DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

70

GEOLOGIC ATLAS

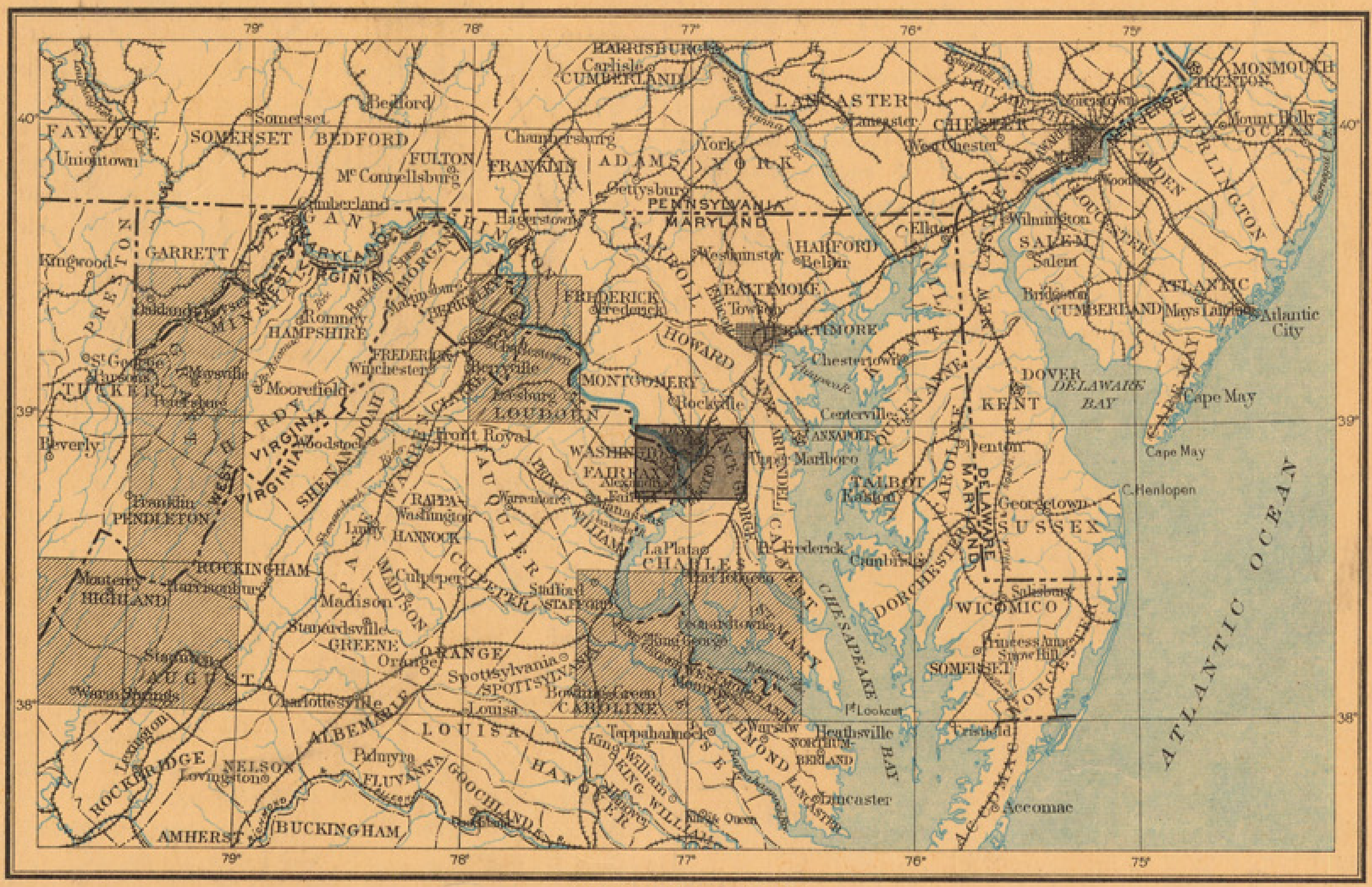
OF THE

UNITED STATES

WASHINGTON FOLIO

DISTRICT OF COLUMBIA
MARYLAND - VIRGINIA

INDEX MAP



SCALE: 40 MILES-1 INCH

AREA OF THE WASHINGTON FOLIO

AREA OF OTHER PUBLISHED FOLIOS

LIST OF SHEETS

DESCRIPTION — TOPOGRAPHY — HISTORICAL GEOLOGY — ECONOMIC GEOLOGY — STRUCTURE SECTIONS

PHYSIOGRAPHIC GEOLOGY

FOLIO 70 — LIBRARY EDITION — WASHINGTON

WASHINGTON, D. C.

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

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EXPLANATION.

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

THE TOPOGRAPHIC MAP.

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

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

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

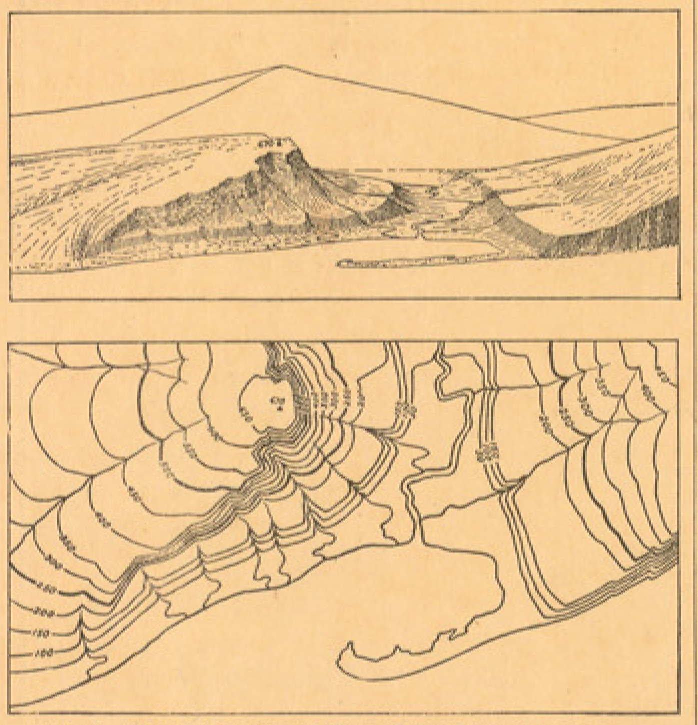


Fig. 1.—Ideal sketch and corresponding contour map.

The sketch represents a river valley between two hills. In the foreground is the sea, with a bay which is partly closed by a hooked sand-bar. On each side of the valley is a terrace. From the terrace on the right a hill rises gradually, while from that on the left the ground ascends steeply in a precipice. Contrasted with this precipice is the gentle descent of the left-hand 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 are drawn at 50, 100, 150, 200 feet, and so on, above sea-level. Along the contour at 250 feet lie all points of the surface 250 feet above sea; and similarly with any other contour. In the space between any two contours are found all elevations above the lower and below the higher contour. Thus the contour at 150 feet falls just below the edge of the terrace, while that at 200 feet lies above the terrace; therefore all points on the terrace are shown to be more than 150 but less than 200 feet above sea. The summit of the higher hill is stated to be 670 feet above sea; accordingly the contour at 650 feet surrounds it. In this illustration nearly all the contours are numbered. Where this is not possible, certain contours—say every fifth one—are accentuated and numbered; the heights of others may then be ascertained by counting up or down from a numbered contour.

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

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

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

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

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

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

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

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

THE GEOLOGIC MAP.

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

KINDS OF ROCKS.

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

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

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

Igneous rocks.—These are rocks which have cooled and consolidated from a liquid state. As has been explained, sedimentary rocks were deposited on the original igneous rocks. Through 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 slowly, and hence are generally of crystalline texture. When the channels reach the surface the lavas often flow out and build up volcanoes. These lavas cool rapidly in the air, acquiring a glassy or, more often, a partially crystalline condition. They are usually more or less porous. The igneous rocks thus formed upon the surface are called *extrusive*. Explosive action often accompanies volcanic eruptions, causing ejections of dust or ash and larger fragments. These materials when consolidated constitute breccias, agglomerates, and tuffs. The ash when carried into lakes or seas may become stratified, so as to have the structure of sedimentary rocks.

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

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

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

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

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

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

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

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

Surficial rocks.—These embrace the soils, clays, sands, gravels, and bowlders that cover the surface, whether derived from the breaking up or disintegration of the underlying rocks by atmospheric agencies or from glacial action. Surficial rocks that are due to disintegration are produced chiefly by the action of air, water, frost, animals, and plants. They consist mainly of the least soluble parts of the rocks, which remain after the more soluble parts have been leached out, and hence are known as residual products. Soils and subsoils are the most important. Residual accumulations are often washed or blown into valleys or other depressions, where they lodge and form deposits that grade into the sedimentary class. Surficial rocks that are due to glacial action are formed of the products of disintegration, together with bowlders and fragments of rock rubbed from the surface and ground together. These are spread irregularly over the territory occupied by the ice, and form a mixture of clay, pebbles, and bowlders which is known as till. It may occur as a sheet or be bunched into hills and ridges, forming moraines, drumlins, and other special forms. Much of this mixed material was washed away from the ice, assorted by water, and redeposited as beds or trains of sand and clay, thus

DESCRIPTION OF THE WASHINGTON QUADRANGLES.

GEOGRAPHY.

GENERAL RELATIONS.

Area and position.—The Washington quadrangles include the District of Columbia and adjoining portions of Virginia and Maryland between the parallels 38° 45′ and 39° north latitude and the meridians 76° 45′ and 77° 15′ west longitude. Of Virginia the counties represented are Alexandria and part of Fairfax; of Maryland, parts of Prince George and Montgomery.

The area represented by the map, 455 square miles, comprises two quadrangles, each of which extends through 15 minutes of latitude and 15 minutes of longitude. Together they form one-eighth of a square degree. The dividing line between them, the meridian of 77°, passes through the eastern part of the city of Washington. They are distinguished as the East Washington and West Washington quadrangles, and in this description their combined area will be referred to as the Washington quadrangles.

PHYSIOGRAPHIC DIVISIONS.

Within the Washington quadrangles are portions of two physiographic divisions, or areas which are marked by general surface aspects recognizable throughout each division. The Piedmont Plateau is the northwestern and higher division, and its characteristic uplands stretch across the northwestern half of the West Washington quadrangle. The Coastal Plain is the southeastern and lower division. Its aspects are seen in the estuary of the Potomac and the elevated plains southeast of Washington, together with the terraced slopes connecting them.

From New York to Georgia these two divisions form a broad slope which descends from the Appalachian Mountains to and beneath the waters of the Atlantic. The boundary between the two divisions is very indefinite and is determined by the amount of erosion by the streams.

The higher, western portion of the region, the Piedmont Plateau, is underlain by very old rocks, which have passed through many changes of structure and position since their formation. The lower, eastern portion of the region, the Coastal Plain, is marked by unconsolidated sediments—gravel, sands, and clays—which lie in beds nearly as they were deposited. The older, crystalline rocks lie under the unconsolidated sediments and descend eastward beneath sea level. Below the points where the crystalline rocks pass beneath the waters the principal streams are sluggish and affected by the tides. Not far above such points falls appear and navigation is impracticable. To this is due the location of many large cities near the border of the two provinces, such as Trenton, Philadelphia, Wilmington, Baltimore, Washington, Richmond, and Petersburg.

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

Characterization of the Plateau.

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

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

Surface forms of the Piedmont Plateau.

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

Altitudes of the Piedmont Plateau.

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

Character of streams, Piedmont Plateau.

Coastal Plain.—The lands adjoining the ocean from New York to Florida rise gradually from beneath tide level into broad, tabular or gently rolling areas intersected by wide, terraced valleys. Originally the province was a smooth plain, covered with a thin sheet of sands and gravels, with its western portion recently uplifted from the sea. It has been trenched by the rivers which cross it, but large areas of the original plain remain between the valleys, and toward the west gradually rise to altitudes of a few hundred feet. To the east the margin of the continental plateau slopes gently far out under the sea, where it is finally terminated by the escarpment which descends into the Atlantic Basin. This submerged portion of the plain is a hundred miles wide near New York and gradually diminishes in width toward the south. As it rises above tide level it presents low, sandy shores with wide bars, often inclosing extensive sounds and bays. The larger rivers from Virginia to New Jersey are wide estuaries in the Coastal Plain, bordered near the sea by low flats and wide marshes, and by higher lands where the intervening plains rise to the west. The smaller streams usually head in the high lands of the old plain, and flow in valleys that are wide, owing to the incoherence of the Coastal Plain formations. The width of the Coastal Plain varies from a few miles on Long Island to 60 miles in New Jersey and 100 miles in Virginia and southward.

A plain of marine deposits modified by erosion.

Along its western margin some features of the topography change as the crystalline rocks rise to the surface and the soft, younger deposits of the Coastal Plain thin out. By a general rise the plain merges westward into the Piedmont Plateau and extends to the foot of the mountains, but in the elevated plateau the valleys also are deeper, and, owing to the hardness of the crystalline rocks, they are narrower and their sides are rocky. From Virginia northward the larger estuaries extend to and slightly beyond the line along which the crystalline rocks rise from beneath the Coastal Plain sediments. From northern Virginia to New Jersey there is also, along the western border of the Coastal Plain, a shallow trough, which is marked mainly by partial southwestward deflection of the Delaware and Potomac rivers and the head of Chesapeake Bay in their course across the Coastal Plain. This trough is apparently due to several slight oblique depressions in the surface of the original deposits, greatly deepened by erosion.

LOCAL TOPOGRAPHIC ASPECTS.

About one-fourth of the Washington quadrangles is in the Piedmont Plateau and about three-fourths are in the Coastal Plain. The higher lands to the west rise to altitudes averaging 300 to 400 feet, one small area being slightly over 500 feet. Farther east the higher plains slope gently eastward, from 300 feet near the center of the district to 200 feet near its eastern border. Originally the entire region was a relatively smooth plain, of which the fragments now remaining have an altitude of 500 feet 13 miles west of Washington and 200 feet south of Upper Marlboro, a general slope of about 10 feet to the mile. In the uplift and tilting of this plain there has been extensive denudation, especially in the higher lands to the north and west. Wide, terraced valleys have been excavated by the rivers and larger creeks, and the plain surface has been deeply invaded by the smaller branches. The valleys are wide in the Coastal Plain area on account of the incoherence of the materials in which they are eroded. In the Piedmont area they are narrower and rocky sided. The dominant feature of the district is the Potomac River, which flows out of a gorge in the Piedmont region into a wide valley and estuary just above Washington. Near the center of the quadrangles the Potomac River is joined by a small branch, the Anacostia River, which flows from a district in which the plateau and higher terraces have been widely eroded to rounded hills of moderate elevation.

