INTRODUCTION

Along the eastern border of the Piedmont plateau, lying for the most part directly on the flanks of its ancient crystallines and constituting the basal element of the Atlantic Coastal plain, is a series of mostly unconsolidated, arenaceous, argillaceous, and often ferruginous sediments of highly varied character. The outcrop constitutes a relatively narrow belt, extending from cape Cod to the Mississippi basin and ranging from a few to 20 miles in width, its landward boundary lying somewhat westward of the so-called Atlantic Fall line.

The general strike of the beds along the Atlantic border is northeast-southwest, the belt being divisible into three districts—northern, middle, and southern—whose strike is progressively more and more southward in passing from the northern district to the southern. The normal dip of the beds within the area of outcrop ranges from 30 to 60 feet per mile, a well marked increase occurring toward the landward margin and a decrease to the seaward. The thickness of the deposits, at the point where they pass beneath tide, ranges from 100 to 1,000 feet, dependent largely on whether the full sequence of formations is present or not. The main body of the deposits lies below tidelevel, although the strata occasionally reach 500 feet above sealevel along the western margin of the Coastal plain.

The belt crosses all of the principal waterways of the Atlantic slope, by which it is divided into a series of broad, low watersheds. The higher elevations have relatively steep and often irregular slopes, the region being one of comparative youth. The streams, when not tidal, are active, but the belt is frequently cut to its western margin by tidal estuaries.

The flora of these deposits includes thallophytes, liverworts, equiseta, ferns, cycads, conifers, monocotyledons, and dicotyledons. A conspicuous feature of the earlier and middle floras was the cycadaceous, one of the most important organic facts, and one which points as well to the prevalence of a subtropical climate as to the Mesozoic age of the deposits.

The remains of conifers are considerably more common than those of other types, though such may not have been actually the case during that period, as the trunks of the former are much better adapted for preservation than most of the other forms.

The most variable element of the flora is the dicotyledonous. In the lower beds the forms are scant, as well as primitive in type. In the succeeding deposits they become progressively more and more specialized and abundant, until, in the uppermost beds, there is a wide range of highly organized genera and species with well marked modern affinities and a great profusion of individuals.

The fauna includes sponges, either worm or insect larvæ borings, insects, lamellibranchs, gastropods, fishes, and reptiles, including plesiosauria and dinosauria. Remains of the last mentioned group, including both diminutive and gigantic species, are by far the most important, and serve to confirm the evidence of the cycads as to the Mesozoic age of the deposits, as well as of the prevailing warm climate. The absence of any strictly marine fossils* and sediments, together with the presence of a few brackish water shells, point to estuarine conditions of deposition.

The sands and clays have been largely drawn upon for building and other purposes, and this fact, together with the alternately argillaceous and arenaceous character of its soils, early gave rise to the name "clay and sand belt."

The name "Potomac" was first applied to the lower and middle portions of these deposits by Professor W J McGee,† of the U. S. Geological Survey, who began his studies in the Potomac River basin near Washington, D. C.

It hardly needs mention here that the Potomac deposits have been the subject of a great amount of study by many independent workers, who have approached the problem from nearly as many different points of view. These facts, together with the proverbially complicated stratigraphy, have given rise to a highly varied taxonomy and nomenclature and a corresponding amount of not always the best-humored controversy. The views of the several writers, including those of the authors of this paper, as set forth in the Journal of Geology in 1897, are shown on the accompanying comparative taxonomic table.

It is believed by the authors that the Maryland section contains more facts on which to base a solution of Potomac problems than any other. To begin with, it is centrally located, well within the belt. A study of the margins of sedimentary formations is apt to convey erroneous im-

*Spicules of sponges are often common in clearly defined estuarine deposits. They occur in abundance in recent estuarine sediments of the Chesapeake as far north as Baltimore.

† Report of health officer, D. C., 1884–'5 (1886), p. 20.

pressions as to their character as a whole. Again, in central Maryland the Potomac beds reach their maximum breadth of outcrop, their greatest thickness, as well as their greatest lithologic and paleontologic diversity. With these facts clearly in view, the authors have attempted the interpretation of the Maryland area, and have brought to bear on its problems the results of a large amount of systematic field work in this region, as well as in the areas both to the north and south.

The constituent formations of the Potomac group, with the exception of the Arundel formation in part, dip at progressively lower angles from below upward, and in general gradually thicken down the dip within the limits of the area of outcrop, although they gradually thin farther to the seaward. Their stratigraphic relation is that of progressive transgression landward from the southwestward, the younger formations extending farther and farther toward the Coastal plain margin northward, until they successively come to rest on the Piedmont plateau. The general relations for the Maryland deposits are shown in the accompanying vertical and columnar sections.

Since the publication by the authors in the Journal of Geology in 1897 of "The Stratigraphy of the Potomac Group in Maryland" field investigations have been steadily in progress during the summer months under the joint auspices of the Maryland Geological Survey, the Woman's College of Baltimore, and the U. S. Geological Survey. Although the position taken by the authors in that paper was based on a moderate field knowledge of the Potomac beds, subsequent work has, in the main, confirmed the conclusions there stated. A great number of comparative sections have been made and collections of fossils obtained from many stations heretofore unknown. Detailed mapping, on the base of the U. S. Geological Survey topographic atlas sheets, is nearing completion in Maryland and the District of Columbia, and much work has also been done in Virginia, Delaware, Pennsylvania, and New Jersey. The lines for the Maryland area are shown on the accompanying map, reduced from those on the atlas sheets to a scale of 12 miles to the inch.

Descriptions of the constituent Formations of the Potomac Group in Maryland

THE FORMATIONS AND THEIR RELATIONS

In the Potomac deposits of the middle Atlantic slope four formations are recognizable, named in order of age the Patuxent, the Arundel, the Patapsco, and the Raritan. Their relations to one another and to their immediately subjacent and superjacent terranes are shown in the following table:

Group.	Formation.	Age.	Origin.
Columbia	Talbot, Wicomico, Sunderland	Pleistocene	Marine, Estuarine, and Fluviatile.
	Lafayette	Pliocene	Marine, Estuarine, and Fluviatile.
	or Aquia	Eocene	Marine.
	or Matawan	Cretaceous	Marine.
Potomac	Raritan	Cretaceous	Estuarine.
	Patapsco	"	Estuarine.
	Arundel	Jurassic (?)	Estuarine.
	Patuxent	"	Estuarine.
	Newark*	Triassic	Estuarine and igneous.
	or Crystalline rocks.	Algonkian (?)	Sedimentary and igneous.

PATUXENT FORMATION

Name and lithologic characters.—The Patuxent formation receives its name from the Patuxent river, in Maryland, in the basin of which the deposits of this horizon were first recognized as an independent formation and systematically studied. The deposits consist mainly of sands, at times quite pure and gritty, but generally containing a considerable amount of kaolinized feldspar (known as arkose), whence Roger's name "feldspathic sandstone" for its indurated derivative. Brown loamy sands are also common and are often indurated. Clay balls are at times distributed through the arenaceous beds, which in places contain lenses of gravel (plate 24, figure 1), sometimes with cobblestones several inches in diameter. Frequently the sands pass either abruptly or gradually over into sandy clays, and these in turn into more highly argillaceous materials, which are commonly of light color, but at times become lead-colored and lignitic and rarely iron-bearing. Massive red and variegated clays also occur, but they are of minor importance. They often bear a striking resemblance to certain of the crystalline residuals, from which they are directly derived by redeposition. Those arenaceous materials which chance to lie adjacent to ferruginous clays are not infrequently indurated by hydrous iron oxide, forming a characteristically corrugated ferruginous sandstone (occasionally inclosing oölitic sand) or conglomerate. The more arenaceous deposits are commonly cross-bedded and exhibit evidence of rapid deposition under varying conditions.

*In Maryland the Potomac sediments rest directly on the crystalline rocks, the Newark formation lying on the western flank of the Piedmont plateau.

Organic remains.—The flora of the Patuxent formation includes equiseta, ferns, cycads, conifers, monocotyledons and a very few archaic dicotyledons, the coniferous and cycadean element being particularly strong. The known fauna of the Patuxent formation is limited to a single unio (Ward) and a fish (Fontaine).

Strike, dip, and thickness.—The general strike of the Patuxent beds in Maryland—and the same may be said of the other formations of the Potomac group—is northeast-southwest. Strictly speaking, however, the strike has toward the north a progressively more and more pronounced eastward trend, ranging from north-northeast to south-southwest to the southward of Washington to east-northeast to west-southwest at the head of Chesapeake bay. A well defined change in strike occurs at the head of the bay and another at or near Washington.

The directions of the dip of the Patuxent, as well as of the overlying beds of the Potomac group in Maryland, ranges from east-southeast toward the south to south-southeast toward the north. The amount of the normal dip of the basal beds of the formation reaches some 60 feet per mile. Along the Fall line or zone, which is toward the landward margin of the Patuxent outcrop, the dip of the basal Patuxent beds is considerably greater than this. South of Washington it ranges from 50 to 75 feet. Near the Potomac river the descent reaches some 90 feet per mile. The dip at other points is as follows:

	Feet.		Feet.		Feet.
Burtonsville	75	North of Joppa.	60–80	Egg Hill	80
Laurel	65	Abingdon	100	Cherry Hill	60
Ilchester Hill	68	Harford Furnace	70	Barksdale	45
Relay	200	Carsins	100	Chestnut Hill	50
Catonsville	114	Aberdeen	109	Clifton Heights, Pa.	63
House of Refuge	75	Aldino	100	Sand Hills, N. J.	70
Baltimore	80–90	Webster	100	The basal Potomac beds of the Raritan River region, N. J. (Cook)	60
Towson	66	Havre de Grace	100		
Cub Hill	58	Battle Swamp	73		
Perry Hall	66	Theodora	100		
Loreley	100	Bay View	90		

From these facts we learn that along the zone of the Fall line the Patuxent deposits of the middle Atlantic border, barring two anomalous exceptions, often exhibit a considerably steeper dip than 60 feet per mile, the average for the section mentioned being 80 feet per mile; that this value exhibits considerable variation and reaches its maximum in the Patapsco depression at Relay at 200 feet per mile or more.

