DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS

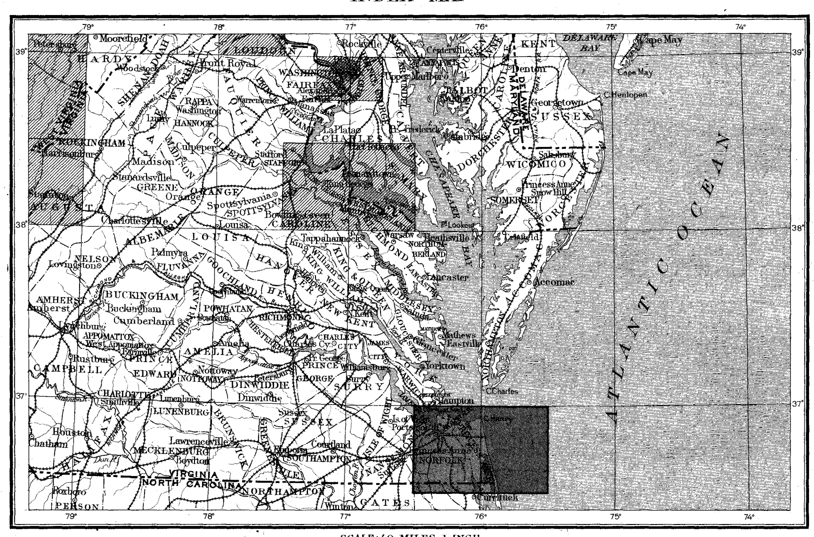
OF THE

UNITED STATES

NORFOLK FOLIO

VIRGINIA - NORTH CAROLINA

INDEX MAP



SCALE: 40 MILES - 1 INCH

AREA OF THE NORFOLK FOLIO

AREA OF OTHER PUBLISHED FOLIOS

LIST OF SHEETS

DESCRIPTION | TOPOGRAPHY | AREAL GEOLOGY | COLUMNAR SECTIONS | ILLUSTRATIONS

FOLIO 80 | LIBRARY EDITION | NORFOLK

WASHINGTON, D. C.

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GEORGE W. STOSE, EDITOR OF GEOLOGIC MAPS   S. J. KUBEL, CHIEF ENGRAVER

1902

EXPLANATION.

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

THE TOPOGRAPHIC MAP.

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

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

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

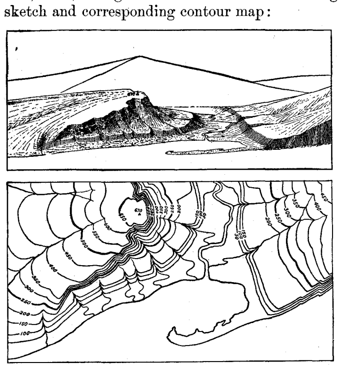


Fig. 1.—Ideal sketch and corresponding contour map.

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

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

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

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

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

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

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

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

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

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

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

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

THE GEOLOGIC MAP.

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

KINDS OF ROCKS.

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

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

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

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

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

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

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

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

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

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

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

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

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

AGES OF ROCKS.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

THE VARIOUS GEOLOGIC SHEETS.

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

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

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

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

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

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

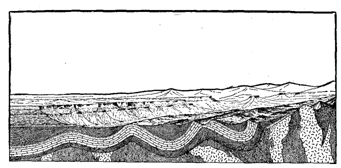


Fig. 2.—Sketch showing a vertical section in the front of the picture, with a landscape beyond.

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

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

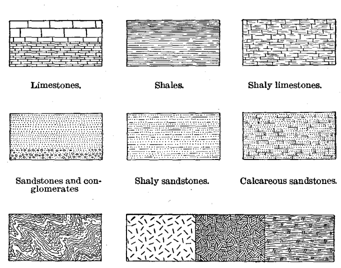


Fig. 3.—Symbols used to represent different kinds of rock.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

CHARLES D. WALCOTT,
Director.

Revised January, 1902.

DESCRIPTION OF THE NORFOLK QUADRANGLE.

By N. H. Darton.

GEOGRAPHY.

General relations.—The Norfolk quadrangle embraces the region lying between the parallels 36° 30′ and 37° north latitude and the meridians 75° 30′ and 76° 30′ west longitude.

Location of quadrangle.

It measures approximately 35 miles from north to south and 56 miles from east to west, and contains about 1913 square miles, of which about one-half is ocean and bay and the other half is land with inlets. In Virginia it comprises Norfolk, Princess Anne, and small portions of Nansemond, Warwick, and Elizabeth City counties. In North Carolina it includes the northern margins of Currituck and Camden counties. The land portion is a low plain extending to the Atlantic Ocean on the east and to Chesapeake Bay and James River on the north. It is deeply invaded by tide water in the channels of James, Nansemond, Elizabeth, Lynnhaven, North Landing, and Northwest rivers, and in Back Bay, North Bay, and some minor waters. Its fresh-water streams are small and reach tide water at no great distance from their sources. The quadrangle includes the greater part of the Dismal Swamp with its central body of water, Lake Drummond.

Coastal Plain province.—The eastern portion of the Atlantic slope of the United States embraces two distinct provinces: the Piedmont Plateau, a region of undulating plains, extending eastward from the Blue Ridge with gradual declivity and underlain by ancient crystalline rocks; and the Coastal Plain, a province bordering the ocean, deeply invaded by tide-water estuaries and underlain by gently east-dipping unconsolidated strata from early Cretaceous to latest Pleistocene in age. The Norfolk quadrangle lies entirely within the Coastal Plain province.

The Coastal Plain continues its slope eastward beyond the Atlantic shore line, its eastern margin lying at a moderate depth at the edge of the continental plateau, 100 miles offshore, where it terminates in the great continental slope, 3000 to 10,000 feet high.

Submarine extension of Coastal Plain.

From the eastern portion of the Piedmont Plateau there extends across the Coastal Plain to the verge of this slope a very smooth and even surface, inclining gently southeastward and broken only by the broad, shallow valleys of the rivers, in the larger of which tide water reaches as far west as the eastern margin of the crystalline rocks of the Piedmont Plateau.

The highest altitudes in the Coastal Plain province are about 400 feet above sea level; its submarine margin is about 300 feet below sea level. So gentle is the inclination and so perfect the unity of the plain that if the land were elevated or depressed 100 or 200 feet the shore line would simply be shifted about the same number of miles. Thus the position of the coast may be considered an accident of the present slope and altitude of the land—indeed, between the mouth of Hudson River and Chesapeake Bay the present coast does not coincide with the trend of the province, but cuts obliquely across it, so that, while only about half the province is submerged in the latitude of Richmond, it is nearly all beneath the ocean in the latitude of New York. Below tide level the province is an even and nearly level sea bottom; above tide level it comprises lowlands of broad, flat terraces which skirt the coast and the estuaries, and extensive areas of higher plateau surfaces lying between the large valleys and rising gradually westward. The principal waterways are broad, shallow estuaries, flanked sometimes by tidal marshes, sometimes by low sea cliffs, and demarked from the higher plateau surface by moderately steep slopes. The lesser waterways are commonly estuarine in their lower reaches, but narrow and steep bluffed in their upper portions, frequently heading in narrow ravines cut sharply in the extensive plains of the divides.

GEOGRAPHIC DIVISIONS.

Low, level plain.—The principal feature of the Norfolk quadrangle is a very level terrace elevated from 10 to 20 feet above sea level and intersected by extensive tide-water areas and a few shallow valleys of fresh-water streams. Upon this plain to the westward is the Dismal Swamp, and to the north and east, along the bay and ocean shores, there are sand dunes, which have a height of 70 feet at Cape Henry. The general terrace is part of a low plain which constitutes the surface of all the Eastern Shore of Virginia and Maryland.

Terrace extending along the Eastern Shore of Virginia and Maryland.

It also forms a moderately wide margin along the western shore of Chesapeake Bay, extends up James River in low terraces as far as Richmond, and, in the area of the Norfolk quadrangle and adjoining region, reaches as far as the western edge of Nansemond County. This plain is traversed by James River and Hampton Roads. It is crossed transversely by a shallow trough which is occupied on the north by the estuarine channel of Elizabeth River and Southern Branch, and on the south by North Landing River. In the middle of the depression, from North Landing to Great Bridge, there is a swamp, through which the Albemarle and Chesapeake Canal has been excavated. The plain is trenched by a number of valleys reaching tide water in their lower portions. Of these Nansemond River, Western Branch, Eastern Branch, Tanner Creek, Mason Creek, Little Creek, Lynnhaven River, and Broad Bay flow to the north into James River or Chesapeake Bay; and Northwest River and its little branches, together with North Landing River, flow southward into Currituck Sound. Knott Island is an outlying portion of the terrace level, cut off by tide-water inlets which join Currituck Sound. North of Knott Island lie Back Bay and North Bay, separated from the ocean eastward by a long spit of beach sand. Wide areas of the terrace level are almost perfectly smooth, without any undulation perceptible to the eye. It is thought probable that the entire plain area aside from the marsh and swamps was originally a forest of short-leaved pine with occasional trees of other varieties. This pine forest, together with many small wooded areas which were occupied by cypress swamp, has been in greater part cleared. In the vicinity of Virginia Beach and thence to Cape Henry stumps are now exposed, mainly of cypress, up to the very margin of the terrace, which is being eroded directly by the waves of the ocean. Portions of these plains in the eastern and northern parts of the quadrangle are fairly well drained, owing to the sandy nature of the soil, but a large area in the southwestern part, with imperfect drainage, is occupied by the Dismal Swamp. A small detached area of swamp is known as The Green Sea.

