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THE

POTOMAC FORMATION

IN

VIRGINIA

BY

WILLIAM MORRIS FONTAINE

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UNIVERSITY OF VIRGINIA, *January 2, 1896.*

SIR: I transmit with this my report on the geology of the Potomac formation in Virginia. The facts embodied therein were obtained by detailed work carried on during 1886 and 1887 at a large number of localities in the different areas occupied by the formation. The local detailed work was supplemented by a comparative examination of the entire formation from its northern to its southern limits. The manuscript was prepared in 1887, but the nomenclature has since been modified.

The Potomac formation is of special interest, both because it fills a gap hitherto thought to exist in the geologic column of the eastern part of the United States and because recent investigations show that strata of like age are widely distributed and cover extensive areas in different portions of the United States.

Respectfully, WM. M. FONTAINE.

To the DIRECTOR UNITED STATES GEOLOGICAL SURVEY.

THE POTOMAC FORMATION IN VIRGINIA.

By WILLIAM M. FONTAINE.

INTRODUCTION.

Most writers in referring to the Mesozoic strata of Virginia have spoken of them as belonging to the Triassic formation. They have assumed that the beds of all the detached areas have the same general character, and also that these areas show strata similar in age to those occurring in the long belt extending from middle Virginia to the Hudson River in New York. These assumptions are erroneous, as Prof. William B. Rogers showed long ago. The annual reports of his survey of the formations of Virginia, made during the years 1835–1841 have been recently reprinted by Mrs. Rogers, and with them a number of independent papers on the geology of the Virginias. All these are embraced in a volume entitled Geology of the Virginias.[1] In the frequent mention herein of the geological work of Professor Rogers reference will be made to this publication.

In his annual reports Professor Rogers regarded the Mesozoic areas of Virginia as composed of strata belonging to two different epochs not remote from each other. The older strata he called "Middle Secondary," and the younger "Upper Secondary." In his Middle Secondary he included all the areas except the most easterly ones and the northern detached portion of the Richmond coal field. The Upper Secondary areas of Professor Rogers are those numbered 6 and 7 by Prof. James D. Dana,[2] with also the northern portion of No. 5, these being the portions mentioned above as excepted.

In his later writings Professor Rogers still maintained the difference in age of the areas, as indicated above, but expressed the opinion that the older areas contain strata of both the Triassic and Jurassic age. The younger ones, however, in his opinion, range in age from the Jurassic into the lower Cretaceous. Accordingly he called the older beds "Jura-Trias," and the younger ones "Jurasso-Cretaceous." These younger beds form the subject of this memoir.

[1] A reprint of Annual Reports and other Papers on the Geology of the Virginias, by the late William Barton Rogers; by Emma Rogers, 832 pp., 1884.

[2] Dana's Manual of Geology, 3d ed., p. 405.

As the typical strata of this younger series are shown in greatest force along the Potomac River, the name "Potomac" has been proposed for them by Mr. W. J. McGee, and this name will be used in this report.

It would seem that Professor Rogers was induced, both by the general geologic character of the Potomac beds and by a few fossil plants found in them, to maintain that they differed in age from those of most of the Virginia Mesozoic areas. The geologic features, in most cases striking, will be noticed later.

I have not been able to obtain any definite information concerning the fossil plants seen by Professor Rogers. It appears that they were found in the beds near Fredericksburg. In his Geology of the Virginias[1] he says of these plants:

> In some instances, however, very distinct impressions have been met with, unequivocal in character, and of such a nature as clearly to show that the sandstones in question were deposited during a comparatively late period of the series of secondary formations, and are to be regarded as of more recent production than the various slates, shales, sandstones, and conglomerates described under the name of the Middle Secondary formation in my last year's report. They may, therefore, for the present, with great propriety, be designated as the Upper Secondary sandstones.

He again alludes to the Fredericksburg plants,[2] but not with any more definiteness. He says,[3] in speaking of the Potomac beds:

> These are the siliceous, argillaceous, and pebbly beds which, underlying the Tertiary in Virginia and the well-marked Cretaceous formation farther north, have, in the latter region, been regarded as belonging to the base of the Cretaceous series of the Atlantic States. In Virginia the formation consists typically of a rather coarse and sometimes pebbly sandstone, in which the grains of quartz and feldspar are feebly cemented by kaolin derived from the decomposition of the latter, and of argillaceous and siliceous clays, variously colored and more or less charged with vegetable remains, either silicified or in the condition of lignite. These constitute the group of beds designated in the Virginia geological reports as the Upper Secondary sandstones, and referred by me long since (1842) to the upper part of the Jurassic series, corresponding probably to the Purbeck beds of the British geologists. From the Potomac northward this group of deposits, as exposed in the deep railroad cuts between Washington and Baltimore and on to Wilmington, is made up of variegated, soft, argillaceous, and siliceous beds, which, from the preponderance of the ferruginous coloring toward the Delaware, has been called by Professor Booth the "Red Clay formation." At a few points only toward the bottom of the deposit it brings to view a bed of feldspathic sand, or crumbling sandstone, above referred to.
>
> How far we may consider this group of sediments in Maryland, Delaware, and New Jersey as merely a continuation of the Virginia formation above described can be determined only by further investigation; but the discovery in them at Baltimore, by Professor Tyson, of stumps of cycads would seem to bring them into near relation with the formation at Fredericksburg containing similar remains, and would favor their being referred, at least in part, to the horizon of the Upper Jurassic rocks. Possibly we may find here a passage group analogous to the Wealden of British geology.

[1] Geology of the Virginias, pp. 437–438. [2] Ibid., pp. 709–713. [3] Ibid., pp. 711–712.

In his annual reports Professor Rogers makes his Upper Secondary stop at Mount Vernon. This results from his first limiting the formation to the sandstone member. From the quotation given last it will be seen that more recently he is disposed to extend the formation into New Jersey. It appears, also, that in his still later publication he fixes the age more definitely.

In his annual reports he notes the fact that there is no exposure of Potomac beds between Chesterfield Station, in Caroline County, and Massaponax Creek, in Spottsylvania County. On the geologic map of the Virginias, which he prepared long after the publication of these reports, he colors as Jurasso-Cretaceous an unbroken strip extending from Hanover County through Caroline County to Fredericksburg and beyond. So far as I know, he has published no explanation of this change of opinion. As will be seen in the course of this memoir, the older view is more nearly correct.

Notwithstanding the fact that the difference in age of the Virginia Mesozoic strata was clearly and positively asserted, both in the annual reports of Professor Rogers and in his later and more accessible papers, the opinion has long been generally held that these beds are all of Triassic age. The obvious stratigraphic and lithologic differences noted by me in my examination of these areas prepared me to admit the correctness of Professor Rogers's view. Paleontologic evidence, however, was at first wanting. For a considerable period it seemed that the apparently younger beds contained nothing but vague impressions of stems and fragments of lignite.

To Prof. P. R. Uhler, of Baltimore, I owe the first sight of recognizable plant fossils obtained from these beds. Several years ago, when visiting that city, I saw a small collection of fossil plants obtained by Professor Uhler from the Potomac beds at Fredericksburg, and as they were very unlike those that I had collected from the beds called Middle Secondary by Professor Rogers, I wished to collect and study them. Professor Uhler was kind enough to point out the exact locality where they were to be found. When the place was examined the outcrop in a limited space gave indications of good specimens. I had the rock quarried out and succeeded in obtaining a number of fairly well preserved impressions, most of which belong to new genera and species and none of which occur in the Middle Secondary beds of Professor Rogers. Encouraged by my success here, I began to look elsewhere for fossil impressions. Strata of apparently the same age as the Fredericksburg beds extend for a long distance in the banks of the James River below Richmond. The canal cut across Dutch Gap during the war of the rebellion runs through these strata, and the recent widening of this canal gave opportunity for the examination of the material taken out. A visit to this place showed that impressions of plants occur in considerable numbers, both at the canal and in the river banks in the vicinity. Continued search in other portions of the Potomac area has

brought to light at several localities a large number of plant fossils, many of which are new to science.

None of these fossils have been found in the Richmond coal field, and, so far as known, none of the supposed older Mesozoic areas contain any of them. It is sufficient to say here that this flora indicates that the Potomac beds were laid down in a period decidedly more recent than that in which the Middle Secondary strata of Rogers were deposited. It is proposed to give descriptions and illustrations of these fossil plants in a future publication.[1] The object of this memoir is to give some account of the geology of the lower Potomac formation in Virginia, where it is perhaps most typically developed.

It should be stated that there is reason to think that the extensive formation of clay and fine sand known in Maryland as the "variegated clay formation," or the "iron-ore clays," may belong to the same general epoch as the Potomac of Virginia, forming an upper member of the group of which the Virginia Potomac is the lower. The Virginia beds and those of Maryland can not now be certainly separated by any sharp differences; hence, for the present, the Virginia strata must be regarded as lower Potomac, and the Maryland formation as upper Potomac.

LOCATION AND BOUNDARIES OF THE POTOMAC TERRANE IN VIRGINIA.

The Potomac strata occur in several apparently disconnected areas that for the most part lie in lines of prolongation of one another running nearly north and south. They form the most easterly of the Mesozoic tracts and rest upon the eastern margin of the pre-Cambrian terrane, sinking to the east beneath the Tertiary. Unlike the older Mesozoic beds, they in no case occupy areas within the pre-Cambrian.

The north-and-south trend of the exposures of the Potomac strata is due to the fact that they were probably laid down as shore deposits along the margin of the pre-Cambrian rocks. At a later period they were covered by other deposits, and now appear only where these have been removed by erosion. The overlap of the Tertiary and more recent deposits upon the pre-Cambrian in the State of Virginia takes a direction almost due north and south, and in consequence of this the Potomac exposures have a similar direction.

In the northern outcrops, from Fredericksburg to Alexandria, the Potomac beds reach a height above tide considerably greater than that attained by those farther south, and the depression of their present surface increases as we go southward. In the Fredericksburg area the Tertiary and later deposits have been removed from a long strip of country several miles wide, so that now the Potomac beds, with the products of their decay, occupy the surface. In the region from

[1] Mon. U. S. Geol. Survey, Vol. XV, The Potomac or Younger Mesozoic Flora, 2 vols. (377 pp. text and CLXXX plates in separate volumes), 1889, 4°.

77°30′ 77°20′ 77°10′ 77°00′ 76°50′ 76°40′ 76°20′

39°20′ 39°10′ 39°00′ 38°50′ 38°40′ 38°30′ 38°20′ 38°10′ 38°00′ 37°50′ 37°40′ 37°30′ 37°20′

BALTIMORE
ELLICOTT
Damascus
Catonsville
PATAPSCO R.
Barnesville
Elk Ridge
Little
HOWARD
Sandy Spring
Savage
MONTGOMERY
Gaithersburg
Laurel
Patuxent
ANNE ARUNDEL
Rockville
Bowie
College Park
Herndon
PRINCE GEORGE
WASHINGTON
Fairfax
Forestville
Upper Marlboro
ALEXANDRIA
Bristol
Friendship
Manassas
Mt Vernon
CALVERT
Chaneyville
Occoquan
PRINCE WILLIAM
White Plains
Aquasco
CHARLES
Prince Frederick
Quantico
Port Tobacco
STAFFORD
POTOMAC
Mechanicsville
Stafford
PATUXENT R.
ST. MARYS
WICOMICO R.
Maryland Point
Chaptico
LEONARDTOWN
FREDERICKSBURG
KING GEORGE
WESTMORELAND
RIVER
CAROLINE
Bowling Green
RICHMOND
ESSEX
RAPPAHANNOCK R.
Hanover
ASHLAND
HANOVER
HENRICO
RICHMOND
CHESTERFIELD
Chester
City Point
PETERSBURG

MAP

OF PORTIONS OF

MARYLAND, VIRGINIA

AND

DISTRICT OF COLUMBIA

SHOWING DISTRIBUTION

OF THE

POTOMAC FORMATION

IN PART OVERLAIN BY COLUMBIA AND LAFAYETTE FORMATIONS

FROM DATA FURNISHED

BY

N. H. DARTON

SCALE 1/500,000 — 8 miles = one inch

8 7 6 5 4 3 2 1 0 8 16 24

1896.

- LATER CRETACEOUS AND TERTIARY FORMATIONS (EXCEPTING LAFAYETTE FORMATION)
- POTOMAC FORMATION (CRETACEOUS)
- NEWARK FORMATION (JURATRIAS)
- PRE CAMBRIAN CRYSTALLINE ROCKS

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

Hanover Junction to Petersburg the Potomac shows itself nowhere except in the banks of the streams or in natural and artificial excavations of considerable depth. In these exposures only a few feet of Potomac material can be seen. In the most southern exposure on the Nottoway the top of the Potomac is barely reached by the deepest waterways.

The eastern margin of the pre-Cambrian rocks is often at the head of tide water in the principal streams that cross from the pre-Cambrian to the Tertiary terrane. In this latter the streams, being tidal, soon fail to cut down to the Potomac strata, which decline in the direction of their flow, and it is therefore useless to seek for Potomac strata in place except in the vicinity of the junction of the Tertiary and the pre-Cambrian. It is true that débris, mostly gravel derived from Potomac beds, may be often found at a considerable distance from this line of contact—a fact whose significance will be noticed presently; we are now dealing with the occurrence of the Potomac strata in situ.

It is clear that the Potomac beds, as now shown, by no means represent the formation in its original thickness and extent. Potomac débris may be found over a wide belt of the pre-Cambrian terrane to the west of the strata in situ, and the character and amount of this material found on the pre-Cambrian and on the surface of the Potomac strata, where they form the country rock, show that a great thickness of Potomac beds must have been removed by erosion. This erosion, however, in part at least, has been produced in recent times, and, indeed, is going on now. There is unmistakable evidence that the Potomac formation had suffered greatly from erosion before the deposition of the Tertiary. Professor Rogers calls attention to this fact in his annual reports. He states that the oldest Tertiary beds rest on the deeply channeled surface of the Potomac sandstone, especially in the region near and south of James River. He says, further, that this worn surface under the Tertiary has often a layer of coarse pebbles which marks "an epoch of violence" prior to the deposition of the Tertiary.[1] The expression "deeply channeled," used by Professor Rogers,[2] correctly describes the surface of the Potomac beds on which the Eocene rests. So marked are the inequalities of the surface that the level of an Eocene exposure may be many feet lower than some adjacent outcrop of the Potomac beds. "Coarse gravel" hardly describes much of the larger material resting on the surface of the Potomac beds and lying under the Eocene. Not uncommonly the stones are large enough to be called cobbles.

The extensive erosion to which the Potomac formation has been subjected has not only greatly diminished its thickness where it remains in situ, but has also removed it more or less completely from areas once covered by it. There are indications that the Potomac formation extended farther westward than it now does, and that it once covered a considerable belt of the pre-Cambrian that now shows no Potomac in place. Over a belt of the pre-Cambrian, of varying width, lying

[1] Geology of the Virginias, p. 261. [2] Ibid., p. 264.

immediately to the west of the present outcrops of Potomac unmodified strata, we find various clays, sands, and cobblestones that, for the most part, are similar to the structureless materials which rest upon surfaces of Potomac beds, and which represent the products of the erosion and disintegration of these beds. The character of these materials found on the pre-Cambrian indicates that they are the débris resulting from the destruction of Potomac strata which at one time covered the surface where they lie.

Along the Potomac terrane extending from Petersburg to Hanover County these unstratified materials spread over a band of the pre-Cambrian from 10 to 15 miles wide. In the vicinity of the northern Potomac area, extending from Fredericksburg to Alexandria, the belt of the pre-Cambrian covered by them is not so wide, having a width of but 5 to 7 miles. There can be hardly a doubt that the Potomac formation once extended westward at least as far as this débris is found.

It may be mentioned in this connection that red clay and cobblestones, the latter precisely like those resulting from the erosion of Potomac strata, may be found up the James River as far as Lynchburg. The cobbles are on top of the hills bordering the river. They do not extend far back from the river, but descend the slopes toward the stream. This lower position is due to surface degradation. Without further examination the significance of these cobbles and clay can not be stated.

The location and boundaries now to be given apply to the Potomac strata in situ. No Potomac beds are positively known to exist south of the Nottoway River in Sussex County, but it is quite probable that they are to be found buried under the deep covering of later deposits which occur in that region. The exposures there are very poor, for only a few of the streams cut through the Tertiary strata, and these deposit so much alluvial matter that any Potomac material that might be reached would be hidden. At best, any exposure of these strata that occurs must be slight, and could be found only by careful and detailed examination of the region.

We have, however, some evidence that the Potomac strata extend into North Carolina. On the banks of the Roanoke River at Weldon, in the bed of a little stream, there is a small exposure of a coarse sand with cobblestones, forming a material that has all the lithologic characters of the Potomac formation. This will be described more particularly in another connection (see p. 25).

In his annual report for 1835[1] Professor Rogers says that the strata now called Potomac are to be found in the counties of Greenville and Brunswick. As in his later reports and writings he does not repeat this assertion, it may be inferred that on further examination he gave up that belief. Some of the post-Mesozoic strata in the counties above named have a striking likeness to some of the Potomac beds, and this, no doubt, was the cause for their being mistaken for the latter.

[1] Geology of the Virginias, p. 70.

LOCATION AND BOUNDARIES OF THE SUBORDINATE AREAS.

THE NOTTOWAY AREA.

The most southern known area of Potomac strata occurs along the Nottoway River, in Sussex County, about 25 miles south of Petersburg. This locality of Potomac beds did not escape the notice of Professor Rogers. He says of it,[1] speaking of the Mesozoic sandstone, his Upper Secondary:

> Only in one instance has rock resembling it been found in the country lying south of the neighborhood of Petersburg. Neither, so far as I know, does it make its appearance in North Carolina. The insulated locality just referred to is in the bed of the Nottoway River about 4 miles above Bollings Bridge, where a rock, forming the natural foundation of the bridge, is exposed for a short distance nearly on a level with the water, bearing a close resemblance to the formation referred to, and which there is strong reason for believing is geologically the same.

On his geologic map he colors as "Jurasso-Cretaceous" a small oval patch at this place.

The exposure of Potomac strata in Sussex County, on the Nottoway River, is more extensive than is indicated by the above-quoted statement. A cursory examination of this locality shows that the formation certainly underlies the surface at Bollings Bridge as well as at the precise spot mentioned by Professor Rogers. Its character at both localities renders it almost certain that these strata may be found beneath the Tertiary throughout the interval between the bridge mentioned by Rogers and Bollings Bridge. Indeed, it is highly probable that the formation extends far beyond these two outcrops. In this portion of the State the Potomac formation is buried beneath a thick covering of more recent deposits. We may expect to find it only in the vicinity of the margin of the pre-Cambrian rocks, where the streams have cut down through more recent beds. The Nottoway is the first river south of Petersburg which has cut its channel deep enough to touch the Potomac beds where they are covered by the later-formed strata. The river in the vicinity of Bollings Bridge has a considerable fall, which gives it a decided current. It is now running on the top of the Potomac sandstone, having excavated its bed 2 or 3 feet in this material. It also forms "riffles" over harder and projecting portions of the sandstone. This being the case, and a great thickness of post-Mesozoic material existing along the river, no exposures of Potomac beds can be found except in the immediate banks and bed of the Nottoway. Even here, as the river has cut so slightly into the formation, exposures would not be conspicuous, and must be carefully sought.

In the main the characters and modes of occurrence of the Potomac beds on the Nottoway and in the area next to the Petersburg area are very similar, so much alike, indeed, that one must think that the strata of both areas were laid down under like conditions and that

[1] Geology of the Virginias, p. 216.

they form parts of the same region of deposition; but this does not appear from connecting exposures. No Potomac strata are shown north of Bollings Bridge until Petersburg is reached, 22 miles distant in an air line. In this interval the post-Mesozoic strata are very thick; and as there are no streams capable of cutting channels deep enough to pass through them, it is evident that no exposures of Potomac strata can be found. Indeed, the erosion is rarely sufficient to penetrate through the Miocene beds.

THE PETERSBURG AREA.

The Petersburg area begins at the city from which it is named and extends northward to Richmond. It might have seemed fitting to give the name of Richmond to the area were it not for the danger of confounding it with the belt of older Mesozoic lying to the west of Richmond, known as "the Richmond coal field."

In the interval between Petersburg and Richmond the western limit of the Potomac area is not well defined, and outcrops of strata in situ can be found only in the immediate vicinity of the larger creeks that cross from the terrane of the pre-Cambrian and older Mesozoic into that of the Potomac and later formations. In this region not only the Potomac but the more recent formations have suffered greatly from erosion, which has produced heavy deposits of unstratified sand, gravel, and clay that usually conceal all strata in place.

The line of the Richmond and Petersburg Railroad, which forms a part of the Atlantic Coast Line, may be taken as pretty closely approximating the western boundary. The eastern limit of Potomac outcrops may be given as follows: Exposures, very slight in extent, occur in the immediate vicinity of Petersburg on the north side of the Appomattox. They extend in greater force down this river to a place about 3 miles above City Point, the confluence of the Appomattox and the James. The exposures are found mostly on the eastern side of the river down to Point of Rocks, 4 miles above City Point. Point of Rocks is on the western side of the river, and forms a bold bluff immediately on the stream. Here may be found the most extensive vertical exposure of Potomac strata visible in the Petersburg area. From this place down the river toward City Point for about a mile outcrops may be found mostly on the right or east bank.

A line drawn from a place on the Appomattox about 3 miles above City Point, in a direction a little east of north, to Deep Bottom, on James River, will touch the most easterly exposures on these streams. From Deep Bottom to Richmond exposures are numerous on James River. In the triangular space between the rivers the thick post-Potomac deposits hide nearly everywhere the older strata, and the same is true north of James River. The nature of the material shown on the two rivers indicates not only that the formation is continuous, underlying the area included between the railroad and the rivers, but that it extends north, south, and east of the last exposures. Between

the rivers and in the terrane under which the Potomac probably lies, in a few places, may be seen the marl bed, which in Virginia forms one of the lowest of the Eocene strata. Heavy deposits of gravel and cobbles composed of quartz and Cambrian quartzite occur along the rivers, resting often on the Potomac beds. These materials are much more extensive near the western margin of the formation, and here the coarser deposits are associated with red and variegated clays.

The coarse and heterogeneous character of the Potomac material, as it is exhibited in the most eastern exposures seen on the two rivers, gives us strong reason to think that the true eastern margin of the formation is to be found much farther east than the points at which it was last seen. The indications given in the amount and character of the most easterly outcrops of this group of beds are confirmed by the disclosures made in boring an artesian well at Fort Monroe. The results obtained from an examination of the material taken out of this well, which will be given farther on (see p. 45), show that there can be no doubt that the Potomac formation extends in force at least as far east as that place.

Fort Monroe is 60 miles in an air line southeast of the last exposures on the James and the Appomattox. The direction of this air line is very nearly the same as that of the average direction of declination of the formation. How much farther eastward beyond this point it extends we have no means of knowing. At Richmond the Potomac may be seen underlying the Tertiary and resting on the pre-Cambrian. It shows only a thin layer, and being near the original western boundary of the formation, it has suffered much from erosion.

THE HANOVER AREA.

North of Richmond no outcrops appear until we reach the vicinity of the confluence of the North Anna and the South Anna rivers. Here, in the neighborhood of Hanover Junction, a thin remnant of Potomac beds may be seen at several points. They rest unconformably on the older Mesozoic or Rhetic beds, which belong to the northern end of the Richmond coal field. The line of the Richmond, Fredericksburg and Potomac Railroad may be taken as approximately the western boundary of the strata in place. This may be called the Hanover area. The fact that exposures of the Potomac do not appear in the interval between this region and Richmond does not necessarily imply that the formation is absent. In this quarter the post-Potomac deposits are thick and conceal everything, for there are no rivers with sufficient erosive power to cut down to the older formation.

Between Hanover Junction and North Anna River the last exposures in this neighborhood occur. The easternmost outcrop of the Potomac in the vicinity of Hanover Junction occurs a little above the confluence of the North and South Anna. Here the Potomac sinks under the Tertiary. At Morris Ford, a little more than a mile above the junction

of the rivers, there is a good exposure, showing the Eocene[1] greensand marl bed resting on the Potomac, with a bed of cobblestones intervening. Professor Rogers noted the disappearance of the Potomac in this region beneath the Tertiary. The occurrence of the formation and its mode of disappearance under the Tertiary, both in this region and at all points south of it, indicate that the group, as a whole, sinks in a southeasterly direction.

It may be repeated here that Professor Rogers in his reports considered all of the Mesozoic strata north of the Chickahominy River as belonging to his Upper Secondary. He does not seem to have found any fossil plants in them, and in the absence of fossils this mistake was very natural, for some of the older Mesozoic beds here are lithologically much like those of the Potomac. I was fortunate enough to find fossils at several localities, and they show that the greater portion of the Mesozoic beds in this region are older Mesozoic or Rhetic in age.

North of North Anna River, toward Fredericksburg, there are no exposures of Potomac strata. It is probable that the formation exists and is continuous in this interval, but it is too deeply buried under the latter formations to be reached by the erosion of the streams. In the vicinity of Milford Station the head streams of the Mattapony do not cut down through the Eocene; and farther west, along the junction of the pre-Cambrian terrane with that of the Tertiary, where outcrops of Potomac might be supposed to exist, the covering of post-Potomac material hides everything. In this interval of about 25 miles, measured on an air line, the lowest stratum visible in place is the greensand marl bed of the Eocene, and this is seen only in the lowest depressions made by the streams.

THE FREDERICKSBURG AREA.

After passing over the interval north of the North Anna we find the first exposures of Potomac strata on Massaponax River 5 miles south of Fredericksburg. From this point to the Potomac River and beyond the outcrops are continuous. This area, which we may call the Fredericksburg area, is much the most important one in Virginia. It is unlike those farther south in that the Potomac beds form the surface rocks over a considerable belt, and they generally are covered only by material derived from themselves.

The exposures begin on the Massaponax near where that stream is crossed by the road leading from Port Royal to Fredericksburg. From this point the western margin of the Potomac terrane may be given approximately as follows:

Beginning on the Massaponax, it sweeps around so as to cross Hazel Run and the narrow-gauge railroad from Fredericksburg to Orange, 2 miles west of the first-named place. It crosses the Rap-

[1]The Eocene deposits of Virginia and Maryland are now designated the Pamunkey formation on the maps of the United States Geological Survey.

pahannock River 1 mile above the village of Falmouth. From this place to Occoquan the Telegraph road runs in general parallel with the western margin and about 1 mile east of it. From Stafford to Occoquan this road has a direction nearly parallel with the course of the Potomac River, and the general direction of the Potomac area now in question shows a striking parallelism with the course of that stream. Opposite Stafford the Potomac River bends abruptly eastward and no longer follows the direction of the Potomac formation, hence exposures of the strata are not found in that river below the mouth of Aquia Creek. The general course of the Telegraph road is such that it crosses all the streams that empty into the Potomac River between Stafford and Occoquan, near the head of tidewater in each. In local usage, the tidal portion of each of these tributaries is called the "creek," while the upper portion is called the "run."

At the village of Occoquan, where the Telegraph road crosses Occoquan River, mica-schist and gneiss are extensively displayed, while in the tops of the hills some small patches of Potomac occur associated with a large amount of gravel, sand, and cobblestones, which resulted from the destruction of Potomac beds. These evidently once formed here a continuous covering over the schists. Two miles below Occoquan, on the river of the same name, at the crossing of the railroad between Alexandria and Fredericksburg, the Potomac has thickened sufficiently to form a continuous covering for the crystalline rocks.

At the village of Occoquan the western margin diverges more widely from the Telegraph road, for while it continues its northeastward curvature to conform to the course of the Potomac River, the road turns more sharply eastward and penetrates farther within the Potomac area. North of Occoquan River the western margin runs northward and then northeastward, crossing Pohick Run about 1 mile west of Pohick church. Thence it continues so as to cross the Virginia Midland Railroad and Little River turnpike about 7 miles west of Alexandria. It here bends rapidly eastward and crosses the Potomac River a little west of Washington. The formation thence continues on to Baltimore, following the line of the Baltimore and Ohio Railroad.

The eastern margin of the area in which the Potomac beds, with the products of their erosion, form the surface material is very irregular and vaguely defined. Where the streams have sufficient erosive power we observe in a number of places that they cut down to the Potomac and expose it at points farther east than the general eastern boundary of the belt of which the formation constitutes the surface rock.

The Potomac beds are covered eastward by the Tertiary. Along the Potomac River the Tertiary has been often, and the Potomac sometimes, removed and replaced by the Pleistocene.[1] All these materials are very

[1]The Pleistocene deposits of this region are now designated the Columbia formation on the maps of the United States Geological Survey.

friable and easily removed by erosion. Each of the three formations, the Potomac, the Tertiary, and the Pleistocene, is often buried beneath a thick covering formed of its own ruins. These materials blend in such a manner and are often so much alike that it is difficult to detect the exact boundaries of the different formations. Some patches of the lowest Tertiary are left uneroded well within the belt in which the Potomac forms the principal surface rock.

The eastern limit of exposures of the formation from Alexandria to near the mouth of Aquia Creek is the Potomac River. Between the mouth of Aquia Creek and the southern end, on the Massaponax, the limit will be approximately determined by a line connecting these two points which curves westward so as to pass by Brooke, on the Richmond, Fredericksburg and Potomac Railroad, and old Potomac Creek church, on Potomac Creek, half a mile below the railroad bridge. It should be added, however, that on the Potomac River the Potomac formation is often concealed by a thick mass of Pleistocene deposits. It shows itself on both sides of the river, in Maryland as well as in Virginia, but in Maryland it is covered by the Tertiary, or by the Tertiary and the Pleistocene, and is visible only in the lower portion of some of the bluffs immediately on the Potomac River.

On the Virginia side the formation constitutes the surface rock in a continuous belt running from the Potomac River north of Alexandria to the Massaponax River 5 miles south of Fredericksburg. The width of this belt ranges from 3 to 7 miles, the maximum width being near Alexandria. The average width is 3 or 4 miles. In the vicinity of the Telegraph road the Potomac, with the products of its erosion, forms the entire surface rock, but away from this road toward the Potomac River the formation is sometimes covered by the Tertiary or the Pleistocene.

It may be well, before leaving the description of the eastern limit of the formation, to mention here some of the more important localities along this margin that show outcrops of the Potomac. Going northward, after leaving the Massaponax we find extensive exposures in the banks of the Rappahannock a short distance above the mouth of the Massaponax. Here the material is a pretty firm sandstone, which was formerly quarried for building purposes. We next find a good exposure on Potomac Creek, about half a mile below the railroad bridge, on the road from Fredericksburg to Brooke, where it leaves the creek. The ruins of the colonial church, named for Potomac Creek, are close by.

The next locality worthy of note is Brooke station. Both here and at Potomac Creek church the Potomac disappears under the Eocene. We find the next most easterly outcrop on Aquia Creek, about half a mile above its mouth, according to Professor Rogers. The exposures are extensive where the railroad crosses the creek, but from that point, which is about 3 miles up from the Potomac River, the Pleistocene generally conceals the formation. Then, proceeding northward along

the Potomac River, we find that for some miles the Pleistocene cuts out the Potomac formation immediately on the river. At the mouth of Quantico Creek, at Shipping Point, and elsewhere, however, extensive exposures also occur. From Shipping Point northward on the Virginia side the outcrops are extensive in all the high bluffs and hills near the Potomac River almost to the mouth of the Occoquan. In these places the Potomac formation contributes most of the material, but it has usually a remnant of the Pleistocene resting upon it. This is the condition of things at Cockpit Point and Freestone Point. In Masons Neck and the promontory of High Point the Pleistocene cuts out the Potomac, immediately on the river. On the Maryland side, about 1½ miles above High Point, there is a fine exposure of Potomac material capped by the Eocene.

North of Hallowing Point, Pohick and Accotink creeks have a common tidal portion which separates Masons Neck from White House Point. On both the southern and the northern side of the common estuary of these creeks there are high bluffs, composed almost wholly of Potomac material. The bluff on the northern side, situated at White House Landing, displays the greatest thickness of Potomac strata to be seen on the Potomac River. Between White House Bluff and Mount Vernon the Pleistocene, for most of the distance, cuts out the Potomac beds; but at the latter place these appear in considerable force.

At Fort Washington, on the Maryland side of the river, and a little above Mount Vernon, occurs the last exposure of the formation on the Potomac River. It shows here only a few feet, barely rising above high tide. There is no doubt that the formation seen along the Potomac River is continued far eastward under the Tertiary. The Potomac strata in these, the most easterly exposures, are far from giving any indication of thinning out or of becoming finer. Some of these exposures show the formation at its maximum thickness, and in all of them the material is often coarse and heterogeneous in composition. At the same time the bottom of the formation is revealed at none of the above-named places, while its top always shows signs of great erosion.

The Fredericksburg area has a large amount of gravel and cobblestones spread over its surface in connection with mottled sandy clay. Southward of Pohick the larger waterworn material is mainly quartz, but northward the proportion of pre-Cambrian quartzite in the gravel and cobblestones is suddenly and greatly increased and the stones become larger. Toward the Potomac, and along that stream, the rounded material is composed mainly of Cambrian quartzite. The gravel and cobblestones which cover the surface of the Potomac formation are extended westward over the pre-Cambrian without material change in lithologic character. It is this material that forms the belt of loose matter mentioned before as skirting the Potomac on the west in a band of varying width.

On the western margin of the Fredericksburg area and over the

adjoining pre-Cambrian rocks the waterworn stones are not associated with clay. Westward of the area, in the vicinity of Hanover Junction, and westward of the Petersburg area, deep-red clay is commonly found with the stones. The stones over all the Potomac areas are well rounded. As we pass from the Potomac formation westward into the pre-Cambrian terrane, they gradually give way to the more or less angular drift that comes from the degradation of the pre-Cambrian. These rounded stones evidently came originally from the Potomac beds, for they abound in the vicinity of outcrops of that formation and diminish as we depart from its exposures.

It is a remarkable fact that cobblestones of Cambrian quartzite are common in the gravel that lies upon the pre-Cambrian along the western margin of the Potomac on the North Anna River. We might explain the existence of such material in the vicinity of the James and the Potomac by assuming that it was brought down by these streams, for west of the Blue Ridge they cross the Cambrian formation; but this is not the case with the North Anna.

The above account gives approximately the location and limits of the several detached Potomac areas.

THE GEOLOGIC CHARACTER OF THE POTOMAC FORMATION AT DIFFERENT LOCALITIES.

We may now turn our attention to the geologic character of the formation. It has been found to be impossible to give a general account of the geology of this group of beds. The materials that form the Potomac change so rapidly that representative sections do not exist. In any given exposure, if vertical sections should be made at intervals of, say, 50 feet, they would be as a rule widely different. The changes, it is true, do not have large range, but they occur suddenly and without any evident law. It is therefore impossible to get connected sections over any considerable space. Then, again, the formation has everywhere suffered much from erosion, and it is usually buried under débris formed by its own destruction or by the decay of the younger rocks which once covered it.

It seems best, then, to give the character of the material exposed at localties which, as nearly as possible, may be representative of the regions in which the exposures occur. In doing this I shall begin at the south and proceed north.

EXPOSURE NEAR WELDON.

Concerning the formation in the Weldon locality, there is but little to add to what was said in giving the location of the Potomac areas. At Weldon there is a thick deposit of post-Miocene material which apparently rests immediately on the crystalline schists. The precise age of these beds has not been determined, but they are certainly younger than the Miocene, and are separated from the latter by an

interval of time in which the Miocene strata were subjected to considerable erosion. These beds are confusedly stratified sands and clays, usually of heterogeneous composition, often pebbly, and mottled in color. They contain no recognizable fossils, only drifted fragments of stems of plants being seen. The material is exhibited in great force along the junction of the pre-Cambrian and Tertiary terranes, and it extends far eastward over the Tertiary region, but with a more uniform character to the east and with a larger proportion of clay than can be found in the vicinity of the pre-Cambrian.

The name Lafayette[1] has been given to this formation. As a rule it forms the surface in the more southerly Potomac areas, the exceptions being along the Appomattox and the James, where the Pleistocene appears in places to rest upon its eroded surface.

As in giving an account of the local sections frequent mention must be made of this group of beds, it appears proper to give the preceding account of their character.

On the north bank of the Roanoke, opposite Weldon, in the cut made for the approach to the railroad bridge, and also in the hills flanking the river, the Lafayette beds are shown in force. They seem to be fully 100 feet thick. The river has barely cut through them, and is now flowing on the surface of the gneiss. If the marine Tertiary was ever present at this locality it has been wholly removed by erosion. The Potomac also, if ever present, has probably been removed. The exposures near the top of the gneiss, the horizon where the Potomac may be looked for, are very poor. In the mouths of the streams that enter the river and cut down to this level there is a thick deposit of recent alluvium that hides everything older.

In only one place, and in a very limited space, did I find the surface of the gneiss laid bare. This was in the channel of a small run that entered the river on the north side of and near the bridge head. Here a deposit, a few inches thick, of coarse, gray grit, with occasional large pebbles, is displayed. The material has all the lithologic characters that distinguish the Potomac formation. It seems to owe its preservation to its firm union with the uneven surface of the gneiss.

EXPOSURE AT BOLLINGS BRIDGE.

North of Weldon, as far as the vicinity of Stony Creek, the thick covering of the Lafayette formation conceals everything older. About 2 miles from Stony Creek the road leading from Weldon to Petersburg crosses the Nottoway River by means of Bollings Bridge. Here, almost immediately under the bridge, in the bed of the river, there is an exposure of typical Potomac sandstone. Between 2 and 3 feet of it

[1] This formation was discriminated by McGee and named Appomattox. Am. Jour. Sci., 3d ser., vol. 35., pp. 328–330, 1888. In 1891 it was agreed by a conference consisting of Dr. Hilgard, Dr. Safford, Dr. Smith, Prof. J. A. Holmes, L. F. Ward, R. T. Hill, and W. J. McGee to adopt the name Lafayette mainly on the ground of priority. Am. Geologist, vol. 8, pp. 129–131, 1891.

are shown, forming the bed of the river, it being the lowest rock seen. The material is a coarse, dark brownish-gray grit, with small gravel and some pebbles that attain a maximum diameter of 3 inches. These pebbles are composed mostly of quartz, or occasionally of a siliceous schist.

The most striking peculiarity of this grit is the presence in it of scattered, large, rounded masses of highly plastic clay. As we shall see later, the occurrence of such clay balls in coarse grit is highly characteristic of the Potomac in all the areas to the north of this one. It is interesting to find this feature present in the isolated Nottoway area. In these clay balls, in the more northern areas, fragments of plants are often found, but none were seen here. The clay masses sometimes have a diameter of 12 or 18 inches. The clay is quite constant in character. When moist, it is dark gray or almost black; when dry, a dark brownish-gray. The masses come from layers of clay intercalated in the grit, which were deposited locally in pauses in the more violent movements of the waters that spread out the sand. In the renewal of the agitation of the waters these clay layers were often torn up and the fragments were rolled away to greater or less distances.

The close resemblance of this clay to much of that occurring in a similar way in the Potomac areas farther north is remarkable. No difference in their character or their mode of occurrence can be found except in the preservation of organic remains, as mentioned. The locality at Bollings Bridge may be taken as giving exposures typical of the Nottoway area, so far as that has been examined.

The spot mentioned by Professor Rogers, where the Potomac forms the natural abutment of a bridge, is found about 4 miles farther up the river. The Potomac material shown here is of the same nature as that at Bollings Bridge, except that no clay is embedded in the stony grit. About 3 feet of this is visible. It would seem that at both of these localities the river in cutting its channel has barely reached the top of the Potomac, and of course its thickness is not disclosed.

A careful examination in this region showed no Cambrian material in the gravels and cobbles embedded in the Potomac grit and none in the loose débris lying on the surface in the vicinity of its outcrops. This is in marked contrast to the condition of things in the Petersburg area. At Bollings Bridge a foot or two of a dark-brownish, friable sandy clay is visible on the top of the Potomac grit. It shows indistinct impressions of shells which are Tertiary. This is the only spot in this area where anything like the Tertiary beds was seen.

EXPOSURE AT PETERSBURG.

From Bollings Bridge northward to Petersburg nothing but the Lafayette formation is visible along the line of the county road, which coincides closely with the route taken by the Petersburg and Weldon

Railroad. The first exposure of the Potomac formation is found in the base of the hill ascending from the north end of Pocahontas Bridge at Petersburg. Here is visible on the roadside a small outcrop of incoherent sandy clay belonging to this formation, about 15 feet in thickness. The material is a loose sandy clay, light gray to nearly white in color, containing a large proportion of white clay resembling kaolin. The finer matter seems to come from the decomposition of granite or gneiss, and appears to be deposited without sorting and stratification. This finer matter is full of rounded stones of various sizes. The largest ones measure 6 to 8 inches in diameter, and one was seen having the dimensions 12 by 7 by 4 inches. Much the greater number have a diameter of 3 inches or less. They are well rounded and smooth, and are scattered irregularly throughout the mass. The material composing these stones is quartz and Cambrian quartzite, a large number being formed of the latter. As is commonly the case in the Petersburg area, the largest Cambrian cobbles are formed of a very compact, dark-gray quartzite. Over the Potomac at this locality there is a thick mass of the Lafayette formation, and in the top of the hill the Pleistocene is found.

