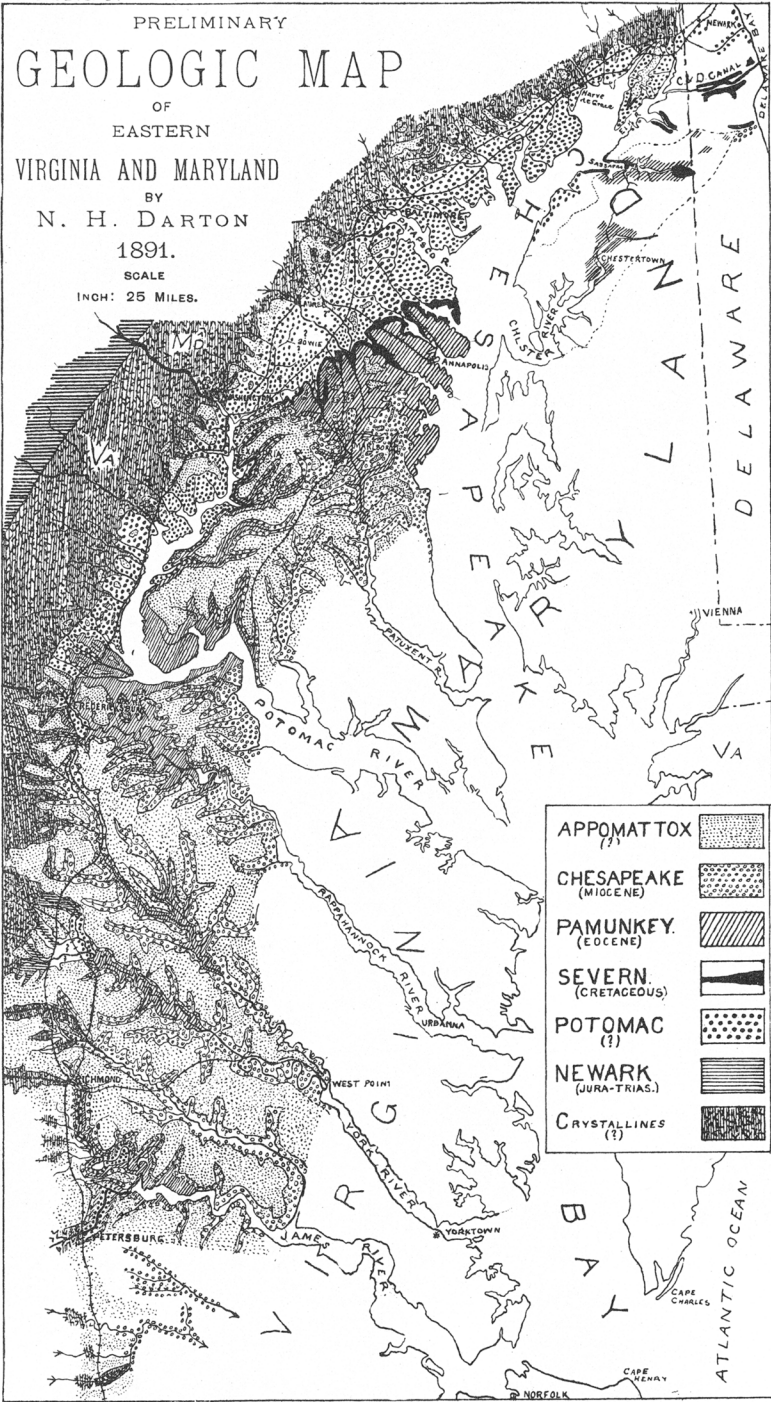


PRELIMINARY
GEOLOGIC MAP
OF
EASTERN
VIRGINIA AND MARYLAND
BY
N. H. DARTON
1891.
SCALE
INCH: 25 MILES.



MESOZOIC AND CENOZOIC FORMATIONS OF EASTERN
VIRGINIA AND MARYLAND.

BY N. H. DARTON, U. S. GEOLOGICAL SURVEY.

(*Read before the Society December 30, 1890.*)

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INTRODUCTORY.

The crystalline rocks of the Piedmont region in Virginia and Maryland are flanked eastward by an overlapping series of deposits of later Mesozoic and Cenozoic age, which extend thence to the Atlantic ocean, a distance averaging one hundred miles. This district has been designated the "coastal plain," and is in general terms the continuation of the Piedmont plains which, with gradually decreasing elevation, finally pass beneath sea-level.

The eastward inclination of the crystalline rock-surface on which the coastal plain deposits lie is slight, and the width of the zone of overlap from the feather edges and outliers of the formations to the final disappearance of this floor below tide-level usually averages about ten miles.

The irregular western terminations of the various formations usually do not give rise to notable topographic features, and in the larger drainage depressions the crystalline rocks finally disappear below the clastics, generally at a considerable distance below the head of tide-water.

Excepting the most recent member, which often forms low terraces, the formations of the coastal plain series constitute a succession of thin sheets, inclined gently seaward and gradually thickening in that direction. Normally their outcrops are from below upward, from west to east; but there is considerable overlapping westward, and the sequence and extent of their relations vary greatly in different parts of the region.

The formations constituting the coastal plain series are as follows: The Potomac of McGee; the southern extension and termination of a portion of the New Jersey Cretaceous greensand series, which I shall designate *Severn*, from typical exposures, described by Clark, on the Severn river near Annapolis; a representative of the Eocene, restricted to Maryland and Virginia, for which the term *Pamunkey* is appropriate on account of the typical nature and extent of the exposures on the Pamunkey river, as described by Rogers; the Miocene formations, which I shall comprise under the group name *Chesapeake* from Chesapeake, bay, adjacent to which the formation attains its greatest development; and the Appomattox and the Columbia of McGee.

