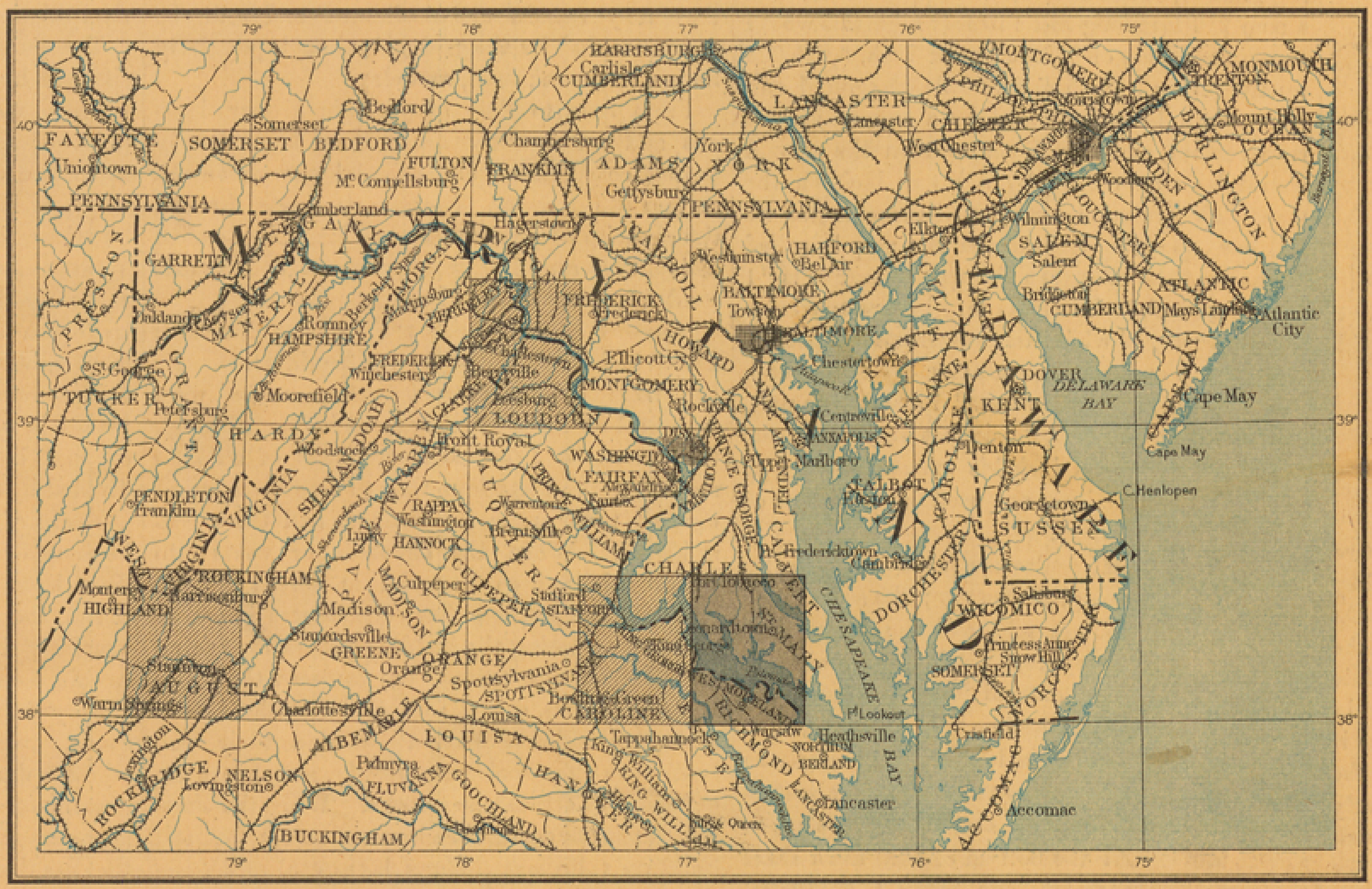
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS
OF THE
UNITED STATES

NOMINI FOLIO
MARYLAND - VIRGINIA

INDEX MAP



SCALE: 40 MILES = 1 INCH

AREA OF THE NOMINI FOLIO

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DESCRIPTION | TOPOGRAPHY | AREAL GEOLOGY | ARTESIAN WELLS

FOLIO 23 | LIBRARY EDITION | NOMINI

WASHINGTON, D. C.
ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY
BAILEY WILLIS, EDITOR OF GEOLOGIC MAPS   S. J. KÜBEL, CHIEF ENGRAVER
1896

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 stated on the map by numbers. It is desirable to show also the elevation of any part of a hill, ridge, or valley; 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 constant 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:

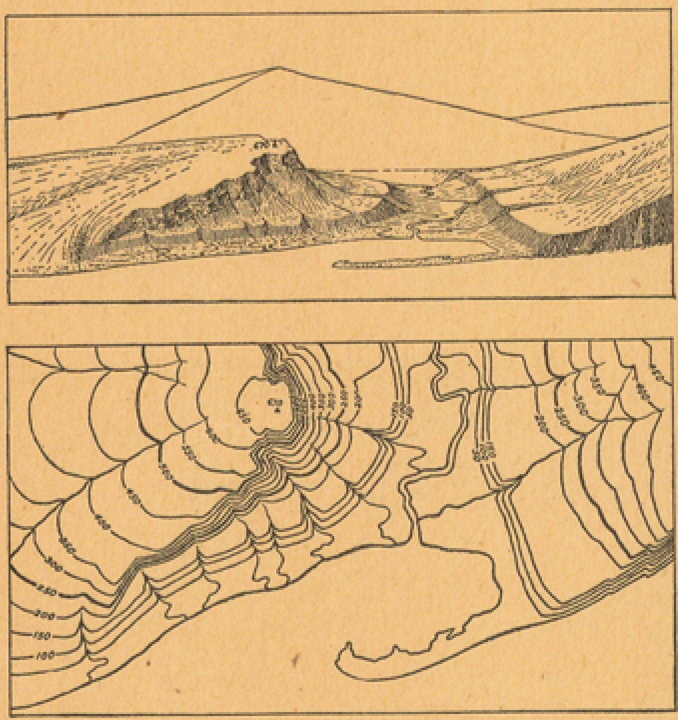


Fig. 1.—Ideal sketch and corresponding contour map.

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 to a precipice. Contrasted with this precipice is the gentle descent of the western slope. 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 occur 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 so with any other contour. In the space between any two contours occur 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.—Watercourses are indicated by blue lines. If the stream flows 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 240 feet long and 180 feet high this would cover, on a scale of 1 mile to the inch, 3,025,000 square inches. 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 special case it is "1 mile to an inch." The scale may be expressed also by a fraction, of which the numerator is a length on the map and the denominator the corresponding length in nature expressed in the same unit. Thus, as there are 63,360 inches in a mile, the scale "1 mile to an inch" is expressed by $\frac{1}{63,360}$. Both of these methods are used on the maps of the Geological Survey.

Three fractional 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 of natural length to an inch of map length. 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 three scales are stated, 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.—The map is being published in atlas sheets of convenient size, which are bounded by parallels and meridians. Each sheet on the scale of $\frac{1}{250,000}$ contains one square degree; each sheet on the scale of $\frac{1}{125,000}$ contains one-quarter of a square degree; each sheet on the scale of $\frac{1}{62,500}$ contains one-sixteenth of a square degree. These areas correspond nearly to 4,000, 1,000, 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. For convenience of reference and to suggest the district represented, each sheet 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 region 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 areal geologic map represents 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 maps show 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 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 either consolidates in cracks or fissures crossing the bedding planes, thus forming dikes, or else spreads out between the strata in large bodies, called sills or laccoliths. Such rocks are called *intrusive*. Within their rock enclosures they cool very 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 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 made are carried as solid particles by the 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

DESCRIPTION OF THE NOMINI SHEET.