For 10 or 15 miles west of the line of the Richmond and Petersburg Railroad there is a heavy deposit of sandy clay and gravel, forming the surface material and overlying all the older rocks which occur in that belt. With these finer materials a notable amount of quartz and Cambrian cobbles occurs. Some of the Cambrian stones are a foot or more in diameter. The gravel and sandy material may be found on the surface of both the granite and the older Mesozoic of the Richmond Coal Field. The creeks that flow out of this belt into the Appomattox and the James bring down into the Potomac terrane large quantities of rounded stones. Where the railroad crosses these creeks such cobbles are conspicuous.

The Appomattox River, from Petersburg to near City Point, gives a number of exposures of the Potomac beds. The most notable of these occurs at Point of Rocks, 4 miles above City Point.

EXPOSURE AT POINT OF ROCKS.

The exposure of the Potomac formation at Point of Rocks is much the most extensive one on the Appomattox, and may be taken as giving a fair representation of the character of the formation in its most eastern outcrops in the Petersburg area. At this place a precipitous bluff nearly 100 feet high, composed wholly of Potomac, abuts on the river. It lies on the western or convex side of the sudden bend made by the river here. The exposure shows for 75 to 80 feet above the water a mass of coarse grit, mostly of a light-gray color, but in places where the proportion of kaolin is large it is nearly white. The material in its finer portions is evidently derived from the decay of granite or gneiss. The greater part of this is quartz in rather large grains, and this is

mixed with a varying amount of kaolin. This latter in some portions is so large in amount that it would seem capable of utilization if separated from the quartz by washing. Throughout this finer material, which forms much the greater part of the mass, there are many small, more or less rounded stones scattered in an irregular manner. These stones are mainly of quartz, and are 2 or 3 inches or less in diameter, but we sometimes find larger stones, which may be called cobbles, and these are often composed of Cambrian quartzite. These are not uncommonly 5 or 6 inches in diameter; some are 8 inches, and one 10 inches in diameter was seen. The smaller stones of quartz, 3 inches or less in diameter, are derived from granite or gneiss.

None of this material is distinctly bedded. The nearest approach to stratification is an arrangement of some parts of the material in irregular, interlocking, lenticular layers, a structure characteristic of the Potomac everywhere. These layers vary so much in texture and composition that no two vertical sections of the bluff would be alike. Current-bedding on a minor scale is visible in much of the material. These structural features, common everywhere in the Potomac formation, make it impossible to get reliable dips and strikes. The more siliceous parts of the material are very firmly consolidated, and some portions of the rock where the grain is most nearly uniform have been used in constructing rough walls. Where much kaolin is present the matter is incoherent, and in outcrop usually forms a loose, sandy clay. About midway up the bluff several angular masses of pale chocolate-colored shale, occurring close together, are embedded in the coarse grit. The largest one of these masses measured 30 by 24 by 8 inches in the portion visible, and a part of it had been broken off. The masses are angular in form, and have been torn from some bed of clay deposited in the grit, formed in the same manner as the clay masses mentioned as occurring near Bollings Bridge. Here, however, they are not rolled into balls.

While most of the finer materials of the Potomac here were evidently derived from the decay of the granite and gneiss which lie west of the Potomac terrane, the Cambrian material must have come from areas west of the Blue Ridge, for no rock like that of these larger cobbles is found east of that range. The material attributed to the Cambrain varies somewhat. That giving the largest cobbles is a compact, dark-gray quartzite. A common kind is a light-gray quartzite, often somewhat friable, sometimes with visible quartz grains. This rock often contains a good deal of white clay with the quartz, and by the comminution of this variety some of the quartz grains and kaolin-like clay of the Potomac may have been produced. The cobbles formed of this kind of stone may often be split into plates with a hammer. The splitting takes place along the bedding planes of the quartzite. This stone when transported was apparently firm and tough, as is indicated by the well-rounded, smooth cobbles which it

furnishes. The friability now shown seems to have been produced by long weathering.

Both kinds of Cambrian cobbles abound at the top of the Potomac grit when this is found in place, and they are numerous along both the Appomattox and the James. There seems to be in this region a continuous bed of these coarse stones separating the Tertiary and Lafayette formations from the Potomac. In these scattered stones casts of *Scolithus linearis* are often found, but none were seen in the cobbles of the bluff at Point of Rocks.

The top of the grit shown in the bluff has evidently lost much from erosion. It is cut down till it presents an uneven, undulating, and sometimes channeled surface. At the top of the coarse grit which forms the greater portion of the bluff there is a noteworthy bed of cobbles and coarse gravel. This is the bed mentioned above as extending widely under the surface of Post-Potomac formations. It appears to result from the erosion of the Potomac, which causes a concentration of the larger stones on the top of the formation where it remains in place. The process of erosion removes the finer matter.

The stratum is composed mainly of rounded stones of considerable size. These are packed in a sandy matter that is the residue of the finer material of the grit upon the top of which the cobble bed rests. In short, this stratum differs from the underlying normal Potomac chiefly in the greater proportion of large stones. Its thickness varies greatly, for it also has lost much from erosion. At Point of Rocks it varies in thickness from 5 to 12 feet, being quite commonly 8 to 10 feet thick. With the rounded stones, which are of quartz and Cambrian quartzite, there are occasional masses of partly rounded pre-Cambrian material, such as granite, gneiss, and mica-schist. The proportion of Cambrian quartzite is great, and the cobbles composed of this material are generally larger than those formed of quartz. Many of the former are as much as 6 or 8 inches in diameter, and some go up to 12 inches, the dark-gray quartzite furnishing the largest. All are well rounded and smoothed, as if they had been long subjected to water action. The material of this bed is without stratification, the stones being confusedly heaped together in it.

Prof. William B. Rogers, in his Virginia reports, made forty years ago, mentions this locality as noteworthy for the number and size of the stones composed of his No. 1 formation, which is of Cambrian age. He alludes to the resemblance which this bed bears to glacial drift, or, as it was then called, "diluvium," saying that it resembles "an ancient diluvium." This cobble bed appears to be considerably older than the Lafayette formation, for this latter rests upon it at the ocher works a few hundred yards farther up the river, and is totally different from it, being a plastic clay and ocher. The material exposed in the bluff at Point of Rocks is of an unusual character, however, in showing no intercalated layers of clay. So far as seen it is all grit and pebbly matter.

In the exposures above and below Point of Rocks, while the greater portion of the material is a coarse, pebbly grit like that at the Point, yet we often find intercalated in the coarse sandy matter thin sheets of clay that have a limited horizontal extent or are lenticular in form. These clays occur without rule and at different levels. In rare cases, as between the Point and the ocher works, the clay thickens up suddenly so as to form a considerable portion of the exposure. The clay mass then has the form of a disk-shaped cake that thins out rapidly on all sides, giving way to the grit. These clays in the exposures on the Appomattox often show unrecognizable bits of plants, but in no case well-preserved fossils.

It is from the erosion of the clays in the process of depositing the sand and grit that the isolated clay masses and balls are formed. Whenever found in the Potomac two colors characterize them, the one being, when the material is damp, dark-gray to black and the other chocolate. It is not an unusual thing to find a thin clay layer inclosed on all sides by coarse sand which is sharply distinct from it. The beds are thin, ranging generally from 4 to 12 inches. Sometimes they are cut away abruptly at the ends, apparently by an eroding current. The peculiar clay balls that are so common on the James River and in all the Potomac areas appear to be rare on the Appomattox River.

About 200 yards above the Point an unusually large proportion of clay is present. The banks of the river are here much lower than at the Point, rising only about 30 feet above the water. Nearly all of this material is a reddish-brown or chocolate-colored, thinly laminated, plastic or sandy clay, with some layers of fine, sandy matter. A considerable portion of the clay is plastic, and obscure fragments of plants occur in some of the layers. A short distance up or down the stream no trace of this clayey material can be found.

About 400 yards above the Point nearly 40 feet of the Potomac grit is exposed, and here there is a bed of highly ferruginous clay, from 4 to 5 feet thick, resting upon it. This latter stratum has so much iron oxide in one portion that it is worked as an ocher. The ocher bed is probably a member of the Lafayette group.

The exposures in the vicinity of the Appomattox show that the Potomac had lost much from erosion before the deposition of the Eocene. In places its surface had been cut down much lower than in others. This is shown by the position of the Eocene at some localities in this region.

In the Potomac areas south of Fredericksburg the lowest Eocene bed visible is a greensand marl. Two miles northwest of Point of Rocks this bed crops out in a ravine called Deep Bottom, a name also given to a locality on the James River below Dutch Gap. The top of the greensand bed here is considerably below the level of the top of the Potomac at Point of Rocks.

Between Point of Rocks and City Point, where it enters the James River, the Appomattox flows due east and soon passes so far within the Tertiary that exposures of the Potomac cease.

EXPOSURES NEAR DUTCH GAP.

The exposures next to be noticed occur on the James River in the vicinity of Dutch Gap. About 17 miles below Richmond the James River makes a bend in the shape of a long, narrow horseshoe whose heels almost touch. The narrow neck which separates the heels, barely 100 yards wide, has long been known as Dutch Gap. Through this the noted Dutch Gap Canal was cut. The promontory around which the river runs has its longest dimension turned to the southwest, and is called Farrars Island. The southern portion of the bend in the river around Farrars Island is known as Trents Reach. The length of the horseshoe is 7 miles.

Exposures of the Potomac formation occur in the left bank of the river for 2 miles above the canal. They are found also at several points in the bend, being most extensive at the northern entrance of the convex portion of the horseshoe at a locality called Osbornes. At the eastern entrance of the horseshoe there is an outcrop that has yielded many fossil plants. Many have been obtained also from the banks of the canal and from the outcrops above the canal. The lower portion of the neck through which the canal was cut, for a height of 10 to 15 feet above the water, is composed of Potomac material. The upper portion is Pleistocene. The canal is cut wholly in the Potomac, and does not pass below it.

The finer Potomac material in the vicinity of Dutch Gap is, as usual, composed of sand and clay, the latter generally forming thin, lenticular layers in the former. Rounded stones and clay balls often occur in this, especially toward the top. This matter is extremely variable from place to place and shows no regular bedding. The structure, so far as seen, is a sort of current-bedding, which does not anywhere permit a determination of dip and strike. This heterogeneous matter forms the lower part of the bank of the river, and its base is nowhere exposed. Material on an average from 10 to 15 feet thick is exposed above the water. The top, however, is uneven, and the formation has evidently lost much by erosion in pre-Eocene times. Near Osbornes as much as 30 to 40 feet is shown.

On top of the Potomac formation we usually find a mass of gravel and cobbles, often containing large fragments of pre-Cambrian rock. This cobblestone deposit is in rare cases absent, but it generally ranges in thickness from 4 to 10 feet. Above the cobblestone bed we often see, in variable thickness, a loam that resembles the clay used in a number of places for the making of bricks. Both the cobblestone bed and the loam are apparently Pleistocene in age. This arrangement of material is not confined to the vicinity of Dutch Gap, but extends down the river to Deep Bottom, and up to Richmond.

The sand which forms much the larger part of the Potomac, and which may be taken as the typical rock, is sometimes locally sufficiently

indurated to form a sandstone, but as a rule, in weathered outcrops at least, it is incoherent. It differs in no essential from the grit of Point of Rocks and other places on the Appomattox. The color at Dutch Gap is often brownish-gray or yellowish-gray, with patches and blotches of light-gray or white, the latter being caused by a larger proportion of kaolin-like clay. The texture of the sand is generally quite coarse. Most of it is quartz in coarse grains. Intimately mixed with the quartz grains there are in some places many more or less fully kaolinized particles of feldspar, a little mica, and a varying quantity of a nearly white clay. The amount of mica is remarkably small if this Potomac material comes principally from the pre-Cambrian on the west, for that is composed of micaceous rocks, such as granite, gneiss, and mica-schist. Some of the light-colored clay is derived, no doubt, from the comminution of Cambrian material, for some of this, now found in cobbles, has a great deal of light-colored clay with the quartz. We find very generally scattered through the sand a number of more or less rounded quartz pebbles 3 inches or less in diameter. These seem to come from the pre-Cambrian. In most of the exposures large cobbles of Cambrian quartzite and quartz do not occur in the body of the sand. Those in Trents Reach are exceptional in this respect.

It would be futile to attempt to use the barometer in taking the dip of this material. Its surface is determined by the accidents of erosion, and no single layer maintains the same character long enough to be traced from one outcrop to another. The dip as a whole sinks gently to the southeast.

EXPOSURES IN TRENTS REACH.

In Trents Reach, near Osbornes, 40 to 50 feet of the sand is exposed, giving much the most extensive outcrops in the vicinity of Dutch Gap. Here very striking and sudden changes of structure, texture, and composition are shown. Lenticular masses and irregularly shaped portions of the sand are fine-grained and comparatively uniform in texture. These are surrounded by material of very heterogeneous composition and varying coarseness, so that the finer material may abut against portions that are full of large cobbles. It is impossible, without tediously minute description, to give an adequate idea of the heterogeneous character of the sand in Trents Reach. Current-bedding and beach structure are very marked, and, so far as any separate portions can be distinguished, the material is arranged in irregular, interlocking, lenticular layers. In some places here the structure seems to indicate that the matter was deposited spasmodically, with intervening periods of erosion, a feature very generally characterizing the Potomac. The freshly deposited sand seems to have been cut away in the body of the mass from time to time, forming pits and trenches, and in these depressions was deposited a mixed mass composed of sand and stones, large and small.

In the confused material above described nests and pockets of

gravel and large cobbles of quartz and Cambrian quartzite occur, generally in the form of short, lenticular layers. The cobbles range in diameter usually from 3 to 8 inches, but some are 10 to 12 inches. At one point near the mill on the bank of the river in Trents Reach a stratum of coarse sandstone occurs near water level, which, for the space of about 100 yards, is packed full of large cobbles. This cobble bed has a maximum thickness of about 6 feet. On each side the stones diminish in size and number until they give way to the usual sand or grit. The cobbles for a considerable space are so numerous as to touch one another, and are remarkable for their uniformly large size and for the large proportion of those composed of Cambrian quartzite. Many of the stones are from 6 to 10 inches, and some 12 inches, in diameter. They are smooth and mostly elliptical in shape. Most of them are composed of Cambrian quartzite, the largest being formed of the compact, dark-gray quartzite. This rock is found west of the Blue Ridge, underlying the typical Cambrian, with Scolithus. These cobble beds never contain any pre-Cambrian masses. They are integral portions of the Potomac formation, and must not be confounded with the cobble stratum which rests upon the Potomac sand, and which frequently contains pre-Cambrian material. Probably the cobbles of this latter came originally from such deposits as have been described above. Cases are very rare where the sand shows any tendency to lamination or to graduate into clay, and when clay is found it is confined to very limited spots, forming, indeed, lenticular pockets in the heterogeneous matter. Clay beds are very rare in Trents Reach, except at and near its southeastern entrance, where the proportion of this material becomes unusually large. In the vicinity of Osbornes, however, clay balls of remarkable size occur embedded in the sand.

Before describing the various modes of occurrence of the clay in Trents Reach it will be necessary to make some general statements concerning the character and occurrence of this material at Dutch Gap, and what will be said of the Dutch Gap clay applies most remarkably to the Potomac clay of the areas farther north.

The clays of Dutch Gap are mostly plastic, and have the usual two colors so commonly found in the formation. They are, when moist, either dark-gray to black or dark-brown to reddish-brown; when the clay is dry the colors are paler. Clay of both colors is found in the original layers, and in balls or more or less rounded masses that have been torn off from the original layers and transported some distance while sand was being deposited. The original clay beds have sometimes been wholly removed, and are represented now solely by masses of clay that are isolated and embedded in the sand. The balls then represent erosion horizons, and they may occur at any level, but are most common near the top of the Potomac. They are often associated with cobblestones. The way in which they are probably formed has been explained in another connection.

The clay layers, when found as originally deposited, nearly always occur isolated and embedded in the sand. They are seldom more than 2 feet thick, generally 10 to 12 inches. They show very great and often sudden changes in thickness, and may split up and graduate into sandy matter, but most commonly they have the form of sharply distinct thin cakes or lenticular layers of very limited extent that disappear by thinning out on all sides. They may occur at any level and may show any inclination in the sandstone. In extreme cases we may even find several radiating from a common center. When partially eroded, very many modifications may occur. Portions may remain buried in fragments of clay, but this is not so common here as in the Fredericksburg area. The ends may be cut squarely off and abut against coarse sand and even gravel. Frequently the layers split before thinning out. In very rare cases we find the layer thickened abruptly, so as to give a mass of clay 8 to 10 feet thick. This is the case at the southeastern entrance to Trents Reach.

All the well-preserved fossil plants found in the Potomac, both here and elsewhere, occur in these clay layers. The plants are much more common in the chocolate-colored clay than in the dark clay.

A remarkable feature of these clays in many cases is the sudden transition from the clay to the embedding sand. In most cases there is no gradation in passing from one to the other. I have seen perfectly pure and plastic clay resting on coarse sand, and even pebbles, with the line of junction so sharply defined that the pebbles and grains of sand could be picked out from the surface of the clay. The dark clay is frequently pyritiferous, and it is then difficult to preserve the fossils found in it. This clay, while not commonly showing good imprints of leaves, very often contains much lignite. This generally occurs in the form of small fragments, but sometimes large logs are found. A portion of a log of lignite was found embedded in the banks of Dutch Gap Canal, indicating a coniferous tree originally 18 inches thick, and it was stated that at least 40 feet had been removed from it.

Nearly all of the undisturbed clay layers show some cleavage, but they are never distinctly laminated when unmixed with layers of sand. Here there is little of the uptorn and redeposited clay beds so common in the Fredericksburg area.

Isolated clay balls and masses are among the special features of the Potomac formation everywhere. They are common at Dutch Gap, and sometimes attain huge dimensions. They range in size from pellets less than an inch in diameter up to masses 4 or 5 feet through. These, as before stated, are derived by erosion from the clay layers. They sometimes give recognizable fossil plants, but generally the plants are reduced to small bits and the clay is contorted, crushed, and very much affected, with rubbed surfaces or slickensides. At Osbornes a number of large balls of dark clay may be seen embedded in the sand, arranged in a row on nearly the same level. They occur at intervals in the face

of the cliff about 30 feet above the water. Some of them are from 3 to 5 feet in diameter. The dark color of the clay contrasts strongly with the light color of the inclosing sand. A remarkable clay ball, abounding in impressions of plants, was found in the banks of Dutch Gap Canal. This will be described further on.

At the southeastern entrance of the bend around Farrar Island, in the right bank of the river, there is an exposure of the Potomac noteworthy for the large amount of clay that is shown in one portion and for the number of fossil plants occurring in another. This locality is almost immediately south of the canal at a point where a small stream enters the river. The banks here range in height from 20 to 40 feet, the upper portion being composed of the cobblestone bed in a large deposit and the lower portion of Potomac material. The exposures of Potomac seen lowest down the river here are composed almost wholly of clay, having a maximum thickness of about 20 feet. This is reddish-brown in color, and is cleavable. No plants are found in it. About 30 yards farther up the river the clay splits up and becomes mixed with fine sand, the material being confusedly mingled. The top of the Potomac here is composed of a stratum of rather uniform clay 6 to 8 inches thick. This last is full of fragments of plants, a large number of them being very well preserved and readily identified. A number of new plants were found in this layer, such as *Williamsonia virginiensis*, several species of Baieropsis, *Frenelopsis parceramosa*, and many specimens of *Dioonites buchianus*. The greater portion of the exposure is composed of mixed sand and clay. A number of plants are irregularly distributed in this, and they are mostly of species different from those found in the top layer. A little farther up the stream a lignite log was found embedded in this material. The log is lignitized at one end and silicified at the other. A heavy bed of cobbles, in places 10 to 15 feet thick, overlies the Potomac in these exposures. The cobbles are of very large size, many of them being 8 to 10 inches in diameter, and some of them a foot.

EXPOSURES ON DUTCH GAP CANAL.

The banks of the canal expose the Potomac for the height of 8 to 10 feet, and give a good illustration of the exceedingly heterogeneous character of its material. The material composing the opposite sides of the canal shows great difference in composition and structure. In the left bank the clay is, in places, unmixed with sand, and rises 6 to 8 feet above the water; but the pure clay soon gives place to clay with seams of sand. In some parts the entire bank is composed of the usual coarse, sandy grit, in which, toward the top, large clay balls are embedded. With these, at the lower end of the canal, many large Cambrian and quartz cobbles are associated. The right bank also is composed of very variable materials. Portions of this bank are formed wholly of grit or sand and small stones. In other portions clay is

irregularly mingled with the sand. In the upper end of the canal the bank is formed of alternations of sand and clay. It is said that the canal below the water line was dug wholly in these. The clay in the right bank is mostly dark-colored; that in the left bank is mainly chocolate-colored or reddish-brown.

Fine fossils are sparingly and irregularly scattered in both banks of the canal. There is no regular layer containing them, and they can be found only by accident, as it were. Specimens of several conifers with acicular and scale-shaped leaves are found, with sometimes scattered fragments of Baieropsis, but *Dioonites buchianus* is by far the most common plant. Impressions of very large leaves of this fine cycad were seen on the surface of the dark clay in the right bank, in some places reaching the length and width of about 18 inches. As these were mere fragments, they indicate that the entire leaves must have been at least a yard long.

The clay here, although in some places abounding in specimens of Dioonites, has but few species. While searching the exposure in a horizontal direction foot by foot for plants I came suddenly upon a rounded mass of pure, chocolate-colored clay embedded in the interstratified sand and dark clay. This, unlike the surrounding material, was somewhat crushed and showed slickensides. It was full of impressions of plants totally different from those in the surrounding material, and the number of different species was remarkably large. At first I thought that I had discovered a rich fossiliferous layer, from which a large quantity of good material could be taken, but on working in this material it disappeared as abruptly as it had appeared. For a time this was a puzzle, but it proved to be a ball of reddish clay embedded in the normal heterogeneous material composing the banks of the canal. This was an unusual mode of occurrence, for in all other known cases in this area the clay balls occur in the sand where it is unmixed with clay. This clay ball was about 5 feet in diameter, and was probably torn off from some richly fossiliferous older clay layer nowhere visible now. It yielded some fossils that were not found anywhere else.

EXPOSURES ABOVE DUTCH GAP.

For about 2 miles above the canal exposures of the Potomac occur in the lower portion of the river bank on the left-hand side. The thickness ranges from 10 to 20 feet. The material is almost wholly a coarse grit or sand similar to that found near Osbornes and at Point of Rocks, on the Appomattox, except that large cobbles are rare, while small gravel, large clay balls, and irregular pockets of clay are common. In many places thin layers of clay of the usual kind are found, and in some of them plant impressions may be seen. The sand has the usual heterogeneous composition and mode of arrangement, being disposed in irregular, interlocking layers, showing current bedding and beach structure. The clay layers show many irregular features, and they are variously affected by partial erosion.

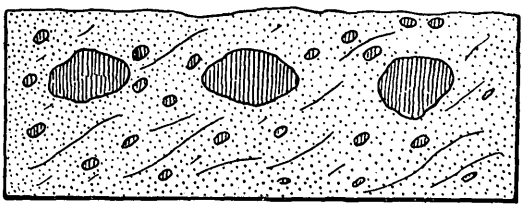

Fig. 1.

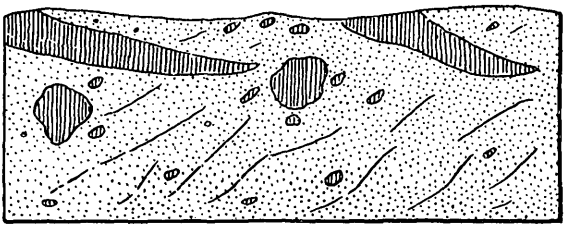

Fig. 2.

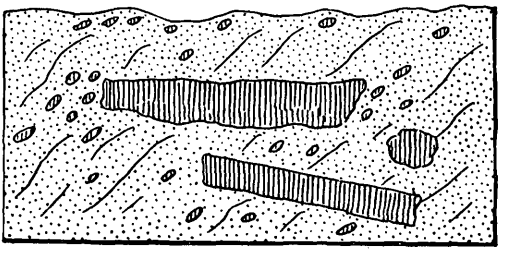

Fig. 3.

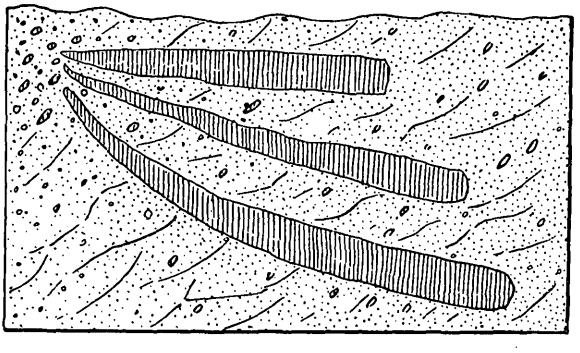

Fig. 4.

MODES OF OCCURRENCE OF CLAY LAYERS AT DUTCH GAP.

In the figures given on Pl. II, I have attempted to represent some of the varying modes of occurrence of these layers. Fig. 1 gives three large clay masses embedded in the sand. Fig. 2 represents two clay balls and two layers that extend to the top of the Potomac and are there cut away by the erosion to which it has been subjected. Fig. 3 gives two layers that are cut away at both ends by erosion. Fig. 4 partially represents the condition of things at the plant locality near a fishing hut about a mile above the canal. Here three clay layers diverge from near a common point a few feet above the level of the water. I have represented these as abruptly cut off on the right, but they really extend beyond the limits of the figure. The upper one is very soon thinned and lost in the sand. The two lower extend some 20 or 30 yards before disappearing in a similar manner, and they approach each other quite closely and run parallel for some distance. Both of these contain impressions of plants. A large number of good fossils were obtained here. Above this point and on toward a large spring that issues from the bank of the river the sand has some irregular pockets of clay, 5 to 10 feet in length near the level of the water. Some of these contain plant impressions.

The clay layers in Fig. 4 do not have the plant impressions throughout their mass. The upper layer has but few, and these are unevenly dispersed. The lower layer has the fossils in two thin seams that run in a very irregular manner through the bed. In places these are rich in fossils. This bed is remarkable for the great variety of plants that it contains. The chief of these are *Dioonites buchianus*, *Sequoia Reichenbachi*, *Equisetum virginicum*, and several species of Baieropsis and Laricopsis. A number of ferns and many other plants are found. This is the richest deposit of fossils at Dutch Gap.

THE COBBLESTONE BED NEAR DUTCH GAP.

At nearly all the Dutch Gap localities a bed of coarse stones caps the Potomac sand. It will be more convenient to give a general description of this and omit the details for each locality, for local descriptions would involve much repetition.

Sometimes the cobblestone bed is separated from the Potomac sand by a thin layer of chocolate clay, but generally it rests immediately upon the sand and is mixed more or less with it, the sandy matter serving as a cementing matrix, in which the stones are packed. This matrix, however, although derived from the Potomac, is apparently later in deposition, and comes from the ruins of the older bed. Indeed, most of the stones seem to have the same origin.

As was stated before, the stratum of cobbles is widespread. It appears all along the Appomattox and the James from Deep Bottom to Richmond. It probably underlies the surface deposits between the two rivers, and is certainly found several miles north of the James wherever the streams cut down to its level. The larger material of

the bed consists of rounded stones of all sizes under 10 inches, with occasional masses of pre-Cambrian rock. While the cobbles are generally under 10 inches in diameter, they sometimes reach 12 inches, and in a very few cases masses of Cambrian quartzite having the diameter of even 24 inches may be seen. These larger stones are subangular, while those from 10 inches in diameter down are well rounded and smooth. This rounded material is sometimes quartz, but more often Cambrian quartzite, the larger stones being composed of the latter. In some cases markings made by Scolithus are quite distinct. In one or two localities near the banks of the river partly rounded slabs 10 to 12 inches in diameter have been picked up. These appear to be Devonion in age, since they show impressions of crinoid stems and shells characteristic of the Chemung formation. On the surface of the Potomac sand, in the left bank of the canal, a fragment of brownish sandstone 5 to 6 inches in diameter was found showing imprints of Chemung shells.

It seems certain that a large portion of the coarse material comes from the Cambrian, and some at least from higher Paleozoic formations. None of these formations in Virginia are found east of the Blue Ridge. One piece of Cambrian quartzite found on the banks of the canal was planed off smooth at one end and showed markings that strongly suggested grooving from ice action. This was the only case of the kind found. Whatever may have been the mode of transport of these stones all the way from the Blue Ridge, it is clear that they have been subjected to much attrition from transportation in water. This may have occurred after their deposition in their present positions. Some of the more compact quartzite cobbles, especially when of large size, have their surfaces covered with crescent-shaped markings resembling the new moon in form. These are often thickly placed, and they seem to be without order. They are not markings left by organisms. The marks seem very slightly depressed. They are on solid quartzite, differing from the rest of the cobble only slightly in color and texture. It is possible that they are imprints produced by the impact of the stones against one another. The blow would produce at the point of impact a slight shattering or weakening of the cohesion of the quartzite, and when the surface had been long exposed to weathering a difference in texture would perhaps show itself.

The pre-Cambrian masses found in the cobble bed occur almost always at its base where it joins the eroded surface of the Potomac. These masses are comparatively rare. The pre-Cambrian bowlders never show much abrasion from transport in water. At most they have their sharper corners and edges worn off. They are usually of large size, ranging from 2 to 5 feet, and in a few cases they reach the diameter of even 10 feet. Those of the smaller sizes occur of rocks that are of the Huronian type; that is, they are composed of such fine-grained rocks as argillite, chlorite-schist, mica-slate, fine-grained

mica-schist, felsite, etc. Such rocks do not occur on the James River nearer than 50 miles west of Richmond. The largest masses are composed of reddish, coarse-grained granite or gneiss. This rock crops out on Devils Reach, in the river bank, about 2 miles (air-line distance) northwest of the canal. The largest of these masses that I have seen is lying near the water's edge a few hundred yards above the canal, where it has fallen from the bank above. It is about 10 feet long, and its surface is only slightly waterworn. Several of these large masses occur along the river here, and one of them has a mortar-like depression in its surface, which was artificially made, probably by the Indians. Two of these artificial depressions occur in the surface of the rock where it crops out in Devils Reach. It is stated that in excavating the canal one of these masses was found "as large as a haystack" and that it had to be broken up by blasting.

The action of the tide at many points near Dutch Gap, as well as below and above that place, combined with the waves set up by the steamers moving in the river, cuts away and undermines the banks, so that the cobblestone stratum is from time to time thrown down. The water washes away the finer matter and leaves the larger stones, causing a gradual concentration of the larger fragments near the water's edge. In many places there are great accumulations of large stones which line the edge of the water. This material presents a strong contrast to the matter now brought down by the stream, which is fine sand and mud.

The cobblestone bed above described is apparently Pleistocene in age where it contains the pre-Cambrian material, but a stratum of similar character without pre-Cambrian matter is spread over the surface of the Potomac, and this is certainly pre-Eocene. As a rule, along the James River the Pleistocene cobble bed has resting upon it a fine, gray loam. At Richmond this is used in making bricks, and the material of this horizon is very generally employed for this purpose, as at Baltimore, near Alexandria, at Petersburg, and at other places. This seems to be Pleistocene, and in most places on the James above the gap it is the highest material seen in the banks of the stream. At the mill in Trents Reach there is a deposit of Eocene capped by Lafayette.

In the hills adjoining the river a thick covering of the Lafayette formation, extending an unknown distance, conceals the Potomac. This younger formation certainly extends over the entire space between the James and the Appomattox rivers that forms the Potomac terrane. Rising through this material, however, in some places are small outcrops of the Tertiary marine beds. In the space between Chester and Osbornes the Lafayette formation is over 100 feet thick, and is composed largely of gravelly, gray sands and stiff, mottled clay, marked with gray, yellowish, and brownish colors. It has some beds of fine gravel. All the material is loose and easily eroded. The formation is

without fossils and seems generally to have been deposited in shallow, unquiet waters.

Along the James between Deep Bottom and Richmond the Tertiary is cut entirely away and replaced by the upper gravel or cobble bed, the brick clay, and the Lafayette, the latter, when present, underlying the two former. To do this work the river at some former time must have had greater fall between Richmond and Deep Bottom than it has now. Immediately below the canal the Potomac sand sinks down until it stands near the level of the water and soon disappears, being covered by the cobble bed and brick loam. For about 1½ miles down the river to Aikens Landing the cobbles are abundant, and a considerable number of pre-Cambrian masses are found, ranging in diameter from 1 foot to 3 feet. The rock composing most of them has the lithologic character of the Huronian, the most common kinds being felsite and argillite. The banks are then low and alluvial as far as Deep Bottom, with no exposures of Potomac.

EXPOSURES AT DEEP BOTTOM, ON THE JAMES.

Deep Bottom is 4 miles below Dutch Gap Canal by the river. The course of the river after leaving Dutch Gap is at first due east for some distance. It then turns due north, making a sharp bend, and returns on itself, so as to form a closely compressed loop. Deep Bottom is situated at the apex of the bend, on the north side of the river. The locality is nearly 3 miles due east of the canal, and is consequently considerably farther on in the direction in which the Potomac formation sinks down. Here the greensand marl, which south of Potomac Creek is the lowest Eocene stratum, makes its first appearance on the James River, and here the Potomac formation appears for the last time in outcrop. At this place we fortunately have exposed in the same vertical section the Potomac, the Eocene, and the upper cobble bed, with its superposed brick loam, so that the relations of these deposits can be made out. At the upper end of the bank exposed at this place a rather bold stream enters the James at a group of huts. This stream results from attempts made about eighty years ago to drain a marsh lying at some distance from the river. A ditch was cut from this to the river, and the fall being considerable and the surface material loose and easily eroded, the ditch soon developed into a gully. It is now a deep ravine, which cuts down a little way into the Potomac formation, the first resistant material which the water has met. The following section was obtained in this ravine:

Section in ravine at Deep Bottom, on the James River.

	Feet.
1. Recent deposits at the top	1 to 2
2. Brick loam	10 to 20
3. Cobblestone bed	5 to 10
4. Greensand marl	1 to 5
5. Potomac cobbles	0 to 3
6. Potomac sand	3

No. 1 is composed of loose matter from No. 2, and is only a foot or so thick.

No. 2, the brick loam, is here thicker than usual, and along the sides of the ravine has weathered and been washed into the peculiar hummocky and ridged shapes so characteristic of exposures of this material. It graduates below into the cobblestone bed, No. 3.

No. 3, the cobblestone bed, is distinguished here by the great number and large size of the stones it contains. A number of them are composed of Cambrian quartzite, while others are of quartz. Some masses of pre-Cambrian rock of considerable size occur in the bed. It is continued in great force for at least 2 miles down the river. Some of the Cambrian stones are as much as 18 inches in diameter.

No. 4, the greensand marl, seems to have been here subjected to great and irregular erosion. It is the only one of the Tertiary beds that remains, and is itself wholly removed in some places. It has very much the same character here that it shows generally in Virginia. The greater portion of the mass of the bed is a sandy clay containing more or less diffused calcareous matter that sometimes acts as a cement and forms a firm rock. Imprints of shells abound in some portions, and sometimes the shells themselves are found. The matrix is colored greenish, with chlorite and some greensand. Elsewhere in the State, where uneroded, the greenish sandy matter is from 10 to 15 feet thick, and the shells occur in the base of the bed. It is the lowest part of the stratum that is preserved here.

No. 5, the stratum of Potomac cobbles, marks the transition from the Eocene to the Potomac sand. It is not always present, for in a few places the marl rests immediately on the sand. This seems to be due to the fact that these cobbles lie on the surface of the Potomac in lenticular sheets. Their presence is accounted for by the erosion of the upper part of the Potomac sand, which has concentrated the cobbles on the remaining surface. The cobblestones in this layer are all well rounded and smooth, and are composed of Cambrian quartzite and quartz. No pre-Cambrian material was seen. This is the only essential difference between this bed and the upper cobblestone bed, if we leave out of the question the greater number and size of the stones in the upper stratum. Most of the stones in the lower layer have a diameter of less than 4 inches, although a few have the dimensions of 6 to 8 inches.

No. 6, the Potomac sand, has been cut into by the creek only so deeply as to expose at most 3 feet, for the sand here is so cemented by ferruginous matter as to form a firm sandstone. The material of this bed is the usual coarse, pebbly grit, without regular bedding, and varies rapidly in structure and texture. It shows current-bedding and in some places is full of finely comminuted, carbonaceous matter. Not enough of it is displayed to show any clay layers.

The section above given was obtained in the ravine about 200 yards above the point where the stream enters the river. The exposure of

material in the river bank is much less extensive than in the ravine. For some 200 yards the Potomac is cut down so low that its top is barely visible above the water. In most of this interval the upper cobble bed rests on the Potomac sand, but in one or two places the Eocene marl rests upon it. Although so little of the formation can be seen here, yet it shows some characteristic features. The banks are undermined by the tide and a great deal of matter is thrown down from the upper cobble bed and from the brick clay. This covers up the Potomac material and adds much to the obscurity of the exposures. Professor Rogers in his reports speaks of the occurrence of the Potomac at this locality, but he does not give details. He merely mentions the juxtaposition of the formation to the marl, stating that this is the last appearance of the formation on the James. He does not seem to have been aware of the existence of the ravine. Immediately below the mouth of the stream that enters from the ravine the river bank is low. The upper part of it is formed of the upper cobble bed, which contains many large, rounded cobbles and a number of masses of pre-Cambrian rock. Beneath this is a peculiar material, exposed to the height of 3 or 4 feet above the water. It is so much covered up by loose sand and cobbles which have fallen from above that it is shown only within a very limited horizontal distance. This material seems to be débris torn off from some underlying strata and redeposited without sorting. Fragments of the original beds, of various sizes and still retaining the structure of the parent strata, stand in various positions buried in finer matter formed by the comminution of similar material. The parent strata were of two kinds: (1) The most abundant material is a rather fine-grained sandy clay of a gray color. A large amount of loose sand has been eroded from strata composed of material of this kind. This serves as a matrix which incloses all the larger fragments. In this sand, as has been stated, there are a number of fragments of the bed, ranging in size from a few inches in diameter to several feet. (2) The other kind of material is a tough, highly plastic clay of dark-gray or chocolate color, being, in fact, the clay so common in the Potomac formation. This sometimes becomes rather sandy and occurs only in isolated lumps and balls embedded in the sandy matrix. The Potomac was not seen in place at this spot, but it is clear that these materials are the ruins of Potomac strata that do not differ essentially in character from those exposed in the vicinity of Dutch Gap. The beds from which this débris was derived seem to have been quite fossiliferous, for impressions of leaves are found both in the masses of sandy clay and in those of purer clay. The most distinct imprints are found in the pure clay, for the sandy matter is a good deal crushed and is quite friable.

The fossils are nearly all angiosperms of the same general character as those found near Brooke, in White House Bluff, and at Baltimore.

This occurrence of angiosperms in predominating numbers is noteworthy, for while this class of plants occurs in the strata about Dutch Gap, they are there very rare. The idea is suggested that the beds whose ruins are here seen are somewhat higher in the Potomac formation than those found in exposures farther up the river. The assemblage of plants found at Deep Bottom certainly has a more modern aspect than that of those at Dutch Gap.

The occurrence of this material gives us a good illustration of what is quite commonly seen in the Fredericksburg area, but is very rare in that of Petersburg. This feature is the production of a deposit of heterogeneous matter formed by the redeposition and consolidation of débris torn off from some older bed. This takes place with no sorting of the matter by water action, and the material seems to have been transported but a little distance. Sometimes, indeed, it buries the outcrops of the parent bed. This sort of material may be called redeposited matter.

Débris fallen from above conceals the rock in place for about 200 feet down the stream from the spot just described. The first material seen in place in descending the river is the marl bed, showing a thickness of 3 to 5 feet, with the upper cobble bed resting on it. Fallen débris conceals for some distance the base of the marl; then for the space of a few yards the marl is cut away and the Potomac is exposed, showing a thickness of 1 or 2 feet. It is here composed almost wholly of dark clay, the remainder being sand of the usual kind. The clay shows some tendency to lamination, and is full of undeterminable bits of plants. The upper cobble bed rests on this formation here, and the lower one seems to be absent. This is the last exposure of the Potomac seen on the James River. From this point for a little over 100 yards down the river the low bank is composed of the marl at base with the upper cobble bed at the top. Then comes the broad mouth of a creek, where the river returns upon itself. Below the mouth of the creek the left bank of the river for about 2 miles is in the form of a bluff from 20 to 30 feet high. This is continually being undermined and thrown down by the action of the water. As the finer matter has been washed away by the river, there is a great accumulation of large stones near the water's edge. Among these we may see large blocks of pre-Cambrian rock, cobbles and subangular masses of Cambrian quartzite, cobbles and pebbles of quartz, with some stones of other kinds of Paleozoic rock. There are, for example, some few partly rounded stones of a hard, reddish-brown sandstone, which is strikingly like the red member of the Medina formation. One of these 2 feet in diameter was seen. Nearly all the largest rounded stones are of Cambrian quartzite. Some subangular masses of the latter 24 inches in diameter, and a good many measuring 18 inches, may be found. On some of these the casts of the borings of *Scolithus linearis* are very distinct.

Many blocks of different kinds of pre-Cambrian rock like those

found near Dutch Gap occur here. They are mostly 2 to 3 feet in diameter, but some masses of the coarse reddish granite 4 to 5 feet through were seen. The stones of all kinds, and especially those of Paleozoic material, are surprisingly large to be found so far from their parent rocks.