The position of the Patuxent deposits of the Lutherville-Timonium area is almost anomalous. Here the beds, which rest on crystalline

limestone of Algonkian age, lie 100 feet lower than the base of the Patuxent at Towson, immediately southeastward. Moreover, they show a slight *northwestward* dip. A similar case occurs in the Conshohocken-Rubicam valley, some 12 miles north-northwest of Philadelphia, where the Patuxent beds, which also rest in part on marble, lie but 200 feet above tide. These sands and clays exhibit unmistakable evidence of local disturbance, due possibly to solution of their calcareous substrata. Whether these two cases are to be explained on the basis of sedimentation on an uneven surface, or to the downthrow westward or some other cause, remains to be determined.

The thickness of the Patuxent formation in central Maryland at the point where its summit passes beneath tide is about 100 feet. The greatest thickness of the exposed beds in a single section of the Maryland area occurs at Schoolhouse hill, Baltimore county, where they reach some 60 feet. At this station there is a heavy bed of Patuxent materials beneath, sufficient probably to raise the total thickness to at least 100 feet. Deep well borings to the southward suggest a well marked thickening of the deposits in that direction, as a glance at the section on the map will show. The well at Saint Elizabeth's Insane Asylum penetrated the Patuxent to a depth of 340 feet, and that of Indian head to a depth of about 353 feet without reaching the base. Allowance must, however, be made for the fact that these borings are at some distance from the margin of the Coastal plain.

Areal distribution and boundaries.—The Patuxent as the basal formation of the Potomac group occupies a position along the landward margin of the Coastal plain. In Maryland its outcrop begins near Indian head on the Potomac river and follows the river shore, generally beneath Potomac deposits of higher horizons to Anacostia, where it passes beneath tide. It extends to the westward beneath the city of Washington and continues northeastward in a deeply dissected and often interrupted belt through Laurel, Relay, Baltimore, Havre de Grace, Northeast, and Elkton to the Delaware line.

It incloses two sorts of Algonkian inliers. One of them, a depressed erosional inlier, due to perforation of the Patuxent terrane by stream erosion, is exposed at many points along the Fall Line zone, notably in the Gunpowder and Laurel quadrangles. The other, a raised original inlier, is exhibited at Grays hill, Maryland, and at Chestnut and Iron hills, Delaware, in the Elkton quadrangle. Though the Patuxtent beds surround these hills, there is no evidence that either this or the superior members of the Potomac ever covered them.

The Algonkian-Patuxent boundary.—This boundary is on the whole the least difficult of the Potomac lines to trace. The chief difficulties are

found in the differentiation of certain massive red and variegated clays near and at the base of the Patuxent formation from residuals of similar character from which they were evidently derived by redeposition. Other residuals closely resemble Patuxent arkosic sands. In cases of imperfect exposures these resemblances are at times the occasion of considerable uncertainty.

Characteristic local section.—Tyson published in 1860 a record of the strata penetrated by an artesian well at "Smith's distillery," situated on Northwest harbor, Baltimore, which is an entirely typical Patuxent section. After passing through 52 feet of river mud, the well penetrated, at 42 feet below tide:

	Feet
1. Sand, gravel, and boulders	6
2. Hard blue clay	9
3. Red clay	6
4. Red ocher	5
5. White sand	4
6. White clay	32
7. White sand and gravel, water-bearing	8
8. White clay	3
9. White sand, gravel, and boulders, water-bearing	7
10. Gneiss rock	..
Total thickness	80

The "boulders" of the first and ninth members are doubtless cobble.

Economic products.—The Patuxent formation, which is on the whole an arenaceous terrane, yields building and other sands (plate 24, figure 2) on a large scale, and road metal in the form of arkosic gravel and iron sandstone and conglomerate. It also yields white and ferruginous clays to some extent as well as black lignitic clays which are in use as a base for pigments. Red and yellow ochers also occur. The drab clays contain a very few workable beds of iron carbonate.

ARUNDEL FORMATION

Name and lithologic characters.—The Arundel formation receives its name from Anne Arundel county, Maryland, where the deposits of this horizon are typically developed and well exposed.

The deposits consist chiefly of large and small lenses of drab or iron-tinted clays. These clays are frequently iron-bearing, the varieties being an earthy spathic ore, occurring in concretions, flakes, geodes, and layers, often in many courses. They are also at times pyritous and occasionally gypseous. The clays may be either massive, exhibiting slickensides surfaces, or laminated. In the latter case they are usually

more or less sandy. They often carry logs of coniferous lignite, usually lying in horizontal position and strongly compressed. Occasionally large upright stumps are encountered, standing where they grew, with the roots and trunks more or less replaced by iron carbonate and iron sulphide. The logs of lignite are not infrequently massed together into a well defined bed of considerable thickness and extent, which has been locally utilized by the miners for fuel (plate 25). The foliaceous remains and seeds of plants are apt to be found in the vicinity of these beds. At times the clay is charged with comminuted lignite, when it is known as "charcoal clay." This clay is apt to be rich in "charcoal ore," and at a few points bears osseous remains. It was one of these beds, situated near Muirkirk, Maryland, from which Mr Hatcher obtained for the late Professor Marsh a considerable collection of dinosaurian and other remains. In the upper portions of the formation, which have long been exposed to atmospheric influences, the carbonate ores have sometimes to a considerable depth changed to hydrous oxides of iron, known to the miners as "brown" or "red" ore. Under these conditions the originally drab-colored clays have suffered a like chemical change, resulting in red or variegated clays. When the Arundel clays at other levels contain scant vegetable matter, they are frequently highly colored, and if they contain ore it is of the red or brown variety and sometimes a red ocher ("Venetian red"). Red ocher generally occurs near the base or summit of the formation, but at times within the main body of the same. To the landward the formation is often arenaceous, and at times exhibits considerable lenses of sand.

Organic remains.—The flora of the Arundel formation includes algæ, fungi, lycopods, ferns, cycads (apparently fronds only), many conifers and monocotyledons, as well as a considerable showing of dicotyledons, which, though not specially advanced in type, are far beyond those of the Patuxent formation in grade as well as in variety and numbers. There is therefore a well defined contrast between the dicotyledonous elements of these two formations.

The fauna of the Arundel formation includes worms (or possibly the borings of insect larvæ), lamellibranchs, gastropods, fishes, and reptiles, including turtles and dinosauria, remains of the latter being comparatively common. Bones of cetaceans are alleged to have been found by Tyson, but the report lacks confirmation. Notwithstanding this, the faunal contrasts between the Arundel and Patuxent are seen to be strongly marked.

Strike, dip, and thickness.—The strike and direction of dip of the Arundel formation within the zone of its occurrence are practically identical with those of the Patuxent formation.

The normal dip of the formation is 40 to 50 feet per mile. At Baltimore it appears to be somewhat less than this. There is a well marked increase in dip to the landward, along or near the Fall line, as in the case of the Patuxent the average rate of descent at twenty stations being about 72 feet per mile, the range being from 34 to 190 feet. Abingdon, 34 feet; Joppa, 40 feet; Loreley, 93 feet; Stemmers run, 53 feet; Homestead (Baltimore), 60 feet; Loudon park, 50 feet; Relay, 80 feet, with one local dip of 133 feet and another of 190 feet; Hanover, 106 feet; Jessups, 40 feet; Annapolis Junction, 80 feet; Savage, 50 feet; Muirkirk, 62 feet; Beltsville, 60 feet; Branchville (local), 80 feet; Riggs' mill, 40 feet; Brookland, 40 feet; Washington, 64 feet.

The thickness of the Arundel formation ranges from 0 to 125 feet or more. The greatest thickness of the exposed beds occurs in the iron mines above Hanover and in the Muirkirk area. The data regarding the thickness of this formation to the eastward, where its summit descends below tide, are from artesian well borings, which must be accepted with caution. They tend to show that the formation does not thicken perceptibly along the dip beyond a certain point, and that the deposits lack horizontal continuity.

The Patuxent-Arundel boundary.—The Patuxent-Arundel boundary is on the whole the most clearly defined within the Potomac group. The occasional occurrence near the landward margin of the Patuxent formation of beds of drab lignitic clays, which are at times slightly iron-bearing and of massive red and variegated clays, although all of relatively small extent, has caused at a few points some uncertainty as to the true boundary line, owing to the fact that the strong increase in the dip of the Patuxent strata has brought its beds of clays into range with the normal dip of the Arundel clays. The difficulty has been further complicated by the occurrence of landslips, apparently dating back to the Quaternary, by which workable masses of Arundel iron ore clay were precipitated from elevated positions above the Patuxent sand and gravel, and are now more or less obscured by more recent sediments.

When organic remains can be found the problem is much simplified, since the floral and faunal contrasts are well marked. In the Patuxent terrane both plant and animal remains are comparatively scant, its dicotyledons being limited to a few very primitive types. In the Arundel, on the contrary, the remains of both plants and animals are relatively abundant. Normal, although still simply organized, dicotyledons are not uncommon. Dinosaurian remains, wanting in the Patuxent terrane, are comparatively common in the Arundel.

Though now for the first time cartographically shown, suggestions of the occurrence of the Arundel-Patuxent boundary have appeared from

time to time in Potomac literature. The Patuxent beds have been designated as the "sandstone member" (Fontaine, McGee, and others), and its superjacent deposit as the "clay member." Tyson indicated in a general way on his map the position of the "iron ore clays" of the "upper oölite," the latter term evidently including everything in the Potomac above the Patuxent formation, which that author designated as the "lower oölite."

At points where the Arundel terrane is wanting, as in Cecil county, the tracing of the superior boundary of the Patuxent becomes more difficult, since there is a closer similarity lithologically between the Patuxent and the super-Arundel deposits than between the Patuxent and the Arundel. This difficulty is increased in the area named by the scarcity of organic remains.

Areal distribution.—The outcrop of the Arundel formation in Maryland occupies a comparatively narrow, irregular, and often interrupted belt extending from the city of Washington to Bush river. A few isolated areas of minor importance occur to the northward and to the southward of these points. At a number of places, notably to the northward, it is wanting in the sections, the deposits of the next higher horizon resting directly upon the Patuxent formation.

A very notable mass of exceedingly tough, drab, lignitic, and highly colored clays, apparently referable to the Arundel, but evidently barren of iron ore, constitutes the foundation of Capitol hill at Washington. A well boring, after passing through some 50 feet of recent and Pleistocene materials, penetrates 131 feet of these clays into the Patuxent sand and gravel. A great body of clays, apparently belonging to the same formation, is now being encountered in a deep sewer in the vicinity of Anacostia bridge.