Dismal Swamp.—The larger portion of this great fresh-water morass lies in the Norfolk quadrangle. It is an area of moderately elevated, nearly level land with such imperfect drainage that it remains constantly inundated to a slight depth. The outlines of the swamp area are irregular, as shown on the map, and usually the limits are not well defined, the position of the edges of the wet portion varying with the rainfall and the presence of the swamp flora. Some marginal areas which are cleared have ceased to be swampy except in wet weather. The swamp is heavily wooded and contains extensive canebrakes (see Illustration sheet, figs. 1 to 4). The swamp, which slopes gradually upward to the southwest, varies in altitude from 12 to 22 feet above mean tide level. Near its center there is a picturesque body of open water, known as Lake Drummond (see Illustration sheet, figs. 5 and 6).

Lake Drummond.

This lake is nearly circular in outline, about 2¾ miles in diameter, and until recently its surface was slightly over 22 feet above mean tide level, being the highest portion of the swamp. At one time its depth was about 15 feet, due in part to damming of the swamp by the banks of canals. Now, owing to the deepening of the canal feeder, the lake is only about 6 feet deep and the surface correspondingly lower, which is lower than it is known to have ever been before. Its floor is largely covered with white sand. The lake water is light brown in color, due to a considerable amount of finely divided vegetal matter in suspension. It is thought to be perfectly wholesome, and as it is famous for its keeping properties, it has been used extensively for supplying ships for long voyages. The lake is surrounded by woods, and at some points cypress trees are found growing in the water (see fig. 6 on Illustration sheet). The depth of the water decreases rapidly in the woods adjoining the lake, and over the swamp area in general it is rarely more than 1½ feet, except possibly in very wet weather. The average depth is from 1 to 3 inches, but in many portions the average depth is from 6 to 8 inches. In very dry seasons the amount diminishes all over the swamp area.

Some marginal portions of the swamp have been drained for farming land, for which the soil is admirably adapted. The swamp area known as The Green Sea was originally a portion of the main swamp, but the Dismal Swamp Canal, which traverses the eastern portion of the area from north to south, has in a measure drained the intervening region.

Reclaimed swamp land.

This canal sustains the water level and the resulting swamp conditions to the west, but has reclaimed from inundation a zone of considerable width to the east, an area which is further drained by the branch ditch known as the Herring Canal. The swamp flora is characterized by the occurrence of bald cypress, juniper, black gum, and extensive canebrakes.

The swamps lie in shallow basins in the surface of the general terrace of the Norfolk region. The basins are now filled to the general level of the surrounding country with vegetal accumulations, which have a maximum thickness of about 20 feet. In recent excavations for a gate on the feeder about half a mile east of Lake Drummond there were exposed 10 feet of peat filled with roots and tree trunks, lying on 8 feet of clear peat which merged with the overlying beds, and this in turn was underlain by fossiliferous sand of late Neocene age. The thickness of the swamp deposits decreases toward the periphery of the present swamp area, but so few excavations have been made along the border zone that the conditions of thinning are not known. The upper beds of peaty materials merge gradually into the sands of the adjoining area, so that no boundary line can be given.

The basin of the Dismal Swamp owes its origin to an extensive depression in the surface of the Columbia formation. At first this hollow was probably a slough in the terrace surface.

Origin of Dismal Swamp.

When the Columbia formation was deposited James River had essentially its present course, but emptied into open water some distance northwest of the swamp. Its main current appears to have built a bar or broad delta which extended eastward and thus built up the terrace plain that lies east and southeast of Norfolk. Between this delta and the steep slope at the edge of the highlands which lie a short distance west of the Norfolk quadrangle there remained an area of lowland, a slough which was not built up appreciably by the Columbia deposits. When the delta was uplifted it became a high terrace with good drainage conditions, while the slough became a swamp filled with luxuriant vegetation, and it has so continued ever since. At first, when the vegetation was young, relatively fine-grained peat accumulated, but as the forest grew older, roots and trunks were intermixed with the finer materials, and finally the depression was filled up to the general level of the country by these accumulations. It is now so remote from the larger drainage ways and so choked with canebrakes that its drainage is still very imperfect and the swamp conditions continue over nearly all the original basin area. Lake Drummond is no doubt the remaining portion of an original center pond, probably greatly encroached on by the forests and canebrakes. It is probable also that during some periods the lake was dry for a short time. Its bottom has been raised somewhat by vegetal accumulations, but probably its water level has just about kept pace with the general rise of the swamp surface.

Tide marsh.—The widest areas of tide marsh are those around Back Bay and at the head of Currituck Sound. Tide marshes occur in all the tide-water inlets, but they are generally of limited extent. Tide marsh extends up North Landing River to North Landing, and up its branch, West Neck Creek. On North Landing River it merges into fresh-water marsh. Tide marsh owes its origin to the growth of marine vegetation and the deposition of fine silt, its materials being partly earthy and partly vegetal. Brackish water is most favorable to its development. It tends to fill up the tide-water inlets, and to grow out into sheltered bays, notwithstanding moderate wave action, and eventually to constrict the bays to tidal channels. It advances along lines where the waves are least violent and makes rapid progress behind sand spits and other similar protections which break the force of the wind. The plants in the marsh grow so close together that they favor the deposition of mud and sand, and their widely extended roots and stout stems bind the deposits together. The wide neck of marsh at the Causeway is an excellent illustration of marsh growth, it having accumulated here under the lea of Knott Island. It is probable that Back Bay and Currituck Sound were once connected by a strait which has been closed by this marsh growth. The marsh is now encroaching upon the bays on the west side of Back Bay, and it is making rapid progress in filling up the bays and inlets north of Back Bay.

Sand dunes.—Along the shores of the ocean and of Chesapeake Bay there are accumulations of dune sand of geologically recent origin. They attain their greatest prominence on Cape Henry.

Dunes along Chesapeake Bay.

In this region the sand dunes are generally confined to a narrow zone near the shore, just out of reach of high tide, where they occur in groups of various sizes. The material is loose beach sand which has been blown back from the beach by the wind. At some localities the sand has largely remained in its present place for centuries, but at other places it is blown by the wind at the present time. At Cape Henry the dunes attain a height of 70 feet and extend along the beach as a high ridge to Lynnhaven Inlet. From this inlet to Little Creek, and again from Little Creek to beyond Ocean View, there is a nearly continuous line of dunes constituting a narrow ridge from 15 to 25 feet high. The finer material from the dunes is often carried some distance inland by the winds and merges into the sandy loam which is derived from the surface of the Columbia formation. On this account it is not possible to indicate on the map any precise boundary for the dune-sand areas. In the vicinity of Cape Henry the dune sand is advancing inland comparatively rapidly. The tops of a few old cypress trees project above the summits and slopes of some of the higher dunes near the cape, and in "The Desert," an ill-drained forested area behind the dunes, the sand is accumulating rapidly about the tree trunks.

Origin of "The Desert".

"The Desert" has a surface of low dunes, which occur mainly in faint ridges approximately concentric to the present curve of the coast line of the cape. This condition indicates a series of physical changes, beginning with the formation on the terrace level of low dunes of sand, which was followed by the advance of forest growth, and this by the reinvasion of sand which is gradually killing and burying the forest.

The sand dunes about Cape Henry were described a hundred years ago by B. H. Latrobe (Trans. Am. Philos. Soc., Vol. IV, 1799, pp. 439–444, 1 plate; see also Am. Jour. Sci., Vol. XL, 1865, pp. 261–264).

Rate of advance of the dunes.

A comparison of his description with the present conditions shows how little change there has been in a century. At that time the dunes were apparently as high as at present and were rapidly encroaching upon the forests in "The Desert." The sand is blown up the steep front of the dune and much of it is carried down the gentler western slope far into the forest. The line of sand dunes, it is thought, has caused the imperfect drainage of the forested area by damming the water which flows down the slight slope of the inland terrace toward the ocean. During the first sixteen years after the establishment of the light-house at Cape Henry it was estimated that the dunes had risen about 20 feet in height, and at one definitely located point, a short distance from the light-house, had proceeded into the desert about 350 yards. It was predicted by Mr. Latrobe more than a hundred years ago that if the dunes should continue to advance at this rate for twenty or thirty years they would swallow up the whole swamp, but it is evident that the rate of accumulation has greatly diminished in later years, for the dunes do not appear to have progressed much farther than they were in Mr. Latrobe's time.

GEOLOGY.

GENERAL SEDIMENTARY RECORD.