Altitudes of the tilted slope.

Relations of the valleys.

In the eastern portion of the quadrangles are the headwaters of the Western Branch of the Patuxent River, in a terraced depression which has deeply invaded the general high-level plateau.

The city of Washington occupies a broad triangular area at the confluence of the Anacostia and Potomac rivers, its western portion extending a short distance up the Potomac gorge. There are two principal series of terraces of the Potomac Valley—a lower series, on which the greater portions of Washington and of Alexandria are built, and a higher series, the two series being separated by steep slopes. The lower series has an average altitude of 90 feet about Washington, and borders the Potomac estuary with a width of from 1 to 3 miles. Southward its altitude gradually decreases to 60 or 70 feet. It extends as a narrow, discontinuous shelf along the northern side of the Potomac gorge to Great Falls, and increases in altitude in that direction to 145 feet. It also extends far up the Anacostia Valley and its branches, and up the many small branches of the main Potomac Valley.

Terrace systems about Washington.

On the higher terrace is built a portion of the northern suburbs of Washington, notably Mount Pleasant; and this terrace is found in a series of wide areas southwest of Washington and west of Alexandria and in the summits of some narrow ridges along the eastern side of the Potomac estuary. The heights representing it about Washington average 200 feet, but southward they gradually descend. To the west they rise, notably west of Alexandria, where they attain elevations of from 240 to 270 feet at the base of the steep slopes by which they are separated from a higher, older plain. Small fragments of this terrace system are found far up the valleys of Rock Creek and Henson Creek, up the Potomac gorge, and in the hills adjoining the Anacostia depression.

GEOLOGY.

THE GENERAL GEOLOGIC RECORD.

The formations which appear at the surface of the Piedmont Plateau and the Coastal Plain form two very distinct groups corresponding with the geographic divisions. The rocks of the Plateau comprise igneous, crystalline, and sedimentary bodies, all more or less altered since their materials were first brought together. The formations of the Coastal Plain are wholly sedimentary and have been little consolidated or altered in position since they were deposited. The Piedmont rocks are ancient, some of them going back to the earliest-known period, while the Coastal Plain deposits are all relatively modern.

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

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

The modern formations of the Coastal Plain consist in the main of gravel, sand, clay, and marl. Only rarely have these been consolidated into stone, and they now lie in layers nearly as horizontal as when deposited. The gravel, sand, and clay of the Coastal Plain represent nearly the condition of the Juratrias and older sediments as the latter were originally formed.

From the relations of the formations to one another and their internal structures many events in their history can be deduced. Whether the crystalline rocks were formed at great depth or at the surface is shown by their structures and textures. The amount and nature of the pressure sustained by the rocks are indicated in a measure by their folding and metamorphism. The composition and coarseness of the sediments indicate the depth of water and distance from shore at which they were produced. Cross bedding and ripple marks in sandstones indicate strong and variable currents. Mud cracks in shales show that their areas were at times above and at times below water. Red sandstones and shales like those of the Juratrias resulted when erosion was revived on a land surface long subject to decay and covered with a deep residual soil. Limestones show that the currents were too weak to carry sediment or that the land was low and furnished only fine clay and substances in solution. Many gravels of the Coastal Plain kind indicate violent action of strong currents during their formation.

The rocks themselves thus yield records of widely separated epochs from the earliest age of geologic history to the present. The entire record may be summarized as follows, from the oldest formation to the latest.

Earliest of all was the production of the great bodies of Carolina gneiss. Its origin, whether igneous or sedimentary, is buried in obscurity. It represents a complex development and many processes of change, in the course of which all original characters have been obliterated. The gneiss is, however, distinct from and much older than any other formation yet identified on the Plateau, and the time of its production is the earliest of which we have record.

During succeeding epochs masses of igneous rock were forced into the gneiss. The lapse of time was great, the nature of the igneous rocks changed repeatedly, and later intrusive masses were forced into the earlier. The granitic texture of some of the formations and the lamination and schistosity of others were produced at great depths below the surface.

Upon these once deep-seated rocks now rest lavas which poured forth upon the surface in pre-Cambrian time. Thus there are in contact two extremes of igneous rock — those which consolidated at a considerable depth, and those which cooled at the surface. The more ancient crystalline complex had therefore undergone uplift and long-continued erosion before the period of volcanic activity began. The complex may safely be referred to the Archean period. Whether these ancient lavas represent a late portion of the Archean or are of Algonkian age is not certain. The latter, however, is more probable.

Next, after a period of erosion, the land was submerged, and sandstones, shales, and limestones were laid down upon the older rocks over much of the Piedmont area. Remnants of these strata are now infolded in the crystallines, and the portions thus preserved from erosion cover large areas of the Plateau. The submergence which caused their deposition began at least as early as the beginning of Cambrian and extended at least into Silurian time. It is possible that the beginning was earlier and the end not until the close of Carboniferous time; the precise limits are not yet known.

These strata comprise conglomerate, sandstone, slate, shale, limestone, and allied rocks in great variety. They were far from being a continuous series, for the land was at times uplifted and certain areas of fresh deposits were exposed to erosion. The sea gradually advanced to the east, however, and land areas which furnished sediment during the early Cambrian were covered by later Paleozoic deposits. As the sediments now reach nearly across the Plateau at the latitude of Washington, the principal land body at the end of the Paleozoic was where the Atlantic Ocean now lies. Farther south it is probable that land existed over much of the eastern portion of the Plateau. This deposition was probably terminated by the same period of uplift and deformation which ended Appalachian sedimentation farther west. The rocks of both regions were deformed by the same general forces and suffered practically all of the folding and metamorphism which they now exhibit.

After a long interval the Mesozoic sediments followed the Paleozoic. The first of these constitute the Newark formation of the Juratrias period. It consists of shale, sandstone, and conglomerate, of a prevailing red or brown color, and it outcrops in disconnected areas ranging from Massachusetts to North Carolina. While its extent was originally much greater than at present, it is probable that it was not deposited over the whole of the Piedmont region, but in separate basins or estuaries.

During and after this deposition eruptions of lava took place. In some cases the lava poured forth in beds upon the sediments and in some cases it broke through or forced itself between the strata. The epoch was closed by movements which raised the Newark basins above the sea, tilted the strata, and established a continent where had been the sea of the Paleozoic era.

The succeeding strata of the Mesozoic system in the Piedmont region constitute the Potomac formation, which as a whole is assigned to the Cretaceous period, although vertebrate fossils of Jurassic types occur in the lowest portion. These strata consist of gravel, sand, and clay and are unconsolidated, except in rare cases. The beds dip slightly toward the southeast, but, as compared with preceding formations, they are nearly flat. The Potomac formation extends eastward from the Piedmont Plateau into and beneath the Coastal Plain.

The later Cretaceous sediments and the series of Neocene and Pleistocene strata record gentle oscillations of sea level associated with uplifts of the Appalachian and Piedmont regions. The amount of uplift varied from place to place and was greatest in the central parts of the Appalachian Province. Thus the accumulated uplift toward the northwest and subsidence toward the southeast tended to fix the areas of land and sea in their present relations. The waste from the rising land formed the sediments of the Coastal Plain. The details of the oscillations and the resulting sediments are summarized later under the heading "Coastal Plain area."

LOCAL GEOLOGY.

General character of the rocks.—The rocks of the Washington district, like those of the adjoining regions, are divisible into two classes, the ancient and highly crystalline rocks, and the unconsolidated formations of the Coastal Plain. The former occur, for the most part, northwest and southwest of Washington, and the latter lie to the east and south. Among the crystalline rocks are found gneiss, schist, granite, diorite, gabbro, peridotite, pyroxenite, and rocks derived from these by metamorphic action, such as granite-gneiss, diorite-gneiss, metagabbro, serpentine, and soapstone. The unconsolidated formations comprise gravel, sand, loam, marl, and clay.

The difference in age between these two groups of formations is very great. The oldest rocks of the region are the mica-gneiss and mica-schist of the early Archean. Long after they had attained practically their present aspect, later Archean rocks, such as the granite, were formed. An immense interval, probably lasting into the Algonkian period, then ensued before the appearance of the volcanic formations, which are represented immediately outside of these quadrangles. Of the succeeding periods, in the Paleozoic and the Mesozoic, no record is found in this area. With the Cretaceous gravels, sands, and clays the record begins again, and for succeeding periods is fairly full and well preserved.

Very great difficulty is encountered in mapping the Archean formations owing to their deep weathering at the surface of the old plains. On the uplands, where these surfaces are least modified, solid rock is very seldom found, and it is only where the streams have removed the weathered material that fresh rock can be seen. Near the heads of the streams there are considerable upland areas in which it is probable that many details of distribution of the formations will remain undiscovered, except as road cuts and excavations may expose them. The formations will be described in order of age, as nearly as their relations have been determined.

PIEDMONT PLATEAU AREA.

ARCHEAN ROCKS.

Carolina gneiss.—This formation occupies about one-fourth of the area of crystalline rocks, and lies in one large area in the northwestern portion of the quadrangles. Its character is well exhibited along the gorges of the Potomac and the small streams. The formation is composed of alternating layers of gneiss and schist of a prevailingly gray color, dark bluish gray where fresh, and greenish or yellowish gray where weathered. Individual bands vary from a few inches up to several feet in thickness, with an average of perhaps less than a foot. Both kinds of layers are highly siliceous and are composed mainly of quartz, orthoclase and plagioclase feldspar, muscovite, and biotite. In places the rock contains numerous small crystals of garnet. Quartz and mica predominate in the mica-schist, and quartz and feldspar in the mica-gneiss, some of the latter having the aspect of a fine granite. Certain layers of the gneiss are to be seen in which the quartz and feldspar bodies have the appearance of sedimentary pebbles, a resemblance which is probably deceptive. These individuals are usually round; occasionally, however, they are flattened into "eyes." They seldom have a diameter greater than one-fourth of an inch. The original nature of the gneiss, whether igneous or sedimentary, is quite unknown. The thickness of the formation can not be determined in any way because there are no distinctive beds, but, judging from the large areas which the formation covers, its thickness is doubtless many thousands of feet.

Under the influence of weather the rock yields very slowly; gradually the feldspar disintegrates and leaves the quartz and mica to be broken up by rain and frost. The durability of the rock is manifest in the fact that ledges appear even on the uplands, and that quantities of schist fragments appear in the soils. Complete disintegration of the rock produces a red or reddish-brown clay. The soils of this formation are light and well drained, owing to the large proportion of mica and quartz in them, and are readily washed away on hillsides. Except with favorable surroundings and good tillage, the fertility of these soils is below the average in this region.

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

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

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

From the fact that the formation was granite, its eruptive nature can be inferred. This is also shown in detail by the inclusion of foreign fragments, which appear in many places near the borders of the mica-gneiss, and also in other situations through the body of the formation.

These inclusions are usually banded and identical in appearance with the mica-gneiss. Some of the inclusions show no banding, but resemble the fine granitic layers of the mica-gneiss. The presence of narrow tongues of the granite-gneiss in the mica-gneiss points to an eruptive nature for the granite-gneiss, but the great metamorphism has so obscured the contacts that they are not conclusive. A somewhat later date than the main intrusion is perhaps possible for some of the granite-gneiss bodies in which the amount of schistosity is small. In several places, for instance west of Annandale and southwest of Bethesda, the contacts of the massive and schistose granite are sharp, suggesting that the massive granites are intruded into the other. At Fourmile Run, above Arlington, also, a massive granite cuts through the beds of schistose granite. These more massive bodies may be part of the granite-gneiss of slightly later age, or may be of the age of the biotite-granite, which is considerably younger.

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

Diorite and diorite-gneiss.—There are many areas of this formation in the quadrangles. The largest extends north and south through Cabin John; a second large area passes north from Georgetown, and a number of small areas are scattered over the Piedmont Plateau, most of them being north of the Potomac. The greater part of the formation consists of diorite which contains a large amount of hornblende. Associated with this and classed in the same formation is a series of quartz-diorites and hornblende-granites. The granitic aspect of this rock is perhaps more prominent south of the Potomac than it is north of the river. The different varieties are closely associated with one another, sometimes in the same rock mass, and it is quite impracticable to represent them separately on the map. The igneous nature of the formation is shown by its internal composition and structure, as well as by the inclusions of foreign fragments and the eruptive contacts which the smaller bodies form with adjacent rocks. Inasmuch as the diorite cuts through the Carolina gneiss and the granite-gneiss, it is the youngest of the three.

The diorite is a massive greenish-gray or black rock which becomes lighter colored by weathering. Near the borders of the large diorite bodies the rock is more basic and contains a greater proportion of hornblende. This preponderance of hornblende occurs in most of the smaller areas of of the formation, and seems to be due to the proximity of the adjoining formation. With an increase of hornblende the green color is more pronounced, while in the granitic varieties the predominance of feldspar and quartz gives a lighter-gray color. The minerals composing the diorite are plagioclase, hornblende, biotite, and a little quartz and orthoclase. In connection with these, rutile, sphene, and epidote are not infrequent. These minerals occur in crystals of medium size, and their texture is very uniform throughout large masses.

Metamorphic action has produced the same structures in this rock as in the granite-gneiss. The commonest of the secondary minerals are hornblende, biotite, and chlorite. By their parallel recrystallization the rocks have obtained a marked gneissoid aspect. The hornblendic and chloritic schists and gneisses thus produced are most noticeable in the small diorite bodies, and along the borders of the large masses the most basic, chloritic portions strongly resemble the metagabbro which lies in the adjoining areas.

Inasmuch as a large portion of this formation lies near the Potomac River and the large creeks, fresh rock is frequently seen; on the uplands, however, decay is deep and outcrops are very rare. The more basic diorite breaks down by disintegration of the hornblende and feldspar, producing spheroidal masses, which finally crumble into small bits. Complete decomposition produces a brown or brownish-red clay, with light, strong, and fertile soils. The more quartzose diorites and hornblende-granites of the formation produce in the end clays and soils of the same character, with a larger proportion of quartz grains. In the intermediate stages of decay, however, the spheroidal form of weathering seldom appears, the disintegration proceeding uniformly through the rock. The hornblende-schists and gneisses yield most slowly to weather, and give rise to large quantities of slabs and flakes of little-decayed rock scattered through the residual clays. The final products of clay and soil are practically the same as for the preceding varieties.