Previous writers on the geology of the coastal plain region of Virginia and Maryland comprise Conrad, W. B. Rogers, McGee, Fontaine, Uhler, and W. B. Clark, together with a few others whose observations have been less extended.

It does not seem desirable at present to give an exhaustive account of the contributions of these observers, and only a brief sketch is here offered: The formation now known as Potomac was described by Rogers* in Virginia, and McGee† and Fontaine‡ have studied it both in Virginia and Maryland. The extension of the Cretaceous through the western shore of Maryland was established by W. B. Clark,§ and Uhler|| has also described some of its features. The Eocene and Miocene formations have been considered at greater or less length in the paleontologic writings of Conrad, by Rogers in reports on geological surveys of Virginia, and in parts of eastern Maryland by Uhler in the paper above referred to.

The Appomattox south of the Fredericksburg region was differentiated by McGee,¶ and to this observer we are also indebted for the separation and study of the Columbia formation.**

While these various investigations have afforded a most valuable basis for the elucidation of coastal plain geology, especially in certain type areas where the relations are more obvious, the greater part of the region is left involved in geologic questions of very great intricacy. This is especially the case in the many districts in which there are complex overlap relations, intergradations and similarity of deposits, weathering, shore phenomena and inter-geologic terracings, which, in soft materials with unsatisfactory exposures, are often exceedingly puzzling.

During the past two years the writer has been engaged in almost continuous field-work in this region; and in this memoir it is proposed to give a brief general abstract of the more noteworthy results, as a preliminary contribution to coastal plain geology. The investigation is still actively in progress, and more extensive reports of results and methods will appear later.

THE FORMATIONS.

THE GEOLOGIC COLUMN.

The components of the geologic column of the coastal plain region of Virginia and Maryland are as follows:

* Report of Progress of Geological Survey of Virginia for 1840, chap. III.

† "Three Formations of the Middle Atlantic Slope:" *Am. Jour. Sci.*, 3d ser., vol. XXXV, 1888, pp. 121-143.

‡ "The Potomac or Younger Mesozoic Flora:" *Monographs U. S. Geol. Survey*, vol. XV, 1889, pp. 1-62.

§ *Johns Hopkins University Circulars*, vol. 8, no. 69, 1889, pp. 20-21.

|| *Proc. Maryland Acad. Science*, vol. 1, 1888, pp. 11 32, 45-98.

¶ *Loc. cit.*, pp. 328-330.

** *Loc. cit.*, pp. 367-388, 448-466; and in "The Geology of the head of Chesapeake Bay:" 7th Annual Report of the Director U. S. Geol. Survey, 1885-'86, pp. 537-646.

<i>Representative.</i>	<i>Age.</i>
Columbia formation.	Pliocene (early).
Erosion interval.	———.
Appomattox formation.	Pliocene (?).
Erosion interval.	———.
Chesapeake formation.	Miocene.
Erosion interval.	———.
Pamunkey formation.	Eocene.
Erosion interval.	———.
Severn formation.	Cretaceous.
Erosion interval.	Cretaceous.
Potomac formation.	Cretaceous (?).
Erosion interval.	Jurassic (?).
Newark formation.	Jura-Trias.
Erosion interval.	Early Mesozoic.
Crystallines.	(?).

GENERAL DISTRIBUTION AND STRUCTURE.

The accompanying map (plate 16) is a generalized reduction, in the main, of large scale sheets mapped in detail during the past year. On account of the thinness of the formations, especially in their feather edges, and the intricacy of the boundary lines, great difficulty has been experienced in producing a small scale map in black and white, and the result is not altogether effective. Careful examination should, however, afford all data of general interest concerning the distribution of the formations in the explored belt.

The cross-sections in figure 1 illustrate, at intervals, the structural relations and the general configuration of the mass of each formation above tide-level.

The Columbia formation is omitted from both the map and the sections to avoid the greatly increased complexity which its representation would introduce. In the western part of the region this formation is confined to the lower terraces along the great transverse drainage depressions and for a short distance up some of the side drainage lines. In the low coasts eastward it fringes the shores for a considerable distance, and in the aggregate covers wide areas.

The Potomac formation lies directly on an irregular surface of the old crystalline rocks excepting in a small area north of Richmond, where an outlying mass of the Newark formation intervenes. Southward from Fredericks-

burg it is overlapped by succeeding formations, and only appears in the larger depressions toward the head of tide-water.

The Severn formation lies on the irregular surface of Potomac sands or clays, and thins out and disappears a short distance south of Washington. Opposite Washington its edge is locally cut off by the overlap of succeeding formations.

The Pamunkey formation lies on a slightly irregular surface of the Severn formation in Maryland and directly on the Potomac sands southward through Virginia. Opposite Washington its western edge is also cut off locally by the next succeeding formation, and for the greater part of its area above tide-level it is so deeply buried under later deposits that it only appears in the deeper depressions.

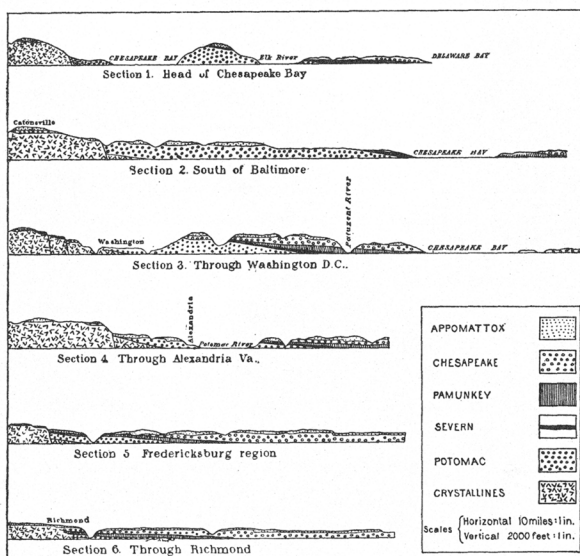


FIGURE 1—Sections through the Cenozoic and Mesozoic Formations and the Crystalline Rocks of eastern Virginia and central Maryland.

