow diabase dikes, which can be traced only for short distances. These dikes are composed of fine-grained green rocks, whose color is due to the hornblende and chlorite which they contain. They have not the same constituents as the diabase of the dikes of Triassic age, are not so fresh, and are presumably much older. Three such dikes are exposed in the granite quarry on Stony Run, 1¼ miles northwest of Northeast on the west side of the Elkton quadrangle; two of them are about 5 feet and the third is about 10 feet in width. Diabase dikes occur in the northern part of the Elkton quadrangle between Little Elk Creek and Andora and about a mile east of Cowentown, as well as at many other places. A fine-grained diabase dike about 10 feet wide is exposed in the Baltimore & Ohio Railroad cut 1¼ miles west of Leslie, in the western part of the Elkton quadrangle.

In this region pegmatite dikes, in which the rocks consist mainly of coarsely crystalline feldspar, quartz, and muscovite, are exceedingly numerous. They intrude all the other formations but are most abundant in the gneiss and schist, which is at some places quite altered by multiple pegmatitic injections. They range in width from a few inches to 200 feet. Only the larger and more persistent dikes have been traced. Several such pegmatite dikes are exposed along White Clay Creek, which has cut into them. The most northerly of these dikes, which strikes about N. 75° E., supplies in the lowlands, where the alkali feldspar has broken down into kaolin, the clay that is refined by the Newark China Clay Co. A mile to the northeast another kaolinized pegmatite is worked by the Peach Kaolin Co. Several small "spar" quarries in other pegmatites are worked only intermittently. In most of them the feldspar is chiefly a soda feldspar, though potash feldspar is found in some of them, and in the rock quarried 1¼ miles northeast of McClellandville it is the chief feldspar. Tourmaline is a common accessory mineral in these pegmatites. In a spar quarry on Big Elk Creek half a mile northeast of Peacedale, near the northern limit of the Elkton quadrangle, it occurs abundantly in crystals that measure several inches in diameter.

STRATIGRAPHY OF THE COASTAL PLAIN AREA.

By Benjamin L. Miller.

GENERAL FEATURES.

The geologic formations that outcrop in the parts of the Elkton and Wilmington quadrangles that lie in the Coastal Plain range in age from Lower Cretaceous to Recent. The Cretaceous and Quaternary systems are each represented by several formations. All the Cretaceous formations have certain features in common. They have a general northeasterly strike and southeasterly dip, and each passes southeastward under the next later one. The shore line during each submergence, with certain exceptions to be noted, evidently lay a short distance southeast of the position it occupied during the preceding submergence, so that the traveler going southeastward crosses the outcrops of the formations in the order of their deposition.

The Pleistocene deposits also strikingly resemble one another in that they constitute terraces that stand at different elevations and form the topographic terraces already described.

The general sequence of the formations is shown in the following table:

Geologic formations of the Coastal Plain in the Elkton and Wilmington quadrangles.

System.	Series.	Group.	Formation.
Quaternary.	Recent.		
	Pleistocene.	Columbia.	Talbot. Wicomico. Sunderland.
Tertiary.	Pliocene (?).		Brandywine.
Cretaceous.	Upper Cretaceous.		Monmouth. Matawan. Magothy. Raritan.
	Lower Cretaceous.	Potomac.	Patapsco. Patuxent.

CRETACEOUS SYSTEM.

Rocks of Cretaceous age form a continuous series of deposits throughout the Atlantic and Gulf coastal plains and have long been differentiated from the overlying Tertiary deposits, with which they were first confused. Fossils that were obtained in the excavation made for the Chesapeake & Delaware Canal between 1824 and 1829 determined definitely the Cretaceous age (or "Secondary" age, as it was then termed) of these deposits. Detailed studies made since then have shown that these strata may be divided into several formations, which have been included in two series—the Upper Cretaceous and the Lower Cretaceous. Probably in no other area of equal size within the Coastal Plain are the Upper and Lower Cretaceous deposits exposed in beds so various as those in the Elkton and Wilmington quadrangles. The section through the canal is one of the most instructive yet found and has contributed greatly to the solution of many puzzling stratigraphic problems. If a tide-level canal is constructed along this route it will undoubtedly furnish important additional information that has long been desired.

LOWER CRETACEOUS SERIES.

POTOMAC GROUP.

GENERAL FEATURES.

The oldest deposits of the Atlantic Coastal Plain belong to the Lower Cretaceous series. Although several deep borings made in different parts of the Coastal Plain have reached the pre-Cambrian or early Paleozoic metamorphic rocks that constitute the "basement complex," none of them have shown that any deposits older than Lower Cretaceous lie in contact with those ancient rocks. Lower Cretaceous deposits seem to extend continuously through an area of the Coastal Plain stretching from Pennsylvania to Alabama and crop out in the valley of almost every large stream within that area. Some islands, which now form Chestnut, Iron, and Grays hills, stood above the Cretaceous sea and were not covered by these sediments.

The distinction between the Upper and the Lower Cretaceous has long been difficult, but recent paleobotanic studies seem to show a rather sharp division, which is indicated in the above table and is discussed in the following pages.

The Lower Cretaceous series of the Elkton and Wilmington quadrangles includes the Patuxent and Patapsco formations. These and the Arundel formation, which is well developed elsewhere in Maryland, constitute the Potomac group. They consist of highly colored sands, gravels, and clays, which outcrop in a sinuous line extending from Pennsylvania to Virginia and beyond, passing near the cities of Wilmington, Baltimore, Washington, and Richmond. The Potomac deposits are of great value because of the excellent brick clays which they contain and which have been extensively utilized in many places. The Patuxent and Arundel formations were long tentatively referred to the Jurassic but are now regarded as unquestionably Cretaceous, so that there are no Jurassic rocks in the Coastal Plain or in the eastern part of North America unless some of the strata generally regarded as of Triassic age may be in part Jurassic.

PATUXENT FORMATION.

Areal distribution.—In these quadrangles the Patuxent formation occurs in a series of disconnected areas that extend from Stanton southwestward to the west-central border of the Elkton quadrangle. Although these areas are now disconnected, they are fragments of a deposit that was once continuous over this region—fragments left by erosion or due to the overlapping of later formations—and there is little doubt that Patuxent strata everywhere underlie the southern parts of the quadrangles. The formation is best exposed near Cherry Hill, Singerly, Egg Hill, Leslie, and Bayview.

The Patuxent formation undoubtedly once covered a much larger area of the Piedmont Upland than it does now, but erosion has at certain places completely obliterated all traces of it and at others the slight indications of its former presence are not conclusive. Rounded pebbles and cobbles that may be of Patuxent age are sparingly distributed over parts of the upland where only crystalline rocks are represented on the accompanying geologic maps.

The Patuxent formation is widely distributed in the Coastal Plain. It has been recognized almost continuously from Elkton, Md., to Richmond, Va., and is again exposed at many places along the principal streams of the Carolinas, Georgia, and Alabama.

Lithology.—The materials composing the Patuxent formation are extremely variable but are prevailingly arenaceous. Abrupt alternations, both vertical and horizontal, of sand, gravel, and clay may be seen in almost every well-exposed section. At some places sand passes gradually into gravel or clay, but at others no transition zone between beds of unlike materials is apparent, the contacts being decidedly sharp.

Although the sands are typically white and consist of angular to subangular grains of clear quartz, in numerous small areas the sand grains are covered with a thin coating of iron or manganese oxide, which imparts a pink, salmon, or purplish color. The iron oxide may be deposited in sufficient quantities to act as a cementing material that binds the grains together to form a ferruginous sandstone. In general, however, the gravel layers are cemented rather than the sands. In many places the sands are cross-bedded, an additional indication that they were deposited in shallow water.

The sandy strata generally contain considerable kaolinized feldspar, forming an arkose, which, when indurated, was designated by Rogers "feldspathic sandstone." The sands also at many places contain much muscovite. In a well near Eder, at a depth of 18 feet, a layer of decidedly micaceous loose white sand was penetrated in which many of the individual flakes were more than one-eighth inch in diameter.

The Patuxent sands are likely to be confused with the Pleistocene sands, from which, however, they can generally be distinguished by their more angular grains, their lighter color, their looser character, due to the absence of particles of plastic clay, and by their large content of kaolin.

The gravel of the Patuxent formation occurs in lenses, some of which are as much as 20 feet thick but occupy small areas. A gravel band commonly occurs at the base of the formation, but the coarse lenses are by no means restricted to that horizon. At many places near Leslie, Bayview, and elsewhere the gravel lenses seem to be predominant in the upper strata, but this appearance is due to the concentration of the pebbles at the surface, the finer sands having been removed by erosion. The pebbles of the Patuxent formation are not well sorted; almost every deposit shows a variation in size from coarse sand to cobbles 10 inches in diameter. The larger cobbles are decidedly angular and can with difficulty be distinguished from disintegrated fragments of the underlying crystalline rocks, especially if they are composed of similar material. Although most of the pebbles and cobbles of the Patuxent formation are composed of vein quartz, which is found everywhere in the Piedmont Upland, the formation includes many pebbles of quartzite and sandstone, some of which contain Paleozoic fossils, and have therefore been brought from remote sources.

At most places the matrix of the pebbles is a loose white to buff sand, but at a few it is decidedly ferruginous and is well adapted for use as road metal. A ferruginous gravel bed a mile south of Bayview has been extensively worked and furnishes great quantities of material for the permanent roads now being constructed. Iron crusts and concretions are abundant in the Patuxent in some localities in Maryland but are seldom seen in these quadrangles.

The sands contain small and large lenses of clay, which are commonly light in color, though locally they are highly colored by iron compounds. The drab clays are in places lignitic and at some localities in the Maryland Coastal Plain they have yielded many impressions of fossil leaves. In the Elkton and Wilmington quadrangles clay lenses are uncommon.

Section in railroad cut one-eighth of a mile west of Childs station, Cecil County, Md.

	Feet.
Patuxent formation:	
Brownish-yellow, buff, white, or locally salmon-colored arkosic angular sand containing locally lenses of gravel, some of which are in part cemented by iron oxide and form a ferruginous conglomerate	10–20
Patuxent formation—Continued.	
Poorly assorted gravel band containing well-rounded to decidedly angular pebbles and cobbles, the largest of which are 8 inches in diameter; matrix of arkosic sand	3–5
Irregular contact.	
Decayed granite gneiss, exposed	10–15

Organic remains.—Although the Patuxent deposits are in general unfossiliferous because of their coarse character, nevertheless a considerable flora has been collected from clay balls and lenses and the more argillaceous sands, especially from beds of this age in the Rappahannock and James river valleys in Virginia.

This flora includes a large element made up of survivors from the older Mesozoic, and is rich in species and individuals referred to the fern genera *Cladophlebis* and *Onychiopsis*. Other genera of ferns, such as *Acrostichopteris*, *Schizaeopsis*, *Scleropteris*, *Taeniopteris*, and *Ruffordia*, are less common. Remains of a variety of cycad testify to the abundance of this type of plant, represented for the most part in the Maryland area by the silicified trunks of *Cycadeoidea*, of which several different species are known. Cycad fronds, less common in Maryland, are abundant in the more argillaceous deposits of this age in Virginia and include a variety of genera, such as *Nilsonia*, *Podozamites*, *Zamites*, *Williamsonia*, *Ctenopteris*, *Ctenopsis*, and *Ctenis*. Perhaps the most striking of these remains are the large forms of *Nilsonia* and the splendid fronds of *Dioonites*.

Among the gymnosperms are species of *Sphenolepsis*, *Baiera*, *Brachyphyllum*, *Frenelopsis*, *Nageiopsis*, *Athrotaxopsis*, *Sequoia*, and *Cephalotaxopsis*. These are for the most part genera that range from the late Triassic to the Upper Cretaceous. They are abundant in the Patuxent and represent families which in the modern flora are largely natives of other continents.

Supposed but altogether doubtful angiosperms, the most ancient known, are represented by the genera *Rogersia*, *Proteaephyllum*, and *Ficophyllum*, which perhaps should be considered the remains of foliage of the gymnospermous order Gnetales.

The known fauna of the Patuxent is represented by a single fish found in the James River area, but it is extremely probable that the rich dinosaurian fauna of the overlying and closely related Arundel formation flourished during Patuxent time, since in the west the representatives of this fauna occur in the Morrison formation conformably below the Kootanie formation, which carries the representatives of the Patuxent flora.[1]

So far as known no fossils have ever been found in Patuxent strata in the Elkton and Wilmington quadrangles.

Name and correlation.—The Patuxent formation received its name from Patuxent River, Md., in the basin of which these deposits were first recognized as an independent formation and systematically studied. Careful work showed that the deposits formerly included in the Potomac "formation" were readily separable into four distinct formations by unconformities and by fossils.[2]

The correlation of the Patuxent formation was for many years in question, and its exact age has been determined only recently by paleobotanic investigations. The Patuxent underlies Arundel strata, in which Marsh found many remains of dinosaurs that he regarded as unquestionably Jurassic, and for this reason many geologists referred these deposits to that period. Fontaine, in his study of the Patuxent flora, also states that there is an "overwhelming percentage of Jurassic types," although he refers the flora as a whole to the Cretaceous. Berry, however, has recently shown conclusively that the Patuxent plant remains are of Lower Cretaceous age and correlates the formation with the Morrison of Colorado, with part of the Knoxville of the Pacific coast, and with the Wealden of England, Germany, and Belgium.

Thickness.—The thickness of the Patuxent formation in this and adjoining regions is extremely variable, owing to the uneven surface upon which it was deposited, to the erosion which it underwent before and since the deposition of the Patapsco strata, and to the conditions under which the beds were laid down.

In some of the areas represented on the map the formation is less than 20 feet thick, whereas in others near by it is two or three times as thick. Its maximum thickness in these quadrangles is probably about 125 feet. Its maximum thickness in Maryland is believed to be more than 350 feet. Well borings indicate a thickening in the area to the southeast, where it is concealed beneath later deposits.

Stratigraphic relations.—The Patuxent formation rests upon the uneven surface of the crystalline rocks of the Piedmont Upland. This uneven erosional surface is well exhibited in the railroad cut just west of Childs station. An examination of the geologic maps will show that its present distribution is only slightly governed by the height of the hills. It may be present on one hill and entirely absent from another one of the same height directly along the strike, and similar anomalies can be found along the dip of the formation. It is overlain unconformably by strata belonging to the Patapsco, Brandywine, and Pleistocene formations.

The deposits strike northeast and dip south-southeast in this region. The normal dip of the basal beds is about 60 feet to the mile.

[1] Maryland Geol. Survey, Lower Cretaceous, pp. 63–64, 1911.

[2] Clark, W. B., and Bibbins, Arthur. The stratigraphy of the Potomac group in Maryland: Jour. Geology, vol. 5, pp. 479–506, 1897.

PATAPSCO FORMATION.

Areal distribution.—The Patapsco formation is widely distributed throughout the Elkton and Wilmington quadrangles and appears in a series of outcrops extending from a point near Wilmington southwestward to the western margin of the Elkton quadrangle near Charlestown. There are many excellent exposures in this band, which is several miles wide and for the greater part is free from the cover of Pleistocene gravels, sands, and loam that conceals so largely the Upper Cretaceous formations. The Patapsco outcrops continuously for many miles along Christiana Creek, is typically displayed in the vicinity of Red Lion, and is well exposed along the north side of Grays Hill, along the Elkton-Northeast road, especially near Bacon Hill, and in many railroad and stream cuttings near Charlestown. The highly colored red and mottled clays are so striking that few travelers on the Philadelphia, Baltimore & Washington Railroad between Wilmington and Baltimore fail to observe them. Southeast of this outcrop the formation probably extends over the entire area, underlying all the later formations. In its wider distribution the Patapsco formation has been recognized in discontinuous outcrops from the valley of Schuylkill River, near Philadelphia, to the valley of the Potomac, in Virginia.

Lithology.—The Patapsco formation is composed chiefly of highly colored and variegated clays, interbedded with sandy clays, sands, and gravels, the materials of different kinds grading into each other both horizontally and vertically. In many places the sandy material in the vicinity of clay beds is indurated to a conglomerate or to rough, irregular, pipelike concretionary masses called "pipe ore." The variegated clays exhibit a great variety of rich and delicate tints in irregular patterns. In places they grade downward or horizontally into massive clays of chocolate, drab, and black tones, locally carrying lignite and pyrite or iron ore and impressions of leaves. The sands, which are very commonly cross-bedded, here and there carry decomposed grains of feldspar and pellets of white clay. A red ocher that is locally known as "paint rock" or "paint stone" is not uncommon, and limonite with botryoidal surfaces is found at several horizons.

At Newport the formation yields white to buff cross-bedded muscovitic sand and a red and mottled stiff plastic clay in the same pit. A mile southwest of Christiana there is a deposit of extremely pure white cross-bedded quartz sand in which are embedded here and there small lenses of white plastic clay. A short distance east of Bacon Hill a drab clay has been extensively used in the manufacture of brick. Half a mile south of Eder there is a bed of fine white clay, about 18 feet thick, containing some small flakes of muscovite. A slight mottling may be observed in places throughout the bed. In a clay pit $1\frac{1}{4}$ miles southwest of Leslie the upper layers are white to buff and contain numerous flakes of muscovite and a few angular clear quartz pebbles; beneath these layers is a mottled red and white clay that grades downward into chocolate-colored to black clay in which are many pieces of lignite resembling charcoal.

Gravel lenses are less numerous in the Patapsco formation than in the Patuxent, but they occur at all horizons and some of them are so firmly cemented as to form ferruginous sandstones and conglomerates, which are exposed at many places along the State road between Elkton and Northeast. The Patapsco, although predominantly consisting of highly colored clays, thus presents a wide range of constituents and characteristics.

Organic remains.—The Patapsco deposits have yielded a few specimens of poorly preserved unios and an extensive flora, including representatives of the Pteridophyta, Cycadophyta, Gymnospermae, and Angiospermae. The ferns, cycads, and conifers represent for the most part the dwindling remnants of the Patuxent-Arundel flora, some species being common to all three formations and the genera being largely identical. The fern genera *Scleropteris*, *Schizaeopsis* and *Taeniopteris* have disappeared, but *Ruffordia*, *Cladophlebis*, and *Onychiopsis* are still common. Petrified remains of a species of *Tempskya* and impressions of fronds of a peculiar new genus of ferns *Knowltonella*, are highly characteristic of this formation. Among the cycads *Podozamites* and *Zamites* are represented, but the genera *Nilsonia*, *Dioonites*, *Ctenis*, *Ctenopteris*, and *Ctenopsis* have disappeared. Silicified trunks of *Cycadeoidea* have been found in the Patapsco, but it is questionable if they have not been reworked from the older formations.

Among the gymnosperms *Laricopsis*, *Baiera*, *Cephalotaxopsis*, and *Athrotaxopsis* are no longer represented. Species of *Widdringtonites* and *Pinus* are new and characteristic, while the genera *Sequoia*, *Sphenolepis*, *Brachyphyllum*, and *Nageiopsis* are present.

The marked distinctness and more modern aspect of the Patapsco flora is due, however, to the abundance of Dicotyledonae, which foreshadow and were undoubtedly for the most part ancestral to the Dicotyledonae of the Upper Cretaceous Raritan formation.

The more characteristic of these are the various species of *Araliaephyllum*, *Sterculia*, *Cissites*, *Celastrophyllum*, *Populophyllum*, etc. The compound leaves of *Sapindopsis* are one of the most striking dicotyledonous elements present. Three species are known, and all are strictly confined to this horizon.[3]

Few Patapsco fossils have been identified from this area, though careful search in the drab to chocolate-colored clays would undoubtedly show the presence of a considerable flora.

[3] Maryland Geol. Survey, Lower Cretaceous, p. 71, 1911.

Zamites tenuinervis and *Sphenolepis sternbergiana* have been collected from strata exposed on the flanks of Grays Hill.

Name and correlation.—The Patapsco formation received its name from Patapsco River, Md., in whose valley it is typically exposed. It was first differentiated and named by Clark and Bibbins.[1] Rogers included it in the "Upper Secondary," or "Jurasso-Cretaceous," and Tyson included it in his "Upper oölite." Marsh, Fontaine, Ward, and Darton included it in the undifferentiated Potomac, which is now separated into several formations. The formation is correlated with the Fuson formation of the Black Hills and with the Albian of Europe.

Thickness.—Near Grays Hill the Patapsco is 130 feet thick, but in the northern part of Elk Neck it is probably as much as 200 feet thick, although its exact thickness there is unknown.

Stratigraphic relations.—At most places in this area the Patapsco formation rests unconformably upon strata of Patuxent age, but at some places it overlaps the Patuxent strata and rests directly upon the crystalline rocks of the Piedmont Upland. Where the overlapping is not extensive a narrow band of Patuxent strata appears between the Patapsco and the crystalline rocks, but elsewhere, as at Newport, Grays Hill, and west of Northeast, the Patapsco strata lie in direct contact with the rocks of the Piedmont Upland.

The formation is unconformably overlain by the Raritan except on some of the stream divides, where it is covered with thin deposits belonging to the Brandywine or Pleistocene formations.

The Patapsco formation strikes northeastward and dips southeastward at an average rate of about 40 feet to the mile.

UPPER CRETACEOUS SERIES.

The Upper Cretaceous is well represented in the Elkton and Wilmington quadrangles by strata that form the tops of some of the hills on Elk Neck and are exposed in the valley of every stream between Elk River and Delaware River. These deposits belong to the Raritan, Magothy, Matawan, and Monmouth formations. In many ways the Raritan and Magothy are similar to the Lower Cretaceous formations, especially in their heterogeneous lithologic composition, but the Matawan and Monmouth, which consist of much more homogeneous materials in which glauconitic sand is a prominent constituent, are markedly unlike the Lower Cretaceous deposits.

RARITAN FORMATION.

Areal distribution.—The Raritan formation appears in a series of outcrops that extend from Farnhurst southwestward to Bull Mountain, on Elk Neck. East of Elk River it is exposed only in the stream valleys, Pleistocene materials covering the divides, but on Elk Neck, where erosion is still active, it is exposed over large areas even to the summits of some of the highest hills. There are good exposures on Elk Neck, where road cuttings show undisturbed strata. One of the best exposures in the region is just south of Farnhurst, where the railroad has opened a great sand and gravel pit that exposes about 30 feet of Raritan materials.

In its wider distribution the Raritan formation has been recognized from Raritan Bay, N. J., to the basin of Potomac River. It dips under the overlying strata and is believed to extend over the entire southeastern area of the quadrangles beneath the younger formations.

Lithology.—The Raritan consists of variable materials similar to those that form the Patuxent and Patapsco formations. In these quadrangles the Raritan is predominantly arenaceous, in this respect resembling the Patuxent, although the sands are less arkosic. Clay is present in lenses in many places, but there is an almost complete absence of the highly colored variegated beds that form so prominent a feature of the Patapsco.

Gravel lenses occur at all horizons but are better sorted than those of the Patuxent and contain few large or angular cobbles. The coarser layers of sand and pebbles are in many places so firmly cemented by iron oxide as to warrant their local use for rough structural work. Where not cemented by iron the sands and gravels are apt to be very loose, owing to the small admixture of clay, and consequently are worn away by erosion with great rapidity. Rain pillars, capped by fragments of iron crust or small pebbles, from half an inch to $1\frac{1}{2}$ inches in height can be seen in many places along the roads of Elk Neck. Near Farnhurst the Raritan consists chiefly of gray to yellowish-brown extremely loose sand and in places a small amount of arkose. It includes thin bands of small pebbles, a few isolated pebbles, and some lenses of drab to chocolate-colored clay. The chocolate-colored clays contain many poorly preserved leaf fragments.

The Raritan deposits can not everywhere be separated with ease from the underlying Patapsco strata, but there is much less difficulty in separating them from those of the overlying Magothy formation, which are much more uniform in character and are less highly colored.

Paleontology.—Both animal and plant remains have been found in the Raritan formation, but the known fauna, like that of the formations of the Potomac group, is very scanty both in individuals and species, the flora being much more abundant. Logs of lignitized conifers exhibiting teredo borings have occasionally been found, and in New Jersey the formation has yielded some bones of a plesiosaur. No dinosaurian remains have thus far been found in Raritan strata.

The flora of the formation includes ferns, fronds of cycads, conifers, monocotyledons, and dicotyledons. The dicotyledons are particularly conspicuous and are relatively modern in aspect.

The Raritan has yielded no silicified trunks of cycads, so far as is definitely known, and in this respect its flora presents a sharp contrast to that of the Patapsco formation.

Berry[2] has described the following plants from Bull Mountain, on Elk Neck:

Pteridophyta:
- Cladophlebis socialis.
- Asplenium dicksonianum.

Cycadophyta:
- Podozamites lanceolatus.

Angiospermophyta:
- Protophyllum sternbergii.
- Araliopsoides breviloba.
- Araliopsoides cretacea.
- Araliopsoides cretacea dentata.
- Araliopsoides cretacea salisburifolia.
- Diospyros primaeva.

Name and correlation.—The formation receives its name from Raritan River, N. J., in the basin of which it is typically developed. It includes the deposits long called "Plastic clays," by the New Jersey Geological Survey. The fossil plants show a marked resemblance to forms of the Cenomanian in Europe, and the formation is therefore regarded as representing the initial deposits of the Upper Cretaceous.

Thickness.—In Bull Mountain, in the southwest corner of the Elkton quadrangle, the Raritan formation attains a thickness of about 200 feet, which is its greatest thickness in these quadrangles. Owing to the gradual overlapping of the Matawan toward the northeast the exposed thickness of the Raritan in the Wilmington quadrangle is scarcely more than 50 feet. In the area to the southwest of this region the formation apparently has a maximum thickness of about 400 feet.

Stratigraphic relations.—The Raritan unconformably overlies the Patapsco formation and is separated from the overlying Magothy by another marked unconformity. In the valley of Red Lion Creek the Raritan is unconformably overlain by the Matawan, which in one place completely overlaps it and rests directly on the Patapsco. In the region of its outcrop Pleistocene deposits of the Talbot, Wicomico, and Sunderland formations and Pliocene (?) deposits of the Brandywine formation overlie the edges of the Raritan and generally conceal the deposits from view except where erosion has removed these later beds.

The strike and dip of the Raritan formation correspond closely with those of the Patapsco. The normal dip of the basal beds is about 30 feet to the mile, but this increases toward the fall line.

MAGOTHY FORMATION.

Areal distribution.—The Magothy formation occupies only small areas in these quadrangles. It crops out in the valleys of several streams between Town Point Neck and the Chesapeake & Delaware Canal, but its principal exposures are along the canal. Without this artificial excavation no one could easily gain an adequate conception of the formation in this region. The most easterly point at which it has been observed is at milepost 101, about half a mile west of Summit Bridge. At one point, opposite milepost 74, the Magothy is not exposed, the Matawan extending to the water level, but it appears both east and west of this point. Its disappearance is due to a rather sharp local unconformity. Its failure to appear in the stream valleys of the Wilmington quadrangle is also explained by the overlapping of the Matawan.

Lithology.—The Magothy formation is composed of extremely different materials and changes abruptly in character both horizontally and vertically. Its most prominent constituents are loose, light-colored sands, which usually show fine lamination and in places considerable cross-bedding. They consist of coarse rounded to subangular grains of quartz, which range in color from pure white to a dark ferruginous brown. At many places lenses or bands of brown sand occur within the light-colored sands. Normally the deposits of sand are loose, but in places the iron derived from this and adjacent formations has cemented the grains firmly together into a hard iron sandstone or conglomerate.