The geologic deposits of the Norfolk quadrangle comprise sandy loams, sands, clays, marls, peat, and muck. They are in greater part of sedimentary origin, but some of the sands are eolian, and the marsh accumulations have been aided and augmented by plant growth. The general surface formation is a sheet of sandy loam of no great thickness. This is underlain by an extensive series of Coastal Plain deposits lying on a floor of the crystalline rocks which constitute the surface of the Piedmont region to the west, but which slope far below sea level in their extension eastward under the Coastal Plain.

Coastal Plain formations.

The rocks of the Coastal Plain consist of broad sheets of sands, gravels, clays, diatomaceous earth, marls, and glauconitic sands comprised in a succession of formations which dip very gently to the southeast. They rise above sea level in regular succession westward and northward, and in the Norfolk region have an aggregate thickness over 2300 feet. They range in age from early Cretaceous to late Pleistocene. The successive formations are in most cases separated by unconformities, each representing a period during which the surface was uplifted above the sea and sculptured by waves and streams, so that when each succeeding deposit was laid down its strata were more or less discordant with the partially eroded strata of the preceding period. The formations which underlie the Coastal Plain region of eastern Virginia are shown in the accompanying table; those which outcrop in the Norfolk quadrangle are in heavy-faced type. The lower formations reach the surface farther west in Virginia, except the marine Cretaceous deposits, the outcrops of which begin in Maryland. The Pleistocene formations are the only ones seen at the surface in the Norfolk quadrangle, but the Neocene, Eocene, and Cretaceous formations have been explored considerably by well borings.

Formations, and associated unconformities, underlying the Coastal Plain region of eastern Virginia.

Period.	Formation.	Character.	Thickness in feet.
Pleistocene	**Alluvium, etc.**	River silt, peat, muck, beach sand, dune sand, etc.	0 to 60
	Unconformity.		
	Columbia formation	Sandy loams, sands, and clays	10 to 30
	Unconformity.		
Neocene	Lafayette formation (Pliocene ?)	Gravel, orange sands, and loams	25 to 40
	Unconformity.		
	Pliocene strata	Marls and sands	10 to 20
	Chesapeake formation (Miocene)	Fine sands, clays, and diatomaceous deposits.	35 to 565
	Unconformity.		
Eocene	Pamunkey formation	Glauconitic sands, marls, and clays	30(?) to 300
Cretaceous	Marine deposits	Clays and sands	0 to 500
	Unconformity.		
	Potomac formation	Sands and clays	200 to 1300
	Great unconformity.		
Archean	Crystalline rocks	Granites, gneisses, etc	

Classified according to origin, these deposits of the Coastal Plain may be divided into two groups: one corresponds more or less closely with those formations now in process of deposition in the estuaries and along the shores in the immediate vicinity; the other corresponds closely to off-shore sediments known from soundings to be in process of deposition over the more deeply submerged portions of the province. In general the shore and estuarine deposits overlie those of the second group, and are thus known to be the younger. They record certain modifications in geography due to changes in altitude of the land, and, moreover, display certain distinctive characteristics indicating the climate of the periods during which they were laid down. The older formations contain abundant remains of marine organisms, preserved as fossils, and thus these deposits are records of periods during which the land stood lower and the sea consequently extended farther inland than at present.

Marine deposits.

The lowest and oldest formation of the Coastal Plain series, which does not come to the surface in the Norfolk district, appears to be devoid of marine fossils, but its beds contain impressions of leaves, together with lignitized wood and other vegetal fossils, as well as the bones and teeth of dinosaurs. In addition, portions of the deposit are coarse and irregularly bedded, so that this formation, like the younger deposits, appears to bear record of land conditions and thus indicates that the land had an altitude many feet higher than that at present.

From the character of the materials it is known that the deposits of the Coastal Plain province were derived from the rocks of the neighboring interior (Piedmont and Appalachian) provinces.

ARCHEAN PERIOD.

The "bed rock" underlying the Coastal Plain sediments has been reached by the well at Fort Monroe at a depth of 2246 feet. It is a light-colored rhyolite of very compact texture and great hardness. In the drilling operation it was penetrated 8 feet and samples were secured by which it was identified. Doubtless the same rock underlies the entire Norfolk area, sloping gently eastward.

CRETACEOUS PERIOD.

Potomac formation.—The deep borings at Fort Monroe and the Norfolk waterworks penetrated sands and clays undoubtedly belonging to the Potomac formation, which is so extensively exposed along the upper estuarine portions of James, Rappahannock, and Potomac rivers in Virginia. It constitutes the lower members of the Coastal Plain series, lying on the floor of granites, gneisses, and other crystalline rocks of the Piedmont region. In the outcrops in Virginia it exhibits a maximum thickness of about 600 feet along Potomac River near Washington, but it thickens to more than double this amount to the east, under the Coastal Plain. It is supposed that the top of the Potomac formation was reached at a depth of 945 feet at Fort Monroe and 782 feet in the Norfolk waterworks boring. The deposits penetrated by the well borings are shown on the Columnar Section sheet. They are mainly sands of light-gray color and varying degrees of fineness. The material is quartz with occasional grains of other minerals and flakes of mica. Pebbles of quartz are of frequent occurrence. Sandy clays occur in scattered thin beds, and at various horizons there is a general admixture of a small amount of clay with the sand.

Impure quartz sand at base of Coastal Plain deposits.

The clay bed at 1218 feet in the Norfolk waterworks boring was a tough, variegated red, gray, and buff clay, strikingly like some of that exposed in Maryland. When this boring was at a depth of 1320 feet in the brown-red sand, there was obtained a specimen of *Exogyra*, but there is some uncertainty as to the authenticity of its occurrence in the formation at this depth. It is a marine Cretaceous fossil which would not be expected in the Potomac formation, as it belongs to a much higher horizon. From the evidence of leaves, wood, and the character of the sediments, as observed in the belt of outcrop, the Potomac formation is probably an estuarine deposit.

Basal sands probably estuarine.

There is considerable uncertainty as to the depth at which the Potomac formation was entered in the deep well at Fort Monroe, for the boring operations were conducted by a method which results in considerable mixing up of material, and the sands and clays between 800 and 1000 feet were not sufficiently distinctive in appearance to indicate their age. In the well sunk at the Chamberlain Hotel, Old Point Comfort, some years ago, marine Cretaceous fossils were found to a depth of 845 feet, with the Potomac formation apparently lying about 100 feet below. As the top of this formation is indicated with a fair degree of distinctness at 782 feet in the Norfolk waterworks boring, there is apparently a considerable westward slope of the top of the formation between the two localities. As there is evidence of considerable unconformity at the base of the marine Cretaceous sediments, this feature may be due to an excavation of a shallow channel on the surface of the Potomac formation in this vicinity.

Marine Cretaceous formations.—Overlying the Potomac formation in the Norfolk region are sands and sandy clays containing abundant fossil shells of Cretaceous age, specimens of which have been found in the deep borings. The fossils are the same as those which characterize the marine Cretaceous formations outcropping extensively in New Jersey and from North Carolina south. In Maryland these formations thin out a short distance south of Washington, and in eastern Virginia they do not reach the surface at all, but their extension underground is well established by the evidence of the deep borings about Norfolk. The evidence, however, is not sufficient to afford grounds for subdividing the deposits so as to apply formation names to them

In the Norfolk waterworks well the Cretaceous shells began to appear at a depth of 715 feet, or possibly 700 feet, and they were found in great abundance down to a depth of 775 feet. Only one species was observed, which is a small *Exogyra*, precisely similar in general form to *Exogyra costata*, but having a smooth surface or showing only very faint crenulations. The shells vary in length from $\frac{1}{4}$ inch to $1\frac{1}{4}$ inches. The containing material is a dark sandy clay with sand streaks. It is somewhat micaceous throughout, and appears not unlike the Matawan formation in Maryland and Delaware. A single shell was thought to have been obtained at a depth of 1320 feet, but this was not positively determined.

Dark sandy clay containing Exogyra.

In the well at Lambert Point, Norfolk, borings at depths of 563 to 610 feet yielded marine Cretaceous fossils, including *Exogyra costata* Say? and the following additional species: *Astarte octolirata* Gabb, *Ostrea plumosa* Morton, *Gouldia? decemnaria* Conrad, *Gryphæa vesicularis* Lam., *Liopistha* (*Cymella*) *bella* Conrad, *Corbula* sp., *Modiolus* sp., and *Baculites*? In the well at Chamberlain Hotel, Old Point Comfort, fragments of *Terebratula harlani* Morton were obtained when the boring was at a depth of 845 feet, presumably from gravel extending from 840 to 845 feet. It is possible that this fossil came from a less depth. It was not expected that the marine Cretaceous would be found here so much deeper than in the wells at Lambert Point and at Norfolk waterworks, which are several miles southeastward. This would indicate a local northwesterly dip of the beds. The dark, sandy, micaceous clay reported from 850 to 920 feet in the Chamberlain well appears to be typical marine Cretaceous material.

Marine fossils in the Cretaceous.

By a comparison of the records of the deep borings at Fort Monroe, Norfolk, and Lambert Point, it is believed that the marine Cretaceous deposits have a thickness of at least 65 feet, and possibly much more. In the Norfolk waterworks well, as above shown, the marine fossils have a range of 80 feet, and a portion of the still lower micaceous gray sands may also be marine.