The Chesapeake formation rises above tide-level for nearly the entire area of the coastal plain region. It lies on a gently eastward dipping plane of unconformity on the Pamunkey formation, but overlaps westward to the Potomac formation at Washington, and to a greater or less degree to the crystalline rocks in the region southward from Fredericksburg into the Carolinas.

The Appomattox formation is a wide-spread, high-level terrace capping, which lies upon and overlaps all of the other formations. Southward from Fredericksburg it is an almost continuous cap on the high lands from the

crystalline rocks to the sea, but northward it is confined to the higher levels and is more widely eroded.

POTOMAC FORMATION.

Distribution.—The areal distribution of the Potomac formation in Virginia and Maryland is represented on the map, and its characteristics and relations have been described by McGee in his memoir on "Three formations of the middle Atlantic slope." There are, however, a number of special questions respecting its distribution, relations and stratigraphy which merit brief discussion.

Stratigraphy.—It has been suggested by McGee and held by Fontaine that the argillaceous member of the formation is superior to the arenaceous member and perhaps separated by a stratigraphic break. A study of this question has, however, led me to believe that while the relative positions of the two members are in the main as above stated, there is both a lateral and vertical intergradation. In Virginia the arenaceous member occupies the entire width of the outcrop belt. Along the Potomac river and northward the argillaceous member is first seen at the top of the formation; but by a gradual lateral intergradation it appears to extend lower and lower in horizon, finally to the exclusion of the arenaceous beds. Vertical intergradation is well exposed in the Washington region, but evidence of the lateral change is fragmental and less decisive. Northward from Washington to Baltimore and beyond, the formation consists of clays, mainly of red and buff tints, with intercalated sand streaks. This is the iron-bearing clay of Tyson, the variegated clays of Fontaine, and the Baltimorean of Uhler.

The evidence offered by Fontaine to prove the stratigraphic break in the formation is in the clay belt at Hanover station and at Federal hill in Baltimore, where the variegated clays are underlain by sands. I have studied these localities and many others of the same character, and have become convinced that the sands are only lenses inclosed in the clay series; a very common occurrence in the Baltimore region. A boring made in the Federal hill exposures passed through the sands into clays below, and in the Hanover district and northward the clays are often exposed lying directly on the crystalline rocks, both at high and at low levels.

There can be little doubt that the Raritan clays of New Jersey are the northern extension of the Potomac clays, for the outcrops are practically continuous, the relations are precisely the same, and there is no evidence of stratigraphic break or overlap.

The "Albirupean."—In 1888, Uhler* announced the discovery of a formation lying unconformably between the Potomac and Severn formations, for which the name "Albirupean" was suggested.

* Proc. American Phil. Soc., vol. XXV, pp. 42-53.

Regarding this formation I have to report adversely, for it is found to consist of certain local sand beds occurring at several horizons in the Potomac clay series. In Uhler's typical section along the banks of the Severn river above Round bay, the "Albirupear" sands graduate above and laterally into typical iron-bearing clays of the Potomac formation. Other "Albirupear" sands were found to be *included* in the clays along the Patapsco and elsewhere in the Baltimore region. Usually these sands are sharply demarked from clays below by sharp unconformities, but above and laterally they become argillaceous and gradually merge into pure clays. There can be no doubt in regard to the wide vertical distribution of these sand streaks in the formation, and they cannot consistently be grouped as a separate formation.

Shore Deposits.—The shore deposits at the western edge of the Potomac formation often lack the distinctive features of the beds further eastward, and some errors have been made in their identification. In Maryland the pure clays sometimes lie directly on the crystalline rocks, but usually they become sandy and gravelly, and in some cases are represented solely by coarse materials. In Virginia the arenaceous beds are usually overlapped by later formations, but a few basal contacts are exposed in which the sands, with clay pebbles and quartz pebbles, lie directly on the crystalline schists. Both in Virginia and Maryland there are regions in which the western margin of the formation is represented by fringes and outliers of coarser shore deposits, usually capped by a protecting mantle of the less destructible Appomattox gravels. The Appomattox formation in these regions consists largely of rearranged Potomac gravels, and this has led them formerly to be mistaken for undisturbed Potomac sediments, but it is almost always possible to discriminate the two formations. In the terraces west of Alexandria, Washington, and Baltimore, notably at Tennallytown and Catonsville, this joint occurrence is especially notable.

In the Sassafra river region I find that McGee* has included a portion of the dark Cretaceous (Severn) beds in the Potomac, and in Maulden's mountain excluded as Cretaceous some gray and brown sands really belonging to the Potomac.

Stratigraphic Position.—The Potomac formation, as originally defined by McGee, is a stratigraphic unit lying between the Newark formation and the New Jersey Cretaceous greensand series and separated from both by structural breaks representing long time gaps. Its upper part or entire thickness in the north may extend more or less above the horizon of the beds in the James and Potomac regions, but the formation represents continuous deposition throughout.

* Geology of Head of Chesapeake Bay; U. S. Geol. Survey, Report of Director, 1885-'86, pp. 585, 587, 590, 613.

The erosion epoch between the Potomac formation and the Cretaceous greensand is one of considerable moment, but the gap between the Potomac and Newark represents one of the great periods of uplift and erosion which is second only to the gap between the Paleozoics and the Newark formation.

SEVERN FORMATION.

Distribution and Characteristics.—In 1888, Clark identified the Cretaceous formation on the "western shore" of Maryland by the discovery of typical molluscan casts at Round bay on the Severn river, on Magothy river, at Millersville and Collington, and at Fort Washington, and so set at rest any question in regard to the southward extension of the formation, at least through Maryland. The writer has found that the formation is a continuous sheet, clearly defined in its stratigraphic relations, and finally disappearing near the latitude of Marshall Hall, on the Potomac river, south of Washington.