At some places the Magothy includes considerable clay, but it is generally made up chiefly of sand. The clay commonly occurs as fine laminae alternating with the layers of sand. The clay is generally drab, but here and there it is made black by vegetable material, which may be either finely divided or may consist of large pieces of lignite. Thus far no bright-colored clays have been found in the Magothy deposits.

About half a mile west of the eastern margin of the Elkton quadrangle, opposite milepost 81, in the south bank of the Chesapeake & Delaware Canal, there is an exposure of blue to black plastic clay containing much lignite and many nodules of gray siderite, the largest of which are 10 inches in diameter. In structure they resemble septaria. The center of every nodule examined contained some lignite, which apparently had caused the deposition of the iron carbonate.

A short distance east of this place, opposite milepost 83, there is a $3\frac{1}{2}$-foot layer of very loose, fine white sand, which underlies the black lignite-bearing clay and also contains fragments of lignite.

One mile east of Pivot Bridge, in the south bank of the canal, between mileposts 67 and 68, large masses of lignite coated or infiltrated with pyrite and marcasite are found in a layer of black plastic clay that grades laterally into a layer of white to chocolate-colored fine mealy sand containing small pieces of lignite in rather definite bands. Many pieces of the lignite show numerous teredo borings, and S. G. Morton[3] reports that the workmen digging the canal found trunks of trees, some of them 30 feet in length, which were perforated in every direction by the teredo. Small pieces of amber are also found with the lignite of the Magothy along the canal.

The Magothy can usually be distinguished from the underlying Raritan formation by its lack of massive beds of bright-colored variegated clay and by the greater variability of its materials. It can be more easily distinguished from the overlying Matawan by its lack of glauconite, though small pockets of greensand have been found in it, by its lack of homogeneity, and by its variations in color. Moreover, the Matawan in Maryland generally contains considerable mica in small flakes, whereas the Magothy contains little mica.

Detailed sections of the Magothy and other formations taken along the canal are given on page 11.

Paleontology.—The only organic remains thus far recognized in the Magothy in this area are impressions of leaves in the drab clays that occur in thin laminae alternating with layers of sand. Although most of these impressions are fragmentary many of them are identifiable. At Cliffwood Point, on the south shore of Raritan Bay, N. J., beds of this formation have yielded a considerable flora and a marine fauna. The flora, which was studied by Berry,[4] is notably varied, including more than a hundred species that have been described. This flora is in many respects similar to that of the Raritan, yet it contains 49 species that are peculiar to the Magothy in this country and one or two that are found also in Europe. The most common fossil plants of Cliffwood Point are 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 "Cliffwood beds" shows Cenomanian characteristics.

Berry[5] has described the following plants from the Deep Cut of the Chesapeake & Delaware Canal:

Pteridophyta:
- Gleichenia zippei.
- Gleichenia delawarensis.
- Osmunda delawarensis.

Cycadophyta:
- Williamsonia delawarensis.

Coniferophyta:
- Brachyphyllum macrocarpum.
- Sequoia heterophylla.
- Sequoia reichenbachi.
- Thuja cretacea.
- Juniperus hypnoides.
- Widdringtonites reichii.
- Raritania gracilis.
- Geinitzia formosa.
- Moriconia americana.

Angiospermophyta:
- Carex clarkii.
- Sabalites magothiensis.
- Salix flexuosa.

Angiospermophyta—Continued.
- Salix lesquereuxii.
- Ficus daphnogenoides.
- Ficus crassipes.
- Magnolia tenuifolia.
- Carpites liriophylli.
- Cinnamomum newberryi.
- Laurus hollicki.
- Cissites newberryi.
- Hedera cretacea.
- Sterculia minima.
- Sterculia cliffwoodensis.
- Eucalyptus geinitzi.
- Eucalyptus wardiana.
- Andromeda parlatorii.
- Sapotacites knowltoni.
- Diospyros rotundifolia.
- Cordia apiculata.
- Carpolithus septloculus.

The animal remains obtained from the Magothy at Cliffwood Point and described by Weller[6] were inclosed in smooth concretionary nodules that were found in beds of clay or lying loose on the beach, where they were left by the erosion of the beds that had contained them. The nucleus of nearly every nodule seems to have been some part of a crab. The fauna includes the remains of great numbers of crustaceans as well as shells of pelecypods, gastropods, and cephalopods. The most abundant forms are the pelecypods *Trigonarca* sp., *Pteria petrosa, Nuculana protexta* (?), *Yoldia evansi, Isocardia cliffwoodensis, Veleda lintea, Corbula* sp., and the crustacean *Tetracarcinus subquadratus.* These are of considerable interest, for, with the exception of a few forms obtained from the Raritan in the same area, they are the earliest marine fossils found in the deposits of the Atlantic Coastal Plain. Weller states that the assemblage of forms constitutes a distinct faunule, which more nearly resembles the faunule of the Matawan formation than any other.

---

[1] Jour. Geology, vol. 5, p. 489, 1897.

[2] Maryland Geol. Survey, Upper Cretaceous, pp. 102–104, 1916.

[3] Morton, S. G., Synopsis of the organic remains of the ferruginous sand formation of the United States, with geologic remarks: Am. Jour. Sci., 1st ser., vol. 17, pp. 274–295, 1830.

[4] Berry, E. W., New York Bot. Garden Bull., vol. 3, pp. 45–103, 1903; Torrey Bot. Club Bull., vol. 31, pp. 67–82, 1904; idem, vol. 32, pp. 43–48, 1905; New Jersey Geol. Survey Ann. Rept. for 1905, pp. 135–172, 1906.

[5] Maryland Geol. Survey, Upper Cretaceous, pp. 102–104, 1916.

[6] Weller, Stuart, New Jersey Geol. Survey Ann. Rept. for 1904, pp. 133–144, 1905.

Name and correlation.—In 1893 Darton[1] described certain deposits in northeastern Maryland for which he proposed the name Magothy, because of the excellent exposures of the beds along Magothy River. Later work in Maryland seemed to indicate that these deposits represented merely phases of deposition within the Raritan. On this supposition most of the beds were included in the Raritan, the fossil plants in them were called Raritan forms, and the stratigraphic break between these and the underlying beds was attributed to contemporaneous erosion. In New Jersey the Magothy deposits in the vicinity of Philadelphia were placed in the Raritan, and those in the region of Raritan Bay, which were called the "Cliffwood beds," were by some geologists included in the Matawan, on account of the glauconite and the great number of post-Raritan plants and marine invertebrates they contain, but by others they were assigned to the Raritan. Recent studies of the fossils and careful stratigraphic work in the field, however, have shown that the Magothy should be regarded as a distinct formation, on both stratigraphic and paleontologic grounds, and these transitional beds from New Jersey southward have been referred by Clark[2] to the Magothy formation as defined by Darton for the Maryland area. Uhler[3] in several articles named a group of beds the "Alternate sand series." Most of these beds are now placed in the Magothy. The flora found in the beds at Cliffwood indicates that the formation should be at least provisionally correlated with the Cenomanian of Europe.

Thickness.—The maximum thickness of the Magothy formation in this area is about 40 feet, but its thickness in other areas is extremely variable, reaching a maximum of about 100 feet. This variability is due to greater deposition in some areas than in others and also to the removal of considerable Magothy material from certain regions.

Stratigraphic relations.—The Magothy formation lies between the Raritan and Matawan formations and is separated from each by an unconformity. The line of contact between the Magothy and the Raritan is very uneven, its irregularity indicating a rather long interval of erosion between the periods of their deposition. In many places the Magothy deposits fill pockets and old channels in the Raritan. The unconformity between the Magothy and the Matawan is also plainly marked. Along the Chesapeake & Delaware Canal the contact between these formations rises and falls with respect to the water level in the canal. The Magothy should also outcrop along some of the tributaries of Delaware River in the vicinity of Delaware City, but careful search has failed to discover any trace of it, and the Matawan there overlaps the Magothy, resting on the Raritan or even on the Patapsco. The Magothy reappears, however, at many places farther northeast, in New Jersey. At many places in the region of its outcrop, especially on the stream divides, the formation is overlain by Pleistocene deposits.

The strike of the Magothy formation is northeast, or roughly parallel to that of the other formations of the Coastal Plain. The dip is southeastward, at a rate of about 30 to 35 feet to the mile.

MATAWAN FORMATION.

Areal distribution.—The Matawan formation outcrops in the valleys of many streams in a band about 2 miles in width extending from Hamburg Cove on Delaware River to the southern margin of the Elkton quadrangle about 2 miles south of Chesapeake City. Throughout this area it is exposed along the margins of the streams but is covered by younger material as it passes under the divides. It is best exposed along the canal, where it can be studied to advantage even if it is in some places concealed by landslides and vegetation. It appears in the canal cutting about 1½ miles east of the Pivot Bridge and disappears beneath the water level near the point where the canal is crossed by the Philadelphia, Baltimore & Washington Railroad.

The Matawan resembles the other Cretaceous formations in dipping to the southeast beneath later deposits. It undoubtedly underlies the entire area southeast of the line of its outcrop. In its broader distribution through the Coastal Plain the Matawan forms a continuous series of deposits that outcrop from Raritan Bay to Potomac River.

Lithology.—The Matawan formation consists chiefly of glauconitic sand intimately mixed with dark-colored clay, and contains nearly everywhere small flakes of mica. At some places the beds consist almost entirely of black clay; at others the beds, particularly the upper beds, consist of sand that ranges in color from white to dark-greenish black. Where the glauconite has been decomposed the iron in it oxidizes and the materials are stained reddish brown and may even become firmly indurated by the iron oxide. Iron pyrites is also a common constituent of the formation, and at some places a small layer of gravel lies at its base. Although the Matawan contains varied materials it is much less variable than the formations of the Potomac group or the Raritan and Magothy formations, and throughout its extent in Maryland and Delaware it can generally be readily recognized by the prevailing dark-colored micaceous glauconitic sand of which it is chiefly composed.

M. I. Goldman has made some detailed studies of Matawan materials collected along the Chesapeake & Delaware Canal and has given the writer permission to abstract certain of his observations and conclusions from an unpublished manuscript. In a sample of black glauconitic clay in which there was a minimum amount of mica he found that the larger quartz grains were well rounded, though nearly all of them were much pitted and corroded, whereas the smaller quartz grains were predominantly angular. The grains of fresh glauconite were numerous and rounded, and the clay contained many concretions of quartz, glauconite, and other minerals cemented by limonite. Less abundant minerals were muscovite, decomposed feldspars, chlorite, biotite, garnet, tourmaline, staurolite, rutile, magnetite, zircon, epidote, enstatite, and kyanite. The clay contained also considerable carbonaceous matter.

In a rather light gray, very micaceous fine-grained argillaceous sand, in which no glauconite was apparent to the naked eye, Mr. Goldman found that the larger grains were almost exclusively mica and that the finer particles consisted of quartz, small rounded grains of glauconite, feldspar, muscovite, biotite, chlorite, serpentine, zircon, and small quantities of garnet, tourmaline, enstatite, calcite, kyanite, and clay, together with abundant carbonaceous matter.

In a typical sample of the Matawan formation of this region, consisting of a dark-gray fine-grained, somewhat argillaceous sand, showing glauconite grains under the hand lens, he found that the predominant constituents were quartz and glauconite, the latter in botryoidal form, and smaller amounts of garnet, tourmaline, deep-blue chlorite, staurolite, epidote, muscovite, biotite, rutile, and carbonaceous matter.

The following sections, taken along the canal, show the characteristics of the Monmouth, Matawan, and Magothy as well as the overlying Wicomico strata and their relations to one another.

Section on south side of Chesapeake & Delaware Canal 1 mile east of Pivot Bridge, between mileposts 67 and 68, New Castle County, Del.

	Feet.
Pleistocene:	
Talbot formation:	
Somewhat disturbed brownish-yellow to gray sandy loam with band of pebbles and cobbles at base	8
Upper Cretaceous:	
Matawan formation:	
Dark greenish-black micaceous glauconitic sand, with small pockets consisting almost entirely of glauconite, decidedly green in color; thin discontinuous band of small subangular quartz pebbles at base	3
Irregular contact.	
Magothy formation:	
White to chocolate-colored, extremely fine, loose sand containing small pieces of lignite in rather definite bands. This layer grades horizontally to the west into black plastic clay, containing much lignite. Many pieces of lignite are coated or infiltrated with pyrite and marcasite. Exposed to water's edge	5

Section on south side of Chesapeake & Delaware Canal 1½ miles east of Pivot Bridge, opposite milepost 83, New Castle County, Del.

	Feet.
Pleistocene:	
Wicomico formation:	
Reworked Matawan glauconite sand	9
Band of pebbles and boulders; some angular boulders as much as 3 feet in greatest diameter	3
Upper Cretaceous:	
Matawan formation:	
Mottled dark micaceous glauconitic sand with blotches of lighter color: discontinuous indurated ledge of ironstone 3 inches thick at base	15
Magothy formation:	
Black plastic clay containing much lignite	1½
Loose fine white sand containing considerable lignite	3½
Loose yellow sand to water's edge	1½

The two lower layers of this section grade horizontally (to the west) into a layer of black plastic clay containing lignite and siderite nodules.

Section on north side of Chesapeake & Delaware Canal three-fourths of a mile west of Summit Bridge, between mileposts 92 and 93, New Castle County, Del.

	Feet.
Pleistocene:	
Wicomico formation:	
Loamy reworked glauconitic sand	5
Gravel and pebble lens; some pebbles 4 inches in diameter	1½
Reworked glauconitic sand	3
Gravel band with matrix of glauconitic sand cemented by iron oxide in places	1
Upper Cretaceous:	
Matawan formation:	
Glauconitic sand containing much mica; a few small pebbles at base	3
Magothy formation:	
Layer of lignite containing a little other material in some places and in other places a considerable admixture of black plastic clay. Lignitized logs have been bored by teredo. A few siderite nodules at top	1½–2
Extremely fine white loose sand in which are thin bands of plastic black clay containing lignite	6
Loose buff or yellowish-brown to salmon-colored sand containing many irregular iron crusts, some of large size	9

Section on north side of Chesapeake & Delaware Canal one-third of a mile west of Summit Bridge, near milepost 105.

	Feet.
Pleistocene:	
Wicomico formation:	
Reworked glauconitic sand derived from Matawan and containing many small pebbles	10
Pebble and cobble band cemented by iron oxide in places	1½
Upper Cretaceous:	
Matawan formation:	
Argillaceous green sand, rich yellow in color, due to weathering	4
Gray (resembling a mixture of pepper and salt) to dark-green glauconitic micaceous sand	24
Gray to green glauconitic sand containing ferruginous bands and nodules from one-half to 4 inches in diameter in which are many fossil gastropods, pelecypods, ammonites, crab claws, and shark teeth and a few crystals of gypsum	14
Material similar to the preceding layer but without fossiliferous nodules and bands of ironstone. Exposed to water's edge	12

Section on north side of Chesapeake & Delaware Canal 30 rods west of Summit Bridge, just west of milepost 116, New Castle County, Del.

	Feet.
Pleistocene:	
Wicomico formation:	
Loose coarse buff to yellow cross-bedded sand	7
Band of pebbles and cobbles, the largest 5 inches in diameter, in matrix of yellow sand, indurated in places by iron oxide	2½
Upper Cretaceous:	
Monmouth formation:	
Yellowish-green to chocolate-colored weathered glauconitic sand containing flattened pellets of clay and small irregular quartz pebbles	3½
Mottled dark-greenish black to light-green glauconitic sand containing angular to subangular quartz pebbles one-quarter inch in diameter and waterworn pieces of lignite, some of which are 1 inch in diameter; a few fossil casts of pelecypods and gastropods were noted	4
Matawan formation:	
Loose gray and buff to yellow weathered micaceous sand	5
Loose ferruginous yellow micaceous sand containing some iron crusts	4
Light to dark green micaceous glauconitic sand	10
Concealed to water's edge	12

Section on south side of Chesapeake & Delaware Canal one-half mile east of Summit Bridge, opposite milepost 136, New Castle County, Del.

	Feet.
Upper Cretaceous:	
Monmouth formation:	
Weathered yellowish-brown indurated glauconitic sand, forming rather firm iron sandstone ledges from 6 to 12 inches in thickness; locally pockets of fresh glauconitic sand are present	3
Matawan formation:	
Gray to yellow fine micaceous sand, grading into underlying stratum	10
Ferruginous yellowish-brown sand containing crab claws	2
Dark bluish-black argillaceous glauconitic sand. Exposed to water's edge	4½

Paleontology.—Although the Matawan formation as a whole is not extremely fossiliferous, it contains bands in which organic remains are crowded together in great abundance. In New Jersey as well as in Maryland the formation has yielded a varied fauna of foraminifers, pelecypods, gastropods, scaphopods, and ammonites.[4]

During the excavation of the Chesapeake & Delaware Canal, between 1824 and 1829, many fossils were found. These fossils were described by S. G. Morton in publications of that period, and some new forms have been described more recently. Morton mentions a specimen of *Ammonites placenta*, found in the Deep Cut of the canal, that measured 2 feet in diameter and another one that measured 15 inches. Fossils, mainly hardened internal casts, can now be found with little difficulty in the Deep Cut of the canal near Summit Bridge.

The following forms from the Chesapeake & Delaware Canal have been described:[5]

Vertebrata:
- Pisces:
  - Lamna elegans.
  - Lamna cuspidata.
  - Corax falcatus.
  - Ischyrhiza mira.

Arthropoda:
- Crustacea:
  - Holoparia gabbi.
  - Holoparia gladiator.
  - Callianassa mortoni.
  - Callianassa clarki.
  - Callianassa sp.

Mollusca:
- Cephalopoda:
  - Baculites ovatus.
  - Baculites asper.
  - Pachydiscus complexus.
  - Placenticeras placenta.
  - Mortoniceras delawarensis.
- Gastropoda:
  - Avellana bullata.
  - Xancus intermedia.
  - Pyropsis perlata.
  - Anchura rostrata.
  - Laxispira lumbricalis.
  - Turritella delmar.
  - Turritella encrinoides.
  - Xenophora leprosa.
  - Gyrodes petrosus.
  - Amauropsis meekana.

Mollusca—Continued.
- Pelecypoda:
  - Nucula slackiana.
  - Yoldia longifrons.
  - Cucullaea vulgaris.
  - Cucullaea carolinensis.
  - Arca (Barbatia) uandi.
  - Glycimeris mortoni.
  - Pinna laqueata.
  - Ostrea larva falcata.
  - Exogyra costata.
  - Exogyra cancellata.
  - Exogyra ponderosa.
  - Gryphaea (Pycnodonte) vesicularis.
  - Pecten venustus.
  - Pecten quinquecostata.
  - Paranomia scabra.
  - Paranomia lineata.
  - Anomia argentaria.
  - Modiolus burlingtonensis.
  - Lithophaga ripleyana.
  - Pholadomya occidentalis.
  - Liopistha alternata.
  - Veniella conradi.
  - Crassatellina carolinensis.
  - Tenea parilis.
  - Cardium eufaulense.
  - Cardium spillmani.
  - Cardium dumosum (?).
  - Cardium kümmeli.

[1] Darton, N. H., The Magothy formation of northeastern Maryland: Am. Jour. Sci., 3d ser., vol. 45, pp. 407–419, 1893.

[2] Clark, W. B., The Matawan formation of Maryland, Delaware, and New Jersey, and its relations to overlying and underlying formations: Am. Jour. Sci., 4th ser., vol. 18, pp. 435–440, 1904.

[3] Uhler, P. R., Maryland Acad. Sci. Trans., vol. 1, pp. 11–32, 1888; idem, pp. 45–61, 1889; idem, pp. 97–104, 1891.

[4] Clark, W. B., Bagg, R. M., and Shattuck, G. B., Upper Cretaceous formations of New Jersey, Delaware, and Maryland: Geol. Soc. America Bull., vol. 8, pp. 330–331, 1897.

[5] Maryland Geol. Survey, Upper Cretaceous, pp. 90–101, 1916.

Mollusca—Continued.
Pelecypoda—Continued.
Meretrix cretacea.
Panope decisa.
Martesia cretacea (?).
Teredo irregularis.

Echinodermata:
Echinoidea:
Hemiaster delawarensis.
Hemiaster sp.

Name and correlation.—The formation was named from Matawan Creek, N. J., a tributary of Raritan Bay, near which large and typical deposits of it are well exposed. The name was proposed by W. B. Clark[1] in 1894 and replaced the term "Clay marls," previously used by the New Jersey geologists. The fossils of the Matawan formation furnish evidence of its Upper Cretaceous age and apparently indicate that it is the equivalent of a part of the Senonian of Europe.

Thickness.—The maximum thickness of the Matawan formation in the Elkton and Wilmington quadrangles is about 65 feet. One of the sections given above shows a thickness of 54 feet, which includes practically the entire series of Matawan strata represented along the Chesapeake & Delaware Canal.

Like many other formations of the Coastal Plain, the beds thicken as they dip beneath later deposits, but the records of wells which have penetrated these formations do not indicate the rate of thickening.

Stratigraphic relations.—The Matawan formation rests unconformably upon the eroded surface of the Magothy, as is well shown along the canal between the Pivot Bridge and the eastern margin of the Elkton quadrangle. The Matawan also overlaps both the Magothy and the Raritan in the vicinity of Red Lion, where it rests directly upon the Patapsco red clay beds. It is conformably overlain by the Monmouth. The Matawan and the Monmouth are separated into two formations chiefly by differences in lithology but in part by differences in their fossils. Although some organic forms range through both the Matawan and the Monmouth, yet each formation contains a few characteristic forms, the assemblage in each being on the whole fairly distinctive. The formation strikes northeastward and dips southeastward at the rate of about 25 feet to the mile.

MONMOUTH FORMATION.

Areal distribution.—The Monmouth formation is well represented by numerous outcrops along the streams in the southern third of the Wilmington quadrangle and in the southeast corner of the Elkton quadrangle. Over the divides it is concealed by a thin cover of Pleistocene materials, but it appears at the surface along almost every stream in those areas. The best exposures occur along the line of the Chesapeake & Delaware Canal between St. Georges and Summit Bridge. In its wider distribution the formation has been recognized by outcrops in a zone extending from the northeastern part of this area to Raritan Bay in New Jersey.

Lithology.—The formation is arenaceous and unconsolidated except where it is indurated by the segregation of ferruginous material derived from the glauconite. The sands range in color from reddish brown to dark green or nearly black. The fresh material invariably contains considerable glauconite, which gives to the deposits their dark color. The more weathered sands generally range from rich brown to reddish brown, but at some places they are dark gray.

M. I. Goldman, who has studied in great detail two samples of Monmouth material obtained from the south bank of the canal 1½ miles west of St. Georges, says that the coarser particles consist of rounded or botryoidal grains of glauconite and angular grains of clear quartz, most of them pitted. The finer particles consist of quartz, glauconite, weathered feldspars, magnetite, red garnet, epidote, aragonite, staurolite, tourmaline, rutile, augite, biotite, muscovite, green zircon, enstatite, hornblende, apatite, andalusite, kyanite, limonite, siderite (?), and much clay and calcareous and carbonaceous matter. The particles of glauconite were unusually fresh, and limonite was scarce, as it usually is in unweathered material. The calcareous material was evidently derived from shells of mollusks, which occur here in great numbers, though some of it may have been derived from the thin shells of Foraminifera that have now disappeared.

The Monmouth beds of New Jersey, which are continuous with those of this region, have been differentiated into three members. These divisions have not been recognized in the Elkton and Wilmington quadrangles. Sections of Monmouth and other formations have been given under the heading "Matawan formation."

Paleontology.—The Monmouth formation is generally very fossiliferous, and the fossils are usually well preserved. They consist of foraminifers, pelecypods, gastropods, and cephalopods. Among the most abundant are *Exogyra costata* Say, *Gryphaea vesicularis* Lamarck, and *Belemnitella americana* Morton. They are typical Upper Cretaceous species.

During the excavation of the Chesapeake & Delaware Canal from 1825 to 1829 large collections of fossils were made, and numerous marl pits in the vicinity of St. Georges furnished additional material. In places layers were composed almost entirely of the shells of *Exogyra costata* and *Gryphaea vesicularis*. One of these layers was encountered in the excavation for the locks at St. Georges. Many of the forms were unusually large. Morton mentions one specimen of *Exogyra costata* that measured 8 inches in diameter. Fossiliferous beds are now exposed at several places along the south bank of the canal between St. Georges and the crossing of the Philadelphia, Baltimore & Washington Railroad, and firm shells of *Exogyra* and *Gryphaea* can be picked up in fields where they were thrown many years ago when the greensand marl was extensively used as a fertilizer.

Gardner[2] has described the following molluscan forms from the Chesapeake & Delaware Canal and near by:

Cephalopoda:
Belemnitella americana. Locality 1.
Gastropoda:
Rostellites nasutus. Locality 2.
Piestochilus bella. Locality 2.
Polynices altispira. Locality 2.
Pelecypoda:
Nucula slackiana. Locality 2.
Cucullaea vulgaris. Locality 2.
Cucullaea carolinensis. Locality 1.
Ostrea larva falcata. Locality 2.
Exogyra costata. Localities 1, 2.
Gryphaea (Pycnodonte) vesicularis. Localities 1, 2.
Gryphaea (Gryphaeostrea) vomer. Localities 1, 2.
Pecten quinquecostata. Locality 2.
Anomia argentaria. Locality 2.
Anomia tellinoides. Locality 1.
Pholadomya occidentalis. Locality 1.
Cardium kümmeli. Locality 2.
Panope monmouthensis (?). Locality 2.
Locality 1. Post No. 156, Chesapeake & Delaware Canal.
Locality 2. Farm of John Higgins, 2 miles west of Delaware City.

Name and correlation.—The name of the formation was first proposed by W. B. Clark,[3] in 1897, when it was decided to combine in a single formation the deposits formerly included in the Navesink and Redbank formations. The name is derived from that of Monmouth County, N. J., where the deposits are typically developed. The formation is the "Lower Marl bed" of the earlier geologists in New Jersey. Its marine fauna is like that of the Upper Senonian of Europe, with which it has been correlated.

Thickness.—Along its outcrop in the Elkton and Wilmington quadrangles the Monmouth formation is 80 to 100 feet thick. In northern New Jersey it is about 200 feet thick, but its thickness steadily decreases toward the southwest, along the strike, until it disappears in the vicinity of Potomac River.

Stratigraphic relations.—The Monmouth is conformable with the underlying Matawan and with the Rancocas, which overlies it in adjoining areas in Delaware and New Jersey. Within these quadrangles it is overlain unconformably by Pleistocene deposits. The Monmouth is readily distinguished from the Matawan, as it lacks the darker micaceous sands and marls of that formation, and it is distinguished from the Rancocas by the great predominance in it of reddish-brown sand. The Monmouth formation strikes northeastward and dips southeastward at the rate of about 15 to 20 feet to the mile.

TERTIARY SYSTEM.

PLIOCENE (?) SERIES.