EOCENE PERIOD.

Pamunkey formation.—In the Norfolk region this formation is deeply buried, but the deep boring at the Norfolk waterworks has afforded a fairly definite conception of its relations. It is a formation which outcrops extensively along Potomac, Rappahannock, Mattapony, Pamunkey, and James rivers in Virginia, toward the western margin of the Coastal Plain belt. It there lies on an eroded surface of the Potomac sands, sandstones, and clays, and has a thickness of over 150 feet. In the Norfolk waterworks boring it is much thinner. The only fossils it has yielded in this boring are foraminifera, of which the following were recognized, at the depths stated:

Eocene foraminifera from boring at Norfolk waterworks.

685 feet; Nodosaria obliqua L.; Dentalina confluens Reuss; Bulimina buchiana d'O.; Uvigerina pygmæa d'O.; U. tenuistriata Reuss; Rotalia orbicularis d'O., and R. propinqua Reuss.

695 feet: Nodosaria sp.; Bulimina buchiana d'O.; Cristellaria cultrata M.; Truncatulina haidingerii d'O., and T. lobatula W. & J.

From a depth of 665 feet there was a sample containing foraminifera, but they give no conclusive evidence as to the age of the formation. There was found an abundance of *Bulimina buchiana* d'O., which is regarded as typical Eocene, together with *Rotalia orbicularis* d'O., which is an Eocene form, although also found in later formations. At 695 feet *Bulimina buchiana* d'O. is associated with forms that are more abundant in Cretaceous rocks but that occur in both older and younger rocks. They are *Cristellaria cultrata* M. and *Truncatulina haidingerii* d'O., both of which are common in the New Jersey Cretaceous marls. On this account, and because of a marked change in the character of the deposits, it is thought probable that the Pamunkey formation extends only to a depth of 680 feet. It appears to begin at 640 feet, where the clays suddenly become dark colored, sandy, and glauconitic. The formation is thus limited to 40 feet of dark, glauconitic sands and sandy clays. The glauconite is a characteristic constituent in the surface outcrops to the west. It is a bottle-green mineral sprinkled in small grains through the deposit in sufficient amount to give a dark-green tint to the sand. The mineral is a silicate of iron and potash, a product of various organisms which live in a moderately deep sea.

Glauconitic green sand characteristic of the Eocene.

The boring at Lambert Point passed through the Pamunkey formation, but the record was not sufficiently definite for its identification. It is nearer the surface than was expected, as marine Cretaceous fossils were obtained at 563 feet. In the deep well at Fort Monroe it is probable that the beds from about 610 feet to at least 710 feet, and possibly those from 710 to 840 feet also, are Pamunkey in age. The glauconite admixture is distinctive, especially when it is associated with foraminifera, as it is from 610 to 710 feet. Some shell fragments were found at a depth of 840 feet which appear to be Eocene species, but their identification is not established and they may have been derived from a higher level in the well. Sharks' teeth of Eocene type were found in the boring from the old well at Fort Monroe between 580 and 590 feet, but they probably do not represent the life existing at the time these beds were deposited. They are probably pebbles from

Eocene rocks inclosed in the overlying Chesapeake formation, a feature often observed in surface outcrops of the basal beds of that formation. It is to be expected that the Pamunkey formation would be found to be thicker at Old Point Comfort than at Norfolk, for in its surface outcrops to the west it is over 150 feet thick.

Pebbles composed of Eocene fossils in the Miocene strata.

NEOCENE PERIOD.

Chesapeake formation (*Miocene*).—Underlying the thin mantle of Pleistocene and Pliocene materials in the Norfolk region there is a thick mass of marls and clays of Miocene age, known as the Chesapeake formation. It does not outcrop at the surface in the quadrangle, but it is reached by several wells. The deep borings at the Norfolk waterworks, Lambert Point, and Fort Monroe pass entirely through the formation and afford complete sections of its beds. The materials are mainly shell marls and light-gray clays, with occasional darker portions and sandy beds. In the Norfolk waterworks boring the formation appears to have been entered at a depth of about 70 or 80 feet, and it extended to 640 feet, a thickness of 565 feet. Its uppermost beds are 70 feet of gray clays, sandy clays, and sands, then 110 feet of light-gray clay, 70 feet of darker sandy clays in part of greenish tint, below which there are light-gray clays extending from 330 to 640 feet in depth. Many of the strata yielded fossil shells, of which the following, found at the depths stated, were the most distinct.

Shell marls of Miocene age.

Upper Miocene fossils from boring at Norfolk waterworks.

75 feet: Pecten jeffersonius Say, P. clintonius Say, Turritella alticosta Conrad, Rangia cuneata Conrad.
85 feet: Rangia cuneata Conrad.
105 feet: Abra æqualis Say, Pecten jeffersonius Say, P. madisonius Say, Yoldia lævis Say, Turritella alticosta Conrad, Cadulus thallus Conrad, Solen.
115 feet: Rangia cuneata Conrad, Ostrea virginica Gmel., Yoldia lævis Say, Drillia limatula, Turritella alticosta Conrad, Rangia clathrodonta Conrad.
125 feet: Leda acuta Conrad, Turritella alticosta Conrad, Cadulus thallus Conrad.
135 feet: Yoldia lævis Say, Cadulus thallus Conrad.
175 feet: Pecten eboreus Say.
185 feet: Pecten clintonius Say.
325 feet: Cardium islandicum Chemnitz (?).
345 feet: Mulinia lateralis Say.
365 feet: Pecten eboreus Conrad.

The fossils listed above indicate upper Miocene age. *Rangia cuneata* has never before been reported from beds as old as these. From the lower borings less distinctive remains are obtained. Diatoms with sponge spicules and foraminifera occur from 580 to 625 feet, notably at 585 and 605 feet, where they are very abundant. The proportion of diatoms is hardly sufficient to entitle the material to be classed as an infusorial earth. They are the same species as those which occur in the lower Chesapeake beds outcropping at Richmond, Va., and other points along the western zone of outcrop of the formation. Sponge spicules occur in various strata between 355 and 505 feet. Foraminifera are present in considerable abundance and variety at a depth of 645 feet, including *Bulimina elongata* d'O., *Uvigerina pygmæa* d'O., *U. tenuistriata* Reuss, *Rotalia soldanii* d'O., *Nonionina scapha* F. & M., and *N. boueana* d'O.

Diatomaceous bed in the lower Miocene.

The Lambert Point boring passed through the Chesapeake formation, affording the section given on the Columnar Section sheet. Unfortunately it was mainly the sandy constituents of the washings that were saved, so that the beds appear to be predominantly sandy and no close comparison can be made with the Norfolk waterworks boring. The only Chesapeake fossils obtained were between 235 and 264 feet. They included *Perna maxillata* Lam. and *Pecten jeffersonius* Say. Foraminifera, echinus spines, and sponge spicules occurred from 17 to 563 feet. As Cretaceous fossils occur at 568 feet in this boring, and the Pamunkey formation is probably represented, the Chesapeake beds are here much thinner than in the other borings, the thick diatomaceous bed is absent, and, if the data are authentic, the base of the formation rises rapidly westward from the Norfolk waterworks boring, where it is at a depth of about 640 feet.

At Fort Monroe the Chesapeake formation extends from 40 to about 590 feet. *Dosinia acetabulum* Conrad and *Pecten madisonius* Say were reported at a depth of 50 feet in the new well. In the old well other distinctive Miocene shells were obtained at intervals to 400 feet, and diatoms in abundance at 558 feet. Between 580 and 590 feet sharks' teeth were obtained, which were either deposited as pebbles in the basal Chesapeake bed or occurred in place in the underlying Pamunkey formation.

The following fossils have been reported from the Chesapeake formation in the new well at Fort Monroe at depths of 50 to 100 feet, the larger number coming from about 50 feet:

Miocene fossils from Fort Monroe well.

Columbella (Anachis) sp ?.	Dosinia acetubulum Conrad.
Cadulus thallus Conrad.	Pecten sp ?
Dentalium attenuatum Say.	Pecten madisonius Say.
Eulima sp ?	Pecten jeffersonius Say.
Olivella sp ?	Glycymeris subovatus.
Scala multistriata Say.	Tellina declivis Say.
Turbonilla.	Ostrea subreflexa.
Turritella alticosta Conrad	Lucina crenulata Conrad.
Nassa acuta Say.	Yoldia limatula Say.
Ptychosalpinx altilis Conrad.	Crepidula sp ?
Venericardia granulata Say.	Crepidula fornicata Say.
Cardium laqueatum Conrad.	Crepidula costata Say.
Corbula sp ?	Venus mercenaria Linne.
Corbula inæqualis Say.	Astarte undulata Say.
Meretrix sayana Conrad.	Balanus proteus.
M. convexa Say.	

The clays are richly diatomaceous between the depths of 530 and 560 feet, and among the fossil forms are those which characterize the great bed of diatomaceous earth in the Chesapeake formation underlying the Coastal Plain through New Jersey, Delaware, Maryland, Virginia, and southward. With the base of the Chesapeake formation at 580 feet at Fort Monroe and at 640 feet at the Norfolk waterworks, 11 miles south-southeast, a dip of about $6\frac{1}{2}$ feet per mile is indicated, and apparently about the same dip is indicated by the diatom beds.

