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COMMONWEALTH OF VIRGINIA
STATE COMMISSION ON CONSERVATION AND DEVELOPMENT
VIRGINIA GEOLOGICAL SURVEY
Arthur Bevan, *State Geologist*

Bulletin 32

Sand and Gravel Resources of the Coastal Plain of Virginia

Prepared in cooperation with the United States Geological Survey and the Virginia State Highway Commission

BY
CHESTER K. WENTWORTH

UNIVERSITY, VIRGINIA
1930

RICHMOND:
DIVISION OF PURCHASE AND PRINTING
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LETTER OF TRANSMITTAL

COMMONWEALTH OF VIRGINIA
VIRGINIA GEOLOGICAL SURVEY
UNIVERSITY OF VIRGINIA

CHARLOTTESVILLE, VA., January 16, 1930.

To the State Commission on Conservation and Development:

GENTLEMEN:

I have the honor to transmit and to recommend for publication as Bulletin 32 of the Virginia Geological Survey series of reports a manuscript and illustrations of a report on the *Sand and Gravel Resources of the Coastal Plain of Virginia,* by Chester K. Wentworth.

This investigation was made in cooperation with the United States Geological Survey and the State Highway Commission (now the Department of Highways).

The report discusses the characteristics and origin of the terraces and surficial formations of the Coastal Plain of Virginia, with emphasis upon the occurrence and nature of usable deposits of sand and gravel. Many mechanical analyses have been made of the materials in these deposits, and the results are shown in an extensive series of graphs. The sand and gravel resources of the Coastal Plain are summarized by counties.

As this report is the only one that treats in detail of the occurrence and character of the sand and gravel of the Coastal Plain, it should be of value to all interested in the resources of that part of the State.

Respectfully submitted,

ARTHUR BEVAN,
State Geologist.

Approved for publication:
State Commission on Conservation and Development,
Richmond, Virginia, January 16, 1930.
E. O. FIPPIN, *Executive Secretary*

CONTENTS

ILLUSTRATIONS

TABLES

ABSTRACT

The Coastal Plain of Virginia is underlain by three great series of rocks: (1) A buried, closely folded mass of pre-Cambrian crystalline and early Paleozoic sedimentary rocks, (2) an overlapping series of Cretaceous and Tertiary sediments, mostly only slightly indurated, and (3) a veneer of Pliocene and Pleistocene gravels, sands, and loams lying in terrace formation on the beveled edges of the next earlier rocks.

This report deals with the terraces and the sedimentary formations of the youngest series. Six principal terraces and terrace formations are recognized and described. The oldest terrace, the Brandywine, is thought to be of Tertiary (Pliocene) age. The Pleistocene terraces, from the oldest to the youngest, are the Sunderland, Wicomico, Chowan, Dismal Swamp, and Princess Anne. The latter two names are used for the first time in this report.

These terraces are typically developed as a series of steps, the highest terrace in a given region being commonly a dissected upland against the margins of which the successively younger terraces have been cut. The older and higher terraces and formations are chiefly fluviatile in origin, whereas the younger are in part marine and in part fluviatile. The development of the higher, fluviatile terraces is more prominent in the northern part of the Coastal Plain of Virginia, but in the southern part the marine terraces occupy a larger part of the width from east to west.

The average thickness of the terrace formations is not more than 30 to 40 feet. They consist of ferruginous, loamy gravels and massive, pebbly loam beds, with well-sorted, clean sands and fine gravels which increase in relative amount in the lower terraces and in situations close to the present waterways.

One of the chief problems in the study of the terrace formations is the discrimination between fluviatile and marine terraces or phases of the same terrace. Physiographic and petrographic criteria for such separation are discussed. The Brandywine and the larger part of the Sunderland formation are interpreted as fluviatile in origin. The larger part of the Wicomico formation in Virginia and the principal areas of the younger formations are thought to be marine, though fluviatile phases exist.