The marl bed continues to be visible at low water for several hundred yards and then disappears in the remainder of the river bluff. This is composed wholly of the upper cobblestone bed and the overlying brick clay or its representative. This condition of things continues until we enter the horseshoe bend around Curls Neck. Here for some distance the banks are low and no exposures occur. In the southeastern portion of this bend, however, there are high bluffs composed wholly of the Pleistocene formation. In this series of high banks the coarse pre-Cambrian and Paleozoic material disappears and the gravel, when found, is composed of comparatively small pebbles. Here, as elsewhere, there seems to be a close connection between the occurrence of the upper cobble bed and the existence of outcrops of the Potomac in the vicinity. From this locality on to City Point nothing but Pleistocene deposits appear.

Although outcrops of the Potomac do not occur farther down the river than at Deep Bottom, there is, as was stated before, good reason to think that the formation is continued beneath the surface at least as far as Fort Monroe. The artesian well formerly bored at this place was mentioned as giving evidence on this point, and we may now examine the character of this evidence.

ARTESIAN WELL AT FORT MONROE.

Fort Monroe is, as was stated before, about 60 miles southeast of the last exposures of the Potomac formation on the Appomattox and James rivers, and it is situated nearly in the direction of the apparent dip of the strata. An account of the character of the material taken out at different depths from this well, and conclusions concerning it, are given by Professor Rogers.[1] He says in a letter to the editor of The Virginias, speaking of the examination that he had made: "I have thence obtained what I think is proof of the presence of Cretaceous between this Eocene and what has the appearance of Jurasso-Cretaceous in the lower part of the borings."

I can find, however, nowhere in the article any evidence of the existence of Cretaceous strata considered as distinct from Jurasso Cretaceous beds, which are Potomac; and in his notes on the well borings he makes no reference to the existence of such strata. Indeed, the above-quoted sentence is all that he says concerning the existence of Cretaceous (or Potomac) beds at Fort Monroe. The entire well section is given by Professor Rogers,[2] and I will quote only so much of it as is

[1] Geology of the Virginias, pp. 733–736. [2] Loc. cit.

necessary to show the change from supposed Eocene beds to supposed Potomac ones, beginning at what he held to be the base of the Miocene and proceeding downward:

Partial well section at Fort Monroe.

	Feet below surface.
Sandy clay, brownish	583
Very sandy clay, about 5 per cent of coarse sand, with sharks' teeth	590
Brownish-gray sandy clay	604
The same, with less sand	628
Greenish-gray, sandy	640
Lightest gray clay	670
Brownish-gray sandy clay; less sand than that at 604 feet; same indeed, as 628 feet	699
Brownish-gray sandy clay, same as 604 feet	784
Gray sandy clay	815
Very coarse sand	835
Conglomerate of clay, sand, and pebbles	853
Rather fine clay with a little sand	863
The same	865
Coarse sandy clay, brownish or reddish blotches	870
Clay embedding fragments of granite	877
Gray clay with occasional fragments of coarse sand	885
The same	890
Clay and sand in layers, with some coarse pebbles and reddish blotches	900
Reddish mottled clay with coarse pebbles	901
The same, with coarse sand	902
The same	903
Total depth of boring below the parade ground	907

According to Professor Rogers the top of the Eocene is to be placed at the depth of 583 feet. He does not say where he thinks the Potomac begins, but in my opinion there is little doubt that this formation is entered not far below the level of 835 feet, for there is at this point a decided change from the gray sandy clay which characterizes the Eocene, and the succeeding strata show the peculiar features of composition and structure that are found only in the Potomac. The conglomerate of clay, sand, and pebbles found at the depth of 853 feet seems to be the mixture of clay balls, sand, and pebbles so common in the Potomac. At 870 feet coarse sandy clay with brownish and reddish blotches occurs, and this is a very common feature in the Fredericksburg area. The coarse pebbles, the fragments in clay, the reddish mottled clay with pebbles, etc., are features that occur in the Potomac, and in it only.

It is to be noted that the well did not pass through the deposits having the character of the Potomac. If we take the top of the Potomac as situated at the level of 835 feet, then the formation has declined at the average rate of 14 feet to the mile in the interval between Deep Bottom and Fort Monroe.

EXPOSURE AT CHAFFINS BLUFF.

The first important outcrop of Potomac seen above Dutch Gap occurs in Chaffins Bluff. This is situated on the left bank of the river. It begins about 1 mile below Drurys Bluff and extends about 1½ miles down the river. The bank in this bluff is abrupt, and has quite uniformly a height of from 20 to 30 feet. The lower portion of the bank is composed of Potomac sand. This sometimes rises to the height of 20 feet, and very commonly shows as much as 10 or 15 feet. It has the same general nature as in the exposure near Osbornes. The amount of diffused white clay everywhere seems to be large, so that the grit is generally light colored to white. Very few layers of colored clay are found, and no plant impressions were seen. Clay balls, however, occur, frequently of large size, and a great many small cobbles are found in pockets and lenticular layers. The Potomac sand is capped by a heavy deposit of large cobbles packed in light-colored sandy matter, the whole seeming to be formed of the ruins of the Potomac.

EXPOSURE AT DRURYS BLUFF.

Drurys Bluff gives the most extensive vertical exposure of Potomac to be seen on the James River. In its highest part it shows about 80 feet of material, most of it exhibited in an almost perpendicular cliff. The structure and composition of the material are very complex, and no two vertical sections, taken even but a few yards apart, would be alike. It is mostly a mass of coarse grit with many stones dispersed through it, and having toward the base a number of large clay balls. In some portions the cobbles become aggregated into lenticular masses of large stones. About midway up the cliff there is an exceedingly variable bed of dark-chocolate clay that swells up and thins out suddenly in the most irregular way, and toward the lower end of the bluff graduates into a fine, light-colored sand. The variations in the character of the cliff, indeed, are such as to defy description within reasonable limits. Toward the top of the cliff there is a heavy bed of large cobbles, which seems to form the uppermost part of the Potomac.

At the upper end of the bluff the current-bedded, coarse, gray grit of the formation composes the lower portion of it. This rises to the maximum height of 10 to 15 feet, but it has no sharply defined upper limit, and its height varies greatly. This material has embedded in it very large clay balls, some of them 4 or 5 feet through, containing fragments of plants, the species not being recognizable. The clay is dark colored and plastic. The grit is full of large stones, composed of both pre-Cambrian matter and Cambrian quartzite, with much quartz. The pre-Cambrian stones are not so well rounded as those of Cambrian quartzite. We may recognize fragments of granite, felsite, mica-schist, gneiss, etc. Sometimes they are as much as a foot in diameter. The stones become predominant at the height of 6 to 8 feet above the water line, forming

a very well defined cobble bed. In some parts occasional masses of a gray sandstone, up to 2 feet in diameter, occur. This sandstone looks like that of the older Mesozoic or Rhetic that is found in the Richmond coal field. In this portion many cobbles of the dark-gray Cambrian quartzite occur, some of them 18 to 24 inches in diameter. On some of these stones may be seen the peculiar crescent-shaped markings before described. Over this very coarse mass we find the chocolate clay above mentioned. This varies in color from dark-chocolate to brownish-gray. It is mostly a rather fine, sandy clay, with interlocking seams of purer sand. Like the cobble bed just described, it does not extend the whole length of the cliff, but disappears toward the lower end. It ranges in thickness from 6 to 30 feet, swelling out suddenly to the latter thickness just before disappearing farther down the cliff.

A few yards below the upper end of the bluff a second cobble bed comes in. This in its contour is much better defined than the lower one and it has a lenticular form. It contains many large, rounded stones of quartz and Cambrian quartzite, but not the large clay masses and pre-Cambrian material seen in the lower cobble bed. The highest portion of the bluff here is composed of incoherent sandy clay of yellowish-brown or yellowish-gray color. This seems to lie horizontal, and it may be Pleistocene. At the lower end of the cliff a third and heavy bed of cobbles makes its appearance in the base of this material. The above-described features appear, with the exceptions noted, in the upper end of the bluff or cliff. It would require too much space to describe all the variations in the exposure, for each few yards would demand a different account. The bluff extends about 300 yards down the river. At its lower end the height is very much diminished, since here the banks of the river are lowered by the entrance of a small run. At this point the clay balls and cobbles found in the basal portion of the bluff at its upper end have disappeared, and we have instead about 6 feet of rather uniform grit. About the middle of this there is a lenticular layer of clay in thin laminæ parted by fine sand, the maximum thickness of the whole being about 12 inches. Some small fragments of coniferous twigs occur in it.

There is an abrupt change in this stream in the character of the material exposed in the river bank, for on the opposite side of the run, within 10 feet of the Potomac bed just described, a grayish, incoherent loam is exposed, which has the character of the Pleistocene. It is certainly not Potomac. From this point this material is exposed in the banks for over a mile down the river, showing a maximum thickness of about 40 feet. This abrupt change suggests the idea of a fault, but it might be accounted for by supposing that at the time of the deposition of the material the surface of the Potomac was deeply eroded, so as to leave an abrupt hill of it at this point. Near Brooke an equally abrupt change is found from the Potomac to the Eocene, but there it is clear that the Eocene is deposited in ravines cut in the Potomac.

EXPOSURES AT WILTON FARM.

The Wilton farm lies on the north side of the river, opposite Drurys Bluff. The Potomac is exposed on the river front of this farm for at least a mile. The outcrops end a little above Drurys Bluff. The top of the formation is very uneven, and rarely more than 5 or 6 feet of the Potomac sand is shown. This latter forms nearly all of the material. The upper part of the bluff is formed of heavy masses of cobbles. The proportion of clay in layers in these exposures is unusually large. A bed of pale chocolate-colored clay, situated near the level of high tide, runs for a long distance and shows great irregularity in thickness. Where it first appears at the upper end of the exposures it shows its maximum thickness, which is 10 feet. It looks much like the clay bed at the eastern entrance to Trents Reach. Only obscure traces of plants have been found in the clay of these exposures.

The cobble bed resting on the sand here seems to be, in part, at least, Potomac in age. It contains in some places large clay balls of the kind common in the Potomac sand. Some of these are 2 feet in diameter. Clay balls are never seen in cobble beds of Pleistocene age. The clay balls are associated with large Cambrian cobbles, and sometimes are full of undeterminable fragments of plants. This cobble bed is on an average about 10 feet thick. Besides the clay balls and cobbles of Cambrian quartzite, we find in it occasionally some rounded masses of a sandstone similar to that found in Drurys Bluff. This sandstone may not come from the older Mesozoic or Rhetic of the Richmond coal field, but may be a harder and more consolidated form of the Potomac. Some fragments of it 2 feet in diameter were seen; no pre-Cambrian bowlders, however, were visible in the cobble bed; and this is confirmatory of the supposition that the deposit belongs to the Potomac rather than to the Pleistocene.

Above the Wilton farm, as far as the immediate vicinity of Richmond, the exposures of Potomac are unimportant, the Pleistocene forming most of the material seen in the river banks.

EXPOSURES AT RICHMOND.

A little below Rocketts, and especially near the wharves of the Chesapeake and Ohio Railroad, there are good exposures of the Potomac. These are given chiefly by the cuts on the railroad made to approach the river. While the top of the formation is shown here, its base is found in the river near by, for the dredges generally reach the granite at no great depth. It does not seem that the formation at this locality can be thicker than 30 or 40 feet at most.

The general character of the formation at Richmond is similar to that seen in the exposures occurring down the river. It is mainly a pebbly grit rock, without regular bedding, showing an arrangement in interlocking, lenticular layers that are affected by current-bedding

and are exceedingly irregular in composition and structure. In this material, toward the top, cobbles abound. Not enough of the rock is shown to indicate whether or not clay layers and balls exist, but there is little doubt that they do.

The lowest rock visible is the coarse current-bedded sandstone so common in the Potomac formation. This shows at its top in one place a thin layer of chocolate clay that has some fragments of Dioonites. The sand has many blotches and irregular markings of reddish and brownish colors and many small stones scattered irregularly in it.

In the cuts made for the approach of the railroad to the wharves the top of the sand is exposed, and also the Pleistocene cobble bed that usually rests upon it. The Potomac sand here shows strong current-bedding, and is very coarse and heterogeneous in composition. In places in its top it has lenticular pockets of large cobbles of Cambrian quartzite and of quartz. These are of the same geologic age as the sand. Some of the stones are 8 to 10 inches in diameter.

The Pleistocene cobble bed is shown here in great force, and it is remarkable for the number of pre-Cambrian masses that it contains in its base, where we find large stones composed of granite, gneiss, chlorite-schist, argillite, schistose felsite, and other crystalline rocks. These occur embedded in numbers of rounded stones of Cambrian quartzite and quartz, the pre-Cambrian masses being, as usual, only partially rounded. Some of the masses of argillite and felsite are decomposed to clay, showing in some places a core of the original rock. They are often 3 or 4 feet in diameter. The granite gives the largest stones, some of them being over 4 feet in diameter. The Cambrian stones in this bed are larger than those in the cobble bed of the Potomac, some having a diameter of 18 inches. The upper cobble bed is covered by a clay, the brick loam, that is extensively used at this spot for the manufacture of bricks.

Another exposure of the Potomac occurs in the bed of Shockoe Creek opposite the shops of the Chesapeake and Ohio Railroad. This is important, because the Eocene and Miocene[1] strata rest upon it here. Only about 4 feet are shown. It is composed wholly of coarse, current-bedded sand of the common kind, with large cobbles in the top. These, as usual, are composed of quartz and Cambrian quartzite. Some of this latter material is now quite friable and easily crushed to sand. Near the Exchange Hotel, which is situated on a hill about 80 feet above the level of the creek where the above-mentioned exposure occurs, a well was sunk through the Tertiary down to the Potomac sand. It was begun in the yellow Miocene marine bed, commonly called the yellow marl, and was carried to the depth of 84 feet, penetrating 7 feet into the Potomac sand. After the lowest Eocene stratum, which is the equivalent of the greensand marl, had been passed through, the top of the

[1] The Miocene deposits of this region have been designated the Chesapeake formation on the maps of the United States Geological Survey.

Potomac sand was struck. It was the usual coarse, heterogeneous grit. This was full of rounded stones and cobbles of the same character as those shown on the surface in the bed on Shockoe Creek. These cobbles were unusually large. One of them, which had an elliptical shape, was 10 inches in diameter. This well gives important information, since it penetrates all the formations in place. It shows that the interval in time between the deposition of the Potomac and of the Eocene must have been a long one and that important topographical changes took place in it. First the Potomac sand and cobbles were deposited; then the region was raised and subjected to great erosion, by which large cobbles were accumulated over the worn surface; then the surface was depressed sufficiently to let the sea invade the area occupied by the Potomac. It is made clear, also, that no beds corresponding to the upper Potomac, or the variegated clay of Maryland, and no marine Cretaceous exist here.

THE TERTIARY AT RICHMOND.

As the Tertiary in Virginia is the formation following next above the Potomac, it will be useful to note briefly the character and succession of the strata which compose it. The beds at Richmond may be taken as very nearly typical of the formation everywhere in the State where it is fully represented. The exceptional features will be noted in the proper places. The exposures of the upper part of this formation made here are more complete than at any other point in the State. These exposures are mostly artificial and are made in the various cuttings formed in the improvement of the city. The lower portions of the formation are well exposed in the faces of the hills that border Shockoe Creek above the point where the Potomac appears. Here, however, the basal beds are shown only in weathered outcrops, and the weathering alters a good deal the color and general character of the material. Unfortunately these strata are for the most part not to be seen in any other condition, for the artificial cuttings rarely penetrate to the lower beds of the Eocene.

At Richmond the Tertiary beds have an exceptional character in being much thinner than they are farther east. This is evidently due in part to the greater erosion to which they have here been subjected and in part to the nearness of the locality to the former shore of the Tertiary sea. The Tertiary strata at Richmond are, at their maximum, about 90 feet thick. At Fort Monroe, as shown in the section obtained from the artesian well, they are about 700 feet thick. The excavations on Twenty-first street and on Marshall street show well the character of the Middle and Upper Tertiary beds. These strata, having much iron in a combined state diffused through them, are apt to change greatly in color on exposure, the iron passing to limonite from the condition of a sulphuret, a silicate, or a carbonate, its forms in the fresh beds. The excavations show that the greater portion of the Tertiary

is essentially a sandy clay. This when fresh has a gray color, which in different portions may be dark-colored, greenish, or light to almost white. The amount of sand varies considerably, some of the material being quite sandy, while other portions are nearly pure clay. On weathering, different shades of color are produced. Some of the clay that is rich in diatom shells and almost free from iron bleaches to a nearly pure white; other portions, according to the amount and condition of the iron, become light-yellowish, yellow, or yellowish-brown, etc.

Except near the top of the formation there is no evidence of unconformity in the beds, and nowhere, except at the top, is there visible any regular separation into distinct strata. The material, when fresh, seems to be an unbedded mass of gray, sandy clay. Weathering brings out in different layers some difference in color, so that in old surfaces we might use the colors to subdivide the mass. A close inspection shows that the differences in color are accompanied by differences in composition, such as in the amount of sand, of vegetable matter, of pyrite, of diatoms, etc., but the portions showing these different characters graduate into one another and do not form distinctly defined, separate strata. For example, that portion of the weathered clay that has much diatomaceous matter is generally conspicuous by its whiteness. The portion above this, when weathered, often has a lead-gray or smoke-gray color from diffused vegetable matter, but the diatomaceous portion shades off into the overlying lead-gray matter.

Beginning at the base, we find a stratum 10 to 12 feet thick that is the representative of the greensand marl. This, when fresh, is grayish in color, often with a shade of blue or green. At Richmond it can not be called a marl, for although the main portion of it is the usually sandy, somewhat calcareous clay, it lacks the abundant shells and proportionally large amount of greensand found in those localities where it assumes the character of a marl. It has, however, imprints of shells, and in some portions a few shells. At some places large numbers of the bones and teeth of fish, and possibly of other animals, occur. So far as I know, the fossils have never been examined by any expert. Sharks' teeth are not uncommon in some localities.

This lowest bed is followed by from 20 to 30 feet of very fine material that does not show any distinct lamination and bedding. It is a mixture of very fine sand and clay, becoming in places nearly pure, plastic clay. About 20 feet above the base of the Tertiary diatom shells appear in this mass, and when they abound the material weathers nearly white; otherwise it becomes light ash-gray. The diatoms extend up to an unknown height, and are most abundant in the material now being described. There is no well-defined bed to which the diatoms are confined, but they are found sparingly much higher than this portion. These shells are not uniformly diffused through that portion or horizon of the Tertiary which is richest in them. They occur in nests and pockets. A particular spot may abound in them, and another near by,

on the same horizon, may have few and even none. It is, then, very misleading to speak of a bed of diatoms so many feet thick as existing at Richmond.

Above the mass of clay last described, which we may call the diatomaceous clay, we find about 40 feet of gray sandy clay, varying to nearly pure clay, which does not essentially differ in lithologic character from the material which underlies it. This, like the matter beneath it, is not subdivided into distinct strata. We may, however, detect differences in composition and in contents in passing upward, and it may be subdivided accordingly, but the subdivisions graduate into one another. Much of this material, when fresh, has a dark-bluish or greenish color, especially if wet. This is the mass of sandy clay and pure clay exposed in the cuts made for grading Twenty-first street and Marshall street. The following characters may be given for the different portions of this material.

The lowest part is exposed on Twenty-first street. Here, at the base, are about 3 feet of a dark-gray, tenacious, rather sandy clay. (The colors given for this and all the succeeding beds are for the wet material; when dry the color is lighter.) This graduates above into a dark ash-gray sandy clay, which is about 6 feet thick on an average. It fluctuates considerably, however, in thickness and in degree of sandiness. It contains, scattered irregularly through it, bits of lignite, sharks' teeth, vertebræ and other bones of fish, and probably bones of other animals, impressions of leaves of angiosperms, pebbles of dark quartz, etc.; all indicating some agitation in the waters, for the fossils seem to be waterworn. Some of the imprints of leaves in this stratum are very well preserved. It is possible that this stratum may mark the last of the Eocene beds. There is no break or want of conformity in the gray mass that would enable one to locate the horizon of change from Eocene to Miocene. The fossils may perhaps give the means of defining the limits of these formations. They have not yet been studied, however, and at present all that can be said is that the lower portion of the Tertiary deposits at Richmond is certainly Eocene and the upper is as certainly Miocene.

The next material in ascending order that may be regarded as perhaps distinct in character is an unlaminated mass of dark-gray to somewhat olive-gray, quite sandy clay. This, in its upper portion, has some impressions of shells, and graduates into the next layer. Its thickness is variable, reaching a maximum of 15 feet. On weathering it assumes a rusty color in blotches. Above this comes a dark-gray clay, which is in the main tough and tenacious, being a nearly pure clay where examined. Its thickness varies greatly, since it graduates into the next stratum, and this thickens, sometimes at the expense of the stratum now being described. Its average thickness may be put at 7 feet. It contains many impressions of shells. The calcareous

matter of these has been taken out by the sulphuric acid formed by the oxidation of pyrite, which seems to have abounded in the bed. The upper portion for 2 or 3 feet becomes rather more sandy than most of the stratum, and has a yellowish-green tinge. This stratum is probably the widely extended Miocene bed called generally the "blue marl." The absence of shells seems to be a local peculiarity, for if this be the blue marl it is noteworthy as a rule for the great number and the perfect preservation of the shells that it contains. The number of imprints of shells at Richmond is very great, but no shells were seen. This bed is certainly Miocene.

In the upper part of the material last described there seems to have been some change in the conditions of deposition, perhaps a renewal of agitation in the waters, for we find here again pebbles and fragments of dark quartz and impressions of angiosperm leaves, etc. The leaf impressions here are more numerous and better preserved than at the lower horizon before mentioned, but on neither horizon are they common. The next distinguishable portion is a layer of sandy clay that is generally dark-gray in color but in many places with a decided greenish tinge. The thickness of this varies greatly, for its top has suffered

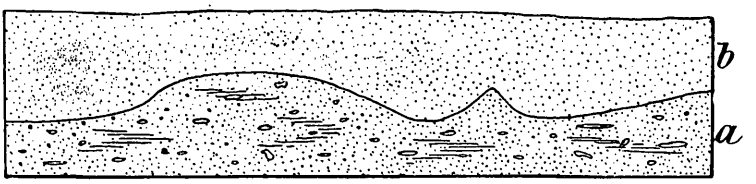

FIG. 1.—Erosion horizon in the Tertiary at Richmond.

much from erosion, which has left it with abrupt changes, such as are indicated in the accompanying cut (fig. 1), in which *a* represents the material now under consideration, and *b* the yellow, sandy, and fossiliferous bed which overlies it. One of the fragments of dark quartz mentioned above was unusually large to be embedded in such fine clay. It was impregnated with pyrite, and had the dimensions 5 by 4 by $1\frac{1}{2}$ inches.

At the top of the mass last described is the first stratigraphic break that was seen in the Tertiary at Richmond. Below this the material forms practically one mass. Over it lies a bed of yellow, somewhat argillaceous sand that is full of large imprints of Pectens, Cytherea, and other Miocene shells. This stratum may apparently be correlated with the bed called elsewhere the "yellow marl," which is quite commonly the highest visible marine Tertiary stratum in the State, all above that generally, if ever present, having been removed and replaced by Lafayette or Pleistocene deposits. This is certainly the highest Tertiary stratum seen at Richmond. This bed is composed mainly of a coarse sand with enough clay to make it cohere when moist. In some places the amount of clay is considerable, and it is so highly colored by iron

that it looks like a handsome yellow ocher. The number of impressions of shells is large, but no shells were seen. This material has suffered greatly from erosion, and it has evidently lost much of its former thickness. It shows a maximum thickness of 8 feet, its top being undulating and quite uneven.

Upon the yellow stratum a heavy bed of large cobbles and large stones rests. This stratum supplies the surface cobbles and gravel that abound in the vicinity of Richmond. It is the stratum so generally found near the large rivers, and which has the character of the Pleistocene. It is quite variable in thickness, but 8 feet may be taken as the average. It is of the usual character, containing cobbles of quartz and Cambrian quartzite with some pre-Cambrian masses. Over this comes, in most places, a layer of stiff, red clay, which has in the city an average thickness of about 2 feet. This clay is spread over the surface for a considerable distance west of Richmond, being found over the pre-Cambrian and the older Mesozoic of the Richmond coal field. It extends far up the James River, accompanying the surface cobbles and varying much in thickness.

The following approximate section, in descending order, represents all the formations seen at Richmond. It was made out from observations taken at different points:

Approximate section at Richmond.

	Feet.
1. Stiff red clay	2
2. Cobblestone bed	8
3. Yellow fossiliferous sand	8
4. Dark-gray sandy clay, often greenish	2 to 5
5. Tenacious dark-gray clay, with many imprints of shells—blue marl	7
6. Dark-gray and olive-gray clay, usually sandy	15
7. Dark ash-gray sandy clay, with fossils	6
8. Dark-gray tenacious clay	3
9. Gray clay with diatoms	30
10. Greenish-gray fossiliferous sandy clay	12
11. Potomac sand, probably 25 feet thick, 10 feet seen	25
12. Heavy-bedded gneiss and granite.	

The Miocene extends from No. 3 to probably some horizon in No. 9. From the top of No. 4 to the base of No. 10 there is no marked lithologic change and no visible stratigraphic break.

EXPOSURES NEAR HANOVER JUNCTION.

From Richmond to the vicinity of Hanover Junction there are no exposures of Potomac. It is probable, however, that the formation exists beneath the surface, for along the eastern margin of the older Mesozoic and the pre-Cambrian, where they are overlapped by the Tertiary and the Lafayette, a large amount of quartz and Cambrian quartzite cobbles, often with red clay, may be found on the surface.

On Falling Creek, at Crowe's mill, about 2 miles north of Ashland, where the road from Ashland to Ellet's Bridge crosses the creek, a great amount of this coarse matter occurs in the face of the hill descending to the creek; and this seems to form a continuous stratum under the surface, extending to Ashland and beyond. Recently a well was sunk at Ashland down to the gneiss. It passed through a thin layer of the Lafayette and a thick mass of cobbles resting on the older Mesozoic. This cobble bed is associated with a few feet of matter which is probably Potomac. No careful examination of the well boring was made to determine the existence of the Potomac formation, so nothing positive can be said on this point.

In the vicinity of Ellet's mill the upper beds of the older Mesozoic have some lithologic features like those of the Potomac, but they contain Rhetic plants and are penetrated by dikes of eruptive diabase. The best and most instructive exposure of Potomac in the vicinity of Hanover Junction is found near Morris Ford, on the North Anna River. In general, exposures of the formation in the Hanover area are very rare and poor, for the Potomac has lost much from erosion, only a small remnant being left, and a covering of Lafayette usually hides even this remnant.

EXPOSURES NEAR MORRIS FORD.

The exposure near Morris Ford is situated on the North Anna River, about 1 mile above its confluence with the South Anna. It is found in the banks of a small stream at its entrance into the river. The lowest portion seen, with its base not exposed, is an incoherent, rather coarse sand of grayish or brownish-gray color. About 8 feet of this material is shown. It is not much like the normal Potomac sand at and below Richmond, since it is quite uniform in composition, and is nearly free from stones and kaolin-like clay. Above it lies a sand, about 4 feet thick, which, when weathered, is yellowish-gray or yellowish-brown in color. The upper part of it, when fresh, has a greenish tinge. These two layers are not separated by any distinct stratification plane, but they form essentially one bed. These sands appear to be much affected by current-bedding, and have no regular stratification.

Next, in ascending order, we find a cobble bed of variable thickness, the average being about 2 feet. Most of the cobbles are of quartz. They are packed closely in a sand like that which underlies them. Most of the stones have a diameter under 4 inches, but some of them are 5 or 6 inches through. In this bed we find some rounded masses of a fine-grained sandstone that appears to come from the older Mesozoic, which lies next to the Potomac on the west in this vicinity. The largest of them are 18 inches in diameter. The cobble bed rests upon the eroded surface of the sand and follows its undulations. It must have a wide extent in this neighborhood, for it is found in a similar position on the opposite side of the river at Wickham's, about 2 miles

distant. Here the Potomac was not seen, but the cobbles were found in excavating greensand marl. On penetrating the marl they were found at its base. On top of the cobble bed there is a stratum, 4 feet thick, of a fine, argillaceous sand, which in the weathered state, in which alone it was seen, has a yellowish-gray color. Above this is a stratum, 2 feet thick and much weathered, of yellowish, sandy clay, packed full of Eocene shells. Above this we have 4 feet of sandy clay like that containing the shells, but which is nearly free from them. These three layers above the cobble bed belong to the greensand marl. The yellowish color comes from weathering, for the iron present is oxidized. Near by, a pit was at one time opened in excavating the marl, and in this the material has the usual greenish and grayish colors.

EXPOSURES AT HANOVER JUNCTION.

Hanover Junction is the junction of the Chesapeake and Ohio and the Richmond and Fredericksburg railroads. It is 2 miles south of the bridge by which the last-named railroad crosses the North Anna River. The Lafayette formation constitutes the surface material of the region around the junction, but the cuts on the Richmond, Fredericksburg and Potomac Railroad between the junction and the river expose this formation as well as the Potomac and the older Mesozoic. As we have here the only known visible contact of the Potomac with the older Mesozoic, these exposures are especially important. For several hundred yards from the junction the Lafayette alone is visible. This is mostly a sandy clay, mottled yellow or brownish and light gray. Occasionally seams of small gravel occur in it. It is sometimes reddish or brownish, marbled and seamed with white. In the base of this, and resting on the surface of the Potomac, we find sometimes large pre-Cambrian stones of such material as gneiss, mica-schist, etc. They are 2 feet and more in diameter. These are angular or subangular. With them occur often large cobbles of quartz. This coarse material seems to belong to the Lafayette rather than to the Potomac. About three-fourths of a mile from the junction there is an exposure of the Potomac showing a thickness of 6 or 8 feet. This is of the usual kind. It is a coarse gray grit, without regular bedding, composed of lenticular, interlocking layers. The top contains cobbles of quartz and Cambrian quartzite, some of them as much as 8 or 10 inches in diameter. The base of this formation is not visible. A little more than a mile from the junction other exposures of Potomac occur in the cuts, showing at most only 4 or 5 feet of the material. They are found at intervals over the space of several hundred yards. A sandy gray loam, which looks like Pleistocene, covers the formation here. The material of the Potomac in these exposures is similar to that shown in the spot first described. A large amount of cobbles and coarse gravel of the usual kinds occurs in it, especially toward the top. In several places toward the bottom of the material balls and masses of dark-chocolate clay occur embedded in it.

Some of them are over 2 feet in diameter and contain unrecognizable fragments of plants. At the base of this material are exposed about 2 feet of a crumbling, reddish-brown sandstone of the older Mesozoic or Rhetic. This older Mesozoic is fairly well stratified and has a uniform composition. It contrasts strongly with the incoherent gray sand and cobbles of the Potomac that rest upon it. The top of the older Mesozoic where the Potomac rests upon it is worn extensively, showing that a considerable interval in time separates the two formations.

Still farther on, and near the North Anna, this older Mesozoic shows considerable outcrops. The brown sandstone is here thinly laminated. On the opposite side of the river there are extensive exposures of the older formation in the cuts along the railroad, and in a number of places there are many large, partly rounded pre-Cambrian stones in it, but no cobbles of Cambrian quartzite. This formation is here totally different from the Potomac.

The Potomac is not seen in place beyond the North Anna River until we reach the Massaponax River, but Cambrian quartzite and quartz cobbles may be found on the surface along the Telegraph road to a short distance beyond Mount Carmel Church, as far as 4 miles north of the river. These cobbles may be seen over the pre-Cambrian to the distance of at least 7 miles west of Hanover Junction. They probably came originally from the Potomac, and their presence on the surface indicates that the Potomac once covered the surface here. They may be traced over the ground, often in great numbers, covering the eastern margin of the older Mesozoic west of Ashland and thence southward over the Richmond coal field as far as the Appomattox River, in the vicinity of the Clover Hill coal pits, the southern extremity of the older Mesozoic. They may extend still farther south in the same line, but examinations have not been made in this direction. They are found, also, over the granite and gneiss between the older Mesozoic of the coal field and the Potomac and Tertiary terranes. They abound in the vicinity of the James River. From the North Anna to the Massaponax, in the belt where Potomac outcrops might be expected, a thick covering of Lafayette conceals everything except in a few places on the streams where the Eocene greensand is shown.

EXPOSURE AT MASSAPONAX RIVER.

The road from Port Royal to Fredericksburg crosses the Massaponax near its mouth, 5 miles south of Fredericksburg. At the crossing a much-weathered outcrop is shown, about 8 feet thick. The base is not visible, and hence its junction with the Potomac can not be seen at this point. The material is an argillaceous sand of a dull brownish-gray color. It has a number of imprints of shells, but no shells were seen. Many small pebbles under half an inch in diameter occur in it, dispersed in the sand. This is an unusual feature, seen nowhere else. About 300 yards north of this spot and on the same road, on the opposite side

of the river, there is a small exposure of Potomac sandstone occurring in the bed of a run that crosses the road.

It may be stated in this connection that the Potomac sandy matter in the southern portion of the Fredericksburg area to and beyond Stafford Court-House is in places rather firmly consolidated, and may be spoken of as a sandstone. Indeed, in a number of places this material was formerly largely used for building purposes. The exposure mentioned above is on a higher level than the top of the Eocene near the river, and this illustrates the uneven character of the surface of the Potomac when the Tertiary was laid down upon it. Only about 2 feet of the sandstone can be seen. It is a coarse gray sandstone, similar to the material so common on the James and the Appomattox rivers. The top is much worn, and it is evident that a good deal of the formation has been removed by erosion. It is streaked and blotched in an irregular manner with yellowish-brown colors. No regular stratification can be seen, but the matter shows current-bedding. Some small balls of gray clay occur embedded in it, the largest being 4 or 5 inches in diameter. There is but little kaolin in the rock here, most of the material being a rather coarse sand. It is proper to state that while, for the sake of brevity, we may call the light-gray and white clay of the Potomac kaolin, it is not in fact a true kaolin, but rather a light-gray to white potter's clay.

EXPOSURES ON THE RAPPAHANNOCK BELOW FREDERICKSBURG.

Exposures occur on the Rappahannock River extending from a point about 2 miles below the town down to the mouth of the Massaponax, 6 miles below. The banks show often from 10 to 15 feet of the Potomac, which is generally a coarse sandstone of the usual character and full of small stones. It has on its surface sandy matter and cobbles belonging to the Pleistocene. Near the mouth of the Massaponax the sandstone was formerly quarried. Where it is last seen it rises 10 to 12 feet above the water in the form of a coarse, pebbly grit. Two or three hundred yards below this point the Eocene greensand marl suddenly appears in the right bank of the river, showing a thickness of about 15 feet. This indicates that the marl rests immediately on the Potomac sandstone. As we descend the river below the last exposure of the Potomac the surface cobbles become rapidly fewer and smaller.

The material of the Potomac sandstone exposed in the river banks is mostly quartz in coarse grains. Little kaolin is present. No clay balls occur, and very little clay in seams was visible. Small quartz pebbles up to the size of 3 inches are numerous, either dispersed through the rock or aggregated in irregular nests and pockets. No dip and strike can be made out, for the sandstone has the usual structure of interlocking, irregular, lenticular layers produced by current-bedding.

EXPOSURES AT FREDERICKSBURG.

Exposures at and near Fredericksburg are numerous and quite variable in character. The changes are so frequent and take place at such short intervals that each exposure would require a different description. The banks of the river extending from the lower end of the town to Falmouth, 1 mile above it, are composed of the Potomac formation, a maximum thickness of about 30 feet being shown. On the north side, east of the Richmond, Fredericksburg and Potomac Railroad, the formation is usually so much concealed by the débris eroded from itself and by the Tertiary that exposures are rare and poor.

West of Frederickburg, on Hazel Run and on the line of the narrow-gauge railroad to Orange Court-House, good outcrops and exposures may be found extending as far as two miles from the town. The pre-Cambrian terrane here borders the formation on the west. The rock next to the Potomac is a heavy-bedded granitoid gneiss, which by its decomposition may have furnished much of the material for the Potomac, but apparently not all of it.

In the vicinity of Fredericksburg, south of the river, the Potomac is largely covered by the Lafayette, Pleistocene, and other formations. These formations are here composed of very fine, loamy sands and clays that occur in fairly well stratified beds, some of which are well laminated. They are much variegated in color, often mottled with deep tints of red, yellow, and brown, the colors being disposed very irregularly in masses of gray. The Lafayette shows no fossils. The Potomac here, as farther south, is composed almost entirely of sand and sandstone. This is a mixture of grains of sand and of kaolin. The proportion of these two components varies much, as does the fineness of the material. Usually the sand predominates. This is the case in the strata that are consolidated enough to be called sandstone. Where there is a large proportion of the white clay or kaolin the material is incoherent and fine. As a rule, little or no mica is present, and this is surprising, since the pre-Cambrian rocks to the west, from which much of the material probably was derived, are rich in mica. Small quartz pebbles are very common scattered through the sandstones. Even those selected for building purposes often contain pebbles up to 1 or 2 inches in diameter. These pebbles show no tendency to aggregation in beds and layers. Dispersed stones, however, as large as 5 or 6 inches in diameter may sometimes be seen. Sometimes much larger stones are found. They are well rounded and are composed of various materials. In the vicinity of Fredericksburg it is a significant fact that there are no Cambrian quartzite cobbles among these stones. These larger cobbles occur in nests and pockets in the sandstone or sand. They are composed of quartz, of pre-Cambrian rock, and sometimes of Potomac sandstone. They are often accompanied by clay balls and seem to mark erosion horizons—that is, periods when, in the formation of the

Potomac, not only deposition ceased, but some of the deposited material was torn up. Such horizons may occur anywhere in the formation, but they are most numerous toward the top. Very commonly the erosion horizons are marked by redeposited clay alone. The layer of sandy shale that yielded so many fossils at Fredericksburg rests on one of these cobble beds, and at several other localities plant-bearing shale may be seen resting on such beds of cobbles.

The most remarkable material found in the Potomac sandstone is the uptorn clay derived from some previously deposited stratum. This is redeposited in the sandstone in two ways. It may occur in the form of single rounded masses that range in diameter from a small fraction of an inch to 5 or 6 feet. The largest masses usually occur singly and remote from one another; the smaller ones are often found intimately mixed with the sand and forming a large proportion of the rock. In the other mode of occurrence the clay in masses, small flakes, and fine particles is aggregated into nests and pockets in the sandstone, and being cemented together forms masses of more or less pure clay, surrounded by the ordinary forms of the sandstone. A mere inspection often does not suffice to distinguish such redeposited clays, as we may call them, from the original clay beds. As, however, such deposits often contain plant remains, I have frequently had occasion to explore them by excavating the material. On digging into one of these masses its nature is soon made known. The clay is often mixed confusedly with sand, the latter having been caught up by it in the process of deposition. It possesses no lamination and no cleavage, but is crushed, contorted, and full of slickensides, the component particles being agglutinated together in all possible attitudes. The plants are generally very fragmentary and stand in all positions in the mass, so that usually it is impossible to get out good specimens. Sometimes, however, a large fragment of clay retaining the cleavage and the character of the original bed may be included, and this may be surrounded by a chaotic mixture that gives no good impressions of plants, while in the unchanged mass good fossils may be found. Such features were for a long time very perplexing, but in time I learned that in these deposits no considerable amount of good fossils could be obtained.

The clays of this region show a most surprisingly close resemblance to those of the Petersburg area. We find the same two kinds containing fossils and in the same proportions. The fossiliferous clay is generally plastic, and when wet is either dark-gray to black or chocolate colored. The latter contains generally more and better preserved fossils than the former, which contains all the lignite found in the Potomac. There is a peculiar irregularity shown in the occurence of the more firmly consolidated and indurated varieties of the sandstone. Sandstones of firm texture do not occur in extended and distinct beds. They are found in the form of lenticular masses and pockets of varying size inclosed in more friable and kaolinic matters. The fossiliferous

clays are generally uniform in color. There is, however, in the Fredericksburg area a large amount of a very different kind of clay. This, for the sake of distinction, we may call the mottled sandy clay. It is an extremely variable material in composition and in color. Usually it is a mixture of very fine sand and clay that passes on the one hand into pure, plastic clay, and on the other into the typical sandstone or sand. It is without lamination and on drying breaks up into angular blocks of an indurated material that looks like mudstone, and is exceedingly irregular in its occurrence. It may occur anywhere, but it does not form definite and continuous strata. It may replace a large portion of the normal sandstone in one spot and a few hundred feet away may disappear wholly, graduating into the typical sandstone. The fossiliferous clays rarely graduate into the normal rock which embeds them. The mottled sandy clay is sometimes uniformly gray (generally ash-gray) in color, and sometimes uniformly red (brick-red to purple-red), but most commonly the red and gray colors are mixed in irregular streaks and blotches, often many together, even in hand specimens. The arrangement of these variegated streaks may be compared to that seen in a piece of mottled castile soap.

The above-described materials are the most noteworthy components of the Potomac formation in the area now under consideration. The sandstone graduating into incoherent sand is, as was said before, the typical material. It is difficult to give any general account of the structure and other physical characters of this rock. Most of the sandstone about Fredericksburg is light-colored to white, the color being lightest when the amount of kaolin is large. But the planes that bound the lenticular layers composing the mass and the curving current-bedding planes that cross these layers obliquely are often stained with yellowish or yellowish-brown colors that make them very distinct. Sometimes irregular patches and seams of the same color are found in the mass of the rock. Owing to the varying nature of the interlocking layers, the irregular erosion of the surface, and the general lack of division into separate and distinct strata, no dip or strike can be made out, although, as before stated, there is a general depression of the formation to the southeast. The sandy material seems to be usually coarser and more firmly consolidated toward the base than toward the summit of the formation, while in the upper portions there is more of the diffused kaolin and the fossiliferous clay in layers.