Characteristic local section.—A section exposed at the Timberneck iron mine near Hanover is as follows:

		Feet
Raritan	1. Reddish sands, at times gravelly, considerably indurated	12
Patapsco	2. Red, white, and brown, more or less argillaceous sands, with clay pellets	20
Arundel	3. Tough, drab, massive, pyritous clays bearing iron carbonate	100
Patuxent	4. White clay, exposed in the bed of Licking run	5
	Total thickness	137

Economic products.—The best known economic product of the Arundel terrane is iron ore, whence the name "iron ore clays" of Tyson. There are several varieties of this, the best being an earthy spathic ore, occurring in nodules, flakes, geodes, and layers. It is locally known as "steel ore," on account of the exceptional toughness of the iron made from it. The

names "white" and "hone" ore are also locally used on account of its color and fine grain. The ore which occurs in beds of comminuted lignite is thoroughly charged by the same, which circumstance is believed to materially aid in its reduction. This variety is known as "charcoal ore." Nodules of white ore weighing a ton are not uncommon, while ledges of the same have been encountered which require blasting, and when broken up have more than filled a railway car.

Other varieties, known as "brown ore," "red ore," etcetera, occur abundantly, often in the same beds with the white ore, from which they are generally derived by alteration near the surface. Both the brown and the white varieties include grades locally known as "velvet ore" from their fine, smooth grain and the beautiful druses of minute crystals of siderite and its derivatives which line the geodes and septarian nodules.

The "red ores" are apt to occur in clays scant in vegetable matter. These are used to some extent as pigments (Venetian red) and to impart desired tints to bricks, etcetera. Red ocher or "keel" also occurs in this formation, notably near the base, and yellow ocher to a less extent.

The Arundel formation has been worked for iron ore more or less continuously since the middle of the eighteenth century. A good part of our Revolutionary ordnance was made of it. At the present time, owing to the low price of iron, only a single furnace smelting Arundel ore is in active operation, but in former years they were scattered all along the belt from Bush river to Muirkirk, and their picturesque ruins are seen at many points.

The most prolific beds occur at Bush, Joppa, Stemmers run, Seven Mile hill, Baltimore, Elkridge, Hanover, Jessups, Annapolis Junction, Patuxent neck, Contee, Muirkirk, and Branchville. The principal workings at the present time are at Muirkirk, where the ore also is smelted.

The Arundel clays are extensively employed in the manufacture of brick and terra cotta, and to some extent for cement, pottery, and modeling. The supplies are inexhaustible, and they commonly lie conveniently for transportation either by land or water or both.

PATAPSCO FORMATION

Name and lithologic characters.—The Patapsco formation is so called from its typical occurrence in the valley of the Patapsco river. Its deposits consist chiefly of highly colored and variegated clays which grade over into or are interbedded with sandy clays, sand, and gravelly sand. Its arenaceous materials, particularly those lying adjacent to ferruginous clay beds, are often indurated, forming "pipe ore" or cor-

rugated iron sandstone (plate 24, figure 1), at times conglomeritic. The "variegated clays," which commonly exhibit a great variety of exceptionally rich and delicate tints in extremely irregular "pied" patterns, often grade downward or horizontally into massive or stratified chocolate, drab, and black clays which are often lignitic, more or less pyritous, and occasionally iron and leaf bearing. The sands sometimes contain decomposed feldspar grains, as well as pellets and balls of white clay. They are frequently crossbedded, though less strongly marked than in the Patuxent formation. Red ocher, known as "paint rock" or "paint stone," occurs near the base and summit and sometimes within the formation, while flakes of sandy and ocherous limonite with botryoidal inferior surfaces are not uncommon at various horizons. The variegated clays often contain great numbers of small flattened pieces of limonite, quite uniform in dimensions. When these are brought to the surface by erosion, they form the resistant caps of innumerable miniature erosion towers which beset the crests and slopes of the verdureless "badland" areas, well shown at Bald hill, Prince George's county.

Organic remains.—The flora of the Patapsco formation includes ferns, cycads, conifers, monocotyledons, and dicotyledons, the last still constituting an inconspicuous element as compared with the other types represented. The range of genera and species is in the main limited, the grade of organization still moderately low, and the number of individuals scarcely greater than that of the preceding formation. At one station, however, near the summit of the formation there occurs a profusion of apparently a single species of leaf resembling Platanus.

The known fauna of the Patapsco formation is limited to a single, much worn, silicified, dinosaurian limb-bone, which was found at the surface and may have been redeposited from the Arundel.

Strike, dip, and thickness.—The strike of the Patapsco formation corresponds practically to that of the formations below it. The normal dip of its basal beds is from 35 to 40 feet per mile. This rate, as in the case of the preceding formations, is strongly emphasized to the landward at a few points, notably in the Principio area, where the formation reaches to the Fall line.

The thickness of the Patapsco formation in central Maryland at the point where its summit descends below tide is estimated at 240 feet. The greatest exposed thickness occurs at Grays hill, Cecil county, where it reaches 100 feet. At Broad Creek hill, south of New Glatz, Prince George's county, 80 feet of Patapsco clays are exposed.

The Arundel-Patapsco boundary.—The Arundel-Patapsco line represents very nearly the line of demarkation between the iron-bearing clays proper, with their barren equivalents and that great mass of variegated

clays, etcetera, mostly barren of iron, which lie between this line and the base of the next succeeding formation. In general the demarkation is well defined, and in many local sections, notably in the Timberneck area, the contact is sharp, leaving little room for doubt that we have to do with something more than local changes in lithology or the effects of other varying local conditions. To the seaward, however, the line is by no means as clearly defined, and there is a suggestion of gradation, as at Federal hill. Again, the circumstance that the two formations are on the whole argillaceous, and the character of their clays often very similar, increases the difficulties of tracing the details of this boundary, and to this may be added the fact that the contrast in the floras and faunas is by no means as well marked as in the case of the Arundel and Patuxent. On the whole, therefore, it may be said that a more intimate relation exists between the Arundel and Patapsco than between the Arundel and Patuxent.

Areal distribution.—The Patapsco formation outcrops in an irregular, crescentic belt, deeply dissected along the drainage lines and often having its subaerial portion interrupted at the principal waterways. It extends from below Indian head on the Potomac to and beyond the head of the Chesapeake bay. To the northward the outcrop is narrow. It broadens toward the center of the belt and narrows again to the southward by virtue of the transgression of the superjacent terranes. In Cecil county, where the Arundel formation is wanting, the Patapsco beds repose directly on those of the Patuxent terrane, and the same is true over a number of smaller areas to the southward. The most notable body of Patapsco materials occupies the highlands between Branchville and Bowie.

Characteristic local section.—The following section occurs at Red hill, Cecil county:

		Feet
Raritan	1. Coarse reddish sand and coarse, evenly bedded, dark-brown iron sandstone	10
	2. Yellow and buff sands and corrugated iron stone containing ferruginated coniferous wood; sand beds near the base, which is marked by springs	10
"	3. Tough white clay	7
Patapsco	4. Massive variegated red and drab clays, the latter slightly lignitic and with obscure leaf impressions; lenses of white sand toward base	130
Patuxent	5. Sands not exposed at surface	60

Economic products.—The Patapsco formation, although on the whole an argillaceous terrane, is often arenaceous, particularly to the landward, where it yields building sands and iron sandstone for road metal.

Its variegated and drab clays, beside constituting vast supplies for the manufacture of terra cotta, brick, etcetera, contain a few workable beds of iron carbonate. The base of the formation is the principal source of the well known Maryland "Venetian red" ocher, which also occurs near its summit. There is a tradition among the inhabitants of the Patapsco belt to the effect that this ocher was formerly used by the Indians for war paint. This rumor is substantiated by the fact that we find on their deserted village sites cobbles of "paint rock," evidently derived from the Potomac beds, which exhibit on their flat surfaces numerous scratches which are clearly attributable to human agency. In Cecil county the basal Patapsco clays, like those of the Patuxent, are highly charged with diffused lignite and are employed to some extent as a base for black pigments. In this area also the base of the formation yields a fine, micaceous "fire" sand.

RARITAN FORMATION

Name and lithologic characters.—The Raritan formation receives its name from the Raritan river, New Jersey, in the basin of which the deposits of this formation are typically developed. The name was given by the senior author of this paper in the annual report of the state geologist of New Jersey for 1892, although the term "Raritan clays" had been somewhat loosely applied to deposits of this age by earlier writers.

In the case of the Patapsco formation it was shown that the argillaceous character was the more prominent. In the Raritan the arenaceous features are emphasized. This is particularly true of the upper portions of the terrane. The sands are often of very fine texture, and when mixed with white clay are known as "fuller's earth." They occasionally contain white clay pellets and balls, and are at times gravelly. They are commonly white, but, particularly in the lower portions of the formation, are often stained by iron oxides. A notable illustration of such coloration occurs on the west shore of Elk neck near the meridian of 76°.

Induration of the sands by hydrous iron oxide is common, the resulting rock being either a very hard,* tubular or corrugated iron stone often having a metallic resonance, or a softer, evenly bedded, brown sandstone, suitable for building purposes. A well known illustration of the former variety is the Black rocks of the Patapsco, while the latter is quarried to some extent at Sandy Brae, in Cecil county. At times the presence of a trace apparently of a vegetable oil imparts to the rock a brilliant iridescence. This feature is also well exhibited at the Black rocks.

* The deserted village sites of the Patapsco Indians which lie within the Potomac belt have yielded a number of arrow-points, spear-heads, and axes made of this rock.

Sometimes the Raritan sands are cemented by silica, producing a highly resistant rock resembling quartzite. An illustration of this occurs at the White rocks of the Patapsco river which afforded the name "Albirupean" applied by professor Uhler to the upper portions of the Potomac group (plate 27, figure 1).

The clays are commonly of light color or white. Sandy, white clays occur on a large scale. These, like the fine arkosic sands, are locally known as "fuller's earth" (plate 27, figure 2). At times the clays become dark colored, lignitic, very slightly iron-bearing, and richly leaf-bearing. They may be either laminated or less frequently massive, and at times exhibit a conchoidal fracture. A characteristic bluish drab tint, with a tendency toward lamination, serves to distinguish them, as a rule, from the drab Patapsco clays. Variegated or "pied" clays greatly resembling the "variegated clays" proper of the Patapsco formation also occur, but they are commonly more sandy and of somewhat lighter tints, often pinks, being known to the northward as "peach-blossom" clays. The Raritan variegated clays are also apt to exhibit obscure stratification and were probably redeposited from the Patapsco. The scale upon which they occur is inconsiderable as compared with those of the Patapsco, and the formation is on the whole considerably less argillaceous and also less homogeneous.