The only deposits of supposed Tertiary age in the Elkton and Wilmington quadrangles constitute the Brandywine formation. Lithologically and structurally these deposits closely resemble the Pleistocene formations, but their general character, firmly indurated layers, and occasional greatly decomposed pebbles suggest a formation much older than any known Pleistocene deposit of the province, and justify their provisional reference to the Pliocene. A short distance south of these quadrangles fossiliferous marine deposits of undoubted earlier Tertiary age are well represented, but if these were ever formed in the Elkton and Wilmington quadrangles they were removed by erosion in pre-Pleistocene time.

BRANDYWINE FORMATION.

Areal distribution.—The Brandywine deposits form wide terraces elsewhere in the Coastal Plain, and there is little doubt that they once extended over the greater part of these quadrangles, but they have now been completely removed by erosion from the Wilmington quadrangle and only small masses of them remain in the Elkton quadrangle. At several places in the parts of these quadrangles that lie within the Piedmont Upland thin beds of waterworn pebbles and cobbles found on the stream divides are probably residual fragments of the Brandywine formation, but these thin beds are so small that they have not been mapped. Thicker remnants of these once extensive gravel beds cap several isolated hills in the southwestern part of the Elkton quadrangle. The most prominent of these is Egg Hill, but the formation is best exposed on a slightly lower hill about a mile west of Egg Hill. The formation occurs also on the tops of several hills on the western margin of the Elkton quadrangle north of Charlestown. Gravel that caps somewhat lower hills at several places on Elk Neck is for convenience mapped with the Brandywine formation, yet it probably represents a later stage of deposition, which, however, was earlier than the Sunderland stage. The Brandywine formation thus includes early and late Brandywine gravel.

Lithology.—The Brandywine formation is composed of gravel, sand, and loam, which were so imperfectly sorted by the waves of the Brandywine sea that they are now intermingled in proportions that differ from place to place. Although the formation as a whole can be divided into two parts, a lower part consisting mainly of gravel and an upper part consisting mainly of sand and loam, yet these materials are in places confusedly mixed together, and no stratum consists wholly of any particular kind of material. Irregular beds or lenses of loam, sand, or gravel also occur in the formation and are exposed in many places in the Elkton quadrangle. The gravel consists of pebbles that are considerably decayed, and at some places they are rather small though at others they are very large. They are embedded in a coarse, compact sand or very stiff clayey loam. The appearance of the gravel also changes from place to place; at some places the pebbles are covered with a dark-brown ferruginous coating, but at others they have no such coating. The heterogeneous character of the deposit shows that it was derived from various sources. The pebbles of quartz and of crystalline rock which it contains were probably derived from the Piedmont region; the broken iron crusts were derived mainly from the Cretaceous formations near by; and some decayed blocks of sandstone were derived from the Newark group. Most of the gravel consists of fragments of quartz.

The small proportion of sand in the Brandywine deposits seems to have been derived mainly from beds of the Potomac formation. Lenses of sand occur at many places in the gravel deposits, but most of them are neither thick nor of great areal extent. The sand is generally a matrix for the gravels or is intimately mixed with the loam.

One mile west of Egg Hill the Brandywine deposits have been extensively dug for use as road material, and the section there exposed is fairly typical of the formation in this vicinity.

Section 1 mile west of Egg Hill, Cecil County, Md.

	Feet.
Brandywine formation:	
Surficial loam	1
Band of gravel and clay intimately mixed; the pebbles are composed of vein quartz or compact quartzitic sandstones averaging three-eighths of an inch in diameter and the matrix is a ferruginous clay that acts as a firm binding material	5
Band of gravel and ferruginous sand; pebbles rounded to subangular, the largest 2 inches in diameter, and contained in a matrix of ferruginous sand; a few lenses of pebbles are cemented by limonite so that they can be used for rough foundation stone	5
Band of gravel in loose, slightly ferruginous sand not distinctly separated from overlying layer (exposed)	8

Topographic expression.—As is noted under the heading "Topographic divisions" (p. 4), early Brandywine deposits rest upon the surface of a peneplain that is widely preserved in the Piedmont Upland, and late Brandywine deposits lie upon the mature slopes that are cut in the early Brandywine peneplain and that decline gently southeastward.

Paleontology.—No fossils have been found in the Brandywine deposits in the Elkton-Wilmington area. Pebbles containing Paleozoic fossils have been found in the formation at many places but are of significance only because they show the source of the materials. Fossils from similar deposits in Virginia are merely reworked Miocene forms derived from the underlying rocks. At present, therefore, no definite statement can be made in regard to the fossils of the formation.

Name, age, and correlation.—Prior to 1891 the deposits now grouped in the Brandywine formation were included in the "Appomattox" formation. In that year Hilgard[4] proposed the name "Lafayette," from Lafayette County, Miss., as a substitute for the term "Orange sand" used in Tennessee and Mississippi, and the term "Appomattox," which had been applied in the north Atlantic coast region. This name was accepted in the belief that the two deposits were of the same age. Since 1891 the term "Lafayette" has been used in many publications, but recent work has shown that the so-called Lafayette at the type locality in the Gulf region is of different age from the formation called by the same name in the Atlantic coast regions, and it is now proposed to drop the name Lafayette. As the term "Appomattox" was loosely used and included deposits now recognized as belonging to different formations, it seemed desirable to adopt a new name for the formation in this and adjoining quadrangles. Accordingly the name Brandywine was proposed. The name is derived from the village of Brandywine, in Prince Georges County, Md., in the vicinity of Washington, D. C., where the formation is characteristically developed. In this area, as in the Elkton and Wilmington quadrangles, the formation has in recent years been regarded by some geologists as comprising two parts, of which the later and topographically lower one is conspicuous in the neighborhood of Brandywine. The earlier and topographically higher division is represented by remnants on hills near Washington, D. C., and Falls Church, Va.

Its firm, hard layers and decomposed pebbles indicate that it is much older than the Pleistocene deposits of the province, and it has therefore been provisionally referred to the Pliocene. Lower gravels on Elk Neck, provisionally included with the Brandywine, may be of early Pleistocene age.

[1] Clark, W. B., Origin and classification of the greensands of New Jersey: Jour. Geology, vol. 2, pp. 161-177, 1894.

[2] Maryland Geol. Survey, Upper Cretaceous, pp. 90-101, 1916.

[3] Clark, W. B., Bagg, R. M., and Shattuck, G. B., op. cit.

[4] Hilgard, E. W., Orange sand, Lagrange, and Appomattox: Am. Geologist, vol. 8, pp. 129, 131, 1891.

Thickness.—The thickness of the Brandywine is somewhat variable. The maximum thickness in the Elkton quadrangle is about 35 feet.

Stratigraphic relations.—A very marked unconformity separates the Brandywine from all underlying formations. At several places in the Coastal Plain it overlies almost every older formation, and thin remnants of it are seen here and there on the eastern border of the Piedmont Upland. In the Elkton quadrangle it rests at most places upon the Cretaceous formations and is a surface deposit, although locally it probably dips beneath beds of Pleistocene age.

QUATERNARY SYSTEM.

PLEISTOCENE SERIES.

COLUMBIA GROUP.

GENERAL CHARACTER.

The Pleistocene formations of the Coastal Plain are included in the Columbia group. They consist of gravel, sand, and loam, have many characteristics in common, and appear to be of similar origin. The Columbia group of Delaware, Maryland, and Virginia comprises three formations, the Sunderland, Wicomico, and Talbot, of which only the Wicomico and Talbot are extensively represented in this area. They cover the surface of different plains or terraces, which possess very definite topographic relations and are described on page 4.

The three formations composing the Columbia group can not be separated on purely lithologic grounds. The materials of all have been derived mainly from older neighboring formations, but they include more or less foreign material brought by streams from the Piedmont province or from the Appalachian Mountain region. The deposits of each of these formations are extremely varied, their general character changing with that of the underlying or neighboring formations. Thus, material belonging to the same formation may differ lithologically in different regions far more than material of two different formations that lie close to each other and to their common source. Cartographic distinctions based on lithologic differences would therefore result in hopeless confusion. At some places the older Pleistocene deposits are more indurated and their pebbles are more decomposed than those of the later formations, but these differences can not be used as criteria for separating the formations, for each contains both loose and indurated and both fresh and decomposed material.

The fossils found in the Pleistocene deposits are too few to be of much service as a means of separating them into distinct formations. They occur only in the exceptional phases of the deposits and are principally the remains of plants preserved in bogs, but at a few places near Chesapeake Bay the deposits contain great numbers of marine and estuarine mollusks.

The Columbia group, as may be readily seen, is not a physiographic unit. The formations are believed to constitute wave-built terraces or plains separated by wave-cut escarpments, their differences of form indicating different periods of deposition. At the bases of many of the escarpments the underlying Cretaceous and Tertiary formations are exposed. The highest terrace is composed of the oldest formation, the Sunderland; the lowest is composed of the Talbot formation.

At almost every place where good sections of the Pleistocene deposits are exposed they seem to be a unit from base to top. At a few places, however, some beds are sharply separated from the underlying beds by irregular lines of unconformity. Some of these unconformities disappear within short distances, showing clearly that they are only the results of local erosion by shifting currents in shallow water, and perhaps all of them would thus disappear if the exposures were sufficient to permit them to be fully traced out. An additional fact which indicates that these unconformities were produced by erosion that was contemporaneous with the deposition of other parts of the same formation is that similar local lines of separation found in closely adjoining regions seem to have no relation to one another. As the Pleistocene formations lie nearly horizontal it should be possible to connect these lines of separation if they are unconformities due to subaerial erosion. In the absence of any definite evidence that these lines mark stratigraphic breaks they have been disregarded, yet in some places the waves of the advancing sea in Sunderland, Wicomico, and Talbot time may not have entirely removed the beds deposited during each preceding period throughout the area covered by the sea. Material laid down in depressions would perhaps be preserved as isolated remnants of a formation that was once widespread, and these remnants would be covered by the next mantle of Pleistocene deposits, so that each formation would be probably represented by scattered fragmentary deposits buried beneath later Pleistocene formations.

In regions where pre-Quaternary materials are not exposed at the bases of the escarpments each Pleistocene formation near its inner margin probably rests upon the thin edge of the next older formation. As lithologic differences afford insufficient criteria for separating the Pleistocene formations, and as sections are not numerous enough to permit distinctions to be made between local and widespread unconformities, the whole mantle of Pleistocene materials at any one locality is referred to a single formation. The Sunderland overlies the Cretaceous and Tertiary deposits and extends from the base of the late Brandywine-Sunderland escarpment to the base of the Sunderland-Wicomico escarpment. The Sunderland may be underlain here and there by thin deposits of late Brandywine material. The Wicomico includes all the gravels, sands, and clays overlying the Miocene and older deposits and extends from the base of the Sunderland-Wicomico escarpment to the base of the Wicomico-Talbot escarpment. In some parts of this general region, however, materials of late Brandywine and of Sunderland age may underlie the Wicomico, and in like manner the Talbot may here and there rest upon the late Brandywine, Sunderland, and Wicomico formations.

SUNDERLAND FORMATION.

Areal distribution.—The Sunderland formation is poorly preserved in the Elkton and Wilmington quadrangles. It is represented by several irregular isolated areas that occupy minor stream divides in a band extending from Wilmington southwestward to Leslie. Since the Sunderland formation was deposited it has been greatly eroded, but enough of it remains to permit it to be mapped and to establish its relations to the other formations. The areas still remaining constitute the remnants of a wide plain of marine deposition that formerly extended over a large part of the two quadrangles. Besides the areas shown on the maps traces of the formation, consisting of scattered waterworn pebbles resting upon the crystalline rocks of the Piedmont Upland may be seen at other places. These materials, however, form a cover so thin that it is inadvisable to represent them on the map.

The Sunderland formation occupies stream divides whose elevations range from about 100 to 140 feet above sea level. It originally extended over somewhat higher areas to the north and northwest, but all of it except a few scattered pebbles has been removed from those areas by erosion.

Lithology.—The materials that compose the Sunderland formation are clay, sand, gravel, and boulders. As has been already explained, these materials do not generally lie in well-defined beds but grade into each other both vertically and horizontally. The coarser materials, with the exception of the ice-borne boulders, are generally cross-bedded, but the clays and the finer materials occur either in lenses or are horizontally stratified. The erratic ice-borne blocks are scattered through the formation and may occur in the gravel, sand, or loam. The coarser material tends to occupy the lower parts of the formation and the finer the upper parts, but the transition from one to the other is not marked by an abrupt change, and at many places the coarse materials are mixed with the surface loam and the finer materials are mixed with the gravel that lies underneath. The pebbles that are composed of quartz look fresh, but most of those that contain feldspar, and these are numerous, are greatly decomposed. Some of the pebbles of granite and schist can be readily crumbled in the hand, as can also many of the pebbles of shale and sandstone.

Topographic expression.—The Sunderland deposits occupy and form the Sunderland terrace, mentioned under the heading "Topographic divisions" (p. 4). As this terrace is now fragmental in these quadrangles, its original form is hard to determine, but if these detached remnants of it could be extended until they united, the product would be a rather broad, featureless plain covering many square miles, sloping gently toward the ocean or toward the larger bodies of water, and separated by escarpments from the higher-lying late Brandywine terrace and the lower-lying Wicomico terrace.

Paleontology.—No fossils have been found in the Sunderland deposits of the Elkton and Wilmington quadrangles. In regions to the southeast some remains of plants have been found in deposits of this age, most of them lignitized stems of grasses, though there are a few impressions of leaves.

Name and correlation.—The formation has been named from the village of Sunderland, Calvert County, Md., near which it is typically developed. The name was first applied to the formation by Shattuck[1] in 1901. The Sunderland corresponds approximately to the "Earlier Columbia" of McGee and to parts of the Bridgeton and Pensauken formations of Salisbury. Its Pleistocene age is indicated by the modern appearance of its plant remains and by its relation to the next younger formation, the Wicomico, which includes boulders bearing glacial striae.

Thickness.—The Sunderland formation was deposited on an irregular erosion surface and consequently differs considerably in thickness in different places. Its maximum thickness is probably nowhere more than 40 feet, and its average thickness in these quadrangles is about 12 feet. In other places in the Atlantic Coastal Plain, where the formation has been less eroded, it has an average thickness of about 35 feet.

Stratigraphic relations.—Throughout the Coastal Plain the Sunderland overlies unconformably several formations of Cretaceous and Tertiary age, and at many places along the edge of the Piedmont Upland it rests upon crystalline rocks of pre-Cambrian age. In the vicinity of Wilmington it rests upon the pre-Cambrian crystalline rocks and elsewhere in the Elkton and Wilmington quadrangles upon the Patuxent, Patapsco, and Raritan formations. The edges of the Brandywine formation may extend beneath a part of the Sunderland deposits, but this can not be determined because there is no definite line denoting a stratigraphic break and because the materials of the two formations are similar.

[1] Shattuck, G. B., The Pleistocene problem of the north Atlantic Coastal Plain: Johns Hopkins Univ. Circ. 152, pp. 69–75, 1901.

WICOMICO FORMATION.

Areal distribution.—The Wicomico is the most widely distributed formation in the Elkton and Wilmington quadrangles. It covers the broad, nearly flat divide between Elk and Delaware rivers, overlaps the crystalline rocks of the Piedmont Upland in a band extending from Elkton to Wilmington, and occurs in many small patches in the southwestern part of the Elkton quadrangle. The distribution of the formation on the two sides of Elk River is markedly dissimilar. On the east side the formation is continuous over the divides for many miles, erosion having removed it only near the streams; on the west side, however, the formation has been so much eroded that only small isolated patches of it remain on the east and west sides of Elk Neck and in the vicinity of Northeast.

Lithology.—The materials that compose the Wicomico formation are clay, sand, gravel, and ice-borne boulders. As already noted, these materials do not generally lie in well-defined beds but grade into one another both vertically and horizontally. The coarser materials are usually cross-bedded, but the clay and the finer materials are either deposited in lenses or are horizontally stratified. The erratic ice-borne blocks are scattered through the formation and may lie in the gravel, the sand, or the loam. The coarser material tends to occupy the lower parts of the formation and the finer the upper parts, but the transition from one to the other is not marked by an abrupt change, and at many places the coarse materials are mixed with the surface loam and the finer materials are mixed with the gravel beneath. In the southern part of the Wilmington quadrangle large quantities of Cretaceous glauconitic sands have been redeposited in the Wicomico formation.

Cobbles and boulders of the pre-Cambrian crystalline rocks are common, and some of them are comparatively fresh, although most are greatly decayed. The largest boulders, some as much as 4 feet in diameter, almost invariably consist of quartzite or compact siliceous sandstone or conglomerate. Although these boulders were undoubtedly carried by floating icebergs from the margin of the great ice sheet which lay many miles to the north, they show little or no indication of glacial striae. Elsewhere in the Coastal Plain, however, striated boulders have been found in the formation. Contrary to expectations, the large boulders do not predominate toward the northern margin of the formation, close to the former shore line, but are more abundant near the southern margins of the quadrangles. Near Mount Pleasant they are especially noticeable along the fences, where they have been thrown by the farmers. Furthermore, some of the largest ice-borne boulders found in the Pleistocene of the Coastal Plain occur near Snow Hill, Md., about 100 miles south of this region.

At some places the ferruginous matter of the Wicomico has been concentrated by the percolating waters to form hollow limonite geodes or has cemented the pebbles together into an ironstone conglomerate.

At many places about the shores of Chesapeake Bay old swamp deposits have been found in the Talbot and Wicomico formations. The only deposit of this kind that has been found in these quadrangles was exposed in the excavation of the Chesapeake & Delaware Canal. The following section shows the character of the material:

Section on south side of Chesapeake & Delaware Canal near milepost 149, one-half mile west of the railroad bridge, New Castle County, Del.

	Feet.
Pleistocene:	
Wicomico formation:	
Reworked Matawan materials consisting of loose micaceous glauconitic sand containing a few pebbles, the largest 1¼ inches in diameter	6
Band of pebbles and cobbles; some of the cobbles are 5 inches in diameter; the matrix is similar to the preceding layer	1
Swamp deposit consisting of peat and lignitized roots of trees and cypress knees, some of which are 1½ feet long and 10 inches in diameter. Considerable micaceous glauconitic sand is present and some white quartz pebbles 2 inches in diameter	3½
Band of pebbles and cobbles; most of the cobbles are well rounded, although some are decidedly angular; the largest cobbles 6 inches in diameter	1
Upper Cretaceous:	
Matawan formation:	
Black micaceous glauconitic sand containing some clay, exposed to water's edge	½

The swamp deposit is exposed for a distance of about 175 feet and gradually diminishes in thickness and disappears.

The amount of loam in the Wicomico is exceedingly variable. Wherever the loam cap is well developed the roads are very firm and the land is suitable for raising grass and grain, but where the loam is thin or absent the roads are apt to be sandy. A large part of the formation in the vicinity of the Piedmont

Upland consists of clay, which in the vicinity of Elsmere and West Junction is utilized in making brick. This clay is reworked material derived from crystalline rocks and includes some rounded to angular quartz pebbles. The following section shows the general character of the Wicomico formation:

Section 1½ miles south of State Road, New Castle County, Del.

	Feet.
Pleistocene:	
Wicomico formation:	
Coarse buff to yellow quartz sand containing some cobbles	10
Layer of angular to subangular cobbles and boulders 3 feet in diameter, consisting of different kinds of siliceous sandstones and crystalline rocks. Mingled with the boulders are numerous flattened geodes of limonite from 2 to 10 inches in diameter and from 1 to 3 inches thick	3

Topographic expression.—The Wicomico formation lies in a terrace which is described under the heading "Topographic divisions" (p. 4) as the Wicomico terrace. In adjoining regions this terrace is separated from the higher Sunderland terrace by an escarpment generally more than 20 feet high, which forms a constant and striking topographic feature. In this area the scarp has been so greatly eroded that it is no longer recognizable. The Wicomico terrace in turn is at most places separated by an escarpment from the Talbot terrace, which wraps around it at a lower elevation. This escarpment also is less distinct in the Elkton and Wilmington quadrangles than in adjacent regions to the southwest. From the Sunderland-Wicomico scarp line the surface of the Wicomico formation slopes gently toward the surrounding waters in the manner of a wave-built terrace.

The Wicomico has been considerably eroded since it was deposited, and its originally level surface, especially of the part of it that lies along the waterways, is now gently rolling.

Paleontology.—The fossils of the Wicomico formation consist only of plant remains and a few bones, preserved in old bogs. In the Elkton and Wilmington quadrangles no fossils have yet been found in the formation.

Name and correlation.—This formation receives its name from Wicomico River, in southern Maryland. The Wicomico represents the higher-lying part of the "Later Columbia" of McGee and a part of the Pensauken formation of Salisbury. The ice-borne boulders it contains show that it was formed during the glacial period, but the particular drift sheet with which it should be correlated has not yet been determined.

Thickness.—The Wicomico formation is not of uniform thickness because it was deposited on an uneven surface. It dips into the valleys and rises on the divides, and though its base at many places is as low as 40 feet and its top at other places is 100 feet above sea level, its thickness is not so great as these figures would indicate. Notwithstanding these irregularities the formation as a whole lies almost horizontal, having only a slight southeasterly dip. Its thickness in this area reaches a maximum of about 50 feet but averages about 20 feet.

Stratigraphic relations.—In this area the Wicomico overlies unconformably the granodiorite and the Cretaceous formations. At many places it is in contact with the Sunderland, which lies above it, and with the Talbot, which lies below it. At some places the Sunderland may extend somewhat below the Sunderland-Wicomico scarp and may run out beneath the edge of the Wicomico formation where the two are in contact. At such places this contact between the Wicomico and Sunderland would be an unconformity.

TALBOT FORMATION.

Areal distribution.—The Talbot formation is extensively represented along both sides of Delaware River, less well represented along Elk River, and sparingly represented along Northeast River. Along Delaware River it forms a broad terrace, 1 to 4 miles wide, extending from the Wicomico-Talbot scarp out to the edge of the surrounding waters and continuing several miles up the larger tributary streams. It is not sharply separated from the Recent alluvial and marsh deposits that are so common along Delaware and Christiana rivers. It covers the flats along Elk River but does not extend to the water's edge, where Cretaceous strata are exposed at the bases of the low wave-cut bluffs.

Where the Talbot overlies the Lower Cretaceous deposits it is now represented by detached outliers, well shown along Northeast River, but in regions where it lies in contact with underlying Upper Cretaceous deposits it has been much less eroded and forms broad terraces, such as border Delaware River.

Lithology.—The Talbot formation consists of clay, peat, sand, gravel, and boulders, which, like the similar material in the Sunderland and Wicomico deposits, grade into one another both vertically and horizontally, and the formation shows the same tendency toward a twofold division, the coarser materials lying beneath and the finer materials above. Some of the boulders are several feet in diameter. The Talbot, on the whole, contains much less decayed material than the Sunderland and Wicomico, and it therefore looks much younger than those formations.

A collection of pebbles, cobbles, and boulders taken from a gravel pit about 1½ miles south of St. Georges contains 23 kinds of light-colored quartzitic sandstone and quartzite, 6 kinds of red sandstone of Newark and Medina (?) age, 6 kinds of white to gray sandstone (many of them containing feldspar), 7 kinds of brown sandstone, 6 kinds of shale, and 7 kinds of crystalline rock—pegmatite, mica schist, and several varieties of gneiss—besides many kinds of black, yellow, and brown chert and an abundance of vein quartz. Many of the pebbles were greatly decomposed, but most of them were remarkably fresh. The following section shows the general character of the formation:

Section in sand and gravel pit one-fourth of a mile northeast of Reybold station, New Castle County, Del.

	Feet.
Pleistocene:	
Talbot formation:	
Sandy loam	3
Band of pebbles	½–1
Numerous irregular layers of ironstone about 1 inch in thickness in matrix of coarse cross-bedded sand	3
Coarse cross-bedded yellow sand containing small pebbles and boulders, the largest of which are 10 inches in diameter. Exposed	7

Topographic expression.—The Talbot formation caps the Talbot terrace, described under the heading "Topographic divisions" (p. 4). It wraps around the lower margin of the Wicomico terrace, from which it is separated at most places by a low escarpment. From the base of the Wicomico-Talbot scarp, which stands at an elevation of 40 to 45 feet above sea level, the surface of the Talbot formation slopes gently toward the surrounding waters. Most or all of this surface has maintained its initial slope—the slope it had when it was deposited. This terrace is generally terminated by a low scarp cut by the waves of estuaries, but at some places it slopes gently to the water's edge. The Talbot formation has been less eroded than either the Sunderland or the Wicomico. It has been elevated above the water for so short a time that the streams which have found their way across it have not materially changed the form of its originally almost level surface.

Paleontology.—Elsewhere in the Coastal Plain fossils, both animals and plants, have been found in the Talbot formation. Along Chesapeake Bay there are numerous cypress bogs from which many varieties of plants as well as remains of insects and vertebrates have been obtained. Near Cornfield Harbor, at the mouth of Potomac River, the formation has yielded a great number of molluscan shells, which represent a varied marine and brackish-water fauna. In the Elkton and Wilmington quadrangles, however, the Talbot formation has thus far yielded no fossils.

Name and correlation.—The Talbot formation was named from Talbot County, Md., where it occupies a broad terrace along the border of numerous estuaries. The Talbot represents the lower part of the "Later Columbia" of McGee and Darton and corresponds approximately to the Cape May formation of Salisbury. Its Pleistocene age is proved by the fossils found in it at Cornfield Harbor, and the fact that it was formed when the ice invaded the region to the north is shown by the numerous boulders it contains.

Thickness.—The thickness of the Talbot formation is extremely variable, ranging from a few feet to 40 feet or more. A boring made by the War Department near the locks of the Chesapeake & Delaware Canal at Delaware City seems to indicate that the Talbot formation is there about 52 feet thick. Its variability in thickness is due to the fact that it was deposited on an uneven surface and, in some places, at or near the mouths of streams that carried large quantities of sediment.

Stratigraphic relations.—In some parts of this area the Talbot rests unconformably upon Cretaceous or pre-Cambrian formations. In other parts it may rest upon Brandywine, Sunderland, or Wicomico deposits, although no positive evidence has yet been found to indicate this fact. The deposits occupy a nearly horizontal position, having only a slight slope toward the larger estuaries.

RECENT SERIES.

In addition to the terraces already discussed, another terrace is now being formed by the waters of the rivers and the waves of the estuaries. This terrace everywhere follows the water's edge, extending from a few feet above tide to a few feet below. It is the youngest and topographically the lowest of the series. Normally it lies lower than the Talbot terrace, wraps about its margin, and is separated from it by a low scarp that is generally not more than 15 to 20 feet high. Where the Talbot formation is absent the Recent terrace may lie at the base of one of the other three terraces. In these places, however, the scarp that separates them is higher in proportion as the upper terrace is older. Peat, clay, sand, and gravel make up the formation and are deposited in deltas, flood plains, beaches, bogs, dunes, bars, spits, and wave-built terraces. Fossils, if the recently buried organic remains can be so called, are very common but consist almost exclusively of vegetable débris that has been covered by swamp deposits and of brackish-water animals of living species that have been entombed in the muds of the estuaries.

STRUCTURE.

PIEDMONT PLATEAU AREA.

By F. Bascom.

GENERAL FEATURES.

