DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

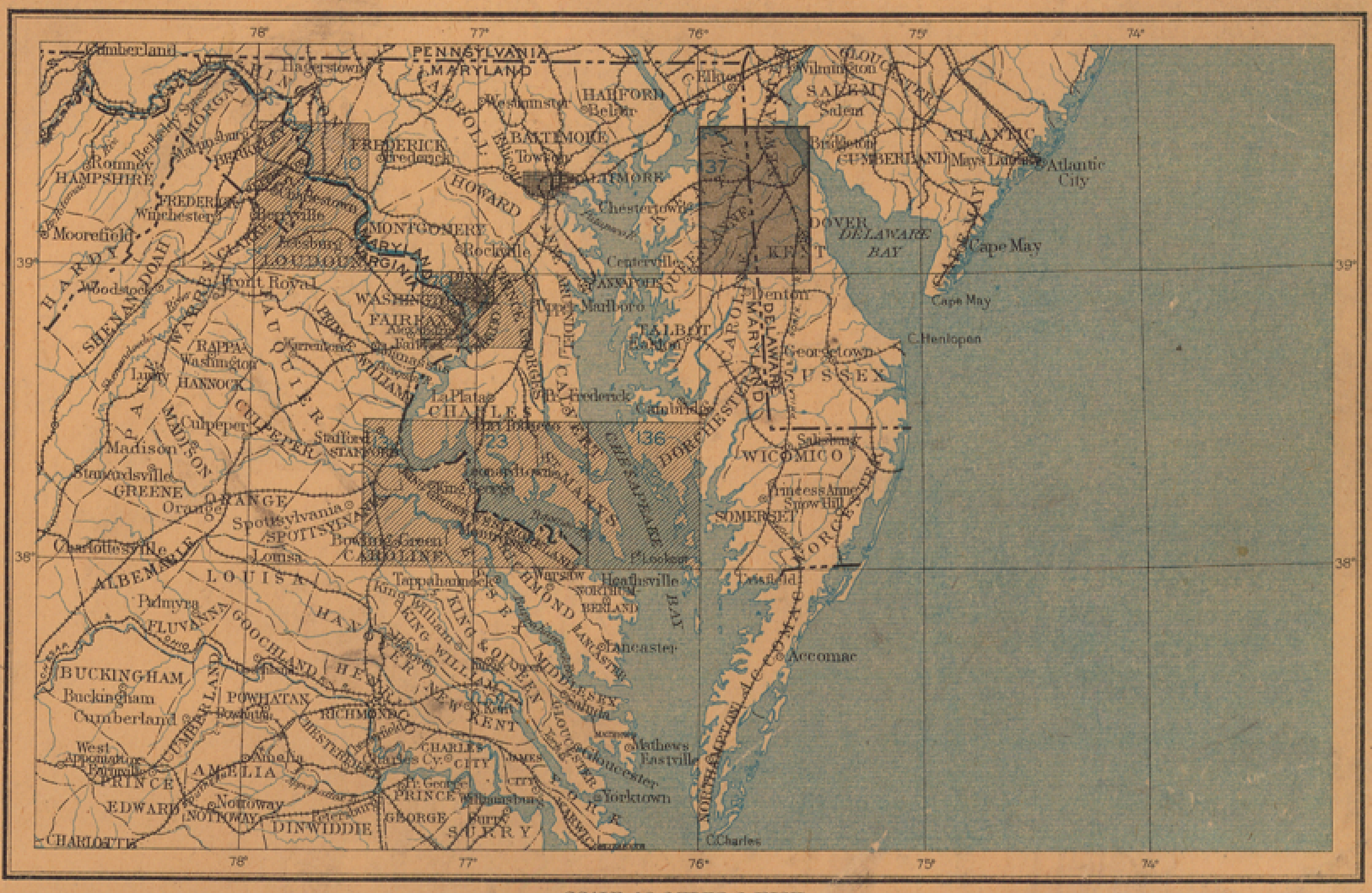
CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS
OF THE
UNITED STATES

DOVER FOLIO

DELAWARE–MARYLAND–NEW JERSEY

INDEX MAP



SCALE: 40 MILES = 1 INCH

DOVER FOLIO

OTHER PUBLISHED FOLIOS

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DESCRIPTIVE TEXT — TOPOGRAPHIC MAP — AREAL GEOLOGY MAP

WASHINGTON, D. C.
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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).

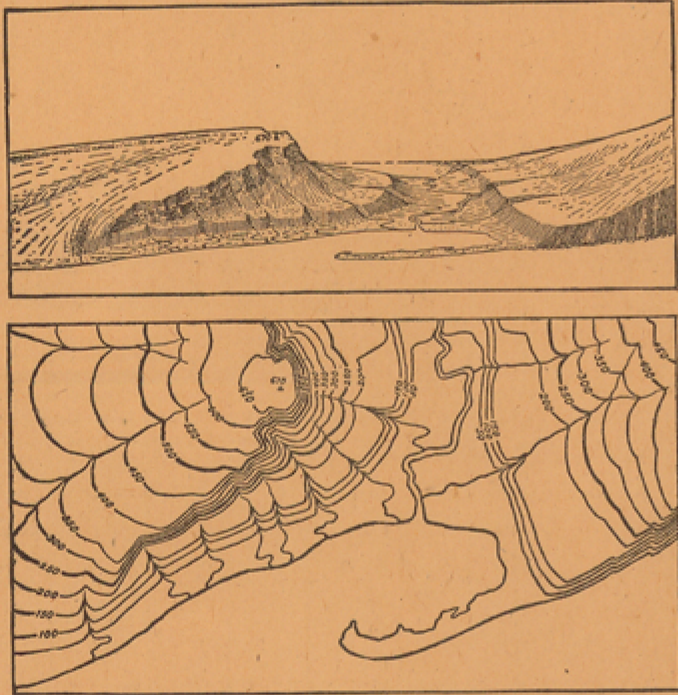


FIG. 1.—Ideal view and corresponding contour map.

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 reëntrant 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 produced 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 DOVER QUADRANGLE.*

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

By Benjamin LeRoy Miller.

INTRODUCTION.

Location and area.—The Dover quadrangle lies between parallels 39° and 39° 30′ north latitude and meridians 75° 30′ and 76° west longitude. It includes one-fourth of a square degree of the earth's surface and contains 925 square miles. From north to south it measures 34.5 miles and from east to west the mean distance is 26.8 miles, being 26.9 miles along the southern and 26.7 miles along the northern border. It occupies the northern part of the long peninsula which extends from the headwaters of Chesapeake and Delaware bays southward to Cape Charles, a distance of about 175 miles. This peninsula contains considerable portions of Maryland and Virginia, and practically all of the State of Delaware. It is washed on one side by the waters of Delaware River, Delaware Bay, and the Atlantic Ocean, while on the other side Chesapeake Bay separates it from the main land mass to the west.

The quadrangle includes portions of Maryland, Delaware, and New Jersey. In Maryland it embraces the southeastern part of Cecil County, the eastern parts of Kent and Queen Anne counties, and the northern part of Caroline County. In Delaware it includes the southern part of Newcastle County and the northern half of Kent County. In New Jersey it includes a small portion of Salem County along Delaware River. Besides the land areas, a small portion of Chesapeake Bay, with parts of the estuaries of Bohemia Creek and of Elk and Sassafras rivers, as well as several square miles of Delaware River, are embraced within its limits.

Outline of the geography and geology of the province.—In its physiographic and geologic relations this quadrangle forms a part of the Atlantic Coastal Plain province, which borders the entire eastern part of the North American continent 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 declivity generally begins at a depth of 450 to 500 feet below sea level, but by common practice the 100-fathom line is regarded as the boundary of the continental shelf. The descent from that line to the greater ocean depths is rapid; at Cape Hatteras there is an increase in depth of 9000 feet in 13 miles, a grade as steep as that often found along the flanks of the greater mountain systems. In striking contrast to this declivity is the comparatively flat ocean bed which stretches away from it to the east with but slight differences in elevation. Seen from its base the escarpment would have the appearance along the horizon 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 western limit of the Atlantic Coastal Plain is defined by a belt of crystalline rocks consisting of greatly metamorphosed igneous and sedimentary materials ranging in age from pre-Cambrian to Silurian. These rocks form the Piedmont Plateau province. In some regions this plateau is covered by sandstones and shales of Triassic age, which in New Jersey are interposed between the crystalline rocks and the Coastal Plain deposits. 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, below which they show a marked decrease in the velocity of their currents, the name "fall line" being given to this boundary on that account. 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. Southward 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 streams are considerably above tide. The position of the "fall line" near the head of navigation or near the source of waterpower 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 the line. A line drawn through these places would approximately separate the Coastal Plain from the Piedmont Plateau.

The Atlantic Coastal Plain province is divided into two parts by the present shore line—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 grade into each other with scarcely 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 by the shifting of the shore line eastward or westward by local and general depressions or elevations of moderate extent, and even at the present time such changes are in progress. Deep channels, probably old river valleys and the continuation 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 the Hudson is particularly well marked and has been shown to extend almost uninterruptedly to the edge of the shelf, over 100 miles east of its present mouth. Another is found 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 Florida and Georgia the subaerial portion is over 150 miles wide, while the submerged portion is very narrow, and along the eastern shore of the peninsula of Florida is almost absent. Northward the submerged portion gradually increases in width, while 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, seldom exceeding 5 feet to the mile, except in the vicinity of the Piedmont Plateau, where the slope is occasionally as great as 10 to 15 feet to the mile, or even more. The submerged portion is monotonously flat, as deposition has destroyed most of the irregularities produced by erosion when it formed a part of the land area. The slight elevation of the subaerial portion, which seldom 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. Occasionally, however, the country along the stream courses shows noticeable relief, though the variations in altitude are only a few hundred feet. Throughout the greater portion of the area this relief is very inconsiderable, the streams flowing in open valleys at a level only slightly lower than that of the broad, flat divides.

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, of which there are many others of less importance. The streams of this area which have their sources in regions 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 upon stream development except in local instances.

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

The materials of which the Coastal Plain is composed are bowlders, pebbles, sand, clay, and marl, mostly loose or locally indurated. In age the formations range from the Jurassic to the Recent. Since the time when 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 entire 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 highest point of land within the quadrangle is found on Elk Neck and is locally known as Maulden Mountain. It has an elevation of 240 feet, and as it rises rather precipitously from the waters of Chesapeake Bay it has the appearance of a mountain in comparison with the flat, low-lying plains in the vicinity. Besides Maulden Mountain there are several other hills on Elk Neck that rise to an elevation of more than 100 feet. In the area southeast of Elk River there is only one point where an elevation of 100 feet is reached and that occurs about 2 miles north of Cecilton. There are, however, several other places on Sassafras Neck where the land rises to a height of almost 100 feet above sea level. The flat divide between Chesapeake and Delaware bays in this region has an elevation of 80 feet or more. Toward the southeast this plain gradually decreases in height until in the southern half of the quadrangle it is in few places more than 60 feet above sea level. On Sassafras Neck there are a few prominences that rise several feet above the general level of the divide, but in the southern half of the region the land is practically a dead-level plain except where streams have cut shallow, open valleys.

Although the Dover quadrangle lies entirely within the Coastal Plain province, it contains areas that represent two very different types of topography. In this part of the province Chesapeake Bay in general separates two regions of unlike relief. The western side of the bay is characterized by rolling hills and valleys, with rather narrow stream divides, while on the eastern side the prevailing topography is much more regular and is characterized by broad, low-lying plains in which the streams have cut only very shallow valleys. Near the head of Chesapeake Bay the dividing line between the two regions diverges to the northeast up Elk River instead of following the main channel of the Susquehanna. Thus, although the Dover quadrangle does not include any territory lying west of Chesapeake Bay it does include a small portion of the region that properly belongs to the western part of the Coastal Plain, so far as topography is concerned. This small area is comprised in Elk Neck, lying west of Elk River and occupying the extreme northwestern portion of the quadrangle.

Elk Neck shows a well-developed topography. In the larger region of which the quadrangle is a part there are four plains, which stand at different levels. These do not everywhere preserve their plain-like character, but in some places have been modified by erosion. Remnants of the two upper plains—that is, those occupying the higher levels—occur on Elk Neck. The other two are well represented in the main portion of the quadrangle, southeast of Elk River. A casual glance at the map will show the irregular topography that is typical of the Elk Neck region, while the main portion of the area to the southeast is characterized by a very flat plain, with little relief. The western part of this plain is cut into by streams which are at some places bordered by precipitous slopes. Toward the east the region descends very gradually to Delaware River and is usually bordered by a line of marshes.

TOPOGRAPHIC FEATURES.

Within the Dover quadrangle five different topographic features may be distinguished. These vary greatly in the areas which they occupy, but are principally unlike in the elevations at which they are found.

Tide marshes.—The first of these topographic features to be described consists of the tide marshes in the northeastern portion of the quadrangle, bordering Delaware River. These cover a number of square miles and lie at a level so low that the waters of Delaware River frequently extend completely over them. The rivers that empty into Delaware River meander through these marshes and some of them disappear within them. Certain portions of these tide marshes have been for a time reclaimed by the construction of embankments which have kept the tide from inundating them. Cedar Swamp is an example. This swamp, which is now at times largely covered by water at high tide, was formerly cultivated. It was reclaimed by the construction of a dam which shut out the waters of Delaware River, but since the destruction of this barrier these waters at high tide have free access to the area, and it has again been converted into a swamp.

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 the mud carried in by streams and by causing the accumulation of vegetable débris.

Talbot plain.—The term plain is used in this discussion 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 tide to an altitude of about 45 feet. This plain borders the larger streams in both the eastern and the western portions of the quadrangle. Along Delaware River it is about 6 miles in extreme width, while on the western side of the quadrangle it is seldom more than half a mile wide. The characteristics of the Talbot plain are well exhibited in the region east of Smyrna and Dover, where it shows very low relief and preserves in general its plain-like character. For miles there is apparently no difference in elevation whatever, the whole region being so flat that it would seem to be not well drained. In general, however, it is drained throughout; there is scarcely a

*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 Geological Survey. The geologic maps accompanying these reports are published on the United States Geological Survey's topographic base, on the scale of 1 inch to the mile.

marshy area in it. In places the Talbot plain adjoins Delaware River, but usually it is separated from the river by a series of tide-water marshes.

The Talbot plain extends up the valleys of the principal streams, becoming gradually narrower as it reaches farther inland. In the eastern part of the quadrangle this plain is almost continuous throughout. A very few streams have cut through it, separating small portions from the larger mass. In the western part of the area, however, the reverse is true. There the Talbot plain is seen to border the large streams, especially in their estuarine portions, but it is seldom continuous for any considerable distance. Instead, the streams have cut through it in so many places that the plain seems to be merely a series of isolated areas separated by the valleys of tributary streams. On Elk Neck the Talbot plain is very poorly represented at the present time, yet small remnants of it are shown on either side of this peninsula.

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. This escarpment is often wanting, so that at some points there seems to be a gradual passage from the Talbot plain to the Wicomico. It is found, however, at so many places that there is little difficulty in determining the line of separation between the two plains. The base of the escarpment stands at an elevation of about 40 feet. From that height the Wicomico plain extends upward to an elevation of about 100 feet. At this higher elevation it is separated from the next higher plain by another escarpment.