Perhaps the best way to give an idea of the character of the formation will be to describe the material shown along a line run from east to west at right angles to the length of the belt of Potomac deposits, beginning in the railroad cut by means of which the Richmond, Fredericksburg and Potomac Railroad makes its approach to the river on the northeast side, continuing on the opposite side of the river over the plant locality, and passing west to the margin of the pre-Cambrian along the line of the narrow-gauge railroad.

Opposite the town of Fredericksburg the lowest material seen is an incoherent, light-gray sand with a large amount of kaolin. This extends down to the level of the water, showing a thickness of over 30 feet. This material, in outcrop, has very slight coherence, for it is little more than a loose sand. It is not uniformly white and homogeneous in composition, but contains undulating patches of yellowish, brown marked out in the form of lenticular layers, which occur irregularly in the gray mass, as is shown in fig. 2, *a a* being the colored patches. The sand contains pockets and lenticular layers of cobblestone which resemble in position and shape the patches of color. The stones have a diameter of 3 or 4 inches or less. Rounded stones are also scattered irregularly in the mass of the sand. On the top of the sand rests a deposit which is commonly present in the vicinity of the river and which contains some material brought from a considerable distance. This layer is here about 2 feet thick, but in other places it is much thicker. It follows the undulating top of the sand, which seems to have been considerably eroded before this layer was deposited. It is a confused mixture of sandy matter with quartz cobbles and masses of pre-Cambrian rock. Some of the pre-Cambrian masses are 4 feet in diameter, the largest of them being composed of heavy-bedded gneiss.

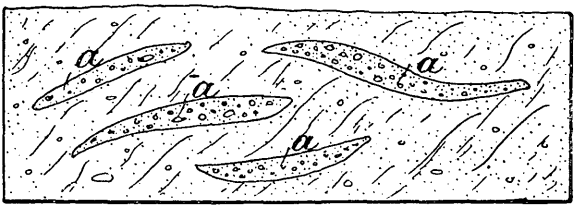

FIG. 2.—Lenticular patches of color at Fredericksburg.

Near the steamboat wharf in Fredericksburg and at the boathouse of the Fredericksburg Boating Club, there was an important exposure of the Potomac material which yielded many fossil plants. This outcrop has been totally changed in the excavations made to obtain the plants. When this exposure was first seen it had the form of a projecting ledge of argillaceous, flaggy, sandstone, 4 or 5 feet thick, resting on a bed of cobblestones and covered by the Pleistocene drift. From the cobblestone bed to the level of the water there is a thickness of about 15 feet of material that is here very imperfectly exposed, but whose nature is disclosed about 50 yards farther up the river both by the digging of a well and by exposures in the banks of the river. It is the mottled sandy clay with many brick-red markings. Although the well was dug only 50 yards distant from the plant locality and passed through the horizon yielding the fossils near by, none were found in it and it may be stated that at no other spot were plant fossils found on the same level, at least in the immediate vicinity of the locality now under consideration.

The material that afforded the plants was a very fine-grained, argillaceous flagstone. This has been almost wholly removed in the search made for fossils and in excavation by the city authorities to procure road stone. The deposit was found to be a lenticular cake of matter

that thinned out on all sides, the underlying cobble bed rising by thickening and cutting it out. The entire layer had a length of about 20 feet and a width of about 15 feet. The upper portion of the flags for the thickness of about 2 feet was full of comminuted vegetable matter, showing rarely identifiable fossils. The greatest variety of plants and the best-preserved ones occurred near the top of the cobble bed, but unfortunately the plane of contact of the flags and cobble bed served in places as a waterway through which a slow seepage took place, and by this means many fine fossils were destroyed. The plants diminished much in numbers and in perfection of preservation as the layer was followed up, and they finally disappeared. It can not be doubted that the outcrop when first found was much richer in fossils. It was discovered by Professer Uhler, and it had been partly removed before I saw it. The fossiliferous stratum became more purely argillaceous toward the top of the cobble bed, and was here, in fact, a sort of claystone. It had the composition and induration of shale, but was not evenly fissile. On the contrary, it was lumpy and very irregular in its splitting, and this made it very difficult to get out good impressions. This argillaceous matter showed no tendency to graduate into the cobble bed. On raising the bottom layers of it the stones of the cobble bed would often be raised at the same time, sticking to the bottom of the clay as if at one time that material had been dumped upon the stones.

When last examined the locality presented an open cut about 30 feet long and 20 feet wide, showing in its walls mostly the material of the cobble bed. The cobblestone bed, as shown in the cut, is divided into several layers by lenticular sheets of argillaceous gray sand. These separating layers do not differ essentially from the normal Potomac sand. They thin out rapidly and give place to cobbles. In the portion of the rear wall of the cut at the right, as one faces west, there are none of these layers, and the cobbles form a stratum showing a thickness of 5 feet, with the base not exposed. A careful examination of the cobbles was made in order to determine, if possible, the identity of their parent rock. There is no Cambrian material present. It may be stated here that none of the streams in this part of the State, the Rappahannock included, rise west of the Blue Ridge so as to touch the Cambrian as now exposed. Nearly all the material is pre-Cambrian, but, contrary to expectation, almost none of it came from the belt of massive gneiss that forms the western boundary of the Potomac area in this region. This gneiss and the associated micaceous rocks form a belt at least 10 miles wide. West of this gneiss there is a wide band of rocks less fully crystalline, that embrace such rocks as mica-slate, argillite, hydromica-schist, chlorite-schist, etc. It is from this last belt that most of the pre-Cambrian material of the cobble bed apparently comes. Some of the cobbles are so much decomposed that it is not easy to determine the character of their parent rocks, for they are in the condition of clay which is of a gray color. Quartz cobbles are

the most numerous. The rock seems to be similar to the quartz that is so common in veins, pockets, and masses in the pre-Cambrian argillites and mica-slates. The largest quartz cobble seen had the dimensions 6 by 8 inches, but most of them were under 5 inches in diameter. The next most abundant cobbles are composed of a schistose, argillaceous material that is now in the condition of a gray clay. In some cases the original rock seems to have been a siliceous, schistose argillite. Some few cases occur in which the original appears to have been a jaspery schist, such as is found occasionally in the chlorite-schist of the Blue Ridge region. This may occur also in the second belt of pre-Cambrian rocks described above. The cobbles of siliceous schist are usually large, the largest one seen having the dimensions 7 by 9 inches; but the cobbles of the softer and more argillaceous schist are generally 4 to 5 inches in diameter.

Cobbles of varieties of fine-grained, siliceous gneiss are common. This rock is similar to the gneiss that forms bands in the imperfectly crystalline, argillaceous schists, and is quite different from the granitoid gneiss forming the western boundary of the Potomac. The largest stones of this kind of rock are 6 or 7 inches in diameter. One cobble only was seen that probably came from the granitoid gneiss. This was composed of a reddish, coarse-grained, granitoid gneiss, such as occurs in some places west of the Fredericksburg Potomac. This measured 4½ by 5 by 7 inches. A number of rounded masses of gray sandstone occur with the pre-Cambrian cobbles. This sandstone seems to be a variety of the Potomac sandstone that is more compact and indurated than usual. The largest of these measured 10 by 12 inches. Rounded lumps of the mottled sandy clay occur also. These range in diameter from 4 to 12 inches. The cobblestone bed now under consideration is remarkable for the great proportion of large stones that it contains. Most of the cobbles range in diameter from 3 to 5 inches, but many are 6 inches in diameter. In some portions of the bed the large stones are so thick as to touch one another and to appear piled up.

The highest exposed strata at the plant locality stand 10 to 12 feet below the level of the plain on which Fredericksburg is built.

Westward, in continuation of the line of section, no exposures are seen for about 300 yards. The first are met with in the cut on the narrow-gauge railroad near the depot of that road. The interval forms a portion of the plain on which the town is built. The greater portion of the depth of the cut (the maximum is over 20 feet) is made through a loose sand of brownish color which belongs to the Pleistocene and appears to be the equivalent of the brick loam. In the base of the cut 4 or 5 feet of a tenacious clay is exposed, which is generally concealed by the loose sand that comes down from above. It was exposed for a few yards only, and this is not sufficient to enable one to speak of its character in general. At the place seen the clay is plastic, unbedded, bluish-gray in color, and mottled with yellowish-brown. Possibly this is a variety of the mottled sandy clay, here less sandy than usual. In

its upper portion it contains a number of cobbles which look as if they had been dropped singly on the surface of the clay. Some of them are 4 inches in diameter. Between this clay and the Pleistocene sand 2 feet of distinctly laminated sandy clay occurs. This is, in the main, yellowish in color, but shows a mottling with gray. These two layers are of uncertain age.

Upon the layers last described there rests a considerable thickness of the Pleistocene sand already mentioned. This sand is noteworthy for showing in its base some very large masses of far-traveled pre-Cambrian rock, which it is difficult to account for except by supposing ice transport. They are composed of gneiss, mica-schist, chlorite-schist, etc. These stones are quite commonly found in the vicinity of the Rappahannock, at the base of the finer Pleistocene deposits, as, for example, over the fossiliferous strata near the wharf. They are also visible in the railroad cut northeast of the river, described as the beginning of the line of section. The pre-Cambrian blocks in the cut are generally but little waterworn. The largest of them, composed of mica-schist and gneiss, are 5 to 6 feet in diameter.

It would seem that in post-Potomac times the Potomac formation had been cut away to a considerable depth upon the plain on which the town of Fredericksburg is built, for the formation makes up the greater portion of the mass of the hills that overlook the plain. Among these is Marye's Hill.

The next exposures are found on Hazel Run at the foot of Marye's Hill and near the Federal cemetery. A mill is situated on this run where the narrow-gauge railroad crosses it. Just back of the mill there is a considerable bluff composed of nearly white Potomac sand. This forms that portion of Marye's Hill which overlooks the run. The bluff shows that the Potomac sand extends nearly to the top of the hill and that the formation stands here at a much higher level than in the plain just described.

The base of the bluff for 20 or 25 feet is hidden by the abundant talus thrown down from its upper portion. A small quarry, however, was opened near by on a level with the lower portion of the concealed part. The material shown in the quarry is probably of the same nature as that composing the hidden part of the bluff. The principal rock seen in the quarry is a very irregular and coarse pebbly sandstone of the normal kind. This contains irregular layers and pockets of indurated clay. This clay is somewhat variable. Some of it is rather firm, and this is bluish-gray in color. Portions, however, are crumbling and light-gray in color. A part that is the continuation of the same mass is quite different, being well laminated and buff colored, but the greater portion is without lamination. In the coarse sandstone that carries this clay large cobblestones of quartz and balls of clay are embedded.

The cliff shows exposed in its upper portion about 20 feet of material with a nearly vertical face. This is composed of an incoherent

unbedded mixture of grains of sand and kaolin, the proportion of the latter being large, giving the material a white color. Numerous quartz pebbles of small size are scattered irregularly through the mass, but in some places they show a tendency to aggregation into beds. These pebbles are mostly under 2 inches in diameter. On the top of the sandstone is a bed of the Pleistocene cobbles with some pre-Cambrian stones.

Hazel Run flows about 50 yards in front of this bluff. On the opposite side of the run the exposures show a totally different material, although they are not 100 yards distant from the bluff and quarry. Here the mottled sandy clay extends from the lowest point visible on the run nearly up to the level of the railroad, a height of at least 25 feet. This would indicate that at this spot the material corresponding to the lower part of the bluff is all mottled sandy clay. The top of this mass is not well exposed, but there is an exposure near the railroad which shows that the mottled sandy clay passes above into the ordinary pebbly sand of the Potomac. The top as seen here has a number of cobblestones in it, which were accumulated by the wear of its surface. From this point on a hillside along the Telegraph road 120 feet of post-Potomac formations are exposed. The Potomac was greatly worn before this latter material was laid down upon it. The cobblestones found in it occur in lenticular pockets, as is usual in such deposits of Potomac age. These are here from 1 foot to 2 feet thick. Most of the stones are of quartz, but some are composed of a highly feldspathic gneiss and some of a bluish, cherty argillite. Most of the stones are large and many of them well rounded. One subangular mass of the cherty rock had the dimensions of 6 by 8 inches. The gneiss forming the western boundary of the Potomac furnishes some of the stones. The Potomac sandstone also forms some of the rounded masses. One of these showed the dimensions of 10 by 12 inches.

To indicate more clearly the nature of the deposits lying above the Potomac formation in this region I will give the section of them obtained in ascending from the top of the Potomac along the Telegraph road from Hazel Run. It must be taken as only an approximate one:

Section near Hazel Run.

	Feet.
No. 1. Ground partly concealed. The space is in part occupied by a sandy incoherent and fine clay, which is in color yellowish-gray mottled with light-gray	20
No. 2. Incoherent fine, reddish-brown sandy clay, mottled with light gray	20
No. 3. Yellowish-brown sandy clay, mottled and seamed with gray and containing blotches of pink	5
No. 4. Gray sandy clay, loose and friable, seamed and blotched with yellowish-brown	15
No. 5. Yellowish to brownish-yellow, massive, argillaceous sand, with some nests of cobbles	40
No. 6. Thinly laminated mottled clay, gray with seams and blotches of deep rich red and pink	20
Total thickness	120

On the top of this rests the usual surface cobbles and débris from the Pleistocene which are here 8 to 10 feet thick.

The formations here contrast strongly with the Potomac in many points. The deposits are divided into distinct beds composed often of well-sorted material. They have none of the clay balls, large cobbles, and other characteristic features of the Potomac, and are more highly colored.

No. 6 in the above section is strikingly like some of the beds exposed in the higher lands about Petersburg. It is in places a plastic clay, marbled and seamed with very rich and deep shades of red, pink, and purple. When plastic it is very thinly laminated, so that in drying it splits into flakes no thicker than cardboard.

In the hill about 250 yards west of the mill, and at about the same distance north of the exposure just described, a small pit was at one time opened to obtain stone for the use of the Federal cemetery. This shows Potomac material at a horizon somewhat higher than the top of the bluff at the mill. The rock exposed is very heterogeneous in composition and changes rapidly. The principal substance is a very coarse grit, which in some spots becomes very firm and hard. These portions seem to have been impregnated with silica deposited from solution, and contain some bits of silicified wood. Numerous balls of fine-grained gray clay as well as quartz pebbles are embedded in the grit. Many of the clay balls are only a small fraction of an inch in diameter. These are intimately mixed with the grit, and in places are so numerous as to comprise most of the rock. Some of them, however, are as much as 12 inches in diameter. Thin partings and seams of pale-reddish clay occur in the grit, having a lenticular shape. This clay contains some fragments of plants similar to those found at Fredericksburg, but they are very imperfectly preserved. A thin layer of the same clay occurs in the top of the exposed material. The stones of quartz are mostly small, but one 5 inches in diameter was seen.

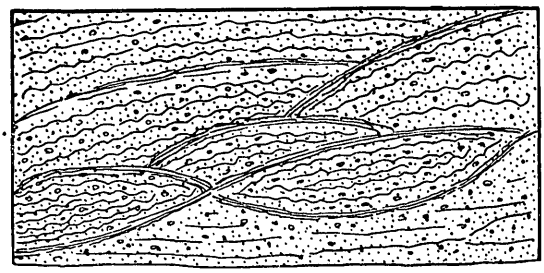

FIG. 3.—Elliptical streaks of color near Fredericksburg.

Continuing the line of section west along the narrow-gauge railroad we find for about 400 yards no exposures. After this interval there is a cut about 30 feet deep on the road, made wholly in the Potomac sand. The bottom of this cut is 10 feet above the exposure last noted on the Telegraph road, at the base of the described section. The greater portion of the mass exposed in the cut is a rather coarse, incoherent sand. The predominant color is light-gray to nearly white, but this is seamed and splotched in many places with yellowish-brown. This latter color

is often disposed in films and streaks that seem to mark the planes of deposition. The stratification is much confused. The streaks of color are sometimes horizontal, but run in wavy lines. They sometimes mark out elliptical layers, the individual films showing minute undulations, as indicated in fig. 3.

Balls of gray clay, some of them 12 inches in diameter, are scattered sparingly in the mass and are sharply distinct from the sandy material in which they are embedded. This clay is plastic. The sandy matter varies much; most of it is a coarse, loose sand with some diffused clay. These parts occur in lenticular layers, or short confused beds that interlock irregularly. But, while the more central portions of these layers may be coarse and sandy, the adjacent surfaces of contiguous layers are often formed of fine, argillaceous material that sometimes approaches a clay in nature. Some of these partings are as much as 4 to 6 inches in thickness. They appear and disappear in the most irregular manner. Some of them that have a color darker than the usual tint contain finely comminuted vegetable matter, many of the larger bits of which are fragments of coniferous twigs.

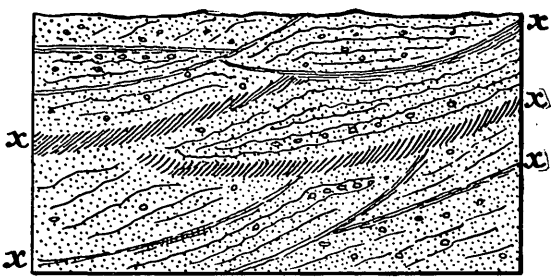

FIG. 4.—Irregular stratification near Fredericksburg.

The larger division planes above described incline to the southwest. They are shown in fig. 4. The lenticular beds of sandy matter often show very distinct current-bedding, as may be seen in fig. 5. Small stones composed of quartz, up to the diameter of 2 inches, occur sparingly. The usual veneering of cobbles comes on the top of the Potomac here and at all the exposures along the railroad.

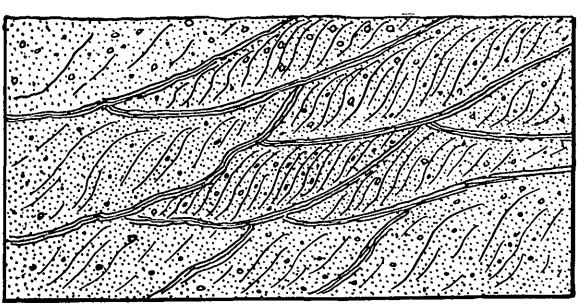

FIG. 5.—Current-bedding near Fredericksburg.

EXPOSURE AT ALUM SPRING.

Alum Spring is situated about 200 yards west of the cut described above. The spring is found on the north side of the railroad and only a few yards from it. The water of the spring trickles from the under side of an overhanging mass of Potomac sandstone and gets its alum and

copperas from decomposing pyrite in the rock, which yields sulphuric acid. There is a deep cut on the railroad at this point made through material on the same horizon as that overhanging the spring. The cut is about 40 feet deep, and makes a good exposure of the Potomac. The bottom of this cut is 10 feet higher than the lowest exposure made in the cut last described. Thirty feet of its depth is composed of Potomac material. The top of the Potomac here has some large, rounded stones, but nearly all the material from the top to near the bottom is a dark gray, rather sandy, claystone, much like the fossiliferous material near the steamboat wharf at Fredericksburg. This material on weathering breaks up into flakes and flat fragments. Its dark color is due to comminuted and diffused vegetable matter. Toward the bottom of the cut the material becomes in places coarser and more indurated, for we find irregular masses, lumps, and nests of the normal sandstone enveloped by the more argillaceous material, the harder portions taking the form of interlocking lenticular layers.

Some large pieces of lignite occur in the coarser portions of the layers, being apparently formed of the limbs of coniferous trees. This lignite, like nearly all that found everywhere in the Potomac, has the conchoidal fracture of jet, but shows often longitudinally the structure of the original wood. It seems here to have a large amount of pyrite associated with it, so that it rapidly disintegrates on exposure. A great deal of it has been thus removed from this rock and from that exposed at the spring, for more or less cylindrical holes running into the sandstone are common. They are hollows left after the removal of the limb or twig. The sandstone that contains this lignite often shows that induration from deposited silica noted as seen in the quarry on the hillside near Hazel Run. It seems to be connected with the presence of vegetable matter in the rock, as the parts immediately surrounding the lignite are those most commonly silicified.

The more argillaceous matter, making up most of the cut, shows a confused and complicated structure, which seems to be due to current-bedding. The apparent bedding planes, as in the other cut, present the outline of lenticular layers which interlock and run into one another in the most intricate manner. The divisional planes are not simple curves, but contain undulations on a small scale. Fig. 6 gives a representation of what may be seen in the upper part of the cut, *a* being the surface cobble bed; *b*, *c*, the Lafayette; *e*, the cobbles in the top of the Potomac, and *d* the current-bedded argillaceous portion of the Potomac. Only the chief points of the structure are given, for the details are too numerous and complicated to be represented fully in any figure.

The ledge of rock that overhangs the spring is composed in its basal portion of material somewhat lower than any shown in the cut, the top of the ledge being about on a level with the base of the cut. This ledge shows that the indurated coarse sand with lignite exposed in

the bottom of the cut is continued downward until it attains the thickness of at least 20 feet. The rock overhanging the spring shows some noteworthy features. The lowest rock seen at the spring is a soft, gray claystone. It is not exposed anywhere except under the overhanging ledge, and it is owing to the ease with which this is eroded that the much harder rock which rests upon it is caused to project and overhang, for the layer of claystone wastes away rapidly and undermines the hard ledge. This layer is not fully disclosed. The rock resting upon it is a thick mass of coarse, pebbly sandstone, which has been so much undermined that the under surface of the hard mass stands from 3 to 4 feet above the face of the claystone. The under surface then slopes down to meet the face of the claystone, so that for a considerable space it is fully exposed, and gives an excellent opportunity for the study of its composition in detail. The ledge of hard sandstone shows a long front of this kind—at least 50 yards. The inclination of

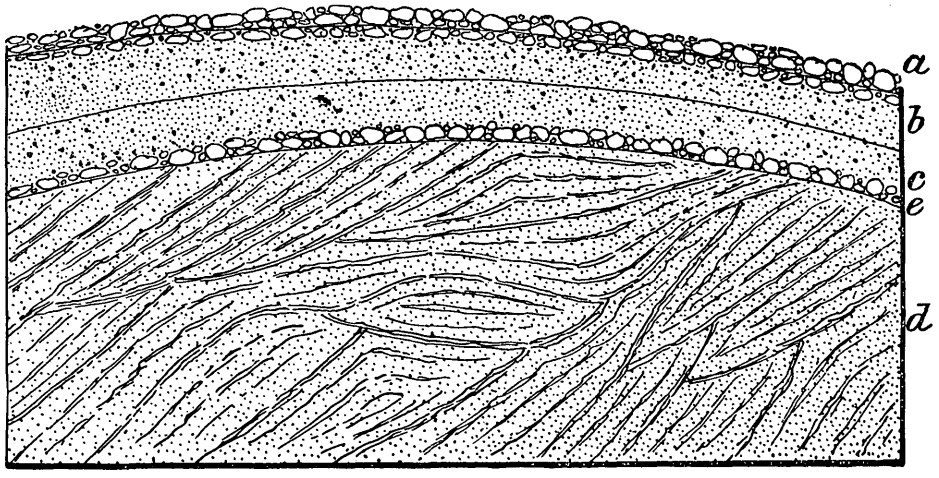

FIG. 6.—Current-bedding outlining lenses near Fredericksburg.

its lower face looks much like the dip of a stratum, but it is very doubtful whether this is the case. Probably the slope of the lower face is caused by the thickening of the mass of coarse matter. It must be borne in mind that in Potomac outcrops the surfaces of apparent strata are more often determined by the alternations of hard and soft lenticular layers, and the way in which they weather, than by the bedding planes. The slope of the lower face of this ledge, as nearly as could be made out, is 10° to 12° ENE.

The lower portion of the ledge is a coarse, indurated sandstone, very heterogeneous in composition and in texture. The induration seems to be caused by the deposition of silica from solution. In certain layers or bands there are many large scattered pebbles. The largest of these pebbles are of quartz and are 4 to 5 inches in diameter. In some places small balls of gray clay are associated with them. The

rock shows on its under face many imprints and molds of the limbs of trees. In most cases the lignite has weathered out. Some of the imprints are 5 or 6 feet long and as many inches wide. A considerable amount of sulphate of alumina and some sulphate of iron form on the under surface of this rock.

The thickness of the hard, pebbly, lower portion of the ledge is about 10 feet, and that of the entire ledge about 20 feet. For the upper 10 feet it is similar to the material exposed in the lower part of the railroad cut near by, but in its lower part it is more argillaceous and not so pebbly.

West of Alum Spring for 400 yards there are no exposures of the Potomac. Then at the second milepost from Fredericksburg we find a slight cut made mainly in post-Potomac formations. They are here of the same general character as on the Telegraph road, but show material only about 15 feet in thickness. It is capped by a bed of large cobblestones, varying from 4 to 7 feet in thickness, which has a parting of brownish-gray sand. This latter is very variable in thickness, but is nowhere more than 3 feet thick. The stones in the cobble bed are all quartz and are well rounded. This cobble bed seems to have once extended over a considerable belt of the pre-Cambrian to the west, for we find a large number of cobbles strewn over its surface along the western margin of the Potomac.

The next exposure of rock in place occurs about 200 yards west of this last cut. Here there is a cut through greatly decomposed mica-schist and highly micaceous gneiss, the latter forming irregular bands in the former. On the eroded top of this pre-Cambrian rock a layer of cobblestones occurs, packed in yellowish sand. Beneath this is a thin stratum of yellowish sand that is filmed and streaked with gray, sandy clay. The mica-schist soon passes on the west into heavy-bedded gneiss that has many of the features of granite. This is the material used at Fredericksburg for building purposes and is called granite.

The above-described features may be seen in the line of section chosen, but they are by no means always to be found at adjacent points on the north and south, even if taken close to the line followed. A few points may be selected to show these variations.

On the side of the river opposite Fredericksburg, a little below the locality yielding the plants, a deep ravine is cut by a run that enters the river at the ferry landing. As this is quite near the plant locality, the ravine was examined with the expectation that at least the flags carrying the fossils on the Fredericksburg side would be found. The exposure, however, showed nothing of the kind. A thick mass of the heterogeneous grit, full of stones and showing no trace of regular bedding, formed the entire thickness of the matter exposed. This vertical interval included the horizon of the plant-bearing beds, no sign of which was found. Going up the bank of the river on the same (the Stafford) side exposures may be seen near the wagon bridge over the

river. Although only about 300 yards distant from the ferry, the Potomac is here quite different in character. The upper part of the matter exposed is largely composed of the mottled sandy clay. This is combined with the typical sand or grit and graduates into it, cutting it out in some places to the depth of 20 feet.

On the Fredericksburg side the changes are even more sudden, for at the end of the railroad bridge, about 50 yards above the plant locality, the entire thickness, exposed for 40 feet, is composed of mottled sandy clay. Here this has much less than the usual number of red blotches that characterize it. A large portion of the mass is dull-gray. It graduates into a mixture of fine sand and light-gray clay which has little indication of arrangement in beds or layers. There is in the river bank on each side of the stream a constant change from material of the sandy mottled clay type to that of the normal sand. All of the material above the town as far up as Falmouth has a large admixture of light-colored clay with the sand, which latter is usually fine-grained. Small stones are common. There is no regular bedding, but the structure is massive or composed of interlocking layers marked with current-bedding.

EXPOSURES BETWEEN FREDERICKSBURG AND FALMOUTH.

There are one or two points between Fredericksburg and Falmouth that deserve a more detailed description.

About halfway between the wagon bridge leading from Fredericksburg into Stafford County and the village of Falmouth, which is in Stafford County, the bank of the river on the Stafford side is about 40 feet high and very precipitous. It is composed wholly of Potomac material. This is mostly a fine sand, rather more colored with iron and more argillaceous than usual. A considerable portion of the mass has the character of the mottled sandy clay. This is irregularly mixed with gray sandy portions. The latter are blotched with yellow, yellowish-brown, and brick-red streaks. Small stones occur scattered in some parts. All the material is incoherent and falls readily to a loose sand. The usual structure of interlocking lenticular forms is found here. At the top a crust of coarse, grayish sandstone, blotched with brown, occurs. This is about 3 feet thick, and contains small scattered pebbles of quartz and small balls of reddish sandy clay. This last occurs on the road which interrupts the exposure. Surface cobbles of large size appear here that seem to have once occurred in materials resting on the sandstone above described.

The next stratum plainly exposed above is shown on the side of the road opposite the river. This is a layer of fine-grained sandy clay 4 feet thick. In some places it has a rude lamination, forming an imperfect shale. Its color is dark-gray, and it contains many fragments of plants, nearly all unrecognizable.

Above this stratum in the hill come about 30 feet of yellowish-gray argillaceous sandstone and sand. This is mostly very incoherent and

is often marked with brownish blotches. This passes above into grayish argillaceous sandstone (thickness not known), variegated with red splotches. Upon this a stiff red clay rests, which seems to be Pleistocene in age.

About 100 yards above this spot a small stream enters the river and forms a bluff that gives a good exposure of material corresponding in horizon to the upper portion of the river bank described above. This, as will be seen, is very different from that shown in the river bank, and illustrates well the rapid changes that the Potomac exhibits here. Beginning with the lowest portion exposed on the small stream, we find the following details. At the base there is a fine-grained, argillaceous, light-gray sandstone, uniform in color, composition, and texture. Of this a thickness of about 2 feet was seen, the base not being exposed, for some 8 or 10 feet of the lower part of the bluff is covered by talus. This layer is quite distinctly separated from that next above. The second layer from the bottom is a well-characterized variety of the mottled sandy clay. It is about 5 feet thick, and is a firm, rather sandy, clay stone. The color is mottled gray and the stone is seamed with a bright-red or brick-red color. It breaks up into angular prismatic blocks in the outcrop, and looks like sun-baked brick. This graduates above into the next kind of material, forming one bed with it. On the top of the last we find a soft and crumbling sandy clay, with gray and deep brick-red colors. This is about 6 feet thick. It is very prone to crumble, and falls to a loose gritty earth. At the top it has some yellowish and brownish colors, and here it graduates into a crumbling, soft, sandy shale, which is about 8 feet thick. This last shows a confused mixture of colors—such as reddish-brown, yellowish, and bluish-gray—arranged in irregular spots and patches. The colors are not sharply distinct or defined. There is a good deal of diffused limonite in this portion.

In this and in all other cases of descriptions of outcrops of the Potomac, although for convenience of description the mass is divided into different layers or beds, it is not to be understood that there is any subdivision of the material into different beds separated by regular planes of stratification. Such a condition of things was nowhere found. The different parts of the outcrop shade into one another and pass very irregularly into different kinds of rock. The descriptions apply to those portions where the characters given predominate. In some cases the transition from one to another kind of matter is so gradual, or so irregular, that no subdivision can be attempted.

EXPOSURES NEAR FALMOUTH.

At Falmouth, the Rappahannock bends sharply west, and about 1 mile above the village passes out of the Potomac terrane. The bed of the river at Falmouth is composed of gneiss, over which the water runs in rapids. The Potomac rests directly on this gneiss, being partly

exposed in the river bank below a church which stands on the top of the bluff. Near the water level the Potomac is poorly exposed, but the material seems to be of the same nature as that composing the bank farther up, which is well disclosed.

The lowest Potomac strata seen in the bluff are the usual light-gray to white sandstones and sand. The material, in the main, is a mixture of coarse grains of quartz and kaolin. The amount of the latter in some places is large, but varies often and suddenly. We may find the rock in one spot nearly all coarse sand, while near by on the same horizon kaolin may predominate. This results from the arrangement of the material here, as usual, in interlocking, lenticular masses, the lenses varying often in composition and in texture. At this locality the thickness of the typical light-colored sand and sandstone is about 40 feet. Some beds and nests of cobbles occur in it, but they are not common. The top of the sandstone shows very distinct current-bedding and a lenticular structure. In this top there are nests and pockets of large cobblestones, some of them 18 inches in diameter.

On the top of the Potomac at this point is a layer of what seems to be Pleistocene cobbles, the top of the sandstone being much worn. The cobbles are quartz, and with them are found large stones from the pre-Cambrian of such material as gneiss and mica-schist. The masses have a maximum diameter of 6 feet. A portion of the pre-Cambrian material of this Pleistocene stratum must come from points farther west than the gneiss belt, for here and elsewhere we sometimes find masses of chlorite-schist, felsite, and other rocks, which are the most abundant ones on the head waters of the Rappahannock. These, however, may occur nearer, for the belt of rocks of Huronian type that runs west of the gneiss belt contains material of this kind.

A little back from the river, at a higher level than the cobble bed last described, we find resting on the Potomac sand a mass of mottled sandy clay. The Pleistocene cobble bed appears to occupy a terrace cut in this clay. This material has the consistency of a claystone. It is about 20 feet thick, quite sandy, and has a predominant yellowish color, which is mottled with gray and brick-red. This is the highest bed of the Potomac exposed at the church. A little back of the church, up the hill on the Telegraph road, the section may be carried to a considerably higher level in the formation. The exposures are not sufficient to permit a connected section to be given. For about 50 feet above the level of the mottled sandy clay last described, the material is imperfectly disclosed. It seems to be all a fine-grained, argillaceous sand, quite incoherent and with a predominant light-gray color. This, however, is mottled and seamed irregularly with yellowish, yellowish-brown, and reddish colors. The matter seems to be without regular bedding. About 50 feet above the mottled claystone there is a very good exposure of material resting on that last described. This latter is shown on the road to the thickness of about 20 feet. It is a very fine mixture of sand and kaolin, light-gray to white in color, and

massive in structure. Above this there is about 20 feet of incoherent sandy matter, gray, with blotches and seams of yellow, brown, etc.

On the Fredericksburg side of the river the Potomac, in the vicinity of the river above Falmouth, has been cut away nearly or quite down to the gneiss. Hence exposures along the river banks are wanting until the western margin is reached. Here, in the base of the hills which bound the plain on which the town of Fredericksburg is built, we may find the formation again displayed.

The road leading up the river to the western margin of the Potomac leaves the river and ascends a hill. This point is about 1 mile above Falmouth. The hill is capped by the Lafayette formation, which here, in the upper portion, is noteworthy for the rich purple, yellow, and red tints that are irregularly distributed in the dominant gray color of the rock, making it highly variegated. This material is mostly a sandy clay of fine texture, ranging into fine sand, all incoherent and not distinctly bedded.

At the foot of the hill the Potomac shows a thin remnant of the normal sand resting on the gneiss and covered by the Lafayette formation. The top shows indications of great erosion prior to the deposition of the Lafayette. Three or four feet of a gray, coarse, crumbling sand is shown here. This contains in its top cobblestones of quartz and subangular masses of pre-Cambrian rock, mostly gneiss and mica-schist. Some of them are as much as 3 feet in diameter.

EXPOSURES ON POTOMAC RUN.

The next portion of the Fredericksburg area examined in detail is the vicinity of Potomac Run, for between that run and Fredericksburg exposures are very rare and imperfect. Potomac Run crosses the Telegraph road 6 miles north of Fredericksburg, and flows across the Potomac terrane at right angles to its length—that is, from west to east. In consequence of this, the course of this run will give a line of section across the formation similar in direction to that followed at Fredericksburg. On Potomac Run exposures of sufficient extent to give details worth noting were found at four points. These are as follows: (1) On the eastern margin of the Potomac area, along the road leading from Fredericksburg to Brooke, where this road crosses Potomac Run near the old colonial church known as Potomac Church; (2) at the crossing of the Richmond, Fredericksburg and Potomac Railroad over Potomac Run; (3) on the Telegraph road where it crosses Potomac Run; (4) at the western margin of the area near the same run on the Woodchopping road. I will give some account of each of these localities, beginning with the most eastern.

EXPOSURE AT POTOMAC CHURCH.

Up from the run, along the road near the site of the old Potomac Church, there is an imperfect exposure of all the material from the top of the Potomac formation to the Eocene. The locality is important,

because it shows the superposition of the Eocene on the Potomac where the latter appears last in this quarter, and also because we see here for the first time, in proceeding from south to north in Virginia, that the richly fossiliferous Eocene bed known as the Greensand does not rest directly on top of the Potomac, but is separated from it by a considerable thickness of nonfossiliferous Eocene material. Prof. William B. Rogers, in his Virginia reports, mentions this point as one where the Potomac disappears under the Tertiary, but he gives no description of it and no account of the Tertiary superposed upon it. The exposure is not sufficient to give a close connection between all the consecutive beds. The following is an approximate section:

Section on Potomac Run, near Potomac Church.

	Feet.
1. Very fine, loose, slightly argillaceous, yellow sand, with imprints of shells sparingly shown	20
2. Greenish-yellow and yellow, fine argillaceous sand, with many imprints of shells, especially in its lower portion=greensand marl	10
3. Brownish-yellow, sandy clay, spotted with white	4
4. Dark-gray clay, mottled with brown	5
5. Gray, argillaceous sand, with small pebbles	3
6. Brownish, sandy clay, speckled and mottled with gray and white	3
7. A thick mass, only partially exposed, of fine argillaceous and variegated incoherent sand	40
(To this point the Eocene extends.)	
8. Potomac cobblestone bed	3 to 4
9. Friable, reddish-brown sand	2½
10. Dark-gray, coarse, somewhat argillaceous sand, the Potomac sand, seen	2 to 3

The base of the last stratum was not seen. It graduates below into the normal, coarse, light-gray grit, which is only partially visible. This extends to the level of the creek, through an interval of about 10 feet.

No. 1 is most probably Eocene. It is a very fine, loose yellow sand, with much argillaceous matter. It has very few imprints of shells.

No. 2 is the greensand marl. Its yellow color is due to oxidation, owing to the long exposure of the outcrop. The stratum overlying it (No. 1) probably owes its color to the same cause. The number of imprints of shells in No. 2 is very large, but no shells were visible, perhaps on account of the weathering of the material. The lowest 3 or 4 feet alone show a remnant of the original green color. It should be noted that the Eocene material on this horizon does not always have the character of a marl, for even when fresh it is sometimes mostly a mixture of sand and clay, with very little calcareous matter and very few shells.

The beds from No. 3 to No. 7, both included, are not seen at any point south of this locality. They contain, as far as seen, no trace of fossils, and by their character indicate a somewhat unquiet condition of the waters.

No. 3 is very argillaceous and almost plastic. It is mottled and specked with white. The white is due to particles of white sand, as fine as flour, which seem to be fragments of some bed of fine sand. These are embedded in the brownish clay. This peculiar inclosure of particles of fine sand was seen at other localities farther north where this horizon is exposed. The sand increases in amount toward the base of the bed and is there disposed in streaks and irregular pockets, the particles being here reduced to a powder and more intimately mixed with the clay.

No. 4 is a dark gray, rather sandy, clay, mottled with brown, the latter being disposed in small streaks and splotches. This material is stiff and much like some of the Potomac mottled sandy clay. It has a number of small shot-like pebbles scattered through it.

No. 5 is a whitish sandy matter which is incoherent and full of small pebbles.

No. 6 is like No. 3, but more sandy.

No. 7 is seen only in part, the upper portion being concealed. The middle and lower portions have a predominant ash-gray color, with yellow and brownish colors disposed throughout the bed in pockets and irregular nests.

No. 8 is somewhat sharply separated from No. 7 and clearly forms the uppermost portion of the Potomac. The cobbles are disposed in lenticular pockets and nests, as is so commonly the case at the top of the Potomac. They are of quartz, are well rounded, and range in size from 6 inches downward. Mingled with the cobbles are partly rounded masses of quartz, the largest of which are 12 inches in diameter. There are also some subangular masses of pre-Cambrian rock ranging from 12 to 18 inches in diameter. All of the stones are packed in light-gray sand.

EXPOSURE AT THE RAILROAD BRIDGE ON POTOMAC RUN.

The railroad bridge is about half a mile west of the locality just described. In this interval the top of the Potomac rises so as to expose about 90 feet of the formation at the bridge. This difference of height in its top here and at the church may be due to the declination of the strata eastward or to their greater erosion toward the east. The strata, however, would be more eroded, it might be supposed, toward the west, where the entire formation rises higher. If not due to erosion, the amount of declination would be about 140 feet to the mile. Where the railroad bridge is thrown across the run it has cut a narrow gorge in the sandstone. The walls of the gorge are used as abutments for the bridge, which stands 70 feet above the bottom of the gorge. The approach to the bridge on the south side is made by a long, deep cut, which gives a good exposure of the Potomac above the horizon exposed in the gorge. The walls of the latter give the continuation downward of the sandstone seen in the bottom of the cut. This is firm and

durable enough to stand with a nearly precipitous face. Some of it has been used in making the piers of the bridge, and although coarse and irregular in composition it has proved quite durable. The lower portion of the walls of the gorge is hidden by talus. The hidden portion is about 12 feet thick. The mass above this to the level of the railroad bed, about 58 feet, is composed of thick layers of hard and coarse sandstone, alternating with more argillaceous and incoherent ones. Many of the harder layers are very coarse and pebbly. The alternating layers vary considerably in thickness, ranging from 3 to 6 feet. Some of the coarser sandstone layers contained rolled subangular masses of gray clay. One fragment embedded in the solid sandstone showed the dimensions 2 by 5 by 7 inches. Numerous small quartz pebbles show themselves on the exposed faces of these layers. The predominant color is gray, but this is often stained rusty-brown or yellowish in patches and irregular layers.