The rock beds in the Piedmont province have not remained in the position in which they were formed. The pre-Cambrian and Paleozoic beds are everywhere turned up on edge—that is, they are in a position in which they have been left by folding—and their edges are in a position in which they have been left by erosion.

The severe compression from the east and southeast to which all the eastern continental shelf was subjected at the beginning, at about the middle, and toward the close of Paleozoic time, owing to the sinking of the Atlantic basin segment, crumpled the originally horizontal beds, fractured them along planes that formed small angles with the beds, and thrust underlying beds along these fracture planes upon younger overlying beds. Thus was produced the type of structure which prevails in the Appalachian province and which is characterized in the Piedmont district by overturned anticlines and synclines, which strike northeast and dip isoclinally southeast, and by thrust faults, which dip approximately with the stratification and which reverse the normal succession of the formations by bringing younger formations beneath the older. The compression that took place since the faulting has folded fault planes as well as bedding planes and has produced crystallization, schistosity, and fissility.

A small part of the province is covered by Triassic sediments and by outliers from the sediments of the Coastal Plain. These sediments, which were laid down after the period of severe compression, exhibit a simplicity of structure and a freedom from metamorphism which readily distinguish them from the older formations.

The Triassic sediments show little or very gentle folding but are tilted at low angles to the northwest and are faulted along many fracture planes. Most of the faults are normal, and the displacement is slight. This structure was a result of the earth movement that uplifted the Triassic sediments and that fractured and presumably faulted the underlying and the adjacent Paleozoic rocks. In the absence of well-defined beds or of beds of any sort, however, it is very difficult to trace slight faults in the crystalline formations. The Triassic sediments cover a broad central area of the province but do not wholly conceal the structure of the underlying crystalline rocks.

The Paleozoic and pre-Paleozoic sediments of the province are folded in an anticlinorium, which exposes the pre-Cambrian gneisses in the central part of the province wherever the Triassic cover has been removed by erosion. In succession on both limbs of this anticlinal crest lie the Cambrian quartzite, the Cambrian and Ordovician limestone, and the Ordovician schist or slate. On the southeastern limb of the anticlinorium there are overturned anticlines and synclines, which have steeply compressed secondary anticlines and synclines on their limbs.

The Chester Valley syncline and the Buck Ridge anticline, at the east, have been traced southwestward through Pennsylvania into Maryland.

ELKTON AND WILMINGTON QUADRANGLES.

The Elkton and Wilmington quadrangles lie on the southeast flank of the anticlinorium, close to the overlap of the sediments of the Coastal Plain on the crystalline rocks. Stratified formations are so scant in this district that there is very little record of dynamic events. The structure, so far as it has been worked out, is shown in the sections forming figures 4 and 5. In these sections the vertical scale is somewhat exaggerated and the dips of the strata as they appear at the surface are correspondingly increased. Of course on a map of the scale used in this folio details of the structure can not be shown, so the secondary folding is generalized. These structure sections show that the pre-Cambrian Baltimore gneiss, intruded by batholiths of massive igneous rocks, appears in a succession of folds overturned toward the northwest; that the interbedded limestone is brought to the surface on the crest of one of these folds; and that the Wissahickon mica gneiss overlies the biotitic Baltimore gneiss on a nearly horizontal plane.

COASTAL PLAIN AREA.

By Benjamin L. Miller.

The geologic structure of the Coastal Plain is simple, for the beds have undergone little deformation since they were deposited. Few if any folds and no faults have been observed in the Coastal Plain formations of the Elkton and Wilmington quadrangles. Low folds and some faults of small throw have been observed in neighboring regions but are nowhere prominent or abundant in this part of the Coastal Plain. The region has been affected by numerous uplifts and depressions, but these movements have been so uniform over wide areas that they are indicated mainly by traces of erosion and deposition, produced by alternate emergence and submergence. As explained elsewhere, some of these vertical movements were accompanied by tilting, but they caused only slight deformation.

The Cretaceous formations of these quadrangles form a series of overlapping beds whose lines of outcrop trend in general northeast and southwest. With a few exceptions, already described in detail, each formation dips to the southeast at an angle greater than the slope of the surface and disappears beneath the next younger formation. Thus successively younger beds are exposed from northwest to southeast. This succession is interrupted, however, by Chestnut Hill, Iron Hill, and Grays Hill, which were islands in Cretaceous time. The strike of the Cretaceous formations ranges in general from north to northeast. The basal Cretaceous beds have a considerably steeper dip than the upper ones. Wells drilled in the Elkton-Wilmington area show that the Magothy formation here has a dip of about 20 feet to the mile.

The basal Cretaceous deposits rest upon the crystalline rocks of the Piedmont Upland. In places near the fall line this crystalline rock floor has a southeast dip of more than 100 feet to the mile, but its dip probably decreases a few miles seaward, for the rock floor has been reached at a depth of about 2,000 feet near Norfolk, Va., and Wilmington, N. C. (See figs. 4 and 5.) No boring has been carried to the rock floor in

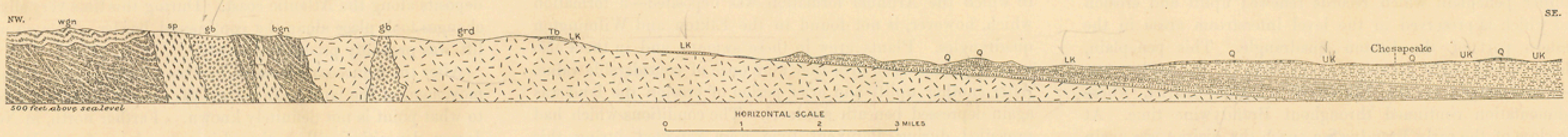


Figure 4.—Structure section across the Elkton quadrangle along line A–A′ on areal-geology map, showing general relations of formations. Vertical scale 10 times horizontal scale.

bgn, Baltimore gneiss; wgn, Wissahickon mica gneiss; grd, granodiorite; gb, gabbro; sp, serpentine; LK, Lower Cretaceous sedimentary formations; UK, Upper Cretaceous formations; Tb, Brandywine formation; Q, Quaternary deposits.

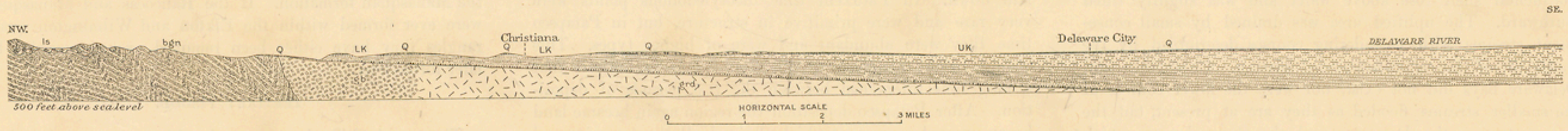


Figure 5.—Structure section across the Wilmington quadrangle along line B–B′ on areal-geology map, showing general relations of formations. Vertical scale 10 times horizontal scale.

bgn, Baltimore gneiss; ls, limestone in the Baltimore gneiss; gb, gabbro; grd, granodiorite and other pre-Cambrian rocks; LK, Lower Cretaceous sedimentary formations; UK, Upper Cretaceous formations; Q, Quaternary deposits.

the area here considered except at the inner margin of the Coastal Plain, so that the total thickness of the sediments and the dip of the bedrock surface here are unknown.

The Pleistocene formations are practically horizontal over the greater part of the area, but in some places they show a slight dip toward the large estuaries. This dip is in few places if anywhere greater than 8 to 10 feet to the mile.

GEOLOGIC HISTORY.

PIEDMONT UPLAND AREA.

By F. Bascom.

The Continental Plateau of North America and the adjacent oceanic basins antedate the earliest recognized sedimentary formations. The American Continental Plateau has not been continuously above sea level, however, for since it was formed interior and bordering epicontinental seas, in which sediments accumulated, have appeared, disappeared, and reappeared. During the period of greatest submergence more than 50 per cent of the Continental Plateau was below water, and at times within this period and other periods of less but still great submergence the American Continent was only a group of islands. The present continent of North America, which is almost coextensive with the Continental Plateau, is of relatively recent origin.

The oldest formations in the Elkton-Wilmington district belong to the island stage of continental development, when a long narrow island or small continent extended along the border of the Continental Plateau from about latitude 30° N., or northern Florida, to about latitude 50° N. It probably extended eastward beyond the present border of the Continental Plateau, and its width was somewhat less than half its length. This land mass has been called Appalachia, and the epicontinental sea on the west has been called the Appalachian Sea. Appalachia contributed the materials and the Appalachian Sea was the basin in which the materials were laid down in beds that ultimately, after they had been folded, uplifted, and eroded, formed the Appalachian Highlands.

Early in the history of Appalachia its western border was submerged. This submergence began in pre-Cambrian time and continued, with one marked interruption, late into Ordovician time, when, perhaps, the Elkton-Wilmington district emerged from the sea and remained a land area for the rest of Paleozoic time. During the early submergence sandy argillaceous sediments, derived from sources not far removed from the area of deposit, were laid down in this region. Interstratified with these sediments were thin calcareous beds of small areal extent, and upon the beds thus formed argillaceous sediments, derived from a denuded and lowered land mass, were laid down in a deepening sea. A widespread interruption of sedimentation followed, and these sediments were consolidated, compressed, uplifted, metamorphosed, and intruded by granitic, dioritic, and gabbroic igneous bodies. The pre-Cambrian biotitic gneiss, marble, and mica schist were thus formed. The Paleozoic era opened with the erosion of the uplifted land mass and the deposition, in an encroaching sea, of sand, calcareous material, and clay.

The Elkton-Wilmington district shows no record of further sedimentation during Paleozoic time, but in areas north and west of this district there is evidence that submergence and sedimentation persisted during Silurian and Devonian time. At the close of Ordovician time this part of Appalachia was probably uplifted, the sediments were slightly folded and faulted, and erosion began and continued in the extreme southeastern part of the Appalachian Highlands while sedimentation was still going on in the province as a whole.

From Middle Devonian until the close of Permian time oscillatory earth movements along the Atlantic border united Appalachia with land masses to the north and south and finally expelled the sea from the entire Appalachian district, uniting Canada and the Great Lakes region with the Atlantic border region. When these movements ceased not more than 1 per cent of the Continental Plateau was left submerged. The great compressive forces that caused or accompanied the earth movements acted in a southeast-northwest direction and crowded the sediments that had accumulated in the Appalachian Sea into long, narrow folds trending northeastward. The strata in the southeastern part of the Appalachian province, where the oceanic segment was thrust directly against the continental segment, show overfolds and thrust faults, which farther west pass into open folds, and those in the northwestern part of the province show a gradual resumption, toward the northwest, of a horizontal position.

During this long period of earth movement the form of the beds and the character of the sediments were greatly altered. The alteration was greatest in the southeastern part of the region, where the folding was closest, and was least in the western part, where the formations have only a gentle dip. The Elkton-Wilmington district is in the area of great metamorphism. The sandstone, which had been formed from beach sand, became quartzite, and the more impure sandstone was crystallized into quartz schist, mica schist, and gneiss. The calcareous sediments were converted into marble, and the clay was altered to a mica schist. The underlying pre-Cambrian gneiss, marble, mica schist, granite, and gabbro were also involved in the folding and metamorphism. This was the third series of earth movements which these rocks had undergone, and the second series of earth movements to which the Cambrian and Ordovician sediments had been subjected.

The uplift was very slow and presumably intermittent, and erosive forces, which it promptly set in operation, never ceased to modify the surface of the rising land. Though the land stood high at the close of the Paleozoic emergence the arches and troughs of the folded beds had already been uncovered and reduced by erosion. The reduction of the height of the land, which was largely the work of streams flowing eastward into the Atlantic, was well advanced when the Triassic sediments were deposited in a slowly sinking basin that extended nearly parallel to the coast and lay northwest of the Elkton-Wilmington district. Near the end of Triassic time, but before the end of Newark sedimentation, igneous material was intruded in sheets and dikes and extruded as lava flows. This igneous action was the precursor of earth movements in this region. The warping of the underlying crystalline floor caused a general disturbance of the Newark sediments, by which they were broken, faulted, tilted, and even gently folded.

The history of the Piedmont province after Triassic time is chiefly a history of erosion. Sedimentation was confined to the eastern margin of the province, but erosion was going on throughout the region. Several continental movements of uplift, which accelerated erosion, were followed successively by longer or shorter periods of quiescence and of less active but continuous erosion, during which eastward-flowing streams scoured and planed their valleys and deposited their sediments on the more or less submerged margin of the reduced upland. Plains were thus successively produced, lifted, and dissected. These sediments were furnished to a sea which advanced and retreated upon the depressed or uplifted margin of planed rocks. The sea was one of the agents of planation but not the principal agent, and it is not certainly known how far inland wave work was carried. Marginal sediments, where they overlap or can be correlated with the remnants of a peneplain, determine the age of that peneplain. Such sediments have accumulated to the depth of several thousand feet and collectively constitute the Coastal Plain, which lies at the foot of the Piedmont province.

The period of freedom from land movement which followed the post-Triassic uplift was longer, perhaps, than any subsequent like period. During this long period of quiescence the main lines of drainage were established along which the streams flowed eastward into the Atlantic Ocean. The divides were pushed westward at first rapidly, then slowly, until erosion finally formed a sloping plain of low relief on its eastern margin, where sedimentation was taking place while peneplanation was advancing in the interior. This great plain, which is generally known as the Kittatinny peneplain, is supposed to have spread away to the north and west and except in North Carolina to have shown but slight relief throughout the Appalachian Highlands. Remnants of this plain are conspicuously preserved in the level crests of Kittatinny Mountain and the ridges of the Appalachian Valley. (See p. 2.)

The crest of Schooley Mountain, which stands lower than that of Kittatinny Mountain, together with associated crests that stand at corresponding heights and at about the same distance from the sea, mark a second cycle of erosion, during which the uplifted Kittatinny peneplain was attacked, reduced, and obliterated, except on certain resistant rocks such as form the Kittatinny Mountain. Peneplains so vast as the Kittatinny and Schooley may not be of one age throughout their area. They are older in the extreme east, where the work of peneplanation began and where early Cretaceous sediments now lie upon their surfaces. They are younger in the north and west, where peneplanation was still going on in Cretaceous time. The Kittatinny peneplain, which probably was begun in Jurassic time, was further developed in Patuxent time, while delta deposits were being spread on the margin of the planed and lowered crystalline rocks. The Schooley peneplain, dating, perhaps, from the uplift which closed Patuxent sedimentation, was developed during the remainder of early Cretaceous time and possibly during a part of late Cretaceous time.

The Elkton-Wilmington district, which lies at the submerged margins of the Kittatinny and Schooley peneplains, was exposed to erosion during only the earlier stages of the development of these peneplains, for in later stages it was repeatedly submerged, receiving Cretaceous deposits on a planed surface of crystalline rocks while these peneplains were successively being developed to the north and west. Adjacent to the exposed edges of the lowest of these deposits, the Patuxent and the Patapsco, there may still remain vestiges of the Kittatinny and Schooley peneplains, newly uncovered and not yet eroded, but nearly everywhere along this margin later planation that uncovered the oldest peneplains has also cut below them, demolishing the old surfaces.

During later Cretaceous time, or possibly at the beginning of the Upper Cretaceous epoch, Schooley peneplanation was interrupted, and the Schooley peneplain was uplifted and tilted southeastward, toward the sea, and in the interior was warped into a low, unsymmetrical ridge which had its greatest extension from northeast to southwest. Erosion was at once renewed on this arched highland, the southeastern slope of which forms the upland surface of the Piedmont province, and was continued during the remainder of Cretaceous time. This period of quiescence and erosion was shorter than the two which preceded it, but it was sufficiently long to permit the partial dissection of the Schooley peneplain and the production of another, less widespread peneplain, the Honeybrook. Owing to later dissection, the Honeybrook peneplain, like the Schooley and Kittatinny peneplains, is now found only in areas of the more resistant rocks or at places remote from the main lines of drainage. As this peneplain is younger, however, these remnants cover a larger area than remnants of the Schooley or Kittatinny peneplains and are everywhere lower than the associated remnants of those peneplains. This peneplain has been completely eroded from the Piedmont province in the Elkton-Wilmington district. If any vestige of it remains it lies adjacent to the Raritan sediments on the Coastal Plain.

At the beginning of Tertiary time and before Honeybrook peneplanation had completely obliterated the earlier peneplains, uplift renewed erosion on the Kittatinny and Schooley peneplain remnants and started the dissection of the Honeybrook peneplain. This interval of erosion lasted long enough to develop the Harrisburg peneplain in the softer rocks along the courses of the master streams. Remnants of this peneplain are preserved on the Delaware south of Delaware Water Gap, on the Schuylkill north of Reading, on the Susquehanna northeast of Harrisburg, and on the Potomac west of Hagerstown. Remnants of the Harrisburg peneplain are believed to be preserved in the 500-foot summits in East Nottingham Township, in the northwest corner of the Elkton quadrangle, where later Tertiary sediments were probably deposited but have been completely removed.

Below the surface of the Harrisburg peneplain there was cut another peneplain which records renewed uplift and erosion and which is preserved in the level interstream areas in the western part of the Elkton quadrangle. This peneplain, which carries early Brandywine deposits on its border, was soon submerged in the Elkton-Wilmington district, where sedimentation continued throughout Brandywine time. At the close of the early Brandywine epoch the district was again uplifted, and it may be that at this time a large part of the continental shelf rose above water and was slightly tilted southward. The uplifted area was drained by small consequent streams with meandering courses determined by the gentle tilt of the sediment-covered plateau. Chesapeake and Delaware bays did not exist, nor were the lower courses of the smaller streams flooded as they are at present, but the master streams, the Delaware and the Susquehanna, which took part in the preceding peneplanation, survived the uplift, found outlets to the sea through their former lagoon channels, which for a considerable distance lay parallel to the old coast line, and southeast of the old coast line cut new valleys to the edge of the continental shelf. During this time there were developed the shallow, open valleys within which gorges were later cut as a consequence of uplifts in Pleistocene time. During this time also a seaward-facing slope was formed below the surface of the early Brandywine peneplain. This is the late Brandywine surface, which lies above the Pleistocene terraces.

After this uplift and the consequent erosion, which stripped nearly all the sediments from the crystalline rocks of the upland, the eastern margin of the continental shelf once more subsided, and all the Coastal Plain and the border of the Piedmont province were again sunk under water. This submergence brought estuarine waters nearly to the present 200-foot level in the Elkton-Wilmington district, making islands of Grays Hill, Chestnut Hill, and Iron Hill, as well as of several of the higher hills on Elk Neck in the Coastal Plain. The Sunderland deposits belong to this period of submergence. There are faint traces of the old wave-cut escarpment of this Sunderland sea between the 180 and 200 foot levels in the Wilmington quadrangle.

Twice again the Elkton-Wilmington district was uplifted and eroded, and twice it was partly submerged, the submergence permitting the sediments of Wicomico and Talbot time to be deposited upon the Coastal Plain and the margin of the upland. The periods of erosion were not long, and the sediments previously laid down were only partly stripped from the margin of the upland; nor were the periods of submergence long enough to permit the formation of well-marked shore escarpments. In each submergence the sea advanced less than in the preceding; the Wicomico escarpment stands at about the present 100-foot level and the Talbot escarpment at about the 45-foot level.

In Talbot time the aspect of the region could not have been very different from that of the present day. The bays and estuaries were essentially of the same form as at present, differing only in extent. Since Talbot time the land has been somewhat higher than it is now, and the bays and estuaries were accordingly contracted. They have been again enlarged by a slow encroachment of the sea on the land, an encroachment which is still going on.

Thus the topographic features of the region are a record of its history. The discordance of the underground structure with the surfaces of the upland, the residual eminences, and the terraced valleys record successive uplifts and accelerated erosion. The nonadjustment of the master streams to the rock formations indicates that their courses were consequent upon a planed surface that sloped southeastward across the trend of the folded rock formations. The deep mantle of soil and the absence of ledges of rock indicate that this region has long been exposed to erosion and has never been stripped of the residual decayed rock by a continental glacier, as has the region to the northeast.

COASTAL PLAIN AREA.

By Benjamin L. Miller.

CRETACEOUS PERIOD.

Lower Cretaceous epoch.—The earliest known unconsolidated deposits found anywhere on the floor of crystalline rocks in the Coastal Plain belong to the Patuxent formation of the Potomac group, of Cretaceous age. They indicate a submergence of the Coastal Plain in this region of sufficient extent to cover the whole area with shallow estuarine water. The cross-bedded sand and gravel found in these deposits indicate shifting currents, as do also the abrupt changes in the character of the materials. The presence of numerous land plants in the laminated clays shows the proximity of the land.

The deposition of the Patuxent formation was ended by an uplift that brought the region above sea level and began a period of erosion which persisted long enough to permit the removal of a vast amount of material. This uplift was followed by a subsidence in which parts of many of the stream valleys, only lately eroded, were occupied by bogs and swamps in which the Arundel formation was deposited—a formation which, however, is not found in the Elkton and Wilmington quadrangles. Plants grew in these swamps, and in them also were deposited iron ores that were once of considerable value. After another uplift and brief period of erosion the land was again depressed beneath sea level. The conditions which had prevailed during Patuxent time were repeated during this period of submergence, in which the Patapsco formation was laid down. In Patuxent time dicotyledonous plants were very rare and were primitive in structure, but in Patapsco time they were abundant and were of higher types. This change in the character of the flora seems to indicate that a long time intervened between the two periods of deposition. After Patapsco deposition the region again became land by an upward movement which drained all the estuaries and marshes and established active erosion, by which the Patapsco surface was dissected. This uplift closed the Lower Cretaceous epoch.

During the Lower Cretaceous epoch the Kittatinny and Schooley peneplains were probably formed on the adjacent land, but there is not yet sufficient evidence to permit the exact correlation of these peneplains of the Piedmont province with periods of deposition and erosion in the Coastal Plain. Iron Hill, Chestnut Hill, and Grays Hill persisted as monadnocks in the region that was peneplained and was later covered with Coastal Plain sediments.

The widespread formation of shallow-water deposits, everywhere cross-bedded and extremely variable in lithologic character, and the presence throughout these deposits of land plants suggest that the Potomac sediments were laid down not in the open sea but in brackish-water or fresh-water estuaries and marshes, which, though not continuously connected with the sea, may have at times been flooded by it. The sea may have been generally shut off from this area by some land barrier that lay east of the present shore line, but the position and extent of this barrier can not be determined. Barrell [1] has suggested another interpretation for the Lower Cretaceous deposits—namely that they were laid down in a series of deltas.

Upper Cretaceous epoch.—The Upper Cretaceous epoch in this region was begun by a downward land movement which again submerged the greater part of the region, leaving only a very narrow marginal strip of Patuxent and Patapsco deposits above water. During this time the Raritan formation was deposited under conditions very similar to those which had existed during the Patuxent submergence. The formation of the Honeybrook peneplain may also have been begun at this time. Raritan deposition was terminated by an uplift, which again converted the entire region into land. A long time elapsed before the region was again submerged, and during this time the streams were able to erode extensively the recently formed deposits.

The Patapsco and Raritan deposits were laid down in estuaries or in bodies of fresh water; the Matawan, Monmouth, and Rancocas deposits were laid down in the sea; and the Magothy deposits were at most places probably laid down in estuaries or in bodies of fresh water, though at other places they were laid down in the sea. The great variability in the lithologic character of much of the Magothy materials, the coarseness of the sands and gravels, and the cross-bedding suggest deposition in estuaries or near the shore, but the pockets of glauconitic sand and the marine invertebrates found here and there in the formation suggest deposition in the sea. The probability is that over most of the area where Magothy deposits are now found the conditions that prevailed in Potomac and Raritan time prevailed also during the greater part of Magothy time, and at some places perhaps during the whole of it, but that occasionally the sea broke down the land barriers which had kept it out and flooded large areas, bringing in marine animals. There is no evidence that such incursions of the sea took place anywhere except in New Jersey.

At the close of Magothy time the region was uplifted and subjected to erosion, which, however, removed comparatively small amounts of material. In some places it is impossible to establish definitely any stratigraphic break between the Magothy and the Matawan, perhaps because the interval of erosion was comparatively short or because the land did not stand high enough above the water to permit the streams to cut channels into the newly formed deposits.

Not until late Cretaceous time, at the beginning of the Matawan epoch, was there a downward movement of sufficient extent to bring the waters of the ocean far and wide into this region. During the Matawan and Monmouth epochs the area included in the Elkton and Wilmington quadrangles probably lay beneath the ocean. The streams from the low-lying land evidently carried into the ocean at this time only small amounts of fine sand and mud, and the conditions were favorable to the production of glauconite and to the accumulation of the beds of greensand that are so characteristic of the Upper Cretaceous deposits along the Atlantic coast. During this time very slight changes took place along the continental border, although uplift was probably proceeding slowly.

After the Rancocas formation had been deposited an upward movement of the land again carried the shore line eastward, but to what point is not definitely known. Farther north, in New Jersey, deposition still continued in some places, for the Rancocas is there overlain by another and later Cretaceous deposit—the Manasquan formation. If the Rancocas and Manasquan were ever formed within the Elkton and Wilmington quadrangles they have either been removed or are concealed by later formations.

TERTIARY PERIOD.

The record of Tertiary events in this region is incomplete, as the only formation assigned to this period is the Brandywine, which is doubtfully Pliocene. In adjoining regions to the south Eocene and Miocene deposits are well represented and indicate several successive submergences and uplifts. The surface of the Elkton-Wilmington district must have undergone the same changes of position except that the subsidences were not sufficiently great to spread the ocean waters over the region. The absence of Eocene and Miocene deposits may, however, be due to their removal by erosion. The Harrisburg peneplain was doubtless formed during the period of erosion that intervened between Upper Cretaceous and Eocene deposition.

At the close of the Miocene the entire region was uplifted into land. Streams at once began to carve valleys on the featureless surface, and erosion continued until the country was reduced to a series of broad valleys and somewhat subdued uplands, so that the weathered products of the Piedmont province were not carried off by the sluggish streams. This surface is called the early Brandywine peneplain. A subsidence followed which again carried the region under water. Coincident with this subsidence there seems to have been a slight uplift and seaward tilting of the region west of the shore line. This tilting gave the streams renewed force at their heads, enabling them to carry down and to spread over this region large quantities of gravel and sand, derived from the rocks of the Piedmont province and the Paleozoic formations to the west. Many of the gravel deposits near Washington contain fragments of rocks that carry Devonian and Carboniferous fossils, brought from regions beyond the Blue Ridge. These fossils show that Potomac River had extended its drainage basin westward to those regions. Susquehanna and Delaware rivers likewise brought down into this region pebbles derived from the Piedmont province and the Blue Ridge province beyond.

During the early Brandywine submergence the conditions were not uniform over the entire area, for gravel beds were being deposited at some places while clay beds were being deposited at others, yet sedimentation was remarkably uniform throughout the area in view of the circumstances under which it took place, and over the former land surface a fairly persistent capping of gravel was deposited. But land movements were again taking place slowly and at last checked the velocity of the streams, which could no longer carry down gravel except in freshets. Upon this gravel were laid down fine sand and loam. This loam, which is spread over a large part of the Coastal Plain, marks the last epoch of early Brandywine sedimentation, which was also the last time that the entire Coastal Plain region was submerged beneath the ocean.