The Wicomico plain is the best developed of any of the five different topographic divisions within the region. It occupies the greater portion of the quadrangle and forms the broad divide between the Delaware and the Chesapeake Bay drainage systems. The Wicomico plain is very similar to the Talbot plain with the exception that it occupies a higher elevation. Along its borders it slopes very noticeably toward the lower plain, but in the interior it is exceedingly flat and monotonous. Over large areas and for distances of 10 miles or more there will not be a difference in elevation of more than 5 or 6 feet between any two of its portions. This is especially the case in the southern half of the quadrangle. In the northern part of the quadrangle the Wicomico plain is much more rolling, so that in some portions of that region its plain-like character is not preserved. Between Bohemia Creek and Sassafras River the plain has been so modified by stream erosion that a rather irregular rolling surface has been produced. In the main portion of the quadrangle the Wicomico plain is continuous and forms the divides between nearly all of the larger streams and many of the minor tributary streams. On Elk Neck the Wicomico plain, like the Talbot, has been very much dissected, so that it now appears merely as isolated remnants. It there occupies the lower portions of the divides between the very small streams that empty into Elk River. At one time these small areas were all connected and formed a continuous terrace bordering the river. Recent erosion, however, has removed a large part of it and destroyed its continuity.

Sunderland plain.—Elsewhere in Maryland a plain called the Sunderland is situated above the Wicomico and bears the same relation to the Wicomico which that plain bears to the Talbot. The Sunderland plain extends from about 100 feet to about 180 feet above sea level. It is usually separated from the Wicomico plain by an escarpment, and where it comes into contact with the next plain above, an escarpment is also usually present. The Sunderland plain is poorly developed within the Dover quadrangle and the topographic features referred to it represent only remnants of what was once an extensive plain. Its typical characteristics are not shown in the quadrangle. It is found only on Elk Neck, where it covers about 2 square miles, consisting of a few small outliers of a large plain lying farther northwest, with which they were formerly united. The largest area is that covering Timber Neck divide. Here it forms the highest land between Chesapeake Bay and Elk River. As developed in this region the Sunderland area does not seem to be a plain because erosion has so effectively dissected it. There is little doubt, however, that the Sunderland plain at one time extended over the greater part of the Dover quadrangle, but before the Wicomico plain was formed erosion had removed the Sunderland from the larger portion of the region, and it could scarcely be expected that the Sunderland of Elk Neck would now show its typical characters. The Sunderland is well developed in other parts of Maryland, where it still preserves its original characteristics and is seen to be a plain similar to the other plains already described.

Lafayette plain.—The Lafayette lies at the highest level of any of the plains developed within the Coastal Plain province. Within the Dover district it is represented by four small outliers occupying the top of Maulden Mountain, on Elk Neck. This plain, like the Sunderland, is so poorly developed in the Dover quadrangle that its characteristics as a plain are not well shown. If its remnants could be joined with one another and with other similar remnants outside but near this area, by filling up the intervening stream valleys, a true plain of great areal extent would be formed. These remnants of the Lafayette plain in the Dover quadrangle occupy an elevation of about 200 feet. Elsewhere in the coastal region this plain rises to elevations ranging from 300 to 400 feet. The Lafayette, like the Sunderland, was at one time very much more extensive, but has been entirely removed from a large area by erosion and is now represented only by isolated remnants. In southern Maryland the Lafayette plain is very extensive and exceedingly flat, so that it has all the characteristics of a true plain. In the Dover quadrangle it does not retain those characters and by itself could not properly be spoken of as a plain. It is only by tracing the connection of the few outliers on Maulden Mountain with the extended Lafayette plain of adjoining regions that we can speak of these remnants as representing a distinct topographic division. Undoubtedly the Lafayette plain would have been entirely removed from Elk Neck, as it has been in the other portions of this region, were it not for the indurated character of the materials that form the surface of the plain on Maulden Mountain.

DRAINAGE.

General features.—The drainage of the Dover quadrangle is comparatively simple, as a result of the simple structure of the formations and the contiguity of the region to Delaware and Chesapeake bays. Except in a few parts all of the quadrangle is naturally drained, some areas principally by underground drainage, as is the case with a large district south of Chester River. All of the northern half of the quadrangle is well drained by streams, for in that region the estuaries of Chesapeake Bay extend inland a number of miles and the side tributaries cut back to the crests of the divides. In the southern half, however, streams are entirely absent over considerable areas, and were it not for the porous character of its soils this upland would be covered with marshes. During the rainy season water does stand on the surface, and in some places it has been necessary to dig series of ditches to connect with the natural streams. In other places, however, no ditches have been dug and there the water escapes slowly underground. The sandy surface soil is underlain by a gravel bed, so that conditions are very favorable for underground drainage.

Stream divides.—As the Dover quadrangle lies between Chesapeake Bay and Delaware River, both of which are at sea level, it would naturally be expected that the watershed between the two drainage systems would divide the quadrangle into two symmetrical parts; yet, notwithstanding the fact that there is little in the character of the materials, the position of the beds, or the comparative proximity to tide water to cause the streams emptying into Chesapeake Bay to cut more rapidly than those emptying into Delaware Bay, the stream divide is considerably nearer Delaware River and Delaware Bay. The asymmetrical character of the divide is much more pronounced in areas farther south on the peninsula, where the streams tributary to Chesapeake Bay extend to within a few miles of the ocean. The cause of this asymmetry is believed to date back to a period when the whole region stood at a higher level, when Susquehanna River emptied into the ocean a considerable distance east of Cape Henry and Cape Charles, when the mouth of Delaware River lay east of Cape Henlopen and Cape May, and when the peninsula was much wider than it is now, comprising land on both sides now submerged by the waters of Delaware River, Delaware Bay, the Atlantic Ocean, and Chesapeake Bay. The old channels of Susquehanna and Delaware rivers can now be traced throughout a great portion of Chesapeake and Delaware bays, notwithstanding the fact that recent deposition has in many places obliterated the depressions. An examination of the soundings in the two regions indicates a deeper channel in Chesapeake Bay, and presumably before the recent submergence of this region the waters of the lower course of the Susquehanna flowed in a channel considerably lower than that occupied by the waters of the lower course of the Delaware. This permitted the streams tributary to the Susquehanna to extend their headwaters much more rapidly than the Delaware River tributaries and thus gradually shifted the divide to the eastern portion of the peninsula.

Tide-water estuaries.—The lower courses of almost all the larger streams emptying into Chesapeake Bay and Delaware River have been converted into estuaries through 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, since they are navigable for several miles from their mouths and thus afforded the means of ready transport of the produce of the peninsula to market. Even the advent of railroads has not rendered them valueless, for much grain and fruit are now shipped to market on steamers and small sailing vessels which pass many miles up these estuaries. Steamboats from Baltimore pass up Sassafras River as far as Fredericktown, while freight sailing vessels go within a short distance of the town of Sassafras. Chester River is similarly navigable almost to the town of Millington. Steamboats plying between this region and Philadelphia pass up Appoquinimink Creek to Odessa, and up Smyrna River to within a short distance of Smyrna. The estuaries also furnish good fishing grounds and during certain seasons are frequented by wild water fowl in such numbers that Chesapeake Bay and its tributaries have long been known to sportsmen as among the finest hunting grounds in the country.

Elk River, Bohemia Creek, Sassafras River, and Chester River are the most important estuaries in the western part of the quadrangle, while on the Delaware River side there are Smyrna River and St. Jones Creek. In the northwestern part of the quadrangle many of the minor tributaries are also estuaries in their lower portions, notably the tributaries of Elk and Sassafras rivers. This fact, together with their greater depth as compared with the streams of the eastern part of the quadrangle, indicates greater erosion subsequent to the drowning of these streams. It is of course possible, though hardly probable, that the filling process, which so rapidly shoals the headwaters of the estuaries, converting them into marshes, has been more effective in the eastern part of the quadrangle.

The channel of the portion of Elk River included within the boundaries of the Dover quadrangle varies in depth from 16 to 20 feet. Bohemia Creek is very shallow; the only places exceeding 10 feet in depth occur in a narrow channel that extends from the point of Middle Neck down the stream for about a mile. The depths in this depression range from 15 to 18 feet. Sassafras River is the deepest of the estuaries of the quadrangle. The maximum depression in this stream lies just west of Ordinary Point, where recent charts of the Coast and Geodetic Survey show 50 feet of water. Another depression, near Cassidy wharf, has a depth of 48 feet. Exclusive of these deep places, the channel as far up as Fredericktown has an average depth of about 14 feet. Beyond this point its depth gradually decreases. In Chester River there is a dredged channel 8 feet deep from Spry Landing to Crumpton, and 6 feet deep from Crumpton to the mouth of Mills Branch. In the eastern part of the quadrangle Appoquinimink Creek has a depth ranging from 6 to 18 feet from its mouth up as far as Odessa, and Smyrna River up as far as Smyrna Landing has a depth varying from 6 to 15 feet.

The estuaries of Elk River, Bohemia Creek, and Sassafras River are bordered by nearly vertical bluffs 10 to 60 feet in height, or by slopes which rise rapidly to the height of the broad upland within the distance of half a mile from the river. That the present estuaries have not carved the bluffs that border them is very evident, since they are now doing little erosive work themselves. The small waves that are produced at times of strong westerly winds are the only notable agents of erosion. Such waves are frequently able to remove the finer débris that accumulates as talus at the foot of the cliffs, especially in the early spring, but are not strong enough to do much undercutting. The present cliffs represent 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.

At Turkey Point, the southern extremity of Elk Neck, the average height of the tides above mean low water is 2 feet.

Minor streams.—Besides the estuaries which form so prominent a feature of the northwestern portion of the quadrangle there are numerous minor streams which drain into these estuaries. 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 estuaries, particularly that of Sassafras River, continue as such almost to the sources of the tributary streams. Further, those streams which flow into the estuaries from the side are seldom more than a few miles in length.

On the Delaware River side of the quadrangle the streams, although not true estuaries in their lower courses, are yet very similar to those just described. Most of them are affected by the tides for a considerable distance from their mouths. The tidewater marshes appear to have been at one time estuaries connecting with Delaware River, which more recently have become partially filled and converted into marshes. Through these marshes the streams take a very tortuous course, and some of them extend for miles in a direction almost parallel to Delaware River before they finally join it. Duck, Appoquinimink, and Blackberry creeks are examples of such streams.

All of the streams in the northern third of the Dover quadrangle have well-developed valleys and moderately rapid flow. In the southern portion of the quadrangle, however, streams of considerable size have scarcely any perceptible valley and seem to flow almost at the level of the surrounding country. The current in such streams is necessarily slow and sluggish. Tuckahoe Creek and the various branches of Choptank River exhibit these features. One passing over the region may observe nothing in the topography which would indicate the proximity of these streams, yet they possess breadths of 15 to 20 feet and are moderately deep.

Although nearly the entire region lies less than 100 feet above the sea, and although the streams descend gradually from the divides to sea level, yet they furnish considerable water power. This is utilized by numerous mills that are located on the various streams which empty into the estuaries. The map shows these numerous millponds and also indicates their relatively large size. Because of the gentle slope of the stream channels, a dam of ordinary height may form a pond that extends for a mile or more up the stream.

DESCRIPTIVE GEOLOGY.*

STRATIGRAPHY.

The geologic formations represented in the Dover area range in age from early Cretaceous to Recent. Deposition has not been continuous, yet none of the larger geologic divisions since Cretaceous time is entirely unrepresented. Periods when deposition occurred over part or the whole

*Maryland Geol. Survey, Cecil County, 1902, pp. 149-173.

of the region are 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 those of the 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 during each successive submergence evidently lay a short distance southeast of the line it occupied during the previous submergence. There are a few exceptions to this, however, which will be noted in the descriptions that follow. Thus, in passing from the northwest to the southeast one crosses successively the outcrops of the formations in the order of their deposition.

Table of geologic formations.

System.	Series.	Group.	Formation.
Quaternary	Pleistocene	Columbia	Talbot. Wicomico. Sunderland.
Tertiary	Pliocene (?)		Lafayette.
	Miocene		Calvert.
	Eocene	Pamunkey	Aquia.
Cretaceous	Upper Cretaceous		Rancocas. Monmouth. Matawan. Magothy.
	Lower Cretaceous	Potomac	Raritan. Patapsco.

CRETACEOUS SYSTEM.

LOWER CRETACEOUS SERIES.

POTOMAC GROUP.

The Potomac group of the Coastal Plain consists of highly colored gravels, sands, and clays which outcrop along a sinuous line that extends from New York to Richmond, passing near the cities of Philadelphia, Wilmington, Baltimore, and Washington. The Potomac deposits are of great value because of the excellent brick clays which they contain. Of the four formations that have been recognized as composing the Potomac group in Maryland—the Raritan, the Patapsco, the Patuxent, and the Arundel—the upper two, the Raritan and Patapsco, are represented within the Dover quadrangle.

Section on southwest side of Maulden Mountain.

	Ft.	In.
Lafayette:		
1. Clay loam	8	0
2. Pebble conglomerate and loose pebbles	2	0
Matawan:		
3. Fine greenish-gray sand with finely disseminated glauconite	5	6
4. Glauconitic sand, lighter gray than above, very micaceous, with small pockets of glauconite and some iron concretions	15	0
5. Persistent layer of ironstone	0	½
Magothy:		
6. Gray iron-mottled sand, less glauconitic, micaceous	10	0
7. Very fine ash-colored micaceous sand with thin lenses and small pellets of white and yellow clay and pockets of coarse yellow sand, the whole becoming somewhat argillaceous toward the base	9	0
8. Mottled yellow and white arenaceous clay with small iron-carbonate concretions, passing insensibly into next member	10	0
9. Finely laminated yellow, gray, salmon, and white cross-bedded fine sand with iron concretions and numerous pellets and lenses of clay of variable thickness	6	0
10. Drab sandy micaceous clay with comminuted lignite	5	6
11. Layer of small loose white quartz pebbles		4–6
Raritan:		
12. Mottled yellow and white clay, with some blotches of red	11	0
13. Ironstone band	0	1
14. Fine white sand with some layers of slightly indurated yellow sand	13	0
15. Buff sand of same character, centrally dark and lighter above and below	11	0
16. Similar white sand	4	0
17. Yellow sand with clay pellets, firmly indurated in places	4	0
18. Cross-bedded yellow, buff, and pink sand	5	0
19. Red and yellow sands with ledges of ironstone and occasional lenses of loose angular quartz pebbles	10	0
20. Finely laminated, somewhat sandy white plastic clay	5	0
21. Talus-covered slope	25	0
22. Loose yellow sand with pink blotches alternating with white clay; the sand indurated in places and containing limestone	27	0
Patapsco:		
23. Compact drab clay with lignite exposed to tide	8	0

The best section of the Potomac within the quadrangle is that exposed at the west end of Maulden Mountain, on Elk Neck. This exhibits both members of the Potomac group, as well as certain overlying beds. In order to show the variability in the character of the materials the section in the preceding column is given.

PATAPSCO FORMATION.

Areal distribution.—The Patapsco formation has a very limited development within the Dover region as a surface formation, although it presumably underlies the entire quadrangle. Its outcrops are confined entirely to Elk Neck, where they appear in a good exposure at the base of Maulden Mountain on the western side of the narrow peninsula and in poor exposures in the valleys of a few small streams tributary to Elk River. In its wider distribution the formation has been recognized in discontinuous outcrops extending from the valley of Schuylkill River, near Philadelphia, to the valley of Potomac River.