The formation consists throughout almost entirely of fine black sand, more or less flecked with scales of mica, very sparingly but irregularly glauconitic, and usually containing considerable carbonaceous materials. The finest exposures are in the high cliffs at Round bay, on the Severn river, a locality to which Clark and Uhler have paid considerable attention. There it is exposed lying on an irregular surface of a local coarse gray sand bed in the Potomac formation; and back from the river, on some of the higher lands, it is in turn capped by weathered beds of the Pamunkey formation, beneath which it also disappears down the river toward Annapolis. Southward there are frequent exposures in road, railroad and stream cuts, in a narrow belt which extends continuously nearly to Washington; thence its edge is cut out for a few miles by an overlap of the Chesapeake formation, but it comes out again opposite Alexandria and is exposed in considerable force in the gullies along the face of the terrace fronting the Potomac and in some of the side drainage ways. At Fort Washington it is exposed in the "bluff," lying on gray lignitic clays of the Potomac formation, and capped by a few feet of weathered Pamunkey deposits.

At every exposure organic remains are found, commonly in the forms of casts or impressions. At several localities east and southeast of Washington and a short distance from the city I have found fossil shells occurring abundantly in the formation, notably *Exogyra costata* and a large *Cyprimeria*, like *densata*.

Northward from Round bay the formation is exposed in the lower Magothy river for the last time on the "western shore." On the eastern side of Chesapeake bay the black carbonaceous sands are again exposed, lying on the Potomac sands and clays at Howell's point, and thence occupying the high banks of the lower Sassafras river, finally sinking beneath the Pamunkey

formation near Lloyd's creek. On the northern side of the Sassafras, again near its head, and in the Bohemia creek depression, the formation is also exposed at intervals. In Delaware the exposures in the Chesapeake and Delaware canal cuts are well known, and in this region the formation comprises a series of more or less distinctly separable beds, which, by Chester, have been correlated with the various members of the New Jersey greensand series.

The thickness of the formation gradually decreases southward; in the lower Sassafras and Round bay regions it is nearly 100 feet; northeast of Washington, 10 to 30 feet; opposite Alexandria, 25 feet; along Henson creek, 20 feet; and in the Fort Washington bluff, 18 feet.

Stratigraphic Relations and Equivalency.—The Severn formation is frequently exposed in contact with the Potomac clays, and lies on an unconformity always sharply defined by great contrast in material and considerable local irregularity of surface. It is in turn unconformably overlain by the Pamunkey formation, from which it is widely separated structurally and faunally.

The Severn formation is the continuous southern extension of the New Jersey Cretaceous greensand series, but whether it represents all or part of these members is not as yet determined. In Maryland it is a stratigraphic unit, distinctly separable from the New Jersey series as a whole by its homogeneity of constitution; and it is with this restriction that the term "Severn" is applied.

PAMUNKEY FORMATION.

Distribution and Characteristics: General Features.—This formation occupies a belt of considerable width extending through Maryland and Virginia above tide-level with a length of about 200 miles. The greater part of its area is buried beneath younger formations, but it is exposed extensively in each of the larger depressions, where it is a conspicuous member of the coastal plain series.

The formation consists of a homogeneous sheet of fine-grained materials, glauconitic sands mainly, usually profusely fossiliferous. Excepting a few local beds of clay, secondary limestones, and some gravels at its base, the formation does not comprise stratigraphic components. Wherever the formation has been bared of overlying formations its glauconitic constituent is either weathered out, leaving fine light-colored sands, or decomposed and the iron redeposited as a red or brown stain and in crusts and concretions. This weathered phase is general in the northern part of the region beyond the edge of the overlying Chesapeake formation, along the western margin in Virginia, and in all old outcrops.

In describing the distribution and noteworthy exposures of the formation it will be convenient to briefly consider each general area separately.

Nottoway River.—The southernmost exposure of the Pamunkey formation is a small outcrop near Bollings bridge, which I have not visited.

Appomattox River.—At Petersburg the formation is represented by a few feet of slightly glauconitic black sands containing casts of Eocene mollusca. This is exposed lying on the Potomac gravels just northwest of the city, and again in the depression at the city water-works, where it is capped by Chesapeake beds.

James River.—In the James river depression and up its side branches the Pamunkey formation is extensively exposed. At Richmond the thin edge of the formation consists of black sands similar to those at Petersburg, and it is exposed lying between Chesapeake and Potomac beds in the Shockoe creek depression.

Descending the James, for several miles the edge of the formation lies some distance back from the river bluffs, and is more or less overlapped by the Appomattox. From a short distance below Dutch gap to Coggins point the formation, with its gentle easterly inclination, gradually crosses tide-level and the river bluff exposures are frequent, and at some points particularly fine, notably at Tar bay. The beds consists mainly of richly glauconitic marls, highly fossiliferous, which are worked to some extent for fertilizers. The overlying Chesapeake beds become prominent in the bluffs below City Point, and in this region there is a thin local bed of white clay in the Pamunkey formation near its summit.

Chickahominy River.—This stream was not explored, but the Pamunkey formation is probably reached by the river channel for a greater or less distance in the district opposite the James river exposures.

Pamunkey River.—The exposures in this depression begin just about Hanover Court-House, and thence for many miles down the river they constitute an almost continuous section. Rogers considered this section typical, and described some of the outcrops in considerable detail. Glauconitic sands predominate, and fossils are abundant.

Mattaponi River.—Exposures are frequent on the Mattaponi, but are not especially noteworthy. Argillaceous materials enter largely into the components of the formation.

Rappahannock River.—In this basin the outcrops of the formation occupy a considerable area. West and northwest of Fredericksburg the beds of buff sand lying on the Potomac formation are found to be Pamunkey in age, representing beds from which the glauconite has been weathered out. Farther eastward the glauconitic marls are seen in many excellent exposures in river bluffs and side drainage depressions, capped usually by the Chesapeake beds.