Following a long period of weathering and erosion in post-Miocene time, there was an increase in stream competence which resulted in building great alluvial fans in Brandywine time. It is thought probable that the cause of this change was climatic rather than tectonic. It is estimated that the duration of Brandywine time may be of the order of 25,000 to 50,000 years. After the close of Brandywine time, the Potomac and other streams cut deep channels through the newly formed deposits and into the underlying rocks.

After a time, an increase of stream competence and a halt in down-cutting led to the formation of the Sunderland fans and other terrace deposits within the post-Brandywine gorges and seaward from the higher parts of the Brandywine accumulations. Along the coastal margin fluviatile Sunderland sediments advanced over marine formations of slightly earlier age. During this and subsequent terrace-forming epochs numerous faceted and striated blocks, thought to have been formed by the action of river ice, were rafted out onto the terrace flats and deposited in situations otherwise devoid of coarse material.

Following Sunderland time, the sea rose slightly and waves encroached on the Sunderland deposits. It is believed that the lower part of the eastern peninsula of Virginia had not been established at this time, and that other drainage conditions were in course of evolution toward their present state. A succession of lower fluctuations of sea-level resulted in the formation of the several lower terraces. In the marine terraces there is clear evidence of several shifts of the level of the sea with respect to the land. No adequate evidence is at hand, in the opinion of the writer, to establish significant differential or tilting movements, and it is thought that all the slopes of existing terrace surfaces are substantially those of original deposition.

Large quantities of loam gravel, suitable for sub-foundation for highway construction, are found in the counties adjacent to the principal streams. Practically no such gravel is found in the eastern counties. Washed gravel of coarse grades is available chiefly from the major streams near the Fall Belt. Large amounts of washed sand are here also and in beaches along various parts of the coast.

Sand and Gravel Resources of the Coastal Plain of Virginia

By Chester K. Wentworth

INTRODUCTION

LOCATION AND EXTENT

The Coastal Plain of Virginia includes all of the State east of the Fall Line, which is along the eastern margin of the Piedmont Plateau. Its relation to the remainder of the State is shown in Figures 1 and 2. In the northern part of the State it is almost co-extensive with Tidewater Virginia, but south of James River it includes a large area which is not adjacent to tidewater.

The Coastal Plain of Virginia has an area of 8,161 square miles or 20.3 per cent of the State. It is one of the most extensive compact areas of land in North America, which is mostly less than 10 miles from tidewater. This is shown in Table 1 below.

Table 1.—*Accessibility of the Coastal Plain of Virginia to tidewater*

Distance from tidewater	Area in square miles	Per cent
0 to 2 miles	2,801	34.3
2 to 5 miles	1,689	20.7
5 to 10 miles	1,209	14.8
Over 10 miles	2,462	30.2
	8,161	100.0

TIDEWATER PENINSULAS

As is shown in Figure 2, the tidewater part of the Coastal Plain in Virginia is divided by long narrow tidal bays and Chesapeake Bay into several prominent peninsulas. From north to south they have been designated as (1) the Northern Neck, between the Potomac and the Rappahannock, (2) the Middle Peninsula, between the Rappahannock and the York, (3) the Peninsula (or Williamsburg Peninsula), between the York and the James, (4) the Norfolk Peninsula, and (5) the Eastern Shore, east of Chesapeake Bay.