Lithologic character.—The materials composing the Patapsco formation, as developed in the Atlantic Coastal Plain, are variable in lithologic character. The deposits consist chiefly of highly colored red and variegated plastic clays, which frequently grade abruptly, both horizontally and vertically, into differently colored clays, sandy clays, sand, and gravel beds. Iron in the form of an oxide or a carbonate is almost everywhere present and is mainly the cause of the high color that is so characteristic of the deposits. Locally the sands, clays, and iron ores are of considerable economic importance. The character of the formation on Elk Neck is shown by the section given above. The arenaceous phases are lacking at this point, and the presence of lignitic material here has rendered the beds much darker than they are ordinarily.

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

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

Thickness.—The exposed thickness of the formation in the Dover quadrangle is only a little over 20 feet. In central Maryland it has a total thickness of 240 feet, and in the artesian-well section at Middletown (fig. 1) a considerable part of the 1053 feet of Potomac materials probably belongs to the Patapsco formation.

Stratigraphic relations.—Elsewhere in Maryland the Patapsco formation overlies the Patuxent or the Arundel formation, and in this region it probably occupies similar relations, although the few deep-well sections available are not complete enough to determine the character of its contact with the underlying beds. It is overlain unconformably by the Raritan formation for the most part, although in the region of its outcrop it is occasionally covered by Pleistocene deposits belonging to the Talbot and Wicomico formations.

RARITAN FORMATION.

Areal distribution.—The Raritan formation has a more extensive distribution than any other member of the Potomac group, having been traced from Raritan Bay, New Jersey, to the basin of Potomac River. In the Dover quadrangle it is represented by outcrops on both sides of Elk Neck and at a few places along the eastern shores of Elk River. It dips to the southeast beneath later deposits and underlies almost the entire quadrangle. It is reached in the Middletown artesian well at a depth of 425 feet.

The location of the outcrops is dependent somewhat on the irregularity of the surface of the formation. This irregularity is shown by small projections of the Raritan through the overlying deposits along the shores of Elk River, where it frequently rises above tide as small knolls. A very prominent projection of this kind is found along Elk River between the mouths of Pond and Pearce creeks, where a hillock of bright-red clay, scarcely more than 15 or 20 feet wide, rises about 10 feet above the water.

Lithologic character.—The materials of the Raritan are extremely variable in character and are similar to those composing the Patapsco formation except that, in general, the clays are not so highly colored. Variegated clays, horizontally stratified and cross-bedded sands and gravels, and occasional ledges of sandstones and conglomerates are all represented within the formation.

The character of its materials changes at many places very abruptly, both horizontally and vertically. Iron in some form, chiefly as an oxide, is commonly present and forms the cementing material for the locally indurated layers of sandstones and conglomerates. The section exposed at Maulden Mountain, given above, is characteristic of the entire formation. The loose sands interbedded with impervious plastic clays form important water-bearing beds and in several places furnish artesian water, as described later.

Paleontologic character.—The fossils of the Raritan formation consist largely of plant remains which have been recognized in many different localities in New Jersey, Maryland, and Virginia. The known flora of the formation includes a thallophyte, a lycopod, ferns, conifers, cycads, monocotyledons, and dicotyledons. There is a wide range of genera and species, especially of the dicotyledons, many of which are very closely related to modern forms. The known fauna is very limited, consisting of a few pelecypods, a plesiosaurian bone, and possibly an insect.

Name and correlation.—The formation receives its name from Raritan River, New Jersey, in the basin of which it is typically developed. The name in its present usage was proposed by W. B. Clark in 1892 (Ann. Rept. Geol. Survey New Jersey for 1892–93, pp. 169–243), although the term had been loosely applied to these deposits by earlier writers. It includes the deposits long called the Plastic clays by the New Jersey Geological Survey. On the basis of the fossil plants, which show a marked resemblance to forms of Lower Cretaceous age found in Europe, the formation has been regarded as representing in part the Neocomian-Albian series.

Thickness.—The thickness of the Raritan formation at its outcrop in the Dover quadrangle, where it has been subjected to extensive erosion, does not at any point exceed 70 feet. Elsewhere in Maryland where the contact with the next younger formation is shown, the thickness is over 200 feet. It thickens gradually southeastward, down the dip. The author believes that at least 500 feet of the Potomac materials penetrated by the Middletown artesian well should be referred to this formation.

Stratigraphic relations.—The Raritan overlies the Patapsco formation, with which it is unconformable. It is separated from the overlying Magothy deposits by another marked unconformity. In the region of its outcrop Pleistocene deposits of the Talbot, Wicomico, and Sunderland formations overlie the edges of the formation and generally conceal the deposits from view except where erosion has removed these later beds.

UPPER CRETACEOUS SERIES.

MAGOTHY FORMATION.

Areal distribution.—The Magothy formation outcrops in the extreme northwestern portion of the Dover quadrangle, where a few good sections may be seen. On the west side of Elk Neck about 31 feet of Magothy materials are exposed between deposits of Raritan and Matawan age. Along Elk River south of Reybold wharf there is an exposure of 16 feet of Magothy sands. Other exposures occur near the mouths of Cabin John and Bohemia creeks and in the valley of a small stream near the northern margin of the quadrangle. Elsewhere the Magothy is concealed by the overlying Matawan and Columbia formations. It dips southeastward and disappears at tide level near the mouths of the estuaries tributary to Elk River and does not again appear at the surface in the quadrangle. In all probability it underlies the remainder of the quadrangle and should be recognized in detailed deep-well sections in the central and eastern parts. The Magothy formation has been traced from the south shore of Raritan River in New Jersey to the valley of Potomac River in the eastern part of the District of Columbia.

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 vary in color from pure white to a dark ferruginous brown. In the exposure along Bohemia Creek there is a layer that is very distinctly pink in color. At many places lenses or bands of brown sand occur within the lighter colored sands. While 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. Such a sandstone is well developed along Cabin John Creek. Small pebbles are apt to be present near the base of the deposits. A band of such pebbles occurs in the Maulden Mountain section described elsewhere on this page.

The argillaceous phase of the Magothy is very prominent in some localities, although it is usually subsidiary to the arenaceous phase. The clay commonly occurs in the form of small pellets in the sand or as fine laminæ alternating with the sand layers. Drab is the characteristic color of the Magothy clay, but occasionally 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 highly 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 greensand have been found in the Magothy at a few localities), by its lack of homogeneity, and by its variation in color. Besides, the Matawan usually contains considerable amounts of mica in small flakes, while 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. These are mostly fragmentary, but careful search would doubtless reveal the presence of many identifiable forms. At Cliffwood Point, on the south side of Raritan Bay, New Jersey, beds of this formation have yielded a considerable flora and a marine fauna. The animal remains described by Weller (Ann. Rept. Geol. Survey New Jersey for 1904, pp. 133–144) 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* Conrad, *Nuculana protexta* (Gabb)?, *Yoldia evansi* Meek and Hayden, *Isocardia cliffwoodensis* Weller, *Veleda lintea* Conrad, *Corbula* sp., and among the crustacea *Tetracarcinus subquadratus* Weller. These are of considerable importance, since 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 upper beds of the Matawan formation than any other.

The flora of the Cliffwood beds, studied by Berry (Bull. New York Botan. Gard., vol. 3, No. 9, pp. 45–103; Bull. Tor. Botan. Club, vol. 31, pp. 67–82; vol. 32, pp. 43–48), is notably varied, over 80 species having been described. Many of the species (37 per cent) occur also in the Raritan formation, but most of them are new. The most common fossil plants of that locality are the imperfectly petrified cones of *Sequoia gracillima* (Lesq.) Newberry. Other common species are *Cunninghamites squamosus* Heer, *Dammara cliffwoodensis* Hollick, and *Sequoia reichenbachi* (Gein.) Heer. Berry and Hollick state that the flora of the Cliffwood beds show Cenomanian characteristics.

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 formation 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 in the region of Raritan Bay, under the name of the Cliffwood beds, they 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 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 Cliffwood beds the formation is provisionally correlated with the Cenomanian of Europe.

Thickness.—Within the Dover quadrangle the Magothy formation is about 40 feet thick, but in its wider extent its 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 material in certain areas.

Stratigraphic relations.—The Magothy formation is included 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, and in the area between Patuxent and Potomac rivers there is a very 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 on the Raritan. Farther south it again makes its appearance. In the region of its outcrop the formation is frequently overlain by Pleistocene deposits.

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

MATAWAN FORMATION.

Areal distribution.—In this area the Matawan formation is poorly developed at the surface, appearing only in places where, through stream erosion, the overlying Pleistocene material has been removed. Its outcrops are confined to the northwestern portion of the quadrangle, exposures occurring on Maulden Mountain, on Elk Neck; in the valleys of Cabin John Creek and of a tributary of Bohemia Creek; and along Sassafras River, at the extreme western border of the quadrangle. The Maulden Mountain exposure is particularly good. The Matawan resembles the Lower Cretaceous formations in having a dip to the southeast, which carries it beneath still later deposits. It undoubtedly underlies all that part of the quadrangle that is southeast of its line of outcrop. In its broader distribution throughout the Coastal Plain the Matawan formation crops out as a continuous series of 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 its 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 that vary in color from white to dark greenish black. When the glauconite in the beds is decomposed 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 a small layer of gravel is sometimes found at the base of the formation. Although the Matawan contains varied materials it is much less variable than the Potomac formations, and throughout Maryland it can generally be readily recognized by the prevailing dark-colored micaceous glauconitic sand. The character of the formation as developed in this quadrangle is shown in the Maulden Mountain section, which has already been given (p. 3).

Paleontologic character.—Within the limits of the Dover quadrangle the Matawan has as yet furnished no determinable fossils. Just outside the borders of the area considerable lignite is present in the glauconitic sand, but no identifiable plant remains are found with this lignite. In New Jersey and elsewhere in Maryland the formation has yielded a varied fauna of foraminifera, pelecypods, gasteropods, scaphopods, and ammonites (Bull. Geol. Soc. America, vol. 8, 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. The name 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.—In its northern extension the formation has a thickness of about 220 feet, but it thins to the south and in the vicinity of Potomac River is only 20 feet thick. At its outcrop in Maulden Mountain it is 30 feet in thickness. Like many other Coastal Plain formations, the beds thicken as they dip beneath later deposits, but the records of wells which have penetrated the formation in the eastern part of the quadrangle are too general to permit a determination of the amount of thickening.

Stratigraphic relations.—A marked unconformity separates the Matawan from the underlying Magothy formation, but the Matawan 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 fossil contents. Although some organic forms range through both the Matawan and Monmouth, yet each formation has a few characteristic ones, the assemblage in each being on the whole quite distinctive.

MONMOUTH FORMATION.

Areal distribution.—The Monmouth formation outcrops along the stream valleys in a belt about 5 miles broad, which extends across the northwestern portion of the quadrangle in a northeast-southwest direction. Over the divides the Monmouth deposits are concealed from view by the materials of the Wicomico formation, while near the streams they are at many places covered by the Talbot loam. Only where the streams have been able to remove this capping of Columbia materials is the Monmouth formation exposed to view. The rather deep valleys, with their precipitous bluffs, along Sassafras River and Bohemia Creek and their tributaries, afford many excellent exposures. On the Delaware River side of the quadrangle there are few exposures of the Monmouth formation, yet its presence in the valleys of the head branches of Drawyer Creek is clearly indicated. In its wider distribution the formation has been recognized by outcrops in a zone extending from Atlantic Highlands to a point a short distance beyond Patuxent River.

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 deposits 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 Dover quadrangle.

The lower beds of this area are somewhat more glauconitic than the upper but are not sharply separated from them. In the vicinity of Cassidy wharf the lower marly beds have a thickness of about 20 feet, while near Ordinary Point they are about 45 feet thick. The material consists of fine, slightly micaceous sand so intermixed with brown iron-stained sand as to give the whole a mottled appearance. Within the iron-stained portions are found pockets of gray-green glauconitic sand. Under the microscope it is seen that the grains of sand from the more ferruginous parts are completely coated with iron, while those from the lighter colored pockets are entirely free from it. On the south side of Sassafras River, near Turner Creek wharf, there is an exposure of about 40 feet of lower Monmouth materials. In the lower portion of the section numerous iron crusts and concretions are present in a brown sand. Most of the iron concretions are exceedingly irregular, but some are pipe-like, long, and straight, and usually hollow. A few iron-incrusted fossil casts are present in this part of the section. The upper 20 feet are composed of light-colored glauconitic sand containing some soft lime concretions and a few fossil casts, although a few iron crusts are also present.

The lower marly beds of the Monmouth occur also at a few places along the tributaries of Bohemia Creek. On the north side of the creek, just east of the bridge, marl for fertilizing purposes has been dug at several places, but none of these marl pits are now worked.

The upper portion of the Monmouth formation in this region consists of beds of rather coarse sands which at some places are decidedly red in color, although usually a reddish brown. Here and there in this portion of the formation are pockets containing considerable glauconitic sand. The sand is frequently casehardened and occasionally firmly cemented by ferruginous material. The sands are exposed at many places along Sassafras River and Bohemia Creek. The best exposure is at Bohemia Mills, where about 15 feet of sands are overlain by 5 feet of Wicomico material. The material here is a reddish-brown, casehardened deposit containing pockets or lenses of grayish-green glauconitic sand. Along the lower tributary of Little Bohemia Creek there is another good exposure, which consists of loose brown sand.

Paleontologic character.—The Monmouth formation is generally very fossiliferous and the forms are usually well preserved. They consist of foraminifera, pelecypods, gasteropods, and cephalopods. Among the most abundant fossils found in the Monmouth in the Dover quadrangle 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 by W. B. Clark in 1897 (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 total thickness of the Monmouth formation along its outcrop in the area of the Dover quadrangle is about 80 feet. In northern New Jersey it is about 200 feet thick, but from there it steadily decreases in thickness along the strike, southwestward, until, in the valley of Patuxent River, the beds are only 10 feet thick.

Stratigraphic relations.—The formation is conformable with the underlying Matawan and with the Rancocas, which overlies it in the eastern part of the quadrangle. Along Sassafras and Chester rivers it is unconformably overlain by Eocene deposits, the Rancocas being absent from this part of the quadrangle. Pleistocene materials conceal it from view over the divides and at some places even in the stream valleys, as in the northwestern part of the quadrangle.

The Monmouth may be readily distinguished from the Matawan, since it lacks the darker colored micaceous sands and marls of the latter. From the Rancocas it is distinguished by the great predominance of reddish-brown sand. The Aquia also contains much more marl and in the valley of Sassafras River carries typical Eocene fossils.

RANCOCAS FORMATION.

Areal distribution.—The Rancocas is the latest Cretaceous formation of the region. It extends entirely across the State of New Jersey and is represented in the Delaware portion of this quadrangle, but owing to a transgression of the Eocene does not appear at the surface in the State of Maryland. It occurs at only a few places in the northeastern part of the quadrangle, in the vicinity of Middletown and Odessa, where it occupies the valleys of Silver Run and Drawyer and Appoquinimink creeks.