Gabbro and metagabbro.—Three areas of little-altered gabbro appear in the quadrangles. With the largest of these, northeast of Cabin John, is associated an area of much-altered gabbro, or metagabbro. Gabbro is a massive rock of a generally dark-gray or black color. It consists of plagioclase, hypersthene, diallage, hornblende, muscovite, and apatite. In the alteration to metagabbro metamorphism of the rock was extensive. Partial recrystallization produced green hornblende from hypersthene and diallage. The secondary minerals are mainly hornblende, chlorite, and biotite; to these are added more siliceous products, such as secondary quartz and feldspar. In the final stages of alteration other less common minerals appear, such as epidote, zoisite, garnet, and rutile. The minerals have a decided parallel arrangement, and the rock is a schist or gneiss which can only with difficulty be distinguished from the more basic varieties of diorite-gneiss.

The unweathered gabbro is a dense black rock of granular texture and extreme toughness. This weathers into round bowlders and lumps with dark rusty surfaces. The color of the metagabbro when fresh is a dark olive green, and it becomes a lighter green or greenish gray on decay. Its weathered blocks are more flattened and angular than those of the gabbro, on account of the schistose partings. The dark-red and brown clays of both altered and unaltered varieties form soils which are deep and rather heavy, but strong and fertile.

Peridotite and pyroxenite.—In this district small areas of highly metamorphosed rocks—soapstone and talcose schist—occur, which are probably derived from pyroxenite and peridotite. Similar rocks of like origin occur in other areas of the Piedmont Plateau. None of them form large bodies and their outcrops have a lenticular shape. Their close association with the eruptive rocks, especially the basic ones, suggests a like nature and age for them all.

The present composition of these rocks is largely the result of metamorphism during deformation, which was specially active in rocks of their original composition. The soapstone, consisting chiefly of impure talc, was probably derived from pyroxenite, composed of plagioclase and pyroxene. Rocks of more complex original nature are perhaps represented by the talcose schists. Soapstone masses are common around the gabbro areas, and many intermediate rocks indicate original transitional forms between the two types.

Very little effect is produced by weather upon these rocks. Their lumps and ledges, mingled with a stiff, yellow or red clay, strew even the most deeply decayed surfaces. These soils are of very little value even where they are of considerable extent.

Granite.—Three classes of granite occur in this area. The most prominent kind is that already described under "Granite-gneiss;" a second is represented by a series of granite dikes which cut the Carolina gneiss here and there throughout its area; and a third variety, less schistose and micaceous, occurs in a belt running north from Georgetown.

The granite dikes are of frequent occurrence in the gneiss, but they are not of sufficient size to be represented on the map. Their similarity in composition to the third type of granite suggests a similar age. They vary from a few inches in thickness up to 10 or 15 feet, and they cut very irregularly through the Carolina gneiss. In color they are a very light gray, weathering out almost white. Quartz and orthoclase feldspar make up nearly the whole body of the rock; plagioclase feldspar and muscovite are usually present in very small amounts. Variations in grain are considerable, and the rock is in places almost a pegmatite; in other places its crystals can barely be seen by the unaided eye. The products of this rock which result from metamorphism and weathering are of small importance, owing to its limited extent.

The third type of granite is exposed in two belts in the basin of Rock Creek; its character is well shown in the quarries on Broad Branch. The rock is a moderately coarse aggregate of quartz and orthoclase, with some plagioclase and biotite. It is very siliceous, and the scattered flakes of biotite do not take away the marked light color produced by the excess of feldspar and quartz. The biotite is very noticeable, however, on account of the large size of its flakes and its contrast with the color of the rest of the rock. Weathering reduces the color of the rock to dull light gray.

A gneissoid structure marked by parallel arrangement of the biotite flakes has been developed to a considerable degree in this rock. The structure is not so well developed as in the adjoining granite-gneiss, for the separate biotite flakes are only approximately parallel and lie in rather wavy planes. Nor does the rock exhibit layers and zones of extremely schistose material, such as occur in the granite-gneiss. On account of the distinctness of the biotite particles, however, their parallel arrangement appears to be more decided. The microscope reveals the process of fracture and recrystallization into new minerals.

While this rock is well distinguished from most of the granite-gneiss by its coarser grain and lighter color, yet its resemblance in both these respects to some of the less schistose parts of the granite-gneiss suggests that the two might have had a common origin, but since this granite plainly cuts through the other formations this probably is not the case. The eruptive nature of the granite is evident from its relations to other formations. At many places, and especially along the electric railroad cuts west of Rock Creek, there are admirable exposures where the granite has been forced into the diorite and granite-gneiss. Inclusions of diorite are contained in the granite. Similar eruptive phenomena characterize the eastern boundary between the granite and the granite-gneiss.

After long exposure to weather this granite becomes a crumbling mass of quartz, mica, and disintegrated feldspar. The weathering process extends to great depths, so that fresh rock can be seen only near stream gorges and in deep cuts. The granitic texture of the disintegrated rock, however, shows in most places not far below the surface because of the resistant nature of the quartz and biotite. A yellow or brown sandy clay results from complete decomposition. Soils on this formation are loose and well drained, but are liable to wash in steep places. In no place do they exhibit any special fertility.

COASTAL PLAIN AREA.

General relations.—The materials of the younger formations about Washington are, as has already been stated, mainly sands, clays, loams, gravels, diatomaceous clays, and marls. They are comprised in nine formations, which extend in age from early Cretaceous to the present time. Each of the formations, except one, represents an epoch of submergence and deposition which followed an interval of uplift and erosion. The names, general characteristics, and dates of the formations and a brief statement of the nature of the erosion intervals are given in the following table. The sequence in time is obtained by reading from the bottom upward.

Table of formations and erosion intervals for the Coastal Plain deposits.

Formations and erosion intervals.	Nature of formations and of erosion intervals.	Dates.
POST-COLUMBIA.	Alluvium (mainly below tide water), marsh, talus, and débris on slopes.	Recent Pleistocene.
Erosion interval.	Dissection of later Columbia terraces and development of present topography.	Later Pleistocene.
LATER COLUMBIA.	Gravels and loams on lower terraces; maximum thickness, 25 feet.	Early Pleistocene.
Erosion interval.	Trenching of earlier Columbia terraces.	Early Pleistocene.
EARLIER COLUMBIA.	Gravels and loams on high terraces; thickness, 20 feet.	Early Pleistocene.
Erosion interval.	Trenching of Lafayette plain; development of outlines of present topography.	Early Pleistocene.
LAFAYETTE.	Gravels, sands, and loams on extensive plain; thickness, 20 to 30 feet.	Pliocene (?)
Erosion interval.	Widespread and relatively complete planing on Coastal Plain and Piedmont region.	Pliocene.
CHESAPEAKE.	Fine buff sands, clays, and diatomaceous deposits; thickness, 0 to 80 feet.	Miocene.
Erosion interval.	Planing of surface of preceding formations.	Eocene.
PAMUNKEY.	Glauconitic sands and marls; thickness, 0 to 120 feet.	Early Eocene.
Erosion interval.	Planing of surface of preceding formations.	Later Cretaceous.
MONMOUTH.	Brown sands; thickness, 0 to 25 feet.	Later Cretaceous.
MATAWAN.	Black argillaceous carbonaceous sands; thickness, 2 to 30 feet.	Later Cretaceous.
Erosion interval.	Planing of surface of preceding formations, with deposition of Magothy formation to the northeast.	Middle Cretaceous.
POTOMAC.	Clays and sands; thickness, 0 to 650 feet.	Early Cretaceous.
Great erosion interval.		

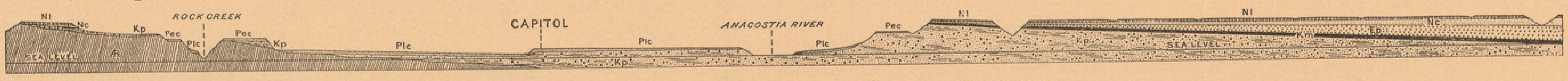


FIG. 1.—GENERALIZED NORTHWEST-SOUTHEAST CROSS SECTION THROUGH WASHINGTON.

Shows the relations of the Coastal Plain formations, and the arrangement of the terraces. Æ, Archean; Kp, Potomac formation; Km, Matawan formation; Ep, Pamunkey formation; Nc, Chesapeake formation; Nl, Lafayette formation; Pec, earlier gravels of Columbia formation; Plc, later gravels of Columbia formation. Horizontal scale, approximately, 1 inch=1 mile. Vertical scale, 1 inch=1000 feet.

The general structural relations of these formations are shown in fig. 1. It will be seen from this generalized section that all but the two younger sedimentary formations constitute a flat wedge lying on an east-sloping floor of crystalline rocks. They are arranged in widely extended sheets which lie one above the other and dip and thicken to the southeast. The formations come to the surface in succession to the west and northwest, but there is considerable overlapping, especially of the Lafayette and Chesapeake formations, which extend locally to and over the crystalline rocks. The two members of the Columbia formation cover terraces in the larger valleys, the earlier deposits being on the higher terrace.

CRETACEOUS PERIOD.

Potomac formation.—This formation occupies the surface over a wide area in the Washington district. In the terraces along the Potomac and Anacostia rivers it is overlain by the Columbia formation, and in the high terraces west of Alexandria and in the northern portion of Washington by the earlier member of that formation. To the eastward it passes beneath the later Cretaceous and Neocene formations. It lies directly on the eastward-sloping floor of crystalline rocks. Along its western edge it extends far westward along the higher ridges, but has been eroded from the crystalline rocks in the intervening channels. West of its main edge there are a number of thin outlying areas of the formation, which have been disconnected by erosion. The largest masses are in the ridge west of Rock Creek and in the high lands west of the earlier Columbia terraces, west of Alexandria. These outliers are overlain to a greater or less degree by the outliers of the Lafayette formation. The slope of the crystalline floor averages about 110 feet to the mile, and the thickness of the Potomac formation amounts to 650 feet where it passes beneath the Matawan formation east of Anacostia. The component beds of the formation abut against the crystalline rocks and the lowest members are those at its base farthest to the east. Higher beds overlap westward, but the westernmost portions doubtless are far below the top of the formation as originally deposited.

The Potomac deposits are mainly clays and sand, both in separate masses and in all proportions of admixture. The formation varies greatly in character throughout, but the variations are so irregularly distributed and distinctive outcrops are so few that it has not been subdivided on the map. The basal and marginal portions are usually coarse arkose sands containing decomposing feldspar, mica flakes, quartz, quartzite, and clay pebbles. These pebbles, at the contact with the crystalline rocks, are often cemented by limonite into irregular conglomeratic masses a few inches in thickness. Quartz pebbles are usually sprinkled through the sands, and sometimes constitute small local lenses. The marginal sands contain streaks of finer sands and sandy clays at some localities, and in rare instances these clays extend to the crystalline rocks. North of Takoma the marginal beds are sandy clays which contain large amounts of quartz fragments and pebbles. There are many extensive exposures of the sands. The notable exposures are at the head of Sixteenth street, northwest Washington; in old excavations for a branch electric railroad to the east side of the Zoological Park; at Arlington station, on Fourmile Run; on the Ridge road, and on Pierce Mill road, just west of Mount Pleasant. At the last-mentioned locality there is an especially heavy bed of gravels and bowlders at the margin of the formation. The marginal sands merge upward and eastward into clays and finer sands. In Virginia they give place to dark-green and brown, sandy, laminated, fissile clay, which extends continuously through the center of the area and is locally a well-defined series. This series is finely exposed in the cuts of the Pennsylvania Railroad north of Franconia. In the District of Columbia and Maryland the marginal sands give place to heterogeneous mixtures and alternations of light-colored clays and sands, which continue to the eastern outcrops of the formation. Clays and sandy clays predominate, especially in the region east of the Anacostia River, and the purer sands are in lenses of no great extent. Clays predominate in the upper members to the northeast. The sands are usually white or gray, are often cross bedded, and vary from moderately coarse to fine. The clays present a great variety of colors, of which buff, white, pink, red, gray, and yellow are the most common, but occasional masses of dark carbonaceous clays and lignites occur. The colors are banded, mottled. and reticulated through the clays, and mottling and frequent alternations of color are general. The cuts of the Pennsylvania Railroad from near Landover to Bowie afford many fine exposures of the clays, and they outcrop widely in the adjoining region. In the Baltimore and Ohio Railroad cut near Rives there are extensive exposures of clays and a lignite bed, of somewhat lower horizon in the formation than those eastward. About Petworth and at Terra Cotta and Lamond there are lenses of nearly pure clays bearing iron ores, inclosed in sands not far above the crystalline rocks. The Potomac members immediately underlying the Matawan formation are mainly very pure clays of bright pink or buff color, but in the northern side of the ridge between Anacostia and Oxon Run there is locally an intervening lens of moderately fine-grained sands. This sand contains thin streaks and small balls of pure gray clay and a few scattered quartz pebbles. It has a length of about 2 miles and attains a thickness of 70 feet. Below and laterally it merges into clays. Fossil plants, mainly tree trunks in a lignitized condition, occur in some of the clay beds of the Potomac formation in the Washington district.

In the northeast corner of the Washington quadrangles there are several thin, discontinuous masses of sands and brown sandstones lying next below the Matawan formation, which may be regarded as representatives of the Magothy formation, but the evidence is not sufficient for mapping them as distinct from the Potomac formation. They are sharply separated from characteristic Potomac clays, sands, and white sandstone by a clear unconformity, and are strongly demarked from the overlying Matawan beds. The maximum thickness is about 20 feet. The more conspicuous exposures are in the hills a mile east of Glenndale station and in the cut of the Pope Creek Branch 2 miles north of Collington. The greater part of the material is a brown sandstone containing scattered pebbles and coarse laminated sands of light color. The cut north of Collington exhibits the irregular unconformable contact with the Potomac sandy clays, with sharp separation of materials, and the relation to overlying partly weathered Matawan beds is plainly exposed a few feet above and to the southward.

Matawan formation.—The narrow outcrop of this formation extends diagonally from near Collington southwestward across the eastern half of the East Washington quadrangle. It extends for some distance down the depressions of the headwaters of the Western Branch and occurs at scattered points in the Oxon Run and Henson Creek valleys and their branches. Near Collington the formation is succeeded by the Monmouth beds. At all other places, except in Good Hope Hill, where there is an overlap of the Chesapeake the Matawan is unconformably overlain by the Pamunkey formation. It lies unconformably upon an irregular, eastward-sloping floor of Potomac formation.