The material exposed in the railroad cut illustrates well the great irregularity of the Potomac deposits, making it plain that no single section of an exposure can represent even adjacent parts. Here we see well displayed a characteristic feature in the Potomac sand and sandstone. Any given layer, if traced horizontally, will soon pass into something quite different. This cut is about 80 yards long, its northern end beginning close to the bridge. The lowest material seen in the base of the cut has a thickness of about 6 feet. This, in some places, is a very coarse, pebbly, current-bedded, light-gray sandstone, with much kaolin in some parts. This material, traced horizontally, soon graduates into a crumbling, gray, sandy claystone, and this again passes back into the coarse sandstone. There are several such changes in this mass. In some places this sandstone has its top cemented by limonite into a ferruginous crust. On the top of this basal portion comes an incoherent, coarse gray sand averaging 5 feet in thickness. This is full of small stones that increase in number and size toward the top. This layer also changes much from place to place. Its top is undulating, as if it had been eroded before the next layer was deposited upon it.

The next layer in ascending order is a cobblestone bed of extremely variable character. The matrix of this bed is a coarse sand, showing strong current-bedding. The cobbles are irregularly scattered in it, or disposed in lenticular layers. This bed varies much in thickness, as well as in the size and the number of the cobbles. Its top is undulating, as if from erosion. In some places it thins down to 2 or 3 feet, and in one place it thickens to 8 feet. Throughout it there are a number of clay balls, formed of both pinkish and gray clay. They are mostly small. With the clay balls quartz cobbles are mingled, and the two components in some portions make up a considerable part of the layer. The largest clay balls come on top of the cobble bed. Most of them are 3 or 4 inches in diameter, but a few reach 12 inches. These largest ones are composed of the pinkish clay.

Throughout most of the length of the cut the layer next above the cobble bed is a stratum of pale pinkish clay with some obscure fragments of plants. Where these are shown the bed is about 2 feet thick. At the southern end of the cut this layer has been removed by erosion or broken up into clay balls and masses that are isolated and embedded in coarse gravel. At this point an isolated cake of such clay 5 or 6 feet long, with a maximum thickness of 2 feet, was seen almost buried in coarse, gravelly sand, thus illustrating the mode of formation of the clay balls. If the clay stratum be traced toward the northern end of the cut, it will be seen to change its character totally. Where the cobblestone bed swells out to 8 feet the clay stratum over it is barely 12 inches thick, and is rather sandy. A little north of this point the clay graduates into a fine-grained, laminated, sandy shale, 4 feet thick. This has some comminuted carbonaceous matter dispersed through it, and it is current-bedded. In one place here the top has a good deal of limonite. Limonite impregnations occur, however, at different horizons and in no definite way. Still farther north the laminated sandy clay graduates into a massive sandstone of the normal kind and it becomes 8 feet thick. Here the lowest portion of the bed, for 6 inches, is a mass of broken bits of lignite and carbonaceous matter resembling charcoal mingled with coarse sand.

Over the variable material last described there comes a pockety layer of incoherent fine-grained argillaceous sand of a pale greenish-gray color. Owing to the undulations of the surface on which it rests, its thickness varies considerably. It is much mottled with brownish and yellowish colors. Its thickness ranges from 4 to 6 feet. It is almost certainly a member of the Eocene. This lowest Eocene bed is covered by a stratum of small gravel 3 to 4 feet thick.

Going up the run from this point 2½ miles we find Potomac débris occupying the surface with Potomac sand and sandstone forming the rock in place, but the exposures are very poor. The materials seem to be of the same nature as those exposed at the railroad bridge. The first tolerably good exposures are seen on the Telegraph road where it crosses the Potomac Run.

EXPOSURES ON THE TELEGRAPH ROAD AT POTOMAC RUN.

The Potomac material is, if possible, more heterogeneous here than at any of the previously described localities. The changes are so numerous and irregular that it is almost impossible to give a complete account of the locality. At this place the road descends a steep hill to the lowland bordering the run. On the slope of the hill and on the side of the road a considerable gully is washed out and this gives fairly good exposures from the bottom to the top of the hill. At the foot of the hill a small stream runs alongside of the road, cutting rather deeply into the material, and this continues the exposures for some distance farther along the road.

Besides the outcrops on the road, additional but slight and imperfect exposures may be found by following a farm road that leaves the Telegraph road at the base of the hill. This road, after a short interval, turns to skirt the base of a small wooded hill, distant from the Telegraph road about 200 yards. Here in the edge of the woods, on the hillside, an important plant-bearing stratum is exposed.

The exposures on the Telegraph road will be described, beginning at the northern end and ending at the top of the hill. As a good many fossil plants were found in the face of the hill, excavations were made and much more was learned concerning the details of composition and structure than would have been ascertained from a mere inspection of the surface. The lowest material seen at the northern limit is normally a coarse siliceous grit or sandstone. This has a light-gray color, mottled and irregularly banded with yellowish and brownish colors in places. Traced horizontally, this is seen to be a greatly variable material and it has lost much from erosion. At the northern end where first seen it is a coarse pebbly grit, showing a maximum thickness of about 8 feet. It contains here clay balls and some scattered quartz pebbles, the largest being 3 by 4½ inches in diameter. The stratum graduates horizontally into a highly argillaceous flag or shale, which is in places a claystone. This, when wet, forms a dark bluish-gray tenacious material. This shale portion, where it first appears, is only 5 feet thick so far as seen, but owing to the undulating character of its top, due to erosion, it swells out suddenly, so that a little south of the spot where it first appeared it is at least 20 feet thick. At this place, however, the entire mass is not of the same kind of material, for the upper portion contains some layers of fine-grained gray flags, stained irregularly with yellow and brown. The claystone here when dry is mostly of a light-gray color. The upper portion shows the marks of extensive and irregular erosion. The sandstone layers that form the upper portion are sometimes cut away so as to leave isolated fragments abutting against the overlying clay.

A little south of this point all the gray shale has disappeared, having graduated into a coarse incoherent gray sand. Then for a short distance up to the point where the small stream leaves the road the ground is concealed. Up to this point the varying material just described forms the only Potomac matter shown. This is covered by a peculiar mottled clay, which seems to be made up of fragments of the variegated Potomac strata seen in place farther up the hill. It is sometimes found dipping down deeply into the Potomac as if deposited in trenches cut out in its surface, and it envelops isolated portions of the top of the Potomac. It varies in thickness from 5 to 20 feet, and in its base small stones were found. It is largely composed of agglutinated fragments of gray, purple, yellowish, and reddish shale. These fragments are generally cemented very thoroughly together, but often the individual fragments may be detected. Between it and the Potomac

there is a decided break, marked by much erosion, and we find here numerous cobblestones of quartz and fragments of pre-Cambrian rock, some of the latter being 12 to 24 inches in diameter.

The first Potomac material seen on the road after the concealed portion occurs at the lower end of the gully mentioned, the succeeding beds being visible in order as we ascend along this gully. The exposures are now continuous to the top of the hill. The lowest stratum is a gray claystone, passing into an argillaceous sandstone. It is variegated with yellowish and reddish streaks and spots. This material seems to be of the same nature as that shown near Fredericksburg and called the mottled sandy clay.

A little farther south and up the gully the claystone is overlain by a thinly laminated, highly argillaceous shale and claystone, tender and crumbling in texture. The first-described material graduates into this, and there is no separation into distinct beds. A thickness of about 15 feet of all these materials is shown. The colors vary much in shade and in distribution. In general the color is gray, mixed irregularly with brick-red or yellowish-red, but for a considerable space, taken horizontally, it is largely red mixed with some greenish spots and streaks. The portions colored red generally form nests and pockets in the gray. Farther south the patches of brick-red are replaced by those of yellowish-brown, and still farther south nearly all the material is colored greenish-gray, with a very little yellowish-brown. The claystone, however, when followed horizontally to the south is seen to graduate into a fine-grained, thinly laminated, gray sandstone and sandy shale that on weathering breaks up into uneven flakes. It has here in its upper portion a cobblestone layer, the cobbles being disposed in lenticular patches. The stones are embedded in coarse sand marked by current bedding. This is the character of the cobblestone layer where first seen in the gully. It is here only 12 inches thick, having suffered from erosion. When followed horizontally this splits up, and the cobbles are diffused in the finer material, occupying a thickness of 2 or 3 feet. Resting on the cobbles and often mingled with them we find fragments, some of large size, of a pale-chocolate clay and shale which have been evidently torn off from some preexisting stratum not now visible. These shale fragments contain some well-preserved impressions of plants. On the cobblestone bed or on its horizon there is a stratum a few inches thick of a pale reddish-brown, indurated clay. This graduates horizontally, in the space of a few feet, into a sandy, gray shale. This layer in the portion colored reddish-brown contains some beautifully preserved plant impressions.

It will be noticed that here, as at Fredericksburg, the fossiliferous layer rests on cobbles. Besides the impressions of leaves a number of fragments of stems of small size, now in the form of lignite, occur in it.

The material showing the plant fossils has the peculiar structure which is not uncommon in the Potomac formation, and which has been

already spoken of as shown in uptorn and redeposited clay. This structure is visible in several places in the deposit which contains plant remains. The fossiliferous stratum is composed of material that was derived from some previously formed bed. The matter thus torn off was deposited largely in the form of fragments that vary in size from considerable masses down to the finest particles. With the distinct fragments more or less of fine mud was formed. All this material, being still soft and plastic, was readily cemented together on being redeposited and a mass was produced that in composition much resembled the original bed from which it was derived. Without the careful examination called for to follow up the plant impressions, such a bed appears to be one formed in the usual way, i. e., by gradual accumulation of fine sediment. When, however, one carefully follows up such a bed, excavating it and splitting up the material to secure the plant impressions, he soon finds that it has not the simple structure of fine, argillaceous matter slowly deposited as mud. A material accumulated as fine mud by gradual deposition, if it does not show lamination, has an even grain and generally has cleavage. It can be split with readiness and regularity, especially if leaves are spread out in it. These leaves will be found disposed in regular planes parallel with the deposition planes. Such fossils in the Potomac formation are often well preserved.

In the stratum now under consideration all of the matter is redeposited, and most of the fossils are poor. In some cases, however, the redeposited matter of the Potomac seems to be laid down on the horizon of the destroyed bed, and then remnants of this bed may remain buried in the débris. The remnants have sometimes well-preserved fossils. In some cases, too, the redeposited masses are quite large, and retain the structure and character of the original bed. These also often give good fossils. This is the case with one of the clay masses on the Telegraph road, and from this good fossils were obtained. The greater part, however, of the plant material here is made up of rather small recemented particles. The plants in the remnants of the original bed often, but not always, differ in species from those found in the recemented small particles; and this is true, not only of beds at the locality on the Telegraph road, but of others elsewhere, especially of those at Brooke. The fossils included in the recemented matter are, of course, somewhat later in deposition than those preserved in the original stratum, but there is apparently no great difference in their age. Geologically speaking, erosion seems to have quickly followed the formation of the parent stratum, the interval not being long enough to permit any material change in the plant remains. The chief difference is in the perfection of preservation of the fossils entombed under the two conditions. Those of the recemented clays are fragmentary, distorted, and bent so as to lie in different planes. They were caught up in every possible position as the fragments were being brought together, and were inclosed between them as they were cemented together. The

recemented clay betrays its character in various ways. More or less sand is caught up in the cementation of the fragments. The clay is without cleavage, and breaks along the junction planes in a very irregular way. It shows slickensides with more or less contortion and crushing. It is very difficult to get good fossils from such material.

The portion of the layer on the Telegraph road that shows good fossils is only about 12 inches thick in its thickest part. It contains one or two large fragments of the original stratum from which the clay was derived. These contain some well-preserved ferns and conifers. This thin layer seems to be in the form of a lenticular pocket. To the south it splits up and disappears at first by being interstratified with flaggy sandstone and then by graduating into this material. At the point where the clay disappears higher strata are shown. These are composed of a mixture of gray shale and coarse current-bedded sandstone. This mixed material shows a maximum thickness of about 2 feet. It contains scattered small pebbles and fragments, both rolled and angular, of the plant-bearing clay. Next above this come about 8 feet of current-bedded, thinly laminated, gray, crumbling sandstone, which contains many balls of gray clay that range in size from 4 inches downward. Above this comes a thick-bedded sandstone, also crumbling, and gray in color. This is about 10 feet thick. Farther south and higher up is a variable deposit. This is a thinly laminated sandstone, with irregular nests and patches of a more argillaceous material, which tends to pass to claystone and to reproduce the mottled claystone seen lower down. The more argillaceous portions are blotched with brownish-yellow and brownish-red colors. Toward its top this material passes into a firm, mottled claystone. The mass just described is 25 feet thick. Up to this point all the material is Potomac, the maximum thickness of the formation exposed being about 80 feet. In the top of the last-described layers comes the same younger mottled clay that was seen farther down. It is here 12 feet thick and has the same character that it possesses at the foot of the hill. In the summit of the hill a thick covering of the usual surface cobbles comes on the top of this last-described material.

Another plant-bearing bed is found in this vicinity which is quite different from that seen on the road. About 200 yards to the northwest of the spot on the road yielding plants there is an outcrop of shale that shows a number of well-preserved plant impressions. This stratum is very nearly, if not quite, on the same horizon with the fossiliferous bed that occurs on the road, but it is totally different from that. The shale now considered is evidently an undisturbed and original layer. It is not associated with any cobbles and is uniform in texture, retaining lamination. It is brownish-gray in color and fine-grained, and is a lenticular pocket in the sand, showing a thickness of about 2 feet, the top having suffered from erosion. Nearly all the plants occurring in this stratum are small and delicately cut ferns, none of which, strange to say, occur on the roadside. Under this shale there

is about 15 feet of fine-grained gray and mottled claystone, that in some places graduates into a finely laminated, gray, sandy shale. The system of beds shown in the exposures here and on the road seems to dip about 4° south-southeast.

About a quarter of a mile southwest of the exposures on the road and in the woods the bed of a small stream exposes the top of a layer of bluish-gray, sandy shale. This may be seen along the stream for about 100 yards, a maximum thickness of about 3 feet being visible. The entire thickness is not displayed. This shale or indurated clay is remarkable for the great number of flattened trunks of trees, now changed to lignite, that lie scattered in it. The trunks and limbs are those of coniferous trees that do not seem to have been drifted, but to have fallen where they grew. The trunks are not piled up thickly, but occur in a scattered manner throughout the entire thickness of the shale exposed. The shale or indurated clay containing these trunks is quite micaceous, an unusual feature in the fossiliferous clays. It has on the top, imperfectly exposed, a stratum of pale reddish-brown shale like that containing the plant impressions on and near the road, and it is probable that it occurs on the same horizon with that. The material holding the lignite logs showed no impressions of leaves except a fragment of *Scleropteris elliptica*. This illustrates a general truth, for it is noteworthy that the clays which contain large amounts of lignite very rarely show leaf impressions. The material of the lignite trunks is similar to that almost universally seen in the trunks embedded in the Potomac formation. It exhibits a peculiar blending of the physical characters of jet and lignite in the narrow sense of the latter word. It splits freely and shows the grain of the wood well preserved along the cleavage planes, but generally the cross fracture is conchoidal and shows the pitchy luster of jet. So far as can be decided by the unaided eye all the lignite comes from the same kind of coniferous tree. This seems to have had a texture like that of the white pine. The trees must have been subjected to great pressure, for the trunks are quite flat. This implies the former presence of a considerable thickness of superincumbent matter. The character of the wood, all of the same kind, would seem to show that the coniferous trees grew in forests composed of the same kind of tree. The size of several of the lignite logs indicates that some of the trees were 24 inches in diameter.

The cobblestone layer occurring on the road at the base of the fossiliferous shale is very slightly developed there, but at other places on or nearly on the same horizon a more extensive cobblestone layer occurs. It appears on the Telegraph road on the north side of Potomac Run, about 300 yards north of the exposure on this road previously described. Here the bed is from 3 to 4 feet thick and it is a mass of cobbles packed closely together. The stones are mainly of quartz and are well rounded. Many of them are large, some attaining the diameter of 6 or 8 inches. Some pre-Cambrian fragments occur here, and this is an unusual

feature in Potomac cobble beds. The bed rests on a layer of gray claystone, and has over it the younger mottled clay.

EXPOSURES ON THE WOODCHOPPING ROAD.

The material of the Potomac is exposed for more than a mile west of the Telegraph road, and is there of nearly the same character as on the road, but is rather more sandy and variable in the western outcrops. The Woodchopping road runs near the western margin of the formation and has a course nearly parallel with this margin. On this road the formation has risen so much that its base is exposed and a considerable thickness of the gneiss foundation on which it rests is to be seen. In consequence of the greater height of the Potomac in this quarter it has suffered much from erosion and remains only in patches.

The gneiss is exposed in ascending the hill from the run. It is exactly like the gneiss on the western margin of the formation at Fredericksburg. It is highly micaceous, very irregular in composition, and deeply decayed. Portions of it have changed almost wholly to clay. This clay is quite different from the sandy matter that constitutes most of the Potomac, but is more like the mottled sandy clay of that formation. Toward the top of the hill the Potomac is shown, and it there reaches the maximum thickness of 40 or 50 feet. It is mostly an incoherent kaolinic sand in the outcrops, but may be more firmly consolidated deeper down where protected from weathering. It is usually light-gray in color, but often has irregular mottlings of yellowish brown. Some portions are full of small balls, streaks, and partings of a gray clay. Great numbers of large cobblestones are scattered about on the surface, and some large pre-Cambrian fragments are found. Some of the latter are 2 feet in diameter and many of the cobblestones have a diameter of 8 or 10 inches.

Along the western margin of the Potomac, as at this locality, it is common to find this formation only in the tops of the hills, while the crystalline rocks form the greater portion of them and occupy the valleys. The amount of erosion indicated is great, for in some places farther north the pre-Cambrian rock has been cut into to the depth of fully 100 feet, and extensive valleys are formed in it.

EXPOSURES NEAR BROOKE.

The next detailed examination of the geology of the formation was made at and near Brooke, on the Richmond, Fredericksburg and Potomac Railroad. This is a portion of the Atlantic Coast Line Railroad. This station is 9 miles north of Fredericksburg and 5 miles northeast of the locality on the Telegraph road, which afforded the fossil plants mentioned above. This latter place is near the western margin of the formation, while Brooke is on the eastern. In passing over the interval between these two localities the Potomac with its débris is seen to form all the rock of the country, but nothing noteworthy is to be met with.

The examination of the Potomac in the vicinity of Brooke is much facilitated by the comparatively recent cuttings made along the railroad between the station and Aquia Creek, a distance of over 3 miles, and also by excavations made a little east of the station for the purpose of utilizing the greensand marl exposed there. The county road, also, near the station, and Accakeek Run give exposures.

The lowest rock seen in the vicinity of the station is the sandy Potomac matter. This is here, and for a considerable distance north to beyond Stafford, rather firmly consolidated, so that much of it is a sandstone even on the weathered outcrops. In a number of places it was formerly largely quarried for building purposes. The sandstone is visible in the banks of Accakeek Run. It shows in all about 20 feet. It is very massive, and is coarse, hard, and firm in texture. In the surface of this rock, as it is exposed on the run, a number of large clay balls may be seen, varying in diameter from 6 to 12 inches. A little distance away from the run, on the north side, about 20 feet of a higher portion of the sandstone may be seen, making the entire thickness of sandstone visible 40 feet. The upper 20 feet, as is very commonly the case, is composed of a more kaolinic and less firmly consolidated material. This is often nearly white and on exposure falls readily to a loose sand. Some small quartz pebbles and clay balls occur in it.

Still higher material reaching into the Eocene may be found on the south side of the run, along the road from the run. Here may be seen the junction of the Eocene and Potomac, the transition from one to the other being very clearly shown. This contact of the two is very rarely seen, and nowhere else in this area is it so well exposed. It may be noted as illustrating the irregular erosion of the surface of the Potomac in pre-Eocene times, that the top of this formation on the north side of the run is considerably above the Eocene greensand on the south side, only 150 yards away. The section was obtained by taking the maximum thickness of the material visible on the south side of the run, where the Potomac shows only 20 feet.

Section at Brooke.

EOCENE.

	Feet.
1. Yellowish, incoherent sand (surface)	6
2. Greensand marl	10
3. Greenish-gray, mottled, argillaceous sand	10
4. Mottled, argillaceous sand	15
Total Eocene	41

POTOMAC.

	Feet.
5. Cobblestone bed	4
6. Potomac sandstone	20
Total Potomac	24

No. 5 is the cobblestone bed so common in the top of the Potomac sand and making a portion of the formation. The stones here, as is commonly the case, are embedded in a coarse, ferruginous sand. The proportion of large cobbles is considerable, many of them being 4 or 5 inches in diameter. All are composed of quartz and are well rounded.

No. 4 is apparently the lowest of the Eocene strata. It is without fossils and was plainly deposited in unquiet waters. It is an incoherent, sandy shale, fairly well laminated. The predominant color is dingy gray, but it is irregularly streaked and spotted with yellowish-brown. It is much affected by current bedding, and the bedding planes are marked out with this color. This and the next layer above have numerous spots and specks of pure white sand embedded in the colored material, much like that occurring on the same horizon at Potomac church.

The next stratum, No. 3, is an argillaceous sand. It is in the main greenish-gray in color, but in some places large masses are colored almost uniformly a deep tint of reddish-brown. The greensand bed, the one coming next above, rests upon this, but is quite distinct from it.

The greensand bed, No. 2, is here considerably weathered, and the lower portion of it, for about 4 feet, is a yellowish-brown sandy clay, full of the imprints and casts of shells. Over this occurs about 4 feet of a greenish-gray sandy clay, with many casts of shells and some shells. Cakes and crusts of varying thickness are formed in this portion by the cementing action of calcareous matter, giving an impure limestone. The highest portion of the bed is grayish in color, but it does not show so many shells.

The higher stratum, No. 1, has lost much from erosion. It is very incoherent, and seems to be the same as the highest bed shown at Potomac church.

EXPOSURES ON THE RAILROAD NEAR BROOKE.

The exposures next to be noticed occur along the line of the Richmond, Fredericksburg and Potomac Railroad, between the station and Aquia Creek. For about 2 miles north of the station to near the seventy-second milepost from Richmond nothing but the incoherent argillaceous sand corresponding to Nos. 3 and 4 of the preceding section is to be seen in the cuts. This material is mostly gray in color, but is often mottled with various colors, due to oxide of iron. It is in places greenish-gray. At some points it shows a tendency in weathering to form crusts and sheets of highly ferruginous sandstone in the incoherent matter. This is due to the cementing action of iron deposited from solution in the percolating waters. Sometimes nests and

irregular layers of nearly pure light-colored sand occur in the grayish matter.

At the seventy-second milepost from Richmond, which is found about three-fourths of a mile south of the railroad crossing over Aquia Creek, there is an exposure of the Potomac. This is important because of the occurrence at this point of numerous well-preserved fossil plants in the clay of the Potomac, and on account of the occurrence of a good exposure of the superposition of the Eocene on the Potomac. At this point the descent of the railroad grade toward the creek brings the roadbed down below the level of the top of the Potomac and the continued descent from this place carries it more and more deeply into the formation. On this account the Potomac is continuously visible as far as the creek.

A considerable amount of material was removed in search of fossil plants, and the careful following up of these disclosed very strikingly the peculiar structure found in redeposited clays which has been mentioned in another connection. A very large number of fossil plants was found here occurring in the clay pockets and seams embedded in the sand and shown in the cut beginning at the seventy-second milepost. The plants are cycads, conifers, ferns, and angiosperms. The cycads and ferns are rare, but the conifers and angiosperms are very common. A comparatively small number of species is represented by great numbers of individuals, while many species have only one or two, or at most a very few, individuals.

The impressions are found both in the confusedly deposited clay and in a thin layer apparently deposited at the same time as the irregular clay. This latter has a more uniform composition and structure, probably because it was formed of fine particles. Although quite irregular in its course, it has a fine grain and good cleavage, showing a number of species of angiosperms found nowhere else. These show only one or two specimens in some cases, but they are beautifully preserved. The plants in the irregularly redeposited clay are very numerous but very fragmentary. They are caught up between the fragments of clay as they were cemented together, and hence occur in all positions and in different planes in the material, being bent and distorted in various ways. They rarely yield good specimens. Some of the conifers found in this material do not occur in the more uniform layer.

The irregular material composing the Potomac forms the lower part of the cuts in the immediate vicinity of the seventy-second milepost, and it is capped by marine Eocene containing imprints of shells. Fig. 7 gives a generalized section of the two formations as superposed in the cuts next to the milepost. The surface of the Potomac was trenched deeply and irregularly previous to the deposition of the Eocene, so that at this place the latter cuts out the former to a point below the level of the railroad track, in the form of two

narrow tongues. These represent two pre-Eocene ravines filled with fossiliferous Eocene deposits. These ravines have a course at right angles to the direction of the railroad—that is, they are directed a little south of east, which is the course of the minor streams of this vicinity at the present time. In fig. 7, *r r* denote the ravines, *p p p* the irregularly eroded Potomac, and *e e* the Eocene. Below this point toward Aquia Creek the Eocene is no longer visible on the surface of the Potomac. The following section is made out from the material shown in the cuts next to and at the milepost. The Potomac deposits found in the lower portion of the cuts are so very complex in nature that it is difficult to give any adequate account of them without describing

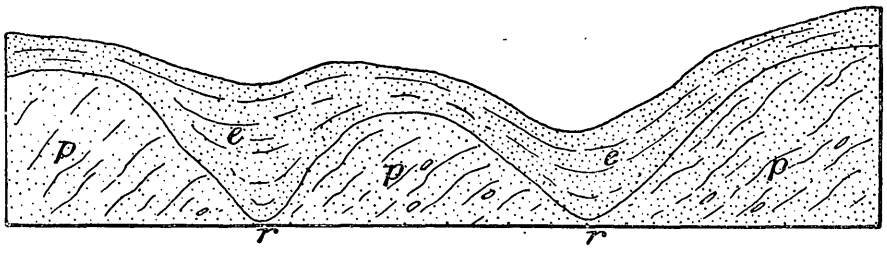

FIG. 7.—Pre-Eocene ravines near Brooke.

every few yards of the exposures. The sand and its contents give indication of deposition in agitated waters, with pauses in the deposition of the sediment, during which erosion took place; so that there is a great deal of redeposited matter, the most noteworthy of which is the clay:

Section at the seventy-second milepost.

EOCENE.

	Feet.
1. Greenish-gray sandy clay (seen)	8
2. Yellowish-brown sand	5
3. Friable, mottled argillaceous sand	12
Total Eocene	25

POTOMAC.

4. Cobblestone bed	1
5. Sand and clay	1½
6. Gray argillaceous sand	2
7. Ferruginous sand and clay	2
8. Gray sand with clay pockets	7
Total Potomac (seen)	13½

No. 1 is considerably eroded at top, and the thickness seen is evidently less than that originally possessed by the stratum. The material is massive and very incoherent. It shows no fossils.

No. 2 is predominantly brownish or yellowish brown in color. It, also, is a loose, argillaceous sand without lamination. It graduates into No. 3, no distinct plane of division existing.

No. 3 shows casts of Eocene fossils. It is a gray, argillaceous sand, showing a tendency to form crusts of ferruginous matter from the cementing of the sand by iron. It shows no trace of plant impressions, but is evidently a marine deposit, indicating a decided change from the conditions prevailing in the Potomac.

No. 4, the cobblestone bed, is not uniform in thickness, but is pockety, the cobbles being packed in argillaceous sand. The stones are of quartz and well rounded, the largest being 3 to 4 inches in diameter. No pre-Cambrian fragments occur with them. It is noteworthy that in the material above this bed no cobbles and no clay fragments occur.

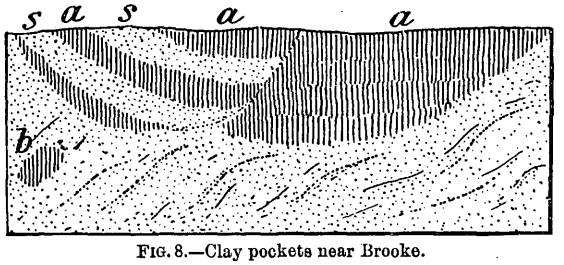

FIG. 8.—Clay pockets near Brooke.

No. 5 is largely made up of fragments of clay which are embedded in sand. This clay was eroded from some pre-existing clay bed and redeposited with sand in the form of more or less distinct fragments. The clay is bluish-gray in color and is disposed on the same horizon in balls, cakes, and short layers so as to form a disconnected stratum of clay in sand.

No. 6 is a very uniform and fine material, graduating irregularly into Nos. 5 and 7.

No. 7 has in some places at the bottom an impure iron ore. It contains numerous balls and cakes of clay disposed in one plane, as in No. 5. It differs from that in having the clay less regularly arranged and in being more ferruginous. The material is a mass of sand mixed with clay particles.

No. 8 is much the most important and most variable material, since it has irregular pockets of clay with many plants. The greater portion of it is a light-gray, kaolinic sand, with blotches of color from iron oxide. It is arranged in lenticular masses, which are affected by current bedding. It has also small stones scattered through it. In a word, it is the typical Potomac sand, the only exceptional features being the fossiliferous clay pockets. The clay is in part pale-reddish to chocolate colored. Most of it is more sandy than that which commonly contains plant impressions. Much of it is ash-gray in color, and this contains the best impressions. Some of the clay occurs in balls and cakes. This does not contain fossils. It occurs also in pocket-like masses, interrupted layers of lenticular form, and in fragments irregularly cemented together and mixed with sand. The three last-mentioned forms contain the plants.

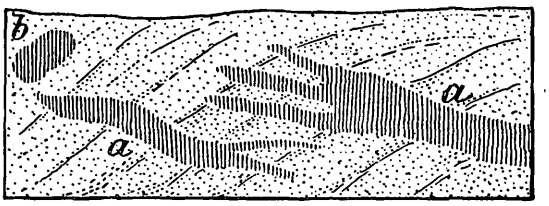

FIG. 9.—Clay pockets near Brooke.

The accompanying figures (figs. 8, 9, and 10) give some of the shapes assumed by the clay pockets formed of redeposited and aggregated clay particles. The pockets of clay are sometimes wedge-shaped and sometimes they split up and disappear. Sometimes the pocket-like masses are made up of alternating layers of sand and clay. In the annexed figures, *a a* represent the clay layers and pockets; *b b* the clay balls; and, in fig. 8, *s s* the interstratified layers of sand. The clay portions are rarely composed of unmixed clay. The aggregated particles have usually caught up more or less sand. The clay balls are mostly of pale-reddish clay. They contain, if any, only obscure bits of plants. The clay of the layers is mostly gray. The layers and pockets lie at different angles of slope and at different levels, as if the material had been laid down on a shifting surface of sand. Most of them are very irregular in thickness and vary much in persistence, having a lumpy structure. These portions have no regular structure, and are clearly composed of fragments torn off from some previously deposited clay layer and recemented in a confused manner. In these portions much sand is mixed with the clay, and many imperfect fragments of plants are found. They are greatly contorted and crumpled. Some of the pockets of clay, such as those represented in figs. 8 and 10, seem to have been deposited in hollows and trenches scooped out in the surface of the sand during the intervals of erosion.

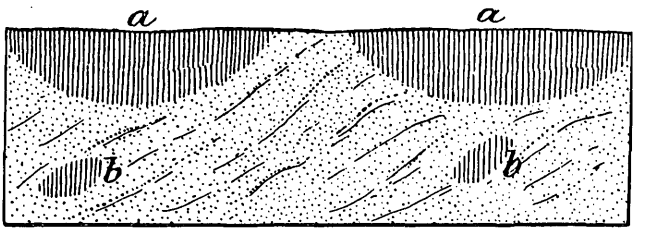

FIG. 10.—Clay pockets near Brooke.

Going north from the seventy-second milepost, where the above-described materials are exposed, we find several cuts and excavations, which mostly show, toward Aquia Creek, little except the basal matter of the Potomac, or No. 8 of the section. In a cut about 100 yards north of the milepost the top of No. 8 is capped by from 4 to 6 feet of sand mixed with the lumpy, gray, and imperfectly bedded clay. Over this comes about 10 feet of very coarse, ferruginous, sandy matter, containing many balls and cakes of gray clay. These are disposed in imperfectly outlined layers that are inclined at various angles to the horizon. Over the whole there is a few feet of yellowish, mottled, sandy matter, which may be Eocene. Most of the clay is gray, but scattered masses and balls of pale-reddish, sandy clay occur. The original stratum furnishing these must have been very rich in plant impressions, for they abound in fragments.

The next cut to the north, which is close to the one last described, shows at the bottom 5 feet of current-bedded sand, which is full of clay balls. Over this come 4 feet of sand and cakes of clay. The

clay is gray and the cakes are arranged in layers, with pretty continuous clay layers at the top. All this is recemented clay. Over this come 4 feet of incoherent sand with clay balls. Above this is a continuous, evenly bedded stratum of gray, sandy clay, evidently an original deposit. The highest layer is about 10 feet thick, and is composed of mottled, argillaceous sand. These materials are probably all Potomac.

About 100 yards north of this point a perpendicular face of Potomac material is shown, a little way off from the railroad. It is about 20 feet high and 10 feet of the base of the cliff is hidden by talus. The greater portion of the exposed mass is a ferruginous, coarse, current-bedded sand. Irregularly shaped portions of it, however, have much kaolin. The coarse sand contains some pebbles and many small balls and cakes of clay. The bottom of the exposed mass is more heterogeneous than the rest. It is a peculiar mixture of balls of clay, pebbles of quartz, and coarse sand. Two feet of this material may be seen.

About 50 yards north of this point material lower than any shown in the last-described exposure may be seen. It, however, may be taken as a continuation downward of the section obtained in the 20 feet of material last described. The highest portion here corresponds to the concealed base of the mass occurring there. The exposure here is made in the banks of a small stream and in the stripping made laterally out from the railroad to obtain material to make a "fill." This stripping has left a considerable space bare, and has been carried out so as to leave, where it stopped, a perpendicular face about 50 yards distant from the railroad. In this face a lenticular layer of clay is exposed, which is very important on account of the plant impressions that it contains. In the description of the plants in the "Potomac or Younger Mesozoic Flora" this spot is designated "Bank near Brooke."[1]

On the stream, which flows at a level about 10 feet below the top of the bare space, about 5 feet of a very coarse, current-bedded sandstone is shown, with the base not disclosed. This is full of quartz cobbles, and has some large clay masses and many clay balls. Many of the cobbles are 4, 6, or 8 inches in diameter. One subangular, prismatic quartz mass was seen with the dimensions 3 by 4 by 9 inches. This material minus the cobbles extends upward so as to occupy the space left bare. In this latter some very large masses of bluish-gray sandy clay are embedded. The largest of them were only partially exposed, being buried in the coarse sand. They measure sometimes 5 feet or more in diameter.

The material in ascending becomes more friable, passing to a sand with more or less clay. In the perpendicular face exposed, the material is finer and more argillaceous than that just described, and has the usual arrangement of lenticular, interlocking layers. In one portion, on the left-hand side, there is a lenticular layer of grayish clay that

[1] Mon. U. S. Geol. Survey, Vol. XV, 1889.

disappears in passing to the right-hand side of the bluff. Here, at the top of the bluff, which is about 20 feet high, there is a lenticular layer of dark-gray, rather sandy clay. This has a maximum thickness of about 8 feet. It is composed of clay in irregular layers with some partings of fine sand and of pure clay. The partings of purer clay are full of impressions of angiosperm leaves, which nearly all belong to the new genus Sapindopsis, most of them belonging to one species. Leaf impressions occur also in the dark-gray, sandy clay layers, but they are not so abundant as in the partings of purer clay. At this place, by taking in the exposures given at the last-described locality, we have as much as 70 feet of Potomac shown, with no Eocene visible.

EXPOSURE AT AQUIA CREEK.

In the last cuttings made near the point where the railroad crosses Aquia Creek, and which are about 200 yards north of the spot last described, the rapid changes in the Potomac are well shown. There are here two exposures close together. The one to the south is a short, deep, cut; the other, a few yards to the north, is an extensive side cutting. In the short cut the following section is shown.

Section at Aquia Creek.

	Feet.
1. Gray sandstone, streaked irregularly with yellowish-brown	5
2. Gray, incoherent sandstone and sand	6
3. Pebbles packed in ferruginous sand	4
4. Clay balls mixed with gray sand	1
5. White, kaolinic sand	10

The last is a very light-colored mixture of coarse grains of sand with much kaolin, and it has a lenticular structure.

In the side cut the basal, kaolinic sand, No. 5, rises up to the height of 30 feet and cuts out the variable beds Nos. 1 to 4, shown in the short southern cut. The uppermost portion of it here, for the thickness of about 4 feet, is full of pebbles, and a stratum of loose gravel, 2 to 3 feet thick, covers the whole. There are some thin, variable, lenticular partings of reddish, sandy clay in this exposed face, and they contain a few imperfect fragments of plants. These layers soon give out.

The Potomac continues to be exposed on the north side of the creek, and is visible at intervals, but is mostly cut away by the Potomac River, which the railroad now approaches. Considerable exposures occur at Quantico. The material is almost wholly the irregular lenticular, bedded sand and sandstone so common in the formation. The railroad crosses Aquia Creek about 4 miles (by the creek) above its mouth. On the north shore of the creek bluffy banks occur in some places, but they are formed of the Pleistocene. This material forms the banks of the Potomac River to the vicinity of Quantico, where the Potomac formation is seen in place in the river banks. The south side of Aquia Creek shows the Potomac sandstone farther down toward the mouth than the north side.

The Eocene greensand marl bed has been worked about three-fourths of a mile east of Brooke Station. The level of this bed here, as compared with that shown at the station, indicates that it, and consequently the top of the Potomac formation, sinks about 30 feet to the mile in a direction a little south of east. At the opening made in the marl its base is not exposed, since the stratum was not cut through. The lowest material seen is a greenish-gray sandy clay, full of the impressions and casts of shells and containing also many shells. Seven feet of this is in sight. Four feet of greenish-gray sandy matter occurs on the top of this, but no imprints of shells are visible in this last. The uppermost material seen is a loose sandy clay that weathers yellowish-gray with bands and streaks of yellow.

At Marlboro, near the mouth of Aquia Creek, there is an imposing exposure of Eocene material shown in bluffs in some places over 100 feet high. The bluffs extend from the mouth of Aquia Creek to the mouth of the Potomac Creek, but nowhere show the Potomac formation. Over 100 feet of the Tertiary may be seen in these exposures. This condition of things shows great inequality in the erosion of the formations along the Potomac River, for north of the mouth of Aquia Creek all this Tertiary is cut away and, as stated above, nothing but Pleistocene is visible in the banks of the river.

About half a mile from Brooke, in a direction a little east of south, a gully exposes about 20 feet of the Potomac formation, which belongs to the same horizon as that shown at the station. But here none of the sandstone or sand occurs. The material is all composed of the mottled sandy clay, almost exactly like that shown at Fredericksburg, on Hazel Run, and on the Stafford side of the river, opposite Fredericksburg. It occurs in rather regular layers. The material is firm and coherent. It is mainly gray in color, but is marked with spots and streaks of brick-red, sometimes of purplish-red, the colors being bright. Large masses, however, have solid colors, sometimes red and sometimes gray. On this rests about 5 feet of yellowish sandy clay.

EXPOSURES NEAR STAFFORD.

Stafford is 10 miles north of Fredericksburg and 3 miles northwest of Brooke. In the vicinity of this place, and between it and the station, patches of the lowest Eocene bed occur within the Potomac terrane. This material, from some cause, is much indurated, and more or less impregnated with silica deposited from solution. Portions of it look like a calcareous sandstone. It is owing to this induration and silicification that the material has been preserved from erosion. About forty years ago, when the Potomac sandstone was largely used as a building stone, the vicinity of Stafford afforded a number of quarries of it. Over a considerable area in this neighborhood the lower portions of the Potomac material seem to be more firmly consolidated than usual, and in some places it has a composition

and a texture sufficiently uniform to furnish a rough kind of building stone. Most of the quarries were located on Austin Run, a tributary of Aquia Run, and on the upper part of Aquia Creek, northeast of the court-house. The old quarries on Austin Run are situated to the west of the Telegraph road, and are found at intervals over the space of about a mile up the run. They are so much overgrown and filled in that they now disclose very little of the details of the texture and the structure of the rock.

The thickness of about 100 feet of Potomac sandstone may be seen along the run. The uppermost part of this shows some reddish and mottled sandy clay. The rock along Austin Run is essentially of the same nature as that shown on Aquia Creek, and as the recently opened quarries there disclose its character very well, the description given for this latter will apply to the rock of the former locality.

The width of the Potomac belt in the vicinity of Stafford is about 5 miles. There is no essential change in the character of the rock in passing from one side of the belt to the other. The exposures near Brooke may be taken as good types of the material on the eastern margin, and those on the upper part of Aquia Creek, near the court-house, of the rock on the western side.

QUARRIES ON AQUIA CREEK.

Several of the old quarries on the creek have been recently reopened in search of stone for railroad culverts and bridge abutments. Two of them were being worked when I made an examination of the Potomac formation along the creek. These quarries showed the uselessness of attempting to make out details of texture and structure from old outcrops. In such variable and easily disintegrated rock many of the most peculiar features were disguised or wholly obliterated after long exposure.

The two quarries examined are situated on the north side of the creek immediately on the water. They are about 1½ miles apart.

THE LOWER QUARRY.

