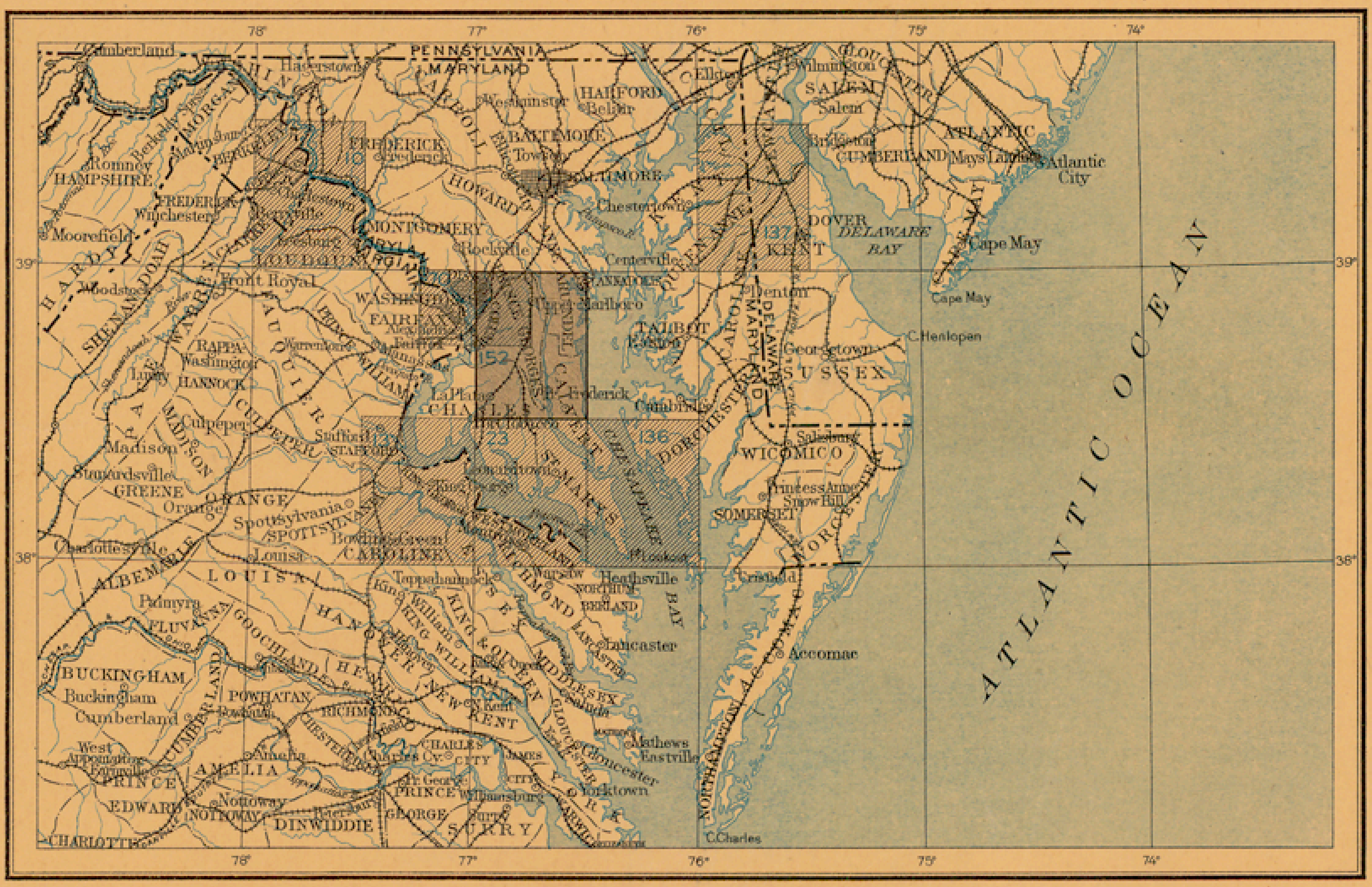
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

# GEOLOGIC ATLAS
OF THE
# UNITED STATES

## PATUXENT FOLIO
### MARYLAND-DISTRICT OF COLUMBIA

INDEX MAP




SCALE: 40 MILES - 1 INCH

PATUXENT FOLIO

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WASHINGTON, D. C.
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GEORGE W. STOSE, EDITOR OF GEOLOGIC MAPS    S. J. KUBEL, CHIEF ENGRAVER
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# GEOLOGIC AND TOPOGRAPHIC ATLAS OF UNITED STATES

The Geological Survey is making a geologic map of the United States, which is being issued in parts, called folios. Each folio includes a topographic map and geologic maps of a small area of country, together with explanatory and descriptive texts.

## THE TOPOGRAPHIC MAP.

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

*Relief*.—All elevations are measured from mean sea level. The heights of many points are accurately determined, and those which are most important are given on the map in figures. It is desirable, however, to give the elevation of all parts of the area mapped, to delineate the 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 altitudinal interval represented by the space between lines being the same throughout each map. These lines are called *contours*, and the uniform altitudinal space between each two contours is called the *contour interval*. Contours and elevations are printed in brown.

The manner in which contours express elevation, form, and grade is shown in the following sketch and corresponding contour map (fig. 1).

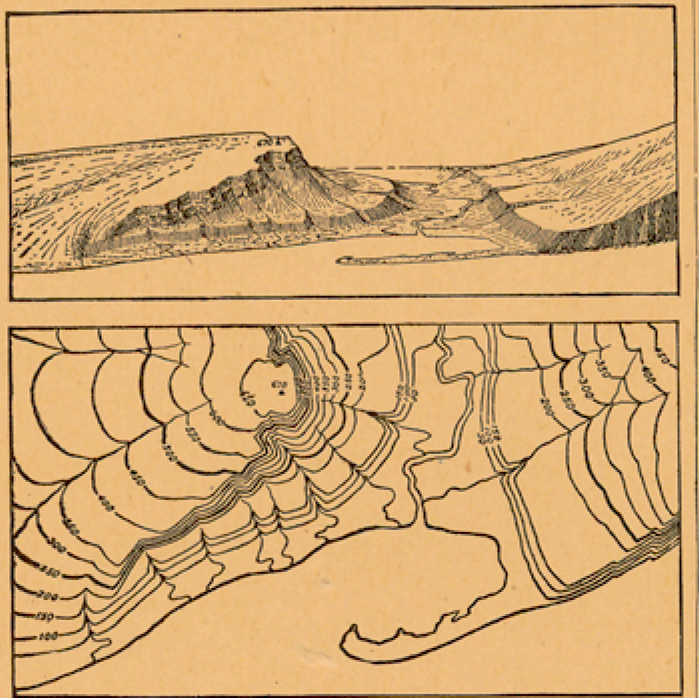


FIG. 1.—Ideal view and corresponding contour map

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

1. A contour indicates a certain height above sea level. In this illustration the contour interval is 50 feet; therefore the contours 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 sea; along the contour at 200 feet, all points that are 200 feet above sea; and so on. In the space between any two contours are found elevations above the lower and below the higher contour. Thus the contour at 150 feet falls just below the edge of the terrace, while that at 200 feet lies above the terrace; therefore all points on the terrace are shown to be more than 150 but less than 200 feet above sea. The summit of the higher hill is stated to be 670 feet above sea; accordingly the contour at 650 feet surrounds it. In this illustration all the contours are numbered, and those for 250 and 500 feet are accentuated by being made heavier. Usually it is not desirable to number all the contours, and then the accentuating and numbering of certain of them—say every fifth one—suffice, for the heights of others may be ascertained by counting up or down from a numbered contour.

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

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

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

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

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

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

Three scales are used on the atlas sheets of the Geological Survey; the smallest is $\frac{1}{250,000}$, the intermediate $\frac{1}{125,000}$, and the largest $\frac{1}{62,500}$. These correspond approximately to 4 miles, 2 miles, and 1 mile on the ground to an inch on the map. On the scale $\frac{1}{62,500}$ a square inch of map surface represents about 1 square mile of earth surface; on the scale $\frac{1}{125,000}$, about 4 square miles; and on the scale $\frac{1}{250,000}$, 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 in English inches, by a similar line indicating distance in the metric system, and by a fraction.

*Atlas sheets and quadrangles*.—The map 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 $\frac{1}{250,000}$ contains one square degree—i. e., a degree of latitude by a degree of longitude; each sheet on the scale of $\frac{1}{125,000}$ contains one-fourth of a square degree; each sheet on the scale of $\frac{1}{62,500}$ contains one-sixteenth of a square degree. The areas of the corresponding quadrangles are about 4000, 1000, and 250 square miles.

The atlas sheets, being only parts of one map of the United States, disregard political boundary lines, such as those of States, counties, and townships. To each sheet, and to the quadrangle it represents, is given the name of some well-known town or natural feature within its limits, and at the sides and corners of each sheet the names of adjacent sheets, if published, are printed.

*Uses of the topographic map*.—On the topographic map are delineated the relief, drainage, and culture of the quadrangle represented. It should portray to the observer every characteristic feature of the landscape. It should guide the traveler; serve the investor or owner who desires to ascertain the position and surroundings of property; save the engineer preliminary surveys in locating roads, railways, and irrigation reservoirs and ditches; provide educational material for schools and homes; and be useful as a map for local reference.

## 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 the structure sections show their underground relations, as 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*.—These are rocks which have cooled and consolidated from a state of fusion. Through rocks of all ages molten material has from time to time been forced upward in fissures or channels of various shapes and sizes, to or nearly to the surface. Rocks formed by the consolidation of the molten mass within these channels—that is, below the surface—are called *intrusive*. When the rock occupies a fissure with approximately parallel walls the mass is called a *dike*; when it fills a large and irregular conduit the mass is termed a *stock*. When the conduits for molten magmas traverse stratified rocks they often send off branches parallel to the bedding planes; the rock masses filling such fissures are called *sills* or *sheets* when comparatively thin, and *laccoliths* when occupying larger chambers pro 'uced by the force propelling the magmas upward Within rock inclosures molten material cools slowly, with the result that intrusive rocks are generally of crystalline texture. When the channels reach the surface the molten material poured out through them is called *lava*, and lavas often build up volcanic mountains. Igneous rocks thus formed upon the surface are called *extrusive*. Lavas cool rapidly in the air, and acquire a glassy or, more often, a partially crystalline condition in their outer parts, but are more fully crystalline in their inner portions. The outer parts of lava flows are usually more or less porous. Explosive action often accompanies volcanic eruptions, causing ejections of dust, ash, and larger fragments. These materials, when consolidated, constitute breccias, agglomerates, and tuffs. Volcanic ejecta may fall in bodies of water or may be carried into lakes or seas and form sedimentary rocks.

*Sedimentary rocks*.—These rocks are composed of the materials of older rocks which have been broken up and the fragments of which have been carried to a different place and deposited.

The chief agent of 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. In smaller portion the materials are carried in solution, and the deposits are then 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 deposits 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*. Rocks deposited in layers are said to be stratified.

The surface of the earth is not fixed, as it seems to be; it very slowly rises or sinks, with reference to the sea, over wide expanses; and as it rises or subsides the shore lines of the ocean are changed. As a result of the rising of the surface, marine sedimentary rocks may become part of the land, and extensive land areas are in fact occupied by such rocks.

Rocks exposed at the surface of the land are acted upon by air, water, ice, animals, and plants. They are gradually broken into fragments, and the more soluble parts are leached out, leaving the less soluble as a *residual* layer. Water washes residual material down the slopes, and it is eventually carried by rivers to the ocean or other bodies of standing water. Usually its journey is not continuous, but it is temporarily built into river bars and flood plains, where it is called *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 a variety of processes, rocks may become greatly changed in composition and in texture. When the newly acquired characteristics are more pronounced than the old ones such rocks are called *metamorphic*. In the process of metamorphism the substances of which a rock is composed may enter into new combinations, certain substances may be lost, or new substances may be added. There is often a complete gradation from the primary to the metamorphic form within a single rock mass. Such changes transform sandstone into quartzite, limestone into marble, and modify other rocks in various ways.

From time to time in geologic history igneous and sedimentary rocks have been deeply buried and later have been raised to the surface. In this process, through the agencies of pressure, movement, and chemical action, their original structure may be entirely lost and new structures appear. Often there is developed a system of division planes along which the rocks split easily, and these planes may cross the strata at any angle. This structure is called *cleavage*. Sometimes crystals of mica or other foliaceous minerals are developed with their laminæ approximately parallel; in such cases the structure is said to be schistose, or characterized by *schistosity*.

As a rule, the oldest rocks are most altered and the younger formations have escaped metamorphism, but to this rule there are important exceptions.

### 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, a rapid alternation of shale and limestone. When the passage from one kind of rocks to another is gradual it is sometimes 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 is constituted of one or more bodies either containing the same kind of igneous rock or having the same mode of occurrence. A metamorphic formation may consist of rock of uniform character or of several rocks having common characteristics.

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 the rocks were made is divided into several *periods*. Smaller time divisions are called *epochs*, and still smaller ones *stages*. The age of a rock is expressed by naming the time interval in which it was formed, when known.

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*.

(Continued on third page of cover.)

# DESCRIPTION OF THE PATUXENT QUADRANGLE.

Prepared under the supervision of William Bullock Clark, geologist in charge.

By George Burbank Shattuck, Benjamin LeRoy Miller, and Arthur Bibbins.

## INTRODUCTION.

*Location and area of the quadrangle.*—The Patuxent quadrangle lies between parallels 38° 30′ and 39° north latitude and meridians 76° 30′ and 77° west longitude. It includes one-fourth of a square degree of the earth's surface and contains 931.5 square miles. From north to south it measures 34.5 miles and from east to west the mean distance is 27 miles, the width being 27.1 miles along the southern and 26.9 miles along the northern border.

The quadrangle includes parts of the State of Maryland and of the District of Columbia. In Maryland it embraces the southern portion of Anne Arundel County, the northern portion of Calvert County, the extreme northern end of St. Marys County, the northeastern portion of Charles County, the southeastern portion of Prince Georges County, and about 1 square mile of the southeastern part of Montgomery County. The District of Columbia is represented in the northwestern part of the quadrangle by about 24 square miles. Besides the land areas a small portion of Chesapeake Bay, with parts of the estuaries of South, West, Patuxent, and Anacostia rivers and Piscataway Creek are embraced within this quadrangle. It includes portions of two physiographic provinces—the Piedmont Plateau and the Atlantic Coastal Plain.

*Outline of the geography and geology of the Piedmont Plateau Province.*—This province is represented by small areas of granite gneiss along tributary streams of Anacostia River in the northwest corner of the quadrangle. The following general description is taken from the Washington folio (No. 70) of the Geologic Atlas of the United States:

The Piedmont Plateau is an upland to which the term "plateau" is applied because of its elevation and general flat aspect. It constitutes a division of the great Appalachian province, and its name, "Piedmont," refers to its position at the foot of the Appalachian Mountains. From the base of the Blue Ridge in Georgia, North Carolina, and Virginia, and from Catoctin Mountain in Maryland and Pennsylvania, it slopes as a whole southeastward. The summits stand at nearly the same height over extensive areas, with gradual changes from district to district. Since its formation the original plain has been uplifted and streams have worn narrow channels down into the old surface. The rugged slopes thus produced are closely confined to the streams and are visible only on near approach. Along the northwestern border of the Plateau there are remnants of the old plain not yet invaded. In passing northward through Virginia, one finds the Plateau and the Mountains gradually merging into each other, so that the separation of the Piedmont and Mountain divisions becomes less prominent. Where the Potomac passes out into the Piedmont region the actual plateau extends far into the Appalachian Valley. Many outliers of the Appalachian Mountains, such as the South Mountains in North Carolina and Southwest Mountain in Virginia, interrupt the seaward slope of the Plateau.

The eastern border of the Piedmont Plateau is much less clearly defined than its western margin. The Piedmont slope gradually descends toward the east and merges into the Coastal Plain. The chief topographic difference between the two provinces lies in the contrast presented by the narrow gorges cut in the Plateau and the wide valleys of the Coastal Plain. The crystalline rocks of the Plateau form a floor on which the sediments of the Coastal Plain were laid down. At first these lapped far over the Piedmont region, but they have been removed more and more by erosion until only small remnants are left upon the Plateau. As the streams cut deeper and wider valleys in the loose sediments than in the hard underlying rocks, a general difference in topography resulted. Later periods of submergence, during which the Coastal Plain was beneath the sea, allowed the waters to extend far up the larger valleys, and in some cases the later gravels reach across the Piedmont Plateau and into the Appalachian Mountains.

*Relief.*—Throughout the entire extent of the Piedmont Plateau the uplands are smooth and rounded, usually to a very marked degree. They represent the ancient plain to which the land was worn down during the long ages of decay. The streams near their heads flow between low divides in the open, shallow valleys of the ancient plain. In their lower courses, however, they have worn channels deep into the old valley floors and now flow through narrow gorges and canyons. These canyons widen out on the softer rocks and toward the east, and their steep walls give place to terraces and to lower and smaller plateaus. In a view across the Piedmont Plateau from one of its summits the monotonous level of the uplands is here and there broken by small ridges and peaks which rise a few hundred feet above the Plateau. These are areas not worn down to the level of the plain and are most common near the union of the Piedmont Plateau and the Appalachian Mountains.

The uniform heights of the Piedmont Plateau distinguish it from the marked relief of the ridges and valleys in the Appalachian Mountains. The Plateau as a whole has a gentle slope toward the east and southeast in that portion which drains into the Atlantic, and toward the south where the streams drain into the Gulf of Mexico. In a wide belt adjoining the Coastal Plain the Plateau summits vary from 300 to 600 feet above sea. This belt comprises almost all of the Plateau north of James River, in Virginia. Over another wide belt adjoining the Appalachian Mountains the Plateau summits are 1000 to 1100 feet above the sea, while along the immediate western borders of the Plateau the summits rise to 1500 feet. The Plateau surface south of James River and lying in the Atlantic drainage is about evenly divided between the lower and higher groups of altitudes. The zone of descent from higher to lower is relatively narrow, and in it the Plateau surface falls rather rapidly. This zone passes from the Appalachian Mountains into the Plateau a little north of James River, and, as its trend is more nearly south than that of the Plateau, it slowly recedes from the Mountains toward the Coastal Plain.

*Drainage.*—The system of drainage of the Piedmont Plateau is fairly simple. Most of the streams flow southeasterly into the Atlantic. Around the southwestern end of the Appalachian Mountains, where the Plateau swings toward the west, the streams flow southerly into the Gulf of Mexico. There are two principal classes of streams—Those which rise near the inland border of the Plateau, and those which rise beyond it, in the Appalachian Valley. Savannah River, in Georgia, is typical of the first class, and James River, in Virginia, of the second class. North of the Virginia–North Carolina boundary these two kinds of streams drain nearly equal areas of the Piedmont Plateau, while south of that boundary no large stream rises far from the border of the Plateau. Most of the larger streams of both classes flow directly across the Plateau at wide angles with the trend of the rock formations. In their general freedom from the control of the rocks, the Piedmont streams are most unlike those of the Appalachian Mountains and Valley. The chief exceptions to this are in Georgia and Alabama, where the main streams follow the rock belts for long distances. The small rivers and the tributary creeks show greater dependence upon the nature and structure of the underlying rocks, and occupy many valleys running northeast or southwest with the rock belts. These courses become general in some regions—for instance, in central Virginia. Most of the Piedmont streams branch uniformly at their heads and occupy basins which are about parallel. This is particularly the case with the smaller rivers which head in the eastern part of the Plateau, near the Coastal Plain.

* * * * *

*Rocks.*—The ancient rocks of the Plateau comprise four series, of widely different age and character. These are the igneous and crystalline rocks, including gneiss, schist, granite, diorite, and similar formations; the volcanic formations, embracing rhyolite, basalt, and their alteration products; the older sedimentary strata, including conglomerate, sandstone, slate, limestone, and their metamorphosed equivalents; and the younger sediments, the conglomerates, sandstone, and shale of Juratrias age, with the eruptive rocks which accompany them. The relative areas of these groups nearly correspond with their ages, the area of the oldest group being greatest and that of the Juratrias least.

The first three series have been greatly changed since their formation, both in composition and in attitude, the alteration being so profound in some of the older gneisses and schists as to destroy their original nature. As a result, a schistose character prevails in these areas. The Juratrias series shows little change save the hardening into compact stone and a moderate degree of tilting from its original attitude. The materials of which the sediments are composed were originally gravel, sand, and mud, derived from the waste of older rocks, together with the remains of plants and animals that lived while the strata were being laid down.

* * * * *

*Structure.*—The structures that prevail through most of the ancient rocks of the Plateau are very complex, but they present much the same types, even in widely separated districts. In complexity they are strongly contrasted with the Juratrias rocks which occupy a small part of the Plateau. These strata are gently tilted and all dip toward the west at angles of from 1° to 30°. The crystalline rocks covering most of the Plateau are tilted at high angles, broken by faults, and altered from their original condition. Folds are frequent, and the forces of compression have usually so acted as to squeeze the sides of the folds together until the beds dip in the same direction. In these cases the existence of the fold is detected mainly by the order in which the formations occur. Portions of the Plateau in North Carolina and South Carolina, however, contain folds of such moderate deformation that they are defined by the angle of the dip as well as by the sequence of the formations.

Faults are not uncommon in the Piedmont region, and doubtless many more might be traced if the rocks could be divided into small and distinct formations. Two types of faults appear: those associated with the Juratrias basins—normal faults—and those connected with the folding and metamorphism of the older rocks—thrust faults. The former are simple breaks directly across the sedimentary layers, and their planes usually dip at high angles—from 75° to 90°—corresponding closely to the dip of the schistose planes in the underlying older rocks. The displacements due to these faults are comparatively slight, being measured by hundreds of feet, and they are noticeable only where the strata dip at small angles and are divided into readily recognized formations. Such faults, therefore, are hard to trace beyond the Juratrias basin, although undoubtedly they exist elsewhere as well. Thrust faults among the highly tilted rocks are comparatively little known, and their place seems to have been taken by the countless minor dislocations of the rock particles. A few have been discovered under conditions especially well adapted to show unusual structures. In these cases the faults seem to have been produced either during or after the later stages of the folding and metamorphism, inasmuch as they cross the formations and the schistose planes rather abruptly. Unlike the usual Appalachian thrust faults, these rarely have any visible origin in anticlines. Their planes dip at high angles, and for the most part lie nearly parallel to the adjoining schistose planes. It is where the two diverge that the faults become apparent.

By far the most prominent of the Piedmont structures is schistosity. Formations which retain their original condition unchanged are extremely rare, and frequently the alteration has quite obliterated the original character of the rock. In most of the sedimentary rocks the bedding planes have been destroyed by the metamorphic action, and even where they are distinct they are usually less prominent than the schistosity. In the igneous rocks planes of fracture and motion were developed, which, in a measure, made easier the deformation of the rocks. Along these planes of localized motion the original texture of the rock was largely destroyed by the fractures and the growth of the new minerals, and in many cases this alteration extends through the entire mass of the rock. The extreme development of this process is seen in the mica schists and mica gneisses, the original textures of which have been entirely replaced by the schistose structure and parallel flakes of new minerals. The planes of fracture and motion are inclined toward the southeast through most of the Plateau, although in certain belts, chiefly along its eastern and central portions, there is a prevailingly northwest dip. The southeasterly dips range from 45° to 90°; the northwesterly dips, from 30° to 90°.

The structures above described, except perhaps the Juratrias tilting and faulting, are chiefly the result of compression which acted most effectively in a northwest-southeast direction, at right angles to the general trend of the folds and of the schistose planes. The earliest-known period of compression and deformation occurred during Archean time, and resulted in much of the metamorphism of the present Carolina gneiss. It is possible that other movements took place in Archean time, producing a portion of the metamorphism which appears in the other Archean rocks. In the course of time, compression became effective again, early in the Paleozoic era, and a series of movements took place culminating soon after the close of the Carboniferous period. The latest of this series was probably the greatest, and to it is chiefly due the well-known Appalachian folding and metamorphism. The various deformations combined have greatly changed the aspects of the rocks—so much so, in fact, that the original nature of some of the oldest formations can be at present only surmised.