Strike, dip, and thickness.—The strike and dip of the Raritan formation in Maryland correspond, in a general way, with those of the preceding terranes. The normal dip of the basal beds of the formation is about 30 feet per mile. When the deposits extend landward as far as the Fall line, as in Cecil county, there are well marked increases in dip. An artesian well boring at Rock Hall, on the Eastern shore of Maryland, encountered the Raritan beds at 240 feet below tide level, indicating a dip of 34 feet per mile for the deposits of central Maryland.

The thickness of the Raritan formation in central Maryland, along the line where its upper beds descend below tide, is estimated at 240 feet. The greatest thickness of the exposed beds in a single section occurs at Maulden mountain on the west shore of Elk neck where it reaches nearly 70 feet (plate 27, figure 2).

Beds of black, massive, pyritous, earthy lignite, bearing prostrate trunks of lignitized conifers, honeycombed by Teredo, and associated with layers of comminuted lignite, occur near the summit of the formation. Overlying these are beds of coarse and fine, often crossbedded, slightly lignitic, white and buff sands with interlaminated brown sandy loam. These are often indurated. This entire series, which is best exposed at cape Sable, on the Magothy river, comprises the so-called "alternate clay-sands" of Uhler and the "Magothy formation" of Darton.

The lignite of the Raritan is, as a rule, in a noticeably less advanced stage of carbonization than that of the preceding terranes; being often of brownish tint, and the logs somewhat less laterally compressed.

The Raritan formation yielded the first American amber. Its original source, cape Sable, on the Magothy river, was described in great detail by Troost early in the last century.

Organic remains.—The known flora of the Raritan formation includes a thallophyte, a lycopod, ferns, conifers, cycads, monocotyledons, and dicotyledons. No silicified stems or frond impressions of cycads have been found in undoubted Raritan beds in Maryland, although certain fronds have been reported by Newberry from the Amboy clays of New Jersey. The endogenous element is weak and the exogenous particularly prominent. There is a wide range of genera and species, with strong modern affinities.

The known fauna of the Raritan formation in Maryland is limited to a single species of Teredo and possibly an insect. Borings of the former are often met with in the trunks of lignitized conifers, so much more commonly, in fact, than in the preceding formations as to suggest a somewhat increased salinity of the Raritan waters. Four genera of lamellibranchs are reported by Whitfield from the Raritan clays of New Jersey, one with well marked Jurassic affinities. The clays of that area are also reported by Cope to have yielded a pleseosaurian bone.

The Patapsco-Raritan and Raritan-Matawan boundaries.—Though at times extremely obscure, owing to local similarities in lithology, the Patapsco-Raritan line is not on the whole a very difficult one to trace. The leaf beds, which are so much more common in the Upper than in the Middle and Lower Potomac, are a great assistance with their strongly exogenous and modern facies.

The Raritan-Matawan boundary is not at all points as readily discernible as might be expected. The clay marls of the marine Cretaceous at times so closely resemble the Raritan carbonaceous clays that even the most careful observers have confused them. The well known "black clays" of Grove point, Maryland, containing little or no glauconite and much pyrite, have as often been referred to the Raritan as to the Matawan and by equally careful observers.

Areal distribution.—The outcrop of the Raritan formation in Maryland occupies a crescentic and deeply dissected belt, often interrupted to the landward, extending from the District of Columbia to the eastward of Baltimore, across Elk neck to and beyond the Delaware border. Outcrops occur along the "Eastern shore" as far southward as Fairlee creek.

Characteristic local section.—The most comprehensive section of the Raritan deposits of Maryland occurs at Giller's hole, Maulden mountain, on the west shore of Elk neck.

Maulden Mountain, immediately above Giller's Hole.

		Feet
Columbia	1. Loam and gravelly loam	6
Matawan	2. Massive micaceous glauconitic sands, mottled with brown, oxidized, and more or less indurated near the top	30
	3. Loose, lighter-colored sands, with less glauconite, oxidized at the surface (brown flecks)	6
	4. Sharp white and yellow sands, indurated at the base	3
	5. Yellow, red, and ash-colored sandy clays	2
	6. Loose sands, micaceous and more argillaceous toward the base	15
	7. Lens of loose carbonaceous and pyritous sandy loam, gravelly at base	6
Raritan	8. Lens of stratified, iron-stained, at times pebbly "fuller's-earth" clay, occasionally lignitic (dicotyledenous? stems), indurated at base	3–10
	9. Light buff and brown crossbedded sands, coated with "fuller's earth"	25
	10. Ledge of corrugated iron sandstone	2–9
	11. Sands similar to 9, brightly iron-tinted in the middle and lower portions and containing white clay pebbles and pellets; undulating base	15
Patapsco	12. Massive variegated and drab lignitic plastic clays, the latter at times containing iron carbonate; obscured by talus and land slip	20
	Total thickness	138

Economic products.—The economic products of the Raritan formation in Maryland include building and glass sands, quartzose and ferruginous sandstones for building purposes and road metals, clays used in the manufacture of buff face brick and pottery, drab clays used for stoneware and modelling, and variegated and red clays also used at times for pottery. White sandy clay and white arkosic sand, known as "fuller's earth," occur on a large scale, and are in local use for polishing metallic surfaces. This will doubtless prove to possess wider economic possibilities. Massive pyritic deposits occur in workable quantities at a few points, notably at cape Sable, on the Magothy river, where they were mined early in the last century, and alum, copperas, and sulphuric acid produced. The amber already mentioned as occurring at this station is only of scientific and historical interest.

Interpretation of the Potomac Deposits

In their former paper the authors pointed out that Potomac deposition was probably preceded by extensive baseleveling of the eastern side of the continent, with widespread rock disintegration. Stimulated by elevation

and seaward tilting, erosion afforded the materials of the Potomac group. The fact that these consist very largely of redeposited Piedmont crystallines, and to a less extent of Appalachian materials, is therefore what might be expected, but the circumstance that no clearly defined trace of redeposited Newark materials has been found in the Potomac deposits of Maryland is at first thought somewhat surprising. From this we must infer either that the Newark was not to any great extent exposed to Potomac erosion, or that its materials were not sufficiently consolidated to permit of transportation except in a so finely divided condition as to be unrecognizable. It is quite certain that during maximum Potomac subsidence a large body of Newark materials, especially beyond the limits of Maryland, was beneath tidelevel, and therefore not exposed to subaerial influences. Inasmuch as the Potomac beds themselves, particularly the basal ones, have since that date undergone considerable induration, often without the agency of iron oxide, we may suppose that the subaerial Newark sandstones of that date, if consolidated at all, were considerably less resistant than, for example, during the early Pleistocene, in the deposits of which the Newark materials are abundantly represented.

The basal deposits of the Potomac group, produced by the initial tilting of the continental border and described as the Patuxent formation, indicate in their arkosic character their proximity to the ancient continent, the rocks of which had suffered extensive disintegration. These features, which are so pronounced where the deposits lie adjacent to highly feldspathic rocks, largely disappear where these rocks are poorly developed or where the deposits themselves were evidently laid down at some distance from the old shoreline. Rapid deposition in shallow waters is seen in the crossbedded character of the strata and their rapid change in lithologic characters. The presence of clay pellets and balls in the sands of this formation, suggesting at first thought the existence of subjacent pre-Patuxent sedimentary clays, may represent local shallowing of the seas with the destruction by wave action of lately deposited Patuxent clay beds and the incorporation of their rolled materials into the later deposits of the same formation.

That the seaward tilting was not continuous or persistent in the same direction is evidenced by the varying character of the deposits and the stratigraphic relations which the several formations sustain to each other.

The close of the Patuxent epoch was marked by the elevation of its deposits and the trenching of its surface by streams. This was succeeded by a subsidence which was emphasized to the landward by the occupation of the ancient valleys by swamp deposits. The tough clays of the Arundel formation, charged with lignitic accumulations, in which tree

trunks are at times found erect with their roots intact, find their most satisfactory explanation on this basis. It was in these ancient marshes that the iron, derived to a considerable extent from the adjacent area of basic eruptives, was deposited, first, no doubt, as bog ore, which by contact with lignite was later altered to the carbonate and redeposited in its present nodular form. It was in these marshes that the remains of dinosauria became entombed, which, with the evidence of dense vegetation, suggests subtropical climate.

On this hypothesis the lenses of Arundel clays, particularly to the landward, represent crudely the ancient drainage lines of the eroded surface of the Patuxent terrane. The widening of the areas seaward may possibly be interrupted on the basis of lagoon deposits into which the Arundel estuaries merged. That the waters in which the Arundel deposits were laid down were not entirely cut off from the sea is evidenced by the occasional occurrence of Teredo-bored conifers, while the absence of strictly marine fossils suggests that the Arundel waters had but imperfect marine communication.

It has been suggested by the students of the Maryland Pleistocene that the "buried-forest" deposits of the Chesapeake shores may furnish some clue to the origin of the Arundel iron ore clays. These deposits appear to have originated by the impounding of the estuaries by sand spits—a process which may be observed at many points within the Chesapeake and elsewhere at the present day. The closed estuary then speedily silted up and was converted into a peaty cypress swamp, in which bog iron ore was deposited. Meanwhile the bay shore adjoining the mouth of the swampy estuary was gradually receding by virtue of wave action until the swamp materials themselves were invaded and more or less cut away. This process was followed, or perchance attended, by gradual subsidence, which resulted in the deposition on the newly wave-cut surface of a new and later member. Emergence followed, and the waves are now actively cutting away both the more recently deposited terrane and the basal remnant of the older one, with its beheaded cypress trunks and their knees, imbedded in peat. In the basal clays of the swamp deposit, penetrated by the roots of the trees, one finds an occasional, imperfectly formed nodule of iron carbonate. When exposed to the air it rapidly changes to a bright vermilion ocher.