Lithologic character.—The formation consists principally of greensand marls. Along Drawyer Creek, northwest of Odessa, a thickness of 9 feet of Rancocas material is exposed. The beds consist of rather coarse, weathered glauconitic sand containing many irregular iron concretions and indurated bands. Numerous casts of small pelecypods are preserved in segregations of ferruginous material. They are usually rather fragile. Just east of the bridge at Odessa a thickness of about 17 feet of Rancocas greensand is exposed. It is greatly weathered, so that part of it is light gray in color, although most of it is brown. It contains numerous iron concretions. One layer of the greensands that is somewhat indurated contains many imperfect casts of fossils. Just below the dam at Noxontown Pond a similar exposure occurs. North of Townsend the following section is found:

Section near Townsend.

	Ft.	In.
WICOMICO:		
Gravel and loam	6	0
CALVERT:		
Impure diatomaceous earth	3	6
RANCOCAS:		
Ledge of weathered indurated greensand	2	0
Loose, coarse, light-green glauconitic sand	2	4
Indurated glauconitic sand	1	6

Marl pits were formerly worked along Appoquinimink Creek below Noxontown Pond.

Paleontologic character.—The Rancocas formation in New Jersey is very fossiliferous, the upper beds consisting almost entirely of the calcareous remains of animals. Although these upper beds are not represented in the Dover quadrangle yet the formation along Appoquinimink Creek has afforded numerous fossils. From the marl pits formerly worked at Noxontown Pond a great many fossils were obtained, from which the calcareous material had not been removed. These were mentioned by Booth in his report on the Geology of Delaware, in 1841. He describes one layer which was exposed in these marl pits, but which is now hidden by accumulations of talus, as consisting almost entirely of the shells of *Ostrea* (*Gryphæostrea*) *vomer* and *Gryphæa vesicularis*. Most of the shells were much broken, but masses of them were firmly cemented by calcareous matter. Besides the forms named above the following have been recognized in the Rancocas deposits along Appoquinimink Creek: *Terebratula harlani* var. *fragilis*, a triangular *Serpula*, spines of echinoids, and a single specimen of the claw of a crab. Many other forms, especially pelecypods, are represented by casts, and there is no doubt that careful search would reveal many determinable specimens, although in the main the shells are poorly preserved. The Rancocas fauna is late Cretaceous.

Name and correlation.—The name of the formation was proposed by W. B. Clark in 1894 (Jour. Geol., vol. 2, pp. 161–177) to include the deposits formerly called the Middle Marl Bed. The name is derived from that of Rancocas Creek in Burlington County, N. J., which cuts through the deposits, exposing a full sequence of the beds. The fauna furnishes evidence for an approximate correlation of the formation with the lower part of the Danian of Europe.

Thickness.—The thickness of the Rancocas in the Dover quadrangle is slightly more than 20 feet. In southern New Jersey it has a total thickness of about 125 feet, but thins southward.

Stratigraphic relations.—The Rancocas formation conformably overlies the Monmouth. In the vicinity of Townsend it is overlain by the Calvert, with which it is unconformable. In the region lying southwest of this quadrangle it is probably overlain by the Aquia, but the contact is obscured by Pleistocene deposits. At Fredericktown the Eocene rests upon the Monmouth, no trace of the Rancocas coming in between; nor is it exposed on Chester River, along which (outside the quadrangle) the succession of beds is Monmouth, Aquia, Calvert. This difference in succession in the Delaware and the Maryland portions of the quadrangle is believed to be due to a transgression of the Aquia sea over the edges of the Rancocas beds, as will be explained later. The exact nature of the transgression cannot be determined, as the region where it occurred, in the vicinity of Vandyke and Golts, lies along the broad divide between the two main drainage systems and is deeply covered with Wicomico materials.

TERTIARY SYSTEM.

EOCENE SERIES.

PAMUNKEY GROUP.

AQUIA FORMATION.*

Areal distribution.—The Aquia is the only Eocene formation in the Dover quadrangle. Its outcrops are found along Sassafras and Chester rivers and their tributaries, in a belt about 4 miles wide. The formation has thus far not been recognized in the State of Delaware, but this is doubtless due to the fact that its deposits there have been so deeply covered by the Talbot and Wicomico formations that they nowhere appear in surface exposures. In Delaware, at places where the Pleistocene deposits do not conceal the contact, the Calvert formation directly overlies the Rancocas. The Aquia formation has been recognized in a series of disconnected outcrops that extend from a point near the border of Delaware southward through Virginia.

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 the deposits range in color from a light blue to a very dark green, but in regions where the beds have been exposed to weathering for a considerable time they have 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.

There are few good outcrops of Eocene material in this region. One very good exposure occurs in the valley of a small stream a mile north of Fredericktown. There the formation is a slightly cemented glauconitic sand, which in fresh exposures has a somewhat streaked and mottled appearance, due to the mixing of the grayish-green and reddish-brown sands. The outcrop may be traced from this place almost continuously down the stream valley to Sassafras River, and at Fredericktown, just north of the bridge, the glauconitic sands have become so indurated that they form a rather hard and prominent ledge about 10 feet thick. This indurated layer is represented also on the south side of Sassafras River, just above Georgetown, and also near the mouth of Sawmill Creek. Wherever this ledge occurs fossil casts are found, many of which are very well preserved. Another very good exposure of Aquia material is seen near the milldam northeast of Galena. The section is as follows:

Section near milldam northeast of Galena.

	Feet.
WICOMICO:	
Gravel in a matrix of coarse sand	4
AQUIA:	
Brownish-yellow, very compact, weathered greensand, grading downward into fresher material, somewhat gray in color	14
Dark-green, coarse glauconitic sand, filled with numerous iron concretions, usually irregular in shape, although sometimes showing a slight tendency to nodular structure	10

The Aquia deposits occupy the valleys of several small streams that drain into Chester River, although there are good exposures at only a few places, the presence of the formation being indicated mainly by the type of soil.

Paleontologic character.—A great many fossils are seen in the outcrops of the Aquia along Sassafras River from Fredericktown to Sassafras, but most of them are poorly preserved and only a few can be identified. In Fredericktown fossils of Aquia and of Rancocas ages have been found in the same beds, this fact indicating that the Rancocas must have been exposed near by and that the fossils of the two horizons became commingled while the Aquia deposits were being laid down.

The forms that have been recognized at Fredericktown are *Dosiniopsis lenticularis*, *Venericardia planicosta*, *Cucullæa gigantea*, *Ostrea* (*Gryphæostrea*) *vomer*, and *Terebratula harlani*. The last two forms named are characteristic fossils of the Rancocas formation, and as they have not been found in the Cretaceous deposits that elsewhere overlie the Rancocas it seems probable that where found in the Aquia deposits they have been washed out from beds of Rancocas age and redeposited in the Aquia. 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., 1895, p. 3).

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

Thickness.—The thickness of the Aquia exposures in the Dover quadrangle is about 35 feet. Toward the south the formation thickens, reaching a total thickness of about 100 feet on the west side of Chesapeake Bay in southern Maryland.

Stratigraphic relations.—By the transgression of the Aquia sea, previously mentioned, the beds of this formation, which should normally overlie merely the Rancocas, have been brought into direct contact with Monmouth deposits along Sassafras and Chester rivers. On the western side of Chesapeake Bay in southern Maryland a higher member of the Eocene, the Nanjemoy formation, is exposed. The Nanjemoy is not represented in the Dover quadrangle, its absence being due likewise, no doubt, to the overlap of the Calvert formation. In the divide between Sassafras and Chester rivers the Aquia is unconformably overlain by the Wicomico formation and in the valleys of these two rivers by Talbot materials, while in the area south of Chester River it is covered unconformably by the Calvert formation.

MIOCENE SERIES.

CALVERT FORMATION.*

Areal distribution.—The Calvert, the only Miocene formation in the Dover quadrangle, crops out along most of the larger streams lying southeast of a line drawn from Townsend to Chesterville. Over the divides it has been so deeply covered by Pleistocene deposits that its presence is shown only in well borings. It has by far the most extensive development of any Cretaceous or Tertiary formation in this region. This statement might perhaps be extended to apply to the 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 composing the Calvert formation in this region are buff to white sands, diatomaceous earth, and dark-colored clays, the light-colored sands constituting the most prominent feature.

Few good sections are to be seen. One fairly good exposure is found along Duck Creek, north of Cheswold, where the material is fine sand varying in color from gray to orange, although in places there are well-defined thin lenses of light-drab clay, the whole thickness being about 10 feet. Another good exposure of the Calvert formation occurs in the southeastern portion of the quadrangle, just below the dam on Spring Creek. Here the water as it falls from the dam has carved out a little amphitheater about 40 feet in diameter, in the walls of which a good section is seen. The material is a blue clay which contains considerable arenaceous material, although at some places the sand predominates. Within the blue clay, which is very compact and not easily eroded, there occur pockets of loose sand, some of which have been removed, leaving large holes in the nearly perpendicular walls. No determinable fossils were seen in this clay, although a small flattened piece of lignite was found. The whole section shows a very well-developed laminar structure. The greatest thickness of the exposure at this place is about 10 feet.

Poorer sections of the Calvert occur along Southeast Creek in the vicinity of Church Hill, and along the headwaters of Appoquinimink Creek and Hangmans Run, northeast of Townsend. In these places the beds consist of impure diatomaceous earth filled with fossil impressions. The character of the Calvert formation is well shown by the following record of the artesian well at Dover:

Section in artesian well at Dover.

	Feet.
TALBOT:	
Yellow gravel	7
Deep orange-colored sand and clay	4
Coarse orange-colored sand	15
CALVERT:	
Light orange-colored sand, finer	16
Sandy clay with a few marine diatoms	12
Sand and marly clay	8
Sand	9
Brownish clay and sand, with marine diatoms	12
Sand and comminuted shells, with marine diatoms and sponge spicules	7
Sand	4
Sand and broken shell	6
Marl	9
Micaceous marly sand; some reddish sand grains	8
Sand, with bad water; comminuted shells, diatoms, and coccoliths	3
Sandy clay with diatoms	8
Clay with diatoms	19
Sand, shells, and diatoms	3
Clay, with a few diatoms	5
Sand, with good water	2
Clay, with pyrite-covered diatoms	10
Dark sand, some grains large as peas; good water	29

From the character of the materials it is evident that all except the first three upper members of this section belong to the Calvert formation. The most striking feature in the section is the great number of beds in which diatoms are present, some of them being really impure diatomaceous earth.

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, this fact indicating a somewhat warmer climate in this region during the period of deposition of the Calvert materials. The fossils of this formation have recently been fully described and illustrated in two volumes on the Miocene issued by the Maryland Geological Survey.

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 name was proposed in 1902 (Science, new ser., vol. 15, p. 906) by G. B. Shattuck. The formation seems to correspond approximately with the Petersburg horizon in Virginia.

Thickness.—The thickness of the Calvert is greater along its outcrop than that of any other formation in this quadrangle. From a point near Townsend where it is $3\frac{1}{2}$ feet thick, its thickness grows much greater toward the southeast, until it is more than 150 feet at Dover and, no doubt, increases toward the extreme southeastern portion of the quadrangle, where it is probably not less than 200 feet. At Crisfield, Md., farther south on the peninsula, a well section indicates over 300 feet of Calvert materials.

Stratigraphic relations.—Near Townsend the Calvert rests unconformably upon the Rancocas formation. In the western portion of the quadrangle, in Kent County, Md., it overlies the Aquia formation, and still farther southwest, in southern Maryland, it rests upon the next younger Eocene formation (the Nanjemoy), a relationship which shows the gradual transgression of the Miocene deposits northeastward. In this region it is overlain by deposits of Wicomico and Talbot age. In the region south of this quadrangle it passes beneath the Choptank formation, the next higher division of the Miocene.

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 is very sparingly represented in the Dover quadrangle, by only a few small outliers, all of which cap the highest portions of Elk Neck. At one time the entire region was undoubtedly covered with deposits belonging to this formation, but through the various changes that have occurred since its deposition, practically all of it has been removed. It is only where the materials were of such character as to firmly resist erosion that any deposits now remain, although not far northwest of the quadrangle there are more extensive areas with which the outliers on Elk Neck were at one time connected. In the region farther northward the formation is represented by a series of isolated deposits that cover the tops of stream divides, while farther south its exposures become larger and more continuous until they combine to form an important division of the Atlantic coast series. In the Middle Atlantic States these deposits commonly reach elevations ranging from 205 to 250 feet, but they are found in a few places overlying the crystalline rocks of the Piedmont Plateau, at an elevation of over 400 feet.

Lithologic character.—The materials composing the Lafayette formation consist mostly of quartzitic sands and gravels more or less firmly united with a cement of iron oxide. In some places on Elk Neck the gravels have become a firm conglomerate, and this material has been used for building purposes. The gravels are all well rounded and range in size from coarse sand to pebbles several inches in diameter. Clay bands alternate with the sand and gravel beds, and small amounts of clay distributed throughout the gravel and sand beds serve to bind the loose particles together. Horizontal and cross stratification are exhibited in every good section and show that the deposits were laid down in shallow water, either marine or estuarine. Most of the deposits on Elk Neck are characterized by indurated blocks of conglomerate, ranging from cobbles up to masses a foot in thickness and weighing several hundred pounds. These have evidently broken away from more or less continuous bands of conglomerate that formerly extended over the summit of Elk Neck.

Physiographic expression.—As has been already stated the deposits of this formation form a plain of deposition which is well developed at many places in the Coastal Plain. The remnants now present in the Dover quadrangle do not exhibit much resemblance to a plain, but have been effective in determining the physiography of the region. Elk Neck owes its present height to these deposits, which by their great resistance to denudation have protected easily eroded Cretaceous materials beneath. Erosion is necessarily very active on the narrow peninsula between Elk River and Chesapeake Bay, and as soon as the Lafayette cover is removed,

*Maryland Geol. Survey, Eocene, 1901.

*Maryland Geol. Survey, Miocene, 1904.

through the process of undercutting, the whole peninsula will undoubtedly be rapidly reduced in elevation.

Paleontologic character.—Fossils are practically absent in the Lafayette deposits of the Atlantic Coast region. Pebbles containing Paleozoic fossils are found in the formation at many places throughout the district but are important 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. Geol., vol. 8, pp. 129–131) to replace the term Orange Sand, used in Tennessee and Mississippi, and the term Appomattox, which had been applied to the deposits of the Atlantic coast. The name was 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 the 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 deposits of this formation were laid down on a rather irregular floor and consequently are variable in thickness. In the vicinity of large streams antedating this period the formation is very thick, as is shown in the 200 feet or more of Lafayette materials about the mouth of the Mississippi. Over many interstream tracts it forms a mere veneer. On Elk Neck the formation has a thickness of about 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 within the region, and thin remnants are found on the eastern borders of the Piedmont Plateau in many places. In the Dover quadrangle it rests upon the Matawan formation and is entirely a surface formation. Elsewhere it dips beneath deposits 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, due to their similar origin. They consist of gravels, sands, and loam, which are stratigraphically younger than the Lafayette formation. The Columbia group has been divided into 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, as already described.

On purely lithologic grounds it is impossible to separate the three formations composing the Columbia group, all of which are represented in this quadrangle. The materials of all have been derived mainly from the older formations which occur in the immediate vicinity, mixed with 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 variable and change in general character according to the underlying formations. Thus materials belonging to the same formation may in different regions differ far more lithologically than the materials 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 are those of younger formations, but these differences can not be used as criteria for separating the formations, since loose and indurated, fresh and decomposed materials occur in each.