In addition to the force which acted in a horizontal direction, this region has been affected by other forces which acted vertically, and repeatedly raised or depressed the surface. The compressive forces were tremendous, but limited in effect to a relatively narrow zone. Less intense at any point, but broader in their results, the vertical movements extended throughout this and other provinces. It is likely that these two kinds of movement were combined during the same epoch of deformation. In most cases the movements have resulted in a warping of the surface as well as in uplift. One result of this appears in overlaps and unconformities in sedimentary formations.

*Outline of the geography and geology of the Atlantic Coastal Plain province.*—In its physiographic and geologic relations, all of this quadrangle except a small area in its northwest corner forms a part of the Atlantic Coastal Plain province, which borders the entire eastern part of North America and which in essential particulars is distinctly separated from the provinces on either side. Its eastern limits are marked by the well-defined edge of the continental shelf, at the summit of an escarpment varying in height from 5000 to 10,000 feet. This scarp edge lies at a general depth of 450 to 500 feet below sea level, but commonly the 100-fathom line is regarded as the boundary of the continental shelf. The descent from that line to the greater ocean depths is abrupt; at Cape Hatteras there is an increase in depth of 9000 feet in 13 miles, a grade as steep as that found in many places along the flanks of the greater mountain systems. In striking contrast to this declivity is the comparatively flat ocean bed, which stretches away to the east with but slight differences in elevation. Seen from its base the escarpment would have along the horizon the appearance of a high mountain range with a very even sky line. Here and there notches, produced, perhaps, by streams which once flowed across the continental shelf, would be seen, but there would be no peaks nor serrated ridges.

The Piedmont Plateau, already described, forms the western boundary of the Atlantic Coastal Plain. Most of the larger streams and many of the smaller ones, as they cross the western margin of the Coastal Plain, are characterized by falls or rapids, and the name "fall line" is given to this boundary on that account. Below the fall line the streams show a marked decrease in the velocity of their currents. In the middle Atlantic region tide-water estuaries, the continuations of the large streams, extend inland to the fall line, which thus marks the head of navigation. To the south the fall line gradually rises, so that in the Carolinas and Georgia, although falls and rapids still mark its location and furnish power for mills and factories, the lower courses of the stream are considerably above tide. The position of the fall line near the head of navigation or near the source of water power has been one of the very important factors in determining the location of many of the towns and cities of the Atlantic coast, New York, Trenton, Philadelphia, Wilmington, Baltimore, Washington, Fredericksburg, Richmond, Petersburg, Raleigh, Camden, Columbia, Augusta, Macon, and Columbus being located along it. A line drawn through these places would approximately separate the Coastal Plain from the Piedmont Plateau.

The Atlantic Coastal Plain province is divided by the present shore line into two parts—a submerged portion, known as the continental shelf or continental platform, and a subaerial portion, commonly called the Coastal Plain. In some places the division line is marked by a sea cliff of moderate height, but usually the two parts grade into each other with scarcely a perceptible change, and the only mark of separation is the shore line. The areas of the respective portions have changed frequently during past geologic time owing to the shifting of the shore line eastward or westward caused by local or general depressions or elevations of moderate extent, and even at the present time such changes are in progress. Deep channels that are probably

[1] This quadrangle has been surveyed in cooperation with the Maryland Geological Survey. A fuller discussion of the Maryland portion of the quadrangle will be found in the county reports of the Maryland Survey, which are accompanied by geologic maps published on the United States Geological Survey topographic base, on the scale of 1:62,500; also in the volumes published by the Maryland Survey on the Eocene (1901), the Miocene (1904), and the Pliocene and Pleistocene (1906).

old river valleys, the continuations of valleys of existing streams, have been traced entirely across the continental shelf, at the margin of which they have cut deep gorges. The channel opposite the mouth of Hudson River is particularly well marked and has been shown to extend almost uninterruptedly to the edge of the shelf, over 100 miles southeast of its present mouth. A similar channel lies opposite the mouth of Chesapeake Bay. The combined width of the submerged and subaerial portions of the Coastal Plain province is nearly uniform along the entire eastern border of the continent, being approximately 250 miles. In Georgia the subaerial portion is over 150 miles wide, while the submerged portion is narrower and along the eastern shore of the peninsula of Florida is almost absent. To the north the submerged portion gradually increases in width and the subaerial portion becomes narrower. Except in the region of Cape Hatteras, where the submerged belt becomes narrower, with a corresponding increase in width of the subaerial belt, this gradual change continues as far as the southern part of Massachusetts, beyond which the subaerial portion disappears altogether through the submergence of the entire Coastal Plain province. Off Newfoundland the continental shelf is about 300 miles in width.

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 Plateau, where the slope is in places as great as 10 to 15 feet to the mile, or even more. The submerged portion is monotonously flat, as deposition has destroyed most of the irregularities that were produced by erosion when this portion formed a part of the land area. The slight elevation of the subaerial portion, which in few places reaches 400 feet and is for the most part less than half that height, has prevented the streams from cutting valleys of more than moderate depth, and throughout the greater portion of the area they flow in open valleys at a level only slightly lower than that of the broad, flat divides. Here and there, however, the country along the stream courses shows noticeable relief, though the variations in altitude amount to only a few hundred feet.

The land portion of the Coastal Plain province—that is, the subaerial division—is marked by the presence of many bays and estuaries representing submerged valleys of streams, carved during a time when the belt stood at a higher level than at present. Chesapeake Bay, which is the old valley of Susquehanna River; Delaware Bay, the extended valley of Delaware River; and the tide-water portions of Patuxent, Potomac, York, and James rivers are examples of such bays and estuaries, and there are many others of less importance. The streams of this area which rise in the Piedmont Plateau or farther west are almost invariably turned in a direction roughly parallel to the strike of the formations as they pass out upon the Coastal Plain. With this exception the structure of the formations and the character of the materials have had little effect on stream development, except locally.

The structure of the Coastal Plain is extremely simple, the overlapping beds having almost universally a southeasterly dip of a few feet to the mile.

The materials which are found at the surface of the Coastal Plain are bowlders, pebbles, sand, clay, and marl, mostly loose or locally indurated. In age the formations range from Jurassic (?) to Recent. Since the oldest formations of the province were laid down there have been many periods of deposition alternating with intervals of erosion. By reason of local variations in uplift and submergence, 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 therefore prevailed in different areas of the province during each period and great variability in the character and thickness of the deposits has been thus produced.

## TOPOGRAPHY.

### RELIEF.

The Patuxent is the most diversified of the 30-minute quadrangles which are located mainly or entirely within the Coastal Plain in Maryland. Elevations vary from tide level along the shores of Chesapeake Bay and its estuaries to a height of 300 feet near the southeastern boundary of the District of Columbia. With the exception of a few localities, everywhere throughout the area stream erosion has destroyed the originally plane surface of the country and has dissected it into a gently rolling upland of low relief. The stream systems that have been most active in the work of erosion are those of Patuxent River, which crosses the middle of the quadrangle from north to south, and South and West rivers, in the northeast corner. In addition to these a few short streams flow directly into Chesapeake Bay along the eastern margin of the quadrangle, and Anacostia River and Piscataway, Mattawoman, and Zekiah creeks, tributary to Potomac River, drain the western portion. The coast line near the eastern margin of the quadrangle exhibits two strongly contrasted types. In the northeast corner South and West rivers form two reentrants and dissect the coast into a multitude of inlets. Farther south, along the Calvert Cliffs, the coast line is much more regular. The streams which enter the bay in this region are short and not of sufficient size to modify materially the prevailing unbroken character of the shore.

As a whole the coast line is low, monotonous, and extremely irregular. The land bordering the estuaries of Patuxent River is, in most places, composed either of marshes or low-lying terraces which pass under the surrounding waters with nothing definite to mark where one begins and the other ends except, here and there, a low cliff which the waves have cut during seasons of storm or high tide. On the bay shore, however, for a distance of 12 miles south of Chesapeake Beach, the character of the coast is entirely different. Here the land descends to the water in a sharp, steep cliff, 100 feet or more in height, broken only at intervals by small streams which have cut their valleys to its base. This is the northern portion of the famous Calvert Cliffs, which extend southward to a point about 25 miles beyond the borders of the quadrangle.

### TOPOGRAPHIC FEATURES.

The Patuxent area as a whole exhibits five general topographic features, which are usually very distinct. These vary greatly in the amount of surface that they occupy, but the most noticeable distinction is that they lie at different elevations.

*Tide marshes.*—The first of these topographic features to be described consists of the tide marshes found in the valleys of most of the larger estuaries, particularly of Patuxent and Anacostia rivers and Piscataway and Zekiah creeks. These extend over a number of square miles and lie at a level so low that the tides frequently submerge them in part. The small streams that empty into many of the estuaries meander through these marshes, which are rapidly encroaching on them. These swamps are filled with a growth of sedges and other marsh plants, which aid in filling up the depressions by serving as obstructions to retain the mud carried in by streams and by furnishing a perennial accumulation of vegetable débris.

*Talbot plain.*—The term plain is used in this folio in a somewhat specialized sense, to include the terraces along the stream valleys and their continuations over the interstream areas, where they are true plains.

The Talbot plain borders the tide marshes and extends from sea level to an altitude of about 45 feet. This plain is present throughout the quadrangle along the larger streams, and also along the bay shore. In the northeastern portion of the quadrangle the Talbot plain is well developed along the lower courses of South and West rivers, where it extends inland from the bay shore for several miles, with a slope hardly sufficient to produce surface drainage. Along the bay shore south of Fishing Creek the Talbot plain is almost entirely absent except for a few remnants situated about a mile north of Parker Creek. In the valley of Patuxent River this plain is characteristically developed. Here it extends in an almost continuous belt from the southern margin of the quadrangle to Hills Bridge, growing gradually narrower as it ascends the streams and broken only by the shallow valleys of small streams which cut across it in their course to Patuxent River. North of Hills Bridge and on the western branch of the Patuxent, the Talbot plain is present only in scattered remnants. In the western portion of the quadrangle this plain is well developed in the lower valleys of Piscataway and Henson creeks, and occurs in an unbroken flat extending up the valley of Anacostia River as far as College Park. The Talbot plain has been dissected by stream action less than any of the other plains described below.

*Wicomico plain.*—The Wicomico plain lies at a higher level than the Talbot, from which it is in many places separated by an escarpment varying in height from a few feet to 10 or 12 feet. At some places this escarpment is absent, so that there seems to be a gradual passage from the Talbot plain to the Wicomico. It is present, however, at so many different places that there is little difficulty in determining the line of separation between the two plains. The base of the escarpment lies at an elevation of about 40 feet. From that height the Wicomico plain extends upward to an elevation of about 100 feet, where it is in turn separated from the next higher plain by an escarpment.

The Wicomico plain is older than the Talbot and has suffered more erosion. The streams which cross it have cut deeper valleys than those in the Talbot plain and have widened their basins to such an extent as to destroy, in great measure, the original continuity of its level surface. Enough of this surface remains, however, to indicate the presence of the plain and to permit its identification. This plain occurs along Chesapeake Bay and also in the valleys of the principal estuaries. It is well developed in the northeastern portion of the quadrangle in the valley of South River, and in the central portion of the quadrangle throughout the valley of Patuxent River. It is not well developed along the bay shore south of Herring Bay nor in the southwestern portion of the quadrangle. In the valley of Anacostia River, in the northwest quarter of the quadrangle, the Wicomico plain is represented by scattered remnants. Capitol Hill, Washington, on which the Capitol building is located, just outside the quadrangle boundary, is one of these remnants.

*Sunderland plain.*—The Sunderland plain lies at a higher elevation than the Wicomico and extends from about 100 feet to about 200 feet above sea level. It is usually separated from the Wicomico plain by an escarpment, and in most places another escarpment marks its contact with the next plain above. The escarpment separating the Wicomico from the Sunderland plain is one of the most striking and constant topographic features in the Patuxent quadrangle. The Sunderland plain is developed extensively throughout the eastern half of the quadrangle. It occupies the highest portions of the divide between Chesapeake Bay and Patuxent River and also is well developed along the western side of Patuxent Valley as far north as the mouth of Western Branch. In the valleys of Zekiah, Mattawoman, Piscataway, and Henson creeks and Anacostia River the Sunderland plain, though present, is represented only by remnants. The surface of this plain reaches an altitude of about 180 feet at Charlotte Hall, just beyond the southern margin of this quadrangle, and of 200 feet near Anacostia. It has suffered more stream erosion than the Talbot and Wicomico plains, which lie at lower levels.

*Lafayette plain.*—The Lafayette plain is the highest of the plains developed within the Coastal Plain province. It has a considerable extent in this quadrangle southeast of Anacostia, forming the divide between the valley of Patuxent River on the east and the basin of Potomac River on the west. Throughout this region the margin of the Lafayette plain has been extensively removed by stream action, but the central portions have been practically undisturbed. East of Patuxent River the only remnant of the Lafayette plain caps Marriott Hill, in the southern part of Anne Arundel County. The escarpment which separates this plain from the Sunderland plain below is well defined in the region about Anacostia, where it attains a height of about 50 feet. Near Hughesville, Bryantown, and Aquasco, and just beyond the southern border of the quadrangle, in the vicinity of Charlotte Hall, the escarpment is present, but here it does not exceed 20 feet in height. Throughout the rest of the quadrangle it seems never to have existed or to have been destroyed or so greatly modified by erosion that its determination is rendered uncertain. The surface of this plain ranges in elevation from about 200 feet in the southern portion of the quadrangle to about 300 feet in the hills southeast of Washington.

### DRAINAGE.

The drainage of the Patuxent quadrangle is comparatively simple, as a result of the simple structure of the Coastal Plain formations and the contiguity of the region to Chesapeake Bay. The greater part of the land of the area is naturally drained. In some places this is effected principally through underground drainage, as on the high divide between Potomac and Patuxent rivers and on the low land lying south of West River, locally known as "the swamp." The remainder of the quadrangle is well drained by streams, inasmuch as the estuaries of Chesapeake Bay extend inland a number of miles and the side tributaries cut back to the crests of the divides. Artificial drainage is seldom employed in this region.

*Stream divides.*—The Patuxent quadrangle, lying, as it does, adjacent to Chesapeake Bay and penetrated by the estuary of Patuxent River, both of which are at sea level, would naturally be expected to show a symmetrical location of divides. Notwithstanding the fact that there is little in the character of the materials, position of the beds, or comparative proximity to tide water to cause the streams entering Patuxent River to cut more rapidly than those entering Chesapeake Bay, the divide between the river and the bay is as a whole considerably nearer the latter, especially in the southern portion of the quadrangle. This asymmetry of the divide is believed to be due to the rapid erosion of the shore line from Herring Bay southward, which has caused the cliffs to recede inland and thus cut off the mouthward portions of the streams that empty into the bay throughout this region. The lower courses of many of these streams have been removed so rapidly that stream erosion has not been able to keep pace with the wave erosion, so that now the weaker streams cascade into the bay from the cliffs above. The divide between the streams entering the Potomac and those entering the Patuxent lies well over toward the Patuxent valley, but as the tributaries of the Patuxent are shorter and more direct than those of the Potomac erosion is now more vigorous in the former basin than the latter, with the result that the divide is being pushed rapidly southwestward toward Potomac River.

*Tide-water estuaries.*—The lower courses of almost all the larger streams emptying into Chesapeake Bay have been converted into estuaries through a submergence which has permitted tide water to pass up the former valleys of the streams. In the early development of the country these estuaries were of great value, as they are navigable for many miles from their mouths and thus afford means for ready transport of the produce of the region to market. Even the advent of railroads has not rendered them valueless and much grain and fruit are now shipped to market on steamers and small sailing vessels which traverse these estuaries. Steamboats from Baltimore pass up the Patuxent as far as Leon, and freight sailing vessels go even higher up the stream. South and West rivers are similarly navigable for several miles from the bay. Chesapeake Bay and its tributary estuaries also furnish good fishing grounds, and during certain seasons they are frequented by wild waterfowl in such numbers that they have long been known to sportsmen as among the finest hunting grounds in the country.

The channel of the portion of Patuxent River included within this quadrangle is about 16 feet in depth in the southern portion and shallows gradually to Leon, which is the head of steamboat navigation. Anacostia River is not navigable above the bridge between the Navy-Yard and Anacostia. South River has a depth of about 16 feet at its mouth, which increases to 21 feet near Ferry Point, and then decreases gradually to the upper portion of the estuary. The West River channel varies in depth from 16 feet at its mouth to 11 feet near the head of the estuary, where navigation ceases.

The estuaries of South, West, Anacostia, and Patuxent rivers are bordered in many places by nearly vertical bluffs, 10 to 60 feet in height, or by slopes which rise to the height of the broad upland within half a mile from the river. That the present estuaries alone have not produced the bluffs which border them is very evident from the fact that in most places they are now doing little erosive work themselves. The small waves which are produced at times of strong winds are the only notable agents of erosion. Such waves are frequently able to remove the finer débris which accumulates as talus at the foot of the cliffs, especially in the early spring, but are not strong enough to do much undercutting. In general the present cliffs represent the bluffs that bordered the valleys of streams whose flood plains as well as channels are now covered by the estuarine waters.

The water in the estuaries is fresh or very slightly brackish, and ebbs and flows with the tide. There is seldom any distinct current to be noticed and such as is seen is due to the incoming or outgoing tide and appears to be nearly as strong when moving upstream as when moving in the opposite direction.

*Minor streams.*—The estuaries that form so prominent a feature in the eastern half of the quadrangle receive the waters of numerous minor streams. At the head of each estuary there is a small stream which in almost every case is very much shorter than the estuary itself. Some of the smaller estuaries, particularly those in the vicinity of South and West rivers and Herring Bay, continue as such almost to the sources of the tributary streams. Hunting Creek is an example of this type. Parker and Fishing creeks, which enter Chesapeake Bay in the southeastern portion of the quadrangle, are occupied by swamps in their lower portions and are now cut off from free communication with the waters of the bay by sand bars which have formed across their mouths. These swamp lands indicate that the estuaries which formerly occupied the lower courses of these streams have been obliterated by detritus washed in from the surrounding uplands. The same tendency to stream filling is shown along the margin of the other estuaries mentioned above.

# DESCRIPTIVE GEOLOGY.

## STRATIGRAPHY.

### GENERAL DESCRIPTION.

The geologic formations represented in the Patuxent quadrangle range in age from Archean to Recent. Deposition, however, has not been continuous and many gaps occur, that between the Archean and Jurassic (?) covering a very long interval of time. None of the larger geologic divisions since Jurassic (?) time is entirely unrepresented. Periods when there was deposition over part or the whole of the region were separated by other periods of greater or less duration in which the entire region was above water and erosion was active. The deposits of all the periods except the Archean and Pleistocene are similar in many respects. With a general northeast-southwest strike and southeast dip, each formation disappears by passing under the next later one. In general also the shore line during each successive submergence evidently lay a short distance southeast of the position it occupied during the previous submergence. There are a few exceptions to this, however, that will be noted in the descriptions which follow. The traveler passing from northwest to southeast crosses the outcrops of the formations in the order of their time of deposition. The general sequence is shown in the following table:

*Geologic formations in the Patuxent quadrangle.*

| System. | Series. | Group. | Formation. |
|---|---|---|---|
| Quaternary | Pleistocene | Columbia | Talbot.<br>Wicomico.<br>Sunderland. |
| Tertiary | Pliocene (?) | | Lafayette. |
| | Miocene | Chesapeake | Choptank.<br>Calvert. |
| | Eocene | Pamunkey | Nanjemoy.<br>Aquia. |
| Cretaceous | Upper Cretaceous | | Monmouth.<br>Matawan.<br>Magothy. |
| | Lower Cretaceous | Potomac | Raritan.<br>Patapsco. |
| Jurassic (?) | | Potomac | Arundel.<br>Patuxent. |
| Archean | | | Granite gneiss. |

## ARCHEAN ROCKS.

### GRANITE GNEISS.

Granite gneiss occupies small areas in the vicinity of Riggs Mills and along Sligo Branch, in the extreme northwestern portion of the quadrangle.



It has been described by Arthur Keith in the Washington folio, as follows:

The rock is remarkably uniform in appearance and has a prevailingly gray color—dark bluish gray where fresh, and yellowish or greenish gray where weathered. The rock has a rather fine and very uniform texture. It is composed, for the most part, of quartz, orthoclase, plagioclase, muscovite, and biotite. With these chief constituents are frequently seen small amounts of garnet, chlorite, hornblende, tourmaline, and pyrite. The principal exceptions to the even texture of the granite gneiss are the round balls and eyes of quartz and the knots and layers of chlorite and pyrite. These can generally be found in good exposures of the rock, and the quartz is conspicuous on weathered surfaces in particular.

The minerals of the granite gneiss have a marked parallel arrangement, in places more, and in places less, but always in some degree. This is the result of metamorphism during deformation, the original rock having been granite. Where the recrystallization of the minerals parallel to one another is far advanced, the rock is a gneiss. Large areas exist, however, in which the schistose planes are not well developed, and even in the most schistose masses portions retain much of their original character in spite of alteration. The formation is therefore termed granite gneiss, as presenting both the original and secondary characters.

The metamorphosing forces which rendered the granite schistose were most effective along two belts which coincide with synclines east of Great Falls and of Washington. At similar situations in sedimentary rocks outside of this region close crumpling and schistosity are found, and the same phenomena appear in the mica gneiss and mica schist near Great Falls. The granite gneiss does not appear immediately along the synclinal axis in that vicinity, but schistosity becomes more pronounced in approaching the axis, until even a second system appears, cutting through and obscuring the earlier planes. The whole rock mass clearly shows extreme deformation. Under the tremendous stresses the round balls of quartz were in places mashed into eyes and lenticular layers. The greatest metamorphism resulted in layers which are now siliceous mica schists. In the latitude of Washington the alteration of the granite is greater than anywhere else in this region, and toward both the north and the south in this belt the schistosity steadily decreases and the rock has a more and more granitic aspect. Toward the south the rock also becomes gradually coarser and less micaceous. These changes are equally clear in the rock mass and on the smallest scale. Under the microscope the fractures, the dislocation of minerals, and the growth of new minerals can everywhere be traced.

From the fact that the formation was granite, its eruptive nature can be inferred. This is also shown in detail by the inclusion of foreign fragments, which appear in many places near the borders of the mica gneiss, and also in other situations through the body of the formation. These inclusions are usually banded and identical in appearance with the mica gneiss. Some of the inclusions show no banding, but resemble the fine granitic layers of the mica gneiss. The presence of narrow tongues of the granite gneiss in the mica gneiss points to an eruptive nature for the granite gneiss, but the great metamorphism has so obscured the contacts that they are not conclusive. A somewhat later date than the main intrusion is perhaps possible for some of the granite-gneiss bodies in which the amount of schistosity is small. In several places [adjoining the Patuxent quadrangle], for instance west of Annandale and southwest of Bethesda, the contacts of the massive and schistose granite are sharp, suggesting that the massive granites are intruded into the other. At Fourmile Run, above Arlington, also, a massive granite cuts through the beds of schistose granite. These more massive bodies may be part of the granite gneiss of slightly later age, or may be of the age of the biotite granite, which is considerably younger.

The disintegration of the granite gneiss by weathering is usually complete at the surface, so that fresh rock can be found only on the steeper slopes near the stream cuts. After the decomposition of the feldspathic materials the rock becomes a crumbling mass. Complete decomposition results in a stiff red clay mixed with a considerable proportion of sand and mica. The deep road cuts between Chevy Chase and Washington exhibit this process finely. Soils of the granite are light and well drained; on moderate slopes they are fertile, unless exposed to drought, but on the higher Plateau surfaces they are leached and poor.

## JURASSIC (?) SYSTEM.

### *POTOMAC GROUP.*

The Potomac group of the Coastal Plain consists of highly colored gravels, sands, and clays which outcrop along a sinuous line from New York to Richmond, passing near the cities of Philadelphia, Wilmington, Baltimore, and Washington. The Potomac deposits are of great value because of the excellent brick clays which they contain. All four of the formations which have been recognized as composing this group are represented within the Patuxent quadrangle. As stated in the descriptions which follow, the two lower formations are here tentatively assigned to the Jurassic system; the Patapsco and Raritan are considered Lower Cretaceous.

### PATUXENT FORMATION.

*Areal distribution.*—The Patuxent formation has a very inconsiderable development at the surface in the Patuxent quadrangle, although it presumably underlies the entire region. Its outcrops are confined entirely to the northwestern portion of the quadrangle, where they occur about Washington and north and west of Anacostia River. In its wider distribution the formation has been recognized in discontinuous outcrops extending from Indian Head, on Potomac River, to Anacostia and Washington and thence northeastward through Laurel, Relay, Baltimore, Havre de Grace, Northeast, and Elkton, to the Delaware boundary. Certain deposits in Virginia are also referable to this formation.