There is little question that some such process as this has figured to a considerable extent in the genesis of certain of the lesser lenses of drab, lignitic, iron-bearing clay occurring at various horizons throughout the Potomac group; but the grand scale—both vertical and horizontal—on which the Arundel formation, or "iron-ore clays" proper, were laid down cannot well be explained entirely by this simple theory. The idea of

landward tilting, also, which appears to find additional support in the very indefiniteness observed at certain points in the Arundel-Patapsco boundary, must therefore be retained until a more satisfactory interpretation can be brought forward.

The well marked unconformity occurring at many points between the Arundel and Patapsco formations, notably in the West Hanover district, indicates emergence and a distinct erosion interval prior to Patapsco deposition. At points somewhat farther seaward and at lower levels, as at Federal hill, the line is less distinct and there is a suggestion of gradation. These facts would seem to indicate that the elevation was not an extensive one, bringing only the landward margin of Arundel deposits under the influences of subaerial erosion. In cases where this erosion resulted in a mere shoaling of the waters only a comparatively slight change in lithology and organic remains would be expected. It is certain that the tendency of the more recent investigations on these two formations has been to show that they are more closely allied than was formerly supposed—stratigraphically, lithologically, and paleontologically.

The highly colored and variegated clays of the Patapsco formation were evidently deposited in the quieter and deeper waters of this epoch, and, like the iron-bearing Arundel clays, bear some relation to the great basic eruptive masses, plentifully iron-bearing, which lie to the north and west of them. This phase of the sedimentation is somewhat more prominent in central Maryland, where the rocks of this character are not only well developed, but nearest the eastern margin of the Piedmont belt. It is also probable that these ferruginous Patapsco clays were also in part redeposited from the more richly iron-bearing clays of the subjacent Arundel. The Patapsco sands were doubtless derived to a considerable extent from those of the Patuxent terrane.

The unconformity separating the Raritan from the underlying deposits is likewise more pronounced to the landward and apt to be obscure to the seaward. To the landward also the lithologic break is more clearly defined. That a considerable erosion interval occurred is evidenced by the undulatory character of the Patapsco-Raritan contact and by the marked advance in the grade, variety, and number of the Raritan dicotyledons. The source of the Raritan materials was clearly in part the sands and clays of the preceding formations. The common occurrence of white sands, "fuller's earth," and white and generally light-colored clays marks another step in the gradual loss of iron in the progressive redepositions of the more richly ferruginous materials of the preceding deposits.

That the conditions of deposition, which the heterogenous character of the deposits show to have been highly varied, were, especially toward

the last, considerably nearer the marine is indicated by the much more common occurrence and more active operations of Teredo.

Raritan sedimentation was closed by an uplift more strongly marked than before to the landward. The westward portions of the terrane were extensively eroded, and resubsidence inaugurated Matawan sedimentation. This depression of the continental border was distinguished from the others by its extent, which was such as to inaugurate the deposition of more or less well defined marine sediments, including greensands, at points where only estuarine materials were laid down during preceding epochs; hence the term "Marine Cretaceous," which has been often used by geologists to distinguish the later Cretaceous deposits from those of the earlier estuarine beds of the Potomac group.

The distinctly estuarine character of the Potomac sediments points to the existence for a long period of an extensive area of more or less brackish water along the eastern border of the North American continent. It must have reached at least from cape Cod to the Gulf. That it was either a sound, a lagoon, an embayment or an estuary, or a series of these, on a vastly greater scale than any along the Atlantic coast today, is probable. McGee's recent studies of the gulf of California suggested the possibility of an Atlantic barrier comparable in scale to the peninsula of Lower California. The evidence available, however, to establish the actual existence of any such type of barrier in early Cretaceous time appears to be scant. The comparatively sudden appearance of marine sediments which marked the beginning of the Upper Cretaceous points, to be sure, to the disappearance of some form of barrier, but what may have been its character or extent seems impossible of determination with the facts at hand. In the succeeding chapters the surface configuration both of the crystalline floor and of the Potomac group is discussed, and some possible interpretations advanced.

The greater thickness of the formations of the Potomac group along a belt somewhat to the eastward of the Fall line may have emphasized the downward movements in this portion of the Coastal plain during Potomac time. On the other hand, the gradual removal of the weight over the Piedmont region by the removal of its residuals has occasioned an upward movement of that area as well as immediately adjacent Coastal Plain regions. The accumulating results of these tendencies, particularly the first mentioned, from the beginning of Potomac time until the present, have been the weakening of the crystalline floor near the landward border of the Coastal plain accompanied by monoclinal folding and even faulting on a limited scale. McGee's studies of the upper Chesapeake area, and others to the northward and southward, fully convinced that author some years since that displacement had actually occurred, though no

very definite evidence was adduced in demonstration of the same. Other writers, including Fontaine, however, believe that we have to do merely with sedimentation across a pre-Potomac escarpment. In the opinion of the authors of this paper, the Fall Line phonomena in Maryland, and elsewhere, afford considerable evidence of monoclinal flexures merging into simple and compound faulting. A number of carefully constructed vertical sections on a large scale have been made across the Fall Line zone, and these show in nearly every instance evidence of one or the other of the above mentioned phenomena, along with the marked increase in the dip of the Potomac deposits already mentioned.

Evidence of the actual displacement in the Potomac beds is most clearly defined in the vicinity of Relay, Maryland, and the evidence is strengthened by the fact that the Miocene beds of Catonsville lie considerably higher than the normal dip of the main body of the Miocene deposits calls for.

At the openings of the Maryland Clay Company, at Northeast, Maryland, there occurs a well defined example of an anticline in the Patuxent beds, which is believed by Ries to have been produced by the hydration of the subjacent feldspathic rock in the process of its decomposition into the residual koalin mined at this point. Though the scale on which the folding occurs is small, the phenomena afford a suggestion as to the possible causes of some of the lesser irregularities in the Patuxent beds which lie near the crystalline floor.

Surface Configuration of Crystalline Floor and its Relation to Potomac Basin of Deposition

The basal beds of the Potomac group rest on a more or less uneven surface of crystalline rocks, in which certain of the more important drainage lines of the present day were already established, as is shown both by the marginal contacts and by the well borings near the landward border of the formations.

The great increase in the dip of the Patuxent and succeeding formations along the Fall line has already been alluded to, as well as the evidence that it represents in part at least a fault scarp.

It is significant, however, that there is a marked though less pronounced decline in the dip of the strata eastward of the Fall line all the way to the seaward margin of the Coastal plain. The evidence for this is furnished by the deep-well borings in Delaware, Maryland, and Virginia, the number of which is not as great as could be desired, although they all show, without exception, a progressively lessened dip of the beds as the distance from the landward margin increases.

The following wells of the middle Atlantic slope reach the crystalline rocks and show the following rates of descent of the crystalline floor:

Location of well.	Distance from point where Algonkian surface reaches tide level.	Depth of Algonkian surface below tide level.	Rate of descent per mile.	Thickness of the Potomac deposits.
	Miles.	*Feet.*	*Feet.*	*Feet.*
Ice works, South Wolf street, Baltimore	¾	150	200	*122
Farnhurst, Delaware	2	111	55+	*211
Baltimore copper works	2	187	93.5	Unknown
Sandy point, Virginia	2	270	135	*170
Quantico, Virginia	2	210	105	*210
Indian Head, Maryland	5½			421.5+
Middletown, Delaware	12	452	37.7	302±
North End point, Virginia	72	1,162	15.7	252

These records indicate a rapid decline near the Fall line in all the landward wells and a marked prominence in the crystalline floor in the Middletown, Delaware, area, which may represent an extension of an axis from Iron, Chestnut, and Grays hills to the southeastward. They also show an actual thinning of the Potomac deposits to the seaward, as shown by the well at North End point, where the thickness of the Potomac beds is only one-half the normal thickness at the outcrop.

The record of the well borings becomes of the highest significance when it is remembered that this crystalline surface has been receiving along its seaward margin progressively greater and greater loading through deposition since Potomac time. The conclusion is readily reached that subsidence gradually took place, and that the land barrier along the eastern margin of the Potomac basin was depressed below sea-level.

Marsh and McGee, as well as most other writers, have expressed their belief in such a barrier, although without adducing any further concrete evidence of the same than the estuarine character of the Potomac sediments. McGee has suggested, as above stated, that the Potomac barrier may have been comparable in character and extent to the existing peninsula of Lower California.

Another possible, although perhaps less plausible, interpretation of

*The full sequence of Potomac deposits is not penetrated in the Baltimore, Farnhurst, Sandy Point, and Quantico wells.

these phenomena is found in the hypothesis of incipient folding in post-Potomac time.

Surface Configuration of Potomac Group and its possible Interpretation

The records of deep artesian well borings to the eastward of the Potomac belt indicate some clearly defined irregularities in the rate of decline of the Potomac surface. It will be seen from the following table that only a single record shows a greater decline than 25 feet, while most of them show a descent much less than this amount, in one instance (Crisfield) even less than the observed average landward dip (12½ feet) of the Eocene deposits which immediately overlie the Potomac beds to the southward.

Location of well.	Distance from point where Potomac surface reaches sealevel.	Depth of surface below tide level	Rate of descent in feet per mile.	Thickness of Potomac deposits.
	Miles.	*Feet.*	*Feet.*	*Feet.*
Middletown, Delaware	6	150±	25±	302±
Rock Hall, Maryland	7	240	34	Unknown
Claiborne, Maryland	19	440	23	"
Tunis Mills, Maryland	24	430	18	"
Tilghmans island, Maryland	27	400	15	"
Gloucester Court-House, Virginia	38	600	16	"
Williamsburg, Virginia	38	550±	14.5	276±
North End point, Virginia	62	920	15	252
Crisfield, Maryland	91	964	10.6	100+

According to these records, there is a marked lessening in the decline of the Potomac surface far to the seaward. There is even an actual rise in this surface in the "Eastern shore" of Maryland and Delaware between the Chester and Choptank rivers, although it again declines eastward a little farther seaward, as shown by the boring at Gloucester Court-House, Virginia. Whether we have to do with an erosional irregularity in the Potomac surface or with incipient deformation, the facts at hand do not permit us to determine. If the irregularity is due to the latter cause, the axis of the anticline would not seem to be coincident with that of the peninsula of Delaware, but would cross the latter in a northeast-southwest direction. A depressed barrier such as has

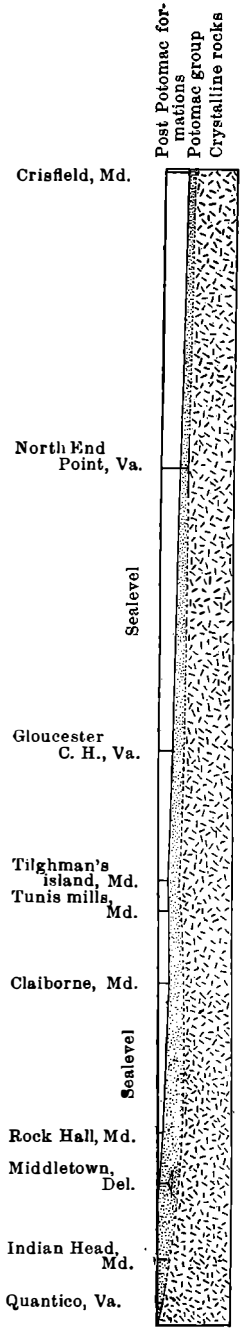


FIGURE 1.—*Generalized Vertical Section Across Atlantic Coastal Plain Showing Potomac Basin of Deposition*

above been indicated may well have served as the seaward buttress in such deformation. Whether there may be more than one of these axial prominences in the Potomac surface is a question of much interest, but which can not be answered with the data at hand.