The deposits consist of moderately fine beach sands containing much carbonaceous material, clay, small flakes of mica, and occasional sprinklings of glauconite. On weathering its color lightens to a dull gray, quite distinct from the warm brownish or greenish-gray aspect usually presented by the weathered Pamunkey beds. The thickness averages about 30 feet, but decreases to 4 feet in Good Hope Hill, and the material is there very argillaceous. It is sharply demarked from the Potomac clays and sands by its dark color and very different composition, and there are many exposures of its basal contact. It may always be distinguished from the overlying Pamunkey beds, unless the exposure is deeply weathered.

The Matawan deposits contain abundant casts and impressions of molluscan fossils at every locality, and several exposures have been found in which the shells remain. The most notably of these are in the gullies a mile north-northeast of Oakland and a mile due southwest of Brightseat. They were also found on the east side of the Fort Foote ridge and on the opposite side of Broad Creek, near the line of the southern border of the East Washington quadrangle. Excellent exposures in which only casts occur may be observed in a large gully near the road 2 miles southwest of Grimesville; in many gullies along the northern side of the high plateau north of Oakland, and in many road cuts from Buena Vista to the railroad cut at Collington. On the road leading from Good Hope to Twining there is an exposure of the attenuated western edge of the formation lying on Potomac gray sands and overlain by a thin eroded edge of weathered Chesapeake deposits.

Monmouth formation.—A small area in the northeast corner of the Washington quadrangles is occupied by the Monmouth formation. It extends into the area from the eastward and thins out in the hill slopes about 2 miles west of Collington. The material is brown sand of moderate fineness. Its greatest thickness, which is in the vicinity of Collington, is about 25 feet. It appears not to be sharply separated from the underlying Matawan formation, but in fresh exposures it is seen to have unconformable contact with the overlying Pamunkey formation.

EOCENE PERIOD.

Pamunkey formation.—The Pamunkey deposits occupy a wide area east of Washington, where they are in greater part overlain by the Chesapeake and Lafayette formations. They appear at the surface over a wide area extending from Upper Marlboro to beyond Collington. In their unweathered condition the beds are a bluish- or greenish-black marl, consisting of moderately fine sand mixed with more or less carbonate of lime, organic matter, clay, glauconite, and molluscan shells. There is considerable local variation in composition, and all the above-mentioned ingredients are not everywhere present, nor present in equal amounts in all the beds. On drying the color lightens somewhat and the glauconite shows as clear green grains. On weathering the material becomes gray, buff, or reddish sands, and in the region drained by the upper waters of the Western and Collington branches, where it is not protected by the Chesapeake formation, this weathered phase is general. The weathering has been attended in most cases by secondary deposition of oxide of iron (limonite), in crusts, nodules, and reticulating streaks.

The fresh glauconitic marls are frequently exposed in the many gullies leading out of the plateau region east of the Anacostia and Potomac rivers, and they usually contain an abundance of fossil shells of about fifteen Eocene species. The most noteworthy exposures of these fossiliferous marls are north of Oakland, south and east of Seat Pleasant post-office, along the lower branches of Henson Creek and of Oxon Run, and along the Western Branch for several miles above Upper Marlboro. One of the best exhibitions of the contact relations with the Matawan formation is in a road cut a few miles south of Buena Vista crossroads, where the basal Pamunkey beds are pebbly for a slight thickness. Often, however, there is considerable Matawan débris in the bottom of the Pamunkey and the separation is not clear. In the region adjoining the Western Branch and the Charles Branch there is, near the upper part of the formation, a thin layer of pink clay, which is exposed in many stream and road cuts, notably near Upper Marlboro. Underlying Upper Marlboro and extending for some distance up the valleys of the Western and Collington branches there is a silicified bed of marl which lies about 75 feet below the pink clays. It is a very hard rock containing many shells. Its thickness varies from 4 to 7 feet.

The thickness of the Pamunkey formation increases from a feather edge on the eastern side of Good Hope Hill to at least 150 feet at Upper Marlboro. As its base passes below tide level to the southeastward and its depth is not precisely known, the maximum thickness could not be determined. In the region east of Woodmoor the amount is 100 feet; west of Collington it is not over 60 feet.

NEOCENE PERIOD.

Chesapeake formation.—The sand and clays of the Chesapeake formation occupy the greater part of the high plateau southeast of Washington. Most of its area has a capping of the Lafayette formation. The formation is abruptly cut off by the Potomac and Anacostia valleys in the high bluff east of Washington, but small masses remain under the Lafayette gravels in the outliers of the higher terrace level at Soldiers Home Park and between Georgetown and Tenley. To the east the formation lies on the Pamunkey formation, but near the Anacostia River it overlaps on the Matawan, and north and west of Washington it lies on sands of Potomac age.

The Chesapeake materials are mainly very fine sands with variable proportions of diatomaceous remains and clay. In their unweathered condition the beds are usually very compact, dark gray to olive green in color, and massively bedded. Surface outcrops consist of soft, meal-like sands of gray or buff color, often with fine laminations, brought out by narrow, discontinuous, darker-buff streakings. Diatomaceous remains are nearly everywhere present and are important constituents of the formation. The beds containing a large proportion of diatomaceous remains are usually of very light weight, pale-buff color, and chalky texture. Some clay beds occur, notably in the eastern part of the District of Columbia. They are in greater part very dark olive green in color when wet, but weather to dark-gray tints. The light-colored, soft sands are also conspicuous in the same region, but these predominate farther east, where they are often finely exposed in road cuts in depressions. The outlying areas west and north of Washington consist of buff-colored, finely laminated, meal-like beds and contain relatively little clay and but few diatom remains. They are overlain by the red loam gravels of Lafayette age, which are finely exposed in contact at several points. The formation is usually fossiliferous, but in this vicinity the remains are casts and impressions so far as observed. Very hard, siliceous concretions, sometimes several feet in length, occasionally occur in the formation in the eastern portion of the region.

In the basal portion of the Chesapeake beds there are usually a few inches of gray gravelly sands lying directly on glauconite marl of the Pamunkey formation, and there are similar beds at the contact with the Matawan formation in Good Hope Hill and with Potomac deposits in the outliers west and north of Washington. In some of the basal beds east of Washington there are bones and pebbles of Eocene and Cretaceous fossils. The plane of demarcation between the Chesapeake and underlying formations is always conspicuously sharp. It gradually slopes upward from 100 feet about Upper Marlboro to 240 feet in Good Hope Hill, 270 feet at Soldiers Home, and 320 feet at Rock Creek. The thickness gradually increases eastward, amounting to about 100 feet at Upper Marlboro.

The most instructive exposures of the formation are in road and stream cuts about Upper Marlboro, at intervals around the northern and western face of the high plateau to Good Hope, in the upper part of Petworth, and in road cuts half a mile west-northwest of the Naval Observatory.

Lafayette formation.—This formation covers the wide, high plains southeast of Washington and caps the elevated area at Soldiers Home, the ridge extending from west of Georgetown to Tenley, and a number of hills on the Piedmont Plateau west of Alexandria. There are several very small outliers possibly of this age about Brightwood and Takoma. East of the Potomac and Anacostia rivers, about Soldiers Home Park, and for some distance west of Georgetown the formation lies on the eroded surface of the Chesapeake formation; farther west it lies on the Potomac formation and overlaps on the crystalline rocks. Its base is a plain which rises gradually from an altitude of 170 feet in the Upper Marlboro region to 300 feet nearer Washington, 400 feet in the high ridges west of Alexandria and Tenley, and 500 feet in Peach Grove Hill. This plain was originally continuous over the entire area of the Washington quadrangles. The deposits consist mainly of quartzite gravel and loams. The basal and marginal beds are in larger part coarse gravels and bowlders, usually stained buff or dull orange superficially and packed tightly in stiff loam and sharp sand. They generally merge upward into a few feet of orange loams, which constitute a fairly distinct member in all the wider areas. Eastward toward Upper Marlboro the gravels gradually decrease in size and the formation consists largely of buff loams irregularly streaked with gravel and coarse sand and containing Chesapeake sands. The thickness averages about 25 feet, but locally in the region southwest of Centerville it amounts to 40 feet. The most extensive exposures of the formation are in the gravel pits at Good Hope and near Suitland, Oakland, and Forestville, about the northern end of the Soldiers Home Park, and along the Tenley, Loughboro, and Ridge roads. The formation differs from the earlier and later Columbia deposits by the more homogeneous character of its gravel and bowlder beds and by its location on the highest terrace of the Coastal Plain.

PLEISTOCENE PERIOD.

Columbia formation.—The higher terraces of the Potomac, Rock Creek, Anacostia, and Patuxent valleys, which gradually decrease in altitude from 260 feet on the west to 100 feet on the southeast, are occupied by the earlier member of the Columbia formation. These terraces are most extensive west of Alexandria and in Mount Pleasant and the adjoining upper portions of the city of Washington. Along the slopes east of the Anacostia River, in the Potomac gorge, and in the Rock Creek depression the terraces have been cut away in greater part by the erosion of many small streams by which these slopes are intersected, but numerous small gravel-capped areas remain and indicate the original continuity of the formation in these areas.

The earlier Columbia member.

The earlier Columbia deposits consist of gravel, loam, and sand, and present somewhat more diversity in structure than is found in the later Columbia member. Usually there are basal gravels which merge upward into loams or sands. The basal beds generally contain a heterogeneous mixture of pebbles, bowlders, and subangular fragments of quartzite, quartz, and crystalline rocks, and more or less of the material on which the deposit lies. The materials vary from very small pebbles to masses 3 feet in diameter. They are usually not assorted and often lie with their larger diameters perpendicular. The proportion of quartzite is considerably greater than in the later Columbia member. The overlying loams vary in composition from very clayey to very sandy, and generally have less of the rich buff-brown tint which characterizes the later Columbia loams. Irregular streakings of clay and of sand are not unusual in the thicker masses. On the deeply eroded areas and smaller terraces the formation is usually represented by quartzite-gravel, sometimes in a discontinuous sprinkling over the subterrane. At the head of Sixteenth street, in the northwestern part of Washington, there are two series of loams and gravels, one upon the other, but this is a local feature which has not been observed elsewhere. There is also a conspicuous streak of pinkish sandy clay in the formation in that vicinity, and several large subangular masses of quartzite and crystalline rocks. A mile south of Anacostia a considerable portion of the lower beds of the formation is consolidated into a conglomerate with a ferruginous matrix, and the stone was used for part of the high fence at St. Elizabeth Asylum.

In the northern part of the city of Washington and up the valley of Rock Creek the altitude of the formation averages very nearly 200 feet above tide. The terrace rises steeply from the lower Columbia plain in the northern part of Washington and extends through Mount Pleasant to the foot of the hills a short distance north of Piney Branch and along the edge of the Soldiers Home Park. In the region west of Alexandria the earlier Columbia terrace gradually rises along a general slope, with several small steeper terrace scarps, from 125 feet to 290 feet. On the east side of the Potomac and Anacostia rivers it slopes from 200 feet on the north to nearly 100 feet in the vicinity of Fort Foote. In the Potomac gorge there are small outliers at intervals 3 and 4 miles west of Georgetown at altitudes of 250 to 270 feet. The top of the ridge at Georgetown is capped by the formation, to a moderate thickness, at an altitude of 180 feet. Up the Rock Creek Valley a large number of small fragments of the terrace are preserved on the many spurs into which the region is now cut, and these are usually capped by quartzite pebbles and accumulations of quartz fragments of greater or less thickness. The altitudes are approximately 200 feet and the terrace fragments beautifully define a general terrace which formerly extended up this depression. At the upper end of this terrace, near the District line, there is an extensive delta deposit of crystalline rock débris.

In the vicinity of Anacostia and for some distance northward there are many very small remnants of the earlier Columbia terrace deposits, at an altitude of 180 feet, on the long spurs of the highlands which rise steeply to the east, and there are also many small outliers in Henson Creek Valley.

The most extensive exposures of the formation are at the head of Sixteenth street, in the cut at the southern edge of the wide terrace of earlier Columbia date that extends to Mount Pleasant; in the upper part of the hollow south of Anacostia; along the Fort Foote road; in the gravel pits on Shuter Hill, west of Alexandria; in old gravel pits for the Southern Railroad just east of Springfield station; at Franconia station; at Baileys Cross Roads, and just south of Rosslyn. The gradual upslope of the formation to the west is due largely to tilting, but in part also to slope of the early Columbia valley. In the regions west and south of Alexandria and near Rosslyn there were some low terrace steps in the floor on which the formation was deposited and by these it rises from 40 to 70 feet.

The later Columbia member.

The lower terraces of the Potomac Valley and its larger branches and of the valley of the Western Branch of the Patuxent are composed of the later member of the Columbia formation, sloping from tide level to altitudes varying from 80 to 145 feet. About the city of Washington the more extensive Columbia terrace levels are at 40 and 90 feet above tide, and the Capitol is situated on the western edge of a prominent outlier of the 90-foot terrace. The formation exhibits its typical development in the District of Columbia, where it consists of two members: a lower series of gravel, which grades upward into a brown or buff, massive loam. The gravel is heterogeneous in character, comprising pebbles, bowlders, and subangular masses of various sizes, of quartzite, quartz, crystalline rocks and sandstones, in large part of local origin. They are irregularly packed in brown sand or loam and are rarely sorted or bedded. They often lie on end, as though dropped by floating ice. Streaks of coarse sands are not unusual. The loams are often fine, but they are frequently intermixed with sand and pebbly streaks and disseminated pebbles. Southward from Washington the later Columbia terraces border the river with widths varying from 1 to 2 miles and the materials as a whole become finer. The altitudes also decrease as the river is descended. In this region the lower portion of the loam becomes finer grained and lighter colored and the basal beds are mainly below tide level. At Alexandria the lower beds exposed are gray sands, but in the bluff at Fort Foote both pebble and loam members are seen lying on the Potomac clays. In the Anacostia Valley opposite and above Washington the formation consists mainly of brown sands with loamy and pebbly streaks, but at Washington these sands merge into loams and gravels of the typical phase. Along the northern side of the gorge of the Potomac above Washington there is a narrow shelf, gradually ascending westward to 145 feet above tide, which is capped at intervals by later Columbia gravels and loams. Up the valley of Rock Creek remain several small outliers of later Columbia gravels and loams on fragments of the 90-foot terrace. The principal one is occupied by a portion of the buildings of the Zoological Park. There are two small areas on the Pierce Mill road east of the creek, and there is a very small mass of gravel a short distance below Woodley lane bridge. In Georgetown the crystalline rocks are bared except in the vicinity of P and Twenty-seventh streets and at a few points near the river side, where the later Columbia formation remains.

Washington.

The lower terraces of the Western Branch of the Patuxent are capped by gravels and sands of the later Columbia member to a point about 6 miles above Upper Marlboro. They are underlain in this valley by the marls of the Pamunkey formation.