*Lithologic character.*—The materials composing the Patuxent formation are extremely variable, although prevailingly arenaceous. Buff and light-colored sands, both fine and coarse, predominate, while beds and lenses of clays and gravels occur less commonly. The sandy strata, which usually contain considerable amounts of kaolinized feldspar and are therefore an arkose, were called by Rogers "feldspathic sandstone." The sands are in many places cross-bedded, and with the gravels are here and there indurated by oxide of iron to form ferruginous sandstones. 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 lignitic in places, and have yielded many impressions of fossil leaves.

The following section exposed in the northwestern part of Washington, just beyond the borders of this quadrangle, is characteristic of the formation:

*Section in northwestern part of Washington, D. C.*

| | Feet. |
|---|---|
| SUNDERLAND: | |
| Red loam | 2 |
| Stratified gravels, sands, and clays | 23 |
| PATUXENT: | |
| Coarse white arkosic pebbly sand, some lignitic; small pellets of white clay, and a lens of light greenish-drab sandy clay 5 feet in thickness. The strata show both horizontal and cross bedding. Amount exposed | 15 |

*Paleontologic character.*—The organic remains of the Patuxent formation are neither plentiful nor varied. No animal remains have thus far been found in deposits of this age within the Patuxent quadrangle, but a teleost fish has been reported from beds of apparently the same age on James River in Virginia. Plant remains are much more numerous and include thallophytes, equiseta, conifers, monocotyledons, and a few primitive types of dicotyledons. Of these remains the more generally observed are the lignitized and silicified trunks of conifers and cycads. During the excavating for the new reservoir in Washington a silicified conifer trunk 50 feet in length and several feet in diameter was found in beds belonging to the Patuxent formation. Another similar trunk about 4 feet in diameter was found in the vicinity of the Maryland Agricultural College.

*Name and correlation.*—The Patuxent formation received its name from Patuxent River, in the basin of which the deposits of this horizon 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 on the basis of unconformities and fossil content (Clark and Bibbins, Jour. Geol., vol. 5, 1897, pp. 479-506).

The presence of dicotyledonous plants not known positively to exist earlier than the Cretaceous has led paleobotanists to regard the Patuxent as Lower Cretaceous. Fontaine, in his study of the Patuxent flora, states that there is an "overwhelming percentage of Jurassic types," although he refers the Potomac flora as a whole to the Cretaceous. As will be shown later, the Patuxent formation lies unconformably beneath the Arundel, in which vertebrate remains of Jurassic types have been discovered. It would thus seem that the evidence furnished by vertebrate paleontology and paleobotany is not in strict harmony. Clark and Bibbins are inclined to regard the evidence furnished by the fossil vertebrates as being perhaps more reliable for correlation and to regard the primitive dicotyledons found in the Patuxent as possibly arising in times prior to the Lower Cretaceous. Until more positive information can be obtained they are inclined to refer the Patuxent tentatively to the Jurassic. The formation probably represents a part of the Neocomian-Albian series of the European geologists.

*Thickness.*—The observed thickness ranges from a few feet to 340 feet, increasing toward the east. On the basis of well data the estimated maximum thickness is about 500 feet.

*Stratigraphic relations.*—The Patuxent formation in this quadrangle overlies the granite gneiss, of Archean age, and is overlain unconformably by the Arundel formation, which also is referred tentatively to the Jurassic. In many places where the Arundel has been removed by erosion the Patuxent is overlain unconformably by clays, sands, and gravels belonging to the Columbia group. The general strike of the Patuxent formation in this quadrangle is from northeast to southwest. Toward the north, however, the strike has a progressively more and more pronounced eastward trend, ranging from north-northeast south of Washington to east-northeast at the head of Chesapeake Bay. A well-defined change in strike is shown at the head of the bay and another at or near Washington.

The dip of the Patuxent, as well as of the overlying beds of the Potomac group in Maryland, ranges in direction from east-southeast in its more southerly exposures to south-southeast farther north. The normal dip of the basal beds of the formation reaches about 60 feet to the mile. In the vicinity of the fall line, which is toward the landward margin of the Patuxent outcrop, the dip of the basal beds is considerably greater than this. Southeast of Washington it ranges from 50 to 75 feet, but near the fall line it amounts to about 90 feet to the mile.

### ARUNDEL FORMATION.

*Areal distribution.*—The outcrops of the Arundel formation within the Patuxent quadrangle are confined entirely to its northwestern portion, in and about Washington, but it is believed to underlie the greater portion of the quadrangle south and east of Anacostia River. In its wider distribution the formation occupies a comparatively narrow, irregular, and much interrupted belt extending from Washington to Bush River, near the head of Chesapeake Bay. There are also outliers of less importance to the north and south of the general outcrop. At Capitol Hill, Washington, a well boring, after passing through about 50 feet of Recent and Pleistocene materials, penetrated 131 feet of exceedingly tough drab and highly colored lignitic clays which apparently belong to the Arundel formation. Beneath these clays the boring passed into the Patuxent sands and gravels. Clays probably belonging to the Arundel formation were encountered in an excavation for a deep sewer in the vicinity of Anacostia bridge.

*Lithologic character.* — The materials composing the Arundel formation are diverse in lithologic character. The deposit is composed, in great measure, of large and small lenses of drab and iron-stained clays which in many places contain concretions, flakes, or ledges of earthy iron carbonate and cellular limonite. Iron pyrite and gypsum occur less commonly. The clays may be either laminated, carrying more or less sand, or massive, with surfaces exhibiting slickensides. Logs of coniferous lignite, usually deposited in a horizontal position and greatly compressed, are found embedded within the formation. These logs are in places massed in well-defined beds of such thickness and extent as to be of local use to the miners for fuel. Occasionally large stumps are discovered standing buried in the position in which they grew, with the roots and trunks fossilized by iron carbonate and iron sulphate. Seeds of plants are found near some of these beds. Locally the clay is charged with comminuted lignite, when it is termed "charcoal clay" or "charcoal ore." Here and there this "charcoal clay" bears osseous remains. Near Muirkirk, a short distance north of the Patuxent quadrangle, Hatcher obtained from it dinosaurian and other organic remains. Where the Arundel formation has been exposed to the atmosphere the carbonate ores have at some places changed to the hydrous oxides of iron to a considerable depth. Where this has occurred, clays which were originally drab colored have become red or variegated. Along the western margin of the formation the material becomes arenaceous and locally consists of lenses of sand.

The section exposed at the Muirkirk iron mine, where the best dinosaurian remains thus far obtained from this formation were found, is as follows:

*Section at iron mine, Muirkirk, Md.*

| | Feet. |
|---|---|
| RECENT: | |
| Surface wash, consisting of loam and gravel | 10 |
| PATAPSCO: | |
| Sands and gravel, indurated in places by iron oxide and containing silicified trunks of conifers and cycads | 10 |
| Massive and stratified, mottled and variegated clays and sandy clays with redeposited nodules of iron carbonate and some limonite, pebbly at base, flanking the subjacent member | 5 to 15 |
| ARUNDEL: | |
| Massive blue clay with flakes and nodules of iron carbonate and containing bones and teeth of dinosaurs at base | 20 to 40 |
| Highly lignitic lens of clay ("charcoal ore") | 2 |
| Tough blue clay containing iron carbonate | 15 |
| PATUXENT: | |
| White sand; amount exposed | 10 |

*Paleontologic character.*—The fossil flora of the Arundel formation includes thallophytes (?), ferns, cycads, conifers, monocotyledons, and dicotyledons. By far the most common of these are the conifers, with whose lignitized trunks the clays are, in places, densely packed, forming local beds of lignite. That these are largely sequoian trunks is suggested by the common association with them of the casts of sequoian cones preserved in iron carbonate. Leaf impressions are also present in the iron ores.

The animal remains, while nowhere abundant, represent a wide variety of forms. They include worm or insect borings, pelecypods, gasteropods, dinosaurs, turtles, and crocodiles. The Dinosauria, of which a number of species have been recognized, greatly predominate. One of them was about 40 feet in length. The occurrence of these animals points to the probable Jurassic age of the Arundel formation.

*Name and correlation.*—The Arundel formation received its name from Anne Arundel County, where the deposits of this horizon are typically developed and well exposed.

Although dicotyledonous plants have been found in the Arundel deposits, yet the presence of saurian remains that seem to belong to undoubted Jurassic types has caused Clark and Bibbins to refer this formation, together with the Patuxent, which underlies it, tentatively to the Jurassic, as stated in a preceding section.

*Thickness.*—The maximum thickness of the Arundel is 125 feet or more and the formation thins out and disappears in some areas. At Washington, as shown in the well boring at Capitol Hill, if the reference of this material to the Arundel formation is correct, the thickness is about 130 feet.

*Stratigraphic relations.*—The Arundel formation of this quadrangle overlies the Patuxent and is overlain by the Patapsco, with both of which it is unconformable. Where the Patapsco has been removed by erosion the Arundel is overlain unconformably by clay, sands, and gravels belonging to the Lafayette and Columbia deposits. The strike and dip of the Arundel formation are approximately the same as those of the Patuxent. The usual dip is 40 to 50 feet to the mile, but there is a well-marked increase near the fall line, where the average is about 72 feet to the mile. At Washington it is 66 feet to the mile.

CRETACEOUS SYSTEM.

LOWER CRETACEOUS SERIES.

*POTOMAC GROUP—Continued.*

PATAPSCO FORMATION.

*Areal distribution.*—The Patapsco has a more extended development within this quadrangle than either of the two preceding formations. Its outcrop is confined to the northwestern portion of the quadrangle, extending from Anacostia northeastward to the boundary and occurring in narrow bands near the headwaters of a few of the streams south of Anacostia. To the southeast of this outcrop it is supposed to extend over the entire quadrangle, underlying all the formations of later age. 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.

*Lithologic character.*—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 arenaceous material in the vicinity of clay beds is indurated to a conglomerate or rough, irregular, pipelike concretionary mass 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 and in some places containing iron ore and leaf impressions. 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 various horizons.

*Paleontologic character.*—The Patapsco formation contains a rich flora of ferns, cycads, conifers, monocotyledons, and dicotyledons. The dicotyledonous plants still constitute a minor element as compared with the other types of vegetation represented. The range of genera and species is limited, the grade of organization low, and the number of individuals scarcely greater than in the preceding formation. The fauna of the Patapsco consists of a few molluscan shells and a single dinosaurian limb bone. This latter fossil, which was found at the surface of the formation, was much worn and may have been redeposited from the Arundel.

*Name and correlation.*—The Patapsco formation received its name from Patapsco River, in whose valley it is typically exposed.

The presence of primitive dicotyledonous types together with other plant remains early led the paleobotanists to refer the Potomac beds as a whole to the lower Cretaceous. Later, work by Clark and Bibbins showed that the deposits which had been included under the name Potomac consisted in reality of four distinct formations. The lower two carry a Jurassic fauna and types of dicotyledons still more archaic than those found in the upper two formations. This led to the separation of the two lower formations, the Patuxent and the Arundel, from the two upper, the Patapsco and the Raritan. The former have been referred tentatively to the Jurassic; the latter are still referred to the Lower Cretaceous.

*Thickness.*—The thickness of the Patapsco is somewhat variable, gradually increasing to the southeast. Within this quadrangle the outcropping thickness is about 100 feet. In some places, east of its outcrop, the formation is estimated to have a thickness of about 200 feet.

*Stratigraphic relations.*—The Patapsco formation elsewhere overlies the Patuxent or the Arundel formation of the Potomac group, and in this region it probably occupies similar relations, although the few deep-well sections are not complete enough to determine certainly the character of the contact with the underlying beds. It is overlain unconformably by the Raritan formation for the most part, although here and there in the region of its outcrop it is covered by Pleistocene deposits belonging to the Talbot and Wicomico formations. The general strike of the Patapsco corresponds practically to that of the formations which lie beneath it. The normal dip of the basal beds is southeastward at the rate of 35 to 40 feet to the mile, but the dip, like that of the preceding formations, increases toward the fall line.

RARITAN FORMATION.

*Areal distribution.*—In its wider distribution the Raritan formation has been recognized from Raritan Bay, New Jersey, to the basin of Potomac River, having a more extensive distribution than any other member of the Potomac group. In the northwestern portion of the Patuxent quadrangle it is represented by a narrow outcrop which crosses the area in a sinuous line from northeast to southwest and is also present near the headwaters of some of the creeks along the western margin of the quadrangle. It dips under the overlying strata and is believed to extend over the entire area of the quadrangle beneath the younger formations.

*Lithologic character.*—The Raritan consists of variable materials similar to those composing the Patapsco formation except that, in general, the clays are not so highly colored. White and buff sands; stratified sandy clays, light chocolate in color, in places containing leaf impressions; light-colored argillaceous sands and sandy clays ("fuller's earth"); and white, yellow, drab, bluish drab, and variegated clays all occur in deposits of this age. The drab clays are here and there lignitic and pyritiferous, and in places exhibit partings of sand indurated with mammillary limonite. Ledges of sandstone, indurated by iron oxide or silica, are common. The light-colored sands show in many localities large blotches of red ocher, locally designated as "paint pots." 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 less highly colored.

*Paleontologic character.*—Both animal and plant remains have been found in the Raritan formation, but as in the case of other formations of the Potomac group, the known fauna 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 last-named forms being particularly conspicuous and 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 is sharply contrasted with that of the Patapsco formation.

*Name and correlation.*—The formation receives its name from Raritan River, New Jersey, in the basin of which it is typically developed. It includes the deposits long called the Plastic clays by the New Jersey Geological Survey. On the basis of the plant fossils, which show a marked resemblance to forms of Lower Cretaceous age in Europe, the formation has been regarded as representing in part the Neocomian-Albian series.

*Thickness.*—Within this area of outcrop in the Patuxent quadrangle the Raritan formation is relatively thin in comparison with its thickness farther northeast. The estimated maximum thickness toward the extreme eastern margin of the belt of outcrop in this quadrangle is about 100 feet. The thickness of the formation seems to increase toward the southeast beyond the line where it disappears beneath later deposits.

*Stratigraphic relations.*—The Raritan unconformably overlies the Patapsco formation, and is separated from the overlying Magothy by another marked unconformity. In the region of its outcrop, Pleistocene deposits of the Talbot, Wicomico, and Sunderland formations 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.

UPPER CRETACEOUS SERIES.

MAGOTHY FORMATION.

*Areal distribution.*—The Magothy formation outcrops in discontinuous areas in the Patuxent quadrangle, extending from the Patuxent River valley in the vicinity of Priest Bridge southwestward to the Potomac River valley just beyond Congress Heights. It does not outcrop in a continuous belt because of an overlap of the Matawan, which is in some places sufficient to bring that formation in immediate contact with the Raritan. An occurrence of this kind can be seen about three-fourths of a mile west of Brightseat. The best exposures lie from half a mile to 3 miles west of Priest Bridge and along the west slope of Good Hope Hill from St. Elizabeth's to the junction of Benning and Bowen roads on the District line.

*Lithologic character.*—The Magothy formation is composed of extremely varied materials and may change abruptly in character both horizontally and vertically. Loose sands of light color are the most prominent constituents. These sands usually show fine laminations and locally considerable cross-bedding. The sand consists of coarse, rounded to subangular quartz grains which range in color from pure white to a dark ferruginous brown. At many places lenses or bands of brown sand occur within the lighter colored sands. Normally the deposits of sand are loose, yet locally the iron derived from this and adjacent formations has firmly cemented the grains together to form an indurated iron sandstone or conglomerate. A thin ledge of such a sandstone near the Catholic Church west of Priest Bridge forms a small waterfall in a tributary of Patuxent River. Just below Overlook Inn, on East Washington Heights, there is a ledge of massive brown sandstone of this character. Less commonly the Magothy quartz sands are cemented together with silica to form very hard siliceous sandstones, which from their lithology can scarcely be distinguished from siliceous sandstones of Paleozoic age that are quite unlike the usual Coastal Plain materials. The very hard white sandstone rocks well exposed on either side of the public road about $1\frac{1}{4}$ miles north of Collington represent this phase.

The argillaceous character of the Magothy is very prominent in some localities, although it is usually subsidiary to the arenaceous phase. The clay commonly occurs as fine laminæ alternating with the sand layers. Drab is the characteristic color of the Magothy clay, but here and there the presence of considerable vegetable remains renders it black. The vegetable material may be finely divided or may occur in the form of large pieces of lignite. Thus far no bright-colored clays have been recognized in the Magothy deposits.

The Magothy can usually be differentiated from the underlying Raritan formation by its lack of massive beds of brightly colored variegated clay, and by the greater variability in the character of its materials. It can be more easily distinguished from the overlying Matawan by the almost complete absence of glauconite (although small pockets of green sand have been found in the Magothy at a few localities), by its lack of homogeneity, and by its variations in color. Moreover, the Matawan in Maryland usually contains considerable amounts of mica in small flakes, whereas the Magothy contains little mica.

*Paleontologic character.*—In this quadrangle the only organic remains thus far recognized in the Magothy are leaf impressions in the drab clays that occur in thin laminæ alternating with layers of sand. Although most of these are fragmentary, many identifiable forms are present. At Cliffwood Point, on the south shore of Raritan Bay, New Jersey, beds of this formation have yielded a considerable flora and a marine fauna. The flora studied by Berry (Bull. New York Bot. Gard., vol. 3, No. 9, 1903, pp. 45–103; Bull. Torr. Bot. Club, vol. 31, 1904, pp. 67–82; vol. 32, pp. 43–48; Ann. Rept. State Geol. New Jersey for 1905, pp. 135–172) is notably varied, over 100 species having been described. The flora presents many points of similarity to that of the Raritan, yet it contains 49 species that are peculiar to the Magothy in this country, one or two of the number having been found in Europe. The most common fossil plants of that locality are the imperfectly petrified cones of *Sequoia gracillima*. Other common species are *Cunninghamites squamosus*, *Dammara cliffwoodensis*, and *Sequoia Reichenbachi*. Berry and Hollick state that the flora of the "Cliffwood beds" shows Cenomanian characteristics.

The animal remains described by Weller (Ann. Rept. State Geol. New Jersey for 1904, pp. 133–144) from the Magothy at Cliffwood Point were found in smooth concretionary nodules in a clay bed or lying loose on the beach, where they were left by the erosion of the clay beds that originally contained them. The fauna is characterized by the presence of great numbers of crustacean remains. Some portion of a crab seems to have been the nucleus about which the nodules were formed in almost every instance. Pelecypods, gasteropods, and cephalopods also occur. The most abundant forms are the following pelecypods: *Trigonarca* sp., *Pteria petrosa*, *Nuculana protexta* (?), *Yoldia evansi*, *Isocardia cliffwoodensis*, *Veleda lintea*, *Corbula* sp., and among the Crustacea *Tetracarcinus subquadratus*. These are of considerable importance, for, with the exception of a few forms 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.

*Name and correlation.*—In 1893 Darton (Am. Jour. Sci., 3d ser., vol. 45, pp. 407–419) 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 the beds were mainly included in the Raritan, the fossil plants described from 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, while those in the region of Raritan Bay, under the name Cliffwood beds, were by some geologists included in the Matawan on account of the presence of glauconite and the great percentage of post-Raritan plants and marine invertebrates, and by others were placed in 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 (Am. Jour. Sci., 4th ser., vol. 18, 1904, pp. 435–440) to the Magothy formation as defined by Darton for the Maryland area. Uhler, in several articles (Trans. Maryland Acad. Sci., vol. 1, 1888–1892), named a group of beds the Alternate sand series. Most of these are now placed in the Magothy. On the basis of the flora found in the beds at Cliffwood the formation is provisionally correlated with the Cenomanian of Europe.

*Thickness.*—Within the Patuxent quadrangle the maximum thickness of the Magothy formation is about 40 feet, but in its wider extent the thickness is extremely variable, reaching a maximum of about 100 feet. This variability is due to greater deposition in some regions than in others and also to the removal of considerable Magothy material in certain areas.

*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 irregular, indicating a considerable erosion interval between the times 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 not so plainly marked; at many places these beds seem to be conformable. Indications of an erosion interval may be seen in some good exposures, however, and in the area of the Patuxent quadrangle between Patuxent and Potomac rivers there is a marked unconformity of overlap. A short distance northeast of the District of Columbia line the Magothy is entirely lacking, its absence being due to an overlap of the Matawan, which rests upon the Raritan. Farther south it again makes its appearance. In the region of its outcrop the formation is in many places overlain by Pleistocene deposits.

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

#### MATAWAN FORMATION.

*Areal distribution.*—In this quadrangle the Matawan formation is found in a sinuous line extending from the head of South River southwestward to Henson Creek. Throughout this area it is exposed along the margins of the streams, but is covered up by younger material as it passes under the divides. The Matawan resembles the other Cretaceous formations in having a dip to the southeast which carries it beneath later deposits. It undoubtedly underlies the entire quadrangle to the southeast of the line of outcrop. In its broader distribution through the Coastal Plain, the Matawan formation extends as a continuous series of outcropping deposits from Raritan Bay to Potomac River.

*Lithologic character.*—The Matawan consists chiefly of glauconitic sand intimately mixed with dark-colored clay, while all through the material small flakes of mica are commonly found. In some places the deposits consist almost entirely of black clay; in others, particularly where the upper beds are exposed, the arenaceous phase is predominant and the beds may consist entirely of sands varying in color from white to dark-greenish black. Where the glauconite decomposes, the iron oxidizes and the materials are stained reddish brown, and may even become firmly indurated by the iron oxide. Iron pyrite is also a common constituent and in places a small layer of gravel lies at the base of the formation. Although the Matawan contains varied materials it is much less variable than formations of the Potomac group or the Magothy formation, and throughout its extent in Maryland can generally be readily recognized by the prevailing dark-colored micaceous glauconitic sand of which it is chiefly composed.

*Paleontologic character.*—Although the Matawan formation as a whole can not be regarded as extremely fossiliferous, yet it contains bands in which organic remains are crowded together in great abundance. Such a band occurs in the cutting where the Chesapeake Beach Railway crosses Central avenue just east of the District line. In New Jersey as well as in Maryland the formation has yielded a varied fauna of foraminifers, pelecypods, gasteropods, scaphopods, and ammonites (Bull. Geol. Soc. America, vol. 8, 1897, pp. 330–331).

*Name and correlation.*—The formation has received its name from Matawan Creek, a tributary of Raritan Bay, in the vicinity of which the deposits of this horizon are extensively and typically developed. It was proposed by W. B. Clark in 1894 (Jour. Geol., vol. 2, pp. 161–177), 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 the beds represent a part of the Senonian of Europe.

*Thickness.*—The maximum thickness of the Matawan occurs along North Run and is about 45 to 50 feet. From this run the formation gradually thins toward the southwest until it is not more than 30 feet thick in the exposures along Henson Creek. Like many other Coastal Plain formations, the beds thicken as they dip beneath later deposits, but the records of wells which have penetrated these formations in the eastern part of the quadrangle are too general to permit the determination of the amount of thickening.

*Stratigraphic relations.*—In places a marked unconformity separates the Matawan from the underlying Magothy formation, but it is conformably overlain by the Monmouth. The separation between the Matawan and Monmouth is made chiefly on the basis of change in lithologic character, but in part on that of the fossil contents. Although some organic forms range through both the Matawan and Monmouth, yet each formation has a few characteristic forms, the assemblage in each being on the whole fairly distinctive. The formation strikes from northeast to southwest and dips southeastward at about 25 feet to the mile.

#### MONMOUTH FORMATION.

*Areal distribution.*—Within this quadrangle the Monmouth formation has only a slight development. It outcrops in the vicinity of Collington and eastward from that place to Patuxent River and thence southward along the banks of the stream to the vicinity of Governor Bridge. It also occurs in the valleys of the headwaters of South River. The Monmouth dips to the southeast and is believed to underlie the Eocene and Miocene deposits to the southeast of its outcrop. In its wider distribution the formation has been recognized by outcrops in a zone extending from the northeastern portion of this quadrangle to Raritan Bay in New Jersey.