The lessening in the descent of the Potomac surface far to the seaward. as indicated by the borings at North End point and Crisfield, is in general in harmony with the relations of the subjacent crystalline floor above described.

AGE OF THE POTOMAC DEPOSITS

There has been much discussion as to the age of the Potomac group. Most geologists, particularly those who have studied the floras, have believed the entire group to be of Cretaceous age, while a few investigators, notably the late Professor Marsh,* of Yale University, have regarded it of Jurassic age. The authors of this paper in an earlier publication pointed out this difference of view, and clearly showed that the dicotyledonous floras were practically confined to the two upper formations, while the dinosaurs on which Professor Marsh based the Jurassic age of the Potomac group were found in the Arundel formation. As the result of these observations, and without attempting to decide finally regarding the paleontologic evidence, they placed the two lower formations of the Potomac group questionably in the Jurassic. Since the publication of the above paper the authors have made a very exhaustive examination of the several formations and collected large numbers of animal and plant remains. As the result of this work a considerable dicotyledonous flora has been found to exist in the Arundel, although

*O. C. Marsh: "Jurassic Formation of the Atlantic Coast." Amer. Jour. Sci., Aug., 1896, pp. 105–115.

of somewhat primitive type. At the same time a single dinosaurian bone, somewhat waterworn, and possibly redeposited from the Arundel, has been found in the Patapsco, although its fragmentary character renders it impossible to determine its systematic relations. The results of these observations, together with the discovery by the late Professor Cope of a plesiosaur in the Raritan formation of New Jersey and of a dinosaurian limb bone by Woolman in the Matawan formation of the same state, although not definitely settling the age of the deposits, cast further doubts on the Jurassic affinities of the Arundel and at the same time of the underlying formation—the Patuxent.

The question as to the age of the Potomac group is therefore narrowed down to two propositions:

First. Is the Arundel dinosaurian fauna conclusive evidence of the Jurassic age of that formation, and therefore of the subjacent Patuxent? No less an authority than Professor Marsh, after a study of its dinosaurian fauna, unquestionably refers the Potomac group to the Jurassic, although at the time not cognizant of the complexity of its deposits. He regarded the Potomac as a single formation, as has been the case with many other geologists. In his view regarding the Jurassic age of the Potomac, Professor Marsh has been supported by a few others, mostly among English geologists, since the question here presented is recognized to involve the age of the Wealden as well. Professor Marsh lays much stress on the equivalence of the Potomac with deposits which he has regarded as Jurassic in the Rocky Mountain district, but some doubts have been expressed by others whether these deposits may not be younger. It seems to the authors that further study by vertebrate paleontologists is required before these questions can be settled and the Jurassic age even of the two lower formations of the Potomac group can be accepted on the evidence of the fossil vertebrates.

Second. Are the floras of the Arundel and Patuxent formations, with their primitive dicotyledonous types, of necessity Cretaceous? There is apparently no question regarding the Cretaceous age of the Raritan and Patapsco formations, the uppermost beds of the Raritan even containing floras that have been regarded by Professor Ward as middle Cretaceous. The paleobotanists who have studied the floras of the earlier formations admit that there are many forms which show Jurassic affinities. Professor Fontaine, in his study of these floras, states that there was an "overwhelming percentage of Jurassic types," but unhesitatingly refers the Potomac flora as a whole to the Cretaceous, correlating the deposits with the Cretaceous beds of England. This view is held by nearly all paleobotanists who regard the presence of dicotyledons, although of primitive types, as unquestioned evidence of the Cretaceous age of the

Arundel and Patuxent formations. Further investigations of these floras may, to be sure, lead to other conclusions, but large collections have already been made, and the paleobotanists who have studied them have registered their decision regarding the Cretaceous age of the deposits in no uncertain way.

From our present knowledge of the floras and faunas it is apparent that there is considerable disparity between the evidence afforded by vertebrate paleontology and by paleobotany. At least such is the case if equal consideration is given the conclusions of each group of investigators. It seems essential, however, to suspend final decision of these questions until more exhaustive investigation of the faunas and floras has been made throughout the entire Coastal region. The authors therefore temporarily place the boundary line between the Jurassic and Cretaceous at the base of the Patapsco formation, but with the feeling that much doubt exists regarding it, and that the question is far from settled.

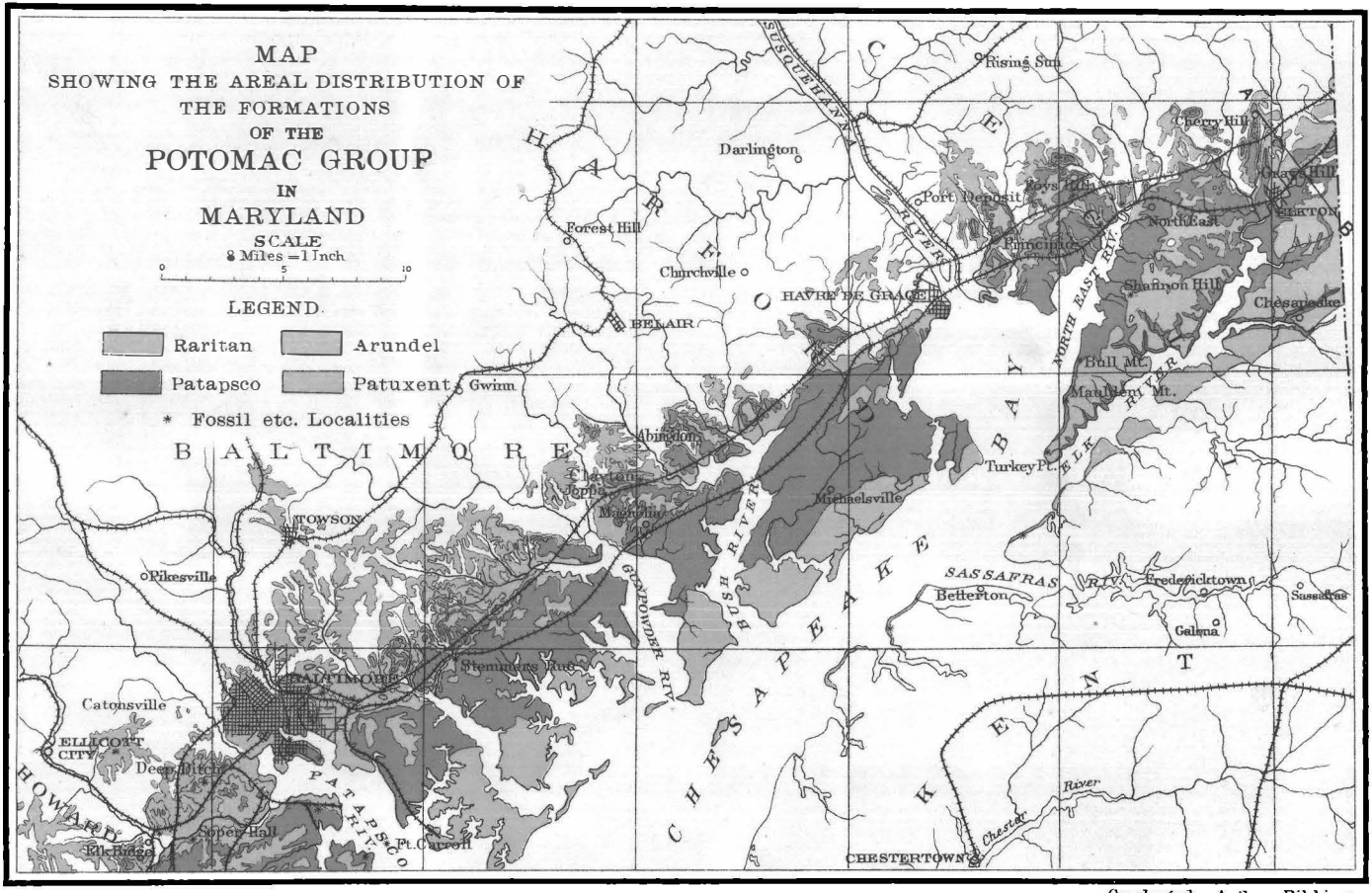
Study of scientific and economic Collections

A large number of new stations yielding fossil plants have been found by the authors, and the collections of silicified stems of Cycadeoidea (plate 28, figure 1) from the middle and lower Potomac have reached more than a hundred specimens. The collection of silicified and limonitized coniferous woods and lignites has likewise been much increased. A large dicotyledonous flora has also been collected from the upper formations. These materials are undergoing monographic study by Ward, Knowlton, and Fontaine.

One notable addition has been made to the collection of Arundel dinosauria—a rib of an exceptionally large dinosaur in a condition of preservation quite unusual in the Arundel beds. This bone, together with the large femur excavated in 1895 and a number of other fragments of huge bones and large teeth (plate 28, figure 2) found at widely separated stations, clearly show what has not been generally supposed, that gigantic as well as diminutive dinosauria inhabited the Arundel swamps. One of these, according to Lucas, who has undertaken the extremely difficult task of deciphering these mostly fragmentary remains, reached at least 40 feet in length.