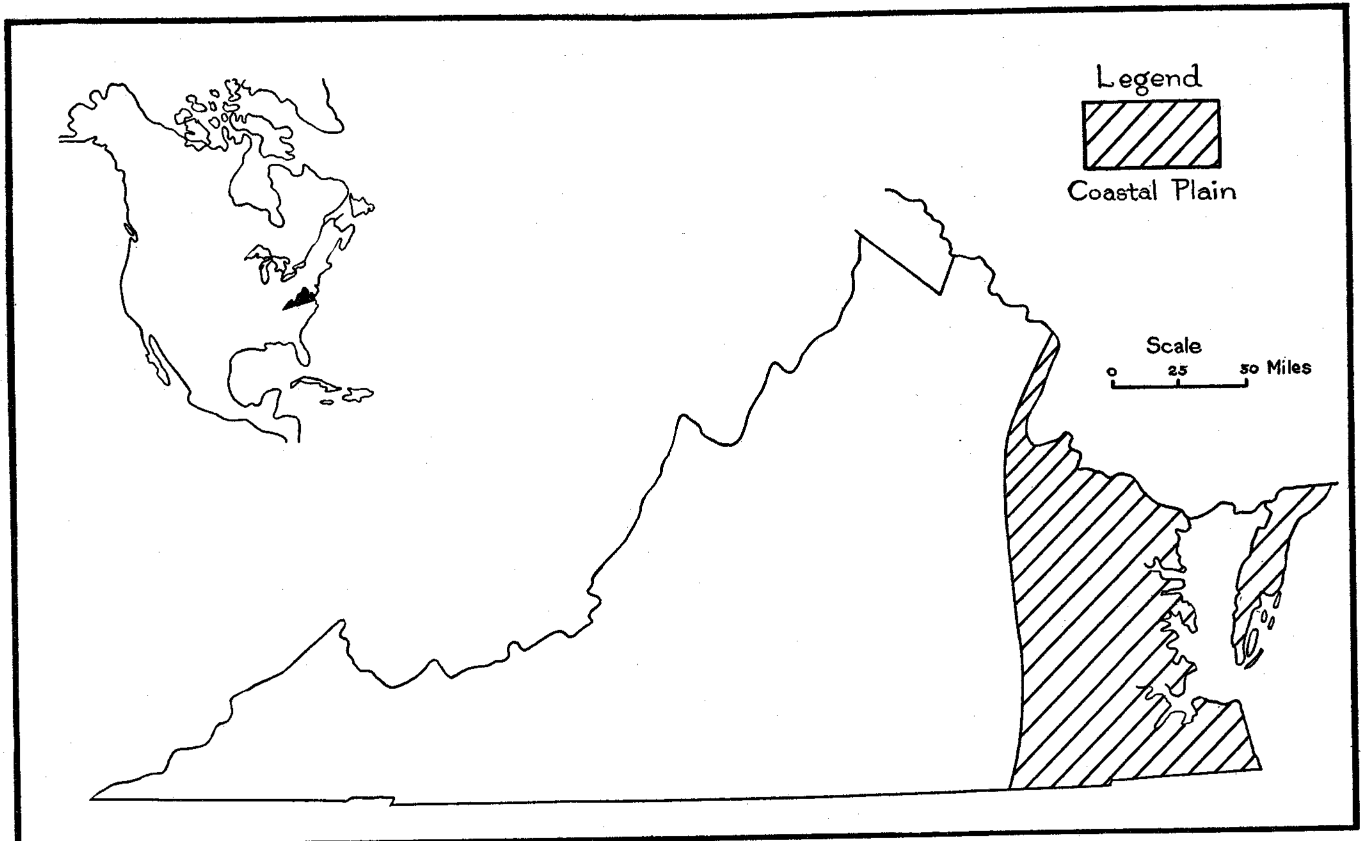


Figure 1.—Index map showing the relation of the Coastal Plain of Virginia to the State and to the continent of North America.