GEOGRAPHY.

The province.—The area lying between the Atlantic Ocean and the Blue Ridge and stretching from the Hudson to Roanoke River is made up of two distinct geologic provinces. The first of these borders the ocean and is trenched by tidal estuaries; it is bounded inland by a line of rapids or cascades in the rivers, known as the "fall-line," along which the principal cities of eastern United States are located. This province is the Coastal Plain. The second province lies between the fall-line and the easternmost range of the Appalachian Mountains (the Blue Ridge in Virginia), and is known as the Piedmont Plateau. The area of the Nomini sheet lies entirely within the Coastal Plain province.

While it is convenient to fix the eastern boundary of the Coastal Plain at the Atlantic shoreline, it may be more justly drawn 100 miles offshore, at the edge of the continental plateau, where the great escarpment, 3,000 to 10,000 feet high, is swept by the Gulf Stream. From the fall-line to the verge of this escarpment stretches a wonderfully smooth and even plain, inclining gently southeastward, broken only by the shallow and broad valleys of the rivers and estuaries and by the present shore, with its wave-built keys and low sea-cliffs. The highest points of the province rise about 300 feet above tide; its submarine margin is about 300 feet below tide. 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 as many 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 the Hudson and Chesapeake Bay the present coast does not coincide with the trend of the province, but cuts obliquely across half its width, so that, while only about half the province is submerged in the latitude of Richmond, it is nearly all beneath tide in the latitude of New York.

Below tide-level the province is an even and nearly level sea-bottom; above tide-level it is a lowland of broad, flat terraces, which skirt the coast and the estuaries and rise into moderately elevated plains toward the low divides. The principal waterways are broad yet shallow estuaries, flanked sometimes by tidal marshes, sometimes by low sea-cliffs; the lesser waterways are commonly estuarine in their lower reaches, but narrow and steep-bluffed in the upper reaches, frequently heading in narrow ravines cut sharply in the extensive plains of the divides.

TOPOGRAPHY.

The Nomini area.—The area included in the Nomini sheet is one-quarter of a square degree, and is bounded by the parallels 38° and 38° 30′ and the meridians 76° 30′ and 77°. It measures approximately 34.5 miles from north to south and 27.3 miles from east to west, and embraces about 938 square miles. The area lies partly in Virginia and partly in Maryland. In Virginia it comprises nearly all of Westmoreland County, with parts of Essex, Northumberland, and Richmond, and in Maryland it includes portions of St. Mary, Charles, and Calvert counties.

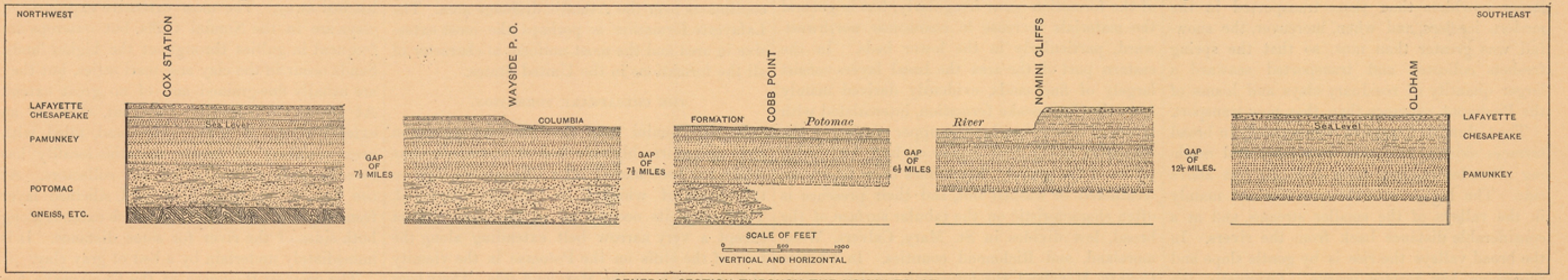
Topographic types.—In addition to the water area (chiefly the Potomac estuary), the tract is characterized by two distinct types of topography: (1) the more elevated, or upland, portions of the Coastal Plain, and (2) the lowlands flanking the waterways.

The first topographic type is that of the higher plain which originally extended over the entire area. It has been widely trenched by the larger rivers, deeply incised by the smaller streams, and sharply notched by the brooklets, but wide, level areas still remain, and throughout the higher lands the upland level is clearly defined, even along narrow divides. Nearly everywhere it is sharply demarked by steep slopes about its margin. The larger upland areas are broad, tabular, and frequently ill-drained expanses out of which slowly meandering brooklets pass abruptly into deep V-shaped ravines. There are many short rivulets, however, which commonly drain only the slopes in such manner as to scallop the margins of the upland area, leaving the interior without active watercourses, sometimes for miles, as in the case of the area southwest of Charlotte Hall. There is thus little relation between the altitude of a given point and the proximity of waterways; and over much of the area of this type, waters do not gather in a uniform way on accordant slopes, but either run rapidly down the narrow ravines of the brooklets or soak into the earth to find their way slowly seaward as ground water.

The second type of topography appears in the broad, low terraces flanking Potomac, Rappahannock, and Patuxent rivers and extending up the larger branches of these streams. These terraces are akin to the higher interstream plains of the plateau region, from which they are usually sharply demarked by steep slopes. Owing to the slight elevation above tide of the greater part of these terraces, they are often ill-drained, but they vary greatly in this respect. In their lower levels they often merge into tidal marshes.

The topographic history.—Classifying the topography by origin, it is found to yield a record of geologic and geographic history. All the topographic forms are the result of sculpture by storms and streams, and the character of the sculpture in different portions of the tract depends on the degree of completeness of the work now accomplished. Throughout the Coastal Plain the carving has affected only a portion of the surface of the ancient plain, and the sculpture of the river-side terraces is much less advanced than that of the higher interstream divides. Thus the two topographic types represent different stages of progress in the sculpture of the land by falling and running waters, and the slightly modified terraces of the river sides and the largely modified interstream plains still retain the original configuration of the tract as it gradually rose from the sea and was thereby transformed from ocean bed to lowland. This record of topographic development is consistent with the geologic record found in the deposits.

The headwater brooklets of upland and lowland mainly gather in steep-sided ravines, which they are rapidly deepening and carrying backward farther and farther into the high tabular divides; and in time of storm they are transformed into torrents and transport seaward great quantities of the débris of the land. Yet the same streams in the lower courses, and the principal rivers of the tract, are not deepening their channels, but are filling their valleys with the flood-borne débris; for they lie at or near the level of the ocean. Moreover, the lower reaches of the streamways are broad plains built up of just such deposits as those brought down in the freshets, and these deposits overlap the edges and rise against the scarps of the lower terraces. This topographic record combines with the record of geology and tells that the lowland, which was lifted from the sea-bottom, is again subsiding and that the sea is encroaching on the land in its estuaries, even unto the margin of the Piedmont Plateau at the fall-line. Thus the topographic types and forms of the tract yield a record of history which supplements and corroborates that found in the deposits.



GENERAL SECTION THROUGH THE NOMINI TRACT.

GEOLOGY.

THE ROCKS AND THEIR RELATIONS.

The geologic deposits of the Nomini area comprise clays, sands, loams, marls, diatomaceous earths, and marshy accumulations. They belong to three extensive formations lying one over another and dipping gently eastward, partly overlain by a fourth deposit, which is thinly spread over the lower areas along the rivers and estuaries, generally in the form of terraces. These formations overlie one or two other similar formations which rest on the irregular surface of the crystalline rocks of the Piedmont region.