Two localities in the Arundel of Maryland have yielded molluscan remains. These have been placed in the hands of Stanton for study.

Extensive collections illustrating the highly varied economic deposits of the Potomac terrane have also been made, notably of clays, whose study by Ries has already reached completion. The results of these several studies, as well as those of the authors, will later appear in monographs of the Maryland Geological Survey.



Geology by Arthur Bibbins

DISTRIBUTION OF THE FORMATIONS OF THE POTOMAC GROUP IN MARYLAND

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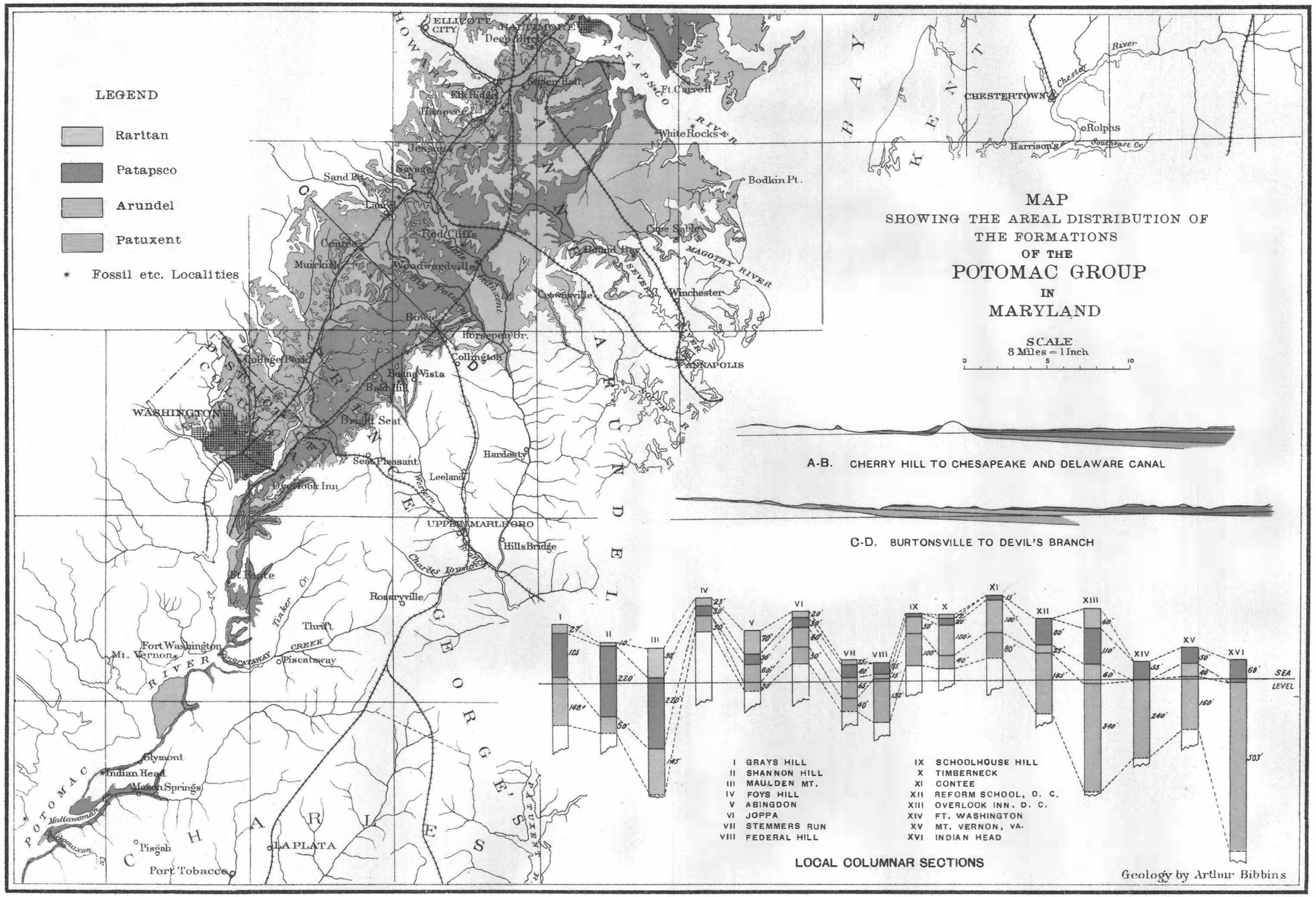

DISTRIBUTION OF THE FORMATIONS OF THE POTOMAC GROUP IN MARYLAND

Comparative Taxonomic Table

rk and Bibbins, 1897.	W. B. Rogers, 1841.	J. C. Booth, 1841.	P. T. Tyson, 1862.	G. H. Cook, 1868.	W. B. Rogers, 1879.	Ch. E. Hall, 1881.	R. P. Whitfield, 1885.	W J McGee, 1888.	P. R. Uhler, 1888.	W. M. Fontaine, 1889.	N. H. Darton, 1893.	J. S. Newberry, 1895.	L. F. Ward, 1895.	O. C. M 189
RARITAN.				Plastic clays (Woodbridge and Amboy clays).			Raritan clays.		Alternate clay-sands.		Magothy.	Amboy clays.	Island series.	
									Albirupean.				Albirupean series.	
		Red clay formation (Upper Secondary in part).				Wealden clay.		Upper or clay member.		Upper or clay member.			Iron ore series.	
PATAPSCO.													Aquia Creek series.	
	UPPER SECONDARY.		Upper Oölite (iron ore clays).		JURASSO-CRETACEOUS.			POTOMAC.	Baltimorean.	POTOMAC or YOUNGER MESOZOIC.	POTOMAC.			POTO OF JURA FORMA
ARUNDEL.								(Varicolored clays).		(Variegated clays).			Mt. Vernon series.	
													Rappahannock series.	
PATUXENT.			Lower Oölite (sands and clays).					Lower or sandstone member.		Lower or sandstone member.			James River series.	

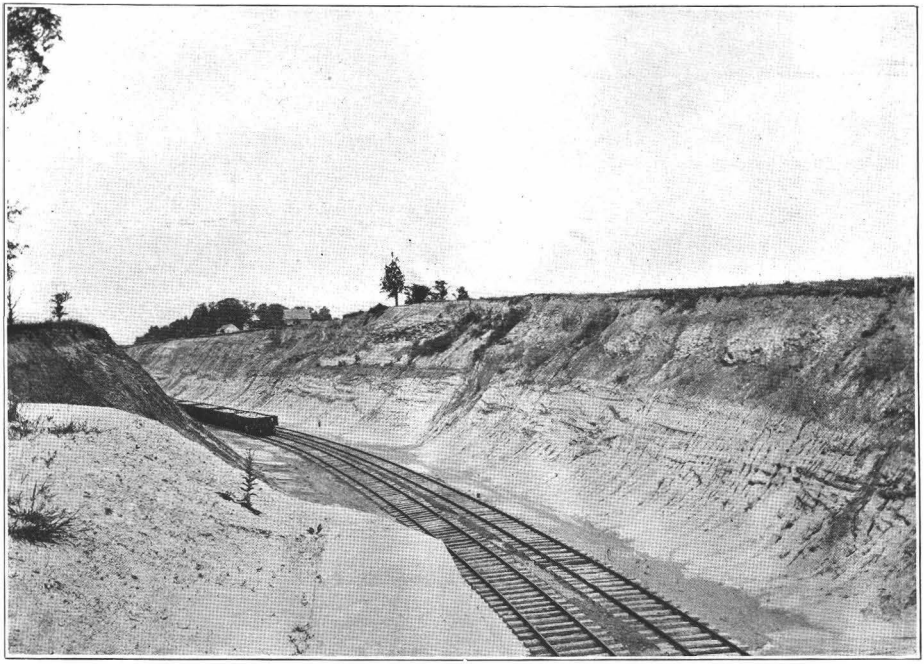

FIGURE 1.—BELT LINE (BALTIMORE AND OHIO RAILROAD) CUT, BALTIMORE CITY
Showing Characteristic Sands and Gravels