QUATERNARY PERIOD.

Pleistocene epoch.—At the close of the Pliocene epoch the region was raised again and the recently emerged land was extensively eroded and in part covered by terrestrial deposits. Then it was again lowered and received the deposits which constitute the first formation of the Columbia group. The

[1] Barrell, Joseph, Criteria for the recognition of ancient delta deposits: Geol. Soc. America Bull., vol. 23, pp. 405-411, 1912.

Sunderland, Wicomico, and Talbot formations, which make up this group, are exposed in a series of terraces that are arranged in steps throughout the Atlantic Coastal Plain from Raritan Bay to southern Virginia and even farther south. The key to the relations between these surficial deposits is the correct correlation of the terraces. Much light may be thrown on these relations by a careful study of the Recent submerged terrace that is now forming along the shores of the Atlantic Ocean and along Chesapeake Bay and its tributaries, which is considered below, under the heading "Recent epoch."

When the uplift that terminated early Brandywine deposition occurred the continent was bordered by a very even, gently sloping plain that extended from the Piedmont Upland to the ocean. Across this plain, which was composed of coarse unconsolidated materials, streams that rose in the Piedmont region gradually extended their courses, and new streams, which were confined to the Coastal Plain, were also formed. At that time the shore line seems to have lain farther east than now, and the present submerged channels of the continental shelf were probably eroded then. The Coastal Plain portions of Delaware River, with its extension, Delaware Bay; Chesapeake Bay, which is the continuation of Susquehanna River; and Potomac, Patuxent, Rappahannock, James, and other rivers date from this late Brandywine uplift. The attitude of the subsequent deposits makes this evident, for the surfaces of the Sunderland, Wicomico, Talbot, and Recent terrace formations all slope toward these several waterways. At some places the streams cut through the early Brandywine formation and eroded valleys in the older strata. Several of these valleys were eroded to a width of many miles before the corrasive power of the streams was checked by the Sunderland submergence.

At the close of this (late Brandywine) erosion period the Coastal Plain was gradually lowered and the Sunderland sea advanced over the sinking region. The waves of this sea cut a scarp against the headlands of Brandywine and older rocks. This scarp was prominent at some places and obscure at others, but traces of it may be easily recognized in certain localities.

As fast as the waves supplied the material the shore and bottom currents swept it out to deeper water and deposited it, so that the basal member of the Sunderland formation—a mixture of clay, sand, and gravel—represents the work of shore currents along the advancing margin of the Sunderland sea, whereas the upper member, consisting of clay and loam, was deposited by quieter currents in deeper water farther from the shore line, after it had advanced some distance westward. Ice-borne boulders are also scattered through the formation at all horizons.

The tendency of the work done was to destroy all irregularities produced by the late Brandywine erosion. At many places old stream courses were undoubtedly obliterated, but the channels of the larger streams, although probably at some places entirely filled, were in the main left lower than the surrounding regions. Thus in the uplift that followed Sunderland deposition the larger streams reoccupied practically the same channels they had carved out in the preceding period of erosion. They at once began to clear their channels and to widen their valleys, so that when the next submergence occurred the streams were eroding, as before, in Tertiary and Cretaceous materials. On the divides also the Sunderland was gradually undermined and worn back.

When the Coastal Plain had been above water for a considerable time after the close of Sunderland deposition a gradual submergence again occurred, so that the ocean waters once more encroached on the land. This submergence was apparently about equal in amount throughout a large part of the district, a fact which shows that the downward movement was not accompanied by deformation. The sea did not advance upon the land so far as it did during the previous submergence. At many places along the shore the waves cut cliffs into the deposits that had been laid down during the preceding period of deposition. In many parts of the Coastal Plain these old sea cliffs are still preserved as escarpments that range in height from 10 to 15 feet. Where the conditions were unfavorable for cliff cutting it is somewhat difficult to locate the old shore line. During this time, as during the preceding stages, large parts of the Elkton and Wilmington quadrangles were submerged. The Sunderland deposits were in part destroyed by the advancing waves and redeposited over the floor of the Wicomico sea, although large areas of these deposits which lay more than 90 to 100 feet above sea level were preserved. Materials brought down by streams from the adjoining land were also deposited. At this time the ice-borne boulders that are now found at many places in the finer material of the Wicomico formation were spread promiscuously over the bottom of the Wicomico sea.

Though the Wicomico submergence permitted the silting up of the submerged channels of the streams, yet the deposits were not thick enough to fill them entirely. Accordingly, in the uplift that followed Wicomico deposition the large streams reoccupied their former channels with perhaps only slight changes. New streams were also formed, and the Wicomico plain was more or less dissected along the watercourses, the divides being at the same time gradually narrowed. This period of erosion was interrupted by the Talbot submergence, which carried part of the land beneath the sea and again drowned the lower courses of the streams.

The geologic activities of Talbot time were a repetition of those of Sunderland and Wicomico time. The Talbot formation was not deposited over so large an area as that covered by the Wicomico. It was laid down in the old valleys and on the low stream divides, where the advancing waves destroyed the Wicomico deposits. The sea cliffs were pushed back as long as the waves advanced and now stand as an escarpment that marks the boundaries of the Talbot sea and estuaries. This Talbot-Wicomico escarpment, which has already been described (p. 14), now lies about 40 feet above sea level and furnishes evidence of the post-Talbot elevation. Ice-borne boulders are also extremely common in the Talbot formation, showing that blocks of ice bearing detritus carried from the land drifted out and deposited their load over the bottom of the Talbot sea.

At some places in the old stream channels the deposits were so thick that the streams in the succeeding period of elevation and erosion found it easier to excavate new courses than to follow the old ones. Generally, however, the streams reoccupied their former channels and renewed the erosion which had been interrupted by the Talbot submergence. As a result of this erosion the Talbot terrace is now in many places rather uneven, yet it is more regular than the remnants of the late Brandywine, Sunderland, and Wicomico terraces, which have been subjected to denudation for a much longer period.

Recent epoch.—The land probably did not long remain stationary with respect to sea level before another downward movement began. Whether this slow downward movement of the North Atlantic Coastal Plain is now in progress is in dispute, but there is evidence to show that along Delaware River it has been in progress within very recent time and probably still continues. The charts of the United States Coast and Geodetic Survey show that from 1841 to 1881 the river between Reedy Island and Liston Point increased its mean width 411 feet—285 feet on the New Jersey side and 126 feet on the Delaware shore. During the same period certain parts of this area have been deepened. Part of these changes might have been the work of waves and currents, but these agencies could probably not alone have produced the great changes that have occurred during the last 40 years. The subsidence began some time after the post-Talbot uplift, as is proved by the old stream channels found in many parts of Chesapeake Bay and its tributary estuaries. Had these channels been cut before Talbot deposition they would have been obliterated in Talbot time.

An area including many square miles that had been land before this subsidence began now lies beneath the waters of the estuaries and is receiving deposits of mud and sand from the adjoining land. The post-Talbot subsidence produced the estuaries and tidewater marshes that form conspicuous features of the existing topography. The waves of the Atlantic Ocean and Chesapeake Bay are now wearing away the land along the shore and depositing the eroded material on a subaqueous platform or terrace, which extends not only along the seashore but up the estuaries to their heads. The materials composing this terrace are various, their nature depending both on the character of the detritus removed from the land by the waves and on the force of the currents which sweep along the shores. On an unbroken coast the material is of local derivation, but near the mouth of a river it consists of débris derived from the entire river basin.

Besides building a submerged terrace, the waves of the ocean and bay are in places cutting a sea cliff along the coast. The height of this cliff depends not so much on the force of the breakers as on the relief of the land against which the waves beat. A low coast yields a low sea cliff and a high coast a high cliff, and the one passes into the other as often and as abruptly as the topography changes, so that along the shores of some of the larger estuaries high cliffs and low depressions appear in alternation.

In addition to these features, bars, spits, and other similar formations are being produced. If the present coast were raised slightly the subaqueous platform which is now in process of construction would appear as a well-defined terrace of variable width, with a surface either flat or sloping gently toward the water. This surface would everywhere fringe the shores of the ocean and bay as well as those of the estuaries. Just after this emergence the sea cliff would be sharp and easily distinguished, but with the lapse of time its less pronounced parts would gradually be leveled by erosion and might finally disappear altogether. Erosion would also destroy in large measure the continuity of the terrace, but so long as parts of it remained intact a geologist could reconstruct the old surface and determine the history of its origin.

ECONOMIC GEOLOGY.

MINERAL RESOURCES.

PIEDMONT UPLAND AREA.

By F. Bascom.

BUILDING STONE.

The granodiorite of the Elkton quadrangle makes a durable and attractive building stone.[1] Its color is light gray to yellowish white softened by disseminated flakes of brown mica. This mica and the quartz and feldspar in the rock are so arranged as to give it a foliated or gneissoid texture. Its grain is medium coarse and is very uniform. Although the rock is cut by several systems of joint planes it is compact and strong, having a crushing strength of more than 21,000 pounds to the square inch and a high resistance to frost and to atmospheric disintegration. The horizontal joint planes and two other sets of nearly vertical planes that intersect almost at right angles may be utilized by the quarryman and the stonecutter in converting the rock into building stone. Not much of the stone is quarried in the Elkton district, where the flat surface and the low altitude of the granodiorite country make it difficult to remove the stone and to keep the quarry dry. There are small quarries on Stony Run 1 mile north of its mouth, on Little Elk Creek half a mile northeast of Childs, and at the paper mill near Providence, on Big Elk Creek half a mile south of Bank, and at a point about one-third of a mile southeast of Appleton. These quarries, however, were operated only temporarily, to supply stone for bridges on the Baltimore & Ohio Railroad. Large quarries have been successfully worked for many years in the same rock where it outcrops in vertical bluffs along Susquehanna River in locations that are admirably fitted for quarrying and shipping.

Along the lower course of Brandywine Creek gabbro has been quarried for many years and placed on the market under the name "Brandywine granite." The Brandywine Granite Co. and the Stewart & Donahue Co. own large quarries just north of Wilmington. The Stewart & Donahue Co. furnishes stone for paving, concrete work, railroad ballast, road metal, railroad structures, and building stone.

The only quarry on Brandywine Creek within the Wilmington quadrangle is operated by the Delaware Granite & Mining Co., which has worked it continuously since 1900. This quarry is in a hillside, and the stone, which is removed by drilling and blasting, is crushed at the quarry and is used exclusively for road metal, railroad ballast, and concrete work.

Crushing tests show that the stone has a strength of 26,000 pounds to the square inch. The stone is shipped by the Pennsylvania Railroad or by water to points in Delaware, Maryland, Pennsylvania, and New Jersey.

The New Castle County Almshouse quarry, which was first operated in June, 1901, is on Red Clay Creek near the Landenberg branch of the Baltimore & Ohio Railroad. The stone, which is a dark-green hornblende gabbro, is known as "bluestone" and is used as road metal and locally as building stone. Other quarries in the gabbro, which are operated in a small way only when the stone is needed, are on White Clay Creek 1 mile northeast of Newark. On Christiana Creek, 1½ miles east of Appleton, hornblende gabbro has been quarried for use in cellars and foundations.

At Richardson's quarry, three-quarters of a mile south of Elsmere, a very silicic gabbro, commercially known as "blue granite," is intermittently quarried.

The Baltimore gneiss has furnished stone for local use only. There are small abandoned quarries in this gneiss at Choate, and at a place three-quarters of a mile northeast of Calvert. The quarry at Choate has been recently reopened and worked for road metal, and the rock is crushed at the quarry.

The four quarries in limestone half a mile east of Pleasant Hill have been abandoned for many years. The stone was burned for lime.

ROAD MATERIAL.

The Elkton-Wilmington district is well supplied with stone from which excellent road material may be made.

The gabbro, granite (granodiorite), and gneiss are all adapted to this use, for which the gabbro and granite are being largely utilized. The first table on page 18 shows the results of laboratory tests on the three rocks—gabbro, gneiss, and granite.

Goldbeck and Jackson point out that the absorption test is of value in judging the behavior of the rock under the action of frost; the higher the absorption the greater the effect of frost. Rocks that have a coefficient of hardness below 14 they call soft, from 14 to 17, medium; and above 17, hard. A coefficient of toughness below 13 they call low; from 13 to 19, medium; and above 19, high. In selecting stone for road

[1] For report of tests of crushing strength, see Gillmore, Q. A., Reports on the compressive strength, specific gravity, and ratio of absorption of the building stone in the United States in most general use: Chief of Engineers Ann. Rept. for 1875, pt. 2, Appendix 2, p. 847, 1875. Also republished separately, 37 pp., New York, Van Nostrand, 1876. Mathews, E. B., An account of the character and distribution of Maryland building stones: Maryland Geol. Survey, vol. 2, pp. 144–145, 1898; The mineral resources of Cecil County: Maryland Geol. Survey, Cecil County, pp. 201–202, 1902.

metal the character of the traffic must be considered;[a] hard, tough rock does not always give the best results. With light traffic relatively soft material that has good cementing value will produce under wear sufficient binding material to keep the road in good condition; under the same amount of wear hard rock will fail to maintain the supply of binding material and will finally form a loose stony road.

Physical tests of gabbro, gneiss, and granite.[a]

	Water absorbed (pounds per cubic foot).		Percentage of wear.		Coefficient of hardness.		Coefficient of toughness.		Cementing value.	
	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.
Gabbro	.97	.04	5.9	1.3	18.8	13.3	23	8	134	6
Gneiss	1.24	.02	16.4	1.7	19.3	9.0	25	2	110	1
Granite	2.77	.04	24.6	1.1	19.6	13.6	33	2	255	2

[a] Goldbeck, A. T., and Jackson, F. H., The physical testing of rock for road building: U. S. Dept. Agr. Bull. 44, p. 26, 1912.

In resistance to wear, in hardness, and in toughness gabbro and all trap rocks are superior to other road metal and can be used on roads that carry heavy traffic. Limestone and serpentine, which are relatively soft and have high cementing value, are suited to light traffic. Granite and gneiss lack the toughness and the binding value requisite for top dressing of macadam roads but may be used as foundation stone. The foliated texture of gneiss renders it inferior to granite in binding value.

The gabbro, gneiss, and granodiorite of the Elkton-Wilmington district have been tested for use as road material. These tests indicate that the granodiorite of Port Deposit is more nearly comparable to the gabbro from Wilmington as a road metal than the average granite and gabbro.

Physical tests of granodiorite of Cecil County, Md., the gabbro of Wilmington, Del., and the gneiss of the Wilmington district.[a]

	Water absorbed (pounds per square foot).	Percentage of wear.	Coefficient of hardness.	Coefficient of toughness.	Cementing value.
Wilmington, Del.:					
Gabbro	0.16	1.6	18.2	17	19
Hypersthene gabbro	.17	3.7	18.0	9	18
Gabbro or "pyroxene quartzite"	.10	2.1	18.5	24	7
Mica gneiss	.27	4.4	17.0	7	55
Mill Creek, Del.:					
Mica gneiss	.83	6.6	([b])	([b])	75
Port Deposit, Md.:					
Granodiorite or "granite"	.17	2.0	18.7	10	13

[a] U. S. Dept. Agr. Bull. 44, pp. 37–45, 1912.
[b] Tests not made.

In addition to the rocks here tabulated, serpentine and metadacite are also available for use as road metal. Serpentine, though soft and not very tough, has a remarkably high cementing value (500), which adapts it to use on roads that have light traffic. Metadacite is hard, of medium toughness, of variable but usually good cementing value, and is also adapted to use on roads that have light traffic.

IRON ORE.

At one time iron working was a considerable industry in Cecil County, Md., as is shown by the old iron mill on Big Elk Creek, three-fourths of a mile west of Appleton, and the now inactive iron works at Northeast. Very little of the ore for these works was obtained from the Elkton-Wilmington district, but a siliceous iron ore was early mined on Chestnut and Iron hills. Three large pits and several small pits in limonitic and hematitic honeycomb rock were worked on Chestnut Hill and abandoned about 30 years ago. Arrangements were made in 1912 to reopen these mines, and a mill was equipped with crushers, James tables, and magnetic separators, but all operations here were stopped several years ago. Magnetite occurs in material taken from prospecting holes drilled since 1912.

On Iron Hill evidences have been found of the work of Welsh miners in the eighteenth century. A century later the Whittaker Iron Mining Co., of Principio, Md., and Wheeling, W. Va., worked three pits on Iron Hill in limonite. They were first opened in 1860 and were finally abandoned in 1891. The ore, which was covered only by hillside wash and decayed material, was reached at a depth of 6 to 10 feet and was mined only in the open cut, which in some places is 100 feet deep. The ore is a brown limonite, which is in some places pulverulent but generally has a fibrous and radiating texture and which occurs in veins that penetrate the gabbro. The wall rock has also been more or less completely replaced by limonite. The richest ore came from a vertical vein that was 50 to 75 feet wide and bounded by rock less rich in limonite. Iron oxide has presumably been leached from ferriferous rocks and precipitated in fissures as a hydroxide. The ore was broken with sledge hammers and loaded on cars, which were lifted by cable from the pits. The ore was then hand picked to get rid of the poorest material and was run through a log washer. Afterward it was hauled by team to Newark, and shipped by rail to Principio Furnace for smelting, and the pig was sent to Wheeling. An old pit on the southwest slope of Iron Hill, known as Cooch's mine, is filled with refuse material.

CHROMITE.

The serpentines along the Maryland boundary contain chromite, but the richest deposits of chromite in these rocks lie west of the Elkton-Wilmington district. They were mined from 1828 to 1868 and from 1873 to 1881 but were eventually abandoned because their product could not compete with that of the rich mines in Asia Minor, near Constantinople. In 1918, however, four of these mines had been reopened and one was being successfully worked. With one exception they are located west of the Elkton quadrangle.

QUARTZ.

A quarry 1 mile east of Appleton was at one time operated for quartz, which occurs here as a constituent of a pegmatite dike. The material was hauled to Tweed's grinding mill, on Big Elk Creek, and was used as glass sand.

FELDSPAR.

Four feldspar quarries in pegmatite dikes between Thompson and McClellandville, near White Clay Creek, were intermittently operated until about 1900. The quarry at Thompson and the quarry 1¼ miles southwest of Thompson were worked for 25 or 30 years by Mansel Tweed. The pegmatite yields a potash feldspar, which was ground by water power in Tweed's mill on Big Elk Creek, and shipped for use in making pottery.

Half a mile south of Thompson there are three abandoned quarries in pegmatitic feldspar. This feldspar contains so much iron that it is unfit for use in making pottery.

KAOLIN.

The clay or kaolin found in the Elkton-Wilmington district is either derived by decomposition in place from the feldspar of a granodiorite, a gneiss, or a pegmatite, and is then said to be "residual clay," or is derived from fragments of these rocks or of disintegrated argillaceous formations which have subsequently been removed and worked over by water and redeposited. Such reworked deposits of clay are classified with other deposits of the same age and are described under the heading "Coastal Plain area" (p. 19).

Residual clay is mixed with sand and mica, from which it must be separated before it is ready for market. Water-deposited clay has already been refined by natural processes, but the value of some of it is impaired by a strong stain of iron. At two of the four places where residual clay has been mined in the Elkton-Wilmington district the kaolin is derived from the feldspar of pegmatite dikes, and at the others it is derived from granodiorite. The dikes are more or less concealed by surface wash or by Quaternary sediments, and their width therefore can not be determined, but presumably few if any of them exceed 100 feet in width and most of them are narrower. Their vertical extent is indefinite, but at a depth of 100 feet the feldspar is less perfectly kaolinized, and at still greater depths it is altogether unaffected by surficial decomposition.

One of the four kaolin mines is 1½ miles east of Corner Ketch, in the northwest corner of the Wilmington quadrangle, where a pegmatite dike cuts the gneiss and limestone. The Peach Kaolin Co., of Newark, Del., has been operating here since 1892. The kaolinized feldspar, which is covered by 8 to 10 feet of surface wash, is dug from three pits southwest of the refining mill; the pits are worked to depths of 50 to 90 feet. The kaolin is exhausted in but few places, but excavation ceases at a little less than 100 feet, because at greater depths the timbers of the shafts are crushed by wall pressure. The raw material is thrown into agitators, where the coarse sand or quartz is removed by sand wheels; the clay is then passed into float boxes, where the fine quartz and the muscovite are separated by specific gravity, and thence into large settling boxes, from which it is pumped into bag presses and hung on open or covered racks to dry. The refined material, which is of a clean yellow-white color, is hauled to Harmony, on the Pennsylvania Railroad, whence it is shipped to East Liverpool and Cleveland, Ohio, and to Trenton, N. J. About 3,000 tons is shipped annually. The sand has been utilized for concrete work.

About a mile southwest of this plant the Newark China Clay Co. began operations in 1913. The clay prepared at this plant is delivered at Thompson station, on the Pomeroy & Newark branch of the Pennsylvania Railroad, and the company is equipped to ship 10,000 to 15,000 tons a year. The clay is refined by putting it through washers, where the sand-wheels take up much of the quartz, and it then flows through horizontal troughs, in which the remaining sand settles. It then passes into vats, from which it is pumped into pressers, whence it goes to driers and is then ready for market—a pure-white kaolin.

Another plant, that of the Maryland Clay Co., is about a mile southwest of Northeast station, between the Philadelphia, Baltimore & Washington Railroad and Northeast River. The kaolin mined here is the residual product of the decomposition of a siliceous facies of the granodiorite. The rock is composed chiefly of quartz and alkaline feldspar but contains a trace of hornblende and magnetite. The rock is impregnated with quartz veins and is thoroughly disintegrated through the complete decomposition of the feldspar to muscovite and kaolinite. It is overlain by 10 to 40 feet of Patuxent and Pleistocene sands, which must be stripped off.

The constituents of the unwashed clay from the pits are muscovite, quartz, and kaolin. Muscovite, which exceeds in amount the other constituents, occurs in microscopic flakes that have an index of refraction of 1.60 parallel to the cleavage and of 1.57 perpendicular to the cleavage and an axial angle of 60°, a combination of characters which distinguishes it from leverrierite or kaolinite. The quartz occurs in microscopic angular grains and the kaolin in very fine powder. No undecomposed feldspar was observed in the clay sampled.

The greater part of the sand and mica was separated from the clay by the usual method and discarded. The washed product was used in making paper. The composition of the washed product, which constitutes only about 30 per cent of the quantity mined, is shown by the following analysis, obtained from the Maryland Clay Co.:

Analysis of washed kaolin from Northeast, Cecil County, Md.

SiO_2	55.65
Al_2O_3	30.53
Fe_2O_3	.97
MgO	.60
CaO	.75
Na_2O+K_2O	.20
H_2O+	.35
H_2O-	12.30
	101.35

After recalculating the analysis to 100 the recalculation of the mineral constituents gives kaolinite 58.05 per cent, muscovite 20.36 per cent, quartz 18.30 per cent, and water 3.38 per cent, of which 3.04 per cent is "combined" water.

In 1908 the Maryland Clay Co. became the Columbia Brick & Plaster Co., and in 1911 this company gave place to the Conroy Manufacturing Co., which ceased operations in April, 1913. The plant in 1919 was occupied by the Maryland Porcelain Co., which obtains its clay from Florida.

The American Clay Co., whose plant is half a mile farther southwest, mined residual clays. It ceased operations in 1911. At the same locality a pit was opened in 1911 in kaolinized granodiorite beneath a cover of Patapsco gravel and clay and conglomerate. Here a deposit of kaolin 25 feet deep is exposed. The upper part of the kaolin is stained red and is discarded.

For a short time residual kaolin was mined at a place about three-quarters of a mile west of Leslie and one-sixth of a mile south of the Baltimore & Ohio Railroad, where it is overlain by Pleistocene sand. A very white kaolin occurs 2 miles north of Mechanic Valley, on the property of A. Thiess. Granodiorite decomposing into clay outcrops in a cut on the Baltimore & Ohio Railroad 2 miles west of Leslie. Residual clays reported to occur at other localities have proved on investigation either not to be of that character or not to be present in paying quantity.

SOILS.

The soils of the upland area of the Elkton-Wilmington district, exclusive of the overlapping Coastal Plain material, are residual—that is, they are derived from the underlying rocks by the action of the atmosphere, ground water, and other natural agents. There is consequently a close relation between the soil and the underlying rock, and, though some allowance must be made for wash on slopes, the distribution of the rocks indicates in a general way the distribution of the soils.

In the Elkton-Wilmington district there are four classes of rock formations, each of considerable areal extent, which yield distinctive soils: The mica schist and gneiss yield the Cecil mica loam, the granodiorite yields the Cecil loam, the gabbro yields the Cecil clay, and the serpentine yields a soil known as the Conowingo barrens. These names are those used by the Bureau of Soils of the United States Department of Agriculture.[1]

The Cecil mica loam, which covers the northern upland areas, is a fine yellowish-brown sandy, clayey loam and is particularly distinguished by its content of large fragments and minute scales of lustrous white mica (muscovite). The smooth yet gritty "feel" of the dirt roads, the warm yellow color of the clay, and the brilliant sparkle of the mica all show unmistakably the source of the soil. The soil derived from the mica schist is even more unctuous than that derived from the mica gneiss. Below an average depth of 2½ feet the mica schist soil grades rapidly into decayed rock. It is mellow, easily tillable, and fertile if properly treated. It yields excellent crops of corn, wheat, and grass.

[1] Dorsey, C. W., and Bonsteel, J. A., Soil survey of Cecil County, Md.: U. S. Dept. Agr. Div. Soils Field Operations, 1900, pp. 103–124, 1901.

The Cecil loam covers the relatively level central and southern parts of the upland which are underlain by granodiorite. It is a yellow sandy, clayey loam, which contains particles of the parent rock and grades into the granodiorite at a depth of 2 to 3 feet. This soil is fairly productive but is deficient in organic matter, which should be supplied to it by means of manures. Grass, wheat, corn, and tomatoes are the chief products of this soil, which yields fair average crops.

The Cecil clay is found wherever gabbro, pyroxenite, or peridotite is the underlying rock, and therefore forms the soil of the northeastern and northwestern parts of the Elkton-Wilmington district and also caps the outlying Chestnut, Iron, Grays, and Elk hills. Gabbro is the most massive rock of the district and, like all truly massive rocks, weathers into spheroidal boulders, which are therefore a characteristic feature of the Cecil clay. These boulders, which are known as "niggerheads," are rather conspicuous in an area that elsewhere contains little rock débris.

The Cecil clay, which is at few places more than a foot deep, is a heavy clayey loam and is distinguished, especially when wet, by its deep-red color. It is a "strong" soil, "capable of standing hard farming," and it may be brought to a higher state of productiveness with less fertilizing than any other soil in the district. The same crops are produced upon this soil as upon the other loams.

The soil called the Conowingo barrens occupies a very small area in the Elkton-Wilmington district. It is found only on the serpentine hills in the northwest part of the Elkton quadrangle. Though this soil is in texture most nearly related to the Cecil clay, it differs widely from that soil in productivity. It is a light-yellow clayey silt and is nearly everywhere very shallow. It contains a large percentage of magnesia and almost no lime, alkali, or phosphoric acid.

Its sterility is due not alone to its lack of nutritive ingredients but even to a greater degree, perhaps, to its shallowness and its consequent incapacity to retain moisture. At some places where the soil is deeper and fertilizers are used it is not notably barren.