Pliocene strata.—Just beneath the covering of Columbia and alluvial formations in the Norfolk region there is a thin layer of marls and sands of Pliocene age. They do not outcrop at the surface, but are reached by many wells and have been uncovered in places by the excavations for the canals. In most localities they contain large numbers of shells, many identical with living or relatively recent forms, with others of late Neocene age intermixed with them. These deposits were extensively exposed by the Dismal Swamp Canal excavations, notably at three points: one on the main canal, 4 miles south of Wallaceton, another on the feeder from Lake Drummond, about halfway between the lake and the main canal, and the other on the main canal in the vicinity of Lilly, N. C. According to L. Woolman (Proc. Phila. Acad. Nat. Sci. for 1898, p. 414), the fossils collected from these beds are as follows:

Pliocene beds exposed in canal excavations.

Fossils from the Pliocene strata at Lilly, N. C.

Arca limula Conrad.	Cæcum cooperi Smith.
A. plicatura Conrad var. sublineolata d'O.	Ostrea virginica Gmel.
	Crepidula plana Say.
Corbula contracta Say (numerous.)	Eupleura caudata Say.
	Fulgur canaliculatum Say.
Meretrix convexa Say.	F. carica Gmel. (numerous).
Mulinia lateralis Say.	Nassa trivittata Say (numerous).
Nucula proxima Say.	
Venus mercenaria Linne.	Scala lineata Say.
Lucina crenulata Conrad.	Turbonilla reticulata Ads.
Olivella nitidula Dillw.	Spisula solidissima Dillw.
Polynices (Neverita) duplicata Say.	Tellina tenera Say.
	Ensis directus Conrad.
Tornatina canaliculata d'O.	Urosalpinx cinereus Say.
Nassa obsoleta Say.	Astrangia danae Agassiz.
Divaricella quadrisulcata d'O.	

In some of the clays containing these shells there are also diatoms in abundance, comprising many species ranging from Miocene to the present, a few never observed in Miocene beds and several which are supposed to belong to the Miocene exclusively. The latter were probably derived from the Chesapeake clays exposed in the outcrops to the west of this region. Similar diatoms are contained in the gray clays lying between 25 and 65 feet below the surface in the Norfolk waterworks boring. At a depth of 25 feet in this boring occurs *Rangia cuneata* Gray, a Recent to Pliocene form. At Great Bridge Pliocene beds were exposed by the excavations of the Albemarle and Chesapeake Canal, and yielded a few fossils, and on the Jericho Canal southeast of Suffolk the same beds yielded a large number of distinctive Pliocene forms. It is evident from the widespread occurrence of the fossils that the entire area of the Norfolk quadrangle is underlain by Pliocene deposits, except probably the deep channel extending down James River and out to the ocean through Chesapeake Bay. This channel undoubtedly cuts into the underlying Chesapeake formation. Judging by its fauna, the Pliocene is of about the same age as the Croatan beds of North Carolina. The Lafayette formation, of supposed Pliocene age, shown in the table of formation names, does not occur in the Norfolk area.

Diatoms abundant in the Pliocene.

PLEISTOCENE PERIOD.

Columbia formation.—The entire land area of the Norfolk quadrangle is covered by a thin sheet of loams and sands, called the Columbia formation, the surface of which constitutes the wide, low plain so characteristic of the region. The formation was laid down along the coast in a belt which, in this region, extended back to the base of the highlands along the west side of the Dismal Swamp. The precise physical conditions under which it was deposited are not known, but it covered a flood plain bordering the sea. The thickness of the Columbia formation is usually from 20 to 55 feet, and in the greater part of the area its base is slightly below tide-water level. The surface on which it lies is known to be somewhat irregular or gently rolling, but the precise configuration of this surface is not everywhere known. The Columbia formation is cut through by the deeper valleys, notably those of James, Elizabeth, and Nansemond rivers, Hampton Roads, and Chesapeake Bay. It is being cut away along the ocean front, where the upper edge often presents a low cliff extending along the beach, ordinarily at the level of high tide. The beach sand is usually banked up against the cliff, and beach or dune sands completely bury the formation locally. The lower portion of the formation extends out under the ocean for a greater or less distance, and sometimes it is bare of sand in the zone between high and low tide levels.

Sands and loams covering low plain.

Under the surface the Columbia formation presents a relatively uniform character throughout, but there are some local variations, and there is considerable range in thickness. Large bowlders are occasionally inclosed in the finer material, and their occurrence can be explained only by the hypothesis that they were transported by floating ice. A very instructive series of borings was made sometime ago by the Norfolk City Water Department in the region east of the city, which passed through the Columbia deposits to the marl of the underlying Chesapeake formation. The results are given in the following sections:

Records of borings in Columbia formation.

Myers farm.

	Feet.	
Fine sand	1	to 11
Loose sand	11	to 18
Sand and sandy clay	18	to 50
Gravel with water, lying on marl which was penetrated to a depth of 117 feet	50	to 52

Taylor farm.

	Feet.	
Muck	1	to 19
Sand and sandy clay	19	to 51
Red sand	51	to 58
Blue clay	58	to 68
Coarse sand with water	68	to $85\frac{2}{3}$
White sand lying on marl	$85\frac{2}{3}$	to $97\frac{1}{6}$

Poorhouse tract swamp.

	Feet.	
Muck	1	to 5
Fine sand	5	to 9
Sand and clay	9	to $32\frac{2}{3}$
Blue clay	$32\frac{2}{3}$	to $35\frac{1}{6}$
Sandy clay	$35\frac{1}{6}$	to $38\frac{5}{12}$
Sand and clay	$38\frac{5}{12}$	to $45\frac{1}{2}$
Gravel with water, lying on marl	$45\frac{1}{2}$	to $51\frac{5}{6}$

Poorhouse tract turnpike.

	Feet.	
Sand	1	to 18
Blue clay	18	to $31\frac{1}{4}$
Sandy clay	$31\frac{1}{4}$	to $34\frac{2}{3}$
Loose sand	$34\frac{2}{3}$	to $42\frac{5}{12}$
Gravel with water, lying on marl	$42\frac{5}{12}$	to 50

City property east of city limits.

	Feet.	
Fine sand	1	to $9\frac{1}{2}$
Sand and sandy clay	$9\frac{1}{2}$	to 44
Small gravel with water, lying on marl	44	to $46\frac{1}{3}$

Babcock farm.

	Feet.	
Sand	1	to $11\frac{1}{2}$
Loose sand with water	$11\frac{1}{2}$	to $25\frac{1}{2}$
Sand	$25\frac{1}{2}$	to $30\frac{2}{3}$
Sand, clay, and muck	$30\frac{2}{3}$	to 53

Lake Lawson.

	Feet.	
Yellow clay with gravel streaks	1	to 10
Sand	10	to $24\frac{3}{4}$
White sand	$24\frac{3}{4}$	to 31
Sandy clay	31	to $36\frac{5}{6}$
Coarse white sand with water, lying on marl	$36\frac{5}{6}$	to 38

Taylor woods.

	Feet.	
Sand	1	to $10\frac{2}{3}$
Sand, clay, and marl	$10\frac{2}{3}$	to $40\frac{1}{2}$
Gravel with water, lying on marl which was penetrated to a depth of 60 feet	$40\frac{1}{2}$	to $40\frac{5}{6}$

Drummond woods.

	Feet.	
Sand	1	to 4
White sand	4	to 13
Sand and clay	13	to 21
Clay and sandy clay	21	to $30\frac{1}{2}$
Sandy clay	$30\frac{1}{2}$	to $36\frac{1}{6}$
White sand	$36\frac{1}{6}$	to $38\frac{1}{3}$
Gravel with water, lying on marl	$38\frac{1}{3}$	to 44

TOPOGRAPHIC DEVELOPMENT.

During the Cretaceous, Eocene, and Neocene periods this region was the center of deposition of widely extended sheets of sands, clays, and marls. The periods of deposition were separated by intervals during which the strata were brought to the surface and more or less eroded. The configuration of the land surfaces in these periods of uplift and degradation is not known, but during the final stages of the Neocene the uplifted area had been smoothed to a nearly level plain. In early Pleistocene time there was an uplift with perceptible tilting to the eastward, during which wide troughs were excavated in the James River and the other larger Coastal Plain valleys, and a coastal lowland was cut which extends westward to a line that passes northward from near Suffolk across the lower ends of the tide-water peninsulas of eastern Virginia lying west of Chesapeake Bay. In this process the Lafayette formation was removed and the underlying formations were leveled to an approximate plain which in greater part lies a few feet below the present tide-water level. There were next flood-plain conditions, during which the thin sheet of Columbia formation was laid down over this eroded area, the product being a smooth plain extending from a short distance west of Chesapeake Bay eastward across the bay and the Eastern Shore and along the James and other large tide-water valleys. Then followed uplift, during which the James and other rivers which have their sources in the higher land to the west, cut their channels through the Columbia deposits, and Susquehanna River with branches from the other Coastal Plain rivers excavated the trough which is now occupied by Chesapeake Bay. At this stage there were also initiated the small streams which now lie entirely in the Columbia plain, such as Elizabeth, Nansemond, Northwest, North Landing, and Lynnhaven rivers in the Norfolk region. Small local streams also isolated a fragment of terrace in Knott Island. It was in this stage of uplift that a channel was cut through the depression now occupied by the Albemarle and Chesapeake Canal. The Atlantic Ocean also cut a sea scarp on the slope of the Columbia terrace, probably several miles east of the present shore line. Next came the submergence in which the deeper depressions were flooded with tide water, the Atlantic Ocean advanced to the vicinity of the present shore line, and the minor drainage ways ceased their active cutting, in most cases having their mouths so drowned as greatly to decrease their grade. This subsidence is still in progress, but at a very gradual rate.