Potomac River.—The formation occupies the western side of this basin from near Washington to Pope's creek, and the eastern side from Acquia

creek to Mathias point. The finest exposures are in the high bluffs that extend eastward along the river from the mouth of Acquia creek. About 100 feet of Pamunkey beds are exhibited, consisting mainly of glauconitic marls and sands, with several limestone beds, and, near the top, a few feet of light-colored sandy clays. Fossils are abundant, and very nearly the entire Pamunkey fauna is represented. West of this region the weathered phase of the formation predominates, and its soft buff sands are conspicuous toward Stafford Court-House, in one area including a thick fossiliferous limestone stratum.

On the eastern side of the Potomac, Port Tobacco river, and Mattawoman, Piscataway and Henson creeks and their branches give frequent exposures of fossiliferous glauconitic marls, and there are outcrops along the Potomac river at Pope's creek, at Clifton Beach and in the bluff at Fort Washington.

Opposite Washington (as shown in figure 1, page 435) the western edge of the formation is cut out and replaced by the Chesapeake formation. This condition prevails in the high ridge lying just east of the Anacostia river; but farther eastward and southward the edge of the formation is exposed again, and its fossiliferous marls are found in every drainage way to within about five miles of the capital.

Patuxent River.—In this valley the formation emerges from beneath the Chesapeake beds at tide-level a few miles below Nottingham, and, rapidly widening in area northward, finally extends around past Marlboro to the drainage of the Anacostia and northeastward to the shores of Chesapeake bay. In the southern part of the area, dark-colored glauconitic marls prevail; but in districts where the Chesapeake mantle has been removed the red sands of the weathered phase occupy the surface. These red sands contain abundant casts and impressions of Eocene species, and there can be no doubt as to their stratigraphic equivalency with the dark beds southward.

Chesapeake Bay.—In the Annapolis region and along the South and Severn rivers the weathered phase attains the greatest development, and red sands with ferruginous crusts, concretions and sandstone layers occupy a wide area. The opposite or "eastern shore" of Maryland is heavily mantled by sands and gravels of undetermined age, and outcrops of the subterranean are infrequent; but I have studied the river banks and traced the Pamunkey formation up the Chester river past Chestertown and up the Sassafras river past Georgetown into Delaware nearly to Nockimixon pond, where it thins out and the Severn and Chesapeake formations come together.

In the "eastern shore" exposures the weathered phase was found to prevail; but casts and impressions of *Cardita planicosta* and *Dociniopsis meekii* occur in every outcrop. On the Sassafras river the Severn formation occurs for some distance near its mouth, and again, I believe, at its head; but there is a wide intermediate belt occupied by Pamunkey beds, which are espe-

cially well exhibited at Georgetown and Fredericktown. The Pamunkey area on the "eastern shore" is indicated on the map (plate 16) by a broken line, which, I should add, is only approximately accurate.

Thickness.—The thickness of the Pamunkey formation along its southeastern outcrops is about 150 feet from the South river to James river, and is apparently quite uniform throughout. Northwestward the thickness diminishes to a mere feather edge lying on the Potomac formation and usually overlapped by the Chesapeake or Appomattox formation.

Stratigraphic Relations.—North of the Potomac river the Pamunkey formation lies between the black sands of the Severn formation and the diatomous beds of the Chesapeake formation, separated in each case by a wide structural and paleontologic gap. Exposures of unconformity with the Severn formation are not abundant, and, owing to close similarity and intermingling of materials at the contact, are not always distinct. Along some of the headwaters of the Northwest branch of the Patuxent and again in the bluff at Fort Washington the weathered red beds of the Pamunkey are at several points exposed lying on a slightly irregular surface of the unchanged black sands of the Severn formation, and contacts are also occasionally observed on the South, Severn and Magothy rivers. A fine exposure of the contact is displayed in a road cutting a few hundred yards south of Buena Vista, Prince George county, Maryland.

At Glymont, Maryland, and thence southward through Virginia, the Pamunkey formation lies directly on an irregular surface of the Potomac formation, usually including more or less numerous Potomac pebbles in its lower beds. In the vicinity of Acquia creek, exposures of contacts are frequent, and along the railroad a few rods south of the bridge there is an exposure, referred to by McGee, in which the base of the Pamunkey formation is seen occupying an old ravine in the Potomac surface. At many points near Fredericksburg and Brooke station, as well as at Richmond and Deep Bottom on the James, and at Petersburg and Bollings bridge, the basal pebble bed of the Pamunkey and the contact with the Potomac are exposed with uniform relations throughout.

The unconformable superposition of the Chesapeake on the Pamunkey formation was frequently referred to by Rogers, and I have traced it through hundreds of exposures in Virginia and through Maryland.

The surface is usually relatively smooth, but there is a sharp contrast in materials and usually a streak of pebbles of quartz or of Eocene fossil casts in the overlying beds.

Along the western border of the coastal plain region at some localities, and in the higher river terraces, the Appomattox formation lies directly on the Pamunkey formation, and in the lower river terraces the latter is overlain by the Columbia deposits.

Taxonomy.—The paleontologic evidence in regard to the age of the Pamunkey formation establishes its equivalency with the Eocene as recognized by Rogers and Conrad half a century ago. It is not possible as yet to definitely state its precise relative position in the Eocene, or to correlate it with other North American deposits. It is not known whether its basal and surface planes are approximately parallel throughout, either to each other or to the bedding of the formation.

CHESAPEAKE FORMATION.