In the greater part of Washington and in the Potomac and Anacostia valleys to the east and south the Columbia deposits lie on the Potomac formation. In the region adjoining Rock Creek and westward up the Potomac gorge they lie on the crystalline rocks. In Washington and over a wide area in its vicinity the thickness of the formation averages from 20 to 25 feet. Of this amount usually about three-quarters are loam. The finest exposures are in street and railroad cuts in the eastern and northwestern sections of Washington; in the vicinity of Rosslyn; at intervals on the banks of the Potomac, and in the extensive clay pits between Washington and Alexandria. On Pennsylvania avenue extended, east of the Anacostia River, the Columbia loam is finely exposed abutting against an old shore of Potomac sandy clays at an altitude of about 85 feet.

Owing to subsidence now progressing in the region, alluvium is deposited mainly in tide water and is a surface deposit only on freshet plains and along small stream valleys, where its presence is relatively transient. Its distribution is not represented on the map, nor are the talus and wash materials on slopes. Marsh growth has kept pace with subsidence over a considerable area about Washington, and there are a number of marshes of greater or less size at intervals along the Potomac and Anacostia rivers in the Coastal Plain portion of the region. The extensive tide marshes of the Patuxent River extend to Upper Marlboro and for a short distance above. Along the Potomac at Washington a large area has been filled in with material excavated from the adjoining channel. This is represented as artificial on the map.

STRUCTURE.

Definition of terms.—Those rocks of the Piedmont Plateau which were deposited upon the sea bottom must originally have extended in nearly horizontal layers. A similar position was taken by the volcanic formations, which solidified in nearly level beds. At present, however, the beds or strata are seldom horizontal, but are inclined at various angles, their edges appearing at the surface. In the description of their positions certain terms are used which may be defined as follows:

The *strike* of a bed is the course which it would take if it intersected a horizontal surface. The *dip* of strata is the angle at which they are inclined from the horizontal. A bed which dips beneath the surface may elsewhere be found rising. A fold or trough between two such outcrops is called a *syncline.* A stratum rising from one syncline may often be found to bend over and to descend into another. A *fold* or arch between two such outcrops is called an anticline. A synclinal *axis* is that portion of a syncline along which any individual bed is lowest, and toward which the rocks dip from each side. An anticlinal *axis* is that portion of an anticline which throughout includes the highest portions of a stratum of the arch, and away from which the rocks dip on each side. The axis may be horizontal or inclined. Its departure from the horizontal is called the *pitch,* and is usually very much less than the dip.

In districts where strata are folded they are also frequently broken across and the parts are compressed until the arch is pushed up and thrust over upon the trough. Such a break is called a *thrust fault.* If the arch is worn away by erosion and the trough is buried beneath the overthrust mass, the strata exposed at the surface may all dip in one direction. They then appear to have been deposited in a continuous series. About the same effect is produced by a series of close folds, all parts of which dip in the same direction. Such arrangements of the strata are termed *isoclinal.* In faults such as are associated with the Juratrias area the break was directly across the strata which appear at the surface, and the parts upon either side were moved past each other in a nearly vertical direction. These dislocations are called *normal* faults.

Folds and faults are often of great magnitude, their dimensions being measured by miles, but they also occur on a very small, even a microscopic, scale. Many typical Appalachian folds are to be seen in the Piedmont region. In these folds the rocks change their forms mainly by adjustment and motion on planes of bedding and schistosity. There are also countless planes of dislocation independent of the original layers of the rock. These are best developed in rocks of an original massive structure, and are usually much nearer together and smaller than the planes on which the deformation of the stratified rocks proceeded. In these more minute dislocations the individual particles of the rocks were bent, broken, and slipped past one another. Attending this was a greater or less growth of new minerals by recrystallization from the old, a process which is called *metamorphism.* Most of the new minerals crystallized with their longer dimensions about parallel to the planes on which the motion took place. The usual effect of this action upon the rocks is to cause an easy splitting, or *schistosity,* parallel to the longer dimensions of the new minerals.

GENERAL STRUCTURE OF THE PIEDMONT PLATEAU.

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

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

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

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

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

As was stated under the heading "The general geologic record," depression of this kind took place at the beginning of the Paleozoic, with several repetitions later in the same era. They alternated with uplifts of varying importance, the last of which closed Paleozoic deposition. A similar depression initiated the sedimentation of the Juratrias, which was in turn closed by an uplift. Cretaceous and Tertiary sediments were also made possible by similar depressions, which are more fully discussed under the heading "Mesozoic and Pleistocene physical history."

Explanation of structure sections.—The sections on the Structure Section sheet represent the strata as they would appear in the sides of a deep trench cut across the country. Their position with reference to the map is on the line at the upper edge of the blank space. The vertical and horizontal scales are the same, so that the actual form and slope of the land and the actual dips of the layers are shown. These sections represent the structure as it is inferred from the position of the layers observed at the surface. On the scale of the map they can not represent the minute details of structure, and they are, therefore, somewhat generalized from the dips observed in a belt a few miles in width along the line of the section. Faults are represented on the map by a heavy solid or broken line, and in the section by a line whose inclination shows the probable dip of the fault plane, the arrows indicating the direction in which the strata have been moved on its opposite sides.

LOCAL STRUCTURES, PIEDMONT PLATEAU AREA.

The rocks of this area have undergone many alterations in form and position since they were formed, and they have been bent, broken, and metamorphosed to a high degree. The structures which resulted from these changes extend in a direction a little east of north, with some variations into a northwest course in the vicinity of Washington. While it is easy to see that the rocks of this area have been greatly disturbed, and the details of the smaller structures are apparent, yet it is difficult to discover the larger features of the deformation of the rocks. One reason for this is that the original shape of most of the formations is unknown, because they are eruptive and consequently irregular. Another reason is that the masses of one kind of rock are so large, and distinctive beds are so rare, that structures of large size can not be detected. In areas adjoining this there is more evidence at hand, and it is chiefly through these outside phenomena that the larger structures here can be correctly interpreted.

In a broad way the structure of the crystalline rocks of the Washington quadrangles is that of an anticline between two synclines. The anticline is composed of two belts of maximum uplift, one passing just east of Cabin John, and a second through Washington. The former is perhaps the more important of the two and can be traced considerable distances both north and south. The main synclinal axis of this region passes just east of Great Falls. A few miles west of this, and outside of these quadrangles, another large anticline appears. West of the Cabin John anticline, the planes of the schistosity dip toward the west at angles ranging from 75° to 90°. East of that belt the dips become considerably less, ranging from 60° at the west to 50° and 40°, and then are again a little steeper in the vicinity of Georgetown and Washington. As the formations west of the Great Falls syncline dip, as a rule, toward the southeast, while most of the dips east of that syncline are toward the west, this upward-radiating arrangement in the vicinity of Great Falls forms a species of fan structure. The details of fan structure are not fully carried out, as the sequence of the formations is not the same on each side.

The synclines in these quadrangles are not well defined, but in adjoining areas, both north and south, they are fairly distinct. The syncline between Washington and Cabin John is subordinate, and is defined chiefly by the presence of anticlines on either side. The principal syncline, just east of Great Falls, is marked by small areas of the surface flows of basic lava, which now appear as epidotic schists in the area north of these quadrangles. This syncline is also defined southwest of Great Falls by infolded areas of sedimentary rocks in the Mount Vernon quadrangle. In the gneiss and schist along the Potomac the great disturbance and deformation along the axis are shown in the close crumpling and in the partial destruction of the old schistose planes by new planes of motion and metamorphism. The eastern syncline is scarcely defined in this area, since its axis, which passes east of Washington and Alexandria, is covered by the formations of the Coastal Plain. Fifteen miles northward along this axis a syncline is shown by a basin of marble included between areas of gneiss, and at the same distance southwest of Washington the syncline appears in a long belt of surface volcanic rocks lying on the older granite and granite-gneiss.

No faults of importance are known in these quadrangles. Just west of Bethesda the irregular arrangement of the formations resembles that of faulting, but it may also have resulted from the original irregularity of the igneous intrusions. Small faults, of a few feet, are seen at many places, chiefly where fresh cuttings expose large surfaces of rock. Their displacement is not so great, however, as to affect the areas of the formations, nor can they be traced beyond the immediate exposures; consequently they are not represented on the map or in the sections.

The detailed results of metamorphism, the most important consequence of deformation in this area, are given in the description of the separate formations. The processes were in general along the following lines: The mineral particles were changed in position and broken during the folding of the rock. As the folding went on they were fractured more and more. New minerals, especially quartz and mica, grew out of the fragments of the old minerals. The new minerals were arranged at right angles to the greatest force of compression at any particular point. Inasmuch as the compression was about uniform in direction over large areas, there resulted a general parallelism of the longer dimensions of the minerals. To this is due the schistosity of the rocks. In folding, the maximum motion in the sedimentary strata was to a large extent along the bedding planes. As deformation became extreme, however, other planes of motion were formed through the separate layers, just as in the case of the massive igneous rocks. In rocks which were already gneissoid or schistose, as the result of previous metamorphism, the existent schistose planes serve to facilitate flexure, as did the bedding planes of the sediments. In the massive igneous rocks there were no planes already formed, but they were developed by fracture and mashing, and the change of form expressed in folds was less than in the laminated rocks. The schistose partings are in a general way parallel to one another for long distances and over large areas. They sometimes diverge considerably for short distances around harder portions of the rock, which have yielded less under compression, but the influence of these portions is only local. Near the boundaries of formations, also, they are usually about parallel to the general contact of the formations, the yielding to pressure having been directed by the differences in strength between the formations. Thus, while the strike of the different formations may vary considerably in adjoining areas, yet the schistose planes swing gradually from one direction to another, and there is seldom any abrupt change. Effects of deformation of later date, the records of which are left in the sediments and topography of this region, are described under the next heading.

MESOZOIC AND CENOZOIC PHYSICAL HISTORY.

The local history of the principal events which have transpired in the Coastal Plain province since early Cretaceous time is particularly clear in the Washington region. Each formation before described, excepting the Monmouth formation, was the product of a separate period of deposition, and the intervals of uplift and erosion gave rise to a variety of characteristic topographic features. Most of these features are deeply buried under succeeding deposits, which have preserved them in their original character, but the youngest ones are covered only by thin superficial formations. Some portions of the older features are now in part bared by erosion.

The first condition which is now clearly exhibited was a moderately steep and somewhat irregular shore of crystalline rocks, with the water mark located along a northeast-southwest line passing a short distance east of Washington. The waters of this sea were depositing the earlier members of the Potomac formation, of which the western edges do not extend to the surface in this vicinity. The Potomac River had not then its present course, if it existed, and the relations of the surface drainage are not known. The land was subsiding, and with every few yards of subsidence the waters encroached much farther westward and laid down higher and higher beds, which overlapped in succession in that direction. This condition is indicated by many actual exhibitions of these overlaps and by the fact that the dip of the members of the Potomac formation is much less than the slope of the floor of crystalline rocks. The period of Potomac depression was characterized by many oscillations together with the presence of strong currents in various localities, which gave rise to the irregular alternations of sands and clays, local unconformities, and the presence of land areas of greater or less size and duration on which an abundant vegetation existed.

A general emergence followed Potomac deposition, and the surface of the formation was planed, probably in the main by wave action, to a relatively flat slope. The amount of material removed is not known, nor how far to the east the ocean shore receded, for the geographic relations of the land and ocean in those times are not clear. In the next submergence the Matawan and Monmouth formations were deposited from marine waters, in consequence of continuous submergence, though probably to but moderate depth. Whether other later Cretaceous formations were laid down in Maryland and Virginia, as in New Jersey, and have since been removed by erosion, or those northern deposits thinned out southward, is not yet determined. The fine sands and sandy clays of the Matawan and Monmouth formations were deposited in quiet waters containing abundant molluscan life, and the shores of the Matawan sea probably bore luxuriant vegetation which supplied the carbonaceous material of the formation. This condition gave place to uplift and planing, as did the preceding emergence. If the later Cretaceous deposits extended southward in large mass, or far into Virginia, there was greater emergence and erosion in that direction, for the Potomac formation was bared and its surface deeply eroded and channeled before the deposition of the Pamunkey sediments. The successive overlap of the Pamunkey over the Monmouth and the Matawan southward indicates tilting to the northward during this emergence.

Immediately preceding Pamunkey deposition there was a general submergence of the Coastal Plain region, and throughout the epoch there was relatively deeper water over the entire area now occupied by the Pamunkey formation. The waters had an abundant molluscan and animal life, and the conditions were such that glauconite was deposited with the other materials. Then followed uplift and planing of the entire surface of the Pamunkey deposits to an amount of which as yet we have no knowledge. Far to the northeast and about Washington these deposits were removed and a portion of the surface of the Matawan and Potomac formations was exposed. Then came deep and widespread submergence and the deposition of the Chesapeake formation. The fine sands and clays of this formation, with their vast number of diatom remains, required a long time for their deposition, for they accumulated to a thickness of at least 800 feet to the eastward, as is shown by well records. The deposits overlapped westward to the crystalline rocks, and probably extended over them for some distance. The extent of post-Chesapeake uplift, amount of tilting, and depth of degradation are not known, but there was widespread planing, similar in character to the preceding erosion. It was during Pamunkey and Chesapeake times that much of the planing of the Piedmont region was effected, but if these formations were spread far westward over the surface of the crystalline rocks their presence retarded erosion for the time being. Following post-Chesapeake erosion there came a moderate amount of submergence, during which the great sheet of Lafayette materials was spread from the Piedmont Plateau far out to sea. The conditions of sedimentation were very different from those of the earlier times, as the deposition of the gravels and sands was largely effected by waves and currents. At the maximum stage of submergence the waters extended entirely over the Washington region to the Mountains westward, but this wide extent was for only a short time and the shore line was for sometime not far west of Washington. There was unevenness in the surface of the deposit—long, wide shoals and bars, as along the present sea coast, and the presence of these defined the location of the present Potomac and Anacostia depressions. It was on the emergence of the Lafayette deposits that these drainage systems were extended eastward. In preceding times there had been general planing and no development of deep channels on the surface of the Coastal Plain in this district; but with post-Lafayette uplift the outlining of the large features of the present topography was begun. There was a long period of relatively rapid uplift, which was somewhat greater in amount to the north than to the south. Wide, flat-bottomed, steep-sided valleys were excavated in both the Piedmont and the Coastal Plain provinces to about 100 feet below the Lafayette plateau. In the vicinity of Alexandria, and possibly elsewhere, there were low terraces. During the uplift a deep gorge was cut by the Potomac, and during a succeeding interval of continued elevation it attained a width of about 10 miles in the Alexandria region and of 2 to 4 miles in the rocks of the Piedmont region. It was on the floor of these valleys that the earlier Columbia member was deposited during a pause in the general uplift. The high terraces about Washington were then continuous over the entire valley and were flooded by wide streams which flowed out of the Piedmont region and to the east merged into a great estuary from the ocean. The most important of these streams was the Potomac, which carried great loads of gravel and sands. These were deposited over the valley bottom, but soon, with increased submergence and diminished velocity of the streams, an extensive mantle of loam was spread over the coarser deposits. The shores were mostly steep slopes, about 100 feet in height, of crystalline rocks to the west, of the Potomac formation to the north and east, and of the Pamunkey formation to the southeast. The river and estuary waters extended up the valleys of Henson Creek, Oxon Run, Rock Creek, and other similar valleys, as long, narrow bays; and northward up the Anacostia Valley as a narrow strait which continued to Baltimore. A branch of the Patuxent estuary extended far north of Upper Marlboro, up the Western Branch Valley, and probably at the time of greatest submergence was connected by several narrow channels northward with the strait above mentioned. The principal deposition was along the main river valleys and apparently the deposits in the region northeast of Washington were thin and composed largely of local materials.