Classified by origin, the geologic deposits of the Coastal Plain consist of little-altered sediments which may be somewhat arbitrarily subdivided into two categories, the first corresponding more or less closely to those now in process of deposition in the estuaries and along the shores in the immediate vicinity, the second corresponding closely to offshore sediments known from soundings and samples to be in process of deposition over the more deeply submerged portions of the province. In general, the deposits of the first category overlie, and are thus known to be younger than, those of the second category. The younger formations 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 next 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. The lowest and oldest formation of the Coastal Plain series, which does not come to the surface in the Nomini district, is nearly 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 deposits are coarse and irregularly bedded; so that this formation, like the younger deposits, appears to be a record of shores, and thus of an altitude of the land not greatly different from that found at present. The formations range in age from early Cretaceous to late Pleistocene and Recent. The successive formations are separated by unconformities, each representing a period during which the surface was uplifted above the sea and sculptured by storms and streams, so that when the succeeding deposit was laid down its strata were more or less discordant with the partially eroded strata of the preceding period.

From the character of the materials it is known that the deposits of the Coastal Plain were originally derived from the rocks of the neighboring interior (Piedmont and Appalachian) provinces; and through extension of the interpretation it is known also that the sedimentary deposits of the younger province correspond to the valleys and ravines of the older ones; so that the Coastal formations and the Piedmont and Appalachian landforms are related in a reciprocal way.

The formations and unconformities which reach the surface in the Nomini tract are shown in the following table:

Period.	Formation.	Character.	Thickness in Feet.
Recent	Alluvium.	River mud, talus, marsh, etc.	0 - 20
	Unconformity.		
Pleistocene	Columbia.	Loams, sands, and gravels.	10 - 30
	Great unconformity.		
Neocene	Lafayette.	Gravelly orange sands and loams.	25 - 40
	Unconformity.		
Neocene	Chesapeake.	Fine sands, clays, and diatomaceous deposits.	35 - 270
	Unconformity.		
Eocene	Pamunkey.	Dark glauconitic sands and marls.	200 - 300

ALLUVIUM.

Commonly alluvium is deposited by rivers in the form of deltas and flood-plains, which rise above the level of tide; but in the Nomini tract the alluvium is mainly laid down below the level of tide, forming a surface deposit only on freshet plains and in the valleys of small streams, where its presence is relatively transient. Accordingly, this deposit is not represented on the map. The practical absence of alluvium within the Coastal Plain in the Nomini tract is due to the subsidence of this province, now in progress at a rate more rapid than that of deposition.

Marsh growth has kept pace with subsidence in a number of localities along Rappahannock, Potomac, and Patuxent rivers, and along the several smaller tributary streams. The marshes are for the most part tidal, and represent the joint operation of sedimentation and vegetal growth. In the valleys of Zekiah and Gilbert swamps and Chaptico Creek there is considerable fresh-water marsh, due to the gradual slackening of flow with the subsidence of the land. In these marshy areas the vegetal accumulations are mixed with sand and clay, deposited during the freshets. The fresh-water marshes are susceptible of modification or reclamation by artificial drainage or by natural changes in the watercourses, and may therefore be regarded as temporary. Within limits the tidal marshes are also subject to modification by natural or artificial changes in drainage.

It may be noted that while the marsh lands are measurably susceptible of artificial control, the area in which they occur is affected by the slow subsidence of the Coastal Plain, so that the natural tendency is toward the drowning of estuaries and thus toward increase of the marsh area.

THE COLUMBIA FORMATION.

One of the more extensive geologic formations of the Nomini tract is a deposit of loam and gravel or bowlders along the waterways and extending for some distance up the tributary valleys toward the lower divides. Along the rivers the deposit is fairly uniform, consisting of a bed of loam (i. e., sand and clay mixed in various proportions) 5 to 20 feet thick, grading downward into a bed of bowlders, gravel, or sand, or all combined, from 3 to 10 feet thick, the loam being commonly unstratified, and the coarser members stratified and cross-bedded. This is the fluvial phase of the formation. Toward the lower divides the deposit is reduced to an irregular bed of water-washed and rearranged materials, composed in part of débris derived from the underlying formations in the immediate vicinity, in part of débris transported from greater distances by streams or currents; this being the interfluvial phase of the formation, which is not well developed in the Nomini tract. The two phases are combined under the name Columbia formation, so called from the District of Columbia, in which the two deposits are typically exposed.

Within the Nomini tract the materials of the Columbia formation are somewhat variable. On the terraces adjoining the larger rivers the upper portion consists of a fairly homogeneous bed of loam, while the lower portion is stratified and contains coarser materials,—mainly quartz and quartzite gravel and bowlders, and coarse sand, together with layers of silt. In the smaller valleys the lower member is coarse, frequently containing pebbles, and even bowlders, from the Lafayette deposits, while the loams are largely replaced by stratified or cross-bedded sands, derived locally from the Chesapeake and Lafayette formations. The prevailing color of the deposit is light-brown or drab, and is determined by the presence of ferric oxide. There is often variegation of buff and brown tints. The coloring of the more heterogeneous lower member is somewhat variable, the sands sometimes assuming light-brown tints, even bleaching nearly white; while the silt layers are commonly ash-colored or whitish, and weather out in pinnacles, giving a peculiar dentate or serrate character to the cliffs. Locally, the gravels toward the base of the formation are sometimes stained and united by a black or blue-black cement composed of ferrous oxide with cobalt, etc. To the southeastward all the beds show a tendency to become finer-grained, and the loams and silts give place here and there to slightly sandy clays, usually of dark color. In some localities, however, these give place to sands and gravelly beds, of which there are notable exposures between Piney Point and the mouth of Herring Creek.

On the whole, the materials of the Columbia deposits resemble in considerable measure those transported to-day by the rivers of the same region during freshets; and the distribution of the materials—the coarser below and the finer above and farther downstream—is similar to that of freshet work. The materials differ from those laid down during ordinary freshets, (1) in greater coarseness and (2) in containing a larger proportion of completely disintegrated and chemically stable rock matter in the upper member. These features are indicative of climatic conditions during the period of deposition of the formation; they point to colder climate, when the ice froze thicker than now and carried larger bowlders than those transported in the modern ice-floes, and when, moreover, the snowfall was greater than now, so that the spring freshets collected and transported seaward a larger quantity of residuary clays and loams of the Piedmont province than they now transport.

The Columbia formation occurs chiefly in broad terraces skirting the main waterways and reaching altitudes ranging from 5 to 60 feet above tide. The higher altitudes are attained mainly in the valleys of the smaller streams, and at a considerable distance back from the rivers. In the broad valleys the rise is by gentle slope and successive low terrace scarps. Originally the deposit floored the broader valleys from side to side, but the rivers have cut channels through it, and some of the smaller streams have cleared the greater portion of the material from their valleys. Along the rivers the formation usually rises in low cliffs, which are kept steep by waves and tidal action. These cliffs are commonly from 5 to 20 feet high, and give clear exposures of the formation, in some cases with the underlying Chesapeake formation at its base. Cliffs of Columbia deposits extend continuously along the northern side of Potomac River from Ludlow Ferry to beyond Piney Point; along the southern side from Wilkerson Wharf to below Thicket Point, except in Nomini Cliffs; at frequent intervals along Patuxent River; and along both sides of Rappahannock River excepting for an interval of 5 miles below Brockenboro Creek. The precipitous cliffs of this deposit constitute one of several indications of the subsidence of the land; for it is known through observations in many districts that the encroaching waters of subsiding shores bear away into the depths materials that ordinarily accumulate as talus. The terrace surfaces are broad, nearly level expanses, which, if sufficiently elevated to be well drained, form fertile fields. Although somewhat variable in altitude, these terraces meander the main valleys and extend into tributaries in such manner as to outline the geography when the land was so depressed as to submerge a considerable part of the Coastal Plain, and the distribution of the formation is at once a record and a measure of the subsidence.