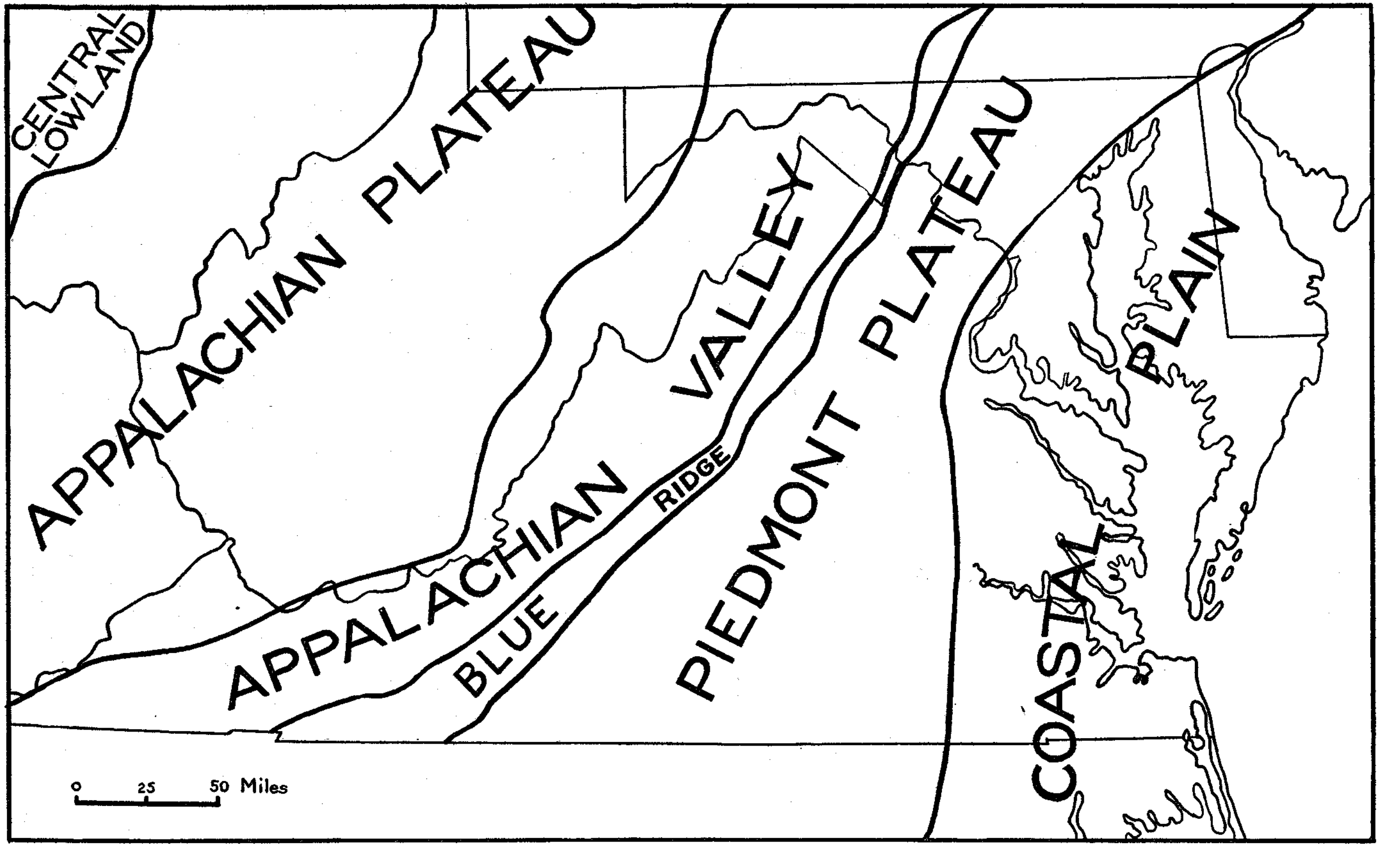


Figure 2.—Sketch map showing the physiographic divisions of Virginia.

PURPOSE OF INVESTIGATION

The purpose of this study was to make an areal examination of the sand and gravel formations of the Coastal Plain in order (1) to determine the location and quality of deposits adapted for commercial use and (2) to obtain a basis for estimating the available sand and gravel in different parts of the Coastal Plain. It was hoped that data might be gathered also on the form, structure, correlation, and relations of the terraces, as a contribution to the areal and historical geology of the Coastal Plain.