The lower quarry is about 2 miles above the railroad crossing over Aquia Creek. At this place the thickness of the Potomac shown, measured by aneroid barometer from the lowest excavations to the highest, is 140 feet, nearly all of which is a coarse sandstone. The hills around show about 40 feet more of similar material. Hence we have now visible about 180 feet of the formation. It has lost much from erosion, and its surface has been left in a very uneven condition. There are two openings or workings here, one about 200 yards farther up the creek than the other.

The greater portion of the Potomac at this quarry is a pretty firm, coarse, gray grit, generally composed of rather large grains of sand, packed in more or less of light-gray clay. This is not true kaolin,

although it is quite light-colored. The normal color of the fresh rock is light-gray, but it often contains irregular patches, spots, and seams of colors due to oxide of iron, such as yellowish, brownish, and reddish. These colors often mark the current-bedding planes and the outlines of the lenticular layers which generally characterize the rock. The rock contains very often scattered pebbles ranging in size from 3 to 4 inches down. In some spots and in some horizons clay balls are common, and occasionally large masses of rolled clay are found. These clay balls sometimes are mingled with pebbles. They seem to mark erosion horizons. Clay seams and partings, lenticular in form and limited in length, may be seen, but they are rare at the quarries because these are located where the rock has such qualities as would exclude clay layers.

The lower opening shows mostly a coarse grit, stained with much ferruginous matter, and lying in heavy, lenticular layers. Most of the stone shows scattered, small quartz pebbles, and clay balls occur sparingly. The latter range in diameter from 3 or 4 to 12 inches, being mostly of the smaller size. About 25 feet below the top of the quarry there is a layer indicating erosion. It is made up mainly of clay balls and quartz pebbles, and is from 1 to 2 feet in thickness.

Near the top of the sandstone there is another erosion horizon. It is marked by an irregular layer composed of sandstone containing numerous clay balls and cobbles. The clay is arranged in more or less continuous layers made up of clay balls. On this horizon there is a huge mass of clay, apparently a rolled portion of the original clay bed. It is isolated and embedded in the coarse sandstone. On the exposed face it is 6 feet long and 4 feet thick. As it is composed of a tenacious and plastic bluish-gray clay, it contrasts strongly with the coarse grit that surrounds it. The stratum of mixed cobbles and clay balls in which this mass lies is from 1 to $2\frac{1}{2}$ feet thick. On the top of this erosion horizon is a layer, 8 to 18 inches thick, of laminated pale-reddish sandy clay, which contains a few obscure plant remains. The sandstone quarried here has at its top a layer 4 feet thick of the mottled sandy clay. It is soft, and in color brick-red, mottled with a little gray. Some portions of it are yellowish-brown.

The upper opening was made on a point 140 feet high that overlooks the creek. Except at the base, near the level of the water, the material is nearly all sandstone from top to bottom. It is, however, very variable, some portions being very siliceous and coarse, and others more argillaceous and incoherent. The mass is arranged mainly in thick, interlocking, lenticular layers. Here and there a thin, irregular layer of clay occurs. One of these clay layers was seen about halfway up the bluff. It was 12 inches thick where seen, and pale-reddish in color. Some fragments of coniferous twigs were found in it.

The lowest portion of the bluff exposed showed 8 to 10 feet of mottled sandy clay, which graduated into the normal Potomac sandstone.

This clay is mottled and marbled with reddish and brownish-red colors, the tints being bright.

The Potomac material is best exposed at and near the top of the bluffy point, for here most of the excavation was made in search of stone for the purposes of construction. Portions of the layers here, over an area of many square yards and sometimes to the thickness of 3 feet, are made up of a mixture of clay balls and sandstone. In some places nearly all the material is clay, and in others the balls are scattered in the sandstone. Most of these balls are small, ranging from the diameter of 4 inches down to a small fraction of an inch. The greater part of the clay is pale-reddish to chocolate in color, and it varies from a sandy clay to a pure plastic clay. Only small, unrecognizable fragments of plants occur in the clay here. Some portions of the sandstone, coming above the horizon of the clay balls, seem to have been at one time full of fragments of the limbs of trees. These fragments, from some cause, have been removed, and are represented now by cavities. Some little lignite still remains.

Much of the rock in the upper part of the bluff is full of small quartz gravel. The largest pebbles do not surpass the diameter of 2 inches. While most of the clay is deposited in the sandstone in distinct balls of some size, this is not the case with all of it. It is sometimes mixed intimately with the sandstone in minute pellets that are hardly larger than the grains of sand. In rare cases the clay occurs in redeposited large cakes and masses, embedded in the sandstone. The small stones abound on the horizon of the clay masses and balls.

THE UPPER QUARRY.

The upper quarry is situated at Coal Landing, a point near the head of the estuary or "creek" portion of Aquia Run. In former times large quantities of stone were taken out from an island in the creek at this point, and some of this was used in the construction of the old Capitol at Washington. The stone taken from the island appears to be more uniform and of better quality than that found in the newly opened quarry near by, which is one of those originally worked and is situated higher up in the hills on the creek, being about 80 feet above the water. A large space has been excavated here, leaving an open pit with abrupt walls on three sides. These walls disclose pretty well the character of the rock, about 20 feet being thus exposed. The lower portion of one of these walls is formed by a massive, projecting ledge of sandstone which has been undermined, and in consequence of this its under face is shown for some distance. If we may take the lower face of this ledge as giving the dip of the rock, this amounts to 15 degrees, in a direction 50 degrees east of south. But in the base of the hill containing the quarry, and near the level of the creek, where 30 feet of the lower rock is shown, the sandstone seems to dip only from 1° to 2°, in a direction

70° east of north. Such apparent dips are probably only the faces of particular masses in the sandstone.

The rock of the quarry is sandstone of the usual kind, showing much variation in composition and texture. The normal color is gray, often very light-gray, but many of the usual irregular markings and blotches of yellowish-brown and reddish colors occur. As a rule, the rock is pretty firmly consolidated, and is a coarse grit. Toward the top of the quarry considerable lignite occurs scattered confusedly in the sandstone. This is formed of the trunks and limbs of coniferous trees, broken into rather small fragments. These occur in pockets, and stand sometimes on end in various positions, as they were thrown down confusedly. Balls and streaks of tenacious gray clay occur scattered irregularly and at different levels in the sandstone. These contain obscure fragments of plants.

The more firmly consolidated parts of the sandstone, as is commonly

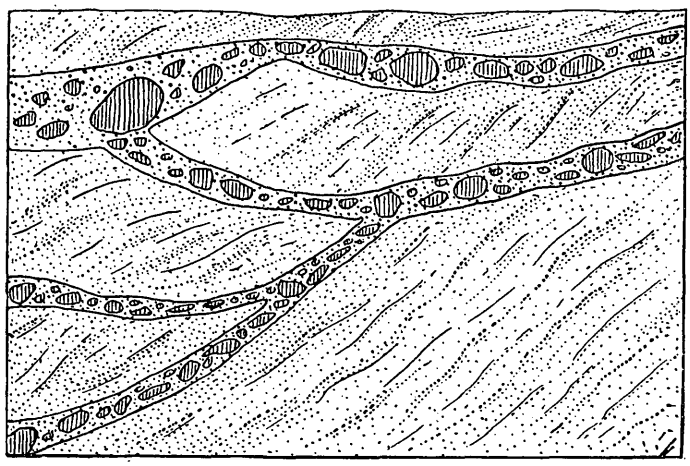

FIG. 11.—Erosion horizons at the upper quarry on Aquia Creek.

the case elsewhere, occur in wedge-shaped masses and lenticular layers that interlock. The walls of the quarry show at several elevations erosion planes or horizons. The most important of these is near the top of the sandstone in the quarry. This is covered by 4 or 5 feet of a very coarse and current-bedded, highly ferruginous sandstone. This erosion horizon is a layer in the sandstone varying in thickness from 6 to 48 inches. It has much lignite in fragments, a number of large balls and masses of clay, and many cobbles of quartz. One of the rounded clay masses lying on this horizon is 3½ feet in diameter.

Another horizon or plane of the same general character occurs at a lower level, but it has a curving course, so as to embrace, with the adjacent erosion planes, a wedge-shaped mass of the sandstone. This horizon also is marked by lignite, clay balls, and cobbles. In one place there is a cavity once occupied by the lignitic trunk of a tree which must have been 18 inches in diameter. The lignite of this tree has mostly wasted away. Other and shorter erosion horizons occur which

also have a winding course, and, by their junction with adjoining ones, mark out on the walls of the quarry wedge-shaped and lenticular spaces. Fig. 11, gives a generalized representation of these erosion planes.

In some parts of the sandstone small clay pellets occur in such numbers as to make up the larger portion of the material. In the upper part of the quarry several thin partings of pale-reddish shale occur. These show a few recognizable imprints of plants. These layers are mere parting films in the sandstone and soon disappear.

The character of the Potomac material here down to the level of the creek does not vary essentially. At the foot of the hill in which the quarry is situated the sandstone is mostly gray, but has many seams and spots of colors from iron oxide. The material is here not so predominantly consolidated as at the quarry. It is composed of friable, argillaceous, and fine-grained layers, alternating with coarse and firm ones. Some large balls of sandy gray clay are embedded in the sandstone. One was seen having dimensions 5 by 10 by 12 inches.

EXPOSURE ON THE TELEGRAPH ROAD AT AQUIA RUN.

Immediately south of Aquia Run (which is the upper part of the stream known in its tidal portion as Aquia Creek), on the Telegraph road, there is a tolerably good exposure of the Potomac. The material here differs from the typical sand and sandstone of the Potomac in its more eastern exposures, for it has a larger proportion of colored clay, and the deposits are finer-grained and more highly colored. The following is an approximate section made in ascending the road from the run:

Section of the Potomac formation along the Telegraph road south of Aquia Creek.

	Feet.
1. Laminated gray and pale-reddish sandy clay	6
2. Greenish-gray mottled sandy clay	15
3. Very variable mottled sandy clay	30
4. Cobblestone bed, partly exposed (seen)	2
5. Sandstone (top only seen)	

No. 5 shows its top only partially, about 20 feet above the level of the run. It is of the usual variable, coarse, gray kind.

The cobblestone bed, No. 4, owing to the waste of its outcrop, was not well enough exposed to show its true thickness. It contains quartz cobbles and subangular fragments of pre-Cambrian rocks.

No. 3 is a thick mass of crumbling, argillaceous matter that is not exposed throughout its whole extent. Toward its base it is dark purplish gray. A little higher up it is more purely gray in color. Portions of it are mottled with yellowish-brown and white colors. An interval of about 4 feet is concealed. The rock is then marbled in the same manner as the mottled sandy clay of Hazel Run, near Fredericksburg. This portion is 5 feet thick and is quite sandy. It graduates above into No. 2.

No. 2 is a sandy clay, predominantly greenish-gray in color. In some

parts it is mottled with yellowish-brown; in other portions large nests and pockets have this tint in solid mass. The material is fine in texture, as a rule, but shows some lenticular masses with a more sandy composition and coarser texture than usual, and these tend to pass into the typical Potomac sand. These masses have a light-gray color, mottled with yellowish-brown.

No. 1 in its lower portion, which is 3 feet thick, is a well laminated fine sandy clay. The color is uniformly gray. The upper 3 feet of the bed, however, differs in character, for it is a pale-reddish well laminated sandy clay of very fine texture, that has many small fragments of plants. It differs in no respect from the reddish clay so common in the Potomac group. The fragments of plants, however, are not recognizable.

EXPOSURES AT QUANTICO.

The Potomac sandstone is well exposed in Shipping Point, at the entrance of Quantico Creek into the Potomac River. It shows the usual features possessed by the sandstone. Current-bedding, clay balls, and cobblestones are prominent in it, and the structure of interlocking, lenticular layers occurs. From this point as far as Fort Washington the Potomac formation is visible on the Potomac River, except in the places where it is replaced by the Pleistocene.

The distance by the Telegraph road from Aquia Creek to Dumfries, on Quantico Run, is about 11 miles. Throughout this distance the road keeps near the western margin of the formation, whereas the mouth of that run is near the eastern margin. The material along the road in this interval differs considerably from that exposed along the river, being more argillaceous and highly colored and of finer grain. In fact, the section given on this road at Aquia Creek would fairly well represent most of the exposed material along the Telegraph road. The formation shows in its upper portion various mottled and incoherent sandy clays and highly argillaceous sands. They are imperfectly displayed, owing to the great erosion of the outcrops. The lowest material seen is the coarse, variable sandstone, which in this quarter is a sand rather than a sandstone. The most abundant material, forming the higher parts of the exposures, is an incoherent fine sand, with varying amounts of clay, sometimes approaching a pure clay. This is mottled and banded with various shades of red irregularly arranged in the predominant gray color. In this interval the Telegraph road runs parallel with the Potomac River and about 5 miles west of it, the Potomac formation making all the surface rock shown in this space. The western border of the formation is generally located from 1 to 2 miles west of the road.

In the vicinity of Dumfries, and south of it, the Potomac formation is mainly composed of a very light-gray to white, friable, loose sand with much diffused kaolin. About 80 feet of this is shown, and it extends for about 2 miles west of the village. It quite commonly contains small

clay balls and scattered small stones. Toward the base some bands of purplish clay, and balls of the same material, occur in it. This Potomac material west of the village and up to it forms the upper portion of the hills.

In approaching the village from the west, and in descending to the level of Quantico Run, on which Dumfries is situated, we pass below the Potomac formation and come upon the crystalline rocks on which it rests. These are exposed in the village and for some distance (about 50 feet) up in the hills. They are laid bare by the run, which has cut down some distance into them.

This crystalline rock is quite different from that which forms the basis and the western margin of the Potomac south of this point, as at Fredericksburg and at Potomac Run. At Dumfries the crystalline rock is a dark-gray to bluish-gray slate. It is lustrous and has a very fine grain, and it contains a great deal of quartz, in nests, pockets, and irregular veins. It is very much like the basal Paleozoic slates. There is a great contrast between the nearly white Potomac sand and the clay which results from the decay of this slate. This indicates that the sandy portion of the Potomac must have gotten its material from some other source than this slate. Slate of similar character bounds the Potomac on the west, and serves as its foundation, as far north, certainly, as Alexandria.

On the northern edge of Dumfries, mottled sandy clay, like that so abundant between that place and Aquia Creek, may be seen resting immediately on the slates and showing a thickness of 15 feet or more. It replaces the white, crumbling sand seen farther west, and seems to be simply a modification of that material, and not a distinct formation. A little north of the village the white sand comes in again, and upon this, or at least at a higher level, various mottled sandy clays appear in force on the road toward Neabsco Run. This sandy material is like that seen on the road before reaching Dumfries; that is, south and west of that village. It is gray, and mottled with reddish colors. In some places large patches are colored solidly reddish. Some of it is nearly pure clay, and is so tenacious in wet weather as to make it difficult for one to force one's way through it.

Neabsco Run is 5 miles north of Dumfries. The Telegraph road crosses all streams emptying into the Potomac above the head of tide; that is, over the "run" portion of them. The following section was taken along the Telegraph road on the south side of the run. The road here is about half a mile from the western margin of the formation:

Section on Neabsco Run.

	Feet.
1. Mottled greenish-gray sandy clay	10
2. Mottled gray incoherent sandstone	15
3. Concealed ground	6
4. Coarse gray crumbling sandstone	10
5. Slate breccia and cobblestones in disintegrated sandstone, partially exposed; thickness unknown.	

The deposit No. 5 is an unusual one on account of the large proportion of slate fragments in it, their sound condition, and their angular form. It is visible at several localities in this neighborhood, but nowhere else. It occurs about 20 feet above the water of the streams and is mainly a mass of angular slate fragments, large, rounded, quartz cobbles, and subangular masses of gneiss, mica-schist, and other distinctly crystallized pre-Cambrian rock. These are all packed in coarse, sandy matter. The slate comes from that bordering the Potomac on the west. All the outcrops showing this stratum were much worn and broken down by erosion. Owing to this it was not possible to determine positively the relations of this material to the Potomac formation. It may be of quite recent origin, the material being brought down by the present runs. In one place, however, it occurs remote from any run. On Neabsco Run the quartz stones range in diameter from 3 to 12 inches, the latter size being rare. Some large rounded stones of Potomac sandstone are found. The slate fragments are very numerous and mostly small. Subangular masses of siliceous argillite, evidently coming from the slate belt, may be seen, having the dimensions 2 by 2½ feet. Subangular masses of quartz from 2 to 3 feet in diameter may occasionally be found. One subangular mass of a hornblendic granitoid rock, having the dimensions 2 by 2½ feet, was present.

No. 4, and indeed all the sandy matter from this point to Alexandria and beyond, is, in outcrop at least, an incoherent sand. In going north from Stafford County there seems to be a change in the consolidation of the Potomac sand, firm sandstone being no longer found anywhere. The material of No. 4 is a coarse, gray sand, but this is banded with yellowish-brown streaks that are formed of sandy clay and contain some balls of sandy clay.

No. 2 is a massive sand of gray color, but its contains irregularly shaped masses colored yellowish-brown, and toward the top embeds some clay balls.

No. 1 is mainly a greenish-gray sandy clay mottled with bright tints of reddish and brownish colors. In this material there are embedded spots of a yellowish, highly ferruginous sand.

EXPOSURE ON POWELLS RUN.

The Telegraph road crosses Powells Run 1½ miles south of Neabsco Run. A partial section was made along this road on the south side of the run ascending from it. On the north side of the run and about 20 feet above it there is a slight exposure of the slate breccia with quartz cobbles. The finer matrix here is a mottled sandy clay. On the south side of the run the material to the height of 50 feet above the run is mostly hidden. It seems to be all a mottled sandy clay or argillaceous sand. The color of the greater portion is dark gray, but this is mottled freely with yellowish-brown, and considerable portions,

irregular in shape, are colored solidly yellowish-brown. Fifty feet above the level of the run the exposures, beginning in a gully, are good and nearly continuous to the top of the hill.

The exposed material is as follows:

Section on Powells Run.

	Feet.
1. Variable and variegated sandy clay	30
2. Cobblestone layer with clay masses	2 inches to 6
3. Greenish-gray clay	1
4. Mottled gray, pebbly sand, thickness unknown.	

No. 1 is composed of very variable material. In some places rounded pockets and nests of quite pure limonite are embedded in the mass, seemingly formed by concretionary action. The ore is nodular and in crusts. About 4 feet above the base the material is a nearly pure clay. It is here pretty well laminated, has a dull reddish-brown to liver color, and contains poorly preserved fragments of plants. This portion is from 2 to 3 feet thick. The material lying over this, farther up in No. 1, is an argillaceous sand of uneven or lumpy structure. It is mainly gray in color, but large irregular portions of it have a yellowish-brown color. In some spots and layers the colors are reddish-brown and pinkish- or greenish-gray. Near the top of the mass there is a brick-red claystone, marbled with a little gray. Associated with this, and lying immediately under it, there appears what seems to be a local layer of gray sandstone 6 feet thick.

No. 2 is composed of balls and masses of greenish-gray clay and of cobblestones packed in a coarse sand like that of No. 4. The cobbles and clay balls are arranged in lenticular layers that thicken, and then thin nearly out. Some of the clay masses are over 2 feet in diameter. Most of the cobbles are composed of quartz and are well rounded; some, however, are formed of a much decayed felsitic rock or of argillite. The original nature of the parent rock could not be made out with certainty, as the material was too much decomposed. Some of the largest cobbles are from 8 to 10 inches in diameter.

No. 3 is a mere remnant left uneroded of some bed that was once much thicker. In some places it has been entirely removed. It is a fine-grained, well-laminated, greenish-gray clay. This bed has apparently furnished by its erosion the clay balls found in No. 2.

No. 4 has its lower portion concealed, and hence its thickness is not known. It seems to be the usual coarse and current-bedded rock of the lower part of the Potomac. It is seamed and blotched with yellowish-brown and reddish colors. This material is full of small quartz pebbles that are scattered irregularly in its mass.

The exposures described along the Telegraph road are all near the western margin of the Potomac formation. Those next to be noticed lie near the eastern margin.

EXPOSURES ALONG THE RAILROAD FROM POWELLS CREEK TO COCKPIT POINT.

The Potomac formation is well exposed from Powells Creek to Cockpit Point, along the line of the Alexandria and Fredericksburg Railroad, and is shown in the cuts. This railroad forms a portion of the Atlantic Coast Line Railroad, and extends from Quantico to Alexandria. It is the only railroad running in the Potomac formation between these points. Its location for a short distance south of Powells Creek is near the Potomac River, and then as far as Quantico it runs immediately on the banks of that stream.

The Potomac material in the series of exposures made along the railroad, in the space between Quantico and Powells Creek, is very variable, but a loose, light-gray to white sand predominates. In most respects this is identical in nature with the typical Potomac sand. It has, however, rather more diffused kaolin than usual, and is quite incoherent.

In the cut nearest to Powells Creek the sand shows a maximum thickness of about 30 feet. It is white and crumbling. Near the top there are some thin, lenticular layers of pale greenish-gray clay, and some lenticular beds of pebbles of small size. Some pebbles are mixed with the sandy clay even. The upper portion of the sand, as followed successively in the cut, shows pretty constantly some lenticular clay beds, and sometimes these layers unite and form beds of considerable horizontal extent.

A few hundred yards farther south, in another cut, the sand is not so white. It now is a gray, sometimes a dark-gray, material. It is also more ferruginous, and shows a number of irregularly shaped portions that are colored yellowish-brown. A sandy clay layer, lenticular in shape, and having a maximum thickness of $2\frac{1}{2}$ feet, now comes in at the base of the mass. It has the character of the mottled, sandy clay, being pale greenish-gray in color, mottled with yellowish-brown in an irregular manner. It is a redeposited and recemented clay, and has small pebbles scattered through it. At its top there is a pebble layer 3 to 4 inches thick. These layers of sandy clay, occurring at both top and bottom of the cuts, seem to represent erosion horizons. The sand under the lower layer of sandy clay and gravel has occasional clay balls embedded in it which attain sometimes the diameter of 8 or 10 inches. The sandy clay which appears in the upper part of the cut here is a lenticular plate with a maximum thickness of 12 inches. It is a well-laminated gray clay with obscure impressions and fragments of plants.

A little south of this spot, and on the horizon of the lower gravel and the sandy clay, we find a lenticular bed of gravel, packed in coarse and current-bedded sand. It seems to be a local expansion of the gravel layer over the lower, sandy clay. For a long distance this lower

horizon of sandy clay and gravel seems to be one indicating the action of tumultuous waters, for the gravel last spoken of passes into a layer of sand varying in thickness from 1 foot to 3 feet. This is full of rolled fragments and balls of greenish-gray clay and gravel. This condition of things continues for several hundred yards.

The sand above this erosion horizon is massive, and contains occasional cakes and balls of gray clay. Some of these have an angular shape and are 10 to 18 inches on the exposed face. Some quartz stones on the erosion horizon are 5 inches in diameter. The massive sand has in many places no trace of structure planes, and it looks like a mass of agglutinated sand.

At one place the upper part of the mass of sand shows a plate of well-laminated pale-reddish clay, 12 inches thick and 20 feet long. This is embedded in the sand and has both ends cut squarely off, as is shown in fig. 12. It has some obscure plant impressions.

A little south of this, and in a cut at Cherry Hill Station, the lower layer of gravel and recemented clay is capped by a plate of sandstone 6 to 7 inches thick. This is covered by a lenticular layer of laminated dark-gray clay, 2 to 3 inches thick, that contains a few well-preserved plant impressions, the most common being coniferous twigs. For three-fourths of a mile south of Cherry Hill Station, where the railroad first strikes the banks of the Potomac River, the cuttings are slight and show only from 6 to 10 feet of the formation. For half a mile south of the station none of the typical sand is visible, but all the Potomac matter in sight is a greenish-gray sandy clay, from 4 to 6 feet thick, with the base not visible. The color and the composition of this material, so far as seen, appear to be quite uniform. In some portions, however, the material is decidedly green, and the tint is brighter than any seen elsewhere in the formation. Some of the argillaceous matter is laminated, but most of it, in the outcrops at least, is lumpy and disintegrates into small angular particles. After passing over the space of about half a mile, some brick-red color begins to shows itself in the predominant gray, appearing in very irregular streaks and patches, and producing a mottling. This, then, is a variety of the mottled sandy clay. From this point for some distance to the south, the cuts are deeper and show more of the formation. The sand, so common in the Potomac, appears over the mottled sandy clay, this last graduating into it and not forming a distinct stratum. This sand is coarse and predominantly gray in color, but it has yellowish and yellowish-brown colors and occurs in irregular masses and pockets. Some of it is laminated locally, although most of it is massive.

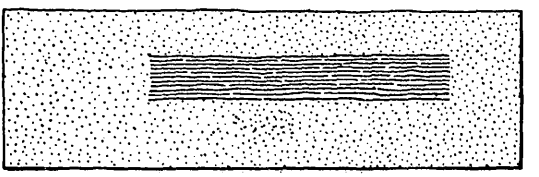

FIG. 12.—Eroded clay layer near Powells Creek.

A little farther south, and near Cockpit Point, a cut in the face of a small bluff indicates that the greenish sandy clay has disappeared, apparently from the thickening of the overlying sand. The lowest material seen here is the typical current-bedded coarse sand. This shows about 10 feet. Its top is eroded and is covered by a layer, 4½ feet thick, of very large cobbles, with occasional large masses of subangular quartz in its base. The cobbles are of quartz and many of them are 8 inches in diameter. One of the subangular quartz masses measured 8 by 12 by 18 inches.

In one place between the cobble bed and the underlying sand there is a small remnant left uneroded of a stratum of pale reddish-brown clay. This, in its thickest portion, is 2 feet through, and it contains some fragments of plants. This and all below it are Potomac, but the cobble bed and all above it are probably Pleistocene. Over the cobble bed comes a brownish and yellowish-gray unbedded sand with several layers of cobbles in it. This is 4 to 5 feet thick. It is the highest stratum exposed here.

Two hundred yards south of this spot is a high bluff cut through by the railroad. As it is situated near Cockpit Point, the exposure there may be identified by this name. Cockpit Point, like many other points on the river, is a low marshy tongue of land extending out into the river.

EXPOSURES AT COCKPIT POINT.

The main cut at Cockpit Point is the most northern one. It shows a considerable vertical height of material. Several cuts farther south give continuations of the horizons exposed in the main cut, and show very important modifications in the material, illustrating well the extreme changeableness of the Potomac strata. In these cuts the level of the railroad track is 12 feet above the river and the material occupying this interval is not fully exposed. It seems, however, to be all composed of the usual current-bedded sand.

The material exposed above the railroad track is so variable that a section taken at one point can not be considered as representing the condition of things even in the same cut a few yards away. At the apex of the curve made in cutting around the principal bluff and in the main cut, the following materials are shown, in descending order:

Section in railroad cut at Cockpit Point.

	Feet.
1. Sandy clay, brownish and unbedded	3+
2. Brownish-yellow sand and gravel	5
3. Grayish stratified sand	5
4. Incoherent brownish to yellowish-gray sand	2 to 3
5. Light-gray coarse and massive sand	20
6. Ferruginous sand	½
7. Greenish sandy clay varying to sand	10

No. 1 forms the top of the nearly vertical face left in the cut. Much of it has evidently been removed by erosion. It is a loose sandy clay

of brownish-gray color, with distinct stratification planes, has small stones scattered though it, and appears to be Pleistocene.

No. 2 is composed mostly of small gravel packed in brownish-yellow sand. The material is well stratified, and the stratum is composed of alternating layers, some full of stones and others almost free from them. In the central part of the stratum there is a conspicuous layer, containing very large cobbles that contrast strikingly in size with the adjacent gravel. All of these stones are of quartz, the largest of them attaining the diameter of 12 inches.

No. 3 is well stratified. The greater portion of the material is gray in color, but the stratification planes are marked out by yellowish-brown colors so as to divide the bed by colored bands. The material of this bed is fine and somewhat argillaceous. It and all the strata above seem to be Pleistocene. All those below are certainly Potomac.

No. 4 appears to be the highest bed of the Potomac formation. It seems to thicken when traced horizontally, and to partially cut out No. 5. This is not due to erosion, but to the graduation of the one kind of material into the other. No. 4 thickens rapidly southward at the expense of No. 5, for it becomes 10 to 15 feet thick and more. It contains at the locality now being described, in its middle, a layer about 1 foot thick that is full of large cobbles. Some of these cobbles are 12 inches in diameter, and they are all of quartz, as are all the larger stones in this exposure. The brownish and yellowish colors of this bed are mingled in a very irregular manner, and the material is much more incoherent than that of No. 5. It has the current-bedded structure and interlocking lenticular layers so common in the Potomac formation.

No. 5 is the most important member in the cut. It is for the most part composed of sand of the normal type. This is arranged in massive and interlocking wedges and lenticular layers. It is in places a sandstone, being firm and coherent. It tends to thin out north and south, and to give place to an incoherent sand. The change takes place to the south in the space of a few yards. Two or three feet from the top of this stratum, there are some lenticular beds of pebbles, arranged on the same horizon along the face of the cut, together with clay balls. They continue beyond the horizontal limits of No. 5. Embedded in the top of No. 5, and extending beyond it, we find a number of clay balls and clay masses, from 12 to 36 inches in diameter. These form a definite horizon of clay balls.

In and near the base of No. 5 is a remarkable exhibition of masses of rolled clay. We find here clay balls and huge masses of clay embedded in the coarse sand. They are generally associated with gravel and cobblestones, forming a well-marked erosion horizon. The original clay bed from which this clay was eroded seems to have been entirely destroyed, for no bed of clay like it is visible. Some of the clay balls of smallest size, 1 foot or 2 feet in diameter, are composed of pale-reddish clay and contain some indistinct fragments of plants. The large rolled masses are sometimes 4 or 5 feet in diameter. They are

composed mostly of pale reddish-brown clay, and are in places full of fragmentary rootlets. These larger masses are found at the very base of No. 5, where it joins No. 6. For the space of 4 or 5 feet above the base of No. 5 many smaller clay balls and numerous cobbles occur. The cobbles are found scattered, and also, in the lower part of No. 5, aggregated into detached lenticular layers.

No. 6 is a local lenticular plate that serves as a capping to No. 7. It soon thins out and disappears. It seems to be merely a portion of the top of No. 7 which has been cemented by iron oxide. In some places it has enough iron to make it a sandy ore of that metal.

No. 7 is the lowest material of the Potomac that is fully exposed at this place. It is essentially the same material as the greenish-gray sandy clay seen toward Cherry Hill, and is on the same horizon with that. It is a variety of the mottled sandy clay so common in the Potomac. It is here, however, more sandy and variable in color. It has a predominant greenish-gray color, but shows much red and reddish brown, arranged in irregular spots, blotches, and films. In some cases a marbling of the colors occurs, so minute as to be shown even in hand specimens, but in the greater portion of the material the colors are found in considerable masses. The material of No. 7, when dry, appears as a firm sandy claystone, with no structure planes.

The above description applies to the material seen in the apex of the main cut. In the next cut a few yards to the south, No. 7 has thickened to 13 feet, the top is more sandy and more firmly consolidated than in the main cut, and the larger portion of the bed is a firm sandy claystone of a pale greenish color.

No. 6 in this cut, which we may call cut No. 2, is 2 feet thick, and is a firm sandstone, being the only firm rock above No. 7. Here it is nearly free from iron. Over No. 6 come 12 feet of soft crumbling white sand, with some clay balls in the lower portion, and some bands of cobbles. This, the representative of No. 5 of the main cut, shows none of the consolidation seen in that, and is much more uniform.

No. 4 is here 10 to 15 feet thick, having increased at the expense of the other strata. It extends to the top of the cut, which is lower here than in the main or most northern cut. It has the same character as in the section given for the main cut; some of the cobbles, however, are unusually large, being 24 inches in diameter.

A few yards farther south, and still in cut No. 2, stratum No. 7 is more than 20 feet thick, increasing at the expense of the overlying beds. Large irregular portions of it are colored bright brick-red or purplish red, the colored parts taking the form of nests and pockets in the greenish-gray material. Nos. 5 and 6 have both disappeared, and all the material overlying No. 7 is a brownish-gray sand, 20 feet thick. In the base of this, resting on No. 7, there is a cobblestone bed with clay balls. When examined closely, this brownish sand, as it seems to be when seen at a little distance, is found to be a coarse gray sand,

with so many minute films and spots colored brownish-yellow, and so intimately mixed with the gray material, that the general effect of the mixture is to produce a brownish-gray color. This sand contains numerous thin short layers and balls of pale-reddish clay, so arranged as to form more or less continuous zones and layers that are made up mostly of this clay. The clay is plainly eroded from some older clay bed and redeposited here.

In the next cut, 30 yards south of the last, which may be called cut No. 3 and which has slight depth, No. 7 may still be traced, but its central portion has become indurated to some extent, and changed to the whitish sand so common in this portion of the Potomac area. This part is 10 to 12 feet thick. It has above and below it two layers with mottled colors, each 2 or 3 feet thick and both belonging to the bottom bed, or No. 7. The upper one is a gray clay stone with brown colors in irregular patches and spots. The lower one, with its base not visible, is the usual mottled sandy clay.

Over No. 7 in this cut comes 12 to 20 feet of the brownish-gray sand described as seen in cut No. 2. Its character here is unchanged, except that it has a number of short seams of small pebbles, and much of the transported clay is in the form of numerous small scattered balls.

LIGNITE DEPOSIT NEAR NEABSCO RUN.

This deposit is situated on the western margin of the Potomac formation about three-fourths of a mile west of the Telegraph road where it crosses Neabsco Run. The lignite occurs in seams of dark-gray and pale-reddish clay, embedded in the Potomac sand. The clay is very tenacious and plastic. It occurs in the original uneroded beds, which take the form of lenticular layers lying in coarse gray sand. This sand has many irregular patches and seams colored yellowish-brown. It rests on a dark-gray to bluish-gray slate, that forms the western boundary of the Potomac formation here. This is similar to the slate seen near Dumfries. The sand and clay combined give a thickness of about 8 feet. The lignite is shown along the channel of a small stream for the space of about 40 yards. The clay contains nearly all of the lignite and all of the plant impressions found here. The clay layers occur very irregularly in the sand, and vary in thickness from 1 to 12 inches. These layers extend through a vertical thickness of about 4 feet. In them may be found a number of the flattened trunks of coniferous trees, now changed to lignite. This lignite has the same character as that found near Potomac Run, uniting the features of ordinary lignite and jet. Some of the trees must have been quite large. One trunk was seen having a maximum thickness of 7 inches, and a width of 42 inches. In the clay a few well-preserved impressions of ferns and coniferous leaves were found. The most important fossil plant occurring here is the fine cycad, *Dioonites buchianus*, which is so common at Dutch Gap, and which is of special interest, as it is

characteristic of the lower Cretaceous (Neocomian) strata of the Wernsdorf beds of Europe. This plant is so abundant in some portions of the clay that the leaves are matted together. They are preserved well enough to retain nearly all their plant substance. Both here and at Dutch Gap, wherever this fossil is very abundant in a stratum, few other impressions are found. It is to be noted that this is the first place north of the James River where this was seen. As has been stated, it was much the most abundant plant on the James River. While a very large number of fossils were at Fredericksburg, Potomac Run, and near Brooke, no trace of this plant appeared. It was therefore surprising to find it in such numbers at this place. It is an important connecting link between the floras of the Petersburg and Fredericksburg areas.

The higher portion of the sand, at the spot now described, contains clay balls, cobbles, and remnants of clay layers left uneroded.

EXPOSURES ON THE COLCHESTER ROAD NEAR NEABSCO RUN.

Immediately after crossing Neabsco Run the Colchester road leaves the Telegraph road and turns northeast to the village of Colchester. This is situated on the north side of Occoquan River. The Telegraph road pursues a course more nearly north, and crosses the Occoquan 2 miles above Colchester at the village of Occoquan. This latter road from Neabsco Run to Occoquan runs close to the western margin of the Potomac formation and usually a little east of it, consequently the Colchester road keeps well within it.

On the Colchester road, about three-fourths of a mile from its point of departure from the Telegraph road, there is an exposure of the Potomac worthy of mention. The formation may be seen in ascending a long hill on the southwest side, and also in descending the same on the northeast side.

Beginning on the southwest side the lowest material seen shows a thickness of about 20 feet. It is mainly a tolerably well laminated sandy clay, of ash-gray color, sometimes dark gray. This is mottled with irregular spots, seams, and films of yellowish-brown. In this material, the sand in which varies in amount, we find at different levels and confusedly distributed irregularly shaped partings and seams of a pale reddish-brown clay, which in some places is associated with and graduates into an ash-gray clay. These clay layers vary in thickness from a few inches to 3 feet. They are mostly lenticular in form, and thicken or thin in a very irregular manner. The color varies irregularly, for in one portion the layers are pale-reddish while in the adjacent parts they are ash-gray. Obscure fragments of leaves of plants and many small pieces of lignite occur in these clays, which are all redeposited matter. In one of these layers, where it is about 3½ feet thick and more sandy than usual, there is a flattened log

of silicified wood. This is coniferous. It is 8 feet long, 2½ feet wide, and 6 inches thick, as now visible. It was once much longer.

On the eroded top of the above-described material comes a bed of cobbles from 3 to 4 feet thick. The stones are of quartz and some of them are of large size. Above the cobble bed there is a mass of material about 50 feet thick. This is not well exposed on this portion of the road. It seems to be in the main a more or less argillaceous sand, usually colored some shade of gray, but much mottled with yellowish and brownish colors. The clay partings are much fewer in this than in the lowest material described above.

As seen on the road descending the hill on the northeast side the highest material exposed in the top of the hill is a mass about 40 feet thick, composed mostly of light-gray sand. Portions are beautifully seamed with yellowish-brown films. These mark the current-bedding planes and are abundant in the material. Near the top is an erosion horizon which is marked by a line of balls of gray and pale-reddish clay. Cobblestones also occur here, and uneroded remnants of a seam of pale-reddish clay. Clay balls and small stones are scattered through the mass of the material below the erosion horizon, and 40 feet from the top there are numbers of clay balls and some thin layers of pale-reddish and gray clay. The exposure is then imperfect to below the horizon of the lignitic material mentioned as seen on the southwest side of the hill. This lignite does not show itself on the northeast side of the hill. On this lower horizon all that was seen was a well-marked clay-stone of a predominantly gray color that is marbled with brick-red.

EXPOSURES AT FREESTONE POINT.

The cut through Freestone Point is the most extensive one on the line of the Alexandria and Fredericksburg Railroad. The cut is made through the promontory which projects into the Potomac River between Powells and Neabsco creeks. The material exposed in this cut is a little north of the northern end of the exposures described before, and which extend from Powells Creek to Cockpit Point. The railroad track in the cut descends slightly from south to north, so that somewhat lower strata are exposed in the northern than in the southern end of it. The material exposed in the cut is so variable and so confusedly mixed that no complete account can be given of it without tedious detail. I shall attempt to give only the leading features that are to be seen in going from south to north. Most of the matter seen is an incoherent, light-colored, coarse sand, with more or less diffused kaolin. It shows numerous alternations in composition, structure, and color.

In the southern end of the cut only 10 to 15 feet of rock can be seen, for the excavation here has its least depth. All the material shown at this point is a gray sandy clay, with some layers of fine-grained, argillaceous sand. The matter is divided into tolerably distinct beds, which

seem to be horizontal. It is all much affected by current bedding, and is seamed irregularly with yellowish-brown films. In some places the more argillaceous layers assume the nature of the mottled, sandy clay, which is a characteristic member of the Potomac formation. This is lumpy and massive in structure. Such is the character of the lowest portion seen, and this has many small pebbles and ferruginous partings.

Going farther into the cut, this material thickens rapidly, causing the top of it to appear to rise. Here the basal portion contains some clay balls, and under the mottled sandy clay, a coarse sand begins to appear. This latter is mainly dark gray, but contains numerous blotches of yellowish-brown. This sand has the usual structure of the coarse portions of the Potomac formation, being composed of interlocking lenticular layers. It also contains some lenticular beds of cobbles or pebbles, the largest being 3 inches in diameter. Many scattered pebbles also occur, most of them being of quartz, but some are composed of argillite and gneiss. The former are much decomposed. Some small clay balls occur with the pebbles.

A little farther on in the cut large rolled masses of greenish-gray sandy clay occur in the sand. Some of these are as much as 6 feet in diameter. This sand, with its contents, does not seem to be a bed distinct from the overlying mottled sandy clay, but graduates into it. It thickens considerably in going north, raising the base of the mottled sandy clay higher and higher. In one place the basal sand shows several layers of pebbles, which are inclined at various angles to one another and have an undulating course. At this point there is, immediately over the sand, a lenticular layer of brownish-purple and greenish-gray clay 4 feet thick. The colors occur mixed together in irregular bands. Here the mottled sandy material that forms the upper part of the cut has graduated into a yellowish sand that is mottled with gray. This latter material toward the northern end of the cut passes through several minor modifications and finally at the northern end becomes a white or light-gray kaolinic sand. This extends from the top downward, so as to make up much the larger portion of the exposed material.

Tracing the basal pebbly sand farther north in the cut we find it graduating into a yellowish, mottled sand, and then into a pale greenish-gray sand. This latter contains small clay balls and pebbles. A little farther on it becomes mottled with yellowish and reddish colors. The colors are mingled confusedly, showing no particular arrangement.