COASTAL PLAIN AREA.

By Benjamin L. Miller.

The mineral resources of those parts of the Elkton and Wilmington quadrangles that lie within the Coastal Plain are neither varied nor are they at present especially valuable. Among the most valuable are clay, sand, gravel, and glauconitic marl. Pits where these products have been dug are shown on the maps. Building stone, lignite, pyrite, and iron ore are also found, but they are not abundant and are of no economic importance. The soils form the most valuable natural resource of the region, which is devoted primarily to agriculture.

CLAY.

Next to the soils the clays constitute the most valuable mineral resource of these quadrangles. As already stated (pp. 8–13), several of the formations contain argillaceous beds. These beds are rather generally distributed through the parts of the quadrangles that lie in the Coastal Plain, but, so far as known, they have in recent years been worked only in a zone extending from Wilmington to Northeast. The clays are found in every series of deposits in the quadrangles. No chemical analyses or special physical tests of them have been made, so far as known. Their uses prove that some of the clays possess high refractory properties, whereas others are suitable only for the manufacture of common brick. In almost every clay pit the clay occurs in the form of lenses of variable thickness. The pits are shallow and the bottom of the clay deposit is not exposed in many of them. For convenience the clays may be discussed under three headings—Lower Cretaceous, Upper Cretaceous, and Pliocene (?) and Pleistocene.

Lower Cretaceous clays.—The clays of the Potomac group are the most valuable in this region. Every formation of the group contains deposits of clay that are adapted to many uses. The Patuxent formation contains much clay, but in these quadrangles the clay of the Patuxent is inferior to that of the Patapsco and is less abundant and has therefore not been utilized. It occurs in lenses of different dimensions and is at most places light in color and highly plastic.

The Patapsco formation contains an enormous quantity of clay of many kinds. It furnishes material suitable for the manufacture of common brick, fire brick and other refractory ware, sewer pipes, and pottery. Clay has been dug from it at several places in these quadrangles, but many of the most valuable deposits still remain untouched. About 2 miles southwest of New Castle white and mottled red and white clays were formerly dug extensively for the manufacture of brick. Some clay was dredged from the bottom of Delaware River at this point. Along Christiana Creek, about 1½ miles northeast of Christiana, large quantities of red and white mottled and white clays have been used for making brick. The white clay was separated from the mottled clay wherever separation was possible, but in parts of the pits the intricate association of the two kinds made it impossible. The brick was loaded on flat boats, which were floated at high tide and were towed to Philadelphia, where the product was marketed. At Newport a mottled, extremely plastic clay is worked by the Kiamensi Clay Co. The clay is run through a rotary kiln drier and then shipped. Much of it is used by steel plants for making open-hearth furnaces, and the remainder is used mainly for mixing with molding sand, for making retorts, for fire-brick cement, and as a filler in linoleum.

Considerable prospecting for clay has been done north of Grays Hill, where a tract has been purchased by a company that intends to manufacture fire brick. A deposit of drab clay near Bacon Hill station has been extensively worked. The clay is said to be especially adapted to the manufacture of terra cotta.

In the vicinity of Northeast the Patapsco formation furnishes a variety of clays, which have been dug at many places. Some of the clay is white, some mottled red and white, some chocolate-colored, and some almost black. The dark-colored clays generally contain small pieces of lignitized stems, which resemble charcoal. Most of the clay is used in the manufacture of fire brick. One firm makes a specialty of fire brick for lining stoves. The clay is dug from many small openings and is hauled by carts to factories at Northeast.

About 3 miles west of Northeast a pink and white mottled clay has been dug for shipment to Sparrows Point, where it is used in making cupolas.

Upper Cretaceous clay.—The Raritan, Magothy, and Matawan formations in these quadrangles contain lenses of clay but none that are large enough to be utilized. The Raritan clays are of good quality, but they occur here in small pockets, although elsewhere the formation furnishes large and valuable deposits; the Magothy clays occur in thin bands, which contain more or less sandy streaks and much carbonaceous matter; and the Matawan clays are at most places so sandy that they can not be utilized.

Pliocene (?) and Pleistocene clays.—The Brandywine and Pleistocene formations contain considerable clay loam that is adapted to making brick and tile. This loam, which forms the surface over extensive areas, is easily obtained but is at few places more than a foot or two deep. In the Elkton and Wilmington quadrangles the clays of only the Wicomico and Sunderland formations have been used in recent years. Near Elsmere the surficial clay loam of the Wicomico has been dug for the manufacture of common brick. It ranges in thickness from 6 to 8 feet and is underlain by sand and gravel. At West Junction similar material is used for making brick. The clay at that place is mottled yellow and white and the bed is about 8 feet thick. It contains scattered pebbles and is underlain by a thin bed of gravel. The Sunderland formation near Leslie includes a capping of clay loam, which has been dug in small quantities.

SAND.

The parts of most of the formations of the Coastal Plain that are represented in the Elkton and Wilmington quadrangles are sandy, and the supply of sand here is therefore abundant. The sand differs in character from one formation to another and is therefore adapted to various purposes. The Patuxent, Patapsco, and Raritan formations contain beds of white quartz sand of great purity; the Magothy, Matawan, and Monmouth contain sands that are of little value for structural uses because they contain much glauconite and clay; the Brandywine and Pleistocene formations at some places contain sand that is sufficiently pure to be used in rough structural work and at others sandy material that is suitable for making roads.

The purest sand of the region is found in the Patapsco formation. At Newport, where large quantities of it are dug and shipped for use as a molding sand, it is white to buff, shows prominent cross-bedding, and contains much muscovite. About 1¼ miles southwest of Christiana a deposit of similar sand has long been worked. The sand is very fine and consists almost entirely of pure quartz and a few flakes of muscovite. In places it contains thin bands of white clay. The sand is exposed to a thickness of about 14 feet, but it is said to be 75 feet thick. The Pleistocene formations in places furnish building sand, which, however, is so readily obtainable in all parts of the region that no large sand pits have anywhere been opened. The Pleistocene sands at some places contain much ferruginous matter, which here and there cements the grains together, forming a ferruginous sandstone. These ferruginous sands are of great value for making roads, as they pack readily and make a firm bed. Where they can be easily obtained in large quantities, good roads can be very economically constructed.

GRAVEL.

The Patuxent, Patapsco, Raritan, Brandywine, and Pleistocene formations contain numerous beds of gravel, which are distributed throughout the region. These beds nearly everywhere contain iron, which cements the sand together and makes it valuable for use as ballast on roads. This sand has been dug at many places, but generally from shallow roadside pits, most of them too small to be shown on the map. Along the railroad south of Farnhurst an immense deposit of Wicomico and Raritan sand, gravel, and some clay has been worked by steam shovel, and the material has been shipped for use as ballast. The material has been removed to a depth of about 40 feet over a large area.

About 1 mile south of Bayview and 1 mile southwest of Pleasant Hill deposits of ferruginous gravel have been worked for many years for use as road material. The deposits contain sufficient iron to bind the gravel together, so that it makes a firm roadbed. It has been used with great advantage on many miles of roads in that vicinity.

BUILDING STONE.

Although the formations of the Coastal Plain are composed almost entirely of unconsolidated material they include local beds of indurated sand and gravel. In the absence of any better stone these hard beds furnish considerable material that is available for the construction of foundations and walls. Some layers of indurated gravel in the Brandywine formation southwest of Pleasant Hill have been used for rough structural work in that vicinity.

GLAUCONITIC MARL.

The Matawan and Monmouth formations of the Elkton and Wilmington quadrangles contain many deposits of glauconitic marl, which is of value as fertilizer. From New Jersey to North Carolina such deposits have been worked intermittently since the early part of the last century, when the marl was first used as a fertilizer, yet their value in enriching the soil is not yet generally recognized. They consist of quartz sand with an admixture of grains of glauconite, a soft green mineral, essentially a hydrous silicate of iron and potassium. The marls are colored green by the glauconite and are commonly known as "greensand marls." They are rich in calcium carbonate, which is derived from the abundant shells in them, and they contain also small quantities of mineral phosphates. They thus contain three valuable plant foods—potash, lime, and phosphate—and although these substances form only a small percentage of the marls, yet wherever they can be obtained at low cost they furnish an economical means of increasing the fertility of the soil. It is said that the beneficial effect of these marls is much more lasting than that of artificial fertilizers.

So far as known, no marl has been dug in this region for many years, but it was once dug on practically every farm on both sides of the Chesapeake & Delaware Canal from Delaware City to the railroad bridge and along many of the small tributary streams. The best marl is found in the Monmouth formation and contains the shells or casts of many mollusks. Large, massive shells of *Exogyra* and *Gryphaea* can now be picked up in fields where they were thrown years ago. It is said that marl of unusually good quality was found in the excavations for the canal locks at St. Georges.

LIGNITE.

Considerable lignite, in the form of small stems and even large trunks of trees, was found in the Magothy formation by the workmen who dug the Chesapeake & Delaware Canal, and similar material has been found in the Raritan formation near State Road and in the Wicomico formation near the place where the railroad crosses the canal. The discovery of this material led some to believe that workable deposits of lignite might be found in this region, but although these deposits may here and there yield material that can be burned they could certainly never be profitably worked as a source of fuel.

IRON ORE.

Nodules of iron carbonate are found in the lignite-bearing beds of the Magothy formation that are exposed in the banks of the Chesapeake & Delaware Canal, but they are of no economic value because of their small number and irregular distribution.

PYRITE.

Large masses of pyrite are found in the Magothy formation and are of interest because elsewhere in the Coastal Plain pyrite was at one time utilized. Although specimens can be obtained in almost every exposure of the formation they do not occur anywhere in sufficient quantities to be mined with profit.

SOILS.

The Bureau of Soils of the United States Department of Agriculture has studied the soils of that part of the Elkton quadrangle which lies in Cecil County, Md., and has published the results of the study.[1] The following descriptions of soil types are abstracted from that report.

Five distinct kinds of soils have been recognized in the Coastal Plain in Cecil County, Md., and all of them are found

[1] U. S. Dept. Agr. Div. Soils Field Operations, 1900, pp. 103–124, 1901. Maryland Geol. Survey, Cecil County, pp. 227–248, 1902.

also in the parts of the Elkton and Wilmington quadrangles that lie in Delaware. These soils have been called the Sassafras loam, Norfolk sand, Susquehanna gravel, Elkton clay, and Susquehanna clay.

Sassafras loam.—The soils known as the Sassafras loam are formed in part from the loam of the Pleistocene formations and in part from the clay of Lower Cretaceous deposits that has undergone considerable weathering by which it has lost much of its plasticity.

The soils consist of 8 to 10 inches of light-yellow loam, which is mellow and light and free from stone and gravel and therefore easy to cultivate, and is underlain by yellow loam, generally heavier than the soil. The subsoils are at some places several feet deep and are everywhere at least 36 inches deep and generally grade into beds of gravel and sand.

These soils are fertile and productive and can be brought to a high state of cultivation. They are nearly everywhere naturally well drained, but in some of the more level parts of the uplands they are swampy and would be much benefited by thorough underdrainage.[1]

These soils are deep and widespread on the flat areas north and west of Iron Hill and in the vicinity of Singerly.

Norfolk sand.—The soils known as the Norfolk sand cover a larger area of the Elkton and Wilmington quadrangles than those of any other type. They are composed almost entirely of Pleistocene materials, which cover the broad, flat divides between the major streams east of Elk River and the lower parts of Elk Neck and differ from the Sassafras loam soils in containing a greater proportion of sand and gravel.

These soils consist of reddish and brown sands, 8 to 12 inches deep, which overlie subsoils consisting of reddish or yellow sands. The subsoils contain much less organic matter than the soils, and the sand in them is generally more compact. On the surface at some places there are pebbles of well-rounded quartz gravel, ranging in diameter from 1 to 6 inches. On the steeper slopes around the outer margin of the upland of the broad terraces there is at many places a belt or zone where large rounded gravel and boulders come to the surface, but outcrops of this zone are seldom seen on the more gentle slopes. Gravel beds underlie the Norfolk sand soils, and thus insure their perfect drainage.[2]

The Norfolk sand soils are less productive than the Sassafras loam but are nevertheless extensively cultivated. As they contain large quantities of sand and gravel these soils are decidedly porous and are better adapted to growing truck and small fruit than grass, wheat, and corn.

Susquehanna gravel.—The Susquehanna gravel soil has been formed mainly from the gravel lenses of the Patapsco and Raritan formations. These coarser parts of the deposits have become concentrated at the surface through the removal of the finer parts. They are best exhibited on Elk Neck.

The soil varies somewhat in its composition but nearly everywhere contains a high percentage of large well-rounded quartz gravel, the pebbles of which range in diameter from one-half to several inches. To a depth of 8 inches the soil is a gravel loam, beneath which its content of gravel increases so much that it can hardly be penetrated with a soil auger. The underlying gravel beds are at places compactly cemented together by a red ferruginous cement. At many places on Elk Neck the surface is thickly strewn with great blocks or boulders of these ferruginous conglomerates, many of which are several feet in length. The gravels in the central part of Cecil County may be deeply stained with iron rust, whereas those in adjoining localities may be bleached perfectly white. The thickness of these beds of gravel differs considerably in different parts of the formation, at places exceeding 10 feet.

The productiveness of this soil also varies greatly, depending on the materials mixed with the gravel. On Elk Neck and the larger hills in the district near Northeast the gravel is mixed with coarse sands and is well-nigh worthless for farming. These lands have always been held in low esteem, and but few if any attempts have been made to cultivate them. They are covered with a thick but small growth of oaks and chestnuts. In many places a small part of the timber is burned for charcoal, and when the iron-ore mines were in operation, many years ago, the charcoal industry was of considerable importance.[3]

Elkton clay.—The Elkton clay is named from Elkton, where it is typically developed. It has been derived in part from the Patapsco clays by weathering and in part from the loamy portions of the Pleistocene formations and differs from the Sassafras loam chiefly in containing a greater proportion of clay.

The soil consists of 8 to 10 inches of soft loam, which is at some places grayish, at others sometimes whitish, but most generally brown and yellow. This soil is not unlike the Sassafras loam. The subsoil, which has a depth of 16 inches, consists of a yellow, light clay loam, which is underlain by mottled clay loam or clay to a depth of at least 36 inches. This subsoil is of various colors—drab, yellow, red, and pink, all mixed together—and is best described as mottled clay. As this clay is very compact its natural drainage is by no means good. Where it is well drained this soil is productive and yields good crops of wheat, corn, grass, and oats, as well as potatoes and tomatoes, but where it is poorly drained it is not adapted to general farming. These soils are likely to be cold and wet late in the spring, for the clay subsoil is very compact. They bake hard in dry years and can be kept in good condition only with great difficulty at any period of the growing season. The wet, poorly drained land north of Grays Hill has just such a soil. About Elkton and in some other parts of the area, however, it makes fine farm lands, on which good crops are generally raised.[4]

Susquehanna clay.—The Susquehanna clay is composed almost entirely of the stiff red and mottled clays of the Patapsco formation and is best developed in the northern part of Elk Neck. It is the most unproductive soil in the Elkton and Wilmington quadrangles. Although the stiff clays are capped by a thin cover of loose gravelly loam they lie sufficiently near the surface to give character to the soils. On the more level areas the capping is 6 to 10 inches thick. On some steep slopes or in other places where washing is more pronounced the gravel has been removed and the refractory clays are exposed at the surface. Whether or not the gravel has been removed the Susquehanna clay produces a distinctive soil and a desolate country. The soil is usually considered too worthless to pay the cost of clearing, and the few attempts made to cultivate it have proved decidedly discouraging to the farmer.[5]

¹ Maryland Geol. Survey, Cecil County, p. 240, 1902.
² Idem, p. 242.
³ Idem, pp. 243–244.
⁴ Idem, pp. 245–246.
⁵ Idem, p. 247.

WATER RESOURCES.

PIEDMONT UPLAND AREA.

By F. Bascom.

SURFACE WATER.

The streams of the Piedmont Upland area in the Elkton-Wilmington district are tributary to Delaware and Chesapeake bays. Though they have been used in the Piedmont Upland as sources of water power, they are of chief value in the Coastal Plain, where they are navigable from tidewater to their mouths, a distance which ranges from 6 to 12 miles. Brandywine, Red Clay, and White Clay creeks, which have the greater part of their drainage basins north of the Elkton-Wilmington district, are capable of considerable use as sources of water supply and power. Brandywine Creek, which rises on the southeast slopes of Welsh Mountain, on the northwestern border of Chester County, Pa., has a drainage area of about 350 square miles and is the source of the water supply of Wilmington. The other creeks are only 30 to 100 feet wide and are usually less than 2 feet deep. They are fed by springs that are maintained by abundant precipitation—about 48 inches annually—which is evenly distributed through the year.

GROUND WATER.

The rocks of the upland area of the Elkton-Wilmington district are crystalline and metamorphic, and the conditions controlling the occurrence of water in such rocks are quite unlike those controlling its occurrence in unmetamorphosed sedimentary rocks. Crystalline rocks, which are made up of closely interlocking grains, are much less porous than sedimentary rocks and have no definite partings, such as the stratification planes of the sedimentary rocks, that may be utilized as channels by ground water. Even the crystalline rocks that are metamorphosed sediments show no alternations of permeable and impermeable beds but are relatively impermeable throughout and therefore include no definite water-bearing horizons.

Crystalline rocks, however, have openings of four sorts that are suited to the flow of ground water—joints, faults, planes of schistosity, and contacts. Joints, which are the chief water carriers of crystalline rocks, although far less reliable than the openings along the bedding planes of sedimentary formations, are vertical, inclined, or horizontal fractures, very irregularly spaced and generally not extending far below the surface. Parallel joints may be a few inches to 10 or more feet apart. Most metamorphic rocks have two or more systems of intersecting parallel joints. Horizontal joints, which are common in granites, become farther apart with increase of depth and disappear altogether at a depth of a few hundred feet. The opening along a joint is widened at the surface by weathering and abruptly decreases in width with increase of depth, becoming first a close joint and ultimately disappearing. Joints which have the greatest linear extension probably have also the greatest downward extension. The unreliability of joints as sources of water is due not alone to their disappearance with increase of depth but also to the possible existence of other deeper joints whose occurrence and character are unknown. The most successful wells drilled in crystalline rocks are those which strike intersecting master systems of joints or a system of horizontal joints. Faults are fractures along which movement has taken place. They are less abundant than joints but are rarely absent in metamorphic rocks and are likely to furnish wider and more persistent openings than joints do. Planes of schistosity are produced by pressure and are directly due to the flattening and the parallel arrangement of the interlocking crystals of the rock. The openings along these planes are therefore commonly of a capillary character, and though they assist in bringing about the saturation of the rock they are not usually large enough to promote the movement of ground water. Contacts of course are not peculiar to crystalline rocks, but as water channels they are relatively more important in crystalline rocks, where openings are few and irregular, than in sedimentary formations, where openings are numerous and determinable. Wherever an igneous rock has intruded another formation the contact between the two formations is likely to furnish a channel for ground water, and streams fed by springs are likely to occur along such contacts.

The gabbro, granodiorite, and gneiss of the Elkton-Wilmington district usually show four systems of jointing. The gabbro has a system of joint planes that strikes N. 50° W. and dips 45° NE.; another that strikes N. 10° W. and dips 85° NE.; a master system of vertical joints that strikes N. 80° E.; and a system of horizontal joint planes. The granodiorite has a corresponding set of joint systems—one that strikes N. 65°–70° W.; one that strikes N. 10° W.; another that strikes N. 35° E., parallel to the strike of the schistosity and vertical; and finally an approximately horizontal joint plane. The mica gneiss shows joint systems that strike N. 80° W., N. 30° E., and N. 85° E., and an undulating horizontal joint plane. Because of these conditions and the abundant rainfall water can probably be obtained from the crystalline rocks by drilled wells of no very great depth. If water is not obtained within 250 or 300 feet there is no use in going deeper. The chances of a moderate supply before that depth is reached have been estimated to be about nine in ten. The water obtained will be soft, except in the mica gneiss area, where it may be moderately hard.

Four wells have been drilled in the gabbro at Wilmington. One well at the Stoekle brewery, which is 400 feet deep and 8 inches in diameter, yielded 15 to 18 gallons a minute but not continuously, and its use is therefore discontinued. Another at the Hartman & Fehrenbach brewery, which is 1,077 feet deep, yielded 10 gallons a minute between 96 and 107 feet. This yield was not sufficient for the requirements of the brewery, and the well has been plugged up. A third, at the plant of Hart & Bros., Fifth and Poplar streets, is 200 feet deep and 4 inches in diameter and yields 75 gallons a minute between 36 and 200 feet. The fourth, at the Bavarian brewery, has a depth of 362 feet and yields about 100 gallons a minute.

On the slopes of the hills and near the level of the creeks water issues in small springs, which supply many of the farmhouses. The water comes from shallow depths, as is indicated by its temperature, and it reaches the surface along joint planes that outcrop on slopes. The springs in the gabbro are somewhat chalybeate. At Brandywine Springs a strong flow of soft water issues from the gabbro in an amusement park of the Peoples Railway Co., of Wilmington. Considerable water is bottled from Kiamensi Spring, near Brandywine Springs, and sold in Wilmington for table use.

WATER SUPPLY OF WILMINGTON.

Wilmington is the only settlement in the upland area of the Elkton-Wilmington district that has a public water supply. The other settlements are small, and their inhabitants depend on privately owned wells and springs. The raw water for Wilmington is drawn from Brandywine Creek at a dam about a mile north of the Wilmington quadrangle and 4,800 feet north of the plant of the City Water Department, at Sixteenth and Market streets, and is conducted by a race on the southwest side of the creek to preliminary filters of sponge clippings and coke. The effluent from these filters is pumped into a sedimentation reservoir. After about three days of sedimentation the water flows by gravity to six slow sand filters, each one-third of an acre in area. The capacity of the pumps is 24,000,000 gallons a day. The capacity of the preliminary filters is 16,000,000 gallons a day at a rate of 50,000,000 gallons an acre a day. The capacity of the slow sand filters is 15,000,000 gallons a day, the rate of filtration ranging from 6,000,000 to 7,500,000 gallons an acre a day. The system comprises a sedimentation reservoir having a capacity of 35,000,000 gallons, an open filtered-water reservoir having a capacity of 45,000,000 gallons, and a covered filtered-water reservoir having a capacity of 6,000,000 gallons. In 1917–18 additional filtering and pumping units were installed, consisting of a 12,000,000-gallon rapid sand-filter plant, at Sixteenth and Walnut streets, one 12,000,000-gallon and two 9,000,000-gallon turbine-driven centrifugal pumps, and a covered filtered-water reservoir having a capacity of 7,500,000 gallons, at Eighteenth and Rodney streets. The average daily consumption in 1916–17 was 13,503,307 gallons, or about 115 gallons per capita. If the consumption in manufacturing plants is deducted this amount is decreased to about 70 gallons per capita.

The available flow of Brandywine Creek for a period of ten years ranges from a maximum of 402 second-feet to a minimum of 64 second-feet and averages 279 second-feet. The city owns half the rights of the stream and is entitled to half the available flow.

The water of Brandywine Creek is fairly soft and has only a moderate mineral content. According to tests of a sample collected August 11, 1913, the raw water had a total hardness expressed as $CaCO_3$ of 59 parts per million and contained 175 parts per million of total solids, of which 2 parts was iron. The average number of bacteria in the unfiltered water for seven years was 13,582 per cubic centimeter, and *Bacillus coli communis* is always present. The turbidity at different times ranges from practically nothing to nearly 1,500 parts per million, the average for thirteen years (1905–1917) being 563 parts. The average color of the raw water for six years (1911–1917) is 21.2 parts per million as found by the platinum-cobalt standard, the average alkalinity is 37.5 parts per million, and the average chlorine content is 8.6 parts per million. The water delivered by the filters is sterilized by the use of liquid chlorine; its alkalinity and chlorine content remain about the same as that of the raw water. The average removal by the combined purification plant during a period of six years (1911–1917) of *Bacillus coli communis* is 93.40 per cent, the average turbidity during a period of seven years was 99.07 per cent, and the average color during a period of six years was 62.05 per cent. The following analysis of the filtered water has been furnished by Edgar M. Hoopes, jr., at one time chief engineer of the Wilmington Water Department.

Chemical composition of filtered water from public supply of Wilmington, Del., August 11, 1913.

	Parts per million.
Silica (SiO_2)	8.4
Iron (Fe)	.1
Aluminum (Al)	.4
Calcium (Ca)	16
Magnesium (Mg)	1.1
Sodium and potassium (Na+K)	5.2
Carbonate radicle (CO_3)	18
Sulphate radicle (SO_4)	8.5
Chlorine (Cl)	8.0
Organic and volatile matter	45
	95

COASTAL PLAIN AREA.

By Benjamin L. Miller.

SURFACE WATER.

Dams have been built at many places along the streams in the Coastal Plain to develop power for small mills. As the streams have low gradients the amount of power developed in proportion to the areas flooded is small. Water from Back Creek at Chesapeake City is pumped into the Chesapeake & Delaware Canal to maintain the high-level stretch of the canal.

Elkton is the only town in the Coastal Plain in the Elkton and Wilmington quadrangles that obtains its entire supply from a stream. Water is pumped from Big Elk Creek, east of the town, into a reservoir, from which it is passed through a charcoal filter before it enters the mains.

Part of the water supply of New Castle is pumped from Nonesuch Creek, a small tributary of Christiana Creek, into a reservoir that is about midway between Newport and New Castle. From the reservoir the water flows by gravity into the mains.

SPRINGS.

The gentle slope of the strata, the alternation of pervious and impervious beds, and the marked dissection of the region by streams constitute favorable conditions for the existence of springs along the valley slopes. Many of these springs are utilized as sources of private supply, and the water from most of them is excellent, though that of some is highly charged with mineral matter, particularly iron, sulphur, and salt. Several springs of good water in the vicinity of Charlestown and Northeast have long been used.

SHALLOW WELLS.

Water supplies generally throughout the Elkton and Wilmington quadrangles are obtained from shallow wells, 15 to 35 feet deep. The water is contained in the rather coarse sand or gravel bed that commonly forms the basal stratum of the Pleistocene deposits. Indeed, the depth of the shallow wells is usually a reliable indication of the thickness of the surficial deposits. Water readily penetrates the rather coarse surface materials until it reaches the less permeable underlying rocks, and though some of it continues downward a great deal seeps along on the upper surface of the less permeable strata until it finds its way into the streams. Consequently wells sunk to these less permeable beds are practically assured of a supply that is sufficient for ordinary uses in seasons of average rainfall, though the wells are likely to be affected by droughts, as their supply depends almost entirely on the percolation following local precipitation. After periods of heavy rainfall the water in the wells may rise to a point within a few feet of the surface and be very turbid. The supply is less variable over the broad divides or on level ground, where the water table is nearer the surface, than in narrow divides, where water finds an easy exit. In some places on the narrow divides near the larger streams wells must be sunk to depths of 100 feet or more in order to obtain permanent supplies. The water of most of the shallow wells contains so little mineral matter that it is soft, and there is little evidence to show that it is unfit for drinking, though some of it contains organic matter.