The writer began to study the terraces and gravels in 1921 and continued the work with some interruption until the winter of 1926. His work prior to 1926, mostly in the basin of the Potomac River, has led to conclusions somewhat discordant with those of Stephenson for North Carolina. It seemed, therefore, desirable to study in some detail the terraces of the Coastal Plain of Virginia and to carry the mapping and correlations from the Potomac to North Carolina. The results of this study are given below.

Because of their historical significance careful search was made for striated and faceted cobbles and boulders, which had been found at many localities in the Potomac River basin. During this field work they were found at scores of localities in the basin of James River and on the terraces of the eastern part of the Coastal Plain, and thus the known occurrence of these erratics was extended south to the State line. This study thus has contributed data to a very interesting problem of geologic history during Pleistocene time.

FIELD WORK

The field work was done mainly between early June and September 15, 1926, and during December, 1926. Travel was mostly by automobile. Ten days in August were spent in a boat on Chesapeake Bay and the James, York, Piankatank, and Rappahannock rivers. Grading of trunk highways in the recent road program has made a large number of excellent exposures of the surficial materials. These cuts are very valuable to geologists and engineers in their search for road materials.

Field observations were confined mainly to exposures of gravel on river banks and in railroad and road cuts. Lack of time prevented extensive digging or boring. Main highways were traversed and river banks were examined at intervals of 2 to 5 miles. Most of the Coastal Plain is covered by excellent topographic maps, which show the principal terraces and their scarps. Hence steep bluffs and other points of probable exposure of the formations were readily determined, and much unnecessary travel was avoided.

Samples of sand and gravel suitable for commercial use, or typical of local terraces, were collected for mechanical analysis and study of their composition. During the boat cruise about 80 bottom samples were collected in an effort to learn something about modern sedimentation in the tidal mouths of rivers of the Coastal Plain.

LABORATORY METHODS

Most of the samples of sand and gravel were analyzed mechanically to determine the proportions of materials of various sizes. The methods were essentially those described elsewhere by the writer.[1] Most of the samples were sifted for a uniform time of 5 minutes in the Tyler Ro-tap sieve shaker. The grade scale, previously described by the writer,[2] consists of a geometric series starting from a 1 millimeter opening and expanding by the multiples and submultiples of two. For the convenience of engineers, the results of the mechanical analyses are given also in this report in the English units of the 10-20-30 mesh scale.

Because of the relatively lesser importance of the finer portion of the gravel in separating the various types, the total amount only of the sample below the 1/16 millimeter sieve size was determined. Each grade of each sample was examined to determine the principal minerals, the shapes of particles, and other features of especial interest. A thorough analysis of most grades or samples was not attempted, but especial attention was given to the more unusual ones.

ACKNOWLEDGMENTS

The work discussed in this report was undertaken primarily for the Virginia Geological Survey. Field work during the month of June, 1926, was supported by the United States Geological Survey as a continuation of studies, begun in 1921, of the terraces and gravels of the Coastal Plain. Field work during July, August, and September, 1926, and subsequent office work were supported by the Virginia Geological Survey and the Virginia State Highway Commission. The Virginia Commission of Fisheries cooperated by the loan and maintenance of the boat "Katie" and a crew of three men for 10 days on Chesapeake Bay and its tributaries. The United States Coast and Geodetic Survey loaned apparatus for

1 Wentworth, C. K., Methods of mechanical analysis of sediments; Univ. of Iowa, Studies in Natural History, vol. 11, no. 11, pp. 1-52, 1926.

2 Wentworth, C. K., A scale of grade and class terms for clastic sediments: Jour. Geology, vol. 30, pp. 377-392, 1922.

Op. cit., pp. 21-24.

taking bottom samples. The writer wishes to thank these organizations for their ready and effective cooperation.

During the field work and preparation of the report the writer has been especially aided by advice and suggestions from L. W. Stephenson, M. R. Campbell, and W. W. Rubey, of the United States Geological Survey, and Shreve Clark of the Virginia State Highway Commission. It is a pleasure to acknowledge also the technical suggestions, counsel, and aid rendered in administrative ways by Wilbur A. Nelson, Director of the Virginia Geological Survey when the field work was done and the report was written. The report has been edited and prepared for publication by the present staff of the Survey.