The fossils found in the Pleistocene deposits are far too meager to be of much service in separating them into distinct formations, even though essential differences between deposits 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, although 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 deposits, the Sunderland, while the lowest terrace 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 other places, however, certain layers or beds are sharply separated from overlying 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, produced by 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. Since the Pleistocene formations lie in a nearly horizontal plane it would be possible to connect these separation lines if they were subaerial erosional unconformities. 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 times did not entirely remove the beds of the preceding period of deposition over the area covered by the sea in its next transgression. Especially would deposits laid down in depressions be likely to persist as isolated remnants which later were covered by the next mantle of Pleistocene materials. If this is the case each formation from the Lafayette to the Wicomico is probably represented by fragmentary deposits beneath the later Pleistocene formations. In regions where pre-Quaternary materials are not exposed in the bases of the escarpments each Pleistocene formation near its inner margin probably rests upon the attenuated edge of the next younger formation. Since lithologic differences furnish insufficient criteria for separating these late deposits, and since 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 point is referred to the same formation. The Sunderland is described as overlying the Cretaceous deposits and 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 occasionally rest upon deposits of the Lafayette, Sunderland, and Wicomico.

SUNDERLAND FORMATION.

Areal distribution.—Although widely distributed in the northern and middle Atlantic Coastal Plain the Sunderland is very sparingly represented in the Dover quadrangle. The only recognized deposits occur on Elk Neck, where a few small outliers are found. At one time the formation evidently extended over the greater portion of the quadrangle, but by far the larger part of it has since been removed by erosion. On Elk Neck and in near-by regions it forms the surface material of a gently sloping plain ranging in elevation from 90 to 180 feet above sea level.

Lithologic character.—No good section of the Sunderland formation occurs in this region. The deposits consist mainly of rather coarse gravel, the finer sands and loams which were doubtless once present having been largely removed. The pebbles are composed of quartz or quartzite, and many of them were doubtless derived from the Lafayette formation. Sections elsewhere show horizontal stratification and cross-bedding.

Physiographic expression.—Erosion has so largely changed the original character of the Sunderland plain that the few remnants of the formation found in this region do not show any marked physiographic features. On the west side of Chesapeake Bay in southern Maryland the formation occurs as a terrace which is so level that its surface drainage is incomplete and which is separated by a pronounced escarpment, 10 to 20 feet in height, from the higher Lafayette plain. In the southeastern part of the District of Columbia an excellent example of such a terrace is found in the hill forming Congress Heights.

Paleontologic character.—The formation in this region has yielded no fossils. In southern Maryland plant remains have been found at a few localities in beds of drab-colored clay. They all belong to living species.

Name and correlation.—The formation has been named from the little village of Sunderland, in Calvert County, Md., near which it is typically developed. The name was first applied to the formation by G. B. Shattuck in 1901 (Johns Hopkins Univ. Circ. No. 152, May, 1901). It 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.—No satisfactory data can be obtained as to the thickness of the Sunderland formation in the Dover quadrangle. Although its materials are found at elevations ranging from 90 to 180 feet above sea level the formation is not very thick at any point. The deposits were laid down on a sloping and dissected plain, for many well records show that the surfaces of the underlying formation rise in passing from the stream valleys to the divides. The thickness of the formation in the Dover quadrangle probably does not exceed 45 feet.

Stratigraphic relations.—Throughout the Coastal Plain the Sunderland unconformably overlies various formations of Cretaceous and Tertiary age. In the Dover quadrangle it rests upon the Matawan wherever any definite contact is exposed. It is not improbable that the edges of the Lafayette formation extend out beneath part of the Sunderland deposits, but this can not be determined in the absence of any definite line denoting a stratigraphic break, because of the similarity of the materials of the two formations.

WICOMICO FORMATION.

Areal distribution.—The next younger Pleistocene division is the Wicomico, which, on account of its extensive development, is the most important formation in the region. It occupies the broad divide between Chesapeake Bay and Delaware River and is the surface formation over nearly two-thirds of the quadrangle. It conceals from view many of the Cretaceous and Tertiary formations which otherwise would be exposed over the divides and which now appear only along the valleys of the streams, where the Wicomico materials have been removed by erosion. The formation is extensively developed throughout the northern and central portions of the Atlantic Coastal Plain and probably extends into the Gulf region. It forms the surface material of a gently sloping plain ranging in elevation from 40 to 100 feet above sea level.

Lithologic character.—The materials composing the Wicomico formation are much the same as those found in the Sunderland. Bowlders, gravel, sand, and loam are all present. These are usually well stratified, yet the lithologic characters of the strata change so abruptly that it is not possible to follow one bed for any great distance. Again, there is no definite sequence of the materials, although in general the coarser constituents are found near the base of the section while the finer form the capping. Fine sands may alternate with coarse bowlder beds several times within a single section. Cross-bedding is also quite common.

The following section, which is exposed in the bank of the south fork of Drawyer Creek about 2 miles northeast of Middletown, shows the varied materials composing the Wicomico formation:

Section on Drawyer Creek near Middletown.

	Ft.	In.
Yellowish-brown loam	3	0
Compact brown sand mixed with loam	9	0
Rather coarse gray to brown sand containing some pebbles and small masses of clay, the whole finely cross-bedded	12	0
Gravel band composed of small pebbles with some large iron concretions, 2 to 3 feet in diameter	3	6
Fine cross-bedded gray to yellow sand	4	0
Indurated iron band	0	1
Gray sand	0	8
Indurated iron band, rather persistent	0	½
Light-green clay, very tenacious	0	3
Gray sand	0	5
Brownish-yellow compact clay	0	3
Thin alternating layers of yellow sand and clay, with occasional nodules of earthy iron oxide	3	6
Iron band	0	¾
Yellow sand	2	6
Indurated iron band	0	½

Many other good sections may be seen throughout the northern half of the quadrangle along the roadsides and near the streams, but there are few good exposures in the southern part of the region.

The Wicomico materials found in almost every exposure have been largely derived from older deposits in the immediate vicinity, and the lithologic character of the formation changes from place to place according to the character of the contiguous older formations. In the northwestern portion of the quadrangle, where a great deal of the Wicomico material has been derived from Upper Cretaceous and Eocene beds, the formation comprises considerable greensand. In the southern portion of the quadrangle greensand is entirely absent, but the formation there contains light-colored sands derived from the Calvert. At places where there is little foreign material mixed with the locally derived débris it becomes somewhat difficult to draw the line between the Wicomico and the underlying Cretaceous and Tertiary formations. Usually, however, a stratigraphic break may be noted if there is a good exposure; if not, the harsher and more loamy character of the overlying materials indicates that they have been reworked and redeposited.

While the Wicomico was being formed as an offshore deposit streams from the adjoining land to the northwest were bearing in quantities of bowlders, pebbles, sands, and loam. These were dropped when the streams entered the ocean, the larger particles first and the finer later. This sorting or arrangement is well shown in the Dover quadrangle, in that the size of the land-derived materials rapidly decreases from the northwest to the southeast. Large bowlders and coarse pebbles are very common all over Sassafras Neck, but they gradually decrease both in size and number toward the southeast until, in the region of Dover, Wyoming, and Henderson, it is very unusual to find a pebble of any kind. Some of the bowlders that occur in the Wicomico deposits in the northern portion of the quadrangle are very large. Near Noxontown Pond bowlders 4 feet in diameter occur where the formation overlies the Rancocas, while on Sassafras Neck many with a diameter of 2 feet or more are to be found. Nearly all the pebbles and bowlders are composed of quartz or quartzite, but some of them are more complex mineralogically. In a ravine about one-half mile northeast of Galena some pebbles and bowlders composed of peridotite, gabbro, gneiss, and quartz-mica schist were found. Similar bowlders also occur elsewhere.

In the Potomac Valley near Washington bowlders carrying glacial striæ have been found in the Wicomico formation, but in the Dover quadrangle no striated rocks have been observed. The great size of the bowlders found here, 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 firm and the land is suitable for producing grass and grain, but in regions where loam is present in small quantities, or absent altogether, the roads are apt to be sandy. The Wicomico on Sassafras Neck and on the divide between Sassafras and Chester rivers is characterized by its well-developed loam cap. In marked contrast with those regions is that portion of the quadrangle lying south and southwest of Wyoming, where there is little loam present and the surface is very sandy.

Physiographic expression.—In the Dover quadrangle the Wicomico possesses the features of a broad, flat plain forming the stream divides. On the west side of Chesapeake Bay it occurs mainly as narrow terraces occupying the lower portions of the stream divides and extending up the sides of the wider valleys. It is at many places separated from the Sunderland above and the Talbot below by well-defined escarpments. In the Dover quadrangle it is separated from the Talbot terraces along the streams by escarpments which are very prominent in the valleys of Chester and Sassafras rivers. Along Delaware River the Talbot-Wicomico escarpments are less distinct, though frequently noticeable.

Paleontologic character.—The Wicomico formation in the Dover quadrangle has thus far furnished no fossils. In other regions plant remains and impure peat have been found in it. The plant remains have marked modern characteristics.

Name and correlation.—The formation receives its name from Wicomico River, in southern Maryland. The name was proposed by G. B. Shattuck in 1901 (Johns Hopkins Univ. Circ. No. 152, May, 1901). 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 Wicomico formation is not at all places uniformly thick, owing to the uneven surface on which it was deposited. Its thickness 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 frequently as low as 40 feet while the surface rises in places as high as 100 feet above sea level. Notwithstanding these irregularities it occupies as a whole an approximately horizontal position, with a slight southeasterly dip.

Stratigraphic relations.—The Wicomico unconformably overlies all of the Cretaceous and Tertiary formations of the quadrangle with the possible exception of the Lafayette. On Elk Neck it is in contact with the Sunderland formation, from which it is separated by a low escarpment whose base stands at an elevation of about 100 feet. In places it may possibly overlie some of the Sunderland deposits, but, as has been already stated, the evidence for this is not conclusive. It is also in contact with the Talbot formation at many places along Delaware River and the estuaries of Chesapeake Bay in the western portion of the quadrangle, where the two formations are separated by an escarpment 10 to 20 feet in height, the base of which is from 38 to 45 feet above sea level.

TALBOT FORMATION.

Areal distribution.—The latest formation represented in this region is the Talbot. It consists of gravels, sands, and loam in the form of a terrace that extends from tide to an elevation of 38 to 45 feet above sea level, where it is separated by an escarpment from the deposits of the Wicomico formation. On the eastern side of the quadrangle the Talbot appears as a terrace bordering Delaware River and extending a few miles up the valleys of the larger tributaries. Here the width of the strip over which the Talbot appears as the surface formation is from 3 to 6 miles. On the western side of the quadrangle, however, the Talbot is confined to the low-lying regions bordering the estuaries, although it extends up some of the valleys of the side tributaries for a short distance. The formation has an extensive development throughout the northern and middle portions of the Atlantic Coastal Plain.

Lithologic character.—The materials composing the Talbot deposits are very similar in lithologic character to those found in the Wicomico formation. There is usually more loam present as compared with the gravel and sand than is found in the Wicomico, but the proportions of these constituents are extremely variable.

The following section, which is exposed near the town of Sassafras, along a tributary of Sassafras River, illustrates the varied character of the material composing the Talbot formation:

Section near Sassafras.

	Ft.	In.
Coarse brown sandy loam	1	6
Fine gravel in matrix of coarse brown sand; no distinct bedding	4	6
Coarse brownish-yellow to buff sand with considerable fine gravel	4	10
Gravel band; pebbles of various sizes, not well sorted	0	5
Medium-fine brownish sand showing distinct cross-bedding, containing large broken masses of iron crust	8	0
Gravel band; pebbles small	3	6
Layer of iron crusts	0	10
Coarse sand, cross-bedded, containing a few drab-colored clay lenses	4	0
Indurated iron band	0	6
Coarse sand (thickness exposed)	2	0

Near Wilson Point wharf a section of the Talbot is exposed in which the material consists of weathered glauconitic sand. Along St. Jones Creek just east of Dover a bowlder bed occurs in the Talbot, in which many bowlders are more than a foot in diameter. About 3 miles east of Wyoming and about 2 miles northeast of Smyrna the Talbot contains beds of clay which have been utilized in the manufacture of brick.

Physiographic expression.—The Talbot preserves the appearance of a terrace in the Dover area better than either of the other two Pleistocene formations. From the base of the Talbot-Wicomico escarpment the terrace slopes to the water's edge with few irregularities except where the surface is cut by streams.

Paleontologic character.—The Talbot is the only one of the Pleistocene formations that has furnished any fossils in this region. About a mile above the mouth of Bohemia Creek, on the north side of Veazey Neck, is a bed of drab-colored clay in which plant remains occur. In this locality a large cypress stump about 5 feet in diameter is exposed on the beach at mean tide level. The stump, which is changing to lignite, is in place, and is nearly covered with beach sand, but its roots are still embedded where they grew, in a mass of dark-colored clay. The base of this peat bed is not visible, but it is evident that the bed rests unconformably in a hollow in the Raritan, for that formation rises to view a few rods away. In the bank above the beach the same peat bed that carries the cypress stump is continued upward for 6 feet and is abruptly overlain by 3 feet of sand and gravel, which in turn grades upward into loam. At Cornfield Harbor, near 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 these deposits occupy a broad terrace bordering numerous estuaries, has furnished the name for the formation. It was first given by G. B. Shattuck in 1901 (Johns Hopkins Univ. Circ. No. 152, May, 1901). The formation represents the lower part of the Later Columbia, described by McGee and Darton, and corresponds approximately with 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 to 40 or more feet. The unevenness of the surface on which it was deposited has in part caused this variability. The proximity of certain regions to mouths of streams during the Talbot submergence also accounts for the increased thickness of the formation in these areas.

Stratigraphic relations.—The Talbot rests unconformably, in different portions of the region, upon various formations of Cretaceous and Tertiary age. It may in places rest upon deposits of 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, with perhaps slight slopes toward Delaware and Chesapeake bays on the two sides of the quadrangle, but the amount of slope is too small to be accurately determined. The Talbot was at some places deposited upon a very irregular surface. A good evidence of this fact may be seen along Elk River on the northwest side of Pond Neck, where, in a bluff of Talbot materials about 15 feet in height, which extends down to the water, a small hillock of Raritan material rises about 10 feet above tide. Greater irregularities, now concealed, no doubt exist elsewhere in the surface upon which the Talbot materials were deposited.

STRUCTURE.

The geologic structure of the Dover area is extremely simple. Although many unconformities separate the various formations, these are comparatively minor unconformities of erosion. Folding of the strata is almost, if not entirely, lacking, while faulting has not been observed in the Dover quadrangle. Along a tributary of Chester River just west of this area faults in Talbot materials are exposed, but in no case is the throw more than a few inches in amount. The numerous uplifts and depressions which the region has experienced have been so uniform over wide areas that the only evidence of these crustal movements is the succession of erosion and deposition periods produced by uplifts and submergences. As explained elsewhere these vertical oscillations were sometimes accompanied by tilting, with but slight deformation.

The formations all have a general northeast-southwest strike and 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 Potomac formations it is as great as 30 or 40 feet to the mile.

The pre-Pleistocene formations of the Dover 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. Thus successively younger beds are encountered as one passes from the northwestern to the southeastern portion of the quadrangle over the upturned edges of the formations.

HISTORICAL GEOLOGY.*

SEDIMENTARY RECORD.