Distribution and Characteristics.—This formation occupies a belt comprising nearly the entire width of the coastal plain region in Virginia and a wide area in southeastern Maryland. All of the water-courses of the region cut more or less deeply into the formation, and it frequently constitutes high bluffs along the larger streams. In Maryland it lies east of the Potomac river, and on the "western shore" its northern termination is in a series of outliers midway on a line connecting Washington and Annapolis. Its northern limit on the "eastern shore" is indicated approximately by the dotted line on the map (plate 16), but the details of its distribution in that region are not yet determined.

The formation is diverse in composition, consisting of sands, clays, marls, diatomaceous beds, and shell fragments, in all several hundred feet in thickness. The lower beds consist mainly of dark-colored clays and fine, mealy sands containing the extensive and well-known diatomaceous deposits. These are succeeded by lighter-colored clays and sands, with occasional local inclusions of blue marl. The upper beds are coarser-grained, and consist chiefly of white beach sands containing shells and deposits of shell fragments, and occasional argillaceous members. These three series intergrade in zones, which vary somewhat in stratigraphic position and vertical extent, and all the members rapidly thicken seaward, apparently reaching a thickness of nearly 1,000 feet at Fort Monroe.

The lower beds of the formation occupy a broad, irregular belt extending through Virginia into Maryland along the western part of the coastal plain region. Its finest exposures are at Richmond, at Petersburg, on the Rapahannock river below Fredericksburg, on the Potomac river at Pope's creek (Maryland), on the Patuxent river near Nottingham, and at Herring bay on Chesapeake bay. On the "eastern shore" it is seen near Wye Mills (Maryland), and on Little Duck creek, south of Clayton (Delaware); and it is found in the deep artesian wells at Atlantic City, New Jersey. On the "western shore" of Maryland I have found that it extends northwestward to Washington, being conspicuous in the high terraces overlooking the city from the east, and represented by an isolated patch lying on the Potomac sands and crystallines just outside of West Washington.

In Virginia, southward from Fredericksburg, it extends far westward on all of the divides, but with gentle seaward inclination follows down the drainage eastward. The diatomaceous deposits are variable in size and purity, and are irregularly scattered through the clays without restriction to any definite stratum.

The medial clays and marls are relatively thin, but they occupy a considerable area in Virginia. The finest exposures are on the James river near Claremont, near Hanover Court-House, in the Bowling Green region, in Nomini cliffs on the Potomac river, on the lower St. Mary's river, and near West Point on the York river.

A well-known exposure of the upper beds of the Chesapeake formation is found in the cliffs at Yorktown; and other fine exposures are at Grove wharf, Smithfield and Claremont on James river, at Suffolk on Nansemond river, at Lanexa on the Chickahominy, at Urbana on the Rappahannock, along the lower Patuxent river and the adjoining shores of Chesapeake bay, and near Easton as well as elsewhere on the Choptank river. At all these points the Yorktown fauna is well represented, and the remains occur in great abundance, Claremont on James river being an especially noteworthy locality, although less known than some of the others.

Stratigraphic Relations.—For the greater part of its area, the clays of the Chesapeake formation lie directly on the eroded surface of the Pamunkey greensands. Westward at some points it overlaps for short distances on the Potomac formation and crystalline rocks. On James river below City Point the medial portion of the formation lies on Pamunkey greensands, indicating an island or local shore bluff in the early Chesapeake seas. Elsewhere the stratigraphic position of the base of the formation appears to be constant, and the basal plane is a smooth surface inclined eastward very uniformly at the rate of about ten feet to the mile.

In the Washington section the base of the Chesapeake formation locally cuts across the thin edges of the Pamunkey and Severn formations, and lies directly on the Potomac formation. At Good Hope hill, in this region, occur the Eocene fossils mentioned by McGee,* but they are found to be casts mixed with casts of Cretaceous species, both imbedded in sands containing impressions of Miocene mollusca. This occurrence of pebbles, in part consisting of fossil casts, is quite common at the base of the Chesapeake formation, notably at Herring bay and on the Pamunkey river. In Maryland, especially near Nottingham and on Pope's creek, the base of the formation consists locally of a thin, hard silicified stratum filled with Miocene molluscan impressions.

The Chesapeake formation is unconformably overlain by the Appomattox formation, and along the bay shores and stream depressions by the Columbia formation.

* "Three Formations of the Middle Atlantic Slope." Am. Jour. Sci., 3d ser., vol. XXXV, p. 136.

Taxonomy.—The Chesapeake formation is abundantly fossiliferous throughout, and the Miocene age of the fauna was recognized by Rogers and Conrad half a century ago.

It has been shown by Heilprin that the fauna of the upper part of the formation differs materially from that of the lower, but I find that there is less difference than is indicated by Conrad's lists, and that the transition is a very gradual one. The formation can hardly, on these grounds, be separated into Marylandian and Virginian, as proposed; and there is every reason to believe that the beds in Virginia in their entirety are of precisely the same age as their extension into Maryland. The paleontologic evidence is fully in accord with this, at least in a general way, and the structural evidence indicates complete continuity.

APPOMATTOX FORMATION.

Distribution and Characteristics.—The differentiation of the Appomattox formation in the southern states by McGee is one of the most valuable contributions ever made to American geologic science. The great extent and prominence of the formation and its significant bearing on the geologic history of North America give it an importance second to that of no other formation on the Atlantic slope.

The northern termination of the deposits was supposed to be near Potomac creek, a few miles north of Fredericksburg; but I have found that while there is a break in its continuity in the region east of the Potomac river, it soon begins again and thence continues northward probably through Maryland, and in attenuated scattered outcrops, through Delaware and into Pennsylvania and New Jersey.

It is displayed in the high terraces about Washington, and it caps nearly all the higher terrace levels of the "western shore" of Maryland northward to the latitude of Baltimore. Still farther northward it is confined to outliers on the divides along the western margin of the coastal plain region; but at the head of Chesapeake bay it extends farther eastward and, in the high Elk ridge, caps the Cretaceous and Potomac formations over a considerable area.