After deposition of the earlier Columbia member emergence was renewed, with strong tilting from the northwest, the streams were revived, and the earlier Columbia deposits were deeply trenched and removed over wide areas, especially near the larger streams and where the deposits were thin, as in the region northeast of Washington. Along the Potomac River a trench was cut within the earlier Columbia trough to a depth of about 150 feet where deepest. In later as in earlier Columbia time, the gorge, which at first was narrow, was widened, but only about half as far as before. In the Potomac Valley in the Piedmont region an inner gorge was cut to a width of about half a mile, and small fragments of the floor of this occur as a shelf along the north side of the river from Washington to Great Falls at about 130 feet above tide. At Washington the later Columbia valley widened to 5 miles in the softer deposits of the Coastal Plain, and there were a number of terraces within it having a range of about 100 feet in altitude. It was during this time that the steep scarp around the northern side of the city was cut, and this scarp was continuous along the entire earlier Columbia plain except where opened by the Potomac River and other streams. This condition was terminated by a submergence of moderate amount, and the terrace plains were then overspread with the later Columbia member. The later Columbia materials in this region are similar to those of the earlier Columbia member, and were also mainly brought down by the Potomac River, widened far beyond its present size even as far up the gorge as Great Falls. The extent of the water at this stage is indicated by the distribution of the later Columbia member, although in a few depressions the deposits have been more or less eroded, as in that part of Washington along Rock Creek. Columbia deposition was discontinued by the resumption of general uplift, which carried the entire region considerably above its present altitude. In this emergence the Potomac River cut a channel eastward through the Columbia deposits to 30 or 40 feet below the present tide level, and in the Piedmont region excavated the lower gorge from Washington toward Great Falls. Then followed a submergence and flooding of the river channels, in which tide water returned to the vicinity of Washington. This submergence is now in progress and tide water is slowly encroaching on the land, except where alluvial deposition and marsh growth are keeping pace with the rise of tide level.

MINERAL RESOURCES.

Within the Washington quadrangles there are numerous deposits of possible economic value. These consist of clay, sand, gravel, and iron ore in the Coastal Plain, and of building stone, road materials, soapstone, and gold in the Piedmont Plateau.

Brick clays.—The supply of brick clay in the vicinity of Washington is abundant and a very large number of bricks are produced. The clays worked are mainly of later Columbia age, but at the intersection of the Bladensburg road and Florida avenue there are extensive excavations in the sandy clays of Potomac age. The principal workings in the Columbia loams are on the west side of the Potomac River between Washington and Alexandria, in the extreme eastern and southern portion of Washington and just south of Alexandria. In the eastern part of Washington wide areas have been stripped of a thin layer of loam for brick making. The upper loam is suitable for brick making over the greater part of the wide later Columbia terraces adjoining the Potomac River. On the smaller areas along creeks and on the terraces adjoining the greater part of the Anacostia River the deposit is usually too sandy. Sandy clays of the Potomac formation are often suitable for brick making and they have been used to some extent. On the wider terraces of earlier Columbia and Lafayette formations there are many local areas of loam which are available. Other sources of supply are detrital clays and alluvium from crystalline rocks, and river muck.

Terra-cotta clay.—The clays of the Potomac formation are often suitable for terra-cotta tiles, etc., and they are extensively worked for this use at Terra Cotta, University station, and Lamond, on the Metropolitan Branch of the Baltimore and Ohio Railroad. There are many large masses of terra-cotta clays in the formation, particularly in the region east of Anacostia River. They are interbedded with and grade into sands, so that it has not been possible to represent the clay outcrops separately on the Economic Geology sheet.

Building stone.—Many formations in this district contain material suitable for building, such as granite, diorite, granite-gneiss, and gneiss. All of these formations have been quarried to a greater or less extent, but on the Economic Geology sheet only the larger openings are represented. Diorite has been but little used, and then only in the immediate vicinity of the outcrops near Georgetown and Annandale. The diorite of Georgetown is massive and is tough and difficult to quarry and dress. That from the vicinity of Annandale is more gneissoid and readily works out into blocks.

Granite has been quarried south of Falls Church, west of Annandale, in the vicinity of Glen Echo, and along Broad Branch of Rock Creek. The rock is similar in all of the three former localities and is taken from less schistose portions of the granite mass. It is homogeneous, of even texture, and good color. It is not materially affected by schistosity, and works out readily in stones of moderate size. Some of the beds in the Falls Church area are colored by pink feldspar. In the Glen Echo quarries schistosity is stronger than in the others and renders the stone less available where large blocks are in demand. The rock quarried on Broad Branch is taken from the biotite-granite. It is a somewhat schistose rock, but not so much so as to impair quarrying or dressing in proper shapes. Its color is light and permanent and its texture is very uniform. The rock stands the weather well, and is probably the most valuable building stone in this vicinity.

Many portions of the granite-gneiss furnish good material for foundations and similar rough work. This stone is schistose and consequently not obtained in large masses. It is easy to quarry and strong. Many portions contain pyrite, which unfits it for ornamental use. Many of the more massive beds of mica-gneiss are suitable for building and resemble the more schistose portions of the granite mass. They are used locally in the construction of dams and foundations. From the thinner and more micaceous beds flagstones can readily be obtained.

Road material.—Road material is obtained in abundance from all the formations above mentioned. The solid rock is only to be obtained near the streams, so that for use on uplands transportation is required. In these latter situations, use is made of the quartz veins and their waste, the last rock to be disintegrated. The quartz beds consist for the most part of lenses varying from a few inches up to a quarter of a mile in length and 50 feet in thickness. These are most frequent near the boundaries of the formation, and are parallel to the schistosity of the inclosing rock. Quartz is also obtained from veins of less thickness but of much greater length, which cut across the schistose planes at a considerable angle. Quartz is the best road material in this region, on account of its angular fracture and great hardness, and its freedom from clay and dust, but it has little cementing quality. Gravels from the unconsolidated formations of the Coastal Plain are also widely used in constructing roads. The coarser stones and pebbles can readily be obtained over most of the extent of the Coastal Plain in this vicinity.

Gold.—Gold occurs in the northwest portion of this district, in several localities near Great Falls. These occurrences are part of an extensive belt of similar deposits extending through Maryland and Virginia along the Piedmont Plateau. In this locality the gold ores lie in the much contorted gneisses and mica-schists of the syncline just east of Great Falls. The gold is found both associated with pyrite and in quartz without pyrite. Most of the quartz veins and lenses contain gold, and so do often the adjacent sheets of mica-schist and gneiss, the latter being perhaps the richer. An ore body thus consists of a group of layers, quartz veins, and country rock. The larger quartz veins can be traced for upwards of half a mile, and possibly extend even farther. The smaller veins may be measured by inches; as one dies out it may be replaced by another in the same or adjoining layer of country rock, the gold content not necessarily stopping with the quartz. Many evidences of motion are seen in and around the veins, and it is possible that they and the mineralization of the country rock result from one system of disturbance. The vein materials and the ore bodies seem both to have replaced portions of the country rock and to have occupied openings of greater or less size in the country rock. To the latter class belong the large quartz bodies in which gold occurs with little or no pyrite. The veins run in a direction a little west of north, which is about that of the schistosity of the adjoining rocks, and have a nearly vertical dip. The presence of gold ores in this vicinity has been known for years, but it is only in recent years that systematic developments have been attempted and shafts sunk to any depth.

Soapstone.—There are many deposits of soapstone and similar materials in this area. The only ones of value are the soapstones, which are indicated on the Economic Geology sheet. Of less amount and of no special value are the talcose schists, which are classed with the soapstone on the geologic maps. All of these rocks are composed largely of talc, the hydrous silicate of magnesia, and are probably derived from the metamorphism of pyroxenite and similar formations. The talcose schists contain too much impurity, particularly chlorite, to be applied to the uses of pure talc, and they are not massive enough for the ordinary uses of soapstone. Few of the soapstone bodies attain large size, that which is found 2 miles east of Annandale being the only large area. One mile east of Tenley is the next largest body, in which are found ancient workings. Similar old quarries appear in the area east of Falls Church. All of the bodies, large and small, have been worked to some extent, usually for local use. East of Annandale considerable developments have been made and much stone has been taken out and sawed; the rock is of even grain, and is free from seams and schistose planes. Blocks of good size can be quarried, and the deposit has an exposed thickness of over 50 feet.

Marls.—The glauconitic shell marls of the Pamunkey formation contain lime and potash in considerable amount and some phosphoric acid, and they should be of great value agriculturally. They have not as yet been extensively employed, but at several localities local tests have yielded most satisfactory results. The extent of the marl is indicated approximately on the Economic Geology sheet. In the extreme northern portion of the district, and on old surfaces generally, the marl is often considerably weathered and its value is thereby greatly decreased. Usually fresh marl may be found by digging below the surface. In portions of the area indicated there are overlying gravels, sand, or surface wash, but the marl is not far beneath the surface throughout. In selecting marl it should be remembered that the portions containing the greatest proportion of shells and dark bottle-green glauconite grains are richest in plant food.

Sands.—Sands of the Potomac formation have been worked for building use at a number of localities in Washington and its vicinity. The principal quarries recently in operation are in the hill slope about half a mile south of Anacostia. Formerly much sand was excavated in the vicinity of the intersection of North Capitol street and New York avenue, in Washington. The sand underlying the clay at Terra Cotta is worked to some extent, mainly as tempering for the clay.

Gravels.—Gravels are dug at many localities about Washington for use as road material. There are abundant supplies in the Lafayette and Columbia formations, over nearly their entire extent, and the marginal beds of the Potomac formation are often gravelly. About Good Hope, on the Suitland and Bowen roads, are the principal sources of Lafayette gravels, but there are many pits for local supply. The later Columbia gravels are dug in the eastern part of Washington, and are produced in considerable amount in the course of street grading. The earlier Columbia gravels are dug extensively in pits on the high hill just east of Benning station, on Shuter Hill near Alexandria, and by the Southern Railroad in pits near Springfield station.

Diatomaceous earth.—The diatomaceous beds in the Chesapeake formation are sometimes locally of sufficient purity for commercial use, but they are not now worked in the Washington region. At Lyons Creek wharf on the Patuxent River they are dug to a considerable extent.

Iron ore.—Iron ore occurs mainly in the Cretaceous formations of the Coastal Plain. The locations of the principal quarries and other excavations are shown on the Economic Geology sheet, together with the distribution of some of the deposits. The Potomac clays contain scattered masses of carbonate of iron, which were formerly worked to some extent in the hills east of Branchville, but the deposits are too meager to be of value. Farther to the north, however, they are profitably worked. Crusts and concretions of sandy limonite often occur in the Potomac and Pamunkey formations, but only in very small quantities at any one place.

Underground water.—There are several horizons of underground water in the Coastal Plain formations which yield supplies to artesian wells. The principal source is in the basal gravels of the Potomac formation, on the surface of the crystalline rocks. The slope of this floor averages about 110 feet to the mile eastward, and it is at tidewater level near the center of the city of Washington. There are many wells which obtain water from this horizon, notably those which supply St. Elizabeth Asylum, and it has proved to be an important source of water for the Coastal Plain region. There are many lenses of sand in the Potomac formation which contain more or less water, but they have not as yet been widely explored. Water may also be expected in sands occurring locally at the top of the Potomac formation, which furnish the artesian flow at Upper Marlboro from a depth of 216 feet. As a guide to the position of the underground waters about Washington, contour lines have been introduced on the Economic Geology sheet of this folio to show the attitude of the Potomac formation. One set of lines shows the position of its top and the others define its base on the bed rock, so far as explored. These lines are referred to tide level, but as they are drawn on a topographic map it is very easy to find the depth to be added for elevation of the land. The basal Potomac waters are available at moderate depths over a wide area adjoining the Potomac and Anacostia valleys, but they lie rather deep farther east. Water has already been obtained from the basal gravels in most portions of the area, but there is a small zone in the northeastern quarter of Washington where its volume is small. Here, however, good supplies have been obtained in slightly higher Potomac sands at less depth. The higher beds of water-bearing sands near the top of the formation are not far beneath the surface in Prince George County, where they furnish the fine flow at Upper Marlboro and satisfactory supplies at other points. The stratigraphy of the Potomac formation is variable and the upper sand beds occur at various horizons and with considerable irregularity of outline. Accordingly it was not possible to show on the map the precise position of the water-bearing beds. The upper set of lines shows the attitude of the top of the Potomac formation, and in most areas it will not be found necessary to penetrate the formation more than a hundred feet to obtain a water supply; while in some districts water-bearing sands will be found at the top, as at Upper Marlboro.

Description of the Coastal Plain by
N. H. DARTON.