Coastal lowland produced during early Pleistocene uplift.

Columbia formation deposited during flood-plain conditions.

Excavation of river channels in Columbia terrace.

Submergence and flooding of the lower channels.

Probably in the later stages of the last uplift and during the early part of the subsidence dune sands began to accumulate on the beaches along the shores adjacent to the ocean. Some of the dunes have continued to rise until now they are over 70 feet high on Cape Henry. They occupy a narrow zone along the beach to Willoughby Spit and are found even on the shore of Elizabeth River. Spits also have been built from the main land, Willoughby Spit and the beach extending from the southern border of the quadrangle northward to Sand Bridge being conspicuous examples. Marsh growth has progressed in many parts of the inclosed area behind the beach along the sea coast. These spits show that the prevailing shore currents are southward along the sea coast and westward along Chesapeake Bay.

Geologic processes which are now in progress and which have continued for sometime during the submergence are the augmentation of the sand dunes and spits, growth of the marshes, and deposition of alluvium, mainly under tide water.

ECONOMIC PRODUCTS.

SOILS.

The soils of the Norfolk quadrangle present considerable diversity in character, varying from pure sand through sandy loam and clay to swamp muck. The greater part of the district has a surface covering of Columbia formation, with a soil consisting mainly of sandy loam. This is the normal soil of the very fertile truck region which is extensively cultivated about Norfolk. The proportion of the organic content of the soil is not large, but with proper fertilization the soil has the physical condition most favorable to the growth of a number of vegetables and fruits. The local variations in the soils are gradual but frequent and the differences are preceived less readily in the soil than in the relative productiveness in garden truck. In the extreme eastern part of the area the soils are more sandy, owing in part to coarser materials in the Columbia formation in that direction and to admixture of blown sand from the beach. The sands on the beach and in the sand dunes are nearly barren of vegetation. The soils of the present swamp areas are often too carbonaceous for immediate use, but in some cases this feature has been corrected by exposure to the weather after the land has been cleared of trees, drained of water, and ploughed. These soils are usually rich in plant food and prove to be highly productive.

Truck soils of Norfolk.

The following are mechanical analyses of typical truck soils form the vicinity of Norfolk made by the Department of Agriculture:

Mechanical analyses of truck soils from vicinity of Norfolk.

Constituent. (Size of grains indicated in millimeters.)	Five miles west of Norfolk.	Four miles west of Norfolk.	Three miles east of Norfolk.	Two-and-a-half miles east of Norfolk.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Clay (.005 to .0001)	7.15	8.40	8.88	14.35
Fine silt (.01 to .005)	5.90	7.33	4.79	8.88
Silt (.05 to .01)	15.14	11.54	20.20	31.45
Very fine sand (.1 to .05)	7.51	5.71	6.63	10.16
Fine sand (.25 to .1)	38.25	41.03	12.96	5.12
Medium fine sand (.5 to .25)	23.27	24.04	42.12	25.17
Coarse sand (1 to .5)	1.42	0.64	0.27	2.67
Organic matter, water, loss	1.36	1.26	4.15	2.20

The first three soils are characteristic of the lighter varieties. The last is much heavier and is suited to cabbage and spinach.

Swamp soils.

The soils of the swamps vary from pure peat to clayey loam. Two leading varieties are recognized, the "juniper" or "light" swamp, and the "black gum" or "dark" swamp. The first is nearly pure peat, consisting of a brown mass of vegetal fragments derived from the juniper or white cedar, which is the characteristic tree of "light" swampy areas. The thickness of the deposit is often 8 to 10 feet. From 75 to 95 per cent of the material is organic. When such land is cleared and drained the peat cakes and hardens so that it resembles charred wood. Land of this sort is practically worthless. The black gum swamp deposits which have been laid down in various portions of the Dismal and other swamps and which bear a forest of cypress, black gum, and red maple, are well adapted to agriculture in most cases. This soil contains a large amount of organic matter, which is mainly in its upper portion. When it is properly drained and cultivated the amount of organic matter gradually diminishes, but it has been found in the drained areas that after being under cultivation for fifty years the soil still retains enough organic matter to remain black in color. The organic matter furnishes nitrogenous materials to plants, so that the soil is a rich one, but its disposition to retain moisture renders it rather slow for the raising of early vegetables. The soils are also notably acid, which has to be neutralized by repeated applications of lime. The percentage of clay in the swamp soils is large, for the sluggish drainage in the swampy areas does not bring much sand, and the principal inorganic sediments are very fine flocculent clayey materials. This character greatly retards artificial drainage of the region, so that in reclaiming swamp lands numerous ditches and extensive tiling are necessary. The recent deepening of the Dismal Swamp Canal has reduced the general water level through most portions of the large swamp, and in the future this condition will greatly facilitate reclamation. There are extensive areas of the swamp which can be economically drained and which have rich and lasting soils, and the region has good prospects of being valuable agriculturally in the future. It is not expected that the soils will be available for truck farming to the same extent as the dry plains of the surrounding region, but they will yield crops of many important staples.

Reclamation of swamp land.

UNDERGROUND WATERS.

Under the greater portion of the area of the Norfolk quadrangle the coarser basal beds of the Columbia formation contain considerable water. This is the source of supply of hundreds of shallow private wells scattered over the region and of a portion of the city supplies for Norfolk and Portsmouth. The water is low in mineral constituents, but contains a moderate amount of organic matter. Unfortunately it is subject to surface contamination, owing to the imperfect protection afforded by the relatively permeable sandy loam under which it lies. Where wells are near sources of pollution they are soon contaminated, and probably throughout the region there is some seepage of surface water containing malarial germs, drainage of manured fields, etc. In sinking wells in this region it is very desirable to locate them as far as possible from stables, cesspools, or ponds of stagnant water.

The present supply for Norfolk is obtained mainly from ponds east of the city, and, although a surface water, its quality is fair. The supply is supplemented by groups of wells driven into the Columbia formation. Portsmouth is supplied by a series of shallow driven wells. In a series of test borings made by Norfolk east of the city the following results were obtained.

Results of test borings made east of Norfolk.

Location.	Depth to water.	Rise of water. (+, above surface; —, below surface.)	
	Feet.	*Ft.*	*In.*
Myers farm	50 to 52	— 7	
Taylor farm	68 to 85⅔	+	20½
Poorhouse tract, swamp	45½ to 51	+	14
Poorhouse tract, on turnpike	42 to 50	— 2½	
City property	44 to 46⅓	— 3	
Babcock farm	38⅔ to 53	— 6	2⅔
Lake Lawson	36⅚ to 38	—22	
Taylor woods	40½	+	6
Drummond woods	38⅓ to 44	— 7	

Deep wells in the Norfolk region so far have not proved successful in obtaining pure water. Water is found in greater volume in some of the deep borings, but it has been rather too salty for domestic use. The first horizon of this saline water is at a depth of 738 feet in the deep well at the waterworks east of Norfolk, and at 608 feet at Lambert Point. Other deeper horizons of saline waters are at 785, 805, 950, 975, 984, 1038, and 1190 feet in the well east of Norfolk and at 945 feet in the well at the Chamberlain Hotel, Old Point Comfort.

Deep well at Norfolk waterworks.

The boring east of Norfolk was made by the City Water Department for the purpose of testing the water contents of all the Coastal Plain formations down to the crystalline rock, or "bed rock." It was made at the waterworks at Moore's bridges, 5 miles east-northeast of the City Hall. The boring was begun April 7, 1896, and continued at intervals, through 1896, 1897, and 1898, to a depth of 1760 feet without obtaining a flow of fresh water. The record of this boring is given on the Columnar Section sheet. The flows were as follows:

At 738 feet, 10 gallons a minute; 785 feet, 35 gallons; 805 feet, 25 gallons; 950 feet, 75 gallons; 975 feet, 10 gallons; 984 feet, 15 gallons; 1038 feet, 25 gallons; and 1072 feet, 150 gallons. At 1190 feet there was water that did not quite overflow, at 1220 and 1227 feet and at several lower levels small volumes of salt water were found; at 1480 feet there was a large flow of very salt water, and at the bottom there appeared to be a strong flow of water which carried so much sand that it choked the casing. The well was cased with 12-inch pipe to a depth of 777 feet 7 inches, with 10-inch pipe to 1207 feet 9 inches, with 8-inch pipe to 1538 feet 11 inches, and with 6-inch pipe to 1730 feet.