Although the Columbia formation occupies less than one-sixth of the Nomini area, it is one of the most extensive in the province; it covers a great part of the surface of the coastward lowland in the middle Atlantic slope, and doubtless floors the ocean-bottom far out to sea. Farther westward the formation exhibits two well-marked members on different terrace levels deposited in successive epochs, to which distinctive designations have been given; but the uplift which developed these terraces did not extend far eastward, and the two members are not clearly separable in the Nomini area.

THE LAFAYETTE FORMATION.

The most extensive formation shown on the Nomini map is a thin but quite uniform deposit of well-rounded gravel imbedded in a matrix of red or orange-tinted loam. This is called the Lafayette formation, from the county of that name in Mississippi in which it is typically displayed. The tabular divides, or original upland areas, between the principal waterways are formed of this deposit. The surface of the formation, like the general upland surface of the Nomini area, of which it forms a large part, inclines gently southeastward from an altitude of about 190 feet along the northern and western border of the area to about 90 feet in the neighborhood of Valley Lee and Kinsale. Its greatest altitude is 200 feet, in a portion of Nomini Cliffs. It has also in most cases a slight slope into each of the river valleys.

The materials of the formation are quite uniform in character, consisting of sandy loams of orange, brown, and buff tints, often variegated, containing irregularly disposed bands, sprinklings, and beds of small quartzite pebbles and coarse sand. The pebbles and larger sand grains are orange-tinted, though the stain is largely superficial. Portions of the loam are clayey, and these portions are sometimes light-colored, the most frequent tints being buff, pink, or cream. The coloration of the deposit is due to ferric oxides; and sometimes the sands and gravels are incrusted or cemented in layers and masses by these oxides. Local variations in the composition of the formation occur irregularly, but in general the materials increase in coarseness northwestward, particularly in the lower beds. In the eastern part of the area the basal layers consist largely of fine sands, evidently derived mainly from the Chesapeake formation, intercalated with layers of coarser sands; the upper portion of the formation being often a gray or buff loam, with layers of fine gravel. Sometimes these layers are weathered or washed out, and their presence is often characteristic on the tabular surface of the broad, low divides in St. Mary, Calvert, Westmoreland, and Richmond counties. In Charles County, Maryland, the formation consists mainly of sandy orange loams, with scattered pebbles and pebble beds. The pebbles are, in general, thoroughly waterworn and well rounded. They were evidently derived originally, in large part, from the quartzite beds in the Blue Ridge, Catoctin, and other Appalachian ranges, but there are indications that many of them had an intermediate history as constituents of the Potomac formation.

The formation ranges from 25 to 40 feet in thickness, though locally it may be slightly in excess of the latter figure. Toward the waterways it terminates in abrupt scarps. In addition to the eastward slope, the surface of the deposit inclines considerably toward the Potomac, Rappahannock, Patuxent, and Chesapeake valleys. It lies on the Chesapeake formation throughout.

From the composition and distribution of the materials it is evident that the formation was originally deposited as a continuous mantle over this portion of the Coastal Plain and extended some distance upon the seaward border of the Piedmont Plateau, and also that the materials were carried down by the rivers and lesser streams and assorted and distributed over the Coastal Plain area by the action of waves and currents. The materials differ from those deposited by the modern streams chiefly in the more abundant elements of quartzite and thoroughly leached loamy matter corresponding with the residuary clays of the Piedmont. From its characteristics of composition and structure it is known to be a littoral formation, deposited when the land, after standing a long time at or near baselevel, was partly submerged and at the same time tilted seaward, so that the streams were stimulated and enabled to transport seaward the chemically stable quartz and residuary products in exceptional quantity.

The originally continuous mantle apparently undulated slightly, inclining toward the larger valleys, the outlines of which are thus known to antedate the formation. Along these valleys the mantle has since been eroded through and carried away, so that the existing areas are but remnants of a once continuous sheet whose extent and continuity vary inversely with the proximity and size of the streams. The post-Lafayette erosion did not cease with the dissection of the Lafayette mantle, but extended into the underlying formations, so that the pre-Lafayette valleys were greatly deepened after the formation was laid down. Moreover, the configuration of the pre-Columbia surface indicates not only that the land stood higher than now above the sea during the post-Lafayette period, but that this period of high level was too short to permit the complete reduction of the surface to baselevel. Thus the presence of the Lafayette formation is a record of submergence, involving the entire Nomini area and extending also some distance westward, while the partial erosion of the deposit is a record of a relatively brief high-level period, during which the land stood higher than now. Thus the unconformity between the Lafayette and Columbia formations, which is one of the most notable within the area, is found to be especially significant in its bearing on the geologic history of the region.

South of the Nomini area the Lafayette formation increases in extent, until in coastal North Carolina it is a nearly continuous mantle; and still farther southward and southwestward it expands in width and increases in thickness, notably in the Mississippi embayment. North of Potomac River the formation is known only in remnants, which grow successively smaller and smaller through Maryland and Delaware and into the peninsula of New Jersey, where only scattered outliers are found within the Delaware drainage basin, though the deposit is much more continuous over the Atlantic drainage area. The Lafayette formation is perhaps the most extensive in area and the most uniform in character of all the formations in the United States.

THE CHESAPEAKE FORMATION.

In the Nomini tract the Lafayette formation rests unconformably on a bed of marine deposits which has been named after Chesapeake Bay, on the shores of which it is typically displayed. These deposits occupy all of the Nomini tract except a very narrow belt extending along the base of the cliffs on the Potomac in the vicinity of Pope Creek, on the Maryland side. Their base rises from beneath tide-level along a line which extends from just above Ludlow Ferry on the Potomac to Spring Hill in the northwestern corner of the Nomini tract. Southeast of this line their base gradually dips to a depth of 270 feet at Piney Point and 235 feet at Kinsale. The formation is covered by the Lafayette deposits on the upland or "ridge" areas, but it is extensively exposed in the depressions which are cut through the Lafayette capping. On the lower terraces it is more or less deeply overlain by Columbia deposits, which extend to tide-level in the river banks, except at intervals along the Patuxent and some of the larger branches of the Potomac, where there are small outcrops of Chesapeake beds beneath the Columbia. The most notable exposures are in the river cliffs, where the Columbia terrace has been removed and there is encroachment on the higher or upland region. Of these the Nomini Cliffs are the most extensive example: they present a superb exposure over 6 miles in length and rising at one point to a height of 200 feet. There are lower cliffs of less extent along the Rappahannock in the vicinity of Carter Wharf; along the Potomac near Pope Creek, Maryland; on Breton Bay opposite Lovers Point; and at intervals along the southern side of Patuxent River.

The materials of the Chesapeake formation are mainly fine sands intermixed or intercalated with clays; accumulations of minute shells of diatoms or Infusoria, forming infusorial earths; and glauconite or greensand, locally known as marl. The sands commonly contain much clay, and when wet and freshly exposed are hard and tough, and dark-gray or dark-olive in color; on weathering, the beds usually assume a light-gray color, though in some localities they are stained buff, probably in part at least by ferruginous solutions from the overlying Lafayette beds. The weathered material is friable, with a peculiarly meal-like appearance and texture. There are also beds of coarser sands, which are usually filled with fossil shells, and extensive beds of gray clays.

In the eastern portion of the Nomini tract the clays and mealy sands of the Chesapeake grade downward into diatomaceous beds, often consisting mainly of diatom remains, with only a small admixture of clay and fine sand. The more richly diatomaceous beds form a characteristic horizon which outcrops in a belt 5 or 6 miles wide extending along the western side of the Nomini tract. The finest exposures of this member are in the cliffs on the northern side of the Potomac in the vicinity of Pope Creek. Diatomaceous beds also occur in the Nomini Cliffs, and in the vicinity of Carter Wharf on the Rappahannock. In many exposures the diatom remains are intermixed in varying proportions with fine sands and clays, though they sometimes predominate and constitute nearly pure layers of considerable thickness. The purest beds observed were at Pope Creek, Maryland. The diatomaceous deposit is light-colored, often snow-white or slightly tinted with buff or gray. When pure, or nearly so, it is of very low specific gravity, so that when dry it readily floats on water, though when saturated with water it is heavy, tough, and gray or pale-olive in color.