The formation was no doubt originally continuous throughout the Atlantic coastal plain, but it has suffered great erosion. Southward it caps all the high terraces, but northward from the Mattaponi the drainage ways have invaded it more widely until north of the latitude of Washington its remaining areas are relatively small isolated outliers.

The Appomattox formation in eastern Virginia consists of light-colored loams of buff and orange tints, containing streaks and beds of pebbles and coarse sand in varying proportions and irregular deposition. Northward

in Maryland coarser materials gradually increase in amount, and in the Washington-Baltimore region and northward gravel beds predominate. On Good Hope hill, east of Washington, the high terrace is capped for some distance by beds consisting mainly of large pebbles and sand, with a buff loam matrix. Farther eastward the proportion of loam increases and the pebbles decrease in size and number. In the high terraces extending westward from Alexandria, in the outliers west of Washington and Baltimore, in the high terraces southeast of Baltimore, and generally along the crystalline border in Maryland and Delaware, the formation consists mainly of iron-stained pebbles in a matrix of more or less sandy orange or buff loam. Thin layers and lenses of ferruginous conglomerates are of frequent occurrence in the northern Maryland belt, in the capping on Elk neck, and in the Pennsylvania and New Jersey outliers. In some cases the formation contains somewhat coarser materials adjacent to the larger drainage depressions, especially on the Potomac river, where the pebble beds are particularly noteworthy.

The thickness of the formation is variable, but it averages between 20 and 30 feet. In Maryland it is generally under 25 feet, but in Virginia it is usually somewhat thicker than this.

Stratigraphic Relations.—The Appomattox formation lies on a terraced surface comprising in various regions all the preceding formations of the coastal plain series. In Virginia and the southern part of the "western shore" of Maryland it lies on the Chesapeake formation over an area of several thousand square miles. It overlaps upon the Pamunkey formation in the Fredericksburg region, northeast of Washington, and in the James, Pamunkey, Mattaponi, Rappahannock and Potomac depressions. In several isolated knobs on Elk neck it lies directly on the Cretaceous greensand series. It lies on the Potomac formation in the Hanover Junction region, about Fredericksburg, in the wide terraces west and south of Alexandria and Washington, in the Baltimore region, and thence northward in Maryland and probably in Delaware. In the Richmond coal field and about Hanover Junction it lies on the Newark formation, and all along the western edge of the coastal plain region it overlaps for a greater or less distance upon the crystalline rocks in Virginia, Maryland and Delaware.

Generally the base of the formation is sharply demarked, but frequently it is composed of local materials which merge more or less gradually into the surface of the underlying formation. This is particularly the case in some contacts with the lower Chesapeake, Pamunkey and Potomac formations, which have furnished much of the Appomattox materials.

The surface on which the Appomattox formation was deposited is a series of gently rolling plains, separated by gentle slopes and low local terrace scarps. These terraces and slopes descend successively eastward with varying intervals and amounts, and the plains have also a very gentle eastward

inclination. There is also a series of similar transverse pre-Appomattox terraces and slopes along the great transverse drainage depressions, which add complexity to the contour of the basal surface, but at the same time throw much light on the geologic history of the region.

In the first place, as all these shallow terraced basins appear to be pre-Appomattox in age, their existence records the interesting fact that the transverse depressions of the coastal plain region were first excavated by the retreating waters which carved the longitudinal terraces during the interval between the deposition of the Chesapeake and Appomattox formations; for the pre-Appomattox formations bear no records of the presence of transverse drainage. In the second place, it is found that these terraces present evidence of a post-Appomattox deformation in their extension to progressively lower minimum levels from north to south from Maryland to North Carolina. In the Roanoke basin the Appomattox is brought down to tide-level at some points by the terraces, but northward the minimum elevation of its base gradually increases finally to an altitude of 250 feet at the head of Chesapeake bay. As it is altogether improbable that there was longitudinal inclination to the floor on which the Appomattox formation was deposited, this gradual northward slope indicates an uplift approximating 250 feet in amount distributed through the interval of about 250 miles.

The origin of the oblique southward deflection of the rivers across the western part of the coastal plain does not appear to be related to this longitudinal uplift. It is probably due either to a shallow pre-Appomattox flexing along the Piedmont shore or to shallow channels just off the mouths of the pre-Appomattox streams. In either case the result would be a southward deflection of the drainage into these lines when emergence took place.

As I have not yet studied the seaward extension of the Appomattox formation, I have not observed its overlap by the Columbia formation; but the two formations are separated by a great uplift and erosion interval. This epoch differed from its base-leveling predecessors by greater relative emergence and consequent stream action which developed the greater part of the present physiography of the region. This erosion deepened and greatly widened the transverse drainage depressions, trenched the side drainage depressions, and cut into the edges of the terraces to an extent gradually increasing northward from North Carolina, and in northern Maryland resulting in the removal of wide areas of the coastal plain formations, especially the Chesapeake and Appomattox.

Taxonomy.—No fossils have yet been discovered in the Appomattox formation in the Virginia-Maryland region, but the structural evidence above presented definitely places its stratigraphic position between the Chesapeake and Columbia formations, and widely separated from both by long erosion intervals. Its precise age is unknown.

COLUMBIA FORMATION.

In regard to this formation I have at present but little of general interest to add to the statements of McGee. I do not find the interfluvial phase so widespread as was originally supposed, and do find that certain high level gravels and terraces of the Washington region are of Appomattox age.

The Columbia terraces border the coastal plain rivers from the fall line region to their mouths, and extend over wide areas in the low regions adjoining Chesapeake bay. The formation lies on terrace planes cut in the various subterranean near tide-level and ranging in position from a few feet above to a moderate distance below.

The altitude of the terraces decreases eastward, and, as shown by McGee, gradually increases northward through Virginia and Maryland. This increase of altitude northward is similar to that of the Appomattox formation, but less in amount, and probably indicates that part of the deformation is of post-Columbia age.