SURFACE FEATURES

TOPOGRAPHY

GENERAL STATEMENT

The Atlantic Coastal Plain extends from the Fall Line on the west to the submerged margin of the continental shelf on the east (Fig. 2), and from Eastern Massachusetts to Florida. Though the present coast line may, from the human viewpoint, seem permanent, it is geologically a very temporary feature, which has at times in the recent geologic past shifted back and forth across the Coastal Plain. (See Pl. 1, A.) It has thus occupied positions at times east of the present shore line and at others almost as far west as the present Fall Line. Parts of the submerged Coastal Plain, as well as the land area, are described because the history of the two sections has been intimately interrelated.

THE LAND AREA

In its simplest aspect the Coastal Plain consists of a gently sloping lowland which rises gradually from the sea to maximum elevations of slightly more than 300 feet at its western margin. The Fall Line, or more properly Fall Belt, is a transition zone to the Piedmont Plateau on the west. This belt is generally characterized by (1) a steeper seaward slope, (2) increased gradients, and (3) falls and rapids in the streams. (See Pl. 1, B.) The Fall Belt is rather sharply marked in the main valleys but elsewhere the slope, though steeper than in the Coastal Plain or the Piedmont Plateau, is so gentle that there is no pronounced break in the topography.

The average east-west width of the Coastal Plain is about 100 miles. Its average slope to the east or southeast is less than 3 feet to the mile. The surface of the plain in detail is more complex than is indicated by a general view. The simple slope of the plain is interrupted by a series of sea-facing terraces which extend from north to south across the province. The highest terraces are in the western part of the plain and the lower terraces occur in succession east of their eastern margins. The Coastal Plain consists almost wholly of the upper surfaces of these terraces, as the area in the slopes and low escarpments that connect adjacent terraces is very slight as compared with the "treads" of the terraces. The maximum widths of individual terraces are 25 to 30 miles. Terraces have been cut away in places during the formation of the next lower terrace. The upper surfaces of the terraces slope seaward generally about 1 or 2 feet to the mile. The escarpments between adjacent terraces are much steeper.

Six principal terraces are recognized in the present report, being from highest to lowest, the Brandywine (Pl. 2, A), the Sunderland (Pl. 2, B), the Wicomico, the Chowan, the Dismal Swamp (Pl. 11, B), and the Princess Anne. (See Fig. 5.) It is apparent from the manner of their formation that the highest terrace is the oldest and that the lowest terrace is the youngest. The distribution of the terraces is shown in Figure 24 (p. 46). Much of the original surface of these terraces was flat with few variations of 10 to 20 feet over considerable areas. The older terraces have been dissected by streams so that areas of only a few acres remain at the original level, but more or less continuous remnants along the branching divides give the appearance of a broad plain.

As the younger terraces are generally less dissected, many areas of several square miles show only slight modification. The scarps separating adjacent terraces range from 10 to 50 feet in height. Where extensive development of a lower terrace has cut away an intermediate one, the scarps are considerably higher. At many placs the lower and younger scarps are very steep, having been but slightly modified since they were eroded by waves along the ancient coast line. Even the older scarps, though notched in places by valleys, are generally rather striking features. Some extend almost unbroken for many miles. (See Figs. 63 and 103.)

The general conception of the Coastal Plain as a lowland composed of gently sloping sea-facing terraces separated by low cliffs (Fig. 6), roughly parallel to the coast line, is subject to further modification. This terraced plain has been deeply dissected by the master streams which flow across it. Their valleys are now largely narrow tidal channels which divide the Coastal Plain into several long peninsulas which extend seaward from the Fall Belt. Considerable dissection has occurred along the margins of these tidal channels or estuaries. There has been formed also in places a series of river-facing terraces which merge seaward with the several sea-facing terraces described above. The detailed pattern of the tidal rivers is described in the section or drainage (pp. 16-21).