The higher portions of the Chesapeake deposits are more argillaceous, and include many beds of gray and bluish clays. These contain layers of fossiliferous sands and sandy clays (or shell marl), of varying dimensions and degrees of purity, which are conspicuous all over the region. In some cases they are sparingly glauconitic. When freshly exposed these marls are light-gray, and often contain a large proportion of fossil shells; but after long exposure near the surface they weather to buff argillaceous sands, with casts and impressions of fossils, the shells being leached away. The most extensive exposures of clays are in the Nomini Cliffs, but outcrops are frequent in gullies throughout the higher lands. Sands occur in the clay and marl series, but they are usually fine-grained and of no great extent. At Drum Cliff, on the Patuxent, there is an extensive bed of coarse, gray sand, filled with great numbers of fossils, and the locality has become quite a famous one for collectors. At the base of the sand is a hard, silicified layer from 6 inches to 2 feet thick, which extends along both sides of the river for some distance. It is immediately underlain by a bed of gray clay.

The greatest thickness of the Chesapeake formation in the Nomini tract is in Northumberland County, where it reaches 270 feet. It thins westward, mainly by the pre-Lafayette erosion of its upper members, and in the vicinity of Pope Creek, Maryland, it is not over 40 feet thick. The basal beds usually contain small black quartz pebbles at the contact with the Pamunkey formation, and for a few inches above. Throughout the Nomini tract the Chesapeake rests on the relatively smooth surface of the Pamunkey formation. Exposures of the contact may be seen along the cliffs in the vicinity of Pope Creek, but elsewhere it is below tide-water level. Its southeastward dip carries it down to tide-water level at a point a short distance above Ludlow Ferry, and well-borings indicate that it reaches a depth of 270 feet at Piney Point.

Fossils occur in greater or less abundance throughout the formation. In the marly beds they are mainly shells, and elsewhere chiefly casts and impressions of shells which have leached away. Fossil bones frequently occur in all the beds of the formation, and more or less complete skeletons of large Cetacea have been found. The diatomaceous or infusorial deposits are beds made up of the fossil shells of a great variety of minute organisms, which are beautifully distinct under a moderately powerful microscope. The age of the formation, as indicated by the fossils, is early Neocene (Miocene), though in this region representatives of the earliest Neocene and of the later (pre-Lafayette) Neocene are lacking.

The Chesapeake formation is a typical offshore marine deposit: the fossils are remains of organisms such as inhabit relatively shallow sea waters some miles or scores of miles offshore; the sands and clays are such as are supplied by rivers of moderate declivity, though assorted and deposited as by waves and littoral currents; the diatoms are such as live in relatively shallow and quiet waters in temperate and subtropical zones; the glauconitic deposits are such as are produced by the action of certain minute organisms subsisting in sea water on feldspathic and other constituents of crystalline rocks. Thus the deposit is a record of the geographic conditions attending its deposition; while the slightly discordant unconformities by which it is bounded indicate that the oscillations of the land by which the period of its deposition was preceded, introduced, and terminated, were of small amplitude.

In the Nomini tract the Chesapeake formation is a unit, and the sole representative of the earlier Neocene; but in both the northern and southern portions of the Coastal Plain province other deposits representing the period come in above and below this well-defined member of the geologic series.

THE PAMUNKEY FORMATION.

All of the Nomini tract is underlain by a fairly homogeneous sheet of dark-colored, glauconitic sands and sandy clays, but this sheet reaches the surface only in the narrow outcrop extending along the northern shore of Potomac River in the vicinity of Pope Creek. The name of the formation is derived from Pamunkey River, Virginia. The formation is exposed beneath the Chesapeake beds in the scarps of the plateau, in the cliff which extends from north of Pope Creek nearly to Ludlow Ferry.

The materials of the formation are mainly glauconitic sands and marls, which in their fresh and moist condition are dark-green or black. They often contain large numbers of shells, with more or less calcareous material. On weathering they become lighter in color, the shells and other calcareous elements are removed by solution, and the resulting material is a buff sand containing more or less redeposited iron in brown streaks or blotches or in limonitic crusts. In the partially weathered material, such as commonly appears in old exposures, there are streaks of brown and buff, carrying greenish grains. Weathered phases of the formation are rare in this area, as the encroachment of the river is continually exposing fresh material.

At the base of the Pamunkey formation there is usually a bed of coarse materials, often gravelly green and gray sands, 1 to 2 feet in thickness, lying on the surface of the Potomac formation, and consisting largely of Potomac débris. It is far beneath the surface in the Nomini tract, but is important because it yields water in some of the wells at Colonial Beach and in the well at Chapel Point, and probably will be found to extend far eastward. Higher sandy beds yield water in wells at Bushwood, Oakley, Rock Point, and Colonial Beach.

The thickness of the Pamunkey formation is not definitely known. An exposure of 100 feet of medial beds has been measured on Potomac River below the mouths of Aquia and Potomac creeks, and the summits of these beds are about 50 feet below the base of the Chesapeake formation. The well at Chapel Point appears to have reached basal beds at a depth of 276 feet below tide-water, and was begun about 30 feet below the base of the Chesapeake, which would indicate a thickness of about 300 feet.

The abundant fossils of the formation are of Eocene age, but the formation appears not to include all the representatives of the Eocene found elsewhere in the province. In the Nomini tract the Pamunkey is the sole representative of a series which farther northward, as well as south of the Roanoke, comprises several distinct formations.

The Pamunkey formation, like the Chesapeake, is a typical marine deposit, and gives a record of the geographic conditions under which it was laid down, while the unconformity at its base indicates with considerable clearness the immediately antecedent geography.

THE POTOMAC FORMATION.

The lowest and oldest formation of the Coastal Plain series is a heavy deposit of gravel and cobbles, sand, silt, and clay, called the Potomac formation, from the river on and near which it was first carefully studied. The deposit underlies the Pamunkey, Chesapeake, and Lafayette formations throughout the portion of the Coastal Plain shown on the Nomini sheet, but it lies far beneath tide-level, and sinks rapidly eastward. It rests on the deeply eroded surface of the Piedmont crystallines, and is unconformably overlain by the Pamunkey and newer formations.

The materials of the Potomac formation are sands and clays, but these are variable in degree of comminution, structure, texture, and color. In general the lower beds of sand are coarse, irregularly stratified and cross-bedded, slightly coherent, and light-gray in color. Commonly they consist of angular or subangular grains of quartz; and frequently, if not usually, these are associated with flakes or irregular particles of kaolin or fine white clay. The clays are red, gray, or buff in greater part, and alternate with sands. The formation lies on an east-sloping floor of the crystalline rocks—granite, gneiss, etc.—and has a thickness of about 350 feet, or possibly somewhat more.

GEOLOGIC HISTORY OF THE COASTAL PLAIN.