*Lithologic character.*—The formation is prevailingly arenaceous in character and unconsolidated except where locally indurated by the segregation of ferruginous material derived from the glauconite. The sands composing the Monmouth deposits vary in color from reddish brown to dark green or nearly black. The fresh material always contains considerable glauconite and this gives to the deposits their dark color. In their more weathered portions the sands generally range in color from rich brown to reddish brown, but at some places they are dark gray.

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 Patuxent quadrangle.

*Paleontologic character.*—The Monmouth formation is generally very fossiliferous and the forms are usually well preserved. They consist of foraminifers, pelecypods, gasteropods, and cephalopods. Among the most abundant are *Exogyra costata* Say, *Gryphæa vesicularis* Lamarck, *Idonearca vulgaris* Morton, *Cardium perelongatum* Whitney, and *Belemnitella americana* Morton. They are typical Upper Cretaceous species.

*Name and correlation.*—The name of the formation was first proposed in 1897 by W. B. Clark (Bull. Geol. Soc. America, vol. 8, pp. 315–358), when it was decided to combine in a single formation the deposits formerly included in the Navesink and Redbank formations. This name was suggested by Monmouth County, N. J., where the deposits of this horizon are characteristically developed. It was employed for the term Lower Marl bed of the earlier workers in New Jersey. On the basis of its marine fauna it is correlated with the Upper Senonian of Europe.

*Thickness.*—The maximum thickness of the Monmouth formation along its outcrop in the area of the Patuxent quadrangle is from 40 to 50 feet. In northern New Jersey it is about 200 feet thick, but it steadily decreases in thickness along the strike southwestward, until it finally disappears as an outcropping formation in the north-central part of this quadrangle.

*Stratigraphic relations.*—The Monmouth is conformable with the underlying Matawan and with the Rancocas, which overlies it on the Eastern Shore of Maryland and in Delaware and New Jersey. Within the Patuxent quadrangle it is overlain unconformably by Eocene and Pleistocene deposits. The Monmouth is readily distinguished from the Matawan, as it lacks the darker colored micaceous sands and marls of that formation. From the Rancocas it is distinguished by the great predominance of reddish-brown sand. The Aquia contains much more marl. The strike of the Monmouth formation is from northeast to southwest, and the dip is toward the southeast at the rate of about 25 feet to the mile.

### TERTIARY SYSTEM.

#### EOCENE SERIES.

##### *PAMUNKEY GROUP.*

##### AQUIA FORMATION.

*Areal distribution.*—Within this quadrangle the Eocene is represented by both the Aquia and Nanjemoy formations. The Aquia is exposed throughout a broad belt, 10 miles or more in width, extending from the northeast corner of the quadrangle southwestward as far as Western Branch of Patuxent River. Beyond the latter point the formation is buried beneath later deposits and outcrops only in a thin band near the headwaters of the creeks along the western margin of the quadrangle. The Aquia formation dips to the southeast and is supposed to underlie the younger Eocene and Miocene beds throughout the southern portion of the area. In its wider distribution it extends from Virginia northeastward across Maryland to Delaware.

*Lithologic character.*—This formation consists usually of loose sand in which there is a considerable admixture of glauconite, the latter in places making up the body of the formation. Where the material is fresh it ranges in color from a light blue to a very dark green, but in regions where it has been exposed to weathering for a considerable time it has assumed a reddish-brown to light-gray color. The beds are in most places unconsolidated, although locally some have become very firmly indurated by oxide of iron. Small, well-rounded pebbles coated with iron oxide occur in a few places near the base of the formation. These gravels are typically exposed about a mile northwest of Westphalia and in numerous places about Collington. About half a mile southwest of Collington this pebble layer, which is about 2 feet in thickness, has been cemented by ferruginous material into a hard, compact rock that has been used for building purposes. Where the Aquia deposits have been exposed to the action of the atmosphere, as on the tops of divides, the iron present in the glauconite has been segregated to form bands of iron ore. These iron bands are very numerous and in places attain a thickness of 1 to 2 feet. Several exposures of the Aquia formation, showing these iron segregations, are to be seen in the region of Rutland and Riverview. Near Upper Marlboro there are a few ledges of indurated marl from which numerous species of fossils have been obtained. This is one of the earliest and best known localities for fossils in the Eocene of the Atlantic slope. The following section is exposed:

*Section east of bridge at Upper Marlboro, Md.*

| | Feet. |
|---|---|
| NANJEMOY: | |
| Glauconitic clay | 22 |
| Pink clay, without glauconite or fossils | 22 |
| AQUIA (Paspotansa substage): | |
| Coarse glauconitic sand | 32 |
| Shell marl with *Gibbula glandula, Fissuridea marlboroensis, Lucina aquiana, Diplodonta marlboroensis, Venericardia planicosta* var. *regia, Pteria limula, Cucullæa gigantea, Leda parilis, Nucula ovula* | 2 |
| Indurated ledge with *Turritella mortoni, T. humerosa, Mesalia obruta, Calyptraphorus jacksoni, Panopea elongata, Meretrix ovata* var. *pyga, Dosiniopsis lenticularis, Venericardia planicosta* var. *regia, Crassatellites alæformis, Astarte marylandica, Glycimeris idoneus, Cucullæa gigantea, Leda parilis, Nucula ovula* | 5 |
| Glauconitic sand (known as Bryozoan sand) full of fine fragments of shells accompanied by Bryozoa, echinoid spines, and Foraminifera; and with *Ostrea compressirostra, Gryphæostrea vomer,* and *Platidia marylandica* | 5 |
| | 88 |

*Paleontologic character.*—A great many fossils are to be seen in the outcrops of the Aquia along South and Patuxent rivers and in the valleys of Piscataway, Monmouth, and Nanjemoy creeks in Maryland, and of Potomac and Aquia creeks in Virginia. An idea of the variety of fossils that occur in these localities may be gained by consulting the section above. The fossils of this formation have been described and illustrated in the report on the Eocene issued by the Maryland Geological Survey.

*Name and correlation.*—The formation receives its name from Aquia Creek, a tributary of Potomac River in Virginia, where deposits belonging to this horizon are characteristically developed. This name was proposed by W. B. Clark in 1895 (Johns Hopkins Univ. Circ., p. 3).

The formation is correlated with the lower division of the Wilcox ("Lignitic") of the Gulf region. According to Dall (Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1898, pp. 327–348) it represents a part of the Suessonian of Europe.

*Thickness.*—The Aquia formation is about 100 feet thick in this quadrangle and gradually thickens toward the east, beneath the later formations.

*Stratigraphic relations.*—The Aquia formation overlies the Monmouth unconformably and is overlain conformably by the Nanjemoy formation. Where the Nanjemoy has been removed by erosion it is covered by Miocene, Lafayette, or Pleistocene beds. The formation has a northeast-southwest strike and dips to the southeast at the rate of about 12½ feet to the mile.

*Subdivisions.*—The Aquia formation has been subdivided into two members or substages known as Piscataway and Paspotansa, which are distinguished from each other by their contained fossils.

The Piscataway member was named from Piscataway Creek, Maryland, where it is typically developed. The member is characterized by two well-marked and rather persistent layers of indurated marls. Its thickness somewhat exceeds 50 feet. It is further characterized by a fossil fauna among which are the following forms:

Thecachampsa sericodon (?) Cope.
Synechodus clarkii Eastman.
Odontaspis elegans (Agassiz).
Otodus obliquus (Agassiz).
Pholadomya marylandica Conrad.
Gryphæa vesicularis Lamarck.
Terebratula harlani Morton.
Textularia subangulata D'Orbigny.

The Paspotansa member was named from Paspotansa Creek, Virginia. It consists of a bed of greensand and greensand marl somewhat less than 50 feet thick. Among the characteristic fossils of this member are the following:

Bythocypris subæquata Ulrich.
Pleurotoma harrisi Clark.
Cancellaria graciloides Aldrich var.
Trophon sublevis Harris.
Chrysodomus engonatus (Heilprin).
Calyptraphorus jacksoni Clark.
Discosparsa varians Ulrich.
Membranipora angusta Ulrich.
Textularia gramen D'Orbigny.
Anomalina ammonoides (Reuss).

NANJEMOY FORMATION.

*Areal distribution.*—The Nanjemoy formation is much less extensively exposed in this quadrangle than the Aquia. It is well developed in the headwaters of the streams south of South River and extends thence across the quadrangle toward the southwest in a very circuitous and broken outcrop. In its larger relations it extends from Virginia northwestward through Maryland as far as Chesapeake Bay. On the Eastern Shore it does not outcrop and is so deeply buried by later deposits that it has not yet been recognized with certainty in well borings.

*Lithologic character.*—The Nanjemoy formation consists primarily of greensand, which is in most places highly argillaceous and locally calcareous, with certain layers carrying abundant crystals and crystalline masses of gypsum. The formation contains considerable clay, especially at its base, as shown in the section at Upper Marlboro already given. The following section is fairly typical and characteristic of the glauconitic phase:

*Section in ravine 1 mile south of Thrift, Md.*

| | Ft. | In. |
|---|---|---|
| MIOCENE: | | |
| Lead-colored clay with Miocene fossils | 40 | 0 |
| EOCENE (Nanjemoy-Potapaco substage): | | |
| Dark argillaceous greensand | 7 | 0 |
| Argillaceous greensand, packed with *Venericardia potapacoensis* | 1 | 0 |
| Dark glauconitic clay | 3 | 0 |
| Layer of *Venericardia potapacoensis* | 0 | 8 |
| Greensand with many scattered specimens of *Venericardia potapacoensis* | 3 | 0 |
| Line of concretions | 0 | 6 |
| Glauconitic clay with *Venericardia potapacoensis* | 4 | 0 |
| Dark greensand | 5 | 0 |
| Layer packed with shells of *Venericardia potapacoensis* | 1 | 6 |
| Argillaceous greensand | 1 | 0 |
| Line of concretions | 0 | 6 |
| Argillaceous greensand | 3 | 0 |
| Greensand with *Venericardia potapacoensis* | 1 | 0 |
| Dark glauconitic clay | 3 | 0 |
| Layer of shells of *Venericardia potapacoensis* | 0 | 4 |
| Dark clay with much glauconite. | | |
| | 74 | 6 |

*Paleontologic character.*—A great many fossils are to be seen in the outcrops of the Nanjemoy formation along South and Patuxent rivers, along Piscataway, Mattawoman, and Nanjemoy creeks in Maryland, and along Potomac and Aquia creeks in Virginia. An idea of the abundance of these fossils may be obtained by examining the foregoing section. The fossils of the Nanjemoy formation have been described and illustrated in the report on the Eocene issued by the Maryland Geological Survey.

*Name and correlation.*—The formation receives its name from Nanjemoy Creek, one of the tributaries of Potomac River in Maryland, in whose valley deposits belonging to this horizon are characteristically developed. This name was proposed by Clark and Martin in 1901 (Eocene, Maryland Geol. Survey, p. 64). In correlating the Nanjemoy formation these authors remark as follows (op. cit., p. 89):

> The only conclusion that can be drawn is that the Nanjemoy of Maryland represents such portion of the Chickasawan (Wilcox or "Lignitic") as lies above that represented by the Aquia, while the occurrence of the highly characteristic species, *Ostrea sellæformis*, in the Nanjemoy stage in Maryland, although not so numerously or typically represented as in the still higher strata in central and southern Virginia, points to the possible Lower Claibornian age of the highest beds of the Maryland Eocene.

According to Dall the Nanjemoy represents a part of the Suessonian of Europe.

*Thickness.*—The Nanjemoy is about 100 feet thick in the Patuxent quadrangle and thickens gradually toward the east.

*Stratigraphic relations.*—The Nanjemoy overlies the Aquia conformably, but is overlain unconformably by the Miocene, and in some places along the line of outcrop by deposits belonging to the Lafayette and the Pleistocene. The formation has a northeast-southwest strike and dips toward the southeast at an average rate of about 12½ feet to the mile.

*Subdivisions.*—This formation, like the Aquia, is subdivided into two members or substages, known as the Potapaco and Woodstock.

The Potapaco member is so called from the early name of Port Tobacco (a corruption of the word Potapaco) Creek, one of the Maryland tributaries to Potomac River. It is characteristically clayey, especially in its lower portions. It is about 60 to 65 feet thick and carries the following characteristic fossils:

Cypræa smithi Aldrich.
Solen lisbonensis Aldrich.
(?) Lucina astartiformis Aldrich.
Periploma sp.
Ceiropora micropora Goldfuss.

This member is further subdivided into six zones which, together with their characteristic fossils, are fully discussed by Clark and Martin in the report already cited (Eocene, Maryland Geol. Survey, 1901, pp. 65–66).

The Woodstock member has been named from Woodstock, an old estate situated a short distance from Mathias Point on the Virginia side of the Potomac. This member is characterized by fine homogenous greensands and greensand marls which are less argillaceous than the underlying Potapaco beds. It ranges in thickness from 60 to 65 feet and contains certain characteristic fossils, a few of which are the following:

Pyrula penita Conrad var.
Meretrix lenis (Conrad).
Leda parva (Rogers).
Spiroplecta clarki Bagg.
Nonionina affinis Reuss.
Carpolithus marylandicus Hollick.

The Woodstock member is further subdivided into two zones distinguished by characteristic fossils. These zones are described in the above-mentioned report on the Maryland Eocene, which also contains a full list of the fossils which characterize the member.

MIOCENE SERIES.

*CHESAPEAKE GROUP.*

CALVERT FORMATION.

*Areal distribution.*—The Calvert is by far the most extensive formation in the Patuxent quadrangle. Although it is largely covered with Lafayette and Columbia gravels, yet stream erosion has cut down to it in so many places that its distribution is very well known. It outcrops in nearly every stream-cutting throughout the southern half of the quadrangle and is represented by outliers well up on the divides over a large portion of the northern half. In its larger distribution it extends from Virginia northeastward across Maryland and Delaware into New Jersey. It has by far the most extensive development of all of the Cretaceous and Tertiary formations in this region. This statement might perhaps be extended to apply to the entire Middle Atlantic Coastal Plain, although not enough detailed work has been done south of Potomac River to show which Miocene members are best developed in Virginia.

*Lithologic character.*—The materials constituting the Calvert formation consist of blue, drab, and yellow clay, yellow to gray sand, gray to white diatomaceous earth, and calcareous marl. Between these all gradations exist. The diatomaceous earth gradually passes into fine sand by the increase of arenaceous material, or into a clay by the addition of argillaceous matter. In a similar way a sand deposit with little or no clay grades over into a deposit of clay in which the presence of sand can not be detected. Notwithstanding this variety of materials a certain sequence of deposits is commonly observed; the basal portions of the formation consist largely of diatomaceous earth, while the upper portions are composed chiefly of sand, clays, and marls. This difference in materials has led to a subdivision of the formation into two members, which are described below.

Extensive and excellent exposures can be seen along the bay shore from Herring Bay southward and also at Hollins Cliff, Lyons Creek, and other localities on Patuxent River and its tributaries. The following section was measured on the bay shore 1 mile north of Plum Point:

*Section 1 mile north of Plum Point, Md.*

| | Ft. | In. |
|---|---|---|
| PLEISTOCENE: | | |
| Yellowish sandy loam | 7 | 0 |
| MIOCENE (Calvert): | | |
| Yellowish sandy clay | 19 | 0 |
| Yellowish sand carrying *Isocardia fraterna* | 7 | 0 |
| Bluish and brownish sandy clay | 25 | 0 |
| Brownish sand | 4 | 6 |
| Bluish clay grading downward into brown sand | 10 | 6 |
| Yellowish-brown sandy clay bearing the following fossils: *Siphonalia devexa, Ecphora tricostata, Turritella plebeia, T. variabilis, T. variabilis* var. *cumberlandia, Polynices heros, Corbula inæqualis, Phacoides anodonta, Crassatellites melinus, Astarte cuneiformis, Pecten madisonius, Venus rileyi, Chione latilirata, Cytherea staminea, Melina maxillata, Atrina harrisii, Arca subrostrata, Glycymeris parilis*, etc | 9 | 0 |
| Bluish-green clayey sand carrying *Corbula elevata* | 2 | 0 |
| Bluish-green clayey sand carrying imperfect casts of *Corbula elevata* (?) | 10 | 0 |
| Bluish-green clayey sand containing large numbers of *Corbula elevata* | 3 | 0 |
| Bluish-green clayey sand containing fossil casts of *Corbula elevata* | 3 | 0 |
| | 100 | 0 |

*Paleontologic character.*—The diatomaceous earth and the dark-colored clays represented in the Calvert of this quadrangle contain abundant casts of marine mollusks, almost invariably of small size. The fossils are allied to forms now living in lower latitudes, thus indicating that the climate in this region during the deposition of the Calvert materials was somewhat warmer than that of to-day. The fossils of this formation have been fully described and illustrated in two volumes on the Miocene issued by the Maryland Geological Survey in 1904.

*Name and correlation.*—The formation receives its name from Calvert County, Md., where, in the well-known Calvert Cliffs bordering Chesapeake Bay, its typical characters are well shown. The formation seems to correspond approximately with the horizon at Petersburg, Va.

*Thickness.*—The full thickness of the Calvert formation has been nowhere actually observed along the line of outcrop. The formation has been diagonally truncated by the Choptank, so that in the region of Davidsonville it shows a thickness of only about 50 feet. The Choptank and younger formations lie above it unconformably. Fortunately, a reliable well record at Crisfield, Somerset County, exhibits the entire thickness of Miocene strata. In this well the Calvert formation is apparently about 300 feet thick. As this well is located in the extreme southern portion of the State and far down the dip, the data probably indicate a rapid thickening of this formation as it passes to the southeast toward the ocean. At Chesapeake Beach, on the bay shore in Calvert County, a well which begins in the Calvert formation a little above tide passes out of it and into the Eocene at a depth of 60 feet; at Centerville it is found at a depth of 81 feet and is 65 feet thick; at Crisfield the formation lies 465 feet below the surface.

*Stratigraphic relations.*—Near the Maryland–Delaware border the Calvert rests unconformably upon one of the Cretaceous formations (Rancocas). Farther southwest it overlies the Aquia formation, and in southern Maryland it lies unconformably upon the Nanjemoy, a relationship which shows the gradual transgression of the Miocene deposits southwestward. In this quadrangle it lies unconformably upon the Nanjemoy, Aquia, and Matawan formations and is overlain unconformably by deposits belonging to the Lafayette and Pleistocene. The strike of the Calvert formation is from northeast to southwest, and it dips toward the southeast at the rate of about 11 feet to the mile.

*Subdivisions.*—The Calvert formation has been divided into two members, known as the Fairhaven diatomaceous earth and the Plum Point marls. These are more fully described in the above-mentioned report on the Miocene of Maryland.

The Fairhaven diatomaceous earth lies at the base of the formation and is characterized by the presence of a large proportion of diatoms embedded in a very finely divided quartz matrix. Calcareous material is present in this bed in only very small amounts. Besides diatoms, there are other Miocene fossils, usually in the form of casts, and organic remains reworked from the underlying Eocene beds. The name for this member is derived from Fairhaven, Anne Arundel County, where the beds are well developed.

The contact of the diatomaceous earth with the Eocene beds lies about 2 feet beneath a band of sandstone from 4 to 8 inches thick, which carries casts of *Pecten humphreysii* and other Miocene fossils. Above this sandstone is the diatomaceous earth proper. This bed, which is about 20 feet thick, is greenish blue when fresh, but weathers to a brown or a light-buff to white color on long exposure to the atmosphere. In the extensive pits at Lyons Creek, where the material is worked commercially, the transition from greenish blue to buff is very conspicuous.

The low cliffs which border Chesapeake Bay south of the pier at Fairhaven are composed of diatomaceous earth with a capping of Columbia gravel. From Fairhaven the diatomaceous beds cross southern Maryland in a northeast-southwest direction, following the line of strike, and are worked at Lyons Creek on the Patuxent, and at Pope Creek on the Potomac, a short distance south of this quadrangle. They may also be found at numerous places between these points, in cuts made by waterways. Southeast of this diagonal line they gradually disappear below tide. The Fairhaven diatomaceous earth is further subdivided into three zones that are recognized by the materials and fossils which they contain.

The Plum Point marls constitute the remainder of the Calvert formation above the Fairhaven diatomaceous earth. At Plum Point, Calvert County, the beds are typically developed, and this fact has suggested the name of this member. It consists of a series of sandy clays and marls in which are embedded large numbers of organic remains, including diatoms. The color of the material is bluish green to grayish brown and buff. Fossil remains, although abundant through the entire member, are particularly numerous in two prominent beds, from 30 to 35 feet apart, in the Calvert Cliffs. These marls vary in thickness from 4½ to 13 feet. They may be easily traced along the Calvert Cliffs from Chesapeake Beach to a point 2 miles below Governor Run. At Chesapeake Beach they lie high up in the cliffs and toward the south they pass gradually downward beneath the surface of the water. Along Patuxent River the Plum Point marls are not exposed so extensively as in the Calvert Cliffs, but they are visible at intervals from the cliffs below Lower Marlboro southward to Ben Creek, in Calvert County. On the west bank of the river they may be seen here and there from a point opposite Lower Marlboro downstream to a point 1½ miles below Forest Wharf, in the Nomini quadrangle.

West of the Patuxent quadrangle, along Potomac River, the banks are usually very low and composed of Columbia sand and gravel. In consequence of this the Plum Point marls are exposed at but few places. On the Maryland side of the river they may be seen in the low cliffs at the mouth of Chaptico Bay, and on the Virginia side a considerable thickness of the marls is exposed along the entire length of the Nomini Cliffs. When fresh, the Plum Point marls and the Fairhaven diatomaceous earth do not differ much in appearance. The thickness of the marls increases constantly down the dip. This member is subdivided into 12 zones, which are distinguished by the lithologic character of the materials and by characteristic fossils.

CHOPTANK FORMATION.

*Areal distribution.*—The Choptank formation is confined to the southern portion of the Patuxent quadrangle. It is exposed along the bay shore south of Plum Point, in the valley of Patuxent River and its tributaries south of Mill Creek, and in the headwaters of Zekiah Swamp. In Calvert County it may be found in a long line of outcrops extending from the hilltops just west of Herring Bay to Patuxent River, but west of the Patuxent it is almost completely obscured by younger deposits. The boundaries of the Choptank formation in Calvert County are better known than in any other portion of southern Maryland, but west of the Patuxent have been determined more by calculation than by observation. They are believed, however, to be approximately correct and are fixed as accurately as present knowledge warrants. In its broader relations the formation extends from Virginia northwestward across Maryland and Delaware into New Jersey, where it has an extensive development.

*Lithologic character.*—The materials composing the Choptank formation are extremely variable. They consist of fine yellow quartz sand, bluish-green sandy clay, slate-colored clay, and, at some places, ledges of indurated rock. In addition to these materials, abundant fossil remains are disseminated throughout the formation. The sandy phase is well shown in the Calvert Cliffs from Parker Creek southward to Point of Rocks, a short distance beyond the borders of the Patuxent quadrangle. The sandy clay and clayey members may be seen in the same cliffs near Point of Rocks and farther south. The formation is best exposed along the bay shore south of Parker Creek. The following section is typical:

*Section one-half mile south of Parker Creek, Maryland.*

| | Ft. | In. |
|---|---|---|
| PLEISTOCENE: | | |
| Reddish sandy loam | 2 | 0 |
| MIOCENE: | | |
| Choptank— | | |
| Reddish sand | 2 | 0 |
| Reddish sandy clay containing *Balanus concavus, Corbula idonea, Astarte thisphila, Pecten madisonius, Venus campechiensis* var. *cuneata, Dosinia acetabulum, Cardium laqueatum, Arca staminea*, etc. | 14 | 0 |
| Yellowish sandy clay containing fossil casts | 20 | 0 |
| Yellow sand containing *Ecphora quadricostata, Turritella plebeia, Panopea americana, Corbula idonea, C. cuneata, Metis biplicata, Macrocallista marylandica, Venus mercenaria, V. campechiensis* var *cuneata, Dosinia acetabulum, Isocardia fraterna, Cardium laqueatum, Crassatellites turgidulus, Astarte thisphila, Pecten coccymelus, P. madisonius, Melina maxillata, Arca staminea*, etc. | 6 | 0 |
| Calvert— | | |
| Bluish clay | 9 | 0 |
| Brownish sandy clay containing *Isocardia fraterna* | 4 | 0 |
| Bluish sandy clay | 10 | 6 |
| Brownish sandy clay carrying *Ecphora quadricostata* var. *umbilicata, Venus mercenaria, Cytherea staminea* | 1 | 6 |
| Bluish clay | 4 | 0 |
| | 73 | 0 |

*Paleontologic character.*—Although the Choptank formation is abundantly supplied with fossils, these are for the most part concentrated in two well-defined beds which seem to be distributed very extensively through the areas of the deposit. These zones, together with many of their characteristic fossils, are shown in the foregoing section. The fossils are allied to forms now living in lower latitudes, thus indicating that a somewhat warmer climate than exists to-day in this region prevailed during the deposition of the Choptank formation; it was, however, probably a little cooler than during the deposition of the Calvert. The fossils of this formation have recently been fully described and illustrated in the two volumes on the Miocene published by the Maryland Geological Survey.