Following Columbia deposition came increased emergence, slightly greater northward, and cutting of the present river channels to depths considerably below present tide-level. Then followed submergence, which buried the great river channels and the eastern edge of the coastal plain under tide-water and ushered in the present epoch.

THE DISPLACEMENT.

Course and Relations.—In studying the physiography of the head of Chesapeake bay McGee found evidence of the existence of a longitudinal displacement, which has depressed the level of the coastal plain considerably below that of the Piedmont region. The line of dislocation is marked by steep slopes along the margin of the Piedmont region, and was traced for several miles along the side of the head of the bay. It was suggested that this displacement probably extended from the Hudson river region southward along the border of the coastal plain, following down the Anacostia river east of Washington, and finally merging into a flexure in the Acquia creek region.

I have found, however, in studying the border zone between the Piedmont and coastal plain regions, that there is a line of dislocation some miles west of this course which is practically continuous from at least as far north as Newark, Delaware, to south of Fredericksburg, and has had a more complicated history than was at first supposed. The details of this history are not as yet fully worked out, and at this time it is possible to give only a brief general account of the more prominent consequences of the displacement.

The dislocation traverses the crystalline rocks and Newark, Potomac, Pamunkey, Chesapeake (?), Appomattox and Columbia formations, but the Potomac, Appomattox and adjoining crystallines are the formations in which

the relations of the actual fault line are mostly exhibited. The displacement, as a whole, appears to be continuous throughout, but its amount varies, and in some areas the effects of dislocation become indistinct through diminution in amount, distribution through a zone, or merging into a flexure.

South of Baltimore, near Relay, the relations of the dislocation are particularly well exhibited, and the amount of displacement is fully 250 feet. The relations in this region are shown in section 2, figure 1, page 435. At the exposures in this vicinity, clay caps the bare steep slope of the crystalline fault scarp, and at the base, on the downthrown block, a greater or less thickness of clay abuts against it. This relationship is general for some miles south from Baltimore, and west of the city it is exhibited in diminished amount near Loudon Park cemetery, beyond which evidence of the dislocation is lost for some distance.

Northeastward from Baltimore the effects of the dislocation soon become prominent, and its line is marked by a steep scarp in the crystallines, which extends with varying heights and degrees of distinctness through northern Maryland into Delaware and beyond. Usually the Potomac and Appomattox materials are either eroded back from the summit of the scarp for some distance or entirely removed, and in the larger depressions the drainage has cut through a greater or less thickness of Potomac materials on the downthrown side, exposing the crystalline floor for a mile or two eastward.

At Washington a dislocation traverses the thin outlying feather edges of the Potomac formation and its Appomattox cap just west of Georgetown, and crosses the Potomac river just below the fall line. Thence through northern Virginia the dislocation gives rise to a prominent scarp on each divide, which is more or less continuous and distinct for many miles. At first it dislocates the Appomattox, together with, at some points, a feather edge of the Potomac; but in the region between Occoquan and Fredericksburg its amount increases greatly and it traverses a considerable thickness of the Potomac, at one point the western edge of the Pamunkey, and in most cases the Appomattox, with a throw of from 150 to 300 feet, as shown in sections 3 and 4, figure 1 (page 435).

This dislocation crosses the Rappahannock a mile above Fredericksburg, and its relations are there well exposed. It has not been definitely traced southward, but there is evidence of displacement near Richmond and Petersburg, which may be along a continuation of this same dislocation.

Date.—The date of the displacement is in the main post-Appomattox, but there is some evidence that a series of local movements occurred before the epoch of Appomattox deposition. The greater part of the displacement was effected between Appomattox and Columbia times, apparently just before Columbia deposition. In the gorge of the Potomac river a narrow Columbia terrace extends for some miles above the line of dislocation, and the relative

altitude of this terrace and the Columbia terraces eastward about Washington suggests some displacement in post-Columbia or intra-Columbia times. Since Appomattox times the scarp west of the displacement has been cut down in the drainage depressions, and in the larger streams has given rise to a special series of gradually receding rapids, of which the Great falls of the Potomac is an example.

GEOLOGIC HISTORY.

The principal events in the history of the coastal plain region, so far as now determined, are as follows :

1. Irregular surface and shore line of crystalline rocks, overlapped in certain areas by the Newark formation.
2. Submergence and deposition of the Potomac formation.
3. Emergence; degradation of the Potomac to an unknown extent.
4. Submergence; deposition of Cretaceous greensand series, including the Severn deposits.
5. Emergence; degradation of the Cretaceous and, toward the south, of the Potomac to an unknown extent.
6. Submergence; deposition of the Pamunkey formation on the Severn and Potomac surfaces.
7. Emergence; degradation of the Pamunkey and its shores westward.
8. Submergence; deposition of the Chesapeake formation.
9. Emergence; terracing and cutting of basins now occupied by the estuaries.
10. Submergence; deposition of the Appomattox formation, overlapping far upon the Piedmont region.
11. Emergence; tilting northward; subaërial development of the outlines of the present topographic configuration; widespread lateral degradation, increasing in amount northward; displacement along the great dislocation.
12. Submergence and deposition of the Columbia materials.
13. Emergence somewhat greater in amount than the submergence of 12; land tilted gently southward; excavation of channels in the Columbia and underlying beds in greater part to somewhat below present tide-level.
14. Slight submergence; marsh, silt and shore formations of recent age.

Of course, this list really comprises only the headings of chapters, which record a vast number of minor events and complications of geologic history, only to be unravelled by a great amount of careful study. At present it would be premature to discuss the events in greater detail, for the data at hand are incomplete and in large part unsatisfactory. In the continuation of the investigation, however, it is hoped that there may be attained a full elucidation of geologic history and relations in the coastal plain region.