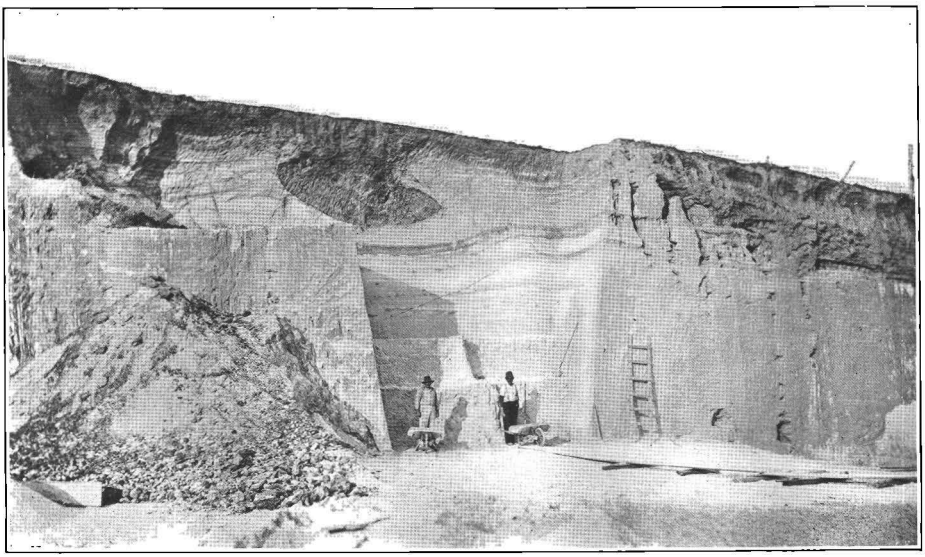

FIGURE 2.—SAND PIT NEAR WESTPORT, BALTIMORE COUNTY

LIGNITE BED AT IRON MINE, SOPER HALL, ANNE ARUNDEL COUNTY

ARUNDEL FORMATION

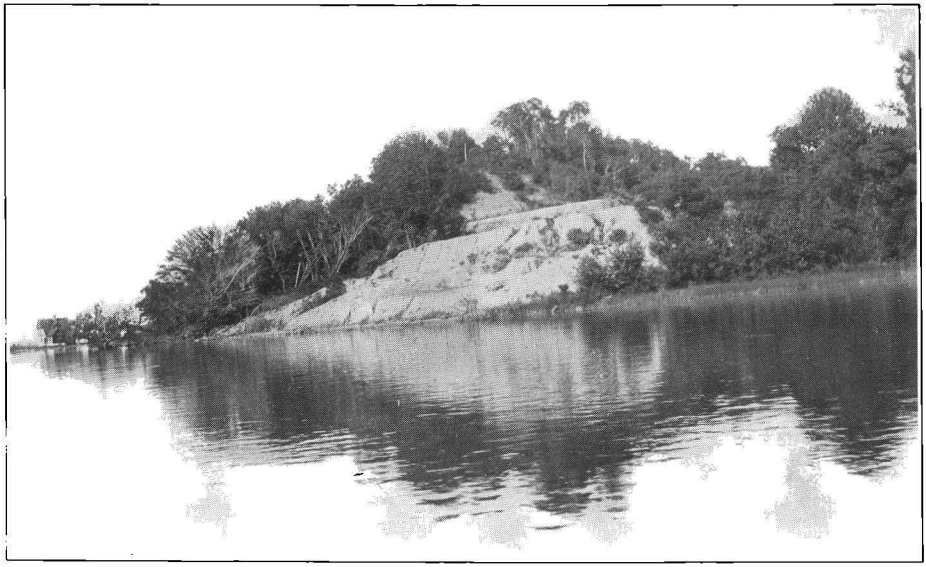

FIGURE 1.—VARIEGATED CLAYS BENEATH THE MATAWAN AT FORT WASHINGTON, PRINCE GEORGES COUNTY

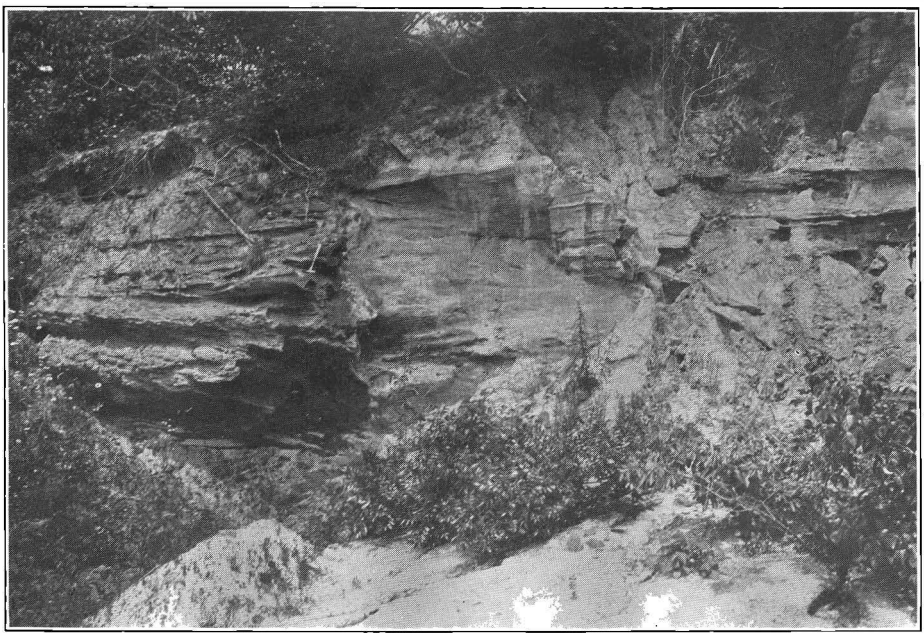

FIGURE 2.—CORRUGATED FERRUGINOUS SANDSTONE NEAR HANOVER, HOWARD COUNTY

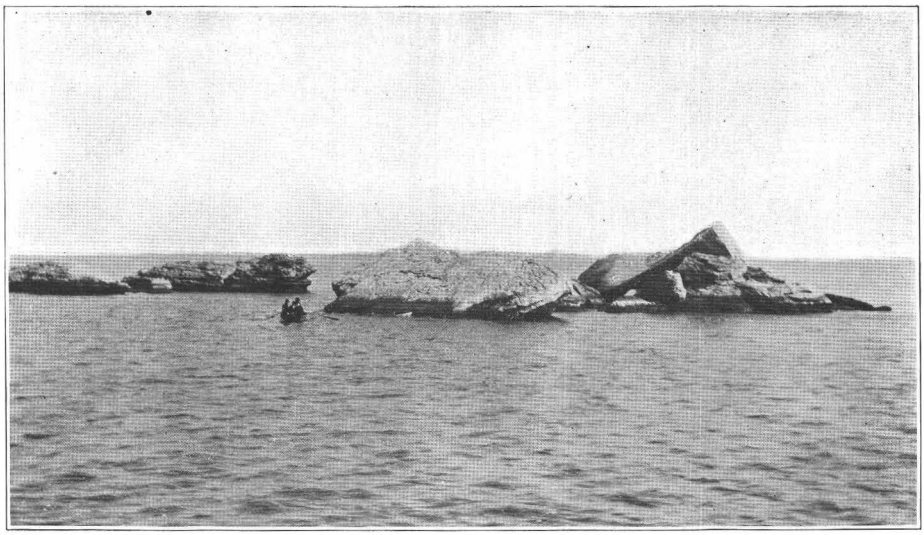

FIGURE 1.—SANDSTONE LEDGES ("WHITE ROCKS") NEAR MOUTH OF PATAPSCO RIVER

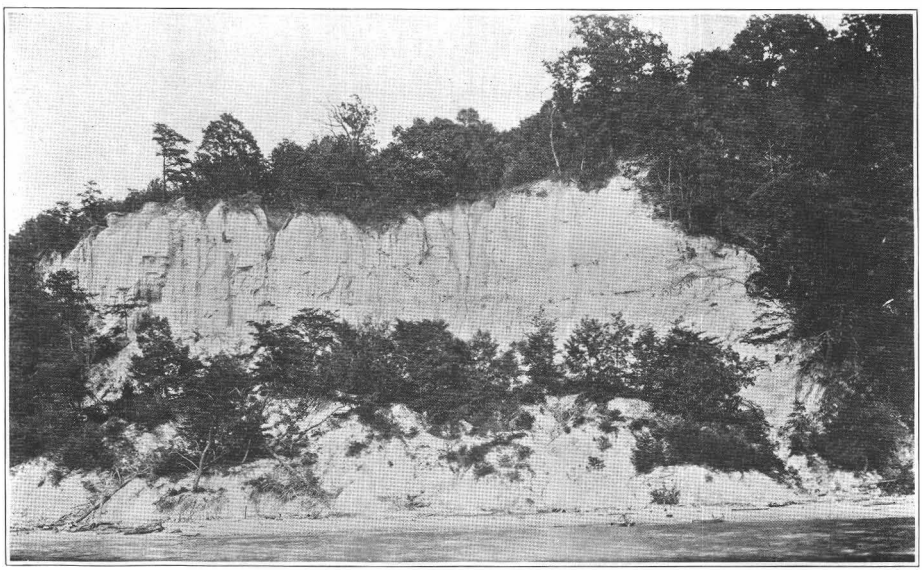

FIGURE 2.—CLIFF OF "FULLER'S EARTH" OVERLYING SANDS AND CLAYS AT LOWER WHITE BANKS, ELK NECK, CECIL COUNTY

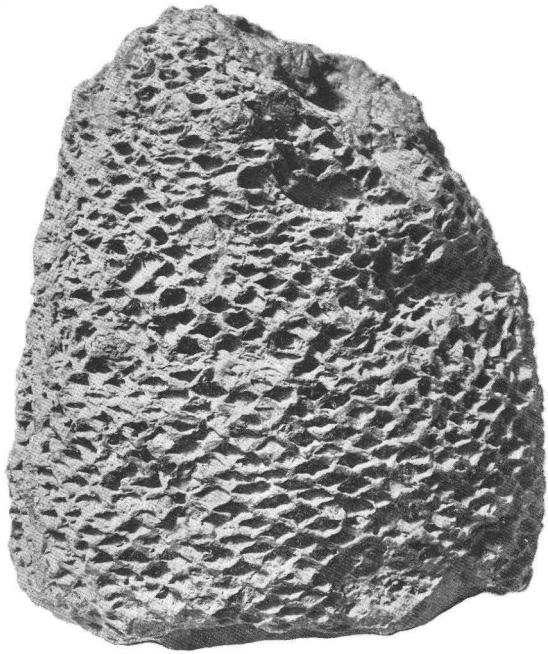

FIGURE 1.—CYCADEOIDEA MARYLANDICA (FONT.) CAP. ET SOLMS

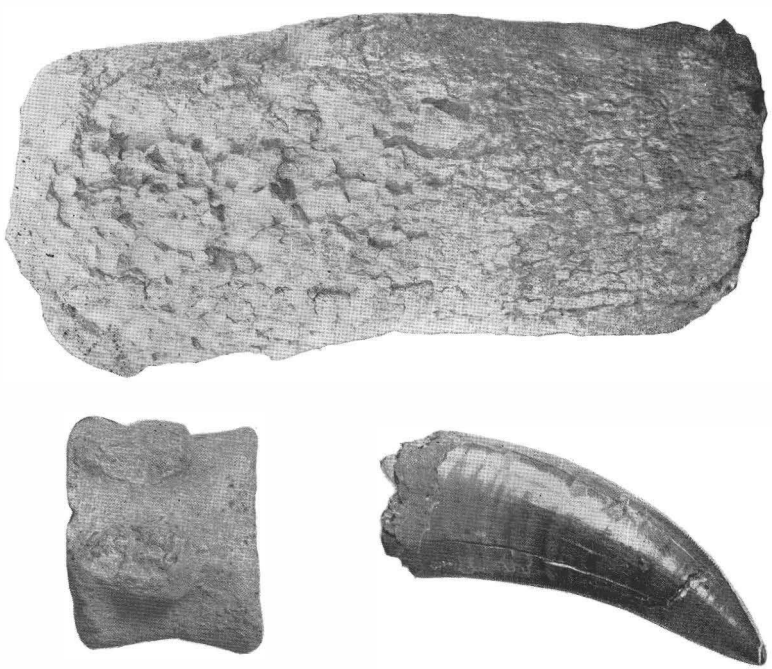

FIGURE 2.—TOOTH, VERTEBRA, AND TIBIA OF ALLOSAURUS (?) SP.

FOSSILS FROM PATUXENT AND ARUNDEL FORMATIONS