*Name and correlation.*—The formation receives its name from Choptank River, Maryland, because of its great development on the northern bank of that estuary a short distance below Dover Bridge. The formation seems to lie approximately at the horizon of the James River series of Virginia.

*Thickness.*—The thickness of the Choptank formation is variable. In the Nomini Cliffs, Virginia, it is present as a 50-foot bed between the Calvert formation below and the St. Marys formation above. This exposure shows a greater thickness than any other known. In the well section at Crisfield, mentioned in connection with the description of the Calvert formation, the Choptank is more than 100 feet thick, so that, like the Calvert, it thickens as it passes down the dip.

*Stratigraphic relations.*—The Choptank formation lies unconformably upon the Calvert formation. The unconformity is in the nature of an overlap, but is not easily discernible even where the contact is visible. The best place to observe the unconformity is in the portion of the Calvert Cliffs just below the mouth of Parker Creek. Even here it can not be seen from the beach, but is visible from a boat a short distance from the shore. This unconformity is also proved by the fact that at the above-mentioned locality the fossiliferous bed which lies lowest in the Choptank formation rests upon the Calvert, while at Mount Harmony and farther north the upper fossiliferous bed of the Choptank rests upon the Calvert formation. How far this unconformity continues down the dip after the beds disappear from view is not known, as the data from well records are too meager to permit any conclusion to be drawn from them. Above the Choptank is the St. Marys formation, which is not represented in this quadrangle.

The strike of the Choptank formation is in general from northeast to southwest; but as a result of erosion, particularly on the Western Shore of Chesapeake Bay, the outcrop is very sinuous and the strike appears to change locally.

The dip does not seem to be constant throughout the extent of the formation. In Calvert County, where the Choptank is best exposed, the northern portion of the outcrop, down to Parker Creek, seems to lie almost horizontal; but farther south the formation at its base dips southward at the rate of about 10 feet to the mile, so that toward the south it occurs at lower and lower levels until in the southern portion of its area it is found in river bottoms and finally disappears beneath tide. The best place to examine the dip of this formation is along the Calvert Cliffs between Parker Creek and Point of Rocks. Here an almost unbroken exposure of the Choptank may be seen dipping gradually toward the southeast.

*Subdivisions.*—The Choptank formation is subdivided into five zones, which are distinguished from one another by the character of material and the fossils they contain. These zones, together with their fossil contents, have been fully described in the State report on the Miocene of Maryland.

PLIOCENE (?) SERIES.

LAFAYETTE FORMATION.

*Areal distribution.*—The latest Tertiary formation of this portion of the Atlantic Coastal Plain is known as the Lafayette, and is probably of Pliocene age. It forms the surface cover over the southwestern portion of the Patuxent quadrangle. At one time, however, it probably formed a mantle over the entire area, for outliers are found north of Washington and on Marriott Hill east of Patuxent River. If such was the case, the Lafayette must originally have rested upon the exposed edges of all the earlier formations represented in this region, but erosion has so reduced its area that it is now in contact principally with the Miocene, although in small areas it rests upon the Patuxent formation and the ancient crystalline rocks. The Lafayette plain is in reality the oldest and highest of a series of five plains which were developed at successively lower levels during various epochs ranging in time from Pliocene (?) to Recent. It extends almost uninterruptedly from the District of Columbia line to the southern boundary of the quadrangle and forms one of the most striking topographic features in this area. It covers the divide between the two great river systems and thus becomes the most conspicuous formation of the region. A gravel capping on Marriott Hill is the only known outlier of the Lafayette east of Patuxent River in this quadrangle.

*Lithologic character.*—The Lafayette formation is composed of gravel, sand, and loam. These materials were so imperfectly sorted by the waves of the Lafayette sea that they are now found intermingled in varying proportions. Although there is a rough bipartite division in the deposit as a whole, the gravel occurring in greater abundance at the base and the sand and loam at the top of the formation, yet these elements are mixed together in a confusing manner. No particular kind of material is confined to any definite stratum, but all kinds may occur anywhere throughout the section. Irregular beds or lenses of loam, sand, or gravel also occur and are exposed in many places throughout this quadrangle. The gravels are considerably decayed and are usually rather small, but in the vicinity of Washington they become very coarse and are embedded in a coarse, compact sand or very stiff, clayey loam. The appearance of the gravels also changes from place to place; near Washington they are almost invariably covered with a dark-brown ferruginous coating, but farther south the amount of iron decreases considerably and the coating of iron oxide is practically absent. The heterogeneous character of the material furnishes evidence of the varied sources from which it has been obtained. Pebbles of quartz and crystalline rocks indicate the Piedmont as the source; broken iron crusts were derived from the Paleozoic formations farther west; and finally, decayed blocks of Newark sandstone are occasionally observed. While all of these various materials are present, the gravels are composed principally of quartz.

Sand forms a rather unimportant part of the Lafayette deposits. Such as is present seems to have been derived mainly from the Potomac beds. Lenses of sand occur at many places in the gravel deposits, but do not commonly form beds of great thickness or extent. The sand usually serves as the matrix for the gravels or else is intimately mixed with the loam.

Throughout the quadrangle the Lafayette is capped by a deposit of loam varying in thickness from a few inches to 10 feet or more, with an average of about 5 feet. Near Washington this loam contains considerable iron and has here and there a decided orange color. To the east and south this color becomes much less pronounced. In many places the loam resembles the loess of the upper Mississippi Valley in color and also in texture. On the broad Lafayette plain in the southwestern part of the quadrangle the loam shows a very pronounced mottling of drab and brick-red. This is particularly noticeable when the material is wet. It is seen in numerous road cuts, especially west of Brandywine. The Lafayette loam is in some places highly argillaceous, in others decidedly arenaceous. As a general rule, it is of very fine texture. Although the loam capping is relatively free from bands of gravel, they are not entirely absent. Single pebbles are not uncommon in the loam and locally there are well-defined beds of gravel and sand. The following section, taken 1½ miles southeast of Piscataway, makes these relations clearer:

*Section 1½ miles southeast of Piscataway, Md.*

| | Feet. |
|---|---|
| Fine grayish-yellow loam | 5 |
| Medium-coarse gravel in a matrix of gray sand | 4 |
| Yellow cross-bedded sand | 3 |
| Unassorted gravel mixed with gray sand | 5 |
| | 17 |

*Physiographic expression.*—As described under "Topographic features" (p. 2), the deposits of this formation form a plain of deposition which is well-developed in many places on the Coastal Plain and slopes gradually toward the sea. In the vicinity of Anacostia the base of the Lafayette plain is at a height of 280 feet and its surface at 300 feet. At Charlotte Hall, 30 miles to the south, the base is not visible, but the surface lies at an altitude of about 200 feet. This shows, therefore, a difference of 100 feet in 30 miles, or a surface slope toward the sea of about 3 feet to the mile. So slight and gradual a decline in elevation might be attributed to the original attitude of the material when it was deposited were it not for the fact that the Sunderland terrace, which wraps about the base of the Lafayette, has suffered a deformation of 20 feet, or about 8 inches to the mile, throughout the same region, and the Wicomico appears also to have been affected by a slight tilting. It is probable, therefore, that the present slope of the Lafayette formation is due both to its original attitude and to subsequent tilting.

*Paleontologic character.*—Fossils are practically lacking in the Lafayette deposits of the Atlantic coast region, none being found in the Patuxent area. Pebbles containing Paleozoic fossils are present in the formation at many places throughout the district, but are of importance only because they show the source of the materials. In regions far to the south some fossil plants and animals of Lafayette age have been reported by McGee, but very little is known concerning them.

*Name and correlation.*—The name Lafayette was proposed by Hilgard in 1891 (Am. Geologist, vol. 8, pp. 129–131) to replace the term Orange sand, used in Tennessee and Mississippi, and the term Appomattox, which has been applied to the deposits of the Atlantic coast. The name is derived from Lafayette County, Miss., a region where the formation is well developed. The exact correlation of the formation has not been definitely settled, as its meager fauna and flora have furnished little clue to its age. It overlies Miocene deposits unconformably and in turn is overlain by Pleistocene materials. Its general character, firmly indurated layers, and occasional greatly decomposed pebbles suggest a formation much older than any known Pleistocene deposit of the province, and hence furnish evidence for a provisional reference to the Pliocene.

*Thickness.*—The thickness of the Lafayette is somewhat variable. In its northwesternmost exposures the formation shows a thickness of 3 to 10 feet, the amount increasing somewhat toward the southeast. Over the broad plain in the vicinity of Brandywine the Calvert, which is the next subjacent formation, is reached at a depth of about 28 feet. The maximum thickness of the Lafayette in this quadrangle probably does not much exceed 40 feet.

*Stratigraphic relations.*—A very marked unconformity separates the Lafayette from all underlying formations. In one place or another within the Coastal Plain province it overlies almost every older formation represented in the region, and thin remnants are present in many places on the eastern borders of the Piedmont Plateau. In the Patuxent quadrangle it rests mostly upon the Calvert and Choptank formations and is, in the main, a surface deposit, although locally it in all probability dips beneath beds of Pleistocene age.

QUATERNARY SYSTEM.

PLEISTOCENE SERIES.

*COLUMBIA GROUP.*

GENERAL STATEMENT.

The Pleistocene formations of the Atlantic Coastal Plain are united under the name Columbia group. They have many characteristics in common, owing to their similar origin. They consist of gravel, sands, and loam which are stratigraphically younger than the Lafayette formation. The Columbia group comprises three formations, the Sunderland, Wicomico, and Talbot, all of which are represented in this region. They appear as the facings of different plains or terraces, possessing very definite physiographic relations (see fig. 2), as described under the heading "Topographic features" (p. 2).

On purely lithologic grounds it is impossible to separate the three formations composing the Columbia group. The materials of all have been derived mainly from the older formations which occur in the immediate vicinity, but include more or less foreign material brought in by streams from the Piedmont Plateau or from the Appalachian region beyond. The deposits of each of these formations are extremely varied, their general character changing with that of the underlying formations. Thus deposits belonging to the same formation may, in different regions, differ far more lithologically than deposits of two different formations lying in close proximity to each other and to the common source of most of their material. Cartographic distinctions based on lithologic differences could not fail to result in hopeless confusion. At some places the older Pleistocene deposits are more indurated and their pebbles more decomposed than those of the younger formations, but these differences can not be used as criteria for separating the formations, inasmuch as loose and indurated, fresh and decomposed materials occur in each of them.

The fossils found in the Pleistocene are far too meager to be of much service in separating the deposits into distinct formations, even though essential differences between some of them may exist. It is the exceptional and not the normal development of the formations that has rendered the preservation of fossils possible. These consist principally of fossil plants that were preserved in bogs, but in a few places about Chesapeake Bay local Pleistocene deposits contain great numbers of marine and estuarine mollusks.

The Columbia group, as may be readily seen, is not a physiographic unit. The formations occupy wave-built terraces or plains separated by wave-cut escarpments, their mode of occurrence 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 occupied by the oldest deposit, the Sunderland; while the lowest is covered with Talbot materials.

At almost every place where good sections of Pleistocene materials are exposed the deposit from base to top seems to be a unit. At some places, however, certain layers or beds are sharply separated from the underlying beds by irregular lines of unconformity. Some of these breaks disappear within short distances, showing clearly that they are only local phenomena in the same formation, the result of contemporaneous erosion by shifting shallow-water currents. Whether all these breaks would thus disappear if sufficient exposures occurred to permit the determination of their true nature is not known. An additional fact which indicates the contemporaneous erosive origin of these unconformities is that in closely adjoining regions they seem to have no relation to one another. Inasmuch as the Pleistocene formations lie in a nearly horizontal plane it would be possible to connect these separation lines if they were subaerial unconformities due to an interval of erosion. In the absence of any definite evidence that these lines are stratigraphic breaks separating two formations, they have been disregarded. Yet it is not improbable that in some places the waves of the advancing sea in Sunderland, Wicomico, and Talbot time did not entirely remove the beds of each preceding period of deposition over the area covered by the sea in its next transgression. Especially would materials laid down in depressions be likely to persist as isolated remnants which later were covered by the next mantle of Pleistocene deposits. If this is the case each formation from the Lafayette to the Wicomico is probably represented by fragmentary deposits beneath the later Pleistocene formations. Thus in certain sections the lower portions may represent an earlier period of deposition than that of the overlying beds. 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 attenuated edge of the next younger formation. Inasmuch as lithologic differences afford insufficient criteria for separating these late deposits, and as sections are not numerous enough to furnish distinctions between local interformational unconformities and widespread unconformities resulting from an erosion interval, the whole mantle of Pleistocene materials occurring at any one locality is referred to the same formation. The Sunderland is described as overlying the Jurassic (?), Cretaceous, and Tertiary deposits and as extending from the base of the Lafayette-Sunderland escarpment to the base of the Sunderland-Wicomico escarpment. The few deposits of Lafayette materials which may possibly underlie the Sunderland are disregarded because they are unrecognizable. Similarly the Wicomico is described as including all the gravels, sands, and clays overlying the pre-Lafayette deposits and extending from the base of the Sunderland-Wicomico escarpment to the base of the Wicomico-Talbot escarpment. Perhaps, however, materials of Lafayette and of Sunderland age may underlie the Wicomico in places. In like manner the Talbot may here and there rest upon deposits of the Lafayette, Sunderland, and Wicomico.

### SUNDERLAND FORMATION.

*Areal distribution.*—The Sunderland formation is developed as a terrace or plain which occupies the top of the divide separating Chesapeake Bay from Patuxent River and the sides of the divide, below the Lafayette formation, between Patuxent and Potomac rivers. Since its deposition it has suffered more erosion than either of the two younger formations, but enough of it still remains within the area to make its mapping possible and to establish its relations to the other deposits. The surface of the Sunderland plain varies in altitude from 200 feet in the northern portion of the quadrangle to 180 feet in the southern portion. Throughout this tract the original surface of the formation was nearly level, but the streams which now flow across it have locally produced a gently rolling surface.

*Lithologic character.*—The materials which compose the Sunderland formation consist of clay, sand, gravel, and ice-borne bowlders. As explained above, these materials as a rule do not lie in well-defined beds, but grade into each other both vertically and horizontally. The coarser materials, with the exception of the ice-borne bowlders, have in the main a cross-bedded structure, but the clays and finer material are either developed in lenses or horizontally stratified. The erratic ice-borne blocks are scattered through the formation and may occur in the gravel, sand, or loam. The coarser material throughout the formation tends to occupy the lower portions and the finer the upper portions, but the transition from one to the other is not marked by an abrupt change, and at many places the coarse materials are present in the surface loam and the finer materials are below, in the gravel. As a whole the material is coarser on the western side of the quadrangle, in the Potomac basin, than elsewhere. In the vicinity of Congress Heights, the gravels of the Sunderland are rather commonly cemented by ferruginous material. The ferruginous conglomerate used in the wall about the grounds of St. Elizabeth's Asylum was obtained from beds of consolidated Sunderland deposits. Many of the pebbles of the Sunderland are much decayed, but in general they show less decomposition than the Lafayette gravels.

*Physiographic expression.*—The Sunderland deposits occupy and form the Sunderland plain mentioned in the discussion of topography (p. 2). This plain is separated from the Lafayette terrace by a well-defined scarp. This scarp has suffered considerable modification since its formation, and where it was not prominent it has been transformed to a gently rolling surface or has been lost altogether. At Charlotte Hall, just beyond the southern margin of the quadrangle, this scarp is preserved in nearly its original sharpness. It is also visible south of Bryantown and north of Aquasco. In all these localities the original scarp was low, not exceeding 20 feet in height, but at Congress Heights, south of Anacostia River, the scarp separating the Lafayette and Sunderland surfaces is over 60 feet high and is the finest and best defined of all the ancient escarpments of this portion of the Coastal Plain. At Congress Heights the surface of the Lafayette plain lies at an altitude of about 260 feet. From this height a steep slope descends, cutting through the Lafayette and underlying Miocene beds, to the 200-foot contour, where the broad Sunderland plain abuts against the scarp and slopes gently and imperfectly away from it. The Sunderland formation is also usually separated from the Wicomico formation by a well-pronounced scarp; this is discussed in the section following, which is devoted to the Wicomico.

As already stated, the Sunderland plain stands at a height of 200 feet near Anacostia and of 180 feet at Charlotte Hall, 30 miles to the southeast. The surface of this plain thus slopes southeastward at the rate of 8 inches to the mile. It also slopes gently toward the larger estuaries.

*Paleontologic character.*—The only locality within this quadrangle at which fossils have been discovered in the Sunderland formation is along the Chesapeake Beach Railroad, in a deep cut between Wilson and Owings stations. At this place a plant bed occurs at the base of the deposit. It consists of a stratum of black clay about 3 feet in thickness, in which are numerous small lignitized stems. No good plant remains have been found, yet the presence of vegetable matter through the entire thickness of clay is indicated by the black color of the material, due to carbonaceous matter.

*Name and correlation.*—The formation has been named from the little village of Sunderland, Calvert County, near which it is typically developed. The name was first applied to the formation by G. B. Shattuck in May, 1901 (Johns Hopkins Univ. Circ. No. 152). The Sunderland corresponds approximately with the Earlier Columbia of McGee and with parts of the Bridgeton and Pensauken 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, in which bowlders bearing glacial striæ have been found.

*Thickness.*—Although the materials of the Sunderland lie at varying elevations above sea level in the Patuxent quadrangle, the thickness of the formation is not great at any point. That the deposits were laid down on a sloping and dissected plain is proved by many well records and observations which show that the surface of the underlying formations rises in passing from the stream valleys to the divides. Consequently, the thickness of the Sunderland can not be determined by the elevation of the deposits, but the evidence furnished by excavations and well records on the stream divides shows that the formation probably has an average thickness of about 35 feet.

*Stratigraphic relations.*—Throughout the Coastal Plain the Sunderland overlies unconformably various formations of Jurassic (?), Cretaceous, and Tertiary age. In the Patuxent quadrangle it lies unconformably upon the Aquia, Nanjemoy, Calvert, and Choptank formations. It is not improbable that the edges of the Lafayette formation extend beneath part of the Sunderland deposits, although this can not be determined because of the absence of any definite line denoting a stratigraphic break and because of the similarity of the materials of the two formations.

### WICOMICO FORMATION.

*Areal distribution.*—The next younger formation of the Pleistocene division is the Wicomico. Like the Sunderland, it was deposited on a terrace or plain. It lies topographically lower than the Sunderland, wraps around it like a border, and extends up the principal stream estuaries which penetrate it. In the Patuxent quadrangle the Wicomico formation is distributed in the stream valleys through the entire area, and is especially well developed in the basin of Patuxent River.

*Lithologic character.*—The materials which constitute the Wicomico formation are similar to those found in the Sunderland—in fact, many of them have been derived from that formation. They consist of clay, peat, sand, gravel, and ice-borne bowlders. The distribution of these materials is similar to that of those in the Sunderland in that they grade one into another both vertically and horizontally, the coarser materials preponderating at the base of the formation and the finer materials toward the top. In the northeast corner of the quadrangle, in the vicinity of Annapolis, large quantities of Eocene materials have been reworked in the Wicomico formation. At some places the materials are very much decayed, as in the Sunderland.

In the Potomac Valley near Washington bowlders carrying glacial striæ have been found in the Wicomico formation. The great size of these bowlders, however, and their occurrence with much finer materials furnish evidence of their transportation by floating ice.

The amount of loam present in the Wicomico is exceedingly variable. Wherever the loam cap is well developed the roads are very firm and the land is suitable for the production of grass and grain; but where the loam is present in small quantities or absent altogether the roads are apt to be sandy.

*Physiographic expression.*—The Wicomico formation is developed in a terrace which is described in the section headed "Topographic features" (p. 2) as the Wicomico plain. This plain is separated from the Sunderland terrace, which lies above it, by a scarp, usually above 20 feet in height, that is one of the most constant and striking topographic features in the quadrangle. The Wicomico plain is in turn in most places separated by an escarpment from the Talbot terrace, which wraps around it at a lower elevation. From the Sunderland-Wicomico scarp line the surface of the Wicomico formation slopes away gently toward the surrounding waters in the manner of a wave-built terrace. In the extreme northern portion of the quadrangle the surface of the Wicomico, at the base of this escarpment, lies at an elevation of about 100 feet, while in the southern portion of the quadrangle the elevation of the corresponding surface is about 90 or 95 feet, indicating a very gentle slope toward the southeast. Since the Wicomico was deposited it has been subjected to considerable erosion and its originally level surface has been transformed, at least along the waterways, into a gently rolling one.

*Paleontologic character.*—About 1 mile southeast of Queen Anne (Hardesty) there is a plant bed within and just at the base of the Wicomico formation. Here, at an elevation of 30 feet above the stream, there is a deposit of carbonaceous material about 20 feet thick. About $1\frac{1}{2}$ feet of this is composed principally of peat. The leaf impressions are mainly of grasses and stems, but some insect remains and beetle-wing covers are also present.

*Name and correlation.*—This formation receives its name from Wicomico River, in southern Maryland. The name was proposed by G. B. Shattuck in May, 1901 (Johns Hopkins Univ. Circ. No. 152). The Wicomico represents the upper part of the Later Columbia of McGee and Darton and a part of the Pensauken of Salisbury. The presence of ice-borne bowlders furnishes evidence for its contemporaneity with the ice invasion, although the particular drift sheet with which the formation should be correlated has not yet been determined.

*Thickness.*—The thickness of the Wicomico formation is not at all uniform, owing to the uneven surface upon which it was deposited. It ranges from a few feet to 50 feet or more. The formation dips down into the valleys and rises on the divides, so that its thickness is not so great as might be supposed from the fact that the base is in many places as low as 40 feet while the surface rises locally to 100 feet above sea level. Notwithstanding these irregularities the formation as a whole occupies an approximately horizontal position, with a slight southeasterly dip. The average thickness of the formation in this quadrangle is about 20 feet.

*Stratigraphic relations.*—In this quadrangle the Wicomico overlies unconformably the granite-gneiss and the various formations of Jurassic (?), Cretaceous, and Tertiary age. It is in many places in contact with the Sunderland on the one hand and with the Talbot on the other. It is probable that the Sunderland formation extends locally somewhat below the Sunderland-Wicomico scarp and may run out beneath and underlie the edge of the Wicomico formation where the two are in contact. In such places this contact between the Wicomico and Sunderland would be an unconformity.

### TALBOT FORMATION.

*Areal distribution.*—The Talbot formation is extensively developed within the Patuxent quadrangle. It occurs as a terrace of varying width extending from the Wicomico-Talbot scarp out to the edge of the surrounding waters. It is well distributed throughout the quadrangle, bordering the various estuaries and streams. Its most continuous and unbroken areas are situated in the northeastern portion of the quadrangle between South River and Herring Bay, in the valley of Patuxent River from Hollins Cliff southward to the quadrangle boundary, and in the valley of Anacostia River.

*Lithologic character.*—The materials which compose the Talbot formation consist of clay, peat, sand, gravel, and ice-borne bowlders. As in the Sunderland and Wicomico deposits, these materials grade into each other both vertically and horizontally, and the formation exhibits the same tendency toward a bipartite division, with the coarser materials beneath and the finer materials above. There is, on the whole, much less decayed material in the Talbot than in the two preceding formations and as a result the formation has a much younger appearance than the other Pleistocene deposits.