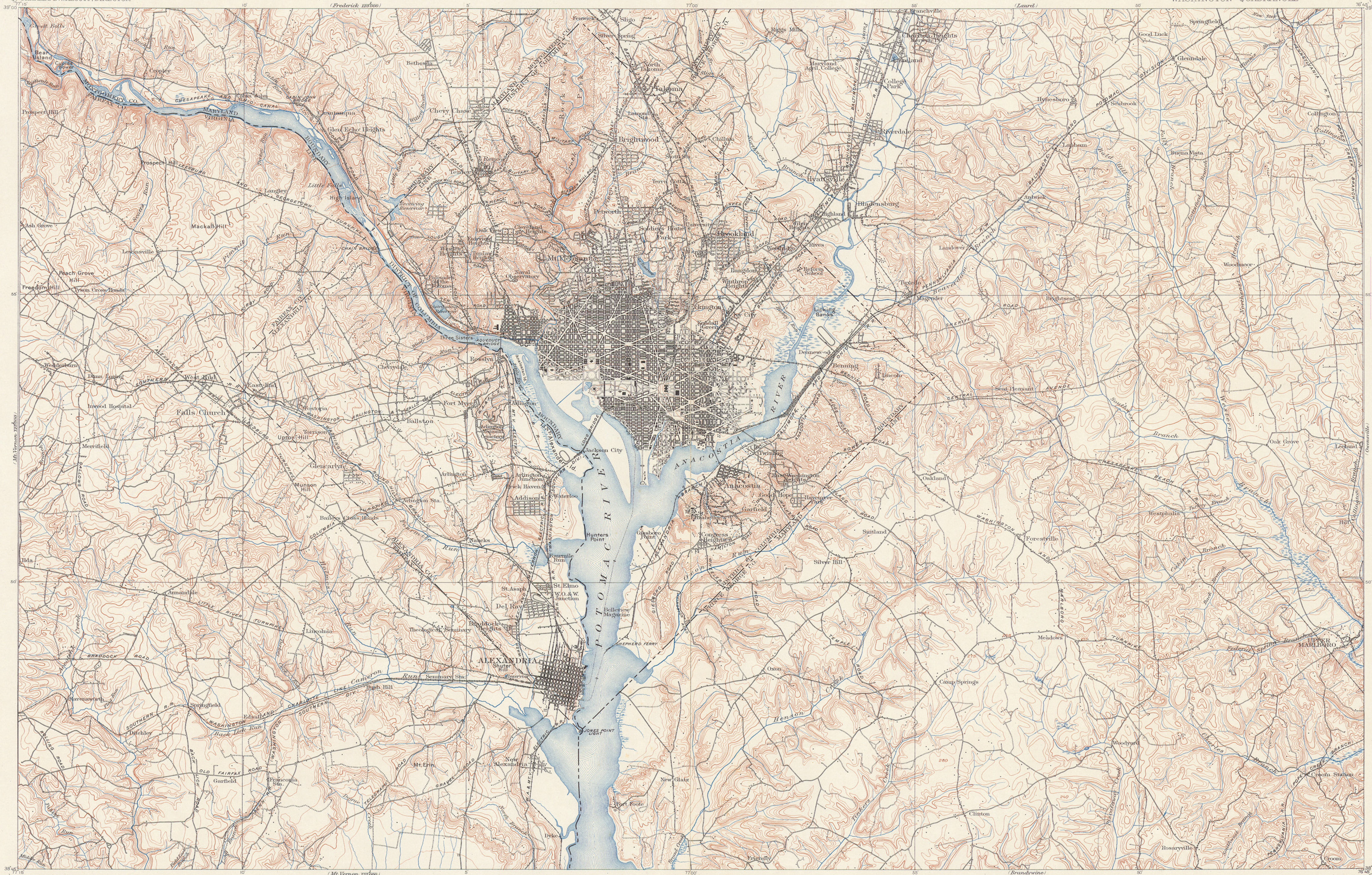
Description of the Piedmont Plateau by
ARTHUR KEITH.

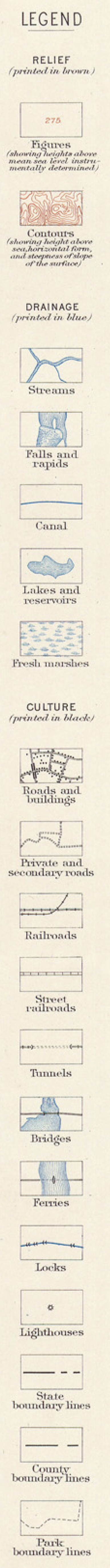
January, 1901.

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

TOPOGRAPHIC SHEET

MARYLAND – DISTRICT OF COLUMBIA – VIRGINIA
WASHINGTON QUADRANGLE





H.M. Wilson, Geographer in charge.
Triangulation by U.S. Coast and Geodetic Survey.
Topography by J.D. Hoffman, D.J. Howell, A.E. Murlin, J.H. Jennings, M. Hackett, W.M. Beaman, H. Munroe, A. Pike, R. Muldrow, W.J. Lloyd, J.W. Thom, A.M. Walker, E.B. Clark, G.E. Hyde, and U.S. Coast and Geodetic Survey.
Surveyed in 1885-86 and 95-97.

Scale $\frac{1}{62500}$

Miles 1 ½ 0 1 2 3 4

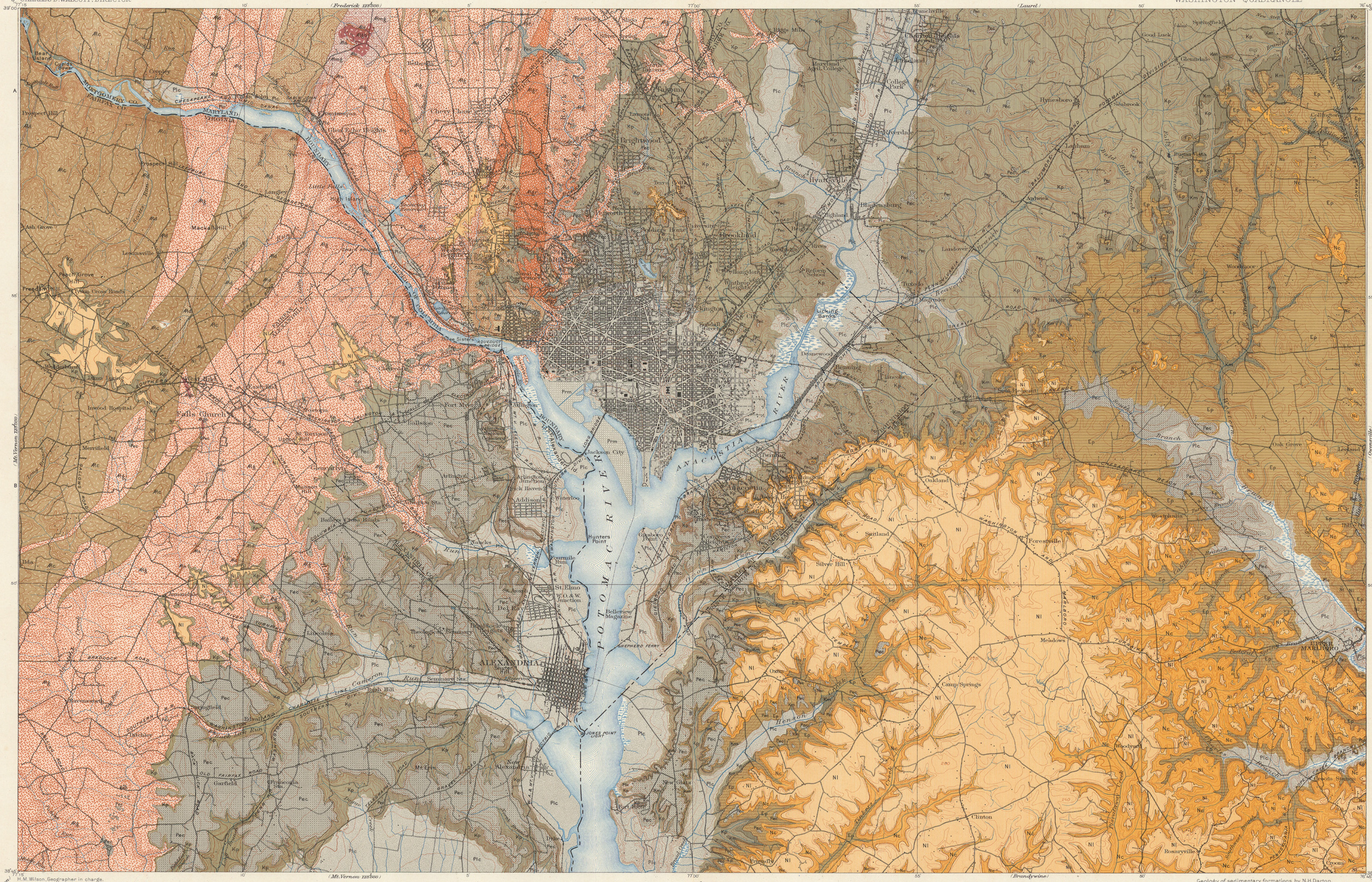
Kilometers 1 ½ 0 1 2 3 4 5

Contour interval 20 feet.
Datum is mean sea level.

Edition of July 1900.

HISTORICAL GEOLOGY SHEET

MARYLAND – DISTRICT OF COLUMBIA – VIRGINIA
WASHINGTON QUADRANGLE



LEGEND

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

PLEISTOCENE
- Prm — Reclaimed tide marsh
- Columbia formation:
  - Plc — *(later loam and gravel)*
  - Pec — *(earlier gravel and loam)*

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

NEOCENE
- Nl — Lafayette formation *(gravel and loam)*
- Nc — Chesapeake formation *(clay and fine sand)*

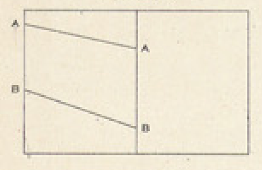
EOCENE
- Ep — Pamunkey formation *(greensand marl)*

CRETACEOUS
- Kmh — Monmouth formation *(brown sand)*
- Km — Matawan formation *(dark sand)*
- Kp — Potomac formation *(sand and clay)*

ANCIENT CRYSTALLINE ROCKS
(Areas of Archean rocks and metamorphic rocks of unknown origin are shown by patterns of short dashes.)

ARCHEAN
- Ægr — Biotite-granite
- Æs — Soapstone and serpentine
- Ægb — Gabbro
- Æmg — Meta-gabbro
- Æd — Diorite and meta-diorite *(including hornblende-granite and some meta-gabbro)*
- Æg — Granite-gneiss *(including granite, gneissoid granite, and schistose granite)*
- Æc — Carolina gneiss *(including mica-gneiss, mica-schist, and small bodies of granite, schistose granite, and diorite)*

Sections



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Surveyed in 1885-86 and 95-97.

Scale $\frac{1}{62500}$

Contour interval 20 feet.
Datum is mean sea level.

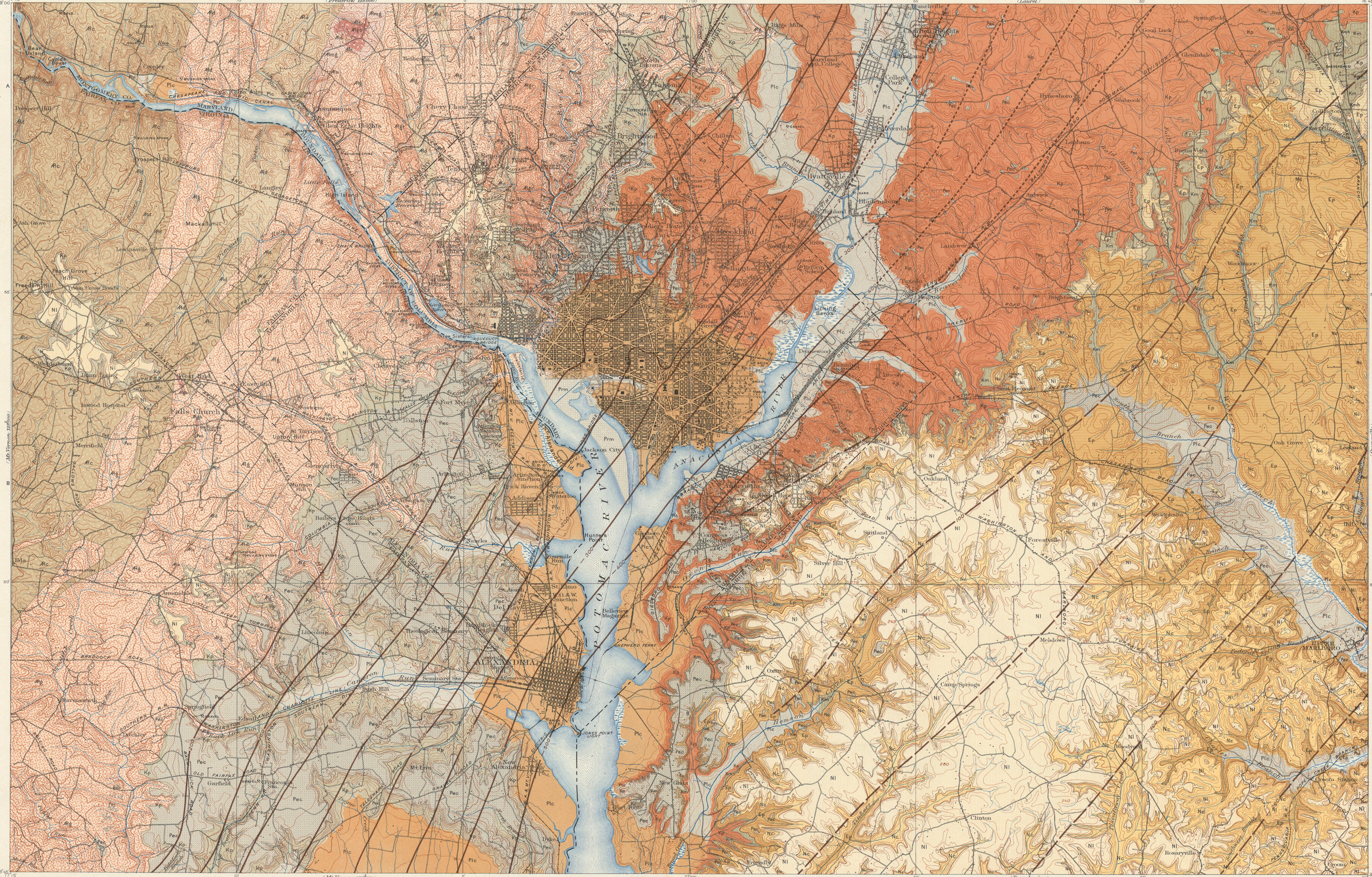
Edition of Oct. 1900.

Geology of sedimentary formations by N. H. Darton.
Geology of crystalline rocks by G. H. Williams and Arthur Keith.
Surveyed in 1893-1899.