The Coastal Plain may also be divided into upland and lowland sections. The upland section includes the area west of the Sunderland-Wicomico scarp between Irvington, Lancaster County, and Boykins, Southampton County. The lowland section consists of the plain east of this scarp. (See Fig. 7.) The upland thus includes the entire area of Brandywine and Sunderland terraces and narrow areas of lower terraces along the rivers of this section.

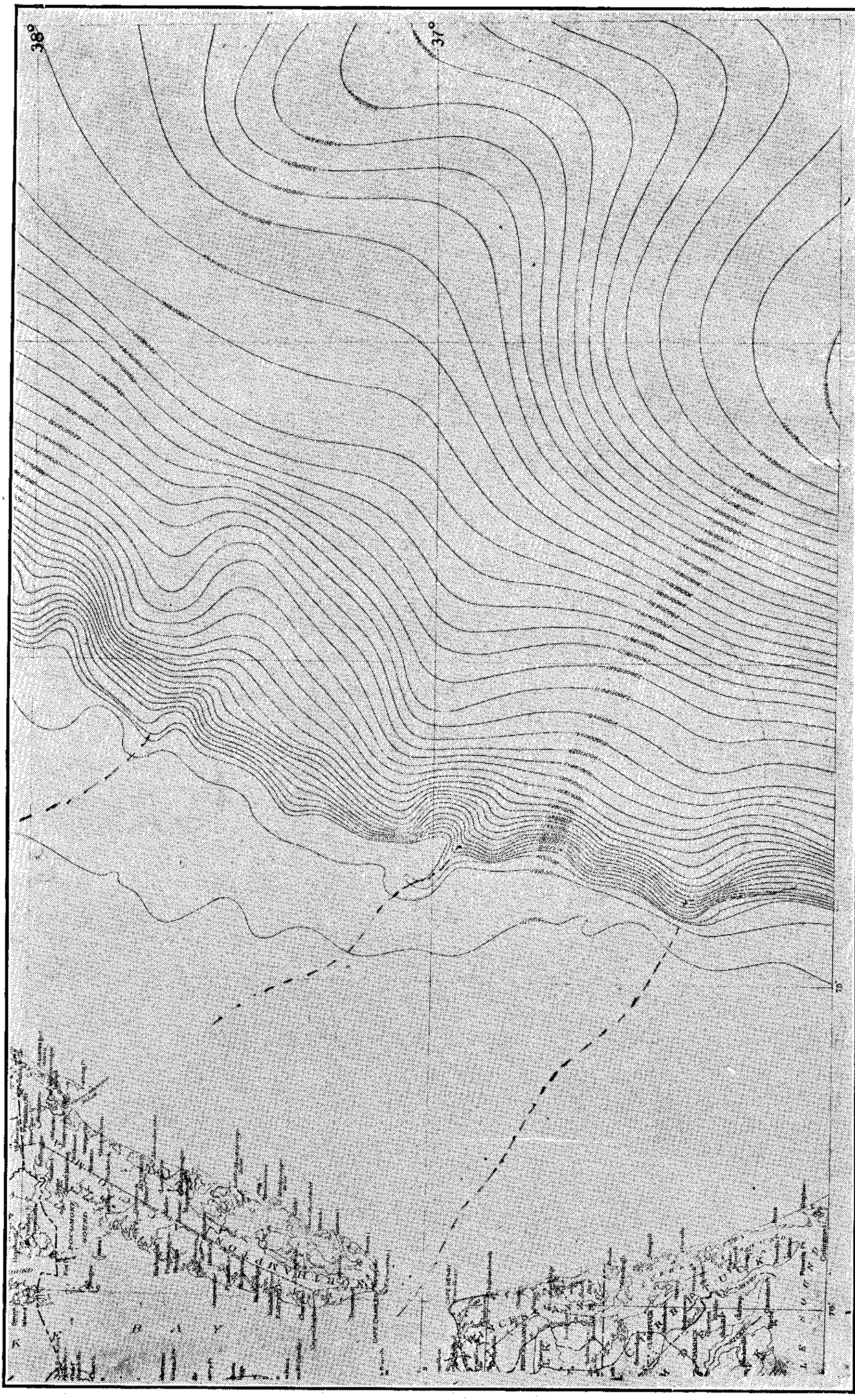


Figure 3.—Contour map of the submerged part of the Coastal Plain off the coast of Virginia. Note the gentle slope from the shore to the 50-meter contour, which is a continuation of the gentle seaward slope of the land, and the rapid descent beyond the 200-meter contour at the edge of the submerged plain. Contour interval is 100 meters below the 100-meter (second) contour. (See pp. 9 and 10.)

Figure 4.—Part of the Sunderland upland in Westmoreland, Northumberland, and Richmond counties. (Part of Morattico sheet.) Scale, 1 inch equals 1.41 miles; contour intervals, 10 and 20 feet. This typical expanse of dissected upland with elevations ranging from 120 to 140 feet is on the divide between Potomac and Rappahannock rivers. (See p. 41.)

Figure 5.—Part of the Dismal Swamp lowland plain south of Cape Henry, Princess Anne County. (Part of Cape Henry sheet.) Scale, 1 inch equals 1.47 miles; contour interval, 5 feet. A small part of the Princess Anne terrace is shown between Virginia Beach and Seatack. This whole area is typical lowland topography dissected by small valleys, in part drowned by late submergence of the coastal area. (See pp. 8, 69, and 81.)

The lowland includes the entire sea-facing area of the Wicomico, Chowan, Dismal Swamp, and Princess Anne terraces. (See Pl. 3, A, and Fig. 7.)

Elevations of the principal terrace surface in the upland range from about 100 to 250 feet. Narrow river- and wave-cut benches occur along the master streams at various elevations down to sea level. Most of the original upland surface is conspicuously flat, departures of more than 10 or 15 feet from the general level being rare. In a few