In the western portion of the quadrangle, in the vicinity of Washington and Anacostia, the Talbot beds contain many large bowlders which have been carried by icebergs and dropped in deposits of much finer material. Some of these bowlders show their glacial origin in that they have been planed by the wearing action of the ice and bear glacial striæ. Cross stratification is very common in the Talbot deposits. One of the best exposures of this structure can be seen in a shallow cut along the Chesapeake Beach Railroad about one-fourth mile from Patuxent River. Another good exposure of cross stratification in the Talbot occurs just north of Lyons Creek, in Anne Arundel County. The following section was taken on the banks of Anacostia River, near Washington:

*Section on west side of Anacostia River south of Pennsylvania avenue, Washington, D. C.*

| | Ft. | In. |
|---|---|---|
| Sandy loam, light yellow to brown in color | 3 | 6 |
| Fine yellow sand with here and there isolated pebbles or thin lenses of gravel 4 to 6 inches thick; gravel up to 6 inches in diameter | 7 | 0 |
| Mass of gravel of all sizes, unstratified, some several feet in diameter; yellow sandy matrix; striæ on gravels; materials generally fresh in appearance; a few small lenses of yellow sand free from gravel. In places iron crusts have formed in the sand and gravel, cementing them together. Amount exposed | 11 | 0 |
| | 21 | 6 |

*Physiographic expression.*—The Talbot formation is developed as a terrace capping, forming the Talbot plain described under the heading "Topographic features" (p. 2). It wraps around the lower margin of the Wicomico terrace, from which it is separated in most places by a low escarpment. From the base of the Wicomico-Talbot scarp, which is at an elevation of 40 to 45 feet, the surface of the Talbot formation slopes gently toward the surrounding waters. This surface has chiefly, if not entirely, the initial slope which was imparted to it during its period of deposition. Usually this terrace is terminated by a low scarp cut by the waves of Chesapeake Bay or its estuaries, but locally it slopes gently to the water's edge. The Talbot formation has suffered less erosion than either the Sunderland or the Wicomico. It has been elevated above the water for so short a time that such streams as have found their way across its surface have not been able to change materially its original level character.

*Paleontologic character.*—In the Maryland portion of the Coastal Plain there are a number of localities at which fossil remains of either plants or animals or both occur in the Talbot deposits. In this quadrangle the most conspicuous of these is near Fairhaven, Anne Arundel County, where the formation contains a lens of drab-colored clay bearing plant remains. Near Cornfield Harbor, at the mouth of Potomac River, the formation has yielded a great number of molluscan shells representing a varied fauna of marine and brackish-water origin.

*Name and correlation.*—Talbot County, Md., where the formation occupies a broad terrace bordering numerous estuaries, has furnished the name for this formation. It was first given by G. B. Shattuck in 1901 (Johns Hopkins Univ. Circ. No. 152). The Talbot represents the lower part of the Later Columbia described by McGee and Darton and corresponds approximately to the Cape May formation of Salisbury. Its Pleistocene age is proved by the fossils found at Cornfield Harbor and by its contemporaneity with a part of the ice invasion of the northern portion of the country, as shown by the numerous ice-borne bowlders found in its deposits.

*Thickness.*—The thickness of the Talbot formation is extremely variable, ranging from a few feet to 40 feet or more. The unevenness of the surface upon which it was deposited has in part caused this variability. The proximity of certain regions to the mouths of streams during the Talbot submergence also accounts for the increased thickness of the formation in such areas.

*Stratigraphic relations.*—The Talbot rests unconformably, in different portions of the region, upon various older formations belonging to the Jurassic (?), Cretaceous, or Tertiary systems. It may in places rest upon deposits of Lafayette, Sunderland, or Wicomico age, although no positive evidence has yet been found to indicate such relations to the older Pleistocene formations. The deposits occupy a nearly horizontal position, having only a slight slope toward Chesapeake Bay and its estuaries.

#### RECENT DEPOSITS.

In addition to the four terraces already discussed, a fifth is now being formed by the waters of the rivers and the waves of the estuaries. This terrace is everywhere present along 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 beneath and wraps about the margin of the Talbot terrace, from which it is separated by a low scarp that as a rule does not exceed 15 to 20 feet in height. Where the Talbot formation is absent, the Recent terrace may be found at the base of either of the other three terraces. In such places, however, the scarp which separates them is higher in proportion as the upper terrace is older. Peat, clay, sand, and gravel make up the formation and these materials 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 covered by swamp deposits, and of brackish-water animals of living species entombed in the muds of Chesapeake Bay and its estuaries.

### STRUCTURE.

The geologic structure of this quadrangle, with the exception of the small area of crystalline rocks in its northwest corner, is extremely simple. The structure of the crystalline rocks of the Piedmont Plateau, on the other hand, is very complex. These rocks are tilted at high angles, dislocated by faults, and greatly changed from the position in which they were formed. Folds are abundant, and the forces of compression have usually so acted as to squeeze the sides of the folds together until the beds on each side dip in the same direction. In the granite gneiss, the only crystalline rock of the quadrangle, yielding to deformation took place along numerous planes cutting the rock. Along these there was motion of one part past another attended by the growth of new minerals out of the broken materials of the old. The new minerals crystallized nearly parallel to one another and to the planes of motion and produced the schistosity which characterizes the granite gneiss of this region. The granite gneiss occurring in the extreme northwest corner of the Patuxent quadrangle forms the eastern part of an anticline whose axis passes through Washington; the axis of the accompanying syncline to the east is covered by the Coastal Plain deposits. The dip of the planes of schistosity is from 60° to 90° NW. A fuller statement of the structure of the Piedmont rocks is given in the Washington folio (No. 70).

In striking contrast with the complex structure of the Piedmont rocks is the extremely simple structure of the Coastal Plain strata. Although many unconformities separate the various formations of the Coastal Plain, these are comparatively minor unconformities of erosion. Folding of the strata is almost, if not entirely, lacking, and faulting has not been observed in this quadrangle. The numerous uplifts and depressions which the region has experienced have been so uniform over wide areas that the only existing evidence of these crustal movements consists of traces of successive periods of erosion and deposition that must have been produced by alternate uplift and submergence. As explained elsewhere, these vertical movements were sometimes accompanied by tilting, with but slight deformation.

The formations all have a general northeast-southwest strike and a dip to the southeast. This dip, though variable in amount in the different formations, agrees in direction with the slope of the crystalline floor upon which the Coastal Plain sediments rest. At some places, particularly in the Pleistocene formations, the dip is very slight—not more than a few feet to the mile—but in the formations of the Potomac group it is as great as 50 to 75 feet to the mile.

The pre-Pleistocene formations of the Patuxent quadrangle constitute a series of overlapping beds with lines of outcrop roughly parallel to the strike. With few exceptions, already described in detail, each formation dips to the southeast at an angle greater than the slope of the country and disappears beneath the next younger formation (see fig. 1). Thus successively younger beds are encountered by one who passes from the northwestern to the southeastern portion of the quadrangle over the upturned edges of the deposits.

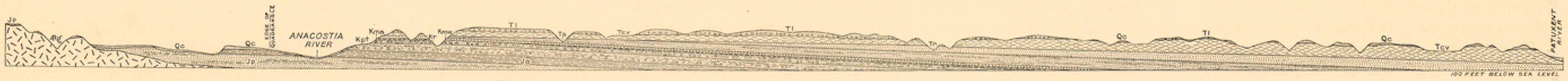


FIG. 1.—Section from Washington to Patuxent River along line A-A on areal geology map.
Qc, Columbia group; Tl, Lafayette formation; Tcv, Calvert formation; Tn, Nanjemoy formation; Ta, Aquia formation; Kmw, Matawan formation; Kma, Magothy formation; Kr, Raritan formation; Kpt, Patapsco formation; Ja, Arundel formation; Jp, Patuxent formation; Æg, granite gneiss.
Horizontal scale, approximately 1 inch = 2 miles. Vertical scale, 10 times horizontal scale.

The accompanying sketch (fig. 2) shows diagrammatically the structural and topographic relations of the five terrace formations, namely, the Lafayette, Sunderland, Wicomico, Talbot, and Recent. It will be noticed that the four older ones are represented as bipartite in character. The landward edge of each formation is represented as lapping up over the seaward edge of the one preceding. This sketch indicates the conditions as they would appear if typically developed, but here and there the lower portions of the scarps are occupied by Miocene or older beds, leaving the Pleistocene materials confined only to the upper portions of the escarpments. In such places the next younger terrace deposit does not lap up on the base of the gravels of the terrace just preceding, but rests unconformably upon the older materials which occupy the base of the escarpments.

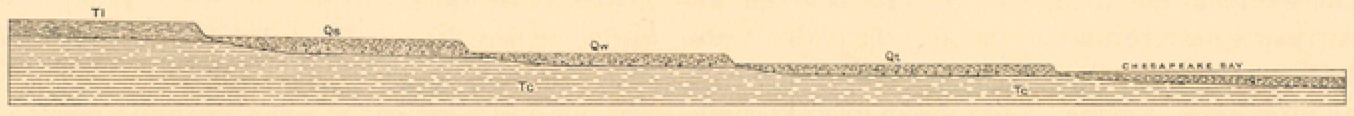


FIG. 2.—Ideal section showing structure and topographic relations of the several terrace formations.
Qr, Recent; Qt, Talbot; Qw, Wicomico; Qs, Sunderland; Tl, Lafayette; Tc, Chesapeake group.

## HISTORICAL GEOLOGY.

### SEDIMENTARY RECORD.

*General statement.*—Almost all the formations which occur within the Patuxent quadrangle have a much more extensive development in the regions beyond its borders. If study were confined to the area of the quadrangle alone many of the conclusions drawn from such investigations might be unsatisfactory and erroneous. The geologic history of the quadrangle, which is here outlined, has been based on work done not only in this area but also throughout the North Atlantic Coastal Plain from Raritan Bay to Potomac River and in certain localities in Virginia and the Carolinas.

A study of the geologic history of the Patuxent quadrangle shows that it has been long and complicated. This is indicated by the many different kinds of strata represented and by the relations which they bear to one another. There are deposits that were formed in fresh or brackish water; others that show evidence of their deposition in marine waters, some in water of shallow depth, others in deep water; while breaks in the conformity of the different strata indicate that from the time of the formation of the earliest beds down to the present day the region has undergone many elevations and subsidences.

*Pre-Potomac history.*—In this quadrangle rocks older than the Jurassic (?) are present only in the Piedmont Plateau. It is exceedingly difficult to interpret the past history of the Piedmont region for the reason that the whole area has been subjected to many great changes which have essentially modified the original materials; yet the studies of Williams, Keith, Mathews, Bascom, and others have revealed many facts concerning the original condition of the rocks now occupying this region. Nearly all the rocks of the Piedmont are metamorphic in character. Many of these rocks were originally sedimentary deposits, but in the processes of metamorphism have now lost nearly all traces of their original character. Consequently it is scarcely possible to explain the conditions under which they were originally deposited. Yet it may be said that a large portion of the area which the Piedmont metamorphic rocks now occupy was under water at one time, or perhaps many times, and received in some places deposits of sand and mud carried in by streams, while in other places beds of limestone were formed. It is not known how long this sedimentation continued or how many breaks took place between successive periods of deposition. It has been thought by most recent workers in the Piedmont region that the rocks there include not only representatives of the Archean, to which most of the earlier geologists referred them, but of the Cambrian and Ordovician as well. These old rocks have been broken through in many different places by sheets and dikes of igneous material. Thus the Piedmont metamorphics comprise representatives of both igneous and sedimentary rocks. The structure of these rocks when first formed was undoubtedly much more simple than at present, but they have been repeatedly subjected to various processes of metamorphism by which the beds have been folded and crumpled and the original mineral composition has been greatly changed.

There is no evidence to show a submergence of this area during the latter part of the Paleozoic era nor during the Triassic period. It probably remained as a land mass during most of this time, furnishing terrigenous materials to the Paleozoic sea to the west and to the Atlantic Ocean far to the east. It is of course possible that it may have been depressed beneath the ocean waters and covered with sediments many times, but, if so, later erosion has removed such deposits from the crystalline surface.

*Potomac history.*—The earliest of the known unconsolidated deposits lying upon the floor of crystalline rocks belong to the Patuxent formation of the Potomac group. This formation, on the evidence furnished by fossil plants and by its position beneath the Arundel, which contains vertebrate fossils of doubtful Jurassic age, is questionably referred to that period. It indicates a submergence of the Coastal Plain in this region of sufficient extent to cover the whole area with shallow water. The cross-bedded sands and gravels furnish evidence of shifting currents, as do also the abrupt changes in the character of the materials, both horizontally and vertically. 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 which brought the region above the water and inaugurated a period of erosion which persisted long enough to permit the removal of a vast amount of material. This was followed by a subsidence in which many of the stream valleys, but lately eroded, were occupied for a portion of their courses by bogs and swamps of the Arundel formation. In these marshes there was an extensive development of plant life and in them also were deposited iron ores that are now of considerable value. After another uplift and interval of erosion the land was again depressed beneath sea level. Physical conditions similar to those which had prevailed during Patuxent time existed during this period of submergence, in which the Patapsco formation was laid down. Dicotyledonous plants, which are very rare and primitive in structure in the Patuxent deposits, are abundant in the Patapsco and belong to higher types. This seems to indicate that a long time intervened between the two periods of deposition, during which the land flora of the region materially changed. After the deposition of the Patapsco formation the region again became land through an upward movement which drained all the previously existing estuaries and marshes. Erosion at once became active and the Patapsco surface was dissected. A downward land movement again submerged the greater portion of the region, leaving only a very narrow strip of Patapsco deposits above water. The Raritan formation was next deposited, under conditions very similar to those which had existed during the previous submergence. Raritan deposition was terminated by an uplift which again converted the entire region into land. A long period elapsed before a resubmergence, so that the streams were able to effect extensive erosion of the recently formed deposits.

The widespread development of shallow-water deposits, everywhere cross-bedded and extremely variable in lithologic character, and the presence throughout these deposits of land plants furnish some evidence that the Potomac sedimentation took place not in open ocean waters but in brackish- or fresh-water estuaries and marshes that were indirectly connected with the ocean, which may have at times locally broken into the area. Some land barrier to the east of the present shore line probably existed and produced these conditions, but its position and extent can not be determined.

*Magothy history.*—The period during which the Magothy deposits were formed was one of transition from the estuarine or fresh-water conditions of Patapsco and Raritan time to the marine conditions under which the Matawan, Monmouth, and Rancocas were laid down. The great variability in the lithologic character of the materials, the coarseness of the sands and gravels, and the cross-bedding all suggest conditions similar to those of the preceding periods. On the other hand, the local pockets of glauconitic sand and the presence of marine invertebrates suggest the marine conditions of the late Cretaceous. The probability is that over most of the area where Magothy deposits are now present Potomac conditions prevailed during the greater part of the period and in some places perhaps during the whole of it, but that occasionally, through the breaking down of the land barriers which had kept out the ocean, there were incursions of sea water, bringing in marine forms of life. Thus far there is no evidence that such incursions took place anywhere except in New Jersey.

At the close of Magothy time the region was uplifted and a period of erosion was inaugurated. During this erosion interval comparatively small amounts of material were removed. In some places it is impossible to establish definitely any stratigraphic break between the Magothy and the Matawan. This may be because the erosion interval was comparatively short or because the elevation of the land above the water was so slight that it did not permit the streams to cut channels in the recently formed deposits.

*Later Cretaceous history.*—Not until late Cretaceous time did a downward movement occur of sufficient extent to permit the ocean waters to transgress widely over this region. During the Matawan, Monmouth, and Rancocas epochs probably all of the quadrangle was depressed beneath the ocean waters. The streams from the low-lying land evidently carried into the ocean at this time only small amounts of fine sand and mud, which afforded conditions favorable to the production of glauconite and permitted the accumulation of the greensand beds 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 elevation was probably proceeding slowly, as the Matawan, Monmouth, and Rancocas formations are found outcropping farther and farther to the southeast.

After the deposition of the Rancocas formation upward land movements again caused the shore line to retreat 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 deposit of Cretaceous age, the Manasquan formation. If the Rancocas and Manasquan were ever formed within the limits of the Patuxent quadrangle they have either been removed or are concealed from view by later formations which have overlapped them.

*Eocene history.*—At the close of the Cretaceous period the recently deposited sediments were uplifted to form a land mass and sedimentation was succeeded by erosion. In early Tertiary time a depression carried most of the region again beneath the waters of the ocean and the Eocene deposits were formed. The great amount of glauconite present in these formations indicates that the adjacent land mass must have been low and flat, so that the streams carried in only small amounts of terrigenous material. The water in which this was dropped was doubtless only a few hundred fathoms deep, as glauconite is not produced at great depths. The land-derived materials at the beginning of the Eocene consisted of small, well-rounded pebbles which were deposited in several places in the region; but later the materials carried consisted of fine sand or clay. Many forms of animal life existed in these waters and their remains now compose layers of marl several feet in thickness.

Studies of the fossils found in the Eocene deposits indicate that there were many changes in the fauna during this time. These changes were probably influenced to a greater or less extent by variations in physical environment, yet the character of the deposits themselves gives little evidence of such changes. Instead it seems that the conditions under which the Eocene deposits were produced were remarkably uniform, considering the great length of time which elapsed from the beginning to the close of the period.

*Miocene history.*—Eocene sedimentation was brought to a close by an uplift by which the shore line was carried far to the east and probably all of the present State of Maryland became land. This was followed by a resubmergence and another cycle was commenced. The deposits of the Miocene were laid down upon the land surface which had just been depressed beneath the water. Sluggish streams brought in fine sand and mud, which the waves and ocean currents spread over the sea bottom. Occasionally leaves from land plants were also carried out to sea and later dropped to the bottom as they became saturated with water.

Near the beginning of Miocene submergence, certain portions of the sea bottom received little or no materials from the land, and the water in those places was well suited as a habitat for diatoms. These must have lived in the waters in countless millions, and as they died their siliceous shells fell to the bottom and produced the beds of diatomaceous or infusorial earth which are so common in the lower part of the Calvert formation. Many Protozoa as well as Mollusca lived in the same waters and their remains are plentifully distributed throughout the deposits. During the Miocene epoch the conditions seem to have been favorable for animal life, as may be inferred from the great deposits of shell marl which were then formed.

After the deposition of the Calvert formation the region was again raised and subjected to erosion for a short period, and then sank once more beneath the sea. The Choptank formation was laid down contemporaneously with the advancing ocean. This formation lies unconformably upon the Calvert, and farther north transgresses it. In neighboring regions to the south of this quadrangle a third Miocene formation, the St. Marys, was deposited conformably upon the Choptank at a later period.

*Pliocene (?) history.*—At the close of the Miocene the entire region was uplifted to form land. Streams at once began to carve valleys on the featureless surface. These conditions continued until the country was reduced approximately to a base-level, so that the weathered products of the Piedmont were not carried off by the sluggish streams. Then a subsidence occurred which again brought the region under water. Coincident with the subsidence there seems to have been a slight elevation and tilting of the region west of the shore line. The heads of the streams were given renewed force, enabling them to carry down and spread over this region large quantities of gravel and sand, derived from the Piedmont deposits and the Paleozoic formations to the west.

The evidence for the source of the material is found in many different pebbles whose origin can be traced by their lithologic character or the fossils they contain. In the vicinity of Washington many of the gravel deposits contain fossils of Devonian and Carboniferous age brought from regions beyond the Blue Ridge. These fossils show that Potomac River had extended its drainage basin westward to those regions. During the submergence beneath the Lafayette sea, conditions were not uniform over the entire area, as gravel deposits were forming in some places at the same time that the clay beds were being deposited in others adjoining. Yet on the whole sedimentation was remarkably uniform throughout the area, considering the circumstances under which it took place. Over the former land surface a fairly persistent capping of gravel was deposited. But land movements were again taking place slowly. The velocity of the streams was checked so that gravel could no longer be carried down except in occasional freshets. Fine sand and loam were laid down over the gravel which had been previously deposited. This loam, which is so extensively developed over a large portion of Prince Georges County, marks the last period of Lafayette sedimentation. It marks also the last time that the entire region was submerged beneath the ocean waters.

*Pleistocene history.*—At the close of the Pliocene epoch the region was raised again and extensively eroded, and was then lowered and received the deposits which constitute the first member of the Columbia group. The Sunderland, Wicomico, and Talbot formations, which make up this group, are exposed over a series of terraces lying one above another throughout the North Atlantic Coastal Plain from Raritan Bay to Potomac River, as well as in Virginia and probably still farther south. The key to the solution of the relations existing between the surficial deposits of Maryland lies almost exclusively in a correct correlation of these terraces. Much light may be thrown on this problem by a careful study of the Recent terrace now forming along the shores of the Atlantic Ocean and Chesapeake Bay and its tributaries. A discussion of this terrace is given below.

After the close of the post-Lafayette 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 existing headlands of Lafayette and older rocks. This scarp was prominent in some places and obscure in others, but may be readily 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 after the shore line had advanced some distance westward and only the finer material found its way very far out. Ice-borne bowlders are also scattered through the formation at all horizons.

After the deposition of the Sunderland formation, the country was again elevated above ocean level and erosion began to tear away the Sunderland terrace. This elevation, however, was not of long duration and the country eventually sank below the waves again. At this time the Wicomico sea repeated the work which had been done by the Sunderland sea except that it deposited its materials at a lower level and cut its scarp in the Sunderland formation. At this time also there was a contribution of ice-borne bowlders which were deposited promiscuously over the bottom of the Wicomico sea. These are now found at many places embedded in the finer material of the Wicomico formation.

At the close of Wicomico time the country was again elevated and eroded, and then lowered to receive the deposits of the Talbot sea. The geologic activities of Talbot time were a repetition of those carried on during Sunderland and Wicomico time. The Talbot sea cut its scarp in the Wicomico formation, or in some places removed the Wicomico completely and cut into the Sunderland or still older deposits. Deposits were made on its terrace, a flat bench at the base of this escarpment. Ice-borne bowlders are also extremely common in the Talbot formation, showing that blocks of ice charged with detritus from the land drifted out and deposited their load over the bottom of the Talbot sea.

Embedded in the Talbot formation at Fairhaven there is a lens of drab-colored clay bearing plant remains. The stratigraphic relations of this and similar lenses of clay occurring elsewhere in the Coastal Plain show that they are invariably unconformable with the underlying formation and apparently so with the overlying sand and loams belonging to the Talbot. This relationship was very puzzling until it appeared that the apparent unconformity with the Talbot, although in a sense real, does not, however, represent an appreciable lapse of time and that, consequently, the clay lenses are actually a part of that formation. In brief, the clays carrying plant remains are regarded as lagoon deposits made in ponded stream channels and gradually buried beneath the advancing beach of the Talbot sea. The clays carrying marine and brackish-water organisms are believed to have been at first off-shore deposits made in moderately deep water, and later brackish-water deposits, formed behind a barrier beach and gradually buried by the advance of that beach toward the land. As a fuller discussion of this question has been given in the St. Marys folio (No. 136) it will not be repeated here.

*Recent history.*—The last event in the geologic history of the region was a downward movement, which is still in progress. It is this which has produced the estuaries and tide-water marshes that form conspicuous features of the existing topography. At the present time the waves of the Atlantic Ocean and Chesapeake Bay are at work tearing away the land along their margins and depositing it on a subaqueous platform or terrace. This terrace is everywhere present in a more or less perfect state of development, and may be observed not only along the exposed shores, but also on passing up the estuaries to their heads. The materials which compose it are varied, depending both on the detritus directly surrendered by the land to the sea and on the currents which sweep along the shore. On an unbroken coast the material has a local character, while in the vicinity of a river mouth the terraces are composed of débris contributed from the entire river basin.

Besides building a terrace, the waves of the ocean and bay are cutting a sea cliff along their coast line, the height of the cliff depending not so much on the force of the breakers as on the relief of the land against which the waves beat. A low coast line yields a low sea cliff and a high coast line the reverse, and the one passes into the other as often and as abruptly as the topography changes, so that along the shore of Chesapeake Bay, high cliffs and low depressions occur in succession.

In addition to these features, bars, spits, and other shore formations of this character are being produced. If the present coast line were elevated slightly, the subaqueous platform which is now in process of building would appear as a well-defined terrace of variable width, with a surface either flat or gently sloping toward the water. This surface would everywhere fringe the shores of the ocean and bay, as well as those of the estuaries. The sea cliff would at first be sharp and easily distinguished, but with the lapse of time the less conspicuous portions would gradually yield to the leveling influences of erosion and might finally disappear altogether. Erosion would also destroy, in large measure, the continuity of the terrace, but as long as portions of it remained intact, the old surface could be reconstructed and the history of its origin determined.