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

ECONOMIC GEOLOGY SHEET

MARYLAND – DISTRICT OF COLUMBIA – VIRGINIA
WASHINGTON QUADRANGLE



LEGEND
(continued)

Known productive formations

- **Plc** — *Brick loam* (in later Columbia formation, merging into sand and gravel, local brick loams of other formations not included)
- **Ep** — *Marl* (in Pamunkey formation, in part weathered and overlain by surface detritus)
- **Kp** — *Terracotta clay* (in Potomac formation, interlaminated with sand and sandy clay)
- *Artesian water* (contours show position of the top of the Potomac formation referred to sea level. Water occurs at various horizons toward the top, which will flow in wells considerably above sea level.)
- *Artesian water* (contours show position of the base of the Potomac formation referred to sea level. Broken contours are based on incomplete data. Water occurs near the base in most areas. No water should be expected in the underlying bed rock.)

Contour interval is 100 feet. Elevations below sea level are indicated by a minus sign.

LEGEND

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

PLEISTOCENE
- **Prm** — Reclaimed tide marsh
- *Columbia formation*
  - **Plc** — (later loam and gravel)
  - **Pec** — (earlier gravel and loam)

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

NEOCENE
- **Nl** — Lafayette formation (gravel and loam)
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ANCIENT CRYSTALLINE ROCKS
(Areas of Archean rocks and metamorphic rocks of unknown origin are shown by patterns of short dashes.)

ARCHEAN
- **Ægr** — Biotite-granite
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- **Ægb** — Gabbro
- **Æmg** — Meta-gabbro
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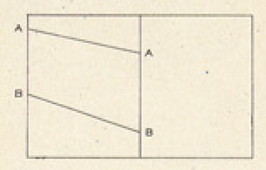
- **Æg** — Granite-gneiss (including granite, gneissoid granite, and schistose granite)
- **Æc** — Carolina gneiss (including mica-gneiss, mica-schist, and small bodies of granite, schistose granite, and diorite)

⚒ *Mines, clay pits, and quarries*
○ *Deep wells*

Sections



Legend is continued on the left margin.

H.M. Wilson, Geographer in charge.
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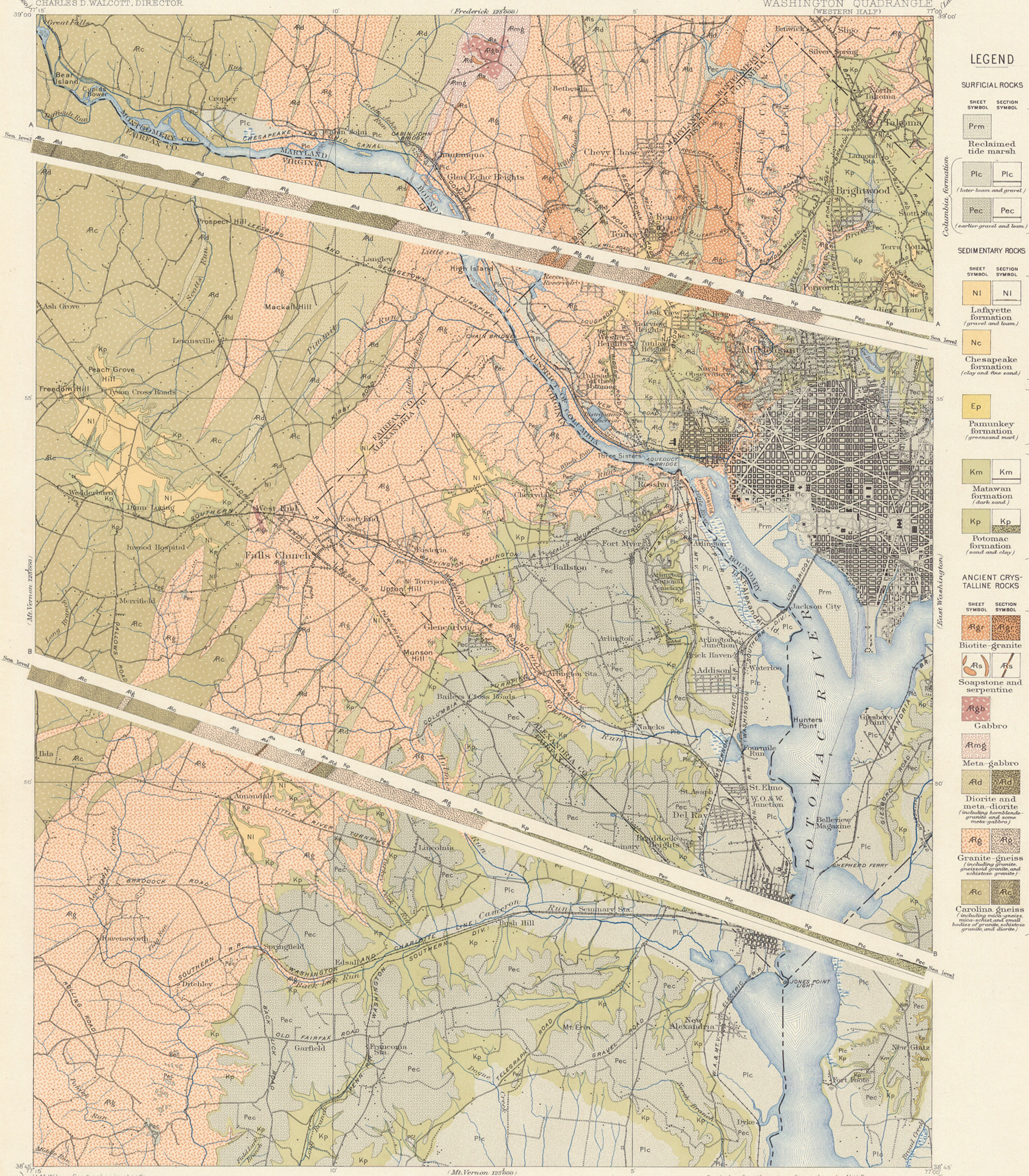
CHARLES D. WALCOTT, DIRECTOR

STRUCTURE-SECTION SHEET

MD.–D.C.–VA.
WASHINGTON QUADRANGLE
(WESTERN HALF)



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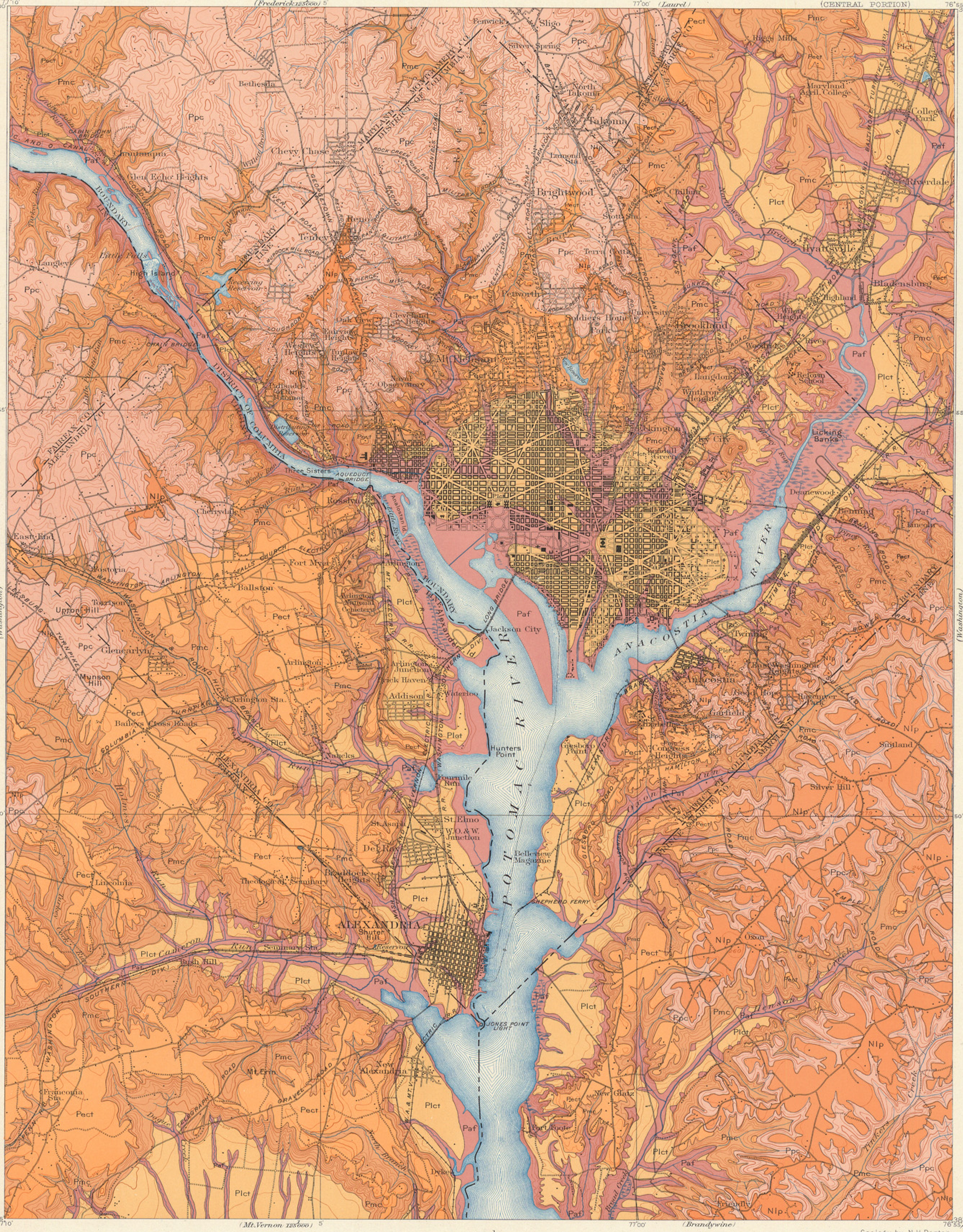
CHARLES D. WALCOTT, DIRECTOR

PHYSIOGRAPHIC GEOLOGY SHEET

MD.—D.C.—VA.
WASHINGTON QUADRANGLE
(CENTRAL PORTION)



LEGEND

Paf — Post-Columbia slopes and alluvial flats
(cut into Later Columbia terraces; channels of small rivulets and street and railroad gradings are not represented)

Plct — Later Columbia terraces
(plain of later Pleistocene sediments dissected by the present drainage)

Pmc — Mid-Columbia slopes
(outlined after early Columbia deposition and extensively developed in late Columbia and recent time)

Pect — Early Columbia terraces
(remnants of an early Pleistocene plain)

Ppc — Pre-Columbia slopes
(outlined in pre-Columbia time and extensively developed in Columbia and recent time)

Nlp — Lafayette plain
(isolated remnants of a once continuous plain of Neocene sediments)

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 20 feet.

Datum is mean sea level.

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Geology by N.H. Darton.
Surveyed 1893-99.

forming another gradation into sedimentary deposits. Some of this glacial wash was deposited in tunnels and channels in the ice, and forms characteristic ridges and mounds of sand and gravel, known as osars, or eskers, and kames. The material deposited by the ice is called glacial drift; that washed from the ice onto the adjacent land is called modified drift. It is usual also to class as surficial rocks the deposits of the sea and of lakes and rivers that were made at the same time as the ice deposit.

AGES OF ROCKS.

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

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

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

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

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

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

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

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

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, excepting the Pleistocene and the Archean, are distinguished from one another by different patterns, made of parallel straight lines. Two tints of the period-color are used: a pale tint (the underprint) is printed evenly over the whole surface representing the period; a dark tint (the overprint) brings out the different patterns representing formations.

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.

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

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

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

THE VARIOUS GEOLOGIC SHEETS.

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

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

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

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

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

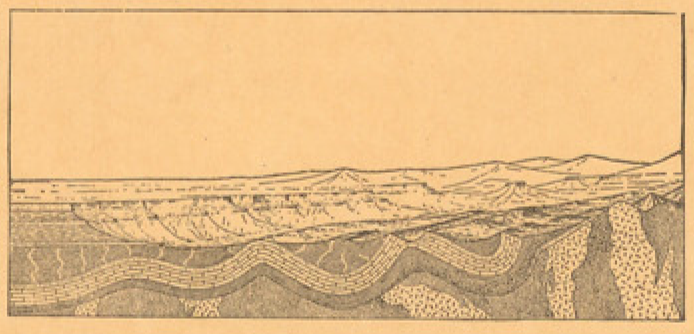

Fig. 2.—Sketch showing a vertical section in the front of the picture, with a landscape beyond.

The figure represents a landscape which is cut off sharply in the foreground by a vertical plane 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·

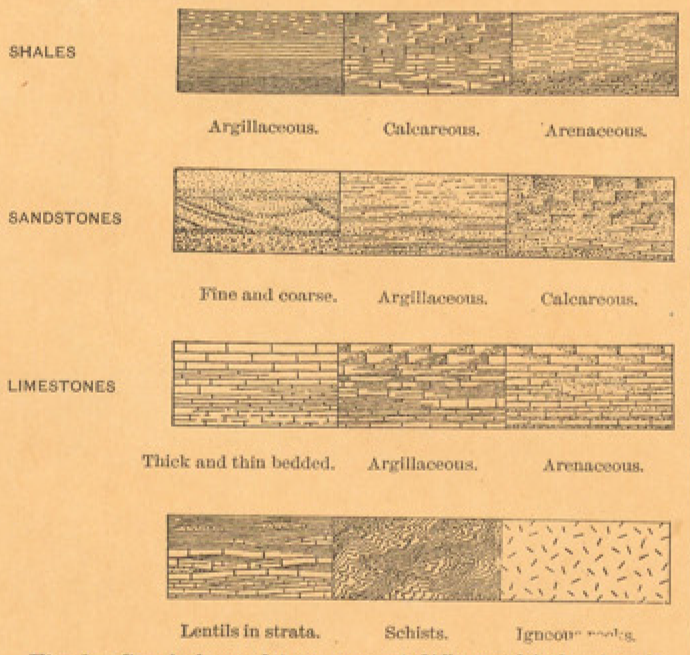

Fig. 3.—Symbols used to represent different kinds of rock.

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 positions, evidently younger than the underlying formations, and the bending and degradation of the older strata must have occurred between the deposition of the older beds and the accumulation of the younger. When younger strata thus rest upon an eroded surface of older strata the relation between the two is an *unconformable* one, and their surface of contact is an *unconformity*.

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

The section and landscape in fig. 2 are ideal, but they illustrate relations which actually occur. The sections in the structure-section sheet are related to the maps as the section in the figure is related to the landscape. The profiles of the surface in the section correspond to the actual slopes of the ground along the section line, and the depth 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 occur in the quadrangle. 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 1000 feet to 1 inch. The order of accumulation of the sediments is shown in the columnar arrangement: the oldest formation is placed at the bottom of the column, the youngest at the top, and igneous rocks or 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.

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Director.

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