The history of the Nomini tract is intimately connected with that of contiguous areas, and in part is interpreted thereby. The history includes the eras and episodes in the building of the Coastal Plain out of materials gathered largely from the Piedmont province. The record is clear, and although some of the minor episodes are obscure, the principal events have been interpreted. The principal movements are summarized in the accompanying table:

Earth-Crust Movements.	Local Records.	Geologic Periods.
Modern subsidence.	Accumulations of alluvium (mainly below tide), marsh growth, and talus building.	Recent.
Post-Columbia uplift.	Trenching of the Columbia deposits, with development of minor details of the topography; interrupted by deposition in neighboring areas.	Pleistocene.
Subsidence and tilting.	Deposition of gravel, sand, loam, and ice-borne bowlders in terraces along the rivers (mechanical sediments); the Columbia formation.	
Post-Lafayette uplift.	Cutting of broad estuaries; degradation of half the Lafayette deposits; shaping of the present topography.	Neocene.
Subsidence, with decided seaward tilting.	Degradation of residual and quartzose material in the Piedmont area, and deposition of material in the Coastal province (mechanical sediments); the Lafayette formation.	
Post-Chesapeake uplift.	Decomposition of older formations, with feeble degradation and slight valley cutting.	
Subsidence, with little if any tilting.	Deposition of fine sand, clay, and glauconitic and diatomaceous deposits, with marine fossils; the Chesapeake formation.	
Post-Pamunkey uplift.	Moderate degradation, with general baseleveling.	
Subsidence, with slight seaward tilting.	Deposition of dark sands and marls, with glauconite and marine fossils; the Pamunkey formation.	Eocene.
Post-Potomac uplift.	Extensive degradation of older formations, with general baseleveling, interrupted by deposition in neighboring areas.	Cretaceous.

The first episode in the history thus epitomized was one of degradation, represented by the unconformity below the Pamunkey formation. During this period the land stood so high that the sea retreated beyond the Nomini tract, yet not so high as to permit the rivers greatly to deepen their channels. It was a period of baselevel planing, of sluggish degradation by the little rivulets toward the divides as well as by the great rivers in the valleys; and there were minor oscillations of such extent that in adjacent regions other deposits (notably the Severn formation of northern Maryland) were laid down. How far westward the Potomac sediments originally extended, and how great a volume of material was degraded during this epoch, are not known; but the configuration of the unconformity between the Potomac and Pamunkey deposits indicates that the Piedmont and Coastal zones were planed to a fairly uniform surface, with few deep valleys or ravines, and that the antecedent Piedmont waterways extended their courses over the nascent Coastal Plain to reach the ocean.

The next event was a subsidence of the land and adjacent sea-bottom, more uniform than the last, of such extent that the ocean again overflowed the Nomini tract; but the new-made sea-floor was fairly smooth and the seaward tilting was slight, so that the rivers were little stimulated and the storm waves weak, and thus the materials laid down in the encroaching waters were fine of grain and in part were reduced to stable chemic condition. For the same reasons marine life prevailed, as shown by the shells of mollusks and the teeth and bones of sharks imbedded in the deposits; rhizopods and other minute organisms abounded, as their remains attest, and some of them subsisted on the feldspathic débris brought in by the rivers, and, through the assimilation of this material with their own substance, produced grains, and even great beds, of glauconite. In this way the Pamunkey formation was built up of more or less oxidized sediments charged with organic remains.

Then came another epoch of degradation, during which the Pamunkey-Potomac surface was lightly sculptured by rain and rivers into a baselevel plain even smoother than that below the Pamunkey. Minor oscillations during this period are recorded in other portions of the Coastal province, and these may have affected the Nomini tract; but the record here is blank, save as to the principal movement of the continent.

Once more a well-marked era was introduced by a subsidence of the land and contiguous seabottom, with little if any seaward tilting; the ocean pushed over the plain far beyond the fall-line; and in the shoal waters by which the growing Coastal Plain was flooded, marine mollusks and predatory fishes abounded, more or less glauconite or greensand was deposited, and during a part of the period diatoms existed in such numbers that their shells formed a continuous bed intercalated with the clays and fine sands. In this way the Chesapeake formation was made.

From the Potomac period to the period of the Chesapeake, in the Nomini tract as elsewhere in the Coastal Plain, the history was one of oscillation of the land, in which every downward movement was accompanied by slight seaward tilting; and from the Potomac to the Chesapeake the amplitude of the oscillations progressively diminished. With the diminution in movement of the earth-crust from era to era, the work of rains and rivers and waves decreased progressively, and the chemical agencies of decomposition and vital reconstruction increased relatively if not absolutely. This series of diminishing mechanical and increasing chemical activity continued after the deposition of the Chesapeake; for, while the land again lifted until the ocean retreated well toward the brink of the Coastal Plain, the lifting was so uniform that the rivers remained sluggish. Thus, while the next era was one of degradation, the stream work was feeble, and decomposition of the rocks outran transportation, until the Piedmont province and parts of the adjacent zone were heavily mantled by residua, and no rocks save the chemically and mechanically obdurate quartzite of the eastern Appalachians and quartz of the Piedmont veins remained within reach of the streams. During this time the Piedmont province was a low-lying plain; most of the rivers flowed along the present lines, but they meandered idly through shallow valleys instead of rushing through sharp-cut gorges as at present, and geologic process was chemical rather than mechanical. In this way the gently undulating plain now constituting the Piedmont Plateau, and the nearly level plain of the sub-Lafayette unconformity in the Coastal province, were fashioned.

At the end of this era of stable land and preponderant chemical action, the diminishing series of oscillations beginning with Cretaceous time came to an end and a new series of earth-crust movements began.

The next episode was introduced by a strong warping of the earth-crust, whereby the interior was lifted and the shoreward periphery depressed; and the subsidence so far predominated that the ocean encroached on the erstwhile land somewhat beyond the fall-line. Through the tilting of the land the sluggish rivers became more active and scoured their channels, transporting the chemically obdurate quartzite and quartz into the sea, while the rapidly retroceding rivulets kept the waters charged with the friable residuary clays and loams. In this way the waves were fed by chemically stable material in which the coarse and the fine were intermingled in unusual fashion. Through this combination of causes and antecedent conditions the widespread and singularly uniform Lafayette formation was built.

The next record is one of degradation; and as the continent-movement initiating Lafayette deposition was more energetic than for ages, so in about the same ratio was the post-Lafayette uplift energetic and ample. The land was lifted so high that the ocean retreated to or beyond the brink of the Coastal Plain, and the rivers excavated great estuaries through this province and carved the steep-sided Piedmont and Appalachian gorges. This attitude of the land persisted not only until the Coastal Plain waterways cut through the Lafayette formation, but until many of them sawed their way deep into the underlying formations, and until at least half of the aggregate volume of the Lafayette deposits was carried away, leaving the formation as a series of remnants only. It was chiefly during this period of high level that the "ridges" and valleys of the Nomini area were shaped and the outcrops of the different formations determined.

It is probable that after this episode of active erosion the land gradually assumed about its present level. Then another stage was introduced by a subsidence of the land in mid-latitudes and the beginning of a series of ice-invasions in northern United States. While the land stood low in the latitude of Potomac River, the climate was somewhat changed, the ice froze thick and probably the snow fell deep, and during the vernal freshets bowlders of exceptional size and clays and loams in exceptional quantity were carried into the estuaries by the ice-floes and waters; but in the Nomini area the subsidence was such as to flood only the lower lands. By these freshets and the tidal currents of the estuaries the Columbia deposits were accumulated and the broad terraces flanking the Rappahannock, Potomac, and Patuxent rivers were built.

In the last stage of the history clearly recorded in the deposits and earth-forms of the Nomini tract, the land and sea-bottom were again lifted so far as to permit the principal waterways to cut into and through the Columbia deposits, and this lifting was followed by slight subsidence, which merged into the present sinking of the Coastal Plain.

ECONOMIC PRODUCTS.

The principal mineral products of the Nomini region consist of marl, fullers' earth, brick clay, pottery clay, building stones, sand, quartz gravel, and underground waters.