## PHYSIOGRAPHIC RECORD.

The history of the development of the topography as it exists to-day is not complicated. The topographic features were formed at several different periods, during all of which the conditions must have been very similar. The physiographic record is merely the history of the development of the four plains already described as occupying different levels, and of the present drainage channels. The plains of the Patuxent quadrangle are primarily plains of deposition which, since their formation, have been more or less modified by the agencies of erosion. Their deposition and subsequent elevation to the heights at which they are now found indicate merely successive periods of depression and uplift. The drainage channels have throughout most of their courses undergone many changes; periods of cutting have been followed by periods of filling, and the present valleys and basins are the results of these opposing forces.

*Lafayette stage.*—Within the borders of the Patuxent quadrangle there are evidences of frequent changes during Cretaceous and early Tertiary time which resulted in the deposition of a succession of formations composed of heterogeneous materials. These changes, however, were to only a very slight extent influential in producing the present topography, so that in beginning the discussion of the physiographic history of the region they may be omitted. Toward the close of the Tertiary, however, a change in conditions occurred which is clearly shown in the existing topography. A layer of gravels, sands, and clays was spread over the entire Coastal Plain and along the borders of the Piedmont Plateau during the Lafayette submergence. These deposits, which, as already stated, must have been laid down on a rather irregular surface, formed a thin mantle of materials, ranging from 25 to 50 feet in thickness. When the uplift which terminated Lafayette deposition occurred, a very even, gently sloping plain extending from the Piedmont Plateau to the ocean, bordered the continent. Across this plain, which was composed of coarse, unconsolidated materials, streams rising in the Piedmont gradually extended their courses, while new ones confined to the Coastal Plain were also developed. At this time the shore line seems to have been farther east than now, and the present submerged channels of the continental shelf were probably then eroded. 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 post-Lafayette uplift. The attitude of the subsequent deposits makes this evident, for the Sunderland, Wicomico, Talbot, and Recent terrace formations all slope toward these various waterways. The Lafayette formation was cut through by the streams, and valleys were opened in the older deposits. Several of these valleys became many miles wide before the corrasive power of the streams was checked by the Sunderland submergence.

*Sunderland stage.*—As the Coastal Plain was depressed, in early Pleistocene time, the ocean waters gradually extended up the river valleys and over the lower lying portions of the stream divides.

The waves worked on the Lafayette-covered divides and removed the mantle of loose materials, which were either deposited farther out in the ocean or dropped in the estuaries formed by the drowning of the lower courses of the streams. Sea cliffs produced on points exposed to wave action were gradually pushed back as long as the sea continued to advance. These cliffs are now represented by the escarpment separating the Sunderland from the Lafayette. The materials which the waves gathered from the shore, together with other materials brought in by the streams, were spread out in the estuaries and constitute the Sunderland formation.

The tendency of the work done was to destroy all irregularities produced during the post-Lafayette erosion interval. In many places old stream courses were undoubtedly obliterated, but the channels of the larger streams, although probably in some places entirely filled, were in the main left lower than the surrounding regions. Thus in the uplift following Sunderland deposition the larger streams reoccupied practically the same channels they had carved out in the preceding erosion period. 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.

*Wicomico stage.*—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 seems to have been about equal in amount throughout a large portion of the district, showing that the downward movement was without deformation. The sea did not advance upon the land as 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 epoch of deposition. Throughout many portions of the Coastal Plain at the present time these old sea cliffs are still preserved as escarpments, ranging from 10 to 15 feet in height. Where the waves were not sufficiently strong to enable them to cut cliffs it is somewhat difficult to locate the old shore line. During this time a large portion of the Patuxent quadrangle was submerged. The Sunderland deposits were largely destroyed by the advancing waves and redeposited over the floor of the Wicomico sea, although those portions which lay above 90 to 100 feet were for the most part preserved. Deposition of materials brought down by streams from the adjoining land also took place.

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

*Talbot stage.*—The Talbot deposition did not take place over so extensive an area as was covered by that of the Wicomico. It was confined to the old valleys and to 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 is the Talbot-Wicomico escarpment, previously described. 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 corrasive work which had been interrupted by the Talbot submergence. As a result of this erosion the Talbot plain is now in many places rather uneven, yet it is more regular than the remnants of the Lafayette, Sunderland, and Wicomico plains, which have been subjected to denudation for a much longer period.

*Recent stage.*—The land probably did not long remain stationary with respect to sea level before another downward movement began. This last subsidence is probably still in progress. Before it began South, West, Patuxent, and Potomac rivers, instead of being estuaries, were undoubtedly streams of varying importance lying above tide and emptying into a diminished Chesapeake Bay. Whether this movement will continue much longer can not, of course, be determined, but with respect to Delaware River there is sufficient evidence to show that it has been in progress within very recent time and undoubtedly still continues. Many square miles that had been land before this subsidence commenced are now beneath the waters of Chesapeake Bay and its estuaries, and are receiving deposits of mud and sand from the adjoining land.

## ECONOMIC GEOLOGY.

### MINERAL RESOURCES.

The mineral resources of this region are neither extensive nor especially valuable, but the Patuxent quadrangle contains some deposits that are of considerable economic importance, although they have not hitherto been very largely worked. Among the most important are clays, sands, gravels, building stone, glauconitic and shell marls, diatomaceous earth, and iron ore. In addition the soils contribute much to the value of the region, which is primarily an agricultural one, and abundant supplies of water, readily obtainable in almost every portion of the quadrangle, form a further part of its mineral wealth.

### CLAYS.

Next to the soils the clays constitute the most valuable economic deposits of the Patuxent quadrangle. As already stated in the discussion of the stratigraphy of the region (p. 3), several of the formations contain considerable quantities of clay. These argillaceous beds are rather generally distributed throughout the quadrangle, but, so far as known, have in recent years been worked only in the vicinity of Washington. In colonial days bricks were made at a number of points throughout the region. The clays are found in each series of deposits represented in the region. For convenience they may be discussed under the headings Potomac, Eocene and Miocene, and Lafayette and Pleistocene clays.

*Potomac clays.*—The clays of the Potomac group are the most valuable within the region under consideration. Each formation of the group contains deposits of clay that are suitable for a variety of uses. Some clays from the Patuxent have been employed for the manufacture of common brick, fire brick, and terra cotta; the Arundel contains clays adapted to the manufacture of common brick, terra cotta, sewer pipes, and pottery; the Patapsco with its great variety of clays furnishes material suitable for the manufacture of common brick, fire brick, and other refractory ware, sewer pipes, and pottery; and the somewhat less argillaceous Raritan formation contains clays adapted to the manufacture of common brick, terra cotta, and fire brick.

*Eocene and Miocene clays.*—Although argillaceous beds occur very commonly in the Eocene and Miocene strata of the quadrangle, in general they are too sandy to be of much economic importance. Considerable lime, derived from the numerous fossil shells which are either generally distributed throughout the sandy clay or concentrated in definite shell beds within the formations, also renders these clays of less value. They are, however, very accessible, being exposed in the cliffs along Chesapeake Bay and Patuxent River and in the valleys of tributary streams, and if a way of utilizing them should be discovered, they could be obtained in great quantities at little expense. The pink clay at the base of the Nanjemoy formation, known as the Marlboro clay, is the most valuable deposit of this group. It is about 25 feet thick and is exposed at many places in the stream valleys between South River and Upper Marlboro, and at a few places still farther southwest. The clay is fairly plastic and no doubt could be used for making pressed brick, but is not plastic enough and is, besides, rather too sandy for pottery.

*Lafayette and Pleistocene clays.*—As already stated, the Lafayette, Sunderland, Wicomico, and Talbot formations are generally composed of coarse materials at the base of the deposits, with a rather persistent loam cap which marks the last stage of deposition during each particular submergence. This surficial loam, which is very similar in all four formations, has been extensively used for the manufacture of brick at many places in Virginia, the District of Columbia, Maryland, and southeastern Pennsylvania. It is generally not more than 3 or 4 feet in thickness, yet, because of its position, many beds no more than 1 or 2 feet thick can be worked with profit. The loam is widely distributed throughout the Patuxent quadrangle and, though not quite coextensive with the formations of which it forms a part, it is present in almost every locality where the Lafayette and Pleistocene formations occupy flat divides that have not suffered much erosion since their deposition. In general the surface loam is adapted only to the manufacture of the common varieties of brick and tile, but in some places it is suitable for making a fair quality of paving brick. In the Patuxent quadrangle the surface loam from the Talbot and Wicomico formations has been utilized at several different times for the manufacture of brick in the eastern part of Washington, near Anacostia River.

### SANDS.

Inasmuch as the arenaceous phase predominates in almost every Coastal Plain formation represented in the region, the Patuxent quadrangle contains an unlimited supply of sand. The sand of the Pleistocene and Lafayette formations is used locally for building purposes, but as it is so readily obtainable in all parts of the region no large pits have been opened.

In some places the quartz sands of the Miocene seem to be pure enough for glass making, suggesting the Miocene glass sands so extensively exploited in southern New Jersey, although they have never been used in that way in this region. Careful chemical analyses and physical tests, which have not been made, would be required to determine their usefulness in this industry.

The Magothy sands in the vicinity of Anacostia have long been worked and at present the most extensive sand pits of the quadrangle are opened in deposits of this age a short distance south of Anacostia. The sand is used for building and filtering purposes. In certain places the Potomac deposits contain molding sand of fair grade, but it has not been used to any great extent.

Locally the Lafayette and Pleistocene sands are rich in ferruginous matter, which in some places cements the grains together, forming a ferruginous sandstone. Sands of this character possess a distinct value for road-making purposes, as they pack readily and make a firm road bed. Where the material can be easily obtained in large quantities, good roads can be very economically constructed with it.

### GRAVELS.

The Pleistocene, Lafayette, and Potomac formations contain numerous beds of gravel widely distributed throughout the region. Those of the Pleistocene and Lafayette deposits are generally rich in iron, which acts as a cementing agent, thus rendering them of considerable value as ballast for roads. There are numerous gravel pits in the eastern part of the District of Columbia in deposits belonging to the Sunderland and Lafayette formations, and elsewhere in the vicinity of Washington there are smaller pits in deposits of Wicomico and Talbot age.

### BUILDING STONE.

The Patuxent quadrangle contains few beds of building stone of much importance, yet in places materials occurring within the region have been used locally. The granite gneiss is the best building stone of the quadrangle and furnishes good material for foundations and other rough work. It is schistose and consequently can not be obtained in large masses, but for that reason can be very easily quarried. Some of the more massive beds furnish stones suitable for building, and in places, where the beds are thinner and more micaceous, flagstones can be obtained.

Although the Coastal Plain formations of the region are composed almost entirely of unconsolidated materials, yet locally indurated beds are not uncommon. In the absence of any better stone these indurated ledges furnish considerable material for the construction of foundations and walls. The best stone of this class is the firmly cemented white sandstone occurring in the Magothy formation about 1 mile north of Collington. The shell beds of the Aquia in the vicinity of Upper Marlboro are so firmly consolidated that they furnish building stone, which though of poor grade is nevertheless suitable for rough work. The gravel bands of the Lafayette and Pleistocene are, in many places, so firmly cemented by iron oxide as to form pebble conglomerates of considerable strength. A portion of the wall about St. Elizabeth's Asylum is constructed of a ferruginous conglomerate of this character.

### MARLS.

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

*Shell marls.*—The shell marls of the Miocene and Eocene formations also possess valuable fertilizing properties for soils deficient in lime. In some places the shells are mixed with so much sand that the lime forms only a small part of the deposit, but in others the amount of lime exceeds 90 per cent. Experiments show that better results have been obtained by the use of shell marl than by that of burned stone lime. The marl acts both chemically and physically and has a beneficial effect on both clayey and sandy soils. So far as known, the shell marls of this region have not been utilized, although they are extensively developed in many localities in the southeastern part of the quadrangle.

### DIATOMACEOUS EARTH.

The principal diggings for diatomaceous earth are at Lyons Creek, although a bed of the material occurring at the base of the Calvert formation extends from Fairhaven, on the bay shore, to Pope Creek, on Potomac River, beyond the quadrangle boundary. Diatomaceous earth, on account of its porosity and compactness, is used in water filters and as an absorbent in the manufacture of dynamite. It is reduced readily to a fine powder and makes an excellent base for polishing compounds, while its nonconductivity of heat makes it a valuable ingredient in packing for steam boilers and pipes and in the manufacture of safes, the latter being the principal use to which it is put. It has been thought that this earth might be of use in certain branches of pottery manufacture which require refractory materials that have no color when burned. Heinrich Ries tested a sample of diatomaceous earth from Lyons Creek at cone 27 in the Deville furnace and found that the material fused to a drop of brownish glass. Its nonrefractory character is thus clearly demonstrated.

### IRON ORE.

The Arundel formation, in the Potomac belt, is a famous source of iron ore. It yields iron carbonate, limonite, hematite, Venetian-red ocher, etc. Similar ores are found at other horizons in the Potomac, and although no valuable deposits are known at the present time within this quadrangle, yet in contiguous regions the iron ores have been mined to a greater or less extent ever since colonial times. They are obtained by open cuts and by shafts. From these ores a very high grade of pig iron is made and the iron, which is noted for its toughness, is in demand at the United States Government arsenals and navy-yards and to some extent in Europe. The only furnace now smelting the ore is located at Muirkirk, not far from the northern border of this quadrangle. This is at present the most important iron district of the entire Arundel belt and mining has been carried on here for over fifty years. The slag has been utilized to a considerable extent as road metal.

SOILS.

The soils which the various formations of the Patuxent quadrangle yield have been carefully mapped by J. A. Bonsteel, and his results, with a full discussion, have been published by the United States Department of Agriculture for those portions of the quadrangle which lie within Prince Georges, Calvert, and St. Marys counties. Those desiring information on this subject are referred to the publications of that Department (Field Operations of Division of Soils, 1900 and 1901) as well as to forthcoming reports by the Maryland Geological Survey on these counties.

PETROLEUM AND NATURAL GAS.

Rumors have been circulated at various times of the discovery of petroleum and natural gas at several different places within the Patuxent quadrangle. Although many of these rumors have been without foundation, small amounts of oil and gas have been observed in some places during the sinking of wells and in the vicinity of streams where there is seepage from porous beds. The gases generated by decaying vegetation have been mistaken in certain cases for natural gas, and the iridescent film of limonite that sometimes appears on the surface of stagnant water in swamps and bogs has been supposed to be petroleum.

Borings have been made about 2 miles west of Annapolis and about 1 mile south of Meadows in the search for oil and gas, but only traces were found. The Meadows well was sunk to a depth of 1511 feet, in all probability nearly to the crystalline rocks, thus practically proving the absence in that place of any considerable amounts of either of these materials. It is not probable that either petroleum or natural gas in paying quantities will be found within the limits of the quadrangle.

WATER RESOURCES.

The water supply of the Patuxent quadrangle is found in the streams and wells of the district. Many of the streams have been used at various times to furnish power for small mills, but little use has been made of them as sources of water supply. Washington, the only city within the quadrangle, obtains its water supply at a point some distance beyond the boundary. Annapolis, the main portion of which lies just east of the quadrangle, is the only city that draws its supply of water from this region, the source being Broad Creek, a tributary of South River. With the exception of the residents of these two cities, the inhabitants of the quadrangle derive their water supply from springs and wells. The wells are divided into two classes—shallow dug wells and deeper bored wells, the deeper usually furnishing artesian water.

SPRINGS.

The gently sloping strata, the alternation of porous and impervious beds, and the great amount of dissection by streams which the region has undergone, all contribute to the formation of springs along the valley slopes. From these springs many of the inhabitants obtain their entire supply of water, which is usually of excellent character. The spring water, as also that in wells, is in places highly charged with mineral matter, particularly iron, sulphur, and salt, and some such waters have been placed on the market. The most important mineral springs of the quadrangle from which waters have been sold are the Bladensburg Spa at Bladensburg and the Algonquin Springs at Oxon.

SHALLOW WELLS.

Nearly all the water supply of the Patuxent quadrangle is derived from shallow wells, varying in depth from 15 to 35 feet. The water is contained in the rather coarse sand or gravel bed so commonly forming the basal stratum of the Pleistocene and Lafayette deposits. So generally is this the case that the depth of the shallow wells is usually a very good indication of the thickness of the surficial deposits. The surface water very readily penetrates the rather coarse surface materials until it reaches the less permeable underlying sedimentary or crystalline rocks. While some of it continues its downward course into these harder rocks a great deal flows along on their upper surface until it finds its way gradually into the streams. Hence wells sunk to this level are practically assured of a supply of water which, while seldom large in flow, is in seasons of average rainfall capable of furnishing sufficient water for ordinary purposes. Such shallow wells are necessarily dependent almost entirely on the amount of water which percolates through the Columbia and Lafayette deposits after rain storms, and are thus apt to be affected by droughts. After periods of heavy rainfall the water may rise in the wells within a few feet of the surface and then is very roily. At other times the wells may become dry, yet this does not often occur because of the fairly equable distribution of rainfall during the year. The supply is less variable over the broad divides or on level ground, where water is always nearer the surface, than in the regions of narrow stream divides, where the water finds an easy exit to the streams. In some places on the narrow divides in proximity to the major streams, it is necessary to sink wells to the depth of 100 feet or more in order to obtain a permanent supply of water.

Most of the water of the shallow wells is obtained at the base of the Lafayette or Sunderland deposits, as each of these formations covers large areas in which the streams have not yet cut through to the underlying deposits. There are also a number of shallow wells in the Patuxent River valley that derive their water supply from the base of the Talbot formation.

The water of the shallow wells usually contains so little mineral matter in solution that it is known as soft water. In many wells, no doubt, it does contain organic matter, yet there is little evidence to show that the water on this account is unfit for drinking purposes. In many places, particularly in the low-lying region bordering Chesapeake Bay between West River and Herring Bay, the old-fashioned well sweep is used to bring the water to the surface.

ARTESIAN WELLS.

Since water is so readily procured at shallow depths in almost all sections of this quadrangle and few establishments in the region require a large supply, there have not been many attempts to obtain artesian water except on the low-lying land adjoining Chesapeake Bay, where flowing wells can be had at small expense. 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 lying 20 feet or less above tide. In areas above this altitude pump wells can probably be had from the water-bearing strata enumerated in the succeeding paragraphs, the water rising under artesian pressure above the point where it enters the well, but not overflowing. The somewhat meager data obtained in this and adjoining regions indicate the occurrence of water at the horizons described in the following paragraphs. Depths to these water-bearing strata in the quadrangle are given on the artesian-water map.

*Waters of the crystalline rocks.*—The waters contained in the crystalline rocks of the Piedmont Plateau are not of especial importance in this quadrangle, since these rocks occur at or near the surface in a very small area. In the vicinity of Washington some wells obtain water from these rocks, but to the northwest of this quadrangle they yield an important water supply. In general water occurs at less definite horizons in the crystalline rocks than in the Coastal Plain deposits, and it is consequently much more difficult to predict the depth to which wells must be sunk to obtain a good supply.

*Crystalline floor horizon.*—Beneath the unconsolidated sedimentary deposits of the Patuxent quadrangle crystalline rocks similar to those exposed at the surface in the northwestern portion of the quadrangle undoubtedly occur. This underlying consolidated rock mass is frequently spoken of as "bed rock." In general the crystalline rocks are less permeable than the overlying deposits and consequently check the downward passage of the percolating soil water, which tends to flow along on their surface or to collect in depressions. The surface of these old rocks dips rather uniformly to the southeast at an average rate of more than 100 feet to the mile. Along this crystalline floor much water flows to lower levels, and it therefore marks a good water horizon. Several artesian wells in the Coastal Plain derive an unfailing supply of pure water from this level. In Washington and the near vicinity water is obtained at this horizon in several wells, of which those at St. Elizabeth's Asylum are the largest. Five of the six artesian wells that supply the water system of Hyattsville probably obtain water at this horizon, which is reached at a depth of 250 feet. Though the water will overflow, the yield is increased by pumping. These five wells, together with another less than half as deep, are all pumped together and yield 130 gallons a minute.

Throughout the greater portion of the quadrangle this crystalline floor can never be very important as a water horizon because of its great depth. It was not reached in a 1511-foot boring about 1 mile south of Meadows, and it is probable that it lies as much as 2000 feet below tide over a large portion of the quadrangle.

*Water horizons in the Potomac strata.*—The Potomac deposits contain many beds of coarse material that constitute good water-bearing strata. Some of these sand and gravel beds lie between impervious clay deposits and thus furnish the requisite conditions for flowing artesian wells. Within the District of Columbia the beds belonging to the Potomac group are the principal water-bearing formations. The water does not seem to come from any one horizon of wide distribution, as is shown by the varying depths at which it is reached and by the failure to obtain any water in these beds at certain places. Wells that were unsuccessful in finding a satisfactory supply of water were the 360-foot well at the ice works and the 133-foot well at the Mount Vernon apartment house. On the other hand, at Hyattsville and in the vicinity there are several wells with small flow that derive their supply of water from Potomac strata at depths between 100 and 112 feet. At Bladensburg flowing wells with capacities ranging from 1 to 15 gallons a minute have been obtained at depths between 73 and 100 feet; at the plant of the National Capital Brewing Company there is a 103-foot well that yields from 100 to 130 gallons a minute; at Langdon a flow of 40 gallons a minute was obtained at a depth of 140 feet; at the Reform School water was encountered at a depth of 270 feet; and near Chesapeake Junction a well which formerly flowed but now has to be pumped obtains its supply of water at a depth of 350 feet. At Annapolis, on the grounds of the United States Naval Academy, a well sunk to the depth of 601 feet penetrated eight water-bearing strata within the Potomac beds, from three of which water flowed out at the surface, 8 feet above tide. At the lowest horizon, between 587 and 601 feet, a flow of water of 75 gallons a minute is obtained. The water contains iron, but is of excellent quality when filtered.

*Water horizons in the Upper Cretaceous.*—The sandy strata of the Magothy formation are in many places water bearing. The water is apt to be strongly impregnated with iron, and locally with sulphur; consequently it is less desirable than that obtained from the Potomac deposits. At Upper Marlboro several flowing wells with an average depth of about 225 feet obtain a good supply of water from the Magothy. In some of the wells the amount of mineral matter in solution renders the water somewhat undesirable for drinking purposes, while in others the mineral matter seems to be present only in very small amounts. The Naval Academy well at Annapolis obtained flowing water from the Magothy at a depth between 180 and 220 feet, but as the supply was not sufficient the well was sunk deeper.

In New Jersey considerable artesian water has been obtained from the greensand deposits of the Upper Cretaceous. In this region no artesian wells are known in which the supply of water is obtained from the Matawan or Monmouth deposits. These are in general more porous than those of the Magothy or Potomac formations and contain fewer clay bands, so that the water passes more readily to lower levels.

*Water horizons in the Eocene.*—The character of the Eocene beds is in the main similar to that of the Upper Cretaceous. More clay members are present, however, and consequently conditions for flowing wells are more favorable. The water is almost everywhere heavily charged with iron, and sulphur is also present in places. Nevertheless, more flowing wells in the Patuxent quadrangle obtain their supply of water from the Eocene than from any other horizon. At Galesville there are several flowing wells ranging in depth from 110 to 150 feet; on the low-lying land to the east of Sudley, locally known as "The Swamp," there are from twenty-five to thirty flowing wells, ranging in depth from 120 to 140 feet; and at Leitch Wharf a flow of water is obtained at 140 feet. Most of the wells have a flow of 8 to 12 gallons a minute, but a few yield only 1 to 2 gallons.

At Chesapeake Beach water has been obtained at a depth of 295 feet from a lower horizon in the Eocene, probably near the base of the Aquia. It contains less mineral matter than the water from the above-mentioned wells, which is derived probably from near the base of the Nanjemoy.

*Water horizons in the Miocene.*—In the southern half of the quadrangle artesian water is obtainable from the Calvert formation. The Miocene deposits in the Coastal Plain contain, intercalated between impervious argillaceous strata, numerous sandy beds which furnish good supplies of water, usually of excellent quality. At North Chesapeake Beach a good flow of water is obtained from the Miocene at a depth of 85 feet. At Governor Run, just beyond the southeast corner of this quadrangle, there is a well a little more than 100 feet in depth that derives a good supply of excellent water from Miocene strata. This well discharges about 10 feet above tide and when it was first sunk had a flow of about 25 gallons a minute, but at present the flow is considerably less.