A little beyond the point last mentioned the cut at its northern end is deepest, the material being here 75 feet thick. Here all the material exposed, except a stratum at the base, is a light-colored kaolinic sand. The basal stratum, which is the continuation of the basal sand described above, is here quite different. It is 3 or 4 feet thick, and is a greenish-gray tenacious clay, the sand having disappeared. This passes horizontally into a layer 5 feet thick, composed of clay balls mixed with

cobblestones. These are packed in a ferruginous sand. Some of the clay balls are 18 inches in diameter, and are composed of greenish-gray clay, which appears to have been torn off from the clay layer that immediately precedes this bed. The overlying kaolinic sand shows occasional seams and blotches of yellow and contains a few clay balls, the largest of which are 12 inches in diameter.

TELEGRAPH ROAD FROM NEABSCO RUN TO OCCOQUAN.

As was stated before, the Telegraph road from Neabsco Run to the village of Occoquan, a distance of 5 miles, runs close to the western margin of the Potomac area. The material exposed on it shows no features not seen near Neabsco Run. The exposures are very poor, and extensive erosion is indicated in the Potomac formation. The surface is mostly occupied by cobblestones and loose material of recent origin, derived from the Potomac formation. A great number of cobbles occur, mostly of quartz. They are often large, a diameter of 8 inches and more being not uncommon. Besides these, a number of large, subangular quartz masses occur. Some of these exceed 12 inches in diameter. Occasional fragments of pre-Cambrian rock are found with these, but none of notable size.

About 2 miles from Neabsco Run there is a small outcrop of Potomac material containing a number of large balls of gray clay. At this point the slate that forms the western margin of the Potomac is shown. It looks much like a metamorphosed form of the Primordial slates. From this point to near Occoquan there are frequent exposures of the Potomac sand on the tops of the hills and on the higher ground, while at the level of the streams and valleys the slates make their appearance.

About 1 mile south of Occoquan a stratum of pale-reddish, laminated clay, with seams of yellow, occurs in the Potomac sand. This, however, contains no plant fossils. In the top of the hill overlooking the river and in the village a thin remnant of the Potomac may be seen. It is composed of gray, argillaceous sand, variegated with yellowish-brown and reddish colors. In this vicinity the Potomac has been almost wholly removed by erosion and is visible only on the highest points. The depth to which the depressions have been cut since the deposition of this formation indicates for it a great age. In the immediate vicinity of the village of Occoquan the thickness of fully 200 feet of pre-Cambrian rock is exposed under the Potomac, being laid bare by erosion in post-Potomac times. These pre-Cambrian rocks are no longer wholly slates, but in the lower portions rather coarse-grained and highly crystalline mica-schist and highly micaceous gneiss may be seen. On the north side of the Occoquan River, opposite the village of Occoquan, the high hills that overlook the river seem to be composed wholly of mica-schist.

From the village of Occoquan due east down the river to Woodbridge, where the railroad crosses the river, the distance is 2 miles.

The station is on the opposite side of the river from the site of the former village of Colchester, where the Colchester road crosses the river. At Woodbridge the railroad approaches the bridge by a long cut. In this cut the Potomac formation may be seen resting on pre-Cambrian slate similar to that which, at Dumfries and northward, forms its western boundary. The bottom of the Potomac formation is here about 40 feet above the river. The formation, in the interval of 2 miles between this station and the village of Occoquan, has declined toward the east certainly as much as 160 feet. We may then conclude that the dip in this direction is as much as 80 feet per mile. The southern end of the cut has the least depth. The slates crop out here with no superposed Potomac. This slate contains some ledges of purplish-brown quartzite. A little farther within the cut, where it is deeper, we find about 2½ feet of Potomac on the slate. This is mostly a dark, slightly reddish shale, with some remnants of the sand which once inclosed it. The shale contains many small fragments of lignite and some recognizable leaf impressions. The most abundant of the imprints is that of *Dioonites buchianus*, the plant so common at Neabsco Run. The dip of the shale seems to be to the northeast and to amount to 5 degrees. The shale a little farther north is covered by from 8 to 10 feet of Potomac sand. On the top of the whole there is a bed of cobbles and loose, sandy matter, varying from 5 to 10 feet in thickness. This bed contains fragments of slate. It extends throughout the cut. Large masses of mica-schist and gneiss occur in its base, some of them more than 4 feet in diameter. The cobbles are of quartz, many of them exceeding 8 inches in diameter. Toward the northern end of the cut 4 feet and more of a yellowish, sandy clay, well stratified, come in over the bed of cobbles. The lignitic shale seen at the southern end of the cut soon gives out, for it is a local lenticular layer composed of redeposited clay. Its place is taken by the overlying sand. In the deepest part of the cut, near the northern end, the Potomac material is nearly all a brownish-gray sand. The lowest portion of this contains subangular masses of quartz, some of them 1 foot in diameter, and partly rounded masses of slate, mica-schist, and other pre-Cambrian rocks equally large. A little north of this point the pre-Cambrian slate shows itself in the bottom of the cut. The lowest Potomac resting upon this is a lenticular layer, about 2 feet thick, of gray clay full of fragments of lignite. Next above this is a stratum 12 inches thick of gray, sandy matter, with partings of yellowish clay, and on the top of this comes the brownish-gray sand with large clay balls. The basal lenticular bed here soon gives place to a stratum composed of a mass of small and large clay balls, mingled with some gravel. The brownish-gray sand above this contains some scattered lignite and short patches of pale-reddish clay. One of the latter contains some good impressions of Dioonites. The old Colchester road, between Woodbridge and Neabsco Run, north of the locality previously described as

occurring on that road, affords at various points imperfect exposures of the Potomac. The material shown is mainly a loose, more or less argillaceous sand, ranging in color from gray to white. This shows, generally, a mottling from the mingling of yellowish-brown with the predominant gray.

TELEGRAPH ROAD FROM OCCOQUAN TO TELEGRAPH STATION.[1]

The Telegraph road, after crossing the Occoquan River at the village of that name, ascends more than 200 feet to the general level of the country on the north side. The road passes over heavy masses of typical mica-schist until the summit of the hill is nearly reached. On this summit there is a thin covering of fragmental rock, which appears to be Potomac. Some 2 miles from the summit the road turns more directly east. Before making this bend it runs toward the western margin of the Potomac, and only remnants of the formation can be seen. There are along here marks of extensive erosion in the formation. The surface shows the loose, unbedded, sandy materials with abundant cobbles that are common where the Potomac has undergone much erosion. The cobbles are often large, and the fragmental rock in place is imperfectly exposed. It is of the usual kind, mainly a gray sandy clay or sand, often mottled with yellowish-brown. The cobbles occur sometimes in heavy beds that seem to be associated with the mottled sands.

The eastward turn of the road takes it in the distance of 2 miles to Telegraph Station, a point on the Alexandria and Fredericksburg Railroad near Pohick Run, 3 miles north of Woodbridge. In approaching this station the road penetrates farther and farther within the Potomac area, so that near that place all the surface rock is Potomac. This is well displayed in the railroad cuts north and south of the station. There is no important change in the character of the material exposed as the station is approached. It becomes coarser and more sandy, taking on more of the typical character of the Potomac. Some of the cobbles seen before the station was reached are 12 inches in diameter. All are of quartz.

A number of cuts on the railroad in the vicinity of Telegraph Station give good exposures of the Potomac. An examination of them was made both to the north and to the south of this place.

EXPOSURES BETWEEN TELEGRAPH STATION (LORTON) AND WOODBRIDGE.

A few yards north of Telegraph Station there is a small cut that shows about 20 feet of nearly white sand. This is arranged in the usual interlocking lenticular layers, and shows the commonly occurring irregular patches of yellowish-brown color. The upper 10 feet of the material contains balls of both pale-reddish and gray clay. Most of the balls are small, the largest attaining the diameter of about 10 inches.

[1] This station is now named Lorton.

Small stones of quartz also occur. The stones and clay balls are found both scattered and showing a tendency to aggregate into layers, since portions of the sand that are lenticular or pocket-like in shape contain them more thickly than usual. Some small slate fragments are scattered through the mass. A cobblestone bed caps the whole, but this is better displayed in the cutting next to be described.

A small side cutting at the station, 30 yards south of the cut above described, shows the following features: The basal portion is composed of sand of the same nature as that just described. This shows a thickness of about 8 feet, and is capped by a cobblestone bed varying in thickness from 1½ to 3 feet. This is composed of layers, lenticular in shape, that are full of cobbles. These interlock with others, in which the material is mainly sand. In one spot from 1 foot to 2 feet of the normal sand occurs above the cobble bed, showing that this latter is a member of the Potomac formation. A large number of clay balls occur mingled with the cobbles, some of them being 10 inches in diameter. Many of the cobbles are from 3 to 5 inches in diameter, the largest not being fully rounded. No Cambrian cobbles were seen. Most of the stones are composed of quartz, but some of them are formed of crystalline pre-Cambrian rocks, and these are much decayed. Some of the pre-Cambrian material seems to have been argillite, and some fragments of gneiss and mica-schist are found. The latter is similar to that seen at Occoquan. It is highly probable that the numerous surface cobbles that occur in this region came from the erosion of this or a similar cobblestone bed in the Potomac.

In another shallow cut, that is found a short distance south of the station, only the lower portion of the sand can be seen, and this contains some short lenticular layers of gray clay and a few balls of the same, some of them 1 foot in diameter.

Half a mile south of the station there is a long cut. This, where deepest, shows as much as 40 feet of the material. Here the lower 20 feet is formed of current-bedded gray sand, which contains scattered clay balls, and some subangular masses of quartz that are sometimes 8 inches in diameter. Over this comes a stratum of gray sandy clay, which at its northern end is single and 2 feet thick. Toward the south it splits into several layers that are interstratified with more sandy matter. The whole is here 5 feet thick. This is capped by 8 feet of sand similar to the basal matter. In this there are layers of gravel, and a little farther south its upper portion is a solid mass of pebbles. Over the whole come the usual surface materials.

One mile south of this point the next cut occurs. In the interval no exposures are found. This cut is 25 feet deep, and shows the Potomac resting on slate of pre-Cambrian age. This slate does not appear throughout the cut, but shows itself locally; seeming to have had an irregular surface at the time of the deposition of the Potomac. Resting on the slate come 10 feet of alternations of clay, sandy clay, and fine

argillaceous sand, all gray in color, but having some thin layers of pale-reddish, sandy clay. Most of the clay and sandy clay is redeposited material, having been torn off from some older layer, then redeposited and cemented together, chiefly in flakes and small fragments. It has consequently a lumpy nature, and is without lamination and cleavage, but some of the clay seems to be remnants of the original layer, in the form of cakes and masses buried in the ruins of the original bed. This structure was disclosed in a search for plant impressions, a number of which were found in the yellowish clay. The plants are chiefly conifers and ferns, with a large number of specimens of *Dioonites buchianus*. The plant-bearing material has over it a cobblestone bed about 4 feet thick. This contains some clay balls, more than 1 foot in diameter. The uppermost portion of the cut is formed of brownish sandy clay, about 6 feet thick at its maximum.

The next cut to the south is only 100 yards distant from that last described. Although so near, it is made wholly through pre-Cambrian slate, and at its maximum is 60 feet deep. The slate cleavage dips to the northwest at an angle of 80 degrees. No Potomac appears on the top of this material. The great height of this outcrop so near the Potomac in the last-described cut indicates that the surface of the slate, at the time of the deposition of the Potomac, must have been very irregular and deeply worn.

Beyond this cut the metamorphic rocks continue to the south for over half a mile. The ground is then, for about one-fourth of a mile, concealed. We then find the Potomac again exposed. The cuts are now of small depth as far as Occoquan River, and do not show more than 10 to 15 feet of material.

The first Potomac deposit met with after passing the cut of metamorphic or pre-Cambrian slate belongs to the mottled sandy-clay type, and material of the same nature extends to the Occoquan. This first exposure is a brownish sand, graduating into yellowish sand. Frequent specks and spots of gray clay are dispersed through this sand, apparently coming from redeposited fragments. This dispersed clay gives the brownish sand a mottled nature. Pebbles and clay balls of small size occur all through the mass. The clay sometimes lies in tortuous, thin layers, which have no particular position and direction. In one part of this cut the base of the material exposed is a stratum 3 feet thick of greenish-gray clay, mottled with reddish-brown.

The next cut, 200 yards south of the last, shows at most 15 feet of typical mottled and marbled sandy clay. It has pockets of large stones scattered through it. This brings us to the immediate vicinity of the Occoquan. Here the cuts are still in the sandy mottled clay. In the long cut by which the approach on the north side of the river is made to the bridge some portions of the material exposed are brick-red in color, without any admixture of gray. In one portion of this cut about 4 feet of the ordinary gray sand of the Potomac shows itself under the

mottled sandy clay. The latter at this point has embedded in it several masses of pre-Cambrian gneiss from 2 to 3 feet in diameter. One of these masses showed a character not possessed by any pre-Cambrian rock seen in place in this region. It is a coarse granitoid gneiss, with a large amount of coarsely crystallized red feldspar. This material is probably Pleistocene.

EXPOSURES IN CUT ON POHICK RUN.

Immediately after crossing Pohick Run the railroad passes northward through a long and moderately deep cut. This is about half a mile north of Telegraph Station. At its southern end it shows from the bottom for about 10 feet a gray current-bedded sand of the usual kind. This contains at its base in one place a mass of clay balls and cobblestones 4 feet thick. Many of the stones are from 4 to 5 inches in diameter. Some masses of pre Cambrian slate occur in this stratum with the cobbles. One of these shows the dimensions 5 by 9 inches on the exposed surface. This sand is the predominant and only constant material in the cut. It is sometimes very coarse and current-bedded, but is full of irregularly shaped layers, varying much in composition, that are more argillaceous than the coarse embedding sand. These layers sometimes assume the form of true clay. They are dispersed in the sand in the form of short lenticular beds. They are sometimes so much thickened that they make up a large part of the material exposed. Some of them extend horizontally a considerable distance, but they vary rapidly in composition and color. The shorter layers are mostly composed of a pale-reddish sandy clay. The longer layers are in some places dark-gray, but mostly show reddish or reddish-brown colors. The cut in its deepest part does not show more than 12 or 15 feet of the Potomac material. The clay layers mentioned above occur in the middle and lower part of this material. The upper portion of it is a coarse, current-bedded grit, full of small stones. All through the cut cobbles and clay balls are sparingly dispersed through the sand.

At the southern entrance of the cut the 10 feet of sand shown has on its top masses and partly torn-up layers of clay. Toward the northern end of the cut a stratum occurs that shows a great degree of variability. Its shape is typical of many occurrences of the clay layers in widely separated places. Beginning as a single stratum, it is soon divided for a short distance into two layers. This is done by the insertion of a lenticular sheet of sand 3 inches thick. The lower member of the divided layer is 7 inches thick and the upper one 10. The two unite to the north, forming again one stratum. The material is up to this point a reddish clay. The united stratum may be traced for some distance, declining to the northeast. In this part of its course it shows many and rapid changes. At first it is 4 feet thick, the lower 2 feet being a very dark-gray tenacious clay (black when wet). The

upper 2 feet is composed of reddish and yellowish clay. Traced farther on to the north, all of the material becomes pale-reddish. In one place where the top and bottom differ it thickens to more than 5 feet and extends to the bottom of the cut on one side of it, while on the opposite side it is only 2 feet thick and rests on a sand which is full of gravel.

At the point mentioned above, where the clay layer is divided by the 3 inches of sand, we find immediately under it 18 inches of current-bedded gray sand, mottled with yellow. At the base of the cut below this last come 3 feet of sand, full of cobbles, clay balls, and fragments of pre-Cambrian slate. Toward the northern end of the cut the variable clay bed rests immediately on the coarse material. Here the basal stratum of coarse matter is full of cobbles of quartz and rounded stones of pre-Cambrian rock, such as gneiss and mica-schist. Some of the cobbles are 8 inches in diameter.

A few yards north of this last-mentioned point the pre-Cambrian floor is exposed on the west side of the cut with the reddish clay resting on it. On the east side, however, the lowest material shown is Potomac, being a gray clay. The pre-Cambrian exposed here is a true gneiss. It shows at most only 2 or 3 feet, and is very much decomposed.

All the matter in this cut is capped by a cobble bed, which contains in its base subangular quartz masses, some of which are more than 1 foot in diameter. With these occur masses of gneiss over 3 feet in diameter.

The next cut occurs 400 yards north of that just noticed and shows a different state of things. This, in its deepest part, displays 35 feet of Potomac material. The floor of crystalline rocks is not exposed. None of the clays so abundant in the cut last described are shown here, although the horizon must be nearly the same. The material visible in the cut now considered is a rather coarse current-bedded sand, light-gray to nearly white in color. It is mottled and streaked with the usual colors from oxide of iron. In the finer parts of the sand much kaolin is diffused. The amount of gravel and cobblestone occurring in the material here is so large that the railroad company has used the material as ballast. The following are some of the features shown:

In the south end of the cut, on the west side, the lowest material exposed is a current-bedded coarse sand 10 feet thick, with the bottom not visible. This is full of small stones. Over this comes a lenticular sheet of coarse sand with a maximum thickness of 3 feet. This sheet soon gives out and is overlain by a light-gray sand 8 feet thick. This in some places is full of stones. In other places the stones are not diffused, but are collected in irregular nests, pockets, and seams. The stones are of quartz, with possibly a few of Cambrian quartzite. The largest of them are not fully rounded and have a diameter of 8 or 10 inches. One subangular fragment of quartz showed the dimensions 5 by 9 by 12 inches. Nearly opposite the point just described and on the east side the lowest portion of the sand visible is, for the thickness of

2 or 3 feet, packed full of cobbles and contains many clay balls. Many of these cobbles are 3 to 4 inches in diameter. Above this bed of cobbles we have 8 feet of current-bedded sand full of small stones. On this rests the stony layer, 8 feet thick, before mentioned. On the top of this come 4 to 5 feet of sand almost free from stones. At the summit of the whole 4 feet of yellowish-brown sand occurs, full of small stones. Some of the material of the cobbles seems to be Cambrian quartzite. This is the first appearance, going north, of Cambrian material in the Potomac of the Fredericksburg area.

For rather more than a mile beyond this point no cuts occur. A little south of Long Branch Station a cut 20 feet deep is made in the usual current-bedded light-gray sand. This sand extends from the bottom of the cut to the height of 12 feet. It is capped by from 2 to 3 feet of brownish-yellow, mottled, sandy clay. On the eroded and undulating top of this a layer of cobblestones 4 to 5 feet thick occurs. This is sharply distinct from the underlying Potomac, and seems to be younger than it. The cobblestone layer is remarkable for the whiteness and uniformly large size of the cobbles. Most of them are from 3 to 5 inches in diameter. Some larger quartz and pre-Cambrian masses lie in the bottom of this bed. It seems to be Pleistocene.

At Long Branch Station a cut 15 feet deep is made wholly in a sandy clay of dark ash-gray color.

North of this station to Alexandria the railroad runs all the way in the Potomac formation, and a number of cuts 10 to 15 feet deep occur. Those nearest to Long Branch Station are occasionally made in light-gray to nearly white sand that contains more or less diffused gravel and cobbles; but most of the cuts here, and all of them as we approach Alexandria, occur in highly colored or mottled sandy clays or argillaceous fine sands. They are gray or greenish-gray in color, often having great patches colored brick-red, purplish, yellowish-brown, and other colors, or are marbled and mottled on a smaller scale with these colors. The proportion of argillaceous matter on the railroad increases toward Alexandria, and the material is almost all of the character shown in the mottled sandy clay variety. An account will be given further on of some typical localities in the vicinity of Alexandria.

Beyond the vicinity of Telegraph Station examinations were made along the Telegraph road to Pohick church. At Pohick church the road to Accotink, a small hamlet, was taken. From Accotink the route to White House Landing and White House Bluff was followed. This last is found on the eastern margin of the Potomac area.

Northeastward from Telegraph Station no exposures of Potomac were seen until beyond the valley of Pohick Run, on the slope of the high hill on which the old colonial Pohick church is situated. The top of this hill is rather more than a mile from Telegraph Station. The road from the bottom to the top of this hill, overlooking the valley

of Pohick Run, affords some imperfect exposures of Potomac material. In ascending the hill the following features were seen:

SECTION NEAR POHICK CHURCH.

At the foot of the hill the lowest rock visible was only partially exposed. Here a yellowish-brown sand was seen whose thickness was not made out. On this rests a bed of ash-gray, sandy clay, 4 feet thick. Traced horizontally this last graduates into a laminated, fine, argillaceous, gray sand. After passing an interval of a few feet of concealed ground, there is an imperfect exposure of gray mottled sandy clay. After another concealed interval of 3 or 4 feet, a whitish sand with yellowish-brown streaks is imperfectly displayed. This contains small pebbles. A little above the last a bed of brownish gray sand 4 feet thick is seen. Over this last, and immediately succeeding it, comes 8 feet of thinly laminated, ash-gray, sandy clay. This has a slight greenish tinge, and is mottled and streaked with yellowish-brown. On this rests a bed, 5 feet thick, of laminated, dark-gray sand, with films of yellowish-brown along the bedding planes. Upon this occurs 5 feet of yellow and ferruginous sand, with partings of ash-gray clay. Then comes 7 feet of yellowish-brown sand. These beds are all consecutive and all seem to be horizontal. The ground then, for the succeeding height of 10 feet, is concealed.

Next above these beds, and forming the upper portion of the hill, there is, well exposed, a mass, 20 feet thick, of coarse, loose-textured, yellowish-brown sand. This is strongly marked by current-bedding and shows the common, interlocking, lenticular structure of the Potomac sand. A close inspection of this material shows that its yellowish-brown tint is due to the intimate mixture of numerous small films and spots of that color with the normal gray of the ordinary gray sand. It is much like a portion of the material seen at Cockpit Point. This deposit is full of small stones, 3 inches and less in diameter. In its base large masses of gray clay occur, embedded in the sand. These attain sometimes the diameter of 4 or 5 feet. Throughout the lower part of this material the pebbles are disposed in irregular lines and layers, but in the upper part they tend to a more regular arrangement in beds.

On the top of this bed comes a thick stratum of cobbles, most of them large. In the base of the cobble bed large, rounded stones occur. Some of these are composed of a gray sandstone that seems to belong to the Potomac. A stone of this kind, having the dimensions 8 by 10 by 12 inches, was seen. With these a number of large, subangular masses of quartz are found. One of these showed the dimensions 10 by 12 by 14 inches. A subangular mass of Cambrian quartzite lies on the roadside, a little below the outcrop of the cobble bed, and seems to have come from it. This is white in color and measures 2 by 2 by $2\frac{1}{2}$ feet. This was the first considerable mass of Cambrian material seen

in the Fredericksburg area. Such masses become abundant between this point and the Potomac River and on the road to Accotink and beyond. They all appear to come out of the base of a bed of very large cobblestones which rests on the eroded surface of the Potomac and which seems to be Pleistocene in age. The spot now considered is more than 3 miles from the nearest point on the Potomac River.

A little beyond the locality showing the exposure last described the road to Accotink leaves the Telegraph road. The exposures along the latter, beyond this point, do not call for special notice. Those along the Accotink road may be disposed of in a few words.

EXPOSURES ON THE ACCOTINK ROAD.

At the distance of about 300 yards the Accotink road crosses the old Colchester road. At the point of crossing there is a slight exposure of Potomac material. It should be stated that all the material seen in ascending the hill, on the highest portion of which this last-mentioned exposure occurs, is above that seen in the railroad cuts in the vicinity of Telegraph Station, except the lowest that occurs in the hill. The railroad runs but a little above the level of Pohick Run.

At the crossing of the roads last mentioned the following beds were seen imperfectly displayed: At base lies a yellowish clay, 4 feet thick. This was interlaminated with thin layers and films of clay, having a rich purple and peach-blossom color. On top of this comes a thinly laminated purplish-red clay, 2 to 3 feet thick. Above this is a layer 1 foot to 2 feet thick, composed of cobblestones of quartz and Cambrian quartzite, packed in a pinkish and peach-blossom colored, sandy clay. Some of the Cambrian cobbles are over 1 foot in diameter. The highest material is a whitish sand, lined and seamed with yellowish brown, $2\frac{1}{2}$ feet thick. In the top of this are some thin partings of mottled clay that weathers a bright purple red.

From this point to Accotink the exposures are very poor. Cobbles and subangular masses of Cambrian quartzite and of quartz are not rare on the surface. Some of the Cambrian masses are 2 to 3 feet in diameter. Descending to the level of Accotink Creek and the hamlet of Accotink, materials are passed over that are of the same general nature as those seen in ascending the hill to Pohick church. The large size and abundance of the surface masses and cobbles of Cambrian material are especially noteworthy. One mass measuring 2 to 3 feet was seen. The masses all evidently come from the base of the uppermost cobble bed before described.

At Accotink there are considerable exposures of Potomac. At the base about 30 feet of the normal, light-colored sand may be found, and over this 12 to 15 feet of ash-gray sandy clay. A cobblestone bed occurs here, and it apparently comes between the two materials just mentioned. The exposures are too poor to give connected sections.

On the slope of a long hill from Accotink on the turnpike, for over

a mile, the exposures are still very imperfect, and give merely glimpses of the rock in place. At the top of the hill the road to White House Landing leaves the turnpike and turns due east. This was followed to White House, distant 3 miles. This road follows the tongue of high land that ends on the Potomac in the tall banks that form White House Bluff. As the road is situated on the crest of this tongue, no exposures worth noting were seen on it.

We may now turn to the description of the Potomac and Pleistocene formations as they were seen along the Potomac River north of Powells Creek, which was the point on the river last described.

EXPOSURE AT FREESTONE POINT.

The Potomac material that is shown in Freestone Point on the river is composed, for about 30 feet above the water, of ledges of pretty firm sandstone. This material is below any shown in the railroad cut made through the point. It is capped by soft and crumbling, light-colored sandstone and sand, similar to the matter shown in the railroad cut. It is much less perfectly exposed here than in the cut. The banks of the river are then low and give very imperfect exposures until we reach the northern shore of the estuary portion of Occoquan Creek. The material that composes them seems to be all Pleistocene. The broad promontory known as Masons Neck, lying between the mouth of the Occoquan and Gunston Cove, faces the Potomac for a long distance with bluffy banks that range in height from 20 to 40 feet. These give good exposures. Exposures are also to be found on the opposite or Maryland side of the river. Gunston Cove is the estuary of the united creeks, Pohick and Accotink.

High Point is a locality marked on the State map as occurring at the apex of Masons Neck. It does not justify its name, as the bank here is not distinguished by a height surpassing that of the average of the shore above and below it, and in this respect it is much inferior to Freestone Point.

Professor Rogers in his reports[1] gives this locality as one of those showing his Upper Secondary, but in this statement he was mistaken, as the material shown is all Pleistocene and of the same character, essentially, as that which occurs at Stony Point fishing shore, but the material is a sand strikingly like that of the Potomac, which it was at first thought to be. Only after a careful examination was the Pleistocene age of the deposit determined.

EXPOSURE AT STONY POINT FISHING SHORE.

Stony Point fishing shore is about one-third of a mile below High Point. Both of these localities are on the Virginia shore. The bluff here is about 30 feet high. All the material exposed is Pleistocene. The lower 20 feet seen from a little distance seems to be very distinctly horizontally bedded. This apparent bedding, however, is due to the

[1] Geology of the Virginias, p. 440.

presence of horizontal plates of highly ferruginous and indurated sandstone. These are caused by the deposit of oxide of iron in particular layers of the sand. This iron has cemented the sand together and formed plates and crusts that are more durable than the layers with which they are interstratified, so that on the weathering of the material these stand out.

The greater portion of the matter composing this lower part of the bluff is a loose, gray sand, much stained and streaked with oxide of iron. It has some pebbles of quartz diffused through it. Like the material in High Point, the sand is so much like that of the Potomac formation that it is not easily distinguished from it. There is little doubt that this close resemblance is due to the fact that it is Potomac débris which, in Pleistocene times, has been eroded and deposited with little or no change of lithologic character. This is a feature not uncommon in Pleistocene deposits near their base, where the Potomac is but a short distance below. It is most probable that the Potomac formation is present here not far below the deposit exposed in the bank now described. No doubt originally the ferruginous crusts had the character of the intervening layers, and it is probable that these ferruginous plates exist only in the weathered substance of the face of the bluff. The bluff throughout its upper 10 feet is formed of an unbedded, yellowish-brown, argillaceous sand that shows the characteristic hummocky surface seen so often in the more argillaceous fine sands of the Pleistocene. This is the portion found at so many places to afford a clay suited for the making of bricks.

The films of color due to oxide of iron found in the sand occur in some places with a waving course. They are sometimes so closely placed and so thin that they look as if painted in imitation of the grain of wood. Toward Sandy Point, at the mouth of the Occoquan, the crusts of ferruginous sand disappear, and the lowest portion of the Pleistocene shows large irregular masses that are colored reddish or pinkish, the colors showing themselves only on weathering.

EXPOSURE ABOVE INDIAN HEAD.

On the Maryland side of the river, above Stony Point fishing shore and High Point, bluffs occur at intervals, beginning at Indian Head and extending for several miles up the stream. Diagonally across from High Point, and about 1½ miles up the river, there is a high bluff that rises immediately from the water's edge. This shows the Potomac formation with the Eocene resting on it. Although on the Virginia side the Potomac formation is wholly removed above water level and replaced by Pleistocene, we find here no less than 70 feet of it displayed. There has been too much slipping down of the higher parts of this bluff, and consequent burying of the lower portions, to permit a detailed and consecutive section to be given, but enough is shown to enable one to determine the general character and thickness of the Potomac material here.

The lowest portion of the bluff is similar to the lower part of the Gunston Cove Bluff, to be described further on. It is composed of tough, lumpy, sandy clay, which, when fresh, is colored green, but which, on weathering, assumes in spots and streaks bright red and purple colors. This material graduates in ascending into a gray sand which, in various places and at different horizons, contains irregular layers of imperfectly laminated sandy clay. This latter substance has varying amounts of fragmentary lignite, and is sometimes dark in color from its diffusion. It is possible that minute search might disclose recognizable plant impressions in some of these argillaceous layers, but none were found when the bluff was visited.

The Eocene rests upon the top of the Potomac here. It shows about 20 feet of a yellowish-gray, somewhat argillaceous sand, which discloses no division into beds or layers. No fossils were seen in it. It is full of the burrows of swallows.

On the Eocene rests about 10 feet of yellowish-brown Pleistocene sand. This has in its base a number of large quartz cobbles and partly rounded masses of pre-Cambrian rock. This exposure is of great importance, since it indicates no diminution in the thickness and no change in the lithologic character of the Potomac formation from which it could be inferred that the eastern limit of the group is anywhere near at hand. This locality and that of Fort Washington give the most eastern exposures of Potomac material in this region, but the locality now under consideration shows much more of the formation than can be seen at Fort Washington. It has here apparently suffered much less from erosion in pre-Eocene times. The great development and unchanged character of the Potomac at this spot confirm the evidence obtained from the artesian well at Fort Monroe, indicating the extension of the formation to the eastward under the Tertiary, far beyond the last outcrops.

EXPOSURE AT GUNSTON COVE BLUFF.

Gunston Cove Bluff is situated on Gunston Cove, opposite White House Bluff. The cove, formed by the united estuaries of Pohick and Accotink creeks, is about 2 miles wide and makes the northern boundary of Masons Neck. Between the bluff now to be described and the banks of the Potomac River, in the vicinity of High Point, there is a long stretch of 4 or 5 miles in which the banks are low and show only a few exposures, and these disclose nothing but Pleistocene.

The bluff now described, although so near to White House, shows very different material from that exposed at the last-mentioned place. About 80 feet of Potomac is visible, the bluff being composed wholly of that formation. It rises in going up the cove, the greatest amount of deposits being shown at the upper end. At the lower end, which is only about 20 feet high, all that is visible is a tough, massive, lumpy, rather sandy, greenish clay, which on exposure weathers so as to

develop bright red and purple colors. These colors occur in irregular spots and streaks. The material is much like the mottled, sandy clay seen at Cockpit Point. At the highest part of the bluff, 50 yards up the cove, this mottled sandy clay becomes more sandy, tending to pass into a sand. It shows here some indications of division into beds. At the same time it is more consolidated, and in places approaches a sandstone in nature. At this spot it has over it about 40 feet of a grayish, incoherent, somewhat argillaceous sand, which has the character of the ordinary Potomac sand. This has no apparent bedding, but is divided here and there by short and thin lenticular layers of laminated, brownish-gray sandy clay. In the lower part of the mass there are two layers of this clay, 12 to 18 inches thick, that are more persistent than the rest. These bend around so as to unite, and inclose a lenticular sheet of the incoherent sand in which they are embedded. They contain a great deal of comminuted vegetable matter, and are in places colored brown by this material. The upper part of the bluff, for 20 feet, is composed of a massive, somewhat argillaceous sand, light-gray in color, that is much bored into by swallows. There are no indications of Eocene and Pleistocene in this bluff.

EXPOSURES AT WHITE HOUSE BLUFF.

White House Bluff is caused by the jutting out into the Potomac of a promontory that lies just north of Gunston Cove. The bluff lies about 2 miles below Mount Vernon. It gives an exposure of the Potomac formation that is very considerable in both height and horizontal extent. This exposure is important also because it displays the Potomac formation well at one of the most easterly points where it is visible in the Fredericksburg area. The features seen here may be taken as characteristic of many of the most easterly outcrops in this region. The air-line distance from east to west connecting this locality with the exposures formerly described near Telegraph Station is a little more than 4 miles.

The bluff at White House begins near the wharf and extends several hundred yards around between the river and Gunston Cove. At no point is the whole face of the bluff exposed so that a continuous vertical section can be given, but this, if obtained at one point, would not apply to others, although near by, owing to the great changeableness of the Potomac strata when traced horizontally. The only way in which any intelligible account of exposures of this kind can be given is to note the more prominent features of the material at different horizons in the face of the bluff.

The first thing that strikes the observer walking along the beach around the point is the close resemblance of the deposit to that shown at various points on the James and Appomattox rivers. It is a repetition of that seen on those rivers. Even the beach between high and low water marks is of the same nature. The sloping shore is paved

with cobbles of quartz and Cambrian quartzite, and large blocks of the latter material may be seen here and there, but the cobbles here are not so large generally. The blocks of quartzite are not so numerous as in the other localities named, but they are larger. The cobbles and large blocks have fallen down from a stratum at the top of the bluff. The large quartzite masses are but little abraded, and although polished quite smoothly they have only the edges and angles worn off. They are of Cambrian quartzite. It is quite probable that these come from the same stratum that furnished the blocks which are strewn over the surface between Accotink and Pohick church. The most abundant material is a white, compact quartzite, but some masses of dark-gray quartzite are found, which resemble some of the rock exposed in the gorge of the river at Harpers Ferry, occuring near the base of the Cambrian formation. One large mass of white, conglomeritic quartzite was seen. This resembles the white member of the Medina formation. These large rock masses must have been transported a long distance, for nothing east of Harpers Ferry resembles the substance forming them. One of the masses of dark-gray quartzite had the dimensions of $2\frac{1}{2}$ by 4 by 5 feet. One, of white quartzite, measured $2\frac{1}{2}$ by 3 by 4 feet. A number of others had nearly as great dimensions. Occasionally blocks of gneiss, mica-schist, and other pre-Cambrian rocks may be seen, but they are fewer and smaller than the quartzite masses.

The bluff, in its highest part, rises fully 100 feet above the water. It declines in height both up and down stream. At the base of the cliff the typical light-colored material of the Potomac formation is found. It is here sufficiently indurated to be called a sandstone. This shows a great tendency to disintegrate, the rate depending upon the amount of diffused kaolin, which varies much. In some portions as much as one-third of the bulk is kaolin. Much of the rock contains very coarse sand, and a portion is pebbly. This part of the cliff shows all the features so characteristic of the Potomac. It has an exceedingly variable composition and structure, with interlocking lenticular beds. The more indurated sandstone portions are lenticular layers in the more incoherent material. These harder parts seem to resist the action of the water very well, and large blocks have been undermined and lie on the beach. In some portions of this material particles of quartz of the size of a pea make up a large proportion of the deposit. The white sandstone and sand above described extend up in the bluff to the height of from 20 to 25 feet. At the top of this there is a decided erosion horizon, which may be traced wherever this top can be seen. It is marked by the presence of clay balls, most of which are small. On this horizon, in some places, patches of clay a few inches thick are found. These seem to be remnants of some stratum left uneroded. Above the basal light-colored stratum there usually comes a mass of sand, which is not so coherent as the material on which it rests. It has a yellowish-gray to brownish-gray color, due to the diffusion of colored

clay instead of kaolin throughout the sand. It contrasts pretty strongly with the underlying light-colored sand. It is also much marked by current-bedding, and is quite coarse. It closely resembles the mass 20 feet thick that occurs in the top of the hill at Pohick Church. The colors are strongest on the planes of lamination, and the yellowish or yellowish-brown lines are very numerous and closely placed. They are often wavy in their course. Many small pebbles occur, scattered irregularly in the mass or aggregated in irregular seams and pockets. The thickness of this mass is variable, but may be taken as averaging from 20 to 25 feet. It is not exposed anywhere sufficiently to show its entire thickness in any one place. On the top of this rests an argillaceous layer, which has generally the character of a somewhat sandy clay of dark-gray to ash-gray color. In some places a more or less pale-reddish clay takes the place of the dark-gray clay. This stratum seems to be composed of redeposited clay, the fragments of some older bed or beds deposited and cemented together by pressure. In the cases where a portion of the stratum is composed of pale-reddish clay it appears that fragments of two kinds of clay are cemented together, the reddish and the gray. This layer may be traced along the face of the bluff for a very considerable distance. Its outcrop appears to be nearly horizontal, lying about 50 feet above the water, and is usually marked by the exit of water from its upper surface. This stratum is from 3 to 5 feet in thickness. It does not always appear at the horizon where it might be expected. This results either from its not having been originally deposited, or from its having been eroded away after deposition. The former is the more probable cause.

This bed is of special interest, since at one locality it contains a number of fairly well-preserved fossil plants. These are mainly angiosperms, similar to those found at the two localities near Brooke. With them occur a few ferns and conifers, which in the main are also like those near Brooke. There can be no doubt that this stratum is similar in age to the deposits near Brooke. The plants occur between the fragments of clay that are cemented together by pressure and in the fragments themselves, in the latter case having been deposited in the original clay layer. As the plants caught up in redeposition are not essentially different from those preserved in the clay, as originally deposited, it follows that no great period of time, geologically speaking, elapsed between the first deposition of the clay and its erosion and redeposition. At many points this clay stratum is inaccessible, since it crops out on the vertical face of the bluff, so that I could not examine it fully at all points to determine the existence in it of fossils. At all places where it was examined traces of plants and bits of lignite were found, but in all cases except one the plants were too fragmentary to be distinguished.

Above this clay bed comes an incoherent sand, mainly gray in color, but it has many irregularly shaped portions that are colored yellowish-brown. This color is distributed in spots, blotches, and films. The

bed is fairly well exposed at the locality yielding the angiosperm plants. It is here 5 feet thick and has in its top a short lenticular layer of pale-reddish clay, 18 inches thick in the thickest part. This is composed of recemented fragments and shows no plants. Above this clay comes 7 feet of brownish-gray sand, with much yellowish color irregularly disposed in the mass. This is a continuation of the underlying material, the lenticular clay layer not being separate from it, but merely differing somewhat in color and composition. No exposures occur at this point above the beds last described. At this height above the river exposures are rare.

A little farther down the river the bluff rises higher, and material above that last described is exposed. The deposits found here at this higher horizon may perhaps be taken as representative of other portions of the bluff at this level. Here everything up to the height of 50 feet above the water is concealed by fallen talus. The lowest stratum shown is 18 inches of sandy gray clay, resting on a gray sand mottled with yellowish-brown. Next above is a bed of recemented sandy clay 4 feet thick, which is the fossiliferous layer. The bottom of this, for a foot, is a dark-gray sandy clay full of small fragments of plants and bits of lignite. Toward the top the color of the material is lighter and more sandy than toward the bottom. Above this comes 4 feet of yellowish-brown ferruginous sand. This is seamed by closely placed partings of yellowish-brown that appear to mark the lamination planes. These partings are 1 inch or less in thickness. Above the last we have 7 feet of gray sand, which also is thinly laminated. This has many thin layers and films, colored dark by finely comminuted vegetable matter. This material is quite argillaceous and the stratum corresponds to the highest seen at the angiosperm locality. The next in order ascending is a bed 6 feet thick of highly ferruginous sand, which is in the main yellowish-brown. It has some layers of gray. The highest portion of the bluff that is exposed shows next in order above the last 5 feet of gray sand, much marked with yellowish-brown in thin films. These materials are exposed in an abrupt bluff which rises from the top of the slope made by the fallen talus that conceals the lower portion of the cliff. This same abrupt bluff in the upper part of the formation is continued for some distance up the river.

About 40 yards above the point last described the bluff exposes the bed just noted with some still higher material, but a considerable change has taken place, even in the short interval, in the material immediately above the fossiliferous stratum. It all now forms one continuous mass of dark-gray coarse sand, showing strong current-bedding. The current-bedding planes are marked with yellowish-brown streaks. On the top of this mass comes a thin layer of gray sandy clay, which is mixed with films and streaks of gray clay. Still higher—and this is material not seen at the locality last described—we have a layer, 8 feet thick, of yellowish-gray sand tinged with brown.