Marl.—The most important mineral resource in the area of the Nomini sheet is marl, large deposits of which exist in the Pamunkey and Chesapeake formations. The Pamunkey formation consists in greater part of marl, and the shell marls which are contained in the Chesapeake formation are of considerable extent and thickness. These marls contain lime and potash in small percentages, and usually also some phosphoric acid. They are of great value for enriching land, and especially for restoring the fertility of worn-out soils. They have not been extensively used in the region, but a number of farmers have tested their efficacy with most satisfactory results. In some other portions of the Coastal Plain province they are in general use and their great value is fully recognized. This is particularly the case in New Jersey, where the marls are dug in large amounts for local use and are to some extent shipped to points outside of the marl belt. The marls are not so powerful and prompt as the chemical fertilizers, but their effect is gradual and more lasting and they do not ultimately exhaust the soil. The fertilizing influence continues for several years, and the land will bear many successive treatments. As the marls underlie many portions of the region and are easy to excavate, the expense attending their use is very small compared with the benefit to be derived from them. All sandy soils and nearly all crops have been found to be benefited by marls. Grasses, grain, and corn are particularly subject to its influence and in many cases have been found to yield from 30 to 40 per cent more after overspreading the soil lightly with marl.

The marl is usually a sand containing grains of the dark-green mineral glauconite (which consists in part of potash), with more or less carbonate of lime in a fine powder and as shells. There is commonly a considerable admixture of clay. The Chesapeake marls consist largely of clay, shells, and fine sand. The Pamunkey marls vary considerably in strength, but richly glauconitic shell marls abound in the formation, particularly in the depression of Port Tobacco River.

More or less highly glauconitic shell marls are exposed in the bluffs at the mouth of Pope Creek, Maryland, but they are not so rich as those lower in the formation.

Shell marl in the Chesapeake formation is of frequent occurrence in Westmoreland, Richmond, St. Mary, and Calvert counties. It is dug in moderate amount from the Nomini Cliffs near the mill just north of Stratford, and mixed with other fertilizers, both for shipment and for local use. Nearly all the shell deposits which abound in the formation are useful for fertilizing land, and they usually contain, in addition to the shells, more or less calcareous material and glauconite. They may be looked for in nearly every gully in the Chesapeake area in the counties mentioned. In selecting marl it should be remembered that the beds containing the largest proportions of shells and grains of the dark, bottle-green mineral, glauconite, are richest in plant food.

Fullers' earth.—Eastward in the Chesapeake formation the beds of infusorial or diatomaceous remains are often sufficiently pure for commercial use as "fullers' earth." The largest deposits are near the base of the formation, and they are best exposed in the bluffs along the Potomac at the mouth of Pope Creek, Maryland, where at one time they were worked for shipment. The deposits underlie the western part of Westmoreland, Richmond, and St. Mary counties and the southeastern part of Charles County, and they are exposed at many points along streams and in road-cuts. The purity of the material is diminished in some portions of the district by admixture with clay or sand, but over much of the area there are large supplies of relatively pure deposits.

Brick clays.—The loams of the Columbia formation, and to a less extent those of the Lafayette formation, are used locally for brickmaking. The deposits are nearly coextensive with the formations, and they are generally well adapted for brickmaking. The Columbia loam is especially valuable for this purpose, as shown by experience in neighboring tracts. Washington and Baltimore are largely built of bricks made from this deposit; and in Philadelphia and Trenton the same material (locally known as Philadelphia brick clay) is extensively developed, and is largely used in these and neighboring cities. The loam forming the terraces of the Rappahannock, Potomac, and Patuxent rivers is in most cases adapted to the manufacture of ordinary and pressed bricks, and is practically unlimited in quantity.

Pottery.—Some of the clays in the Chesapeake formation in the central and eastern portion of the Nomini tract are probably of the proper character for the manufacture of pottery, tiling, and terra-cotta, but so far as known they have not been tested.

Building stone.—The only rocks in the tract are occasionally sandy ironstone streaks in the Lafayette formation and a local siliceous bed in the Chesapeake formation. Both are used for foundations and rough work. The ironstone occurs on or near the surface at many places on the Lafayette "ridges," but seldom affords large blocks. The siliceous layer in the Chesapeake formation is found along both sides of the Patuxent below Jones Wharf and Broome Island.

Sand.—The lower or middle beds of the Columbia formation are made up largely of sand, which is frequently of such character as to excel as building sand. Building sands are also found locally in the lower part of the Lafayette formation. The Lafayette sands often require screening, but after passing through this process they are usually excellent, consisting of sharp grains of firm quartz; such sand is highly valued among the builders in neighboring cities. Molding sand of good quality is found in the Chesapeake in the adjacent portions of the Coastal Plain, and will doubtless be a useful resource in the Nomini tract.

Gravel.—The gravel beds found in the Lafayette and Columbia formations are a rich source of most excellent material for roadmaking and railway ballasting, and their use can not be too strongly advocated. The well-rounded quartz pebbles are easily handled and transported, and are practically indestructible.

Underground waters.—In that portion of the Coastal Plain area which is shown on the Nomini sheet the water supplies are mainly derived from shallow wells, springs, and surface streams. Where there is no contamination from drains, barnyards, and other similar sources of impurity the waters are often of satisfactory quality, but it is probable that much of the malaria so prevalent in the lower lands is attributable to waters on or near the surface. In many places in eastern Virginia and Maryland wells have been sunk to deeper-seated waters, and it is found in most cases that a marked diminution in malarial diseases has resulted. These deep-seated waters underlie all of the area of the Nomini sheet, at several horizons, at depths which vary from 100 to 700 feet. Some of these waters have been reached by wells at Colonial Beach, Rock Point, Bushwood, Oakley, Leonardtown, Kinsale, Coles Point, Ragged Point, Sandy Point, Piney Point, and near Sotterly, at depths of from 160 to 305 feet. The principal horizons are in the Chesapeake and Pamunkey formations, and consist of coarse sands and gravel in thin but widely extended sheets which dip gently eastward. Lower horizons probably also underlie the entire region, but their easterly dip has carried them far beneath the surface and no wells have been sunk to them.

In the artesian-well sheet of this folio there are shown the location and depth of the wells and the depths to the three principal water horizons. The depths to these horizons are indicated by underground contour lines which show the direction and rate of slope of the water-bearing beds. From these lines approximate depth of the waters below sea-level may be quite closely ascertained for any given point. It should be borne in mind in calculating depths that the amount of surface relief, as indicated by the brown topographic contour lines, should be added to the estimate of the depth below sea-level. Along the western margin of the tract the waters at the base of the Pamunkey formation will be found most serviceable. They yield the flows in the deeper wells at Colonial Beach and in the well at Chapel Point, Maryland. They slope nearly due eastward at the rate indicated by the pair of underground contour lines shown on the artesian-well sheet. The next higher water-bearing horizon is in sands which along Potomac River lie at an average of about 80 feet above the basal beds, the amount increasing gradually northeastward. These sands yield water at Colonial Beach at a depth of 160 feet, at Rock Point at 254 feet, at Bushwood at 287 feet, and at Oakley at 305 feet. They have not been reached by wells farther eastward. Their rate and direction of slope, and their depth for each 50 feet, are indicated by the second set of underground contours—heavy, full lines—on the artesian-well sheet. The basal sands of the Chesapeake formation lie about 200 feet above the Pamunkey horizon. They are tapped by the wells at Leonardtown, Piney Point, Rock Point, Coles Point, Sandy Point, Kinsale, and near Sotterly. Their direction and rate of dip, and depth below mean tide-level for each 50 feet, are shown by the third set of underground contour lines on the artesian-well sheet.

The head or pressure of the water of these various horizons is sufficient to afford flowing wells only in the lowest lands of the Nomini area. Along Potomac River the water rises 10 to 16 feet above mean tide-level in greater part, but at Rock Point it is reported to rise about 24 feet above tide. On Patuxent River, so far as yet developed, the height to which the waters will rise is considerably less than in any of the wells on the Potomac. The area that is sufficiently low to be within reach of artesian flows is shown approximately on the artesian-well sheet by a distinctive tint. The underground waters extend under the higher land, where, in many cases, they will no doubt be found available through pump wells.