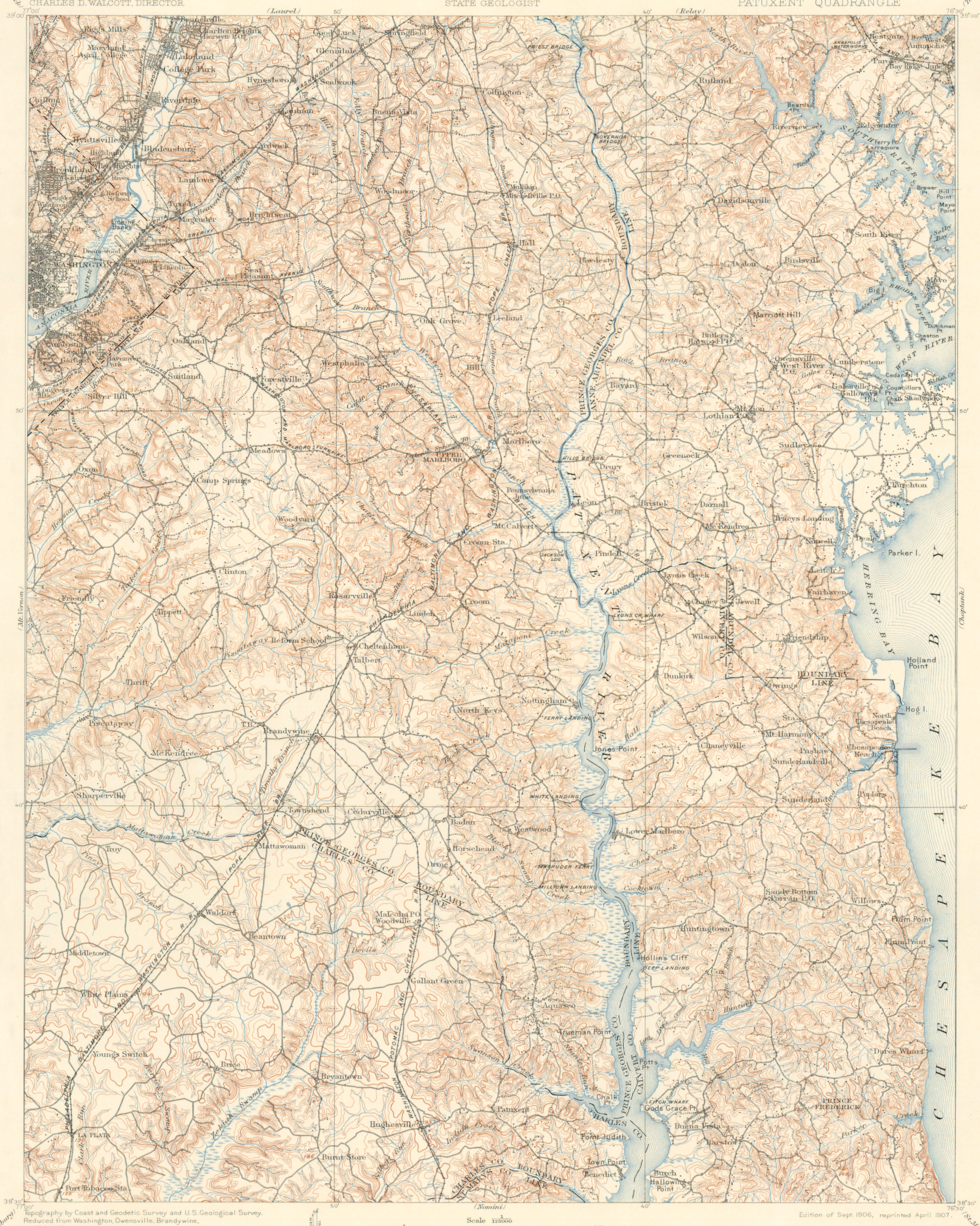
April, 1907.

# TOPOGRAPHY

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

STATE OF MARYLAND
WILLIAM BULLOCK CLARK
STATE GEOLOGIST

## MARYLAND–DISTRICT OF COLUMBIA
## PATUXENT QUADRANGLE




## LEGEND

**RELIEF**
*printed in brown*

Figures
*showing heights above mean sea level instrumentally determined*

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

**DRAINAGE**
*printed in blue*

Streams

Lakes and ponds

Salt marshes

Fresh marshes

**CULTURE**
*printed in black*

Roads and buildings

Churches and school houses

Private and secondary roads

Railroads

Bridges

Drawbridges

State lines

County lines

Topography by Coast and Geodetic Survey and U.S. Geological Survey.
Reduced from Washington, Owensville, Brandywine, and Prince Frederick sheets.
Surveyed in 1886, 1890 and 1895-97.

PARTIALLY REVISED IN 1900 AND 1904-1905 IN COOPERATION WITH THE STATE OF MARYLAND.

TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1906.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 20 feet.
*Datum is mean sea level.*

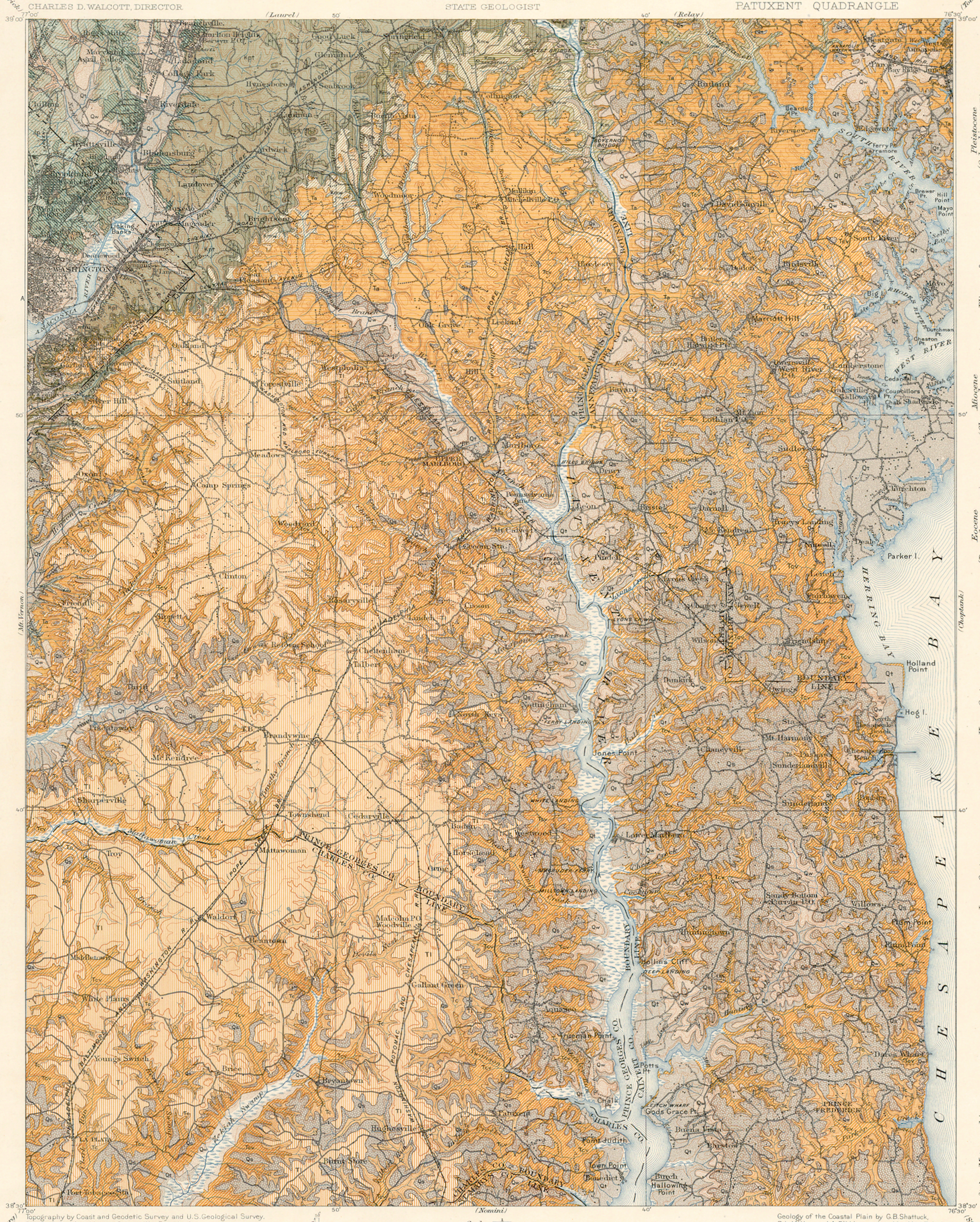
Edition of Sept. 1906, reprinted April 1907.

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

# AREAL GEOLOGY

STATE OF MARYLAND
WILLIAM BULLOCK CLARK
STATE GEOLOGIST

## MARYLAND–DISTRICT OF COLUMBIA
## PATUXENT QUADRANGLE

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Edition of June 1907

Geology of the Coastal Plain by G.B. Shattuck, B.L. Miller, and A. Bibbins, assisted by M.W. Twitchell and W.D. Neal.
Geology of the crystalline rocks by Arthur Keith.
Surveyed in 1900-1906.

SURVEYED IN COOPERATION WITH THE STATE OF MARYLAND.

## LEGEND

### SEDIMENTARY ROCKS

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 ?*

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

UNCONFORMITY

*Miocene (Chesapeake group)*

Tc — **Choptank formation** *(fine sand, sandy clay, and shell marl)*

UNCONFORMITY

Tcv — **Calvert formation** *(blue clay, sandy clay, shell marl, and diatomaceous earth)*

UNCONFORMITY

*Eocene (Pamunkey group)*

Tn — **Nanjemoy formation** *(glauconitic sand, pink clay, and shell marl)*

Ta — **Aquia formation** *(light and dark glauconitic sand and shell marl, in places firmly cemented by iron oxide)*

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

*Lower Cretaceous (Potomac group)*

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

UNCONFORMITY

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

UNCONFORMITY

JURASSIC ?

Ja — **Arundel formation** *(drab, red, and black clay carrying lignite and iron ores)*

UNCONFORMITY

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

### IGNEOUS ROCKS

ARCHEAN — *Metamorphic*

Ag — **Granite gneiss** *(including granite, gneissoid granite, and schistose granite)*

*Quarries*

*Clay, gravel, and sand pits*

*Note – Building stone is obtainable from the granite gneiss, building sand from all Coastal Plain formations, brick and tile clay and gravel from Qt, Qw, Qs, Tl, Kr, Kpt, Ja, and Jp; marl for fertilizer from Tc, Tcv, Tn, Ta, Km, and Kmw; iron ore from Ja, and diatomaceous earth from Tcv.*

# ARTESIAN WATER

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

STATE OF MARYLAND
WILLIAM BULLOCK CLARK
STATE GEOLOGIST

MARYLAND–DISTRICT OF COLUMBIA
PATUXENT QUADRANGLE


## LEGEND

Elevation of artesian water horizon near base of Calvert formation
(water occurs chiefly below sea level)

Elevation of Eocene artesian water horizon
(probably near base of Nanjemoy formation; yields flowing wells 10 to 20 feet above sea level)

Elevation of artesian water horizon in Magothy formation
(yields flowing wells 10 to 40 feet above sea level)

Elevation of base of Potomac group
(water occurs in basal beds in most places, water not to be expected in the "bed rock" beneath)

Contours show elevation above and depth below sea level in intervals of 100 feet. Dashed lines indicate approximate location

◎130 Artesian wells with depth in feet

● Flowing wells, numerous other flowing wells in the lowland southeast of Sudley

Deep boring for oil

Topography by Coast and Geodetic Survey and U.S. Geological Survey.
Reduced from Washington, Owensville, Brandywine, and Prince Frederick sheets.
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PARTIALLY REVISED IN 1900 AND 1904-1905 IN COOPERATION WITH THE STATE OF MARYLAND.

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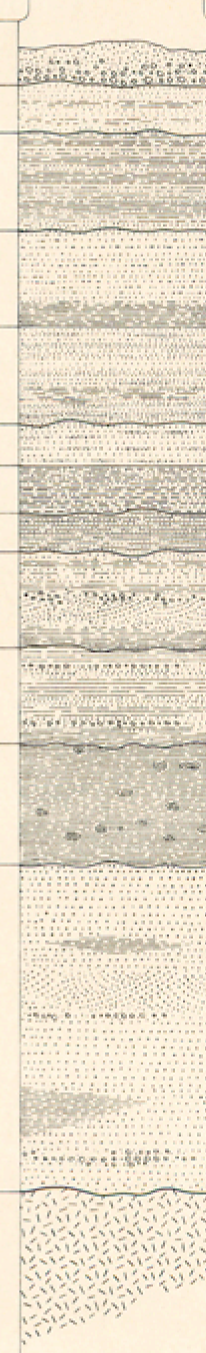
# COLUMNAR SECTION

GENERALIZED SECTION FOR THE PATUXENT QUADRANGLE.

SCALE: 1 INCH = 200 FEET.

| System. | Series. | Formation Name. | Symbol. | Columnar Section. | Thickness in Feet. | Character of Rocks. | Character of Topography and Soils. |
|---|---|---|---|---|---|---|---|
| QUATERNARY | PLEISTOCENE (COLUMBIA GROUP) | Talbot formation. | Qt | OCCUR ONLY ON RIVER TERRACES ON OLDER FORMATIONS. | 40 | Loam, sand, and gravel, with clay lenses and ice-borne bowlders. | Very flat to gently rolling low lands, 0 to 45 feet above sea. Sandy to loamy soil adapted for truck farming. |
| | | UNCONFORMITY | | | | | |
| | | Wicomico formation. | Qw | | 20 | Loam, sand, and gravel, with ice-borne bowlders. | Flat to gently rolling lands, 40 to 100 feet above sea. Sandy or loamy soil suitable for truck farming and grain. |
| | | UNCONFORMITY | | | | | |
| | | Sunderland formation. | Qs | | 35 | Loam, sand, and gravel. | Flat to undulating uplands, 90 to 200 feet above sea. Loamy or sandy soil suitable for grain and fruit. |
| | | UNCONFORMITY | | | | | |
| TERTIARY | PLIO-CENE? | Lafayette formation. | Tl |  | 40 | Loam, coarse sand, and gravel. | High rolling lands, 180 to 300 feet above sea. Clayey loam to gravelly soil, not very fertile. |
| | | UNCONFORMITY | | | | | |
| | MIOCENE (CHESAPEAKE GROUP) | Choptank formation. | Tc | | 50 | Fine sand, sandy clay, and shell marl. | Steep slopes along streams. Sandy soil. |
| | | UNCONFORMITY | | | | | |
| | | Calvert formation. | Tcv | | 50-100 | Blue clay, sandy clay, shell marl, and diatomaceous earth. | Slopes along streams. Light soil of medium fertility. |
| | | UNCONFORMITY | | | | | |
| | EOCENE (PAMUNKEY GROUP) | Nanjemoy formation. | Tn | | 100 | Glauconitic sand, pink clay, and shell marl. | Level land with broad, open valleys. Moderately heavy, fertile soil. |
| | | Aquia formation. | Ta | | 100 | Light- and dark-colored sand, largely glauconitic, occasionally firmly indurated by iron oxide, and shell marl. | Level land with broad, open valleys. Moderately heavy, fertile soil. |
| | | UNCONFORMITY | | | | | |
| CRETACEOUS | UPPER CRETACEOUS | Monmouth formation. | Km | | 40-50 | Reddish-brown and greenish-black sand with many irregular iron crusts. | Gentle slopes along streams. Rich brown soil. |
| | | Matawan formation. | Kmw | | 45-50 | Gray and black micaceous sandy clay carrying glauconite. | Slopes along streams. Rich soil containing many small flakes of mica. |
| | | UNCONFORMITY | | | | | |
| | | Magothy formation. | Kma | | 0-40 | Thinly laminated sand and clay with much lignite and occasional ferruginous sandstone. | Gentle to steep slopes along streams. Sandy soil. |
| | | UNCONFORMITY | | | | | |
| | LOWER CRETACEOUS (POTOMAC GROUP) | Raritan formation. | Kr | | 100 | Variegated clay, sand, and gravel, with some lignite. | Irregular topography. Sandy to argillaceous soil of low fertility. |
| | | UNCONFORMITY | | | | | |
| | | Patapsco formation. | Kpt | | 100 | Highly colored variegated clay interbedded with sand and gravel. | Irregular topography. Sandy to argillaceous soil of low fertility. |
| | | UNCONFORMITY | | | | | |
| JURASSIC? | | Arundel formation. | Ja | | 0-125 | Drab, red, and black clay carrying lignite and iron ore. | Irregular topography. Sandy to argillaceous soil of low fertility. |
| | | UNCONFORMITY | | | | | |
| | | Patuxent formation. | Jp | | 340 | Light-colored arkosic sands with clay lenses and gravel bands. | Irregular topography. Sandy to argillaceous soil of low fertility. |
| | | UNCONFORMITY | | | | | |
| ARCHEAN | | Granite gneiss. | Ærg | | | Gray granite gneiss. | Steep slopes along streams. Light to heavy clay soil containing sand and mica flakes |

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

Stratified rocks often contain the remains or imprints of plants and animals which, at the time the strata were deposited, lived in the sea or were washed from the land into lakes or seas, 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. When 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 found 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 often difficult or impossible to determine the age of an igneous formation, but the relative age of such a formation can sometimes 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 is sometimes 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 of their metamorphism.

*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.

*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....... | ..................... | Ꞧ | Peacock-blue. |
| Paleozoic | Carboniferous. | Permian....... Pennsylvanian Mississippian.. | C | Blue. |
| | Devonian..... | ..................... | D | Blue-gray. |
| | Silurian....... | ..................... | S | Blue-purple. |
| | Ordovician.... | ..................... | O | Red-purple. |
| | Cambrian..... | Saratogan..... Acadian....... Georgian...... | € | Brick-red. |
| | Algonkian.... | ..................... | A | Brownish-red. |
| | Archean...... | ..................... | AR | Gray-brown. |

Patterns composed of parallel straight lines are used to represent sedimentary formations deposited in the sea or in lakes. 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 by which formations are labeled 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 recognized series, in proper order (from new to old), with the color and symbol assigned to each system, are given in the preceding table.

## SURFACE FORMS.

Hills and 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; sea cliffs are made by the eroding action of waves, and sand spits are built up by waves. Topographic forms thus constitute part of the record of the history of the earth.

Some forms are produced in the making of deposits and are inseparably connected with them. The hooked spit, shown in fig. 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, and these are, in origin, independent of the associated material. 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 afterwards 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. When a large tract is for a long time undisturbed by uplift or subsidence it is degraded nearly to base-level, and the even surface thus produced is called a *peneplain*. If the tract is afterwards uplifted the peneplain at the top is a record of the former relation of the tract to sea level.

## THE VARIOUS GEOLOGIC SHEETS.

*Areal geology map.*—This map shows the areas occupied by the various formations. On the margin is a *legend*, which is the key to the map. To ascertain the meaning of any colored 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 given formation, its name should be sought in the legend and its color and pattern noted, when the areas on the map corresponding in color and pattern may be traced out.

The legend is also a partial statement of the geologic history. In it the 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.*—This map represents the distribution of useful minerals and rocks, showing their relations to the topographic features and to the geologic formations. The formations which appear on the areal geology map are usually shown on this map by fainter color patterns. The areal geology, thus printed, affords a subdued background upon which the areas of productive formations may be emphasized by strong colors. A mine symbol is printed at each mine or quarry, accompanied by the name of the principal mineral mined or stone quarried. For regions where there are important mining industries or where artesian basins exist special maps are prepared, to show these additional economic features.

*Structure-section sheet.*—This sheet exhibits the relations of the formations beneath the surface. In cliffs, canyons, shafts, and other natural and artificial cuttings, the relations of different beds to one another may be seen. Any cutting which exhibits those relations is called a *section*, and the same 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 the 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 of the earth to a considerable depth. Such a section exhibits what would be seen in the side of a cutting many miles long and several thousand feet deep. This is illustrated in the following figure:

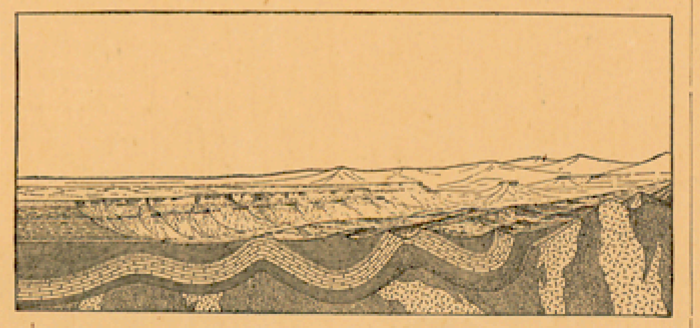


Fig. 2.—Sketch showing a vertical section at the front and a landscape beyond.

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

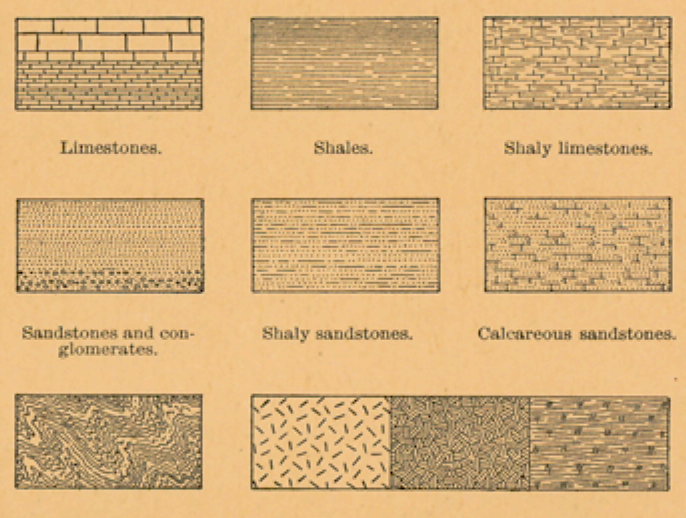



Fig. 3.—Symbols used in sections to represent different kinds of rocks.

The plateau in fig. 2 presents toward the lower land an escarpment, or front, which is made up of sandstones, forming the cliffs, and shales, constituting the slopes, as shown at the extreme left of the section. The broad belt of lower land is traversed by several ridges, which are seen in the section to correspond to 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 that the intersection of a bed with a horizontal plane will take is called the *strike*. The inclination of the bed to the horizontal plane, measured at right angles to the strike, is called the *dip*.

Strata are frequently curved in troughs and arches, such as are seen in fig. 2. The arches are called *anticlines* and the troughs *synclines*. But the sandstones, shales, and limestones were deposited beneath the sea in nearly flat sheets; that they are now bent and folded is 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 fig. 4.

On the right of the sketch, fig. 2, the section is composed of schists which are traversed by masses of igneous rock. The schists are much contorted and their arrangement underground can not be

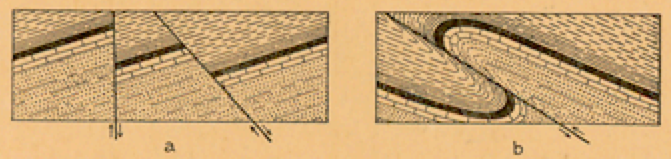



Fig. 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* fault.

inferred. Hence that portion of the section delineates what is probably true but is not known by observation or well-founded inference.

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

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

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

The third set of formations consists of crystalline schists and igneous rocks. At some period of their history the schists were plicated by pressure and traversed by eruptions of molten rock. But 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 suffered metamorphism; they were the scene of 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 fig. 2 are ideal, but they illustrate relations which actually occur. 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 which appears in the section may be measured by using the scale of the map.

*Columnar section sheet.*—This sheet contains a concise description of the sedimentary formations which 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 which state the least and greatest measurements, and the average thickness of each is shown in the column, which is drawn to a scale—usually 1000 feet to 1 inch. The order of accumulation of the sediments is shown in the columnar arrangement—the oldest formation at the bottom, the youngest at the top.

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

CHARLES D. WALCOTT,
*Director.*

Revised January, 1904.

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