General features.—The area in which the Dover quadrangle lies has undergone many changes throughout past geologic time, some of which can be readily interpreted by the character of the deposits and their physical relations. The region has alternately been submerged and elevated, and deposition of materials has frequently been succeeded by erosion. At certain times the entire quadrangle was beneath the water and received deposits; at other times it was land and was degraded by surface streams; at still other times the shore line crossed the quadrangle, so that part of it was in the zone of denudation and part in the zone of deposition. The erosion intervals are indicated by erosional unconformities, while the beds of various materials represent periods of submergence. Further, the physical conditions prevailing during ages of sedimentation are revealed by the lithologic characters of the beds and their included organic remains.

Pre-Potomac history.—The floor upon which the Coastal Plain deposits were laid down is a great mass of crystalline rocks of pre-Cambrian and early Paleozoic age. These crystallines do not appear at the surface in this region, nor have they been reached by any deep-well borings, not even in the 1478-foot well at Middletown. They form the surface rocks in near-by regions to the northwest, disappearing gradually beneath the overlying sediments to the southeast.

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 was probably 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 the deposits from the crystalline surface.

*Potomac history.**—The earliest of the known unconsolidated deposits lying upon the floor of crystalline rocks belongs 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 does not appear at the surface within the Dover quadrangle, but has been reached by the deep-well boring at Middletown. It outcrops a few miles to the northwest, in Cecil County, and seems to underlie the entire quadrangle. It indicates a submergence of the Coastal Plain of 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 rapid changes in the characters 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 an erosion period which persisted long enough to permit the removal of a vast amount of material. To the south a submergence, during which the Arundel formation was laid down, and a reelevation occurred before the area of this quadrangle was again depressed beneath the water 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 period intervened between the deposition of the two formations, 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 of 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 now 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 extensively erode the recently formed deposits.

The extensive development of shallow-water deposits, everywhere cross-bedded and extremely variable in lithologic character, and the presence throughout of land plants furnish some evidence that 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 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 a period of transition from the estuarine or fresh-water conditions of the Patapsco and Raritan periods to the marine conditions of the Matawan, Monmouth, and Rancocas periods. The lithologic characters of the materials as shown by their great variability, the coarseness of the sands and gravels, and the cross-

*Maryland Geol. Survey, Cecil County, 1902, pp. 173-194.

*Bull. Geol. Soc. America, vol. 13, pp. 187-214.

bedding all suggest conditions similar to those of the former periods. On the other hand, the occasional pockets of glauconitic sand and the presence of marine invertebrates suggest the marine conditions of the later Cretaceous periods. The probability is that over most of the area where Magothy deposits are now found Potomac conditions prevailed during the greater part of the period and in some places perhaps during the whole period, 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 they occurred anywhere except in New Jersey.

At the close of the Magothy period 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 erosion 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 all of the Dover quadrangle, except perhaps a small portion in its northwestern corner, 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 epoch along the Atlantic border. During this time very slight changes took place along the continental border, although elevation was probably proceeding slowly, as the Monmouth and Rancocas formations are found outcropping farther and farther southeastward.

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. In areas lying farther north in New Jersey, deposition still continued in some places, for the Rancocas is there overlain by another later deposit of Cretaceous age. If such deposits were ever formed within the limits of the Dover quadrangle they have either been removed or are concealed from view by later formations which have overlapped them.

Eocene history.—During early Eocene time a portion of this area again became a region of deposition through a submergence which carried it beneath the ocean waters. This Eocene ocean seems to have transgressed the Rancocas surface, as Eocene deposition took place immediately upon the Monmouth formation in many places along Sassafras River and its tributaries. The Eocene waters probably did not cover the northeastern part of the quadrangle, for near Middletown and Townsend the later Calvert deposits are in contact with the Rancocas. During this Eocene submergence the waves doubtless worked on a Rancocas shore somewhere near Sassafras River and there picked up numbers of Rancocas fossils which were redeposited with the Eocene materials, for the characteristic Rancocas fossils *Terebratula harlani* and *Ostrea* (*Gryphæostrea*) *vomer* are found in the Eocene deposits near Fredericktown.

The conditions that prevailed during the time of the deposition of the Aquia formation must have been very similar to those existing during late Cretaceous time. The presence of great quantities of glauconitic material indicates quiet and deep water where foraminifera abounded and where only fine terrigenous detritus was being carried in small amounts by streams from the land. The waters were also well suited for marine life of higher forms, and numerous pelecypod and gasteropod fossils occur in the deposits.

Miocene history.—The Eocene deposits are unconformably overlain by the Calvert formation. The unconformity indicates that an erosion interval succeeded Eocene deposition, during which the area was above water and the streams of the region were cutting drainage channels in the Eocene deposits. A subsequent depression of the district submerged all that portion of the quadrangle lying southeast of a line drawn from Middletown to Kennedyville. At this time all of the land to the west must have been worn down to such an extent that the streams which drained it had very little force. Fine sands and mud were carried into the ocean and laid down as an offshore deposit, but no coarse materials were brought in. Diatoms lived in abundance in the waters near the shore and as they died their siliceous tests dropped to the bottom. Although diatoms are extremely small, yet their remains form a very considerable portion of the Calvert deposits, and in places beds several feet in thickness, composed almost entirely of their tests, are found. The Calvert deposits must therefore represent a very long interval of time. The waters also abounded in other forms of life, particularly corals, pelecypods, gasteropods, and fishes, although all the main groups of marine animals are represented.

After the deposition of the Calvert formation most if not all of this region remained above the water for a long period, during which those portions of the Atlantic Coastal Plain that lie farther east and south were alternately submerged and uplifted. Two Miocene formations, not represented in this area, are developed in those districts. During this time erosion was active, and much material was removed by the streams that meandered across the region.

Pliocene (?) history.—The erosion interval that followed Calvert deposition was finally terminated by a more extensive submergence, which carried the whole region beneath the waters of the ocean and at the same time elevated the adjoining land through a southeastward tilting of the continental border. This tilting rejuvenated the rivers and they were enabled to carry much coarser materials than they had borne during Eocene and Miocene time. As a result the entire submerged region near the shore was covered with a mantle of coarse gravel and sands, while the finer materials were carried out to sea beyond the confines of the Dover quadrangle. These deposits constitute the Lafayette formation. The thickness of this formation, in view of the coarseness of the materials, indicates that this submergence was not of long duration. This material was deposited on a gently sloping surface, probably similar to the present continental shelf. In time upward-moving forces became dominant and the entire Coastal Plain was again raised above the water. When the region was uplifted the recently deposited material formed a broad, nearly level plain, which extended from the Piedmont Plateau in a gradual slope to the ocean. Erosion succeeded deposition and large quantities of the Lafayette material were removed. During this erosion interval streams rapidly cut into the Lafayette and earlier formations. Over considerable areas the Lafayette plain was entirely destroyed, while in other places the tributary streams succeeded in isolating large portions, which remained as outliers. During this time the Lafayette was probably removed from a considerable portion of the Dover quadrangle.

Pleistocene history.—During the next depression, which occurred in Pleistocene time, the Sunderland deposits were formed. The depression was not great enough to carry all portions of this quadrangle beneath the water, and only those regions which now have an elevation less than 180 feet above sea level were submerged. This left a part of Elk Neck projecting above the water as an island. Probably other islands also existed for a while in this region, but were gradually reduced to sea level by the beating of the ocean waves. The materials that were carried in by the streams and deposited in the ocean, there to be re-sorted by the waves, indicate that the relation of the land to the sea must have been about the same as during Lafayette time. In the valleys which had been carved out by the streams during the erosion interval following the Lafayette period the deposits formed were much thicker than on the former stream divides. Had the period of submergence been a long one the old stream valleys must have been obliterated. That the Sunderland period, like the preceding, was comparatively short may be inferred from the thin layer of sediments which accumulated over the submerged region.

An elevation sufficient to bring the entire area above water permitted the streams to extend their courses across the newly-formed land and in a short time the Sunderland deposits were extensively eroded. A portion of those that remained after this period of denudation were destroyed by the waves, when a gradual subsidence again permitted the ocean waters to encroach upon the land. In this submergence the regions now lying above 100 feet were not covered with water; hence a considerable part of Elk Neck remained as land. At this time the Wicomico sea cut cliffs along the shore and these now appear as escarpments whose bases are at an elevation of 90 to 100 feet above sea level. Streams of considerable velocity and volume brought down gravel and sand, which the waves spread over the ocean bottom. The coarser materials were dropped near the shore, while the finer were carried farther out to sea. This accounts for the fact that the gravel of the Wicomico formation is larger and more abundant in the northwestern portion of the quadrangle than in the southeastern portion.

During the time that the Wicomico formation was being laid down the country to the north was covered by the glacial ice sheet. A great deal of ice evidently formed along the streams that were bringing in the Wicomico materials, and at times large masses were broken loose and floated down to the ocean. These ice masses carried within them bowlders, frequently of large size, which were dropped as the ice melted, and in this way the bowlders that are found in Wicomico deposits, mixed with much finer materials, reached their present positions. Some of these ice-borne bowlders included in Wicomico deposits found elsewhere show their glacial origin by numerous striæ. Toward the close of Wicomico time an upward land motion caused the ocean to retreat gradually again and at the same time checked the velocity of the streams through a landward tilting, by which the lower courses of the streams were elevated to a greater degree than the upper courses. The streams with less carrying power were then unable to transport coarse materials and as a result the upper beds of this formation are composed principally of fine sand and loam.

During the succeeding erosion interval the principal streams that are now present in this region developed, in large part, their main and lateral channels as they now exist.

The lower courses of Delaware River, Bohemia Creek, and Elk, Sassafras, and Chester rivers in their present form date from this time. Before the next subsidence all of these streams had cut through the Wicomico deposits and opened wide valleys in the old channels. With later submergence the water entered these valleys, converting them into wide estuaries or bays. The greater portion of the region was not submerged; those areas that have now an elevation more than 40 feet above sea level remained as land. In the estuaries and bays the Talbot deposits were laid down.

Within the Dover quadrangle the Atlantic shore line at this time extended irregularly from Dover to Middletown, and along this shore the waves were sufficiently strong to cut sea cliffs at many exposed points. These remain as escarpments and may be plainly seen at several points, particularly near Odessa and Smyrna. The waters of Chesapeake Bay advanced up the valleys of the various streams, forming broad estuaries in which sedimentation took place. Although the bay was then, as now, merely an arm of the ocean, yet the waves were of sufficient magnitude to cut sea cliffs at many places. In the region west of the Dover quadrangle some of these old sea cliffs can be traced continuously for several miles as escarpments, in places 15 feet high. Within the Dover quadrangle few of these sea cliffs are now well preserved. During this period of submergence the waters of Chesapeake Bay extended far enough inland to permit deposition in areas as far east as Sassafras on Sassafras River and Millington on Chester River.

The Talbot materials closely resemble those of the Wicomico formation, which indicates similar conditions during the two periods. Along the shore at some places marshes were formed in which an accumulation of vegetable débris took place, as in the swamp on Veazey Neck, which was produced at this time.

The Talbot stage of deposition was brought to a close by an uplift, as a result of which the shore line once more retreated and the previously submerged regions were drained. When this elevation occurred the region that emerged from the sea appeared as a broad terrace about the borders of the Wicomico plain, above described. During this time of uplift the streams again became active and rapidly removed large quantities of the loose material that had just been deposited. The land after the uplift undoubtedly stood at a higher elevation than at present, so that the material recently deposited formed a larger addition to the continent than would appear from the present outlines of the Talbot formation. Although a comparatively short period has elapsed since the Talbot deposits were converted into land, yet already in many places the streams have succeeded in cutting through these to the underlying beds.

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 so conspicuous features of the present topography. The movement is very slow and in many places has not kept pace with the filling process which is very noticeable in certain regions of the Coastal Plain. Many of the estuaries are not now navigable as far inland as they were a century ago. Deposition is very active in the estuaries, as nearly all the material brought down by the streams from the land is dropped in their quiet waters. From 1841 to 1881 Delaware River between Reedy Island (which lies just a few miles north of the Dover quadrangle) and Liston Point increased its mean width 411 feet, 285 feet on the New Jersey side and 126 feet on the Delaware shore. During the same period certain portions of this area have been deepened while certain others have been shoaled. Except in the region of Liston Point the river bed shows an excess of shoaling over deepening. The region includes an area of 15 square miles and shows an excess of filling of 8,096,150 cubic yards, representing an average decrease in depth of 0.4 foot in forty years. (Rept. United States Coast and Geodetic Survey for 1884, Appendix 12, pp. 433–434).

PHYSIOGRAPHIC RECORD.

The history of the development of the topography as it exists to-day is not a complicated one. 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 Dover quadrangle are all 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 height at which they are now found indicates merely successive periods of uplift and depression. 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 Dover 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 the changes that occurred during these periods 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 were 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, produced 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 having their sources in the Piedmont region gradually established their courses, while new ones, confined to the Coastal Plain, were developed. At this time the shore line seems to have lain farther east than now, and the present submerged channels of the continental shelf were probably then eroded. The Coastal Plain portion of Delaware River, with its extension as 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 Lafayette formation was cut through by streams, and in the older deposits valleys were opened, several of which 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 escarpments 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 to make 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 that followed Sunderland deposition the larger streams reoccupied practically the same channels they had carved out in the preceding erosion period and at once began to clear their beds and to widen their valleys, so that when the next submergence occurred the streams were eroding their channels, 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 a gradual submergence again occurred, so that the ocean waters once more encroached upon the land. This submergence seems to have been about equal 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 deposition epoch. Throughout many portions of the Coastal Plain 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 nearly all of the Dover 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 that lay above 90 to 100 feet were for the most part preserved. Streams also brought in and deposited materials from the adjoining land. A small portion of Elk Neck was probably all that remained above water in this region. Whether this appeared as an island or was connected with the main land mass lying farther north and west is not positively known.

While 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 stream 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.—Talbot deposition did not cover so extensive an area as 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 of the succeeding period of elevation and erosion found it easier to excavate new courses. An old pre-Talbot channel filled with Talbot débris has been found in the region of Havre de Grace, Md. Generally, however, the streams reoccupied their former channels and renewed their corrasive work, which had been interrupted by the Talbot submergence. As a result of erosion the Talbot plain is now in many parts 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 this subsidence occurred Bohemia Creek, and Elk, Sassafras, and Chester rivers, instead of being estuaries, were merely small streams lying above tide and emptying into a diminished Chesapeake Bay. Whether this movement will continue much longer can not of course be decided, but sufficient evidence is given on a preceding page with respect to Delaware River to show that this movement has been in progress within very recent time and it 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 Delaware River, and are receiving deposits of mud and sand from the adjoining land.

ECONOMIC GEOLOGY.

MINERAL RESOURCES.

The mineral resources of this region are not extensive nor extremely valuable, yet the Dover quadrangle contains some deposits that are of considerable economic importance, although they have not been very largely worked.

Clays.—The Pleistocene formations of this region contain a number of clay beds, some of which are available for the manufacture of brick and tile. About a mile northeast of Smyrna Landing there is a bed of Talbot clay which has been used for the manufacture of tile. The bed is only about 3 feet thick, yet as it occurs at the surface it can be profitably worked. The clay is of a light-blue color. Near Isaac Branch, about 3 miles east of Wyoming, another bed of clay is found in the Talbot deposits and is here used for the manufacture of brick. The deposit is about 4 feet thick and is overlain by a few feet of gravel and loam.