Boring was discontinued on account of a string of tools having dropped into the well; otherwise there would have been no difficulty in sinking the casing much deeper. It is probable that within the next 600 feet the bed rock would have been penetrated and that water not too saline for use would have been found in the coarse sand immediately above it. The boring was dynamited at 1070 feet, with the expectation of opening the pipe to the 150-gallon flow at that depth, but the operation appears to have failed. The chemical character of the principal flows from the Norfolk boring is as follows:

Chemical character of principal flows from Norfolk boring.

[In grains per United States gallon.]

Constituent.	738 feet.	1,038 feet.	1,072 feet.
Chloride of sodium	112.33	158.83	164.10
Carbonate of soda	30.21	....	....
Carbonate of lime	4.06	....	....
Total mineral matter	150.36	195.12	213.03
Organic matter	....	.40	.41
Ammonia, free	.18	.13	.17
Ammonia, albuminoid	.006	.005	.002

Lambert Point well.

The boring at Lambert Point was made several years ago for the Norfolk and Western Railroad Company. Its depth is 616 feet and its casing, which is a 6-inch pipe, extends to a depth of 606 feet. The pipe stands about 4 feet above the ground and the water rises 19 feet above the outlet. The flow is stated to be 65 gallons a minute. Temperature, about 70°. The water is bright and clear, but it contains the following large amounts of mineral matters, which give it a saline taste:

Mineral matter in water from boring at Lambert Point.

	Grains per U. S. gallon.
Chloride of sodium	28.92
Sulphate of potash	1.39
Sulphate of soda	2.77
Bicarbonate of lime	.93
Bicarbonate of magnesia	.78
Bicarbonate of soda	28.09
Oxide of iron and alumina	.08
Silica	.50

This flow appears to be from the same bed of the marine Cretaceous as the one yielding the flow at 738 feet at the Norfolk waterworks boring. The well record is given on the Columnar Section sheet.

Fort Monroe well.

At Fort Monroe three deep wells have been bored. The first, in 1864, was sunk in the fort by the Government to a depth of 907 feet, but yielded only a small quantity of saline water at 599 feet. The second, sunk in 1896 at the Chamberlain Hotel, reached a depth of 945 feet, where a flow was obtained which is estimated at about 50 gallons a minute and which rises over 17 feet above the surface, or about 22 feet above tide level. The water is reported as being slightly saline. The third well was sunk at the fort by the Government in the early part of 1902 to a depth of 2254 feet. It passed entirely through the Potomac formation and entered the crystalline rocks 8 feet. At depths of 1320 and 2131 feet water was struck and found to be salty and of small flow. The water at the lower horizon rose in the pipe to within 20 feet of the orifice, or to a height of 17 feet below tide. Other horizons of water not tested were struck at depths of 285, 630, 985, 1520, 1630, 1915, and 1945. The well is cased to the 2131-foot flow and an unsuccessful effort has been made since its completion to cut the casing at the untested water levels. The record of these wells is given on the Columnar Section sheet. It is thought that the water horizon at 945 feet in the Chamberlain Hotel well is the same as that which yields saline water at 1038 feet at the Norfolk waterworks well, 11 miles south-southeast. This would indicate a dip in that direction of about 9 feet to the mile, but it is probable that the maximum dip of the water-bearing beds is due east, which would make the dip approximately 20 feet per mile. On an east-west line passing through Fort Monroe the crystalline rock is now known to descend at a rate of about 34 feet per mile.

At Newport News a boring was made several years ago to a depth of 600 feet and no water was obtained. This fact and the absence of water at a similar depth in the Fort Monroe borings indicate that the higher water horizons at Lambert Point and Norfolk waterworks do not extend far west. At Money Point, 5 miles south of Norfolk, a 5-inch well was sunk to a depth of 562 feet, and furnished a good supply of slightly ferruginous water which rose 10 feet above tide level. Its source of supply is low in the Chesapeake formation, in sand under an 8-foot bed of rock. Another well, about half a mile southwest, was sunk 450 feet and yielded salt water.

At Virginia Beach various attempts have been made to obtain artesian water, but the borings have not been sufficiently deep. One well is stated to have been sunk about 600 feet without finding water in appreciable amount. A well having a depth of 70 feet yielded a moderate supply of somewhat ferruginous water.

A well bored to a depth of 147 feet in Norfolk formerly yielded a fair supply of hard water, but after the introduction of the city waterworks it fell into disuse and was finally abandoned.

In the vicinity of Jacksondale and Lynnhaven wells are reported to be from 12 to 14 feet deep, through stiff clay and red sandy clay into white sand, and have plenty of excellent water. Near London Bridge, on the ridge east of Lynnhaven River, the depths vary from 8 to 10 feet. About Kempsville, in the region at the head of Eastern Branch of Elizabeth River, the water is generally brackish or hard in shallow wells. Fairly good water is obtained from driven wells at a depth of 80 feet. Owing to some hard stratum at that depth at Kempsville no deeper driven wells have been practicable. Around Thalia an abundant supply of good water is obtained from wells 12 to 15 feet deep. One at the post-office, 12 feet deep, furnishes water for 190 head of stock and for dairy use. The water is in sand under a 2-foot layer of clay. In the low ridge passing through Nimmo good water occurs in sand at depths of 10 to 15 feet. At Sigma, nearer the ocean, the wells are deeper, varying from 20 to 25 feet, but the water is slightly brackish.

About North Landing wells vary from 10 to 14 feet in depth. On the wide, flat area about Hickory there are numerous wells from 10 to 15 feet deep, all of which obtain good supplies of excellent water in sand and gravel, in places overlain by blue sandy clay. In the region about Fentress wells from 10 to 15 feet in depth obtain satisfactory water supplies. In the vicinity of Cornland wells are from 8 to 12 feet deep, the deeper ones usually furnishing a satisfactory volume of water. They pass through about a foot of dark soil, 3 or 4 feet of clay, and 6 to 8 feet of sand. There are several driven wells 18 to 45 feet deep. Below 12 feet these usually pass through black quicksand, which contains very bad water. The beds from 25 to 30 feet contain but little water; from 36 to 45 feet there is sand, with clear, cool water in abundance, but slightly mineralized. In the settlement of Benefit, east of Cornland, plenty of water is obtained in wells 10 to 12 feet deep. Farther north, at Grassfield, the wells are 8 to 10 feet deep on the lower lands, but yield poor water. On the higher slopes to the south wells 12 to 14 feet deep furnish good water. About Gilmerton wells average 8 to 10 feet deep, but a few are sunk from 20 to 80 feet. On the peninsula north of Norfolk, about Tanner Creek, the wells are 8 to 10 feet deep.

It is reported that in the North Carolina portion of the Norfolk quadrangle the wells average from 10 to 15 feet in depth and obtain plenty of water for local use. In the vicinity of Lilly, which is on the reclaimed portion of the Dismal Swamp area, the water is not of satisfactory quality. A well at the post-office 20 feet deep yielded water which had such a brackish taste that it could not be used for household purposes. The Lake Drummond water is taken from the canal and used at this place.

June, 1901.

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

TOPOGRAPHIC SHEET

VIRGINIA–NORTH CAROLINA
NORFOLK QUADRANGLE

LEGEND

RELIEF
(printed in brown)

Figures
(showing heights above mean sea level instrumentally determined)

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

Beach sand and dunes

DRAINAGE
(printed in blue)

Streams

Canals and ditches

Lakes and ponds

Salt marshes

Swamps

CULTURE
(printed in black)

Roads and buildings

Private and secondary roads

Railroads

Bridges

Ferries

Locks

Lighthouses

State lines

County lines

Brown figures in ocean areas indicate depth of soundings in fathoms. The character of the sea bottom is expressed by the following abbreviations.

C.	for	Clay.
G.	"	Gravel.
M.	"	Mud.
P.	"	Pebbles.
S.	"	Sand.
Sh.	"	Shells.
Sp.	"	Specks.
bk.	"	black.
brk.	"	broken.
bu.	"	blue.
crs.	"	coarse.
dk.	"	dark.
fne.	"	fine.
gy.	"	gray.
lt.	"	light.
rd.	"	red.
sml.	"	small.
wh.	"	white.
yl.	"	yellow.

Henry Gannett, Chief Topographer.
Gilbert Thompson, Geographer in charge.
Triangulation and soundings by U.S. Coast and Geodetic Survey.
Topography by W.R. Atkinson and R.M. Towson.
Surveyed in 1888-91.
Culture revised in 1896 by A.M. Walker.
H.M. Wilson, Geographer in charge.