The New Castle County Almshouse and the State Insane Asylum near Farnhurst are supplied by a 40-foot well. Delaware City is supplied by an incorporated company with water from a 20-foot well 12 feet in diameter at the top and 8 feet in diameter at the bottom, from which about 100 gallons a minute is pumped. The water is without objectionable taste and is comparatively pure. Wells about 1½ miles west of Delaware City are 20 to 25 feet deep. Those that obtain their supplies from the Wicomico formation contain good water, but some that penetrate the underlying Monmouth marls contain water that has a decidedly unpleasant taste and odor because of its high content of iron and sulphur. About 2 miles west of Delaware City some wells have been sunk to the depth of 60 feet, which indicates that there is little water in that area at the base of the Wicomico deposits.

Most wells in the vicinity of Mount Pleasant are 18 to 25 feet deep, and obtain good water from the base of the Wicomico, though the supply is not abundant. Some wells sunk to 60 feet have obtained a larger supply from the underlying Monmouth or Matawan, but the water from most of them is scarcely suitable for drinking.

In Elkton many dug wells 18 to 30 feet deep furnish good water. At one time the Southern Pulp Co. had at that place a well 28 feet deep and 22 feet in diameter, which furnished a large supply of good water. As much as 300,000 gallons have been pumped from it in 24 hours. Few deeper wells in that vicinity have been successful.

On Back Creek Neck the dug wells range in depth from 16 to 28 feet and furnish sufficient good water for the farms. In and around Chesapeake City there are many dug wells 15 to 22 feet deep. Some of them furnish fair supplies of good water, but others are not satisfactory because of the unpleasant taste of the water and its scarcity during droughts.

On Elk Neck water is procured with more difficulty because of the deep dissection of the region by streams. Most wells are 50 to 75 feet deep, and some are considerably deeper. The water is in most places so strongly mineralized that it is objectionable.

In and near Northeast large quantities of good water are procured at depths of 14 to 30 feet. Dug wells at Charlestown are 20 to 65 feet deep, and most of them yield highly mineralized water. Good water is obtained near Eder at 25 feet and at Cherry Hill at 18 feet.

DEEP WELLS.

General features.—Not many attempts to obtain flowing wells have been made in these quadrangles, not only because water is so readily procured at shallow depths almost everywhere and because few establishments require large supplies but also because so few of the wells that have been drilled yield water of good quality. In nearly all the deeper wells the water rises under pressure, but flowing wells are not numerous. The area in which wells may be driven with the expectation of discovering a pressure sufficient to force the water to the surface is restricted to land that lies 20 feet or less above sea level. In areas above this altitude wells can probably obtain water that will rise above the level at which it enters the well but that will not reach the surface. The somewhat meager data obtained in this and adjoining regions indicate the occurrence of water in the beds mentioned below. The depths to the water-bearing strata in the quadrangles are not well enough known to be indicated on the areal-geology maps.

Water in rocks of the crystalline floor.—Crystalline rocks, frequently spoken of as "bedrock," similar to those exposed at the surface in the northwestern part of the quadrangles undoubtedly underlie the unconsolidated sedimentary deposits. In general the crystalline rocks are less permeable than the overlying deposits and consequently check the downward passage of percolating water, which tends to flow along their surface or to collect in depressions. The surface of these old rocks dips rather uniformly southeastward approximately 100 feet to the mile. Much water flows along this crystalline floor to lower levels, but throughout the greater part of these quadrangles this water is not available because of the great depth at which it lies. The only place where it seems to have been reached is at Farnhurst, at a depth of 211 feet. The water obtained was of good quality, but the quantity was insufficient.

Water-bearing beds in the Potomac group (Lower Cretaceous).—The deposits of the Potomac group contain many beds of coarse sand and gravel that constitute good water-bearing strata. Some of these beds lie beneath impervious clay deposits and thus furnish the requisite conditions for flowing wells. Within these quadrangles the beds belonging to the Potomac group are the principal deep-seated water-bearing strata. The water does not seem to lie at the same horizon over wide areas, as is shown by the different depths at which it is reached and by the failure to obtain any water in these beds at certain places. The Patapsco formation contains the most productive water-bearing beds. Water was found in this formation at a depth of 130 feet at Charlestown, at 210 feet at Hares Corner, at 40 and 60 feet at Farnhurst, at 80, 100, and 155 feet at New Castle, at 720 feet at Fort Dupont, and at 570 feet at Reedy Island. Neither the Patapsco nor the Patuxent formation yielded much water at Elkton. Most of the water of the Lower Cretaceous in this region is so heavily charged with iron and sulphur that it is unsatisfactory. At Fort Dupont, where the water was used for a time, it became necessary to distill it for drinking.

The following log shows the character of the beds penetrated in one of the wells at Fort Dupont:

Log of United States Government well at Fort Dupont, Del.[a]

	Thickness.	Depth.
Talbot formation:	*Feet.*	*Feet.*
Yellowish sand and fine gravel; brackish water	24	24
Rancocas (?) formation:		
Gray, slightly clayey sand and fine gravel	16	40
Dark-greenish limy sand containing shells and much glauconite	20	60
Monmouth formation:		
Dark sandy micaceous clay	80	140
Medium gray sand containing very little glauconite	10	[b] 150
Brownish-gray sandy clay containing some glauconite	20	180
Matawan formation:		
Dark coarse sand and clay containing some glauconite	17	197
Hard light-red, slightly sandy clay	26	223
Dark micaceous sandy clay	17	240
Fine to medium drab or brownish-gray clayey sand containing a little glauconite	40	280
Fine to coarse brownish micaceous clay containing some glauconite	20	300
Magothy formation, in part:		
Medium to coarse drab or brownish sand containing different amounts of glauconite and in places some clay	18	418
Fine to medium, light-gray sand containing no clay and very little glauconite	3	421
Raritan, Patapsco, and Patuxent formations:		
Light brick-red clay, containing some sand	46	467
Fine to medium, slightly clayey pinkish-buff or pinkish-brown sand	33	500
Fine to medium brownish-gray micaceous sand	10	510
Medium to fine pinkish-brown sand containing red and white clay	130	640
Fine to medium light-brown micaceous sand and clay	10	650
Brownish-gray micaceous clayey sand containing lignite	11	661
Fine to medium pinkish-brown sand containing beds of pink, red, and white clay and lignite	49	710
Medium varicolored sand containing lignite	15	725
Coarse light pinkish-brown sand	5	730
Light-brown sand containing lignite and many brown granules	4	734
Dark-brownish clay and coarse sand	2	736
Medium pinkish-brown clayey sand	4	740
Brown clay with coarse sand containing lignite	5	745
Medium brownish clayey sand	5	750
Fine to coarse pinkish-brown sandy clay containing brown granules and lignite	5	755
Medium grayish-brown clayey sand	7	762

[a] Fuller, M. L., and Sanford, Samuel, Record of deep-well drilling for 1905: U. S. Geol. Survey Bull. 298, pp. 194–195, 1906.

[b] The published record does not show the character of the material for 10 feet, from 150 to 160 feet.

Rig used, jet. Diameter of casing, 8 inches. This well was lost by the slipping of a coupling on the casing, and another was drilled 10 feet away. Depth of water-bearing stratum is 720 to 734 feet. Water rises nearly to surface and flows over casing at and after high tide. Yield by pumping is 20 gallons a minute. Water is alkaline, yellowish brown in color, contains iron, has a slight odor of sulphur, and is distilled for drinking. Mouth of well is 11 feet above mean low tide.

Water-bearing beds in the Upper Cretaceous series.—The Upper Cretaceous series in these quadrangles consists of the Monmouth, Matawan, Magothy, and Raritan formations. The abundant sand in the Raritan formation furnishes suitable beds for water, but the relatively few impervious strata permit much of the water to pass into underlying formations. In the well at Fort Mott the water-bearing horizons reached at depths of 389 feet and 498 feet probably are in the Raritan formation. The sandy strata of the Magothy formation are water bearing in many places, but as the water is likely to be impregnated with iron and sulphur it is less desirable than that obtained from the Potomac group. The amount and character of mineral matter in solution render the water of some of the wells somewhat undesirable for drinking; however, in water from other wells mineral matter is present only in very small amounts. The only artesian wells in this region in which the Magothy seems to be the water-bearing formation are at Fort Delaware, where water was encountered at a depth of 374 feet, and at Fort Mott, where water was encountered at a depth of 309 feet. The water, which is strongly mineralized, overflows at the rate of about 50 gallons a minute at low tide and 75 gallons at high tide. The local character of the sandy strata of the Magothy formation is shown by the fact that the deep wells at Fort Dupont failed to obtain any water in the formation though they passed entirely through the strata into underlying formations. For this reason no predictions concerning water supplies can be made in regions where the Magothy is developed.

In New Jersey artesian water has been obtained from the greensand deposits of the Monmouth and Matawan formations, As these beds are generally more porous than the beds of the Magothy formation or the Potomac group and contain fewer clay bands the water in them passes more readily to lower levels. At Fort Delaware the water obtained at 100 and 146 feet apparently comes from the Monmouth.

Data in regard to the deep wells in the Coastal Plain in the Elkton and Wilmington quadrangles are given in the table below.

NAVIGATION.

Estuaries.—The estuaries of this region were important arteries of trade before the construction of railroads, and New Castle, Elkton, and Northeast were centers of river commerce. At present Delaware River is the only estuary on which much water transportation is conducted, but it is steadily increasing in importance as the shipping trade of Philadelphia grows. Elk River and Back Creek, which form part of the all-water route between Philadelphia and Baltimore, would carry much more tonnage if the Chesapeake & Delaware Canal were enlarged. Salem Creek is also utilized by light-draft vessels that pass up the creek to Salem.

A dredged channel of 30 feet is maintained in Delaware River, and it has been proposed to increase the depth to 35 feet. From Reedy Island to Elsinboro Point the general depth exceeds 40 feet and in some places exceeds 50 feet. The channel is also more than 40 feet deep east of Pea Patch Island and exceeds 45 feet in the vicinity of Deepwater Point. Borings in the channel show that the bottom consists of mud and sand, doubtless of recent origin. The tendency for many years has been for the river gradually to widen itself by erosion of its banks and to become shallower by deposition in the channel.

The greatest depth in Northeast River is 40 feet, which is the depth off Courthouse Point. The water in Back Creek ranges in depth from 10 to 17 feet, and the portion of Northeast River included within the Elkton quadrangle has depths that range from 7 to 19 feet.

There is seldom any noticeable current in the estuaries, and such as is seen is caused by the tide and appears to be nearly as strong when moving upstream as when moving in the opposite direction. The average mean tide at Delaware City is 6 feet, and the extreme is 10 feet. As Chesapeake City is much farther from the mouth of Chesapeake Bay than Delaware City is from the outlet of Delaware Bay, high tide at one place is almost exactly synchronous with low tide at the other.

Chesapeake & Delaware Canal.—Much traffic between Philadelphia and Baltimore and other points passes through the Chesapeake & Delaware Canal, which, as its name suggests, connects Delaware and Chesapeake bays. The canal is $13\frac{5}{8}$ miles long and extends from Delaware City, on Delaware River, to Chesapeake City, on Back Creek, a tributary of Elk River. Water was let into it on July 4, 1829. The canal cost $2,250,000, of which $450,000 was paid by the United States, $100,000 by Pennsylvania, $50,000 by Maryland, $25,000 by Delaware, and the remainder by citizens of the three contributing States. A lock at Delaware City maintains a level of 7.66 feet above mean low tide in Delaware River between Delaware City and St. Georges, a distance of 4.39 miles, and locks at St. Georges and Chesapeake City maintain the summit level of 17.28 feet above mean low tide at Chesapeake City between those two places, a distance of 9.32 miles. The original width of the canal at the water line was 66 feet, the width at the bottom 36 feet, and the depth 10 feet. The depth of excavation at the summit of the divide, known as Deep Cut, was 75 feet.

No hard rocks were encountered in the excavation, as the region through which it passes is underlain by unconsolidated clays, sands, and gravels belonging to the Cretaceous and Quaternary systems. Several times during the construction of the canal and later, when the sands have become filled with water, there have been landslides in Deep Cut, and dredging must be done annually to keep the channel clear.

The plan to convert this waterway into an enlarged tide-level canal has long been discussed, and three investigations have been made by the Federal Government to determine the feasibility of the plan. Borings in several places show that the strata below the prism are similar to those exposed in Deep Cut.

January, 1920.

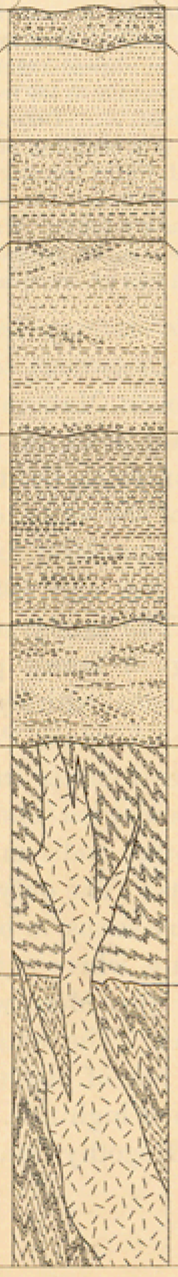
Deep wells in the Coastal Plain in the Elkton and Wilmington quadrangles.

Location.	Depth of well.	Depth to water-bearing strata.	Water-bearing formation.	Depth to water.	Yield per minute. Flow.	Yield per minute. Pump.	Remarks.
	Feet.	*Feet.*			*Gallons.*	*Gallons.*	
Charlestown	130		Patapsco			Many.	Much iron in water.
Upper part of Elk Neck	364					Few.	Well abandoned.
Chesapeake City	100		Patapsco or Raritan				Much iron in water.
Elkton[a]	490						Water very unsatisfactory.
Do.[a]	400						Abandoned.
Do.[a]	407						Unsuccessful.
Hares Corner[b]	228	210 228	Patapsco Patapsco or Patuxent	100 feet			
Farnhurst[c]	211	40 60 211	Patapsco Base of Patuxent				
New Castle[d]	160	85 100 155	Patapsco				No good water.
Two miles south of New Castle[d]	111		do	14 feet			Good water.
Fort Dupont[e]	742	720	do	Flows at high tide		20	Water contains iron and hydrogen sulphide.
Do.[f]	734	720	do	do		Many.	
Do	762	720	do	do			Well abandoned
Do.[g]	740	720	do	do	12	149	
Fort Delaware[h]	390	100 146 374	Monmouth Magothy	Flows	50–75		Flows 50 gallons at low tide, 75 gallons at high tide.
Fort Mott[i]	320	309	do	do	50		
Reedy Island[j]	593	389 498 570	Raritan Patapsco	do	20		Good water.

[a] U. S. Geol. Survey Water-Supply Paper 149, p. 63, 1905.
[b] New Jersey Geol. Survey Ann. Rept. for 1896, p. 140, 1897.
[c] Idem, p. 142; U. S. Geol. Survey Water-Supply Paper 114, p. 112, 1905.
[d] New Jersey Geol. Survey Ann. Rept. for 1896, p. 139, 1897.
[e] U. S. Geol. Survey Bull. 298, pp. 194–195, 1906.
[f] New Jersey Geol. Survey Ann. Rept. for 1900, pp. 132–134, 1901.
[g] U. S. Geol. Survey Bull. 298, pp. 46–47, 1906.
[h] New Jersey Geol. Survey Ann. Rept. for 1898, pp. 114–115, 1899.
[i] New Jersey Geol. Survey Ann. Rept. for 1900, pp. 131–132, 1901.
[j] New Jersey Geol. Survey Ann. Rept. for 1896, pp. 140–142, 1897; idem for 1897, pp. 248–249, 1898.

GENERALIZED SECTION FOR THE ELKTON AND WILMINGTON QUADRANGLES.

SCALE: 1 INCH=200 FEET.



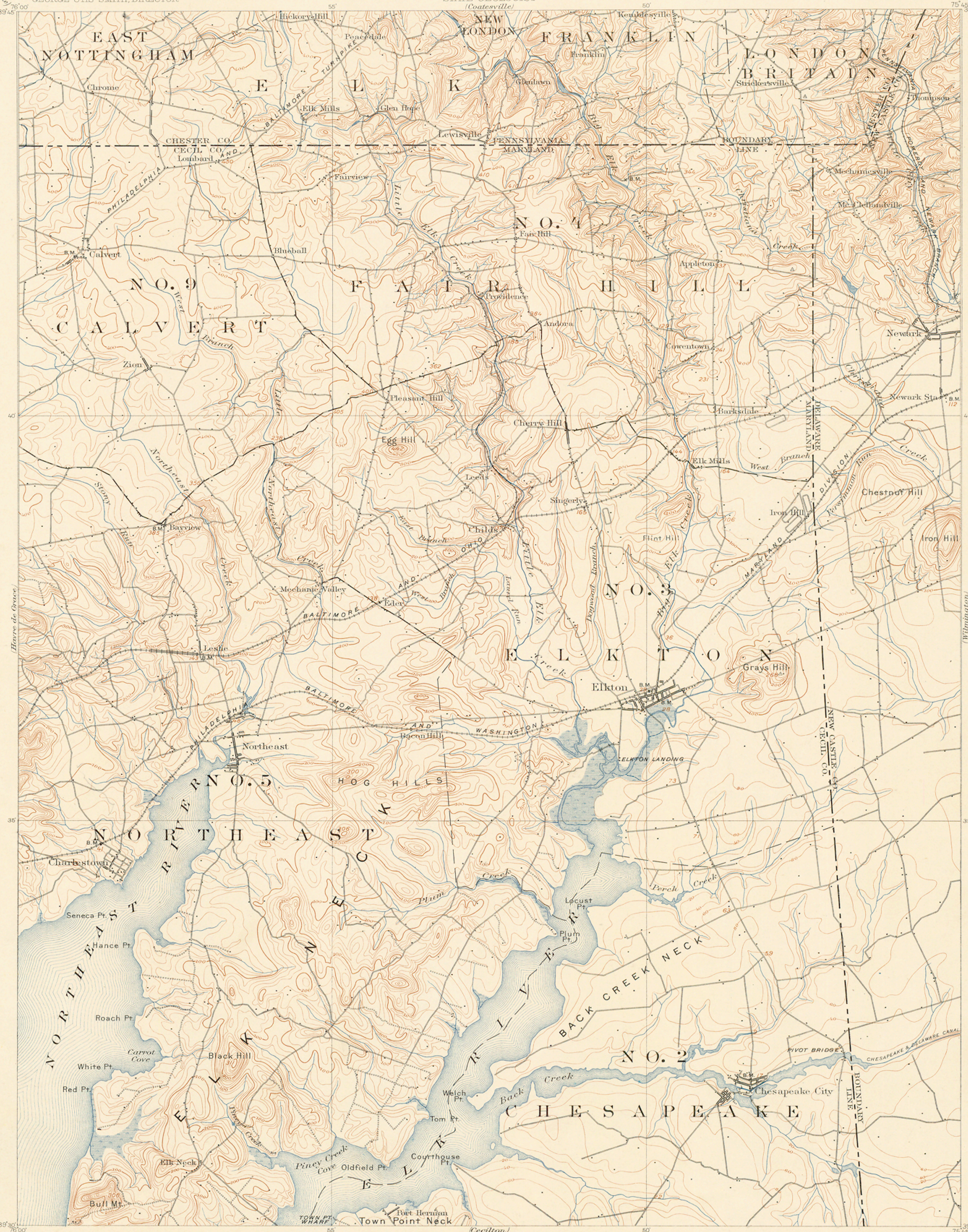
System.	Series and Group.	Formation.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography and Soils.
QUATERNARY	PLEISTOCENE (COLUMBIA GROUP)	Talbot formation.	Qt	Terraced deposits lying on older formations.	52	Loam, sand, and gravel, containing lenses of clay and ice-borne boulders.	Very flat to gently rolling low lands, from sea level to 45 feet above sea level. Sandy to loamy soil suitable for truck farming.
		Wicomico formation.	Qw		50	Loam, sand, and gravel, containing ice-borne boulders.	Flat to gently rolling lands, 40 to 100 feet above sea level. Sandy to loamy soil suitable for truck farming and for grain.
		Sunderland formation.	Qs		40	Loam, sand, and gravel.	Flat to undulating uplands, 90 to 200 feet above sea level. Loamy or sandy soil suitable for grain and fruit.
TERTIARY	PLIOCENE?	Brandywine formation.	Tb		35	Loam, coarse sand, and gravel.	High rolling lands, 180 to 300 feet above sea level. Clayey loam to gravelly soil; not very fertile.
		UNCONFORMITY					
CRETACEOUS	UPPER CRETACEOUS	Monmouth formation.	Km		100	Reddish-brown and greenish-black sand in which many irregular crusts of iron occur.	Gentle slopes along streams. Rich brown soil.
		Matawan formation.	Kmw		65	Gray and black micaceous clayey sand carrying glauconite.	Slopes along streams. Rich soil containing many small flakes of mica.
		UNCONFORMITY					
		Magothy formation.	Kma		40	Thinly laminated sand and clay containing much lignite and in a few places ferruginous sandstone.	Gentle to steep slopes along streams. Sandy soil.
		UNCONFORMITY					
		Raritan formation.	Kr		200	Sand, gravel, and variegated clay.	Irregular topography. Sandy to argillaceous soil of low fertility.
		UNCONFORMITY					
	LOWER CRETACEOUS (POTOMAC GROUP)	Patapsco formation.	Kpt		200	Highly colored variegated clay interbedded with sand and gravel.	Irregular topography. Sandy to argillaceous soil of low fertility.
		UNCONFORMITY					
		Patuxent formation.	Kp		125	Light-colored arkosic sand containing bands of gravel and a few lenses of clay.	Irregular topography. Sandy to argillaceous soil of low fertility.
		UNCONFORMITY					
PRE-CAMBRIAN		Wissahickon mica gneiss.	wgn		250±	Schistose quartz-feldspar-muscovite rock.	Relatively high, slightly rolling country. Yellow micaceous clay loam (Cecil mica loam).
		Crystalline limestone.				White saccharoidal marble interbedded in the gneiss.	A flat-bottomed valley. Red clay soil.
		Baltimore gneiss.	bgn			Banded quartz-feldspar-biotite rock.	Relatively high, rolling country. Yellow micaceous clay loam (Cecil mica loam).
		Granite and gabbro intrusive in Baltimore and Wissahickon gneisses.				Massive quartz-feldspar-biotite or hornblende rock and massive feldspar-augite or hornblende rock.	Red and yellow clay soil (Cecil loam and Cecil clay).

DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, SECRETARY
U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

TOPOGRAPHY

STATE OF MARYLAND
EDWARD B. MATHEWS
STATE GEOLOGIST

MARYLAND-DELAWARE-PENNSYLVANIA
ELKTON QUADRANGLE



EXPLANATION

RELIEF
printed in brown

Altitude
above mean sea level instrumentally determined

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

DRAINAGE
printed in blue

Streams

Canal and lock

Lake or pond

Marsh

CULTURE
printed in black

Roads and buildings

Private or secondary roads

Railroads

Bridges

State line

Township line

Triangulation station

Bench mark

H.M.Wilson, Geographer in charge.
Triangulation by U.S.Coast and Geodetic Survey and H.S.Wallace.
Shore line by U.S.Coast and Geodetic Survey.
Topography by H.S.Wallace, J.W.Thom, and Albert Pike.
Surveyed in 1896 in cooperation with the States of Maryland and Pennsylvania.

APPROXIMATE MEAN DECLINATION 1917.

Scale $\frac{1}{62500}$

Contour interval 20 feet.

Datum is mean sea level.

Edition of Aug. 1900, reprinted Feb. 1920.

DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, SECRETARY
U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

TOPOGRAPHY

DELAWARE–NEW JERSEY
WILMINGTON QUADRANGLE

EXPLANATION

RELIEF
printed in brown

Altitude *above mean sea level instrumentally determined*

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

Levees and embankment

DRAINAGE
printed in blue

Streams

Canal and lock

Lake or pond

Salt marsh

Fresh marsh

CULTURE
printed in black

Roads and buildings

Church or schoolhouse and cemetery

Private or secondary roads

Railroads

Electric railroad

Bridges

Drawbridges

Wharf or pier

State line

Township line

City, village, or borough line

Bench mark

Lighthouse

H. M. Wilson, Geographer in charge.
Topography by W. Carvel Hall, W. M. Beaman, and Geological Survey of New Jersey. Assistant, J. S. B. Daingerfield.
Control by U. S. Coast and Geodetic Survey, and F. T. Fitch.
Delaware River by U. S. Coast and Geodetic Survey.
Surveyed in 1904.

TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1917.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 20 feet.
Datum is mean sea level.

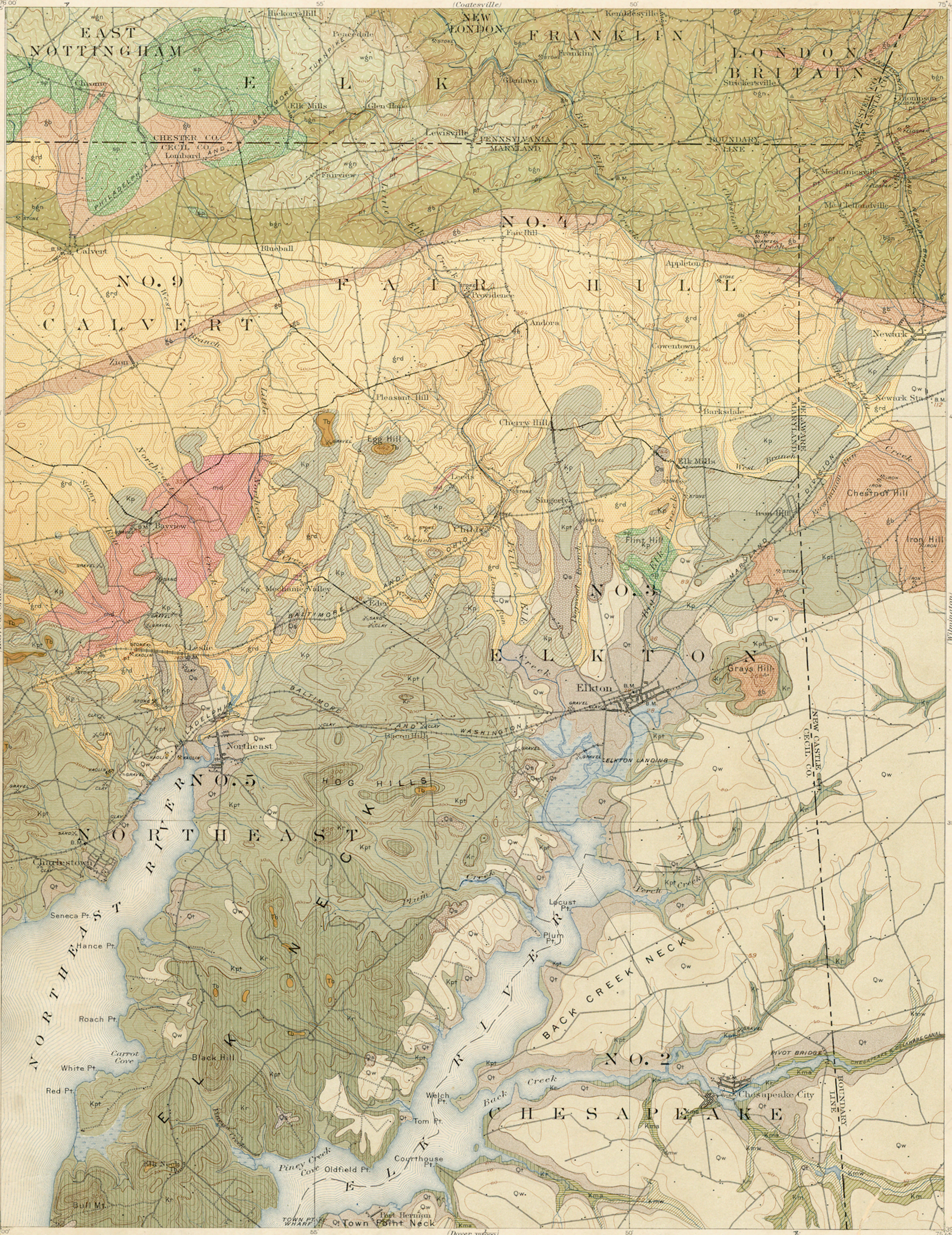
Edition of Mar. 1906, reprinted Feb. 1920.