At the base of the Columbia and Lafayette deposits there are widely extended beds of gravel and coarse sands, which furnish water to hundreds of shallow wells. The supply at the base of the Columbia formation, which occurs at low levels, is particularly abundant; while wells finding their supply at the base of the Lafayette are notably persistent. The ground waters of both of these horizons are of great importance to the people of the Nomini tract; yet precaution is necessary in utilizing them, since both are particularly liable to surface contamination. The Lafayette deposits are chemically stable and moderately pervious, and water passing through them is filtered mechanically, but is not necessarily freed from organic impurities; and in somewhat less degree the same is true of the Columbia deposits. Wells taking water from these deposits are safe only when remote from houses, barns, stock-yards, privies, and other possible sources of contamination.

N. H. DARTON,
Geologist.

W J McGEE,
Geologist in charge.

April, 1896.

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

TOPOGRAPHY

MARYLAND—VIRGINIA
NOMINI SHEET

Henry Gannett, Chief Topographer.
Gilbert Thompson, Chief Geographer in charge.
Triangulation and shore line by U.S. Coast and Geodetic Survey.
Topography by A.E. Murlin.
Surveyed in 1890.

Scale 1/125000
5 Miles
5 Kilometers
Contour Interval 20 feet.
Datum is mean Sea level.
Edition of Dec. 1895.

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

AREAL GEOLOGY

MARYLAND – VIRGINIA
NOMINI SHEET

LEGEND

SURFICIAL ROCKS

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

PLEISTOCENE

- **Pc** — Columbia formation *(brick clay and sand; underlain throughout by Chesapeake formation)*

SEDIMENTARY ROCKS

(Areas of Sedimentary rocks are shown by patterns of parallel lines.)

NEOCENE

- **Nl** — Lafayette formation *(gravelly sand and loam)*
- **Nc** — Chesapeake formation *(clay, infusorial earth, and shell-marl)*

EOCENE

- **Ep** — Pamunkey formation *(greensand-marl)*

Henry Gannett, Chief Topographer.
Gilbert Thompson, Chief Geographer in charge.
Triangulation and shore line by U.S. Coast and Geodetic Survey.
Topography by A.E. Murlin.
Surveyed in 1890.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour Interval 20 feet

Datum is mean Sea level

Edition of Dec. 1895.

W J Mc Gee, Geologist in charge.
Geology by N. H. Darton.
Surveyed in 1891.

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

ARTESIAN WELLS

MARYLAND–VIRGINIA
NOMINI SHEET

Henry Gannett, Chief Topographer.
Gilbert Thompson, Chief Geographer in charge.
Triangulation and shore line by U.S. Coast and Geodetic Survey.
Topography by A.E. Murlin.
Surveyed in 1890.

Scale $\frac{1}{125000}$

Contour Interval 20 feet.
Datum is mean Sea level.
Edition of Dec. 1895.

Geology by N.H. Darton.
Surveyed in 1891.

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 rocks 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 a guide 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 and formed 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 one was deposited first.

Fossil remains found in the rocks of different areas, of different provinces, and of different 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 color or colors and symbol assigned to each, are given below. The names of certain subdivisions 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 first (Pleistocene) and the last (Archean). The formations of any one period, with the exception of Pleistocene and Archean, are distinguished from one another by different patterns, made of parallel straight lines. Two tints of the

PERIOD.	SYMBOL.	COLOR.
Pleistocene	P	Any colors.
Neocene { Pliocene / Miocene }	N	Buffs.
Eocene { including Oligocene }	E	Olive-browns.
Cretaceous	K	Olive-greens.
Juratrias { Jurassic / Triassic }	J	Blue-greens.
Carboniferous { including Permian }	C	Blues.
Devonian	D	Blue-purples.
Silurian { including Ordovician }	S	Red-purples.
Cambrian	€	Pinks.
Algonkian	A	Orange-browns.
Archean	Æ	Any colors

period-color are used: a pale tint (the underprint) is printed evenly over the whole surface representing the period; a dark tint (the overprint) brings out the different patterns representing formations. Each formation is furthermore given a letter-symbol of the period. 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 of surficial formations of the Pleistocene is so great that, to distinguish its formations from those of other periods and from the igneous rocks, the entire series of colors is used in patterns of dots and circles.

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 rock is known to be of sedimentary origin the hachure patterns may be combined with the parallel-line patterns of sedimentary formations.

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 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. The formations are arranged according to origin into surficial, sedimentary, and igneous, and within each class are placed in the order of age, so far as known, the youngest at the top.

Economic 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 areal 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:

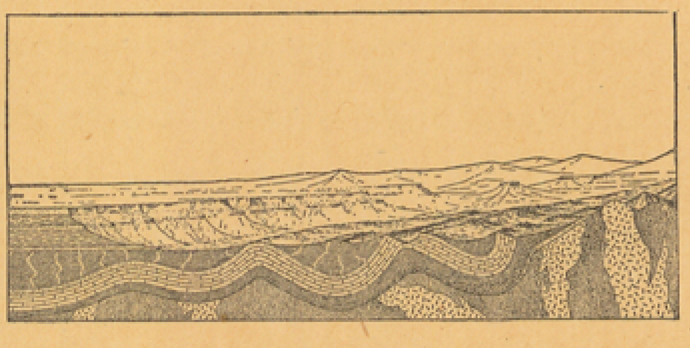


Fig. 2.—Sketch showing a vertical section in the front of the picture, with a landscape above.

The figure represents a landscape which is cut off sharply in the foreground by a vertical plane that cuts a section 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:

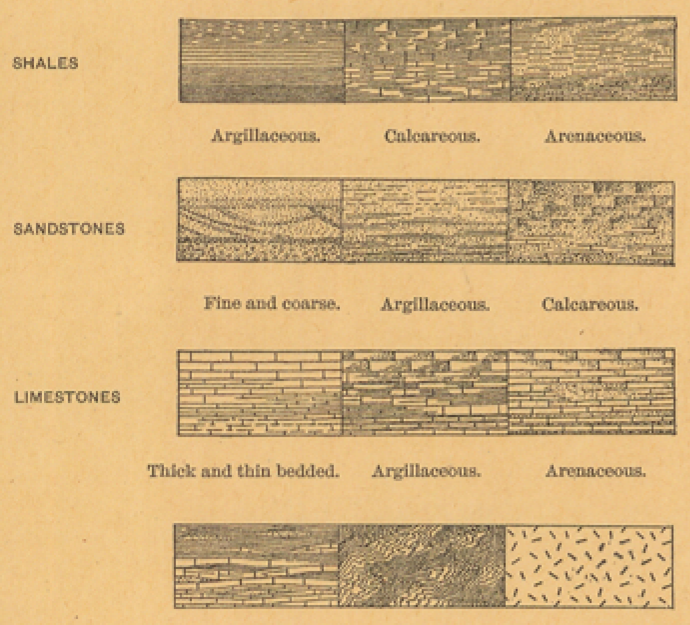


Fig. 3.—Symbols used to represent different kinds of rock.

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.

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. But these 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.

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 horizontal strata of the plateau rest upon the upturned, eroded edges of the beds of the second set at the left of the section. The overlying deposits are, from their position, 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 consist 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 of any mineral-producing or water-bearing stratum which appears in the section may be measured from the surface by using the scale of the map.

Columnar-section sheet.—This sheet contains a concise description of the rock formations which constitute the local record of geologic history. The diagrams and verbal statements form a summary of the facts relating to the character of the rocks, to the thicknesses of the formations, and to 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 under the heading "Thickness in feet," 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 1,000 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 other formations, 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 may be indicated graphically or by the word "unconformity," printed in the columnar section.

Each formation shown in the columnar section is accompanied by its name, a description of its character, and its letter-symbol as used in the maps and their legends.

CHARLES D. WALCOTT,
Director.

Revised July, 1895.