APPROXIMATE MEAN DECLINATION 1902

Scale $\frac{1}{125000}$

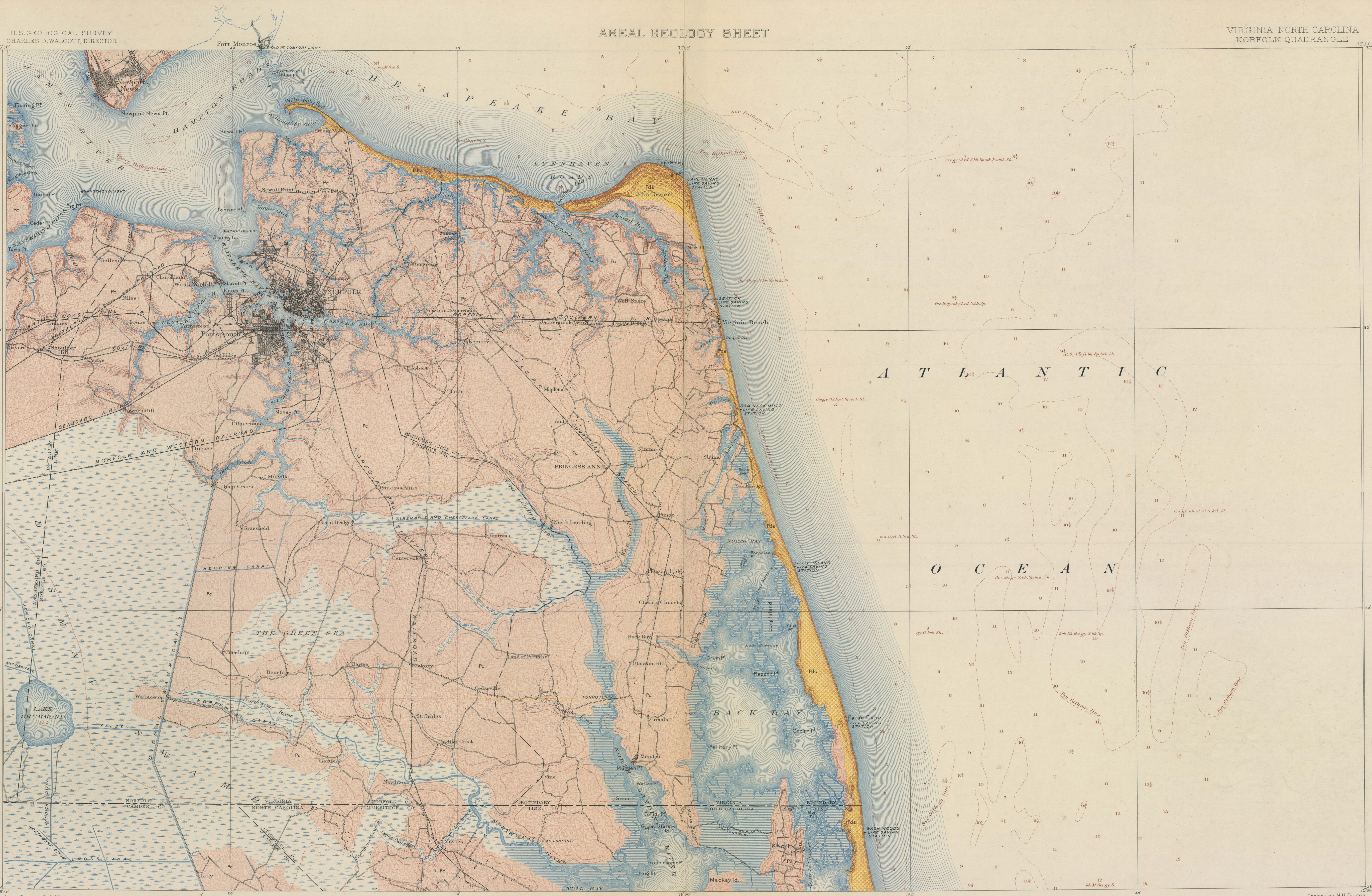
Contour interval 5 feet.
Datum is mean sea level.

Edition of June 1902.

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

AREAL GEOLOGY SHEET

VIRGINIA-NORTH CAROLINA
NORFOLK QUADRANGLE



LEGEND

SURFICIAL ROCKS

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

PLEISTOCENE

Pds — Dune sand *(chiefly wind-blown sand)*

Pc — Columbia formation *(loam, sand, and clay)*

Henry Gannett, Chief Topographer.
Gilbert Thompson, Geographer in charge
Triangulation and soundings by U.S. Coast and Geodetic Survey.
Topography by W.R. Atkinson and R.M. Towson.
Surveyed in 1888-91.
Culture revised in 1896 by A.M. Walker.
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TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1902

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 5 feet.

Datum is mean sea level.

Edition of June 1902.

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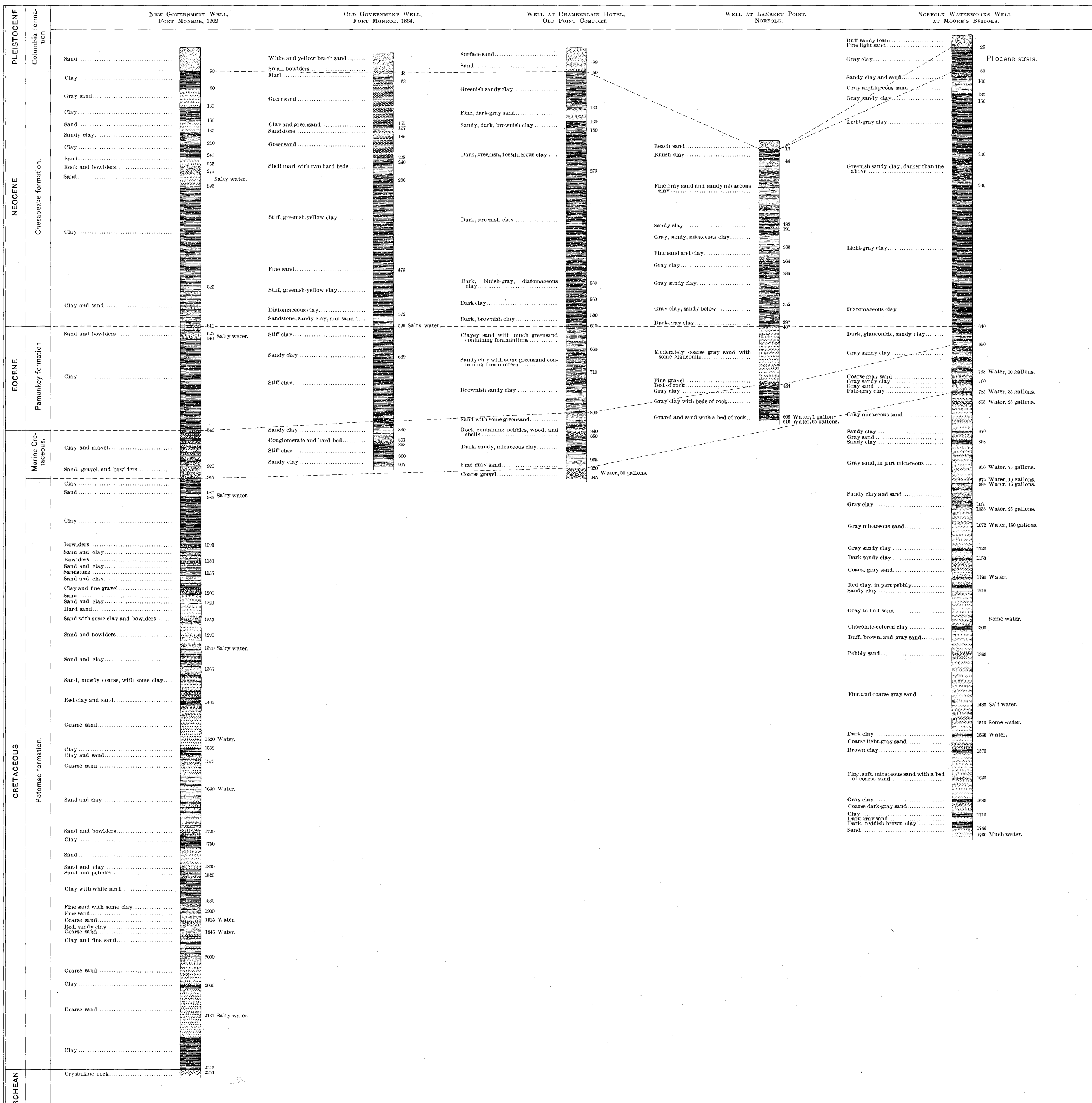
COLUMNAR SECTION SHEET

SECTIONS OF DEEP BORINGS IN NORFOLK QUADRANGLE.

SCALE: 1 INCH = 150 FEET.



N. H. DARTON,
Geologist.

ILLUSTRATION SHEET

FIG. 1.—CYPRESS TREES AND "KNEES," CHARACTERISTIC OF THE DISMAL SWAMP.

FIG. 2.—WESTERN MARGIN OF DISMAL SWAMP, SHOWING OVERFLOW DURING WET SEASON.

FIG. 3.—JERICHO DITCH, DISMAL SWAMP. CANEBRAKE AT THE RIGHT.

FIG. 4.—JERICHO DITCH, DISMAL SWAMP. OVERGROWN BY WOODS AND CANEBRAKE.

FIG. 5.—WESTERN SHORE OF LAKE DRUMMOND, SHOWING DENSE WOODS EXTENDING INTO THE WATER.

FIG. 6.—CYPRESS TREES GROWING IN LAKE DRUMMOND.

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