The Wicomico formation also contains some clay beds, although no such beds are now being worked. Near the village of Blackbird brick was made at one time from a clay obtained from this formation. So far as is known these are the only places where the Pleistocene clays of the region have been utilized, yet there is little doubt that numerous other local clay deposits might prove suitable for the manufacture of common brick and tile.

Marls.—The Monmouth, Rancocas, and Aquia formations all contain considerable glauconitic and calcareous materials. It is well known that glauconitic marl has considerable value as a fertilizer. Similar deposits have been extensively worked in New Jersey, where the importance of utilizing the marls has long been recognized. The marls of this region seem to be somewhat inferior in quality to many of the New Jersey deposits, for analyses show a smaller percentage of the potassium compounds, yet the results obtained by the use of the Delaware and Maryland marls are said to have been very satisfactory. In the early part of the last century many marl pits were opened in the northern part of this quadrangle, where these glauconitic beds either appear at the surface or are only thinly covered by later deposits. These marl pits were located near Silver Run and Drawyer and Appoquinimink creeks in Delaware, and along Bohemia Creek and Sassafras River and their tributaries in Maryland. Marl was obtained also at a few places on the divide west of Middletown by removing the overlying Wicomico materials, but the pits were abandoned because of the expense incurred in this work. Analyses made a long time ago by the Delaware Geological Survey show from 7 to 9 per cent of potassium. In places where the marl can be obtained at low cost such a percentage of potassium would seem to justify the opening of marl pits for local use.

Sands.—In the Pleistocene and Miocene formations there are numerous and extensive beds of fine quartz sands. The sand from these beds has been used locally for building purposes, but no large openings have been made in any of the deposits. In the southern portion of the quadrangle an unlimited amount of sand of excellent quality for building purposes could be obtained.

Gravels.—The Wicomico and Talbot formations contain many beds of gravel that is suitable for road-making, and in a few places these beds have been extensively worked. Along the north branch of Appoquinimink Creek, south of Middletown, a large gravel pit has been opened in a deposit of the Wicomico formation. Gravels from this pit have been used on the streets in Middletown and on some of the neighboring country roads. The deposit contains enough ferruginous clay and sand to cause it to pack well and to make a firm road bed. Although there are extensive gravel pits in the region yet many beds not opened would yield a good quality of gravel for road making. In the northern half of the quadrangle gravels are found almost universally beneath the loam cap of the Wicomico, and these have been used here and there for local purposes. At some places these gravel beds contain very little sand or clay and consequently are not well suited for roads; at others there is considerable iron oxide and sandy clay mixed with the gravel and it has considerable value as road-making material.

Diatomaceous earth.—The Calvert formation of the region contains a great deal of diatomaceous earth, but this has never been used in this district. Outcrops of it are seen along some of the southern tributaries of Appoquinimink Creek and in the valley of Hangmans Run. It is somewhat impure, however, so that its value is certainly not very great. A continuation of this diatomaceous bed has been worked along Patuxent River in Maryland, near the mouth of Lyons Creek, and at Popes Creek, on the Potomac, where it is very much purer than in this region.

SOILS.

The soils of that part of the Dover quadrangle that lies within the counties of Cecil and Kent, Md., and most of the part included within Kent County, Del., have been carefully studied by members of the Bureau of Soils of the United States Department of Agriculture, and maps showing the distribution of the various soil types, accompanied by reports on these areas, have been published (Field Operations of the Division of Soils, 1900, pp. 103–124 and 173–186 and Field Operations of the Bureau of Soils, 1903, pp. 143–164). The soils of the remaining portions of the quadrangle are very similar to those of the areas studied.

WATER RESOURCES.

The water supply of the Dover quadrangle available for use is found in the streams and wells of the district. As the quadrangle contains no large cities the streams are not used as sources of water supply. They are, however, used to furnish water power in many places, as has been already mentioned. The sluggishness of many of the streams, which permits the growth of marsh plants in them, would probably render their water objectionable for drinking purposes during the summer, when vegetable decomposition is most active. Besides, the stream valleys are under cultivation and the water would thus be liable to contamination. For these reasons the inhabitants of this region derive their water supply from wells. These are divided into two classes—the shallow dug wells and the deeper bored or artesian wells.

SHALLOW WELLS.

Nearly all the water supply of the Dover quadrangle is derived from shallow wells, ranging in depth from 15 to 35 feet. The water is contained in the rather coarse sand or gravel band that commonly forms the basal beds of the Pleistocene deposits. So frequently is this the case that the depth of the shallow wells in any locality is usually a good measure of the thickness of the Pleistocene covering. The surface water very readily penetrates the rather coarse Pleistocene materials until it reaches the less permeable deposits of the underlying Cretaceous and Tertiary formations. While some of it continues its downward course a great deal flows along on the contact between the two formations until it finds its way gradually into the streams. Hence, wells sunk to this level are practically certain to get a supply of water which, although seldom large, is in seasons of average rainfall sufficient to meet all ordinary requirements. These shallow wells depend for their supply almost entirely upon water that percolates through the Columbia deposits after rain storms, and are thus apt to be affected by droughts. After periods of heavy rainfall the water rises in the wells within a few feet of the surface and is then very roily. At other times the wells become dry, yet not often, because the rainfall is rather equably distributed throughout the year. The supply is less variable on the broad divides, where the level of ground water is always nearer the surface, than along narrow stream divides, where the water finds an easy exit to the streams.

Most of the water of the shallow wells is obtained at the base of the Wicomico formation, which covers large areas where the streams have not yet cut through to the underlying deposits. At the eastern border of the quadrangle, however, a number of shallow wells derive their water supply from the base of the Talbot formation. The Sunderland formation occupies far too small an area to be capable of holding much water. Rain water that penetrates the Sunderland very soon finds its way into near-by streams.

Shallow wells furnish the water supply of almost all the farmers of the district and also of the resi-

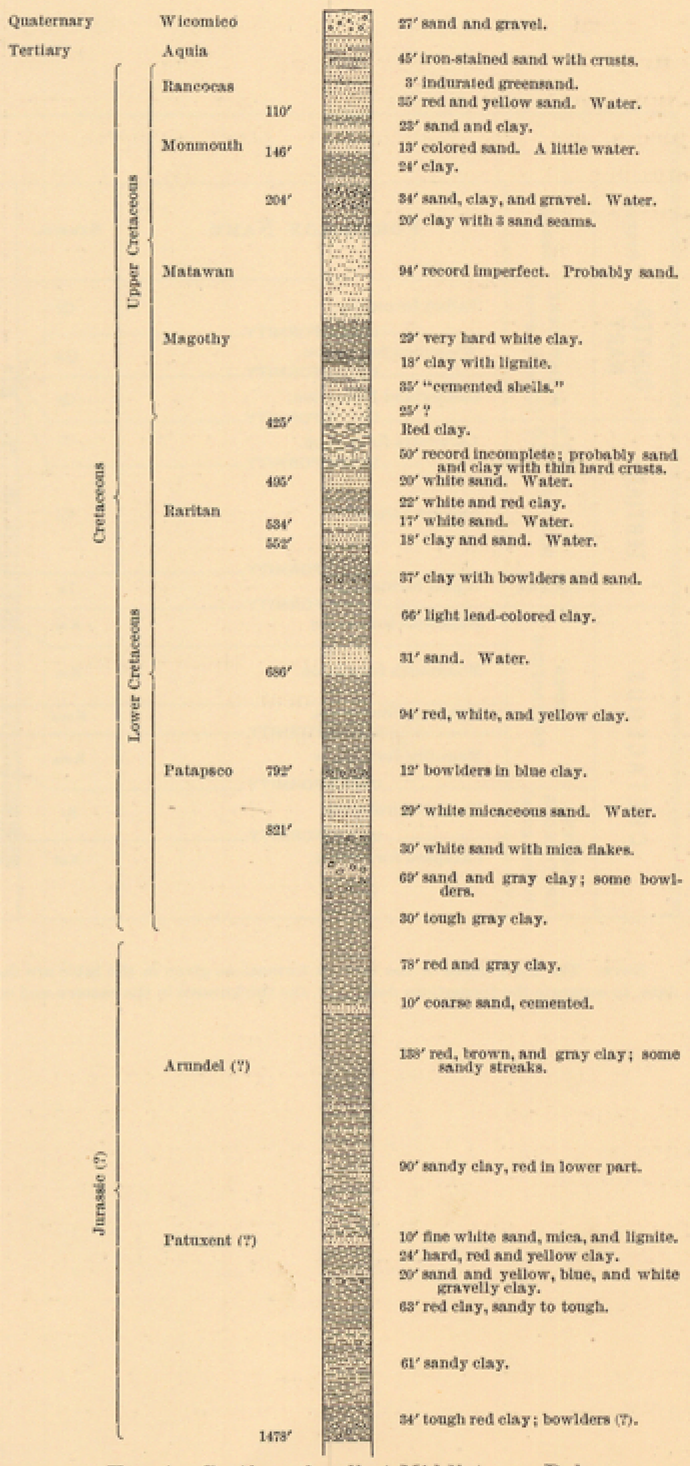


FIG. 1.—Section of well at Middletown, Del.
Scale: 1 inch=200 feet.

dents of the smaller towns. The water contains so little mineral matter in solution that it is known as soft water. In many places, no doubt, it does contain organic matter, yet no evidence is available to show that it is on this account unfit for drinking purposes. At many places the old-fashioned well sweep is used to bring the water to the surface.

ARTESIAN WELLS.

As water has been so readily obtainable at shallow depths in almost all sections and as not many establishments in the district require a large supply, there have been few attempts to obtain artesian water. The borings that have been made, however, have shown that several excellent water-bearing strata are contained within the underlying older formations. But even without any such records in these regions, we should expect to find good water-bearing strata in the older deposits, since not far to the north, in southern New Jersey, the same formations carry an abundant supply of artesian water. The meager data obtained in this and adjoining regions indicate the occurrence of water-bearing beds at the horizons noted below.

Crystalline floor horizon.—Beneath the unconsolidated Cretaceous, Tertiary, and Quaternary deposits of the Dover quadrangle, crystalline rocks similar to those exposed at the surface a few miles northwest of this quadrangle undoubtedly occur. This underlying consolidated rock mass is frequently known 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, as indicated by their outcrop, dips rather uniformly to the southeast. Along this surface much water flows to lower levels, and the floor of the crystallines therefore marks a good water horizon. Many artesian wells in the Coastal Plain derive an unfailing supply of pure water from this horizon. It seems that the drill has at no place in the Dover quadrangle reached the crystalline rocks, although in the northwest corner of the area they probably lie within a few hundred feet of the surface. At Middletown the drill was stopped at a depth of 1478 feet by a hard rock which could not be penetrated. The fact that no water was obtained just before the rock was struck is evidence that the drill encountered a quartz bowlder in the Potomac deposits rather than the hard floor of the crystalline rocks, but from what is known elsewhere in regard to the thickness of the Potomac deposits it is probable that the crystalline floor could be reached there at a slightly greater depth.

As Middletown lies in the northern part of the quadrangle and the crystalline floor dips steeply to the southeast it can readily be seen that the crystalline floor water-bearing horizon can never be very important economically to the greater portion of the district, even though it may be reached at Middletown at a depth of about 1500 feet. Other horizons, at shallower depths, will be utilized instead, on account of the expense involved in sinking wells to the great depth necessary to reach the crystalline floor.

Potomac water horizons.—The Potomac deposits contain many beds of coarse material that constitute water-bearing strata. Some of these sand and gravel beds lie between impervious clay bands and thus furnish the requisite conditions for flowing artesian wells. Several artesian wells at Middletown obtain water from the Potomac formations. In order to show the relations of the water-bearing beds to the other strata the complete section at that place is given (see p. 9). Part of the section has already been published by the New Jersey Geological Survey (Rept. for 1901, p. 108).

The section shows that there are water-bearing beds at five horizons in the Potomac formations at Middletown. The stratum at 792–821 feet furnished a good supply of water for about three years, when the well became choked with sand. When the well was sunk pumping at the rate of 150 gallons a minute lowered the surface of the water to a depth of only 110 feet. This bed seems to furnish more and better water than any other water-bearing stratum in this area, and its horizon is indicated on the geologic map by depth contours. These lines show approximately the depth below sea level to this water-bearing stratum. The depth to this stratum from the surface at any place may be obtained by adding to the figure indicated by these depth lines the elevation of the place above sea level. These depth contours must be considered as provisional only.

A fair supply of water is obtained in two other wells at Middletown about 536 feet in depth. The water seems to come from two beds that lie at horizons located about 485 and 534 feet below the surface. Other artesian wells at the same town are 552 and 686 feet deep. The artesian head is not great, and flowing wells can probably be obtained only on very low land.

Upper Cretaceous water horizons.—In New Jersey considerable artesian water has been obtained from the greensand deposits of the Upper Cretaceous. The water is not so pure as that found in the quartz-sand beds of the Potomac formations, nor is it so abundant. The Upper Cretaceous deposits are in general more pervious than those of the Potomac formations and contain fewer clay bands, so that the water passes more readily to lower levels. Ferruginous material derived from glauconite makes the water from some wells very unpalatable. At Middletown three wells were sunk to a depth of 88 feet, where a good supply of water was obtained, which rose within 13 feet of the surface. The iron content of the water, however, caused the wells to be abandoned and lower water-bearing horizons to be sought. The water was probably derived from the base of the Monmouth formation.

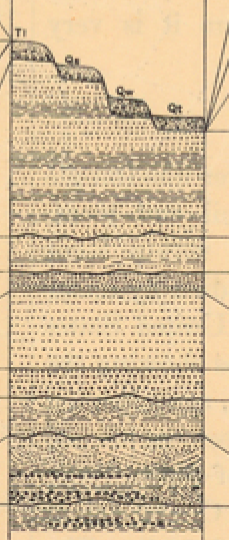
Miocene water horizons.—In the southern half of the quadrangle artesian water is obtainable from the Calvert formation. The Miocene deposits in the Coastal Plain contain many sandy beds that are intercalated between impervious argillaceous strata. These furnish good supplies of artesian water, usually of excellent quality. In New Jersey, from Atlantic City southward, numerous wells draw water from these deposits, and on the peninsula between Delaware and Chesapeake bays many artesian wells, some of them flowing, derive water from Miocene beds. Two of these wells are at localities within the Dover quadrangle.

At Clayton a good supply of water is obtained from the Calvert formation at depths ranging from 60 to 85 feet, while at Dover there is a flowing artesian well 196 feet deep, the water rising about 6 feet above the surface. The natural flow is 35 gallons a minute, but 218 gallons a minute have been obtained by pumping. Other wells at Dover are 145, 165, and 185 feet deep. It seems probable that the supply of water at Dover is obtained from the same horizon that furnishes the water for the artesian wells at Clayton and along Mahon River, Delaware, and for the numerous artesian wells at Federalsburg, Md., about 20 miles south of the Dover quadrangle. The probable depths below sea level at which this water-bearing horizon can be reached are shown on the southern part of the geologic map.

November, 1905.