AREAL GEOLOGY

DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, SECRETARY
U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

STATE OF MARYLAND
EDWARD B. MATHEWS
STATE GEOLOGIST

MARYLAND-DELAWARE-PENNSYLVANIA
ELKTON QUADRANGLE



H.M. Wilson, Geographer in charge.
Triangulation by U.S. Coast and Geodetic Survey and H.S. Wallace.
Shore line by U.S. Coast and Geodetic Survey.
Topography by H.S. Wallace, J.W. Thom and Albert Pike.
Surveyed in 1896 in cooperation with the States of Maryland and Pennsylvania.

APPROXIMATE MEAN DECLINATION 1917.

Scale $\frac{1}{62500}$

Contour interval 20 feet.
Datum is mean sea level.
Edition of April 1920

Geology of Coastal Plain by B.L. Miller.
Geology of the crystalline rocks by F. Bascom.
Surveyed in 1900-1913.
SURVEYED IN COOPERATION WITH THE STATE OF MARYLAND.

EXPLANATION

SEDIMENTARY ROCKS

(Areas of subaqueous deposits are shown by patterns of parallel lines, subaerial deposits by patterns of dots and circles)

QUATERNARY — Pleistocene (Columbia group)

Qt — **Talbot formation** *(loam, sand, and gravel, with clay lenses and ice-borne bowlders; forms terraces and lowlands from 0 to 45 feet above sea level)*

UNCONFORMITY

Qw — **Wicomico formation** *(loam, sand, and gravel, with ice-borne bowlders; covers rolling terraces and divides from 40 to 100 feet above sea level)*

UNCONFORMITY

Qs — **Sunderland formation** *(loam, sand, and gravel; covers terraces and divides from 90 to 200 feet above sea level)*

UNCONFORMITY

TERTIARY — Pliocene ?

Tb — **Brandywine formation** *(coarse sand, loam, and gravel; covers divides from 180 to 300 feet above sea level)*

UNCONFORMITY

CRETACEOUS — Upper Cretaceous

Km — **Monmouth formation** *(reddish-brown to greenish-black sand with many iron crusts)*

Kmw — **Matawan formation** *(gray to black micaceous sandy clay carrying glauconite)*

UNCONFORMITY

Kma — **Magothy formation** *(thinly laminated alternating sand and clay with much lignite and ferruginous sandstone layers)*

UNCONFORMITY

Kr — **Raritan formation** *(variegated clay, sand, and gravel, with some lignite)*

UNCONFORMITY

Lower Cretaceous (Potomac group)

Kpt — **Patapsco formation** *(highly-colored variegated clay interbedded with sand and gravel)*

UNCONFORMITY

Kp — **Patuxent formation** *(light-colored arkosic sand with clay lenses and gravel bands)*

PRE-CAMBRIAN SEDIMENTARY AND IGNEOUS ROCKS

(metamorphism is indicated by hachures)

PRE-CAMBRIAN — *Igneous rocks intrusive in Baltimore and Wissahickon gneisses; in part metamorphosed*

pt — **Pegmatite dikes** *(coarsely crystalline quartz-feldspar-mica rock)*

sp — **Serpentine, steatite, and associated alteration products** *(metapyroxenite and metaperidotite)*

gb — **Gabbro** *(quartz gabbro, gabbro, hypersthene gabbro, hornblende gabbro, olivine gabbro)*

md — **Metadacite** *(fine-grained quartz-feldspar-hornblende-biotite rock)*

grd — **Granodiorite** *(quartz-orthoclase-oligoclase-hornblende-biotite rock)*

Chiefly metamorphosed sedimentary rocks

wgn — **Wissahickon mica gneiss** *(schistose quartz-feldspar-muscovite rock provisionally regarded as pre-Cambrian)*

bgn — **Baltimore gneiss** *(banded quartz-feldspar-biotite rock)*

IGNEOUS ROCKS

TRIASSIC OR OLDER

db — **Diabase dikes** *(augite-labradorite rock)*

ECONOMIC AND STRUCTURE DATA

Quarries and mines — *Stone, quartz, feldspar, kaolin, and iron. Iron mines and some quarries are at present abandoned.*

Gravel, sand, and clay pits

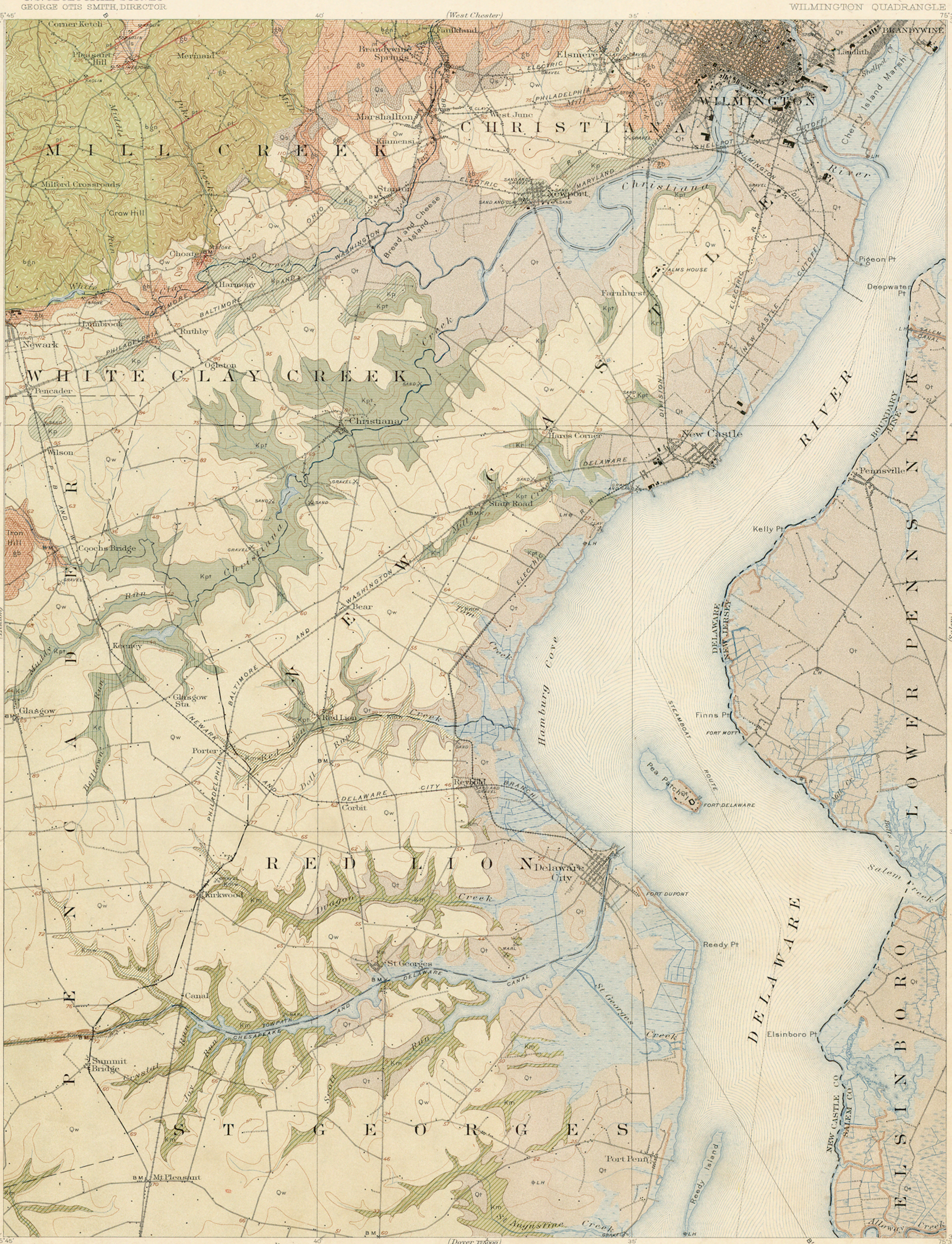
Economic note: *Building stone can be obtained chiefly from granodiorite, but also from gabbro, Baltimore gneiss, and Wissahickon gneiss; road metal and ballast chiefly from gabbro, but also from granodiorite, Baltimore gneiss, and Wissahickon gneiss; quartz for glass sand, feldspar and kaolin for pottery manufacture from pegmatite dikes and their residual products. Iron ore has been mined from the gabbro of Chestnut Hill and Iron Hill, and chromite from serpentine. In the coastal plain area water may generally be obtained in shallow wells, 15 to 35 feet deep; artesian water at depths of 200 or more feet; flowing wells may be expected only in areas below 20 feet altitude.*

Note: *Structure section along line A-A' is illustrated in the text.*

DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, SECRETARY
U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

AREAL GEOLOGY

DELAWARE–NEW JERSEY
WILMINGTON QUADRANGLE



EXPLANATION

SEDIMENTARY ROCKS

(Areas of subaqueous deposits are shown by patterns of parallel lines; subaerial deposits by patterns of dots and circles)

QUATERNARY — Pleistocene (Columbia group)

- **Qt** Talbot formation *(loam, sand, and gravel, with clay lenses and ice-borne bowlders; forms terraces and lowlands from 0 to 45 feet above sea level)*

UNCONFORMITY

- **Qw** Wicomico formation *(loam, sand, and gravel, with ice borne bowlders; covers rolling terraces and divides from 40 to 100 feet above sea level)*

UNCONFORMITY

- **Qs** Sunderland formation *(loam, sand, and gravel; covers terraces and divides from 90 to 200 feet above sea level)*

UNCONFORMITY

CRETACEOUS — Upper Cretaceous

- **Km** Monmouth formation *(reddish-brown to greenish-black sand with many iron crusts)*
- **Kmw** Matawan formation *(gray to black micaceous sandy clay carrying glauconite)*

UNCONFORMITY

- **Kma** Magothy formation *(thinly laminated alternating sand and clay with much lignite and ferruginous sandstone layers)*

UNCONFORMITY

- **Kr** Raritan formation *(variegated clay, sand, and gravel, with some lignite)*

UNCONFORMITY

Lower Cretaceous (Potomac group)

- **Kpt** Patapsco formation *(highly-colored variegated clay interbedded with sand and gravel)*

UNCONFORMITY

- **Kp** Patuxent formation *(light-colored arkosic sand with clay lenses and gravel bands)*

PRE-CAMBRIAN SEDIMENTARY AND IGNEOUS ROCKS

(metamorphism is indicated by hachures)

PRE-CAMBRIAN — Igneous rocks intrusive in Baltimore gneiss; in part metamorphosed

- **pt** Pegmatite dikes *(coarsely crystalline quartz-feldspar-mica rock)*
- **gb** Gabbro *(quartz gabbro, gabbro, hypersthene gabbro, hornblende gabbro, olivine gabbro)*

Chiefly metamorphosed sedimentary rocks

- **ls** Limestone *(crystalline white limestone interbedded in the Baltimore gneiss)*
- **bgn** Baltimore gneiss *(banded quartz-feldspar-biotite rock)*

ECONOMIC AND STRUCTURE DATA

- *Quarries and mines* — Stone, limestone, and kaolin. Iron mines and some quarries are at present abandoned.
- *Gravel, sand, clay, and marl pits.*

Economic note: *Building stone, road metal, and ballast can be obtained from gabbro and Baltimore gneiss; limestone for lime from the pre-Cambrian limestone; quartz for glass sand, feldspar and kaolin for pottery manufacture from pegmatite dikes and their residual products. Iron ore has been mined from the gabbro of Iron Hill. In the coastal plain area water may generally be obtained in shallow wells, 15 to 35 feet deep; artesian water at depths of 200 or more feet; flowing wells may be expected only in areas below 20 feet altitude.*

Note: *Structure section along line B-B′ is illustrated in the text.*

H. M. Wilson, Geographer in charge.
Topography by W. Carvel Hall, W. M. Beaman, and Geological Survey of New Jersey. Assistant, J. S. B. Daingerfield.
Control by U.S. Coast and Geodetic Survey, and F. T. Fitch.
Delaware River by U.S. Coast and Geodetic Survey.
Surveyed in 1904.

TRUE NORTH — MAGNETIC NORTH — APPROXIMATE MEAN DECLINATION 1917

Scale 1/62500

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 20 feet.
Datum is mean sea level.

Edition of April 1920

Geology of Coastal Plain by B. L. Miller
Geology of the crystalline rocks by F. Bascom.
Surveyed in 1900-1913.

and still smaller ones *stages*. The age of a rock is expressed by the name of the time interval in which it was formed.

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

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

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

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

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

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

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

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

Symbols and colors assigned to the rock systems.

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

SURFACE FORMS.

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

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

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

THE VARIOUS GEOLOGIC SHEETS.

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

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

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

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

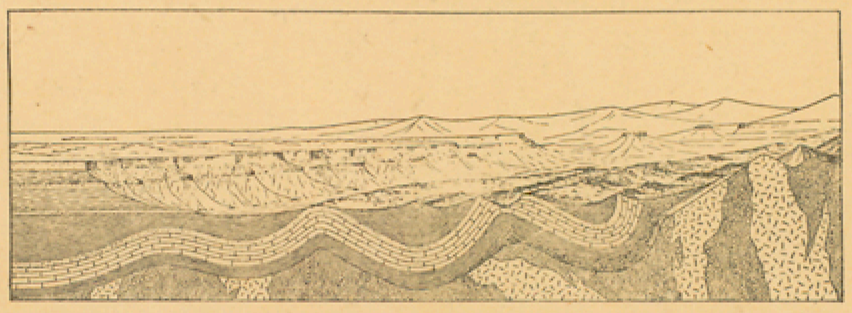


FIGURE 2.—Sketch showing a vertical section at the front and a landscape beyond.

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

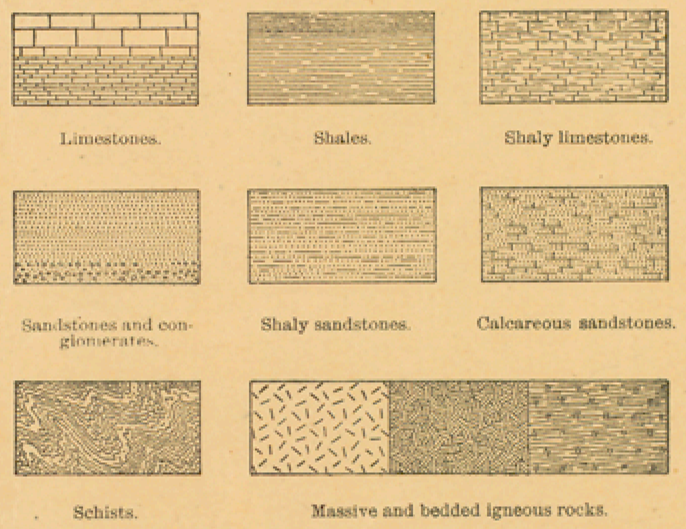


FIGURE 3.—Symbols used in sections to represent different kinds of rocks.

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

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

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

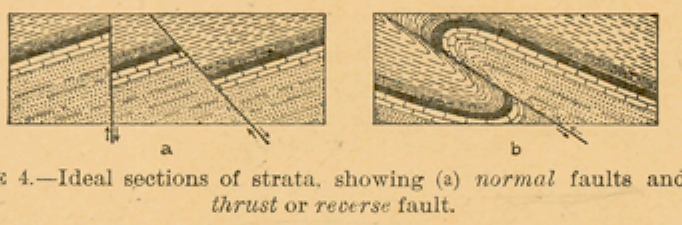


FIGURE 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* or *reverse* fault.

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

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

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

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

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

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

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

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

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

GEORGE OTIS SMITH,
Director.

May, 1909.

PUBLISHED GEOLOGIC FOLIOS

No.*	Name of folio.	State.	Price.†
			Cents.
‡1	Livingston	Montana	
‡2	Ringgold	Georgia-Tennessee	
●3	Placerville	California	
‡4	Kingston	Tennessee	
●5	Sacramento	California	
‡6	Chattanooga	Tennessee	
‡7	Pikes Peak	Colorado	
‡8	Sewanee	Tennessee	
‡9	Anthracite-Crested Butte	Colorado	
‡10	Harpers Ferry	Va.-Md.-W.Va	
●11	Jackson	California	
‡12	Estillville	Ky.-Va.-Tenn	
‡13	Fredericksburg	Virginia-Maryland	
‡14	Staunton	Virginia-West Virginia	
‡15	Lassen Peak	California	
‡16	Knoxville	Tennessee-North Carolina	
‡17	Marysville	California	
‡18	Smartsville	California	
‡19	Stevenson	Ala.-Ga.-Tenn	
20	Cleveland	Tennessee	5
‡21	Pikeville	Tennessee	
‡22	McMinnville	Tennessee	
‡23	Nomini	Maryland-Virginia	
‡24	Three Forks	Montana	
‡25	Loudon	Tennessee	
‡26	Pocahontas	Virginia-West Virginia	
‡27	Morristown	Tennessee	
‡28	Piedmont	West Virginia-Maryland	
‡29	Nevada City Special	California	
‡30	Yellowstone National Park	Wyoming	
‡31	Pyramid Peak	California	
‡32	Franklin	West Virginia-Virginia	
‡33	Briceville	Tennessee	
‡34	Buckhannon	West Virginia	
‡35	Gadsden	Alabama	
‡36	Pueblo	Colorado	
‡37	Downieville	California	
‡38	Butte Special	Montana	
‡39	Truckee	California	
‡40	Wartburg	Tennessee	
‡41	Sonora	California	
‡42	Nueces	Texas	
‡43	Bidwell Bar	California	
‡44	Tazewell	Virginia-West Virginia	
‡45	Boise	Idaho	
‡46	Richmond	Kentucky	
‡47	London	Kentucky	
‡48	Tenmile District Special	Colorado	
‡49	Roseburg	Oregon	
‡50	Holyoke	Massachusetts-Connecticut	
‡51	Big Trees	California	
‡52	Absaroka	Wyoming	
‡53	Standingstone	Tennessee	
‡54	Tacoma	Washington	
‡55	Fort Benton	Montana	
‡56	Little Belt Mountains	Montana	
‡57	Telluride	Colorado	
‡58	Elmoro	Colorado	
‡59	Bristol	Virginia-Tennessee	
‡60	La Plata	Colorado	
‡61	Monterey	Virginia-West Virginia	
‡62	Menominee Special	Michigan	
‡63	Mother Lode District	California	
‡64	Uvalde	Texas	
‡65	Tintic Special	Utah	
‡66	Colfax	California	
‡67	Danville	Illinois-Indiana	
‡68	Walsenburg	Colorado	
‡69	Huntington	West Virginia-Ohio	
‡70	Washington	D. C.-Va.-Md.	
‡71	Spanish Peaks	Colorado	
‡72	Charleston	West Virginia	
‡73	Coos Bay	Oregon	
‡74	Coalgate	Oklahoma (Ind. T.)	
‡75	Maynardville	Tennessee	
‡76	Austin	Texas	
‡77	Raleigh	West Virginia	
‡78	Rome	Georgia-Alabama	
‡79	Atoka	Oklahoma (Ind. T.)	
‡80	Norfolk	Virginia-North Carolina	
‡81	Chicago	Illinois-Indiana	
‡82	Masontown-Uniontown	Pennsylvania	
‡83	New York City	New York-New Jersey	
84	Ditney	Indiana	5
85	Oelrichs	South Dakota-Nebraska	5
86	Ellensburg	Washington	5
87	Camp Clarke	Nebraska	5
88	Scotts Bluff	Nebraska	5
‡89	Port Orford	Oregon	
90	Cranberry	North Carolina-Tennessee	5
91	Hartville	Wyoming	5
92	Gaines	Pennsylvania-New York	5
93	Elkland-Tioga	Pennsylvania	5
‡94	Brownsville-Connellsville	Pennsylvania	
95	Columbia	Tennessee	5
96	Olivet	South Dakota	5
97	Parker	South Dakota	5
‡98	Tishomingo	Oklahoma (Ind. T.)	
99	Mitchell	South Dakota	5
100	Alexandria	South Dakota	5
‡101	San Luis	California	
102	Indiana	Pennsylvania	5
‡103	Nampa	Idaho-Oregon	
104	Silver City	Idaho	5
105	Patoka	Indiana-Illinois	5
106	Mount Stuart	Washington	5

No.*	Name of folio.	State.	Price.†
			Cents.
‡107	Newcastle	Wyoming-South Dakota	
108	Edgemont	South Dakota-Nebraska	5
109	Cottonwood Falls	Kansas	5
‡110	Latrobe	Pennsylvania	
‡111	Globe	Arizona	
112	Bisbee (reprint)	Arizona	25
113	Huron	South Dakota	5
114	De Smet	South Dakota	5
‡115	Kittanning	Pennsylvania	
‡116	Asheville	North Carolina-Tennessee	
117	Casselton-Fargo	North Dakota-Minnesota	5
118	Greeneville	Tennessee-North Carolina	5
119	Fayetteville	Arkansas-Missouri	5
‡120	Silverton	Colorado	
‡121	Waynesburg	Pennsylvania	
‡122	Tahlequah	Oklahoma (Ind. T.)	
123	Elders Ridge	Pennsylvania	5
‡124	Mount Mitchell	North Carolina-Tennessee	
‡125	Rural Valley	Pennsylvania	
‡126	Bradshaw Mountains	Arizona	
‡127	Sundance	Wyoming-South Dakota	
‡128	Aladdin	Wyo.-S. Dak.-Mont	
‡129	Clifton	Arizona	
‡130	Rico	Colorado	
‡131	Needle Mountains	Colorado	
‡132	Muscogee	Oklahoma (Ind. T.)	
‡133	Ebensburg	Pennsylvania	
‡134	Beaver	Pennsylvania	
‡135	Nepesta	Colorado	
136	St. Marys	Maryland-Virginia	5
‡137	Dover	Del.-Md.-N. J	
‡138	Redding	California	
‡139	Snoqualmie	Washington	
‡140	Milwaukee Special	Wisconsin	
‡141	Bald Mountain-Dayton	Wyoming	
‡142	Cloud Peak-Fort McKinney	Wyoming	
‡143	Nantahala	North Carolina-Tennessee	
‡144	Amity	Pennsylvania	
‡145	Lancaster-Mineral Point	Wisconsin-Iowa-Illinois	
‡146	Rogersville	Pennsylvania	
‡147	Pisgah	N. Carolina-S. Carolina	
148	Joplin District (reprint)	Missouri-Kansas	50
‡149	Penobscot Bay	Maine	
‡150	Devils Tower	Wyoming	
‡151	Roan Mountain	Tennessee-North Carolina	
‡152	Patuxent	Md.-D. C	
‡153	Ouray	Colorado	
‡154	Winslow	Ark.-Okla. (Ind. T.)	
155	Ann Arbor (reprint)	Michigan	25
156	Elk Point	S. Dak.-Nebr.-Iowa	5
‡157	Passaic	New Jersey-New York	
158	Rockland	Maine	5
‡159	Independence	Kansas	
‡160	Accident-Grantsville	Md.-Pa.-W. Va.	
‡161	Franklin Furnace	New Jersey	
‡162	Philadelphia	Pa.-N. J.-Del	
‡163	Santa Cruz	California	
‖164	Belle Fourche	South Dakota	5
‖165	Aberdeen-Redfield	South Dakota	5
‡166	El Paso	Texas	
‡167	Trenton	New Jersey-Pennsylvania	
‖168	Jamestown-Tower	North Dakota	5
‡169	Watkins Glen-Catatonk	New York	
‡170	Mercersburg-Chambersburg	Pennsylvania	
‖171	Engineer Mountain	Colorado	5
172	Warren	Pennsylvania-New York	5
‡173	Laramie-Sherman	Wyoming	
‡174	Johnstown	Pennsylvania	
‡175	Birmingham	Alabama	
‡176	Sewickley	Pennsylvania	
‡177	Burgettstown-Carnegie	Pennsylvania	
‖178	Foxburg-Clarion	Pennsylvania	5
‡179	Pawpaw-Hancock	Md.-W. Va.-Pa	
‖180	Claysville	Pennsylvania	5
‖181	Bismarck	North Dakota	5
‖182	Choptank	Maryland	5
‖183	Llano-Burnet	Texas	5
¶184	Kenova	Ky.-W. Va.-Ohio	5
§185	Murphysboro-Herrin	Illinois	25
§186	Apishapa	Colorado	5
§187	Ellijay	Ga.-N. C.-Tenn	25
§188	Tallula-Springfield	Illinois	25
189	Barnesboro-Patton	Pennsylvania	25
§190	Niagara	New York	50
§191	Raritan	New Jersey	25
192	Eastport	Maine	25
§193	San Francisco	California	75
194	Van Horn	Texas	25
195	Belleville-Breese	Illinois	25
196	Philipsburg	Montana	25
§197	Columbus	Ohio	25
198	Castle Rock	Colorado	25
199	Silver City	New Mexico	25
200	Galena-Elizabeth	Illinois-Iowa	25
§201	Minneapolis-St. Paul	Minnesota	25
202	Eureka Springs-Harrison	Arkansas-Missouri	25
203	Colorado Springs	Colorado	25
204	Tolchester	Maryland	25
§205	Detroit	Michigan	50
206	Leavenworth-Smithville	Missouri-Kansas	25
207	Deming	New Mexico	25
208	Colchester-Macomb	Illinois	25
209	Newell	South Dakota	25
210	Herman-Morris	Minnesota	25
211	Elkton-Wilmington	Md.-Del.-N. J.-Pa	25
212	Syracuse-Lakin	Kansas	25

* Order by number.
† Payment must be made by money order or in cash.
‡ These folios are out of stock.
● The texts and economic-geology maps of the Placerville, Sacramento, and Jackson folios, which are out of stock, have been reprinted and published as a single folio (Folio reprint Nos. 3, 5, and 11), the price of which is $1.

‖ Octavo editions of these folios may be had at same price.
¶ Octavo editions only of these folios are in stock.
§ These folios are also published in octavo form at 50 cents each, except No. 193, which is 75 cents.

The stock of folios from Nos. 1 to 184 and No. 186 was damaged by a fire in the Geological Survey building, but those folios that were only slightly damaged and are usable will be sold at 5 cents each. They are priced accordingly in the list above. Circulars showing the location of the area covered by any of the above folios, as well as information concerning topographic maps and other publications of the Geological Survey, may be had on application to the Director, United States Geological Survey, Washington, D. C.