Resting upon this, and forming the top of the bluff, is a bed of large cobblestones. This bed, judging from the débris thrown down, once formed, everywhere in the bluff, the capping of the Potomac material, but it is now generally undermined and destroyed. The cobbles are composed of quartz and of Cambrian quartzite. A large proportion is of the latter material. With the cobbles occasionally come large, partly rounded masses of Cambrian quartzite. It is from this stratum that the large Cambrian and pre-Cambrian masses lying on the beach came. One cobblestone of Cambrian quartzite coming from this bed had the dimensions 8 by 10 by 12 inches. This cobble bed is of uncertain age, but it is most probably Pleistocene.

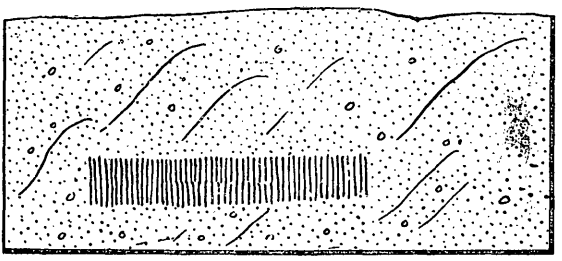

FIG. 13.—Remnant of clay layers at White House Bluff.

At a point lower down the river and 200 yards from the last described locality the highest material visible in White House Bluff may be seen, for it lies upon the cobble bed. At this point the cobble bed is 5 feet thick. It has at its base some cobbles of Cambrian quartzite 12 inches in diameter. Above the cobblestone bed is a layer 5 feet thick composed of pale yellowish-gray sand and containing pretty regular seams of small stones. This material is distinctly stratified, and is apparently Pleistocene in age.

From this account, which embraces all the different kinds of beds visible in White House Bluff, it will be seen that no Tertiary strata occur here.

The above is a general description of the strata that occur in succession at this place. We may add to this several features seen at different spots, in order that some of the peculiarities of the beds may be noted. The angiosperm locality should be specially described, as the mode of occurrence of the plants is a common one in the Potomac strata. The locality of the plants is not easily found, as they occur in a limited space at a spot difficult of access. This place is a few yards below the old wharf at White House. As the fossils are found in the fossiliferous clay bed before described, they occur about 50 feet above the water. All the material below the plant bed is here concealed by talus, and this makes a steep slope up to the stratum yielding the plants. A precipitous cliff about 15 feet high overhangs the plant layer. The fossiliferous clay bed seems to contain material different from that found in it at most other places. Usually it is a gray sandy clay, but here it seems to vary locally, the gray clay being replaced by a mixture of very light-reddish clay and sand. The clay alone contains the plants, and it seems to be a redeposited material, being in the

form of lumps, which are sometimes isolated in sand. In other cases the clay is cemented together, but is mixed with more or less sand. This clay mingled with sand is at its maximum about 3½ feet thick, but the pure clay can rarely be obtained more than a foot thick. It then oftentimes thins out entirely. In the clay with the plants several imprints of Estheria[1] were found. These appear to be of the same nature as those found near Brooke.

As illustrating the character of the white sand forming the lower part of the bluff the following features, seen at different places, may be given. Clay balls are occasionally to be seen in it, distributed without any particular order. Besides the balls patches of clay occur that are plainly uneroded remnants of beds that furnished the material of the balls. In one place a patch of reddish clay 5 feet long and about 10 inches thick was seen embedded in the sand, as shown in fig. 13. This was cut off abruptly at both ends and abutted against the sand. The clay balls are most commonly reddish in color, but in one place several balls composed of a beautiful white clay were seen embedded in the sand. This clay is much indurated, is of very fine texture, and is quite plastic. Some of these balls are from 12 to 18 inches in diameter. They occur 2 or 3 feet below the top of the white sand.

A detailed section of the white sand member was taken at one point, but owing to the great changeableness of the material it can be regarded as holding good only for the spot where it was determined. The lowest portion seen here is 5 feet of grayish-white current-bedded sand. This contains a good deal of diffused kaolin and some scattered clay balls. Above this comes a lenticular sheet having a maximum thickness of 10 inches. This is composed of small clay balls, pebbles, and kaolinic sand. It thins out at one end and at the opposite end is concealed. On the top of this rests 2 feet of sand of the same kind as that shown at the bottom. Both this and the bottom layer have some yellowish wavy lines and films. These are most numerous in the top layer. Above the last we find a layer 1 foot to 2 feet thick, composed of a coarse whitish grit full of pebbles 2 inches or less in diameter. With the pebbles there are many clay balls, mostly small, but measuring in some cases 10 inches in diameter. The clay is mostly pale-reddish. Above this we have 2 to 2½ feet of material similar to that at the base of the bluff. Then comes a lenticular layer with a maximum thickness of a foot. This is composed mainly of balls of gray clay cemented together. But in this same layer some balls of pale-reddish clay occur mixed with the gray. The largest of them are 10 to 12 inches in diameter. On the top of the last is a layer, 10 inches thick, of incoherent gray sand containing many thin films of yellowish-brown. Next in order ascending is a sheet, 2 to 4 inches in thickness, of plastic dove-colored clay. This lies horizontally, thinning out at

[1] The imprints of Estheria occurring here and near Brooke were determined as such by Dr. C. A. White.

one end and cut squarely off at the other. Above the last come 2 feet of light-gray sand full of clay balls, large and small. This forms the uppermost portion of the light-gray sand which constitutes the lower part of the bluff. The top for a thickness of several inches is an argillaceous sand passing into clay. It should be noted that the amount of argillaceous material occurring at this horizon is larger than is usual in the white or light-colored sand of the Potomac.

On the road leading from the wharf to the top of the hill, and just above the upper end of the bluff, the strata are partially exposed. Descending from the top of the hill we find in succession the following materials:

The highest rock seen in place is a brownish-gray and mottled sandy clay, showing here and there a good deal of brick-red color. This is not continuously exposed, but seems to be about 20 feet thick. The next bed under it is a yellowish-brown ferruginous sand, about 4 feet thick, containing white seams. It is followed below by a stratum, 4 feet thick, of a rather sandy liver-colored clay, with spots and patches of gray. Some portions of the bed have the pale-reddish color so common in the Potomac clay. This stratum is formed of recemented clay, and the differently colored parts are due to fragments that come from beds originally different. This seems to be the bed that elsewhere shows the angiosperms. None of these were found at this locality. The bed, however, contains a good deal of lignite in small fragments and many small bits of leaves. Some of these can be identified. Among them we find fragments of the leaflets of *Dioonites buchianus* and a conifer with acicular leaves. Underneath this stratum we find a bed of gray sand, which is marked with large spots and patches of yellowish brown. It contains a number of flakes of gray clay and lumps of the same mixed with the sand in its upper portion. About 3 feet of this material is shown. The strata are then concealed down to the level of the water.

Although the bluff at White House rises to the height of about 100 feet and is composed almost wholly of Potomac material, yet in the space of a few hundred yards it sinks down to the height of even 10 or 15 feet and finally disappears when followed upstream. Both up and down the Potomac River the material forming the bank of the river is all Pleistocene. When the bluff is followed around to the mouth of Gunston Cove, it is found to rapidly diminish in height, until, within 300 yards of the highest portion, there is exposed only about 10 feet of the deposit. This is a light-gray pebbly loam belonging to the Pleistocene. Up the river also the Potomac soon gives place to the Pleistocene. The character of this, as exposed at Red Bank, will be noted below. This condition of things shows that in Pleistocene times a high bluff of Potomac age must have stood at this place. If any Tertiary ever capped it, this must have been removed by erosion. The very irregular character of the surface left by erosion in Pleistocene times is noteworthy here.

EXPOSURE AT RED BANK.

Red Bank is the name of a bluff about 20 feet high, exposed at the water's edge about half a mile above the upper end of White House Bluff. It is formed wholly of Pleistocene, the Potomac having been removed by erosion. The base of the bluff, to the height of about 12 feet, contains a series of horizontal layers of brownish-red sand. These are interstratified with layers formed of mixed sand and cobbles. The cobbles are formed of quartz and Cambrian quartzite. Some of them are 5 to 6 inches in diameter. The upper 8 feet of the deposit is composed of a brownish-yellow sand. This has numerous layers or crusts of the sand firmly consolidated by limonite. These layers are from 1 inch to 2 inches thick. This material seems to be the equivalent of that which occurs in White House Bluff, above the uppermost cobble bed.

The distance by river from White House to Mount Vernon is about 2 miles. Along the shore to the immediate vicinity of the last-named place no Potomac is displayed, and the Pleistocene alone is visible in the banks. The banks do not in their highest parts rise more than 40 feet above the water. The exposures of the Pleistocene begin about three-fourths of a mile below Mount Vernon, where the banks first show bluff-like faces.

At a point near where these bluffs begin there is a very fair exposure of the material in the highest part of the bank. The lower 30 feet of the bank is hidden because of the undermining and throwing down of the upper part. The exposed material is about 15 feet thick. At its base occur masses, 2 feet or more in diameter, of brownish-gray Potomac sand embedded in mottled clay. These masses have been torn up and redeposited. They are full of small clay balls. Owing to the incoherent character of this substance it cannot have been transported far. This brownish-gray sand is similar to that which occurs in White House Bluff at the top of the white basal sand. The mottled clay that surrounds these masses is about 3 feet thick. It is a brick-red sandy claystone rather than clay marbled with gray. The red color is bright. On this rests a cobble bed averaging about 3 feet in thickness. The cobbles are packed in mottled clay similar to that on which they rest. With the cobbles occur some large, partly rounded masses of Cambrian quartzite. They reach the diameters of 3 or 4 or even 5 feet. This stratum is evidently the equivalent of the bed of cobbles and large stones that occurs at the top of White House Bluff and near Pohick church. Above the cobble bed come 10 feet more of mottled clay. All of these mottled clays are decidedly sandy, and look much like the mottled sandy clay of the Potomac, but they appear to be of Pleistocene age. Deposits of similar age occur all the way up to the immediate vicinity of Mount Vernon, where the Potomac white sand, here mostly a sandstone, shows itself in the lowest portion of the bank

EXPOSURE AT MOUNT VERNON.

At Mount Vernon the hills that border the river slope back gently from it, so as to expose only occasionally a precipitous face immediately at the water's edge. At one or two points immediately above and below the wharf we find the banks showing abrupt faces ranging in height from 6 to 15 feet. These abrupt faces are formed by a light-gray to white sandstone of Potomac age. This appears to be pretty firmly consolidated. It has many irregularly shaped portions colored yellowish-brown. The hill on which the Mount Vernon mansion stands, at its upper end, as Professor Rogers long ago stated, is the last locality to show the white sandstone on the river in a coherent form. As will be noted later, this light-colored Potomac material is visible at Fort Washington, but it is inconspicuous there, and is in the form of a crumbling sand. The greatest thickness of the Potomac sandstone at Mount Vernon is shown at the pavilion, just below Mount Vernon wharf. Here about 15 feet of it may be seen. This has some thin layers of pinkish indurated clay. These are inclined to one another at various angles, and are irregularly arranged in the mass. This clay occurs both in remnants of the original layers and in recemented fragments. This material contains some fragments of plants, among them a fragment of Sapindopsis.

At the wharf the light-gray sand rises about 10 feet above the water, and is succeeded by a fine-grained sandy shale and argillaceous sand. The shale occurs as subordinate layers and partings in the more sandy portions. The shale partings, when purely argillaceous, are usually only 1 inch or 2 inches thick. In the lower part of the mass, however, they sometimes swell up to 12 inches. In some of the shale or clay partings poorly preserved fragments of plants occur, but they are not numerous. The flaggy, fine-grained sandy shale or sandstone is mostly dark gray in color, but it often has a yellowish-brown color, arranged in streaks and films. The thickness of the material seen was about 20 feet. This substance is strikingly like the shaly beds that occur in Baltimore, Md., and which there lie just above the white sand. These Baltimore beds are rich in angiosperm plants, and also contain many other kinds. This deposit differs widely lithologically from the light-colored coarse sand or sandstone that always forms the lowest of the Potomac materials. The occurrence of such material here and at Baltimore and the frequent appearance of redeposited clay of similar kind near the top of the light-colored sand suggest the idea that there was once an extensive formation of flaggy argillaceous matter lying upon the sand. A precisely similar deposit occurs at the locality in the woods near Potomac Run, on the Telegraph road, but this lies within the sandy member.

Above this horizon only small and detached outcrops could be seen. They show that, at the height of about 70 feet above the water, several

feet of pale-reddish and gray sandy clay occur. The highest part of the hill seems to be formed of reddish clays that are apparently Pleistocene in age.

EXPOSURE AT FORT WASHINGTON.

Fort Washington is on the Maryland side of the Potomac River, diagonally above Mount Vernon, and about 4 miles distant from the latter in a northeasterly direction. There is here a pretty high bluff a little below the wharf. The following approximate section was obtained at this point:

Section at Fort Washington, Md.

	Feet.
1. Sandy clay, with cobbles at base	5
2. Gray sandy clay, with shell imprints[1]	15
3. Variegated clays (upper Potomac)	30

No. 1 is Pleistocene of the usual kind. It is composed of sand and clay in the upper portion and has at its base a cobblestone bed of variable thickness. Five feet may be taken as the average thickness of this stratum.

No. 2. The base of this stands at nearly the same level, showing that the top of the variegated clay is eroded down to a quite uniform plane. This is marked by a crust of impure sandy iron ore, which is not continuous. At the junction of No. 2 with the variegated clays there is much gypsum; and this is often well crystallized, sometimes forming rosettes of crystals. No. 2, taken on an average, is an argillaceous, gray, often greenish-gray, sand, showing, in the weathered portions, crusts and concretions of ferruginous matter, which is often a fair iron ore. There is no apparent stratification in the old outcrops, and the material is loose in texture and very incoherent. Impressions of shells and a little imperfectly formed lignite occur in it in some places. The lower portion, extending up for about 12 feet from the base, is dark gray, with a slight greenish tinge, and is full of streaks and spots of brown pulverulent oxide of iron. This part is decidedly more argillaceous than the upper portion and contains imprints of shells. The upper part of No. 2, for the thickness of from 3 to 5 feet, is a light greenish sandy clay that weathers to an olive color. This appears to be without shell imprints.

No. 3 is the variegated clay, or iron-ore clay, so abundant in Maryland. It appears here for the first time on the Potomac River, not showing itself at White House Bluff, Gunstone Cove, or other points farther down the river. This group of beds, so far as investigations yet go, is not to be separated from the Potomac as seen in Virginia, but it is probably an upper member of the same formation. The upper most portion, for the thickness of about 5 feet, is mostly light-gray in color, with a lumpy and uncleavable structure. It shows many small

[1] These are of Eocene fossils near the top, and, according to Dr. W. B. Clark, marine Cretaceous in the lower beds. This marine Cretaceous has been designated the Severn formation on the maps of the United States Geological Survey.

streaks and spots of bright-red color. These make this clay look much like the variegated Lafayette matter to be seen at Petersburg. The material below the portion last described is in the main lead-gray or dark-gray in color. It is clear that this was the original color of all this lower deposit, so long as it was fresh and unweathered, but owing to the oxidation of the iron in some portions on the weathering of the mass bright-red and purplish-red colors are developed. These form numerous spots and streaks in the gray clay. Sometimes large masses are colored in this way. The amount of red color seems to be in inverse proportion to the amount of comminuted and diffused lignite. This latter appears to have prevented the oxidation of the iron. In some places the clay seems to be composed of spots of dark-gray and pinkish clay mixed in about equal proportions. The clay contains a good deal of iron ore scattered irregularly through it in the form of lumps and crusts. It is mostly impure, and was evidently formed by percolating waters taking iron in solution from the clays and concentrating it by concretionary action. The same clays, between Washington and Baltimore, have long been worked for the iron they contain. Sometimes the iron concretions strikingly resemble fragments of lignite in shape and structure, and it is probable that they are formed by the petrifaction of that material by a pseudomorphic process. A good deal of diffused lignite is found, mostly in the form of small fragments. The lead-gray clay, as well as the uppermost lighter colored material, is lumpy and uncleavable, showing no traces of lamination and bedding. It has the same peculiar structure as was seen in the torn-up and redeposited clays of the lower Potomac, but it has not the irregular admixture of sand shown by that. On the contrary, the material is quite uniformly a pure and plastic clay.

From an examination of this spot, as well as of numerous localities between Baltimore and Washington, it is clear that much of the lignite found in the variegated clays does not come from vegetation entombed for the first time in these clays, and there taking the form of that material. It almost certainly comes from the lower Potomac formation, the lignite of that group being eroded, comminuted, and redeposited in the upper Potomac or the variegated clay group. Logs and limbs of trees now changed to lignite are not uncommon in the lower Potomac, lying, more or less entire, as they were originally entombed; but such features are rarely seen in the upper Potomac. The clay above described extends down to the water level, and at the base of the bluff no lower Potomac was visible.

Fifty yards above the bluff, and between it and the wharf, the top of the lower Potomac may be seen. This spot is important, because we have here the variegated clay group superposed on the lower Potomac, a contact that is very rarely visible. Unfortunately the contact is near water level, and is seen only close to the edge of the water, so that it is not well displayed. The lower Potomac shows over the space of a

few yards at low tide only 4 or 5 feet of material. The greater portion of the lower Potomac visible at this spot is composed of the typical light-gray sand with clay balls, which is much stained with irregular markings, due to oxide of iron. This sand contains dark-gray clay, almost exactly like the overlying variegated clay when this latter is unweathered. It occurs in lenticular pockets, which are composed partly of the relics of large fragments of the original clay pockets, and partly of the smaller and confusedly redeposited fragments of these layers. The smaller recemented fragments cover and bury the larger fragments. The larger fragments of the original clay pockets may be distinguished by the possession of cleavage and by their content of plant impressions. The redeposited and cemented clay has the usual lumpy nature and confused structure, and in these points resembles strongly the variegated clay which overlies the lower Potomac.

There are strong indications here that the variegated clays are formed of material eroded from the upper part of the Lower Potomac. If this be true, then the upper part of this latter formation was originally composed mainly of argillaceous matter. This conclusion would be drawn from the exposures on Covington street, also near Federal Hill, Baltimore, where a remnant of this upper argillaceous portion is still visible, apparently furnishing from its ruins the clays of the variegated clay group which rests upon it. Unfortunately, at Fort Washington the variegated clay is not visibly superposed on the lower Potomac, for at the spot where the latter is exposed the river has cut away the variegated clay so as to leave a low bench of the older formation. There is certainly some unconformity between the two members of the Potomac formation here, established by an interval of time in which a considerable amount of erosion took place in the lower Potomac.

Lignite occurs in both the sand and the clay. It is sometimes in small fragments, but not rarely considerable portions of trunks and limbs of trees may be found, a feature rarely occurring in the variegated clay. Some comminuted lignite is found in the sand and clay, but the greater portion in the latter is evidently, so far as size is concerned, in the state in which it was first embedded.

The redeposited and cemented clay takes the form of lenticular pockets, and is sometimes mixed with some sand. In the larger fragments of clay, which retain the cleavage of the original layers, we find fragments of the leaves of *Dioonites buchianus*, portions of stems of *Frenelopsis ramosissima*, fragments of both an undetermined angiosperm leaf, and of other undetermined leaves.

EXPOSURES FROM ACCOTINK TO NEAR ALEXANDRIA.

On the turnpike leading from Accotink to Alexandria the exposures are very few and poor. Little is to be seen besides the débris arising from the disintegration of the Potomac and Pleistocene deposits. As

we approach Alexandria, in the top of the hill overlooking the mouth of Hunting Creek we may see a brownish-red, sandy clay, which is without stratification, and which seems to be Pleistocene. This apparently rests on a cobblestone bed which contains some large masses of Cambrian quartzite. The cobblestone bed rests on a layer of current-bedded, brownish-gray sand, in which many small pebbles are dispersed. The exposures are then interrupted. At a lower level in the hill there is an isolated outcrop of a white, highly argillaceous sand, which appears to be the representative of the light-colored sand member of the Potomac. This differs somewhat from the material on the same horizon in White House Bluff. It is of a finer grain and more uniform composition and texture and is more argillaceous.

Near the bridge at the mouth of Hunting Creek a light-gray to white argillaceous sand has been excavated and utilized to some extent for building purposes. It is mottled with yellowish-brown. This seems to be Pleistocene. On the opposite side of the creek, between it and the Potomac River, the Pleistocene sands and loams are well displayed. The loams have long been used for the manufacture of bricks.

The low-lying plain on which the city of Alexandria is built is composed of Pleistocene deposits. The Potomac formation is barely visible at a few points near water level. It is the usual light-colored sand. As the high hills west of the town that overlook this plain are composed of Potomac material, it follows that in the vicinity of the river there has been extensive erosion of the Potomac, by which this formation has been cut down much below its ordinary level, the Pleistocene lying upon it. This is not an unusual feature along the Potomac River, for, as we have seen, it is quite common to find the high land near the river formed of Potomac material, while the banks are Pleistocene.

The Pleistocene deposits near the mouth of Hunting Creek are, in their lower portion, composed of well stratified sands and clays, gray, yellow, red, and brown. The uppermost portion is a fine, massive, brick loam of gray color. This latter is about 15 feet thick at its maximum, but, being at the surface, it has been much eroded.

EXPOSURES NEAR SEMINARY STATION.

Seminary Station is on the Alexandria and Fredericksburg Railroad, 2 miles west of Alexandria. In the vicinity of this place there are several partial exposures.

On the road leading from a mill near the station to the theological seminary there is a small exposure showing at base about 12 feet of a brownish-gray sand and over that 5 to 6 feet of mottled claystone, marbled with reddish and brownish colors. The basal sand is, in the main, dark-gray, but it has broad, undulating bands, lenticular in form, of a brownish-red color. The sand contains embedded clay balls. There are thence no exposures on this road till a point is reached near the top of the hill not far from the seminary. Here we may see 10 feet

of yellowish, sandy clay, mottled with light-gray, and occasionally with peach-blossom and pink colors. It has some layers of gravel in it.

On the road leading from Alexandria to the Episcopal high school there are some slight exposures. A gray clay, of sandy nature, and mottled with red and reddish-brown, occurs near the high school. It may be seen on the road leading from the high-school gate up the hill to the old redoubts on the top of the hill. Immense numbers of large Cambrian quartzite cobbles occur on the western slope of this hill and in the valley west of the line of redoubts. Similar cobbles with occasional large masses of pre-Cambrian rocks may be seen on the surface between the high school and Alexandria. It is noteworthy that this surface in its highest parts is not less than 200 feet above the plain on which Alexandria is built. It is on a level with the tops of the hills, composed of Potomac material, that overlook Alexandria. These materials are wanting on the surface of the Pleistocene which underlies Alexandria.

In order that some idea may be formed of the materials composing these higher lands the following section is given. It represents only matter near the surface. It was obtained at a spring on the road leading from the high school to Alexandria, at a level from 30 to 50 feet below the top of the hill before mentioned, on which the old redoubts are situated.

SECTION ON ROAD BETWEEN ALEXANDRIA AND THE EPISCOPAL HIGH SCHOOL.

1. The highest material seen is a yellowish-brown sand. This contains undulating thin layers and streaks of gray sand, and shows in its base small balls of clay. The thickness is 2 feet. The clay is found in the form of numerous small balls, cakes, or short films, and is clearly material that has been eroded and redeposited in the sand.

2. Next under this comes 6 feet of brownish-yellow sand. This has in places small clay pellets, arranged in undulating layers, and some lighter colored sand disposed in thin, wavy layers.

3. Under No. 2 comes 5 feet of brownish-red sand. This is full of small balls of gray clay that are arranged rudely in layers or are scattered through the mass.

4. Under No. 3 comes 6 feet of brownish-yellow sand with some thin layers having a peach-blossom and pink color.

5. The lowest material exposed is a mass of coarse, brownish-yellow sand, about 12 feet thick, much affected by current-bedding. A considerable portion of this material is replaced, in a very irregular manner, by a gray argillaceous sand which, in some places, graduates into a tenacious and true clay. This forms irregular patches in the sand. The color and texture of this material contrasts strongly with the enveloping brownish-yellow sand. The gray material looks like matter eroded from a source different from that furnishing the brownish sand.

and seems to have been deposited in masses in that sand. This illustrates a feature rather common in the Potomac, for one kind of material is not uncommonly found embedded in, but distinct from, another kind. Toward the top of No. 5 occur layers of gray clay, formed of recemented material. Many distinct and large balls of this clay are scattered through the brownish-yellow sand.

Over the material shown in this section heavy beds of large cobbles occur. These may be well seen on the road ascending from the level of the spring and near by it. Here is an exposure of several feet of gray, sandy clay, mottled with yellowish brown. A heavy bed of cobbles rests on this.

EXPOSURES ON THE RAILROAD NEAR SEMINARY STATION.

Several exposures may be seen in the cuts on the Alexandria and Fredericksburg Railroad going south from Seminary Station. They occur beyond the crossing of this road and the Virginia Midland Railroad. The first cut that makes any disclosure of the Potomac is found about 1½ miles from the station. This cut shows in its lowest part from 2 to 3 feet of a light-gray sand, much stained with brown and yellow. It seems to be the usual light-colored Potomac sand. At the northern end of the cut this sand is abruptly replaced by a mottled, sandy clay. This latter is dark gray mottled with brick red. On one side of the cut only 3 or 4 feet of this material is shown, but on the opposite side it has thickened to 8 feet. On this side 6 feet of the sand appears beneath it. A layer of pebbles intervenes between the sand and the clay.

A few yards farther south the mottled clay swells up to 15 feet and overlies 4 to 5 feet of dark-gray sand that is mottled and stained with yellowish-brown. The basal sand seems to have been eroded before the clay was laid down upon it. At this point the sandy clay is dark ash-gray, varying to violet-gray, and is mottled with various reddish tints.

A few yards still farther south the basal sand rises in the form of an arch to the height of 15 feet, and above it appears 10 feet of the clay. The lower portion of the mottled clay here, for the thickness of 3 or 4 feet, shows parallel seams of the material, cemented and indurated by the deposition of limonite. At this spot the basal sand is in some places almost white in color and it is all strongly marked with current-bedding.

At the south end of the cut the mottled clay is abruptly replaced by a coarse, brownish-yellow grit, which is full of layers of small gravel and has large cobblestones in its base. All of these materials are covered by heavy deposits of coarse gravel and cobblestones which form the surface.

Between the point last described and the localities in the vicinity of Telegraph Station there are several cuts of small depth that expose materials which, in the main, are similar to those just described. In

several of the cuts the proportion of sandy clay having various colors is quite large, in many cases from 10 to 15 feet being shown with little other materials. The colors in these sandy clays are generally distributed in irregular masses and they are often bright. Among them brick-red, purplish-red, and reddish-brown are most common. Ash-gray and violet-gray colors are also found. Occasional exposures of the white sand occur, but this is not so common as the highly-colored sandy clay.

EXPOSURES ON LITTLE RIVER TURNPIKE.

Little River turnpike runs nearly due west from Alexandria, leading to and beyond Fairfax. Exposures of such material as was seen between the high school and Alexandria occur occasionally on this road, but as there are few excavations, and as the surface is covered by a great sheet of débris arising from the waste of the Potomac, the exposures are very imperfect and disconnected. There are many cobblestones on the surface, often of large size, composed mainly of Cambrian quartzite.

The superficial capping extends for a long distance west of Alexandria along this road. Seven miles west of that town an outcrop of Potomac may be seen in a gully on the side of the road. This rests on eroded and much-decayed crystalline rocks. These are fine-grained mica-schists and chlorite-schists. The lowest portion of the Potomac is a brownish-gray sand, 3 feet thick, which contains in its base some yellowish-gray sandy clay. On this rests a gray sandy clay, mottled with yellowish-brown, 1 foot thick. Above this comes 3 feet of brownish-gray sand, mottled and banded with yellowish-brown. This latter contains some small clay balls and pebbles. Above the last-named material we have 2½ feet of yellowish sandy clay, containing some particles of gray clay that look like eroded and redeposited fragments. On the top of the whole is the usual surface cobble deposit. In a thin seam of clay occurring in the 1-foot layer some fragments of coniferous plants were found.

About half a mile west of this point the Potomac has nearly disappeared, and is represented by a few feet of reddish-brown sandy clay. Half a mile west of the last-named point the crystalline rocks form the surface, and all traces of the Potomac have disappeared.

It is noteworthy that the abundant surface cobbles that have accompanied us up to this point disappear when we pass into the terrane of the crystalline rocks and give place to the angular quartz fragments and other substances set free by the decay of these rocks. This is strong evidence that these cobbles came originally from the Potomac formation. We may place the western limit of the Potomac on the Little River turnpike at about 7 miles from Alexandria. It then sweeps around to the northeast, toward the Potomac River, so as to enter the District of Columbia a little west of Washington.

THE POTOMAC AT AND BETWEEN WASHINGTON AND BALTIMORE.

On entering the District of Columbia two members of the Potomac formation may be recognized. The lower is that traced through Virginia, and this is the only member recognized in that State. From the predominance of sand and sandstone in this it may be called the sandy member. The other, or upper member, is composed of sands and clays, mostly the latter, both being usually highly colored with tints due to oxide of iron. The clays greatly predominate. They have the colors arranged in irregular spots, patches, and seams, and on account of this they have been called by Mr. Philip Tyson and Professor Rogers the variegated clay group. This is the upper member of the Potomac described at Fort Washington.

The sandy lower member of the Potomac is visible at Washington and at several points between Washington and Baltimore, in the vicinity of the Baltimore and Ohio Railroad. The farthest point north at which it has as yet been seen is Baltimore. This member is deeply buried under the variegated clays, and it is reached only in the deepest excavations. At Baltimore it contains all the plants there found whose horizon has been determined, with one exception. These occur in flaggy sandstone and shale at the top of the sandy member. The fossil which forms a possible exception is the cycad, *Tysonia marylandica*, found by Mr. Tyson. The exact horizon of this is not fully established, but from Mr. Tyson's account its place is either the base of the variegated clays or the top of the sandy member of the Potomac. The upper member of the Potomac, or the variegated clay member, is younger than the basal sandy member, as is shown by its superposition and its want of conformability, the former resting on the eroded surface of the latter. This upper member extends far beyond Baltimore to the north. It has been traced by Mr. McGee to and beyond the head of Chesapeake Bay.

THE GEOLOGICAL POSITION OF THE POTOMAC FORMATION.

In dealing with the question of age only the lower or sandy member will be taken into consideration, for this is the only portion of the formation known to be present in Virginia. In fixing the age of the Potomac formation we are aided somewhat by its stratigraphical relations to known formations and to a greater extent by the plant remains that it contains.

The stratigraphical relations of the formation unfortunately do not fix within narrow limits its place in the geologic column. In Virginia the youngest formation upon which the lower, or sandy member of the Potomac is seen to rest, is the older Mesozoic or Rhetic formation. The interval of time, however, between the deposition of the Rhetic and the deposition of the Potomac beds must have been a considerable one. There are several reasons for coming to this conclusion: (1) Where the superposition of the Potomac on the Rhetic is visible

the latter is seen to have been greatly worn before the deposition of the former. (2) The lithologic and structural character of the two formations is very different, implying a total change in the conditions of deposition. (3) The Rhetic is made up of sandstones and shales which are distinctly bedded, so that the dip and strike can be easily made out. The materials composing these beds were well sorted by water action. Before the deposition of the Potomac the Rhetic strata had been consolidated and, in the main, indurated, so as to form firm sandstones and shales, or even slates. The Rhetic beds are in many places crushed, contorted, and faulted, all of which changes took place before the Potomac age. No traces of them are found in the Potomac. The Rhetic is also penetrated by numerous dikes of igneous rock, none of which pass into the Potomac beds. The interval of time separating the two formations must, then, have been long enough to permit the occurrence of important geologic changes. These resulted in the draining off of the Rhetic waters and in the lateral compression of the Rhetic areas, which caused crumpling and faulting of the strata and outpours of igneous rock. The Rhetic basins were elevated and formed into dry land, subjected to great erosion, and the most eastern of them then depressed and brought under water again. Certainly no Rhetic species of plant survives into the Potomac.

In Virginia the oldest formations coming next above the Potomac are the Eocene. In Maryland, and probably northward, the group of variegated or iron-ore clays comes next above the Virginia or sandy member of the Potomac, but with an unconformity produced by erosion. The age of this group is unknown, and its relation to the New Jersey Amboy clay has not as yet been determined. This Maryland group, which at present must be regarded as an upper member of the Potomac formation, is probably somewhat older than the New Jersey beds. If it should prove to be not older, it is most probably of the same age as the last-named formation.

The New Jersey beds, as is shown by their fossil plants, are certainly considerably younger than the Virginia member of the Potomac. So far as is yet known, the Amboy clay is not younger than the Cenomanian of Europe.

So far, then, as can be determined by the stratigraphy, the Virginia Potomac is considerably older than the Cenomanian, and much younger than the Rhetic. The evidence from the stratigraphy, so far as it goes, agrees well with that of the fossils found in the Potomac.

The Wealden formation is most probably not uppermost Jurassic, but the estuary and marsh equivalent of the oldest marine Neocomian. What will be said therefore concerning the Neocomian will include the Wealden.

The animal remains found in the Potomac are very rare. At Dutch Gap a single impression of the posterior part of a fish was found. This has a homocercal tail, and is about as large as a shad. Its affinities have not been determined. At the bank near Brooke, and at

White House Bluff, three or four species of Estheria have been found. They were identified as Estheria by Dr. C. A. White, but as yet their geologic significance has not been made out. These are all the animal fossils that have been found.

When we consider the great numbers of fossil plants yielded by the Potomac beds, it is surprising that no traces of insects have been met with. The negative evidence in this case is entitled to more than common weight. A very large amount of material was collected at widely separated localities and carefully worked over. A close search was made always for animal fossils. We are then fairly entitled to conclude that in the areas of Potomac material now exposed animal life was not abundant. The rarity of animal fossils can not be attributed to any character of the rocks unfavorable to their preservation, for many of the clays are well adapted to this.

The flora of the Potomac seems to have been an abundant one. It was rich in species of certain groups, but, as compared with modern floras, it was poor in types. A large amount of fossiliferous material was obtained from points located at intervals between James River and Baltimore. The fossils found will give a fair idea of the general character of the flora. This flora has been studied by me, and is described in Monograph XV of the United States Geological Survey. The comparison of these plants with those of known fossil floras shows somewhat complex relations.

There is present in the Potomac flora a Jurassic element which is large in the very considerable number of genera that characterize that system. Some few of the genera begin as far back as the Rhetic. This element shows indications of decadence. The number of species of each genus is very small; generally only one or two. Very few individuals of the species are met with, and they are usually local in occurrence. The species are nearly or quite all peculiar to the Potomac.

There is an important Wealden element in the flora. Many species of Potomac plants are identical with species found in the Wealden of Europe, and this is the oldest known fossil flora that gives any considerable number of plants identical with Potomac species. Some of these species of the European Wealden are abundant and widely diffused plants in the Potomac. But while the species common to the European Wealden and the Potomac are noteworthy, there is a still larger number of important species found in the Potomac which are so nearly allied to Wealden species that they are with difficulty distinguished from them. These, although regarded as new species peculiar to the Potomac, are probably forms representing Wealden species, being modified by differences of environment.

The Jurassic and the Wealden elements combine to give a Jurassic or Mesozoic facies to the flora, and hence, so far as they go, give it a comparatively ancient character. The Jurassic or Mesozoic type of flora is, as is known, characterized by the overwhelming predominance

of four elements, viz: Equiseta, ferns, cycads, and conifers, and by the absence of angiosperms.

The formations which possess the largest number of species identical with those of the Potomac are those of the Middle Neocomian or Urgonian. The strata of this age which occur in Greenland (in Kome and other localities) and the Wernsdorf beds of the northern Carpathians yield an Urgonian flora, which Heer and Schenk have described. In the plants coming from these regions we find the largest number of forms identical with Potomac species. The number of Potomac species nearly allied to Urgonian forms is still larger. These identical and nearly allied species include many of the most characteristic, abundant, and widely diffused species of the Potomac. If we are to determine the age by the largest number of important species identical with those of known fossil floras, then we would without hesitation set it down as ranging from the Lower through the Middle Neocomian. A very large and important element of the Potomac flora is peculiar to this series. In this we find without doubt the most abundant, characteristic, and widely diffused species. As these are new, they can not give any direct evidence concerning the age of the formation, but, indirectly, the existence of such a large proportion of peculiar forms is favorable to the assumption that the age is Neocomian. The flora of this formation is one of the least known, and any large collection of richly fossiliferous material from beds of Neocomian age could not fail to furnish a great number of new species.

Then again, the relatively great development of the conifers, along with the existence of an important cycadaceous element, points strongly to the Neocomian as the era of the formation. The survival of a considerable Jurassic element in the flora also indicates that it can hardly be younger than Neocomian. While much the most important elements of the flora indicate an age not more recent than the Urgonian or Middle Neocomian, there are some species which point to a more recent era of deposition for the formation. There are one or two species which are probably identical with forms found by Heer in the Cenomanian beds of Greenland. These are local and are represented by very few individuals. A few of the species also may be considered as nearly allied to some occurring in the Greenland Cenomanian. These Cenomanian types are probably to be regarded as precursors not yet fully established, just as the Jurassic types must be considered as survivors not yet extinct.

The angiosperm plants present in the flora are much more important in giving a more recent facies to the flora. They show quite a large number of species, but these are almost always local in occurrence, and are represented in most instances by few individuals. In a number of cases only one or two specimens were found. It has been generally held that any considerable development of angiosperms in a fossil flora is strong, indeed conclusive, evidence that its age is not greater

than that of the Cenomanian. But apart from the evidence given by the older and predominant elements of the flora, there is reason to think that the Potomac flora is older than Cenomanian, even if we take into consideration the angiosperms alone.

The conclusion above mentioned is based solely upon the fact that in no flora older than Cenomanian has any considerable angiosperm element been found up to the present time, but various writers have with justice maintained that it is improbable that the apparently sudden appearance of angiosperms in great force in the Cenomanian represents the true state of the case. It is highly probable that they had numerous precursors and ancestors, which existed in the Neocomian, and perhaps some of them, at least, in the Jurassic. It is probable that some of the forms called Protorhipis are ancient angiosperms. The existence then of numerous angiosperms in a flora which is predominantly Neocomian, but which contains many surviving Jurassic types, is just what we would expect to find. But we have direct evidence of the existence of angiosperms in the Necomian. Heer has described from the Kome beds of Greenland, which are Urgonian in age, an angiosperm which he called *Populus primæva*. Only a few specimens were found. This single occurrence has remained so long unsupported by other discoveries of angiosperms in the Neocomian that doubts have been expressed concerning the correct localization of these specimens. It was thought possible that they really came from a younger flora. If the Potomac flora is in fact Neocomian, we have in this case a noteworthy illustration of the truth that positive evidence, however scanty, should outweigh any amount of negative evidence.

The Potomac angiosperms in their general character give evidence of an age greater than Cenomanian. It is true that we find in them genera, and possibly some species, that survive into the Cenomanian and even down to the present time, but taken as a whole they form a peculiar group, totally unlike the floras of the Dakota and the Amboy beds. It is in the flora of the Dakota group, and of the Amboy clays of New Jersey, especially the latter, that we would expect to find the greatest number of plants identical with Potomac forms. Both of these floras are Cenomanian probably, and the Amboy flora, so far as yet known, is the one that comes next above the Potomac. There are one or two species that are probably common to the Potomac and the Dakota beds, or that are nearly allied, but they are long-lived types, that come down to the present time with little modification.

By the kindness of Dr. J. S. Newberry, who studied and described the New Jersey Amboy flora, I have been enabled to examine a large number of drawings of the New Jersey plants. These plants are totally different from those of the Potomac. It is not certain that a single species survives from the Potomac into the Amboy beds. What is even more significant, even the genera that are most abundant in the Potomac and most characteristic of that formation have no representative

in the New Jersey flora. It is clear that a very important gap exists between these two floras, and that an interval of time separates them, in which changes took place that produced an extensive destruction of vegetal types and altered the entire character of the flora.

The localization of the species of Potomac angiosperms and their slight development, as shown in the very few individuals that in most cases represent them, indicate that these forms are, comparatively speaking, newcomers and precursors or ancestors of forms destined to become the predominant ones. This indication is confirmed by the character of a number of the species. They appear to be complex or comprehensive types, uniting in one form features that in the process of differentiation will later distinguish separate species.

We may then conclude that the Potomac flora is not exactly like any known, but on the whole coincides most nearly with that of the Lower and Middle Neocomian. If this be true, then, we find that in this flora the development of angiosperms in considerable numbers has been pushed back through a long period of time.

The extent of the area over which the Potomac beds are found entitles the formation to rank among the more important ones of the United States. If we limit its extent to the area occupied by the lower or sandy member, we still find it to be very considerable. If we take this member as stopping at Baltimore and existing no farther south than the Nottoway River, with an eastward extension to a north-and-south line passing through Fort Monroe, we would still have it spreading over 12,000 square miles of territory. The character of the Potomac materials indicates that they were deposited in comparatively shallow waters that were fresh or at most brackish. The waters appear to have been agitated and subjected to changing, and sometimes powerful, currents. As these deposits all show "beach" and "ebb and flow" structure, we may conclude that they were laid down in estuaries or along shore. From the position and character of the lower Potomac deposits between Baltimore and the Nottoway River the idea is suggested that they were mostly formed in the united estuaries of two great rivers corresponding to the present Potomac and James. It is clear that the waters in which they were deposited were loaded with sediment, and this was constantly changing in character. The assumption that the Potomac was formed in or near the estuaries of great rivers best explains all the peculiarities of the formation. If this is true, we have in the conditions of deposition a resemblance to the European Wealden, the flora of which, in part at least, shows affinities with that of the Potomac.

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