GENERALIZED SECTION FOR THE DOVER 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		40	Unconsolidated sandy loam underlain by cross-bedded sand; occasional ice-borne bowlders.	Very flat to gently rolling low lands. Fine sandy soil adapted to trucking.
		UNCONFORMITY					
		Wicomico formation.	Qw		50	Sandy loam underlain by persistent bed of gravel; ice-borne bowlders.	Gently rolling lands. Sandy loam to coarse sand, suitable for truck, fruit, and grain.
		UNCONFORMITY					
		Sunderland formation.	Qs		45	Coarse sand and gravel.	Undulating surface. Coarse sand and gravel, not adapted to cultivation.
		UNCONFORMITY					
TERTIARY	PLIOCENE	Lafayette formation.	Tl		40	Coarse sand and gravel, occasionally indurated.	High, rolling lands. Much coarse sand and gravel; seldom cultivated.
		UNCONFORMITY					
	MIOCENE	Calvert formation.	Tc		150-200	Yellow sand, compact dark-blue clay, and beds of impure diatomaceous earth.	Level land with broad and shallow valleys. Sandy soil, suitable for raising early vegetables.
		UNCONFORMITY					
	EOCENE	Aquia formation.	Ta		35	Gray sand with green glauconitic sand, weathering brown; numerous fossil casts.	Moderately steep slopes along streams. Very fertile sandy soil.
		UNCONFORMITY					
CRETACEOUS	UPPER CRETACEOUS	Rancocas formation.	Krc		20	Dark greensand marl, weathering brown; numerous fossils.	Steep slopes along streams. Fertile sandy soil.
		Monmouth formation.	Km		80	Gray and brown sand containing some glauconite and many irregular iron crusts; numerous fossil casts.	Nearly vertical bluffs bordering streams. Brown sandy soil.
		Matawan formation.	Kmw		30	Dark-colored micaceous glauconitic sand with occasional indurated bands.	Steep slopes along larger streams. Dark sandy soil.
		UNCONFORMITY					
		Magothy formation.	Kma		40	Light-colored fine laminated sand, occasionally cross-bedded, alternating with drab and lignitic clay.	Steep bluffs along streams. Sandy soil.
		UNCONFORMITY					
	LOWER CRETACEOUS (Potomac group)	Raritan formation.	Kr		70	Red and buff clay and cross-bedded sand with gravel lenses frequently cemented into conglomerate.	Irregular surfaces and steep bluffs along streams. Clay or sandy soil of little value.
		UNCONFORMITY					
		Patapsco formation.	Kpt		20+	Variegated clay, light-colored sand, and gravel lenses.	Gentle slopes along streams. Clay soil possessing little fertility.

NOTE: The thicknesses of the various formations given in the table are those at or near their outcrop. Well records show conclusively that most, if not all, of the Tertiary and Cretaceous formations increase in thickness toward the southeast beneath the more recent formations. Since it is impossible, from such data, to separate the formations definitely, the thicknesses in the eastern and southeastern portions of the quadrangle are not given.

BENJAMIN LeROY MILLER,

Geologist.

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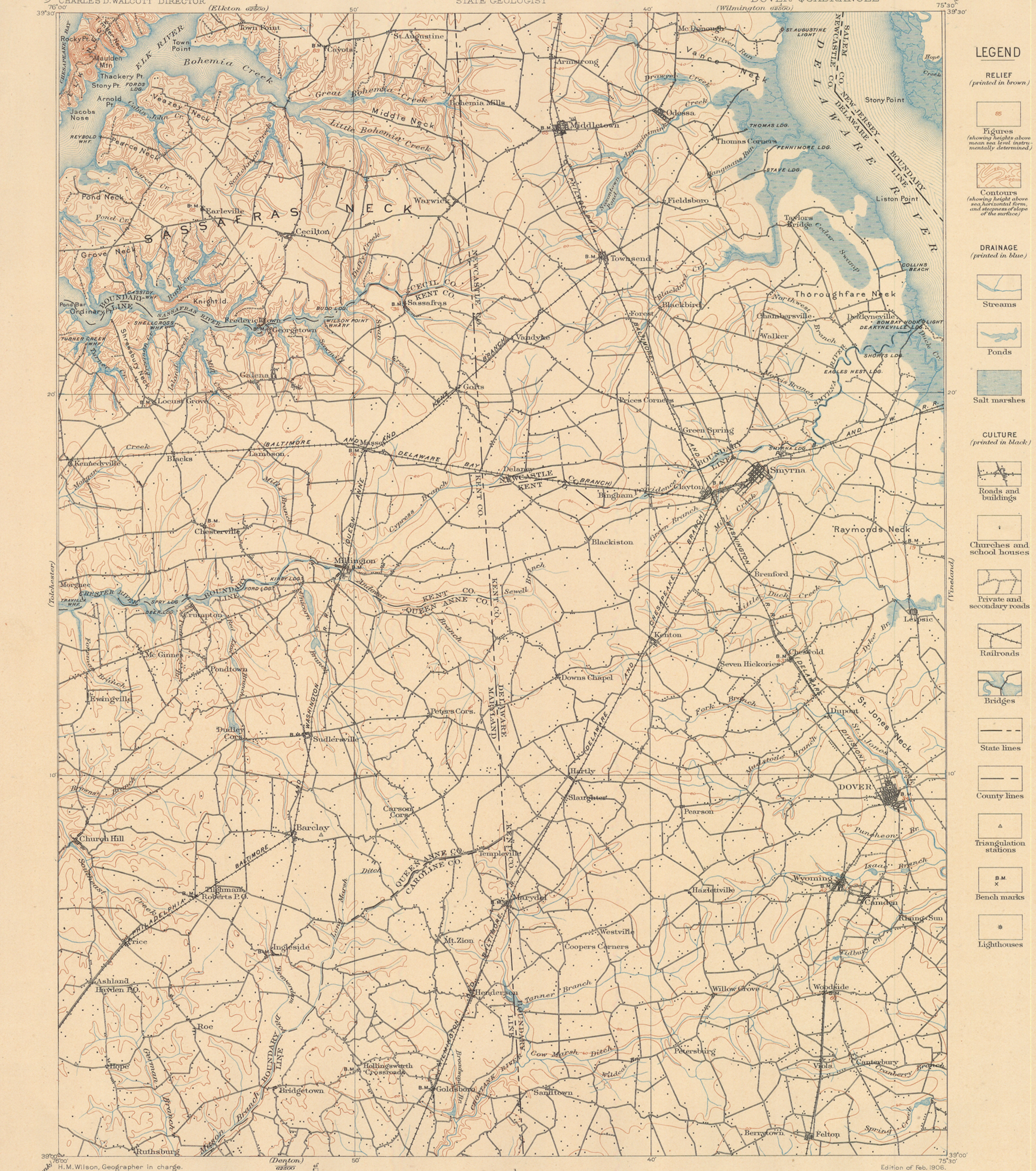

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Scale 1/125000

Contour interval 20 feet.
Datum is mean sea level.

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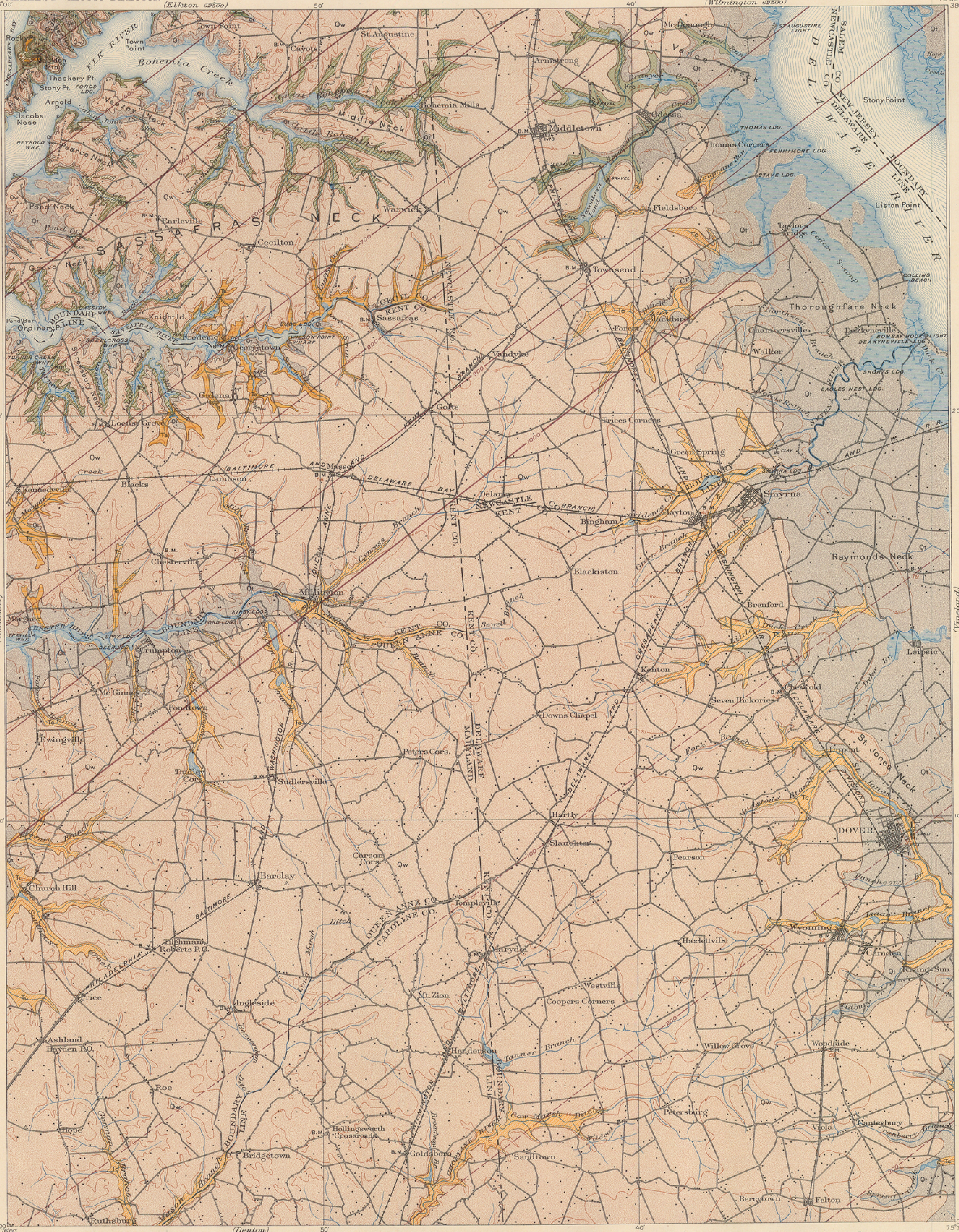

LEGEND

SEDIMENTARY ROCKS

QUATERNARY

Pleistocene (Columbia group)

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

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

Qs — **Sunderland formation** *(coarse sand and gravel, covering undulating uplands from 90 to 180 feet above sea level)*

TERTIARY

Pliocene ?

Tl — **Lafayette formation** *(coarse sand and gravel, often cemented by iron into conglomerate; covers high, flat or rolling lands 200 feet above sea level)*

UNCONFORMITY

Miocene

Tc — **Calvert formation** *(blue clay, light-colored sand, and diatomaceous earth)*

UNCONFORMITY

Eocene

Ta — **Aquia formation** *(light and dark-colored sand largely glauconitic, occasionally firmly indurated by iron oxide)*

UNCONFORMITY

CRETACEOUS

Upper Cretaceous

Krc — **Rancocas formation** *(dark greensand marl)*

Km — **Monmouth formation** *(green to brown sand with numerous ferruginous plates)*

Kmw — **Matawan formation** *(dark-colored, micaceous, glauconitic sand, locally indurated)*

UNCONFORMITY

Kma — **Magothy formation** *(light-colored sand alternating with drab and lignitic clays)*

UNCONFORMITY

Lower Cretaceous (Potomac group)

Kr — **Raritan formation** *(variegated clays, cross-bedded sand, gravel, and conglomerate)*

UNCONFORMITY

Kpt — **Patapsco formation** *(variegated clays, locally lignitic; cross-bedded sands, and gravel lenses)*

Note—Brick and tile clay and gravel are obtainable from Wicomico and Talbot formations; marl from Monmouth, Rancocas, and Aquia formations; sand from all Pleistocene and Miocene formations; diatomaceous earth from Calvert formation.

Gravel, sand, and clay pits

Artesian wells, showing depth

Indicates flowing well

Depth below sea level to artesian water horizons (solid lines refer to horizon in Potomac formation, dashed lines to horizon in Calvert formation; contour interval is 100 feet. Flowing wells can be obtained only on very low land.)

H. M. Wilson, Geographer in charge.
Triangulation by U. S. Coast and Geodetic Survey.
Topography by H. S. Wallace and J. W. Thom.
Surveyed in 1896. Southwest quarter revised in 1904 by Robert Coe.

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Scale $\frac{1}{125000}$

Contour interval 20 feet.
Datum is mean sea level.

Edition of Mar. 1906.

Geology by Benj. L. Miller.
Lower Cretaceous rocks by A. Bibbins.
Surveyed in 1902 and 1905.

SURVEYED IN COOPERATION WITH THE STATE OF MARYLAND.

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.......	....	Ћ	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......	....	Æ	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:

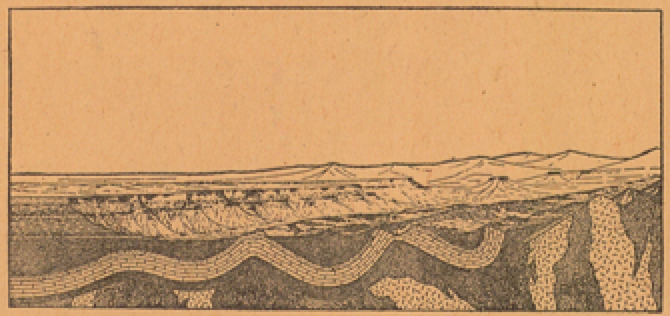

Fig. 2.—Sketch showing a vertical section at the front and a landscape beyond.

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:

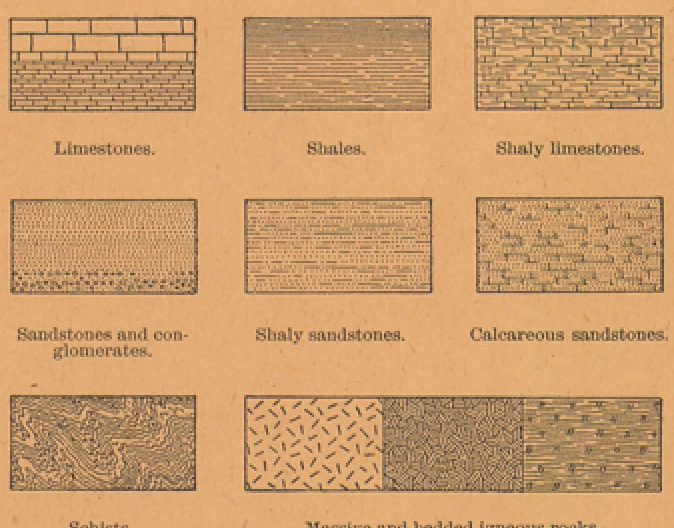

Fig. 3.—Symbols used in sections to represent different kinds of rocks.

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

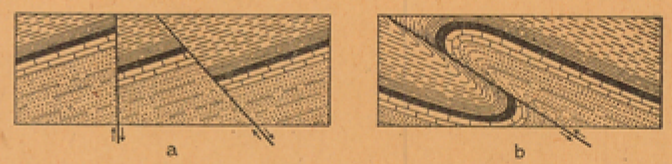

Fig. 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* fault.

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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