places, notably near King George, scattered remnants rise slightly above the general level without being sufficiently numerous to indicate clearly the presence of a distinct terrace. The western part of the Coastal Plain upland within 5 miles of the Fall Belt is considerably more rolling and irregular than the part which extends eastward along each of the peninsulas.

The present upland surface consists of winding and branching tabular divides which are deeply cut by the headwater tributaries of the principal streams. Undissected upland areas more than 1 mile wide are not common. In many places, however, the branching remnants of the tableland give the impression of an unbroken plain. Tabular remnants, although forming probably not over 15 per cent of the upland area, dominate the region and give validity to its description as a plain. The remainder of the area consists of (1) scarps between adjacent terraces and (2) narrow valleys. These slopes range generally from 100 to 500 feet to the mile. Steep cliffs are common in places. (See Fig. 4.)

The lowland part of the Coastal Plain consists of plains and terraces ranging from sea-level to 100 feet above the sea. Its surface is commonly flatter and much less dissected than the upland surface, though the margins of the terraces have been frayed by the headward erosion of small streams. On the other hand, no single lowland terrace level is as extensive as some of those on the upland. About one-third of the lowland area consists of unbroken flats, whereas the remainder is in valleys and slopes. These slopes are as a rule much more gentle than those in the upland part of the Coastal Plain. (See Fig. 5.)

The topographic features of the individual terraces are described in detail on pages 38, 41, 55, 63, 69, 75, and 81.

THE SUBMARINE AREA

The submerged part of the Atlantic Coastal Plain, or Continental Shelf, off the Virginia coast is a broad flattish, submerged plain which extends to the steep escarpment at the rim of the ocean basin. (See Fig. 3.) The submerged valleys of the ancient Susquehanna River, now Chesapeake Bay, and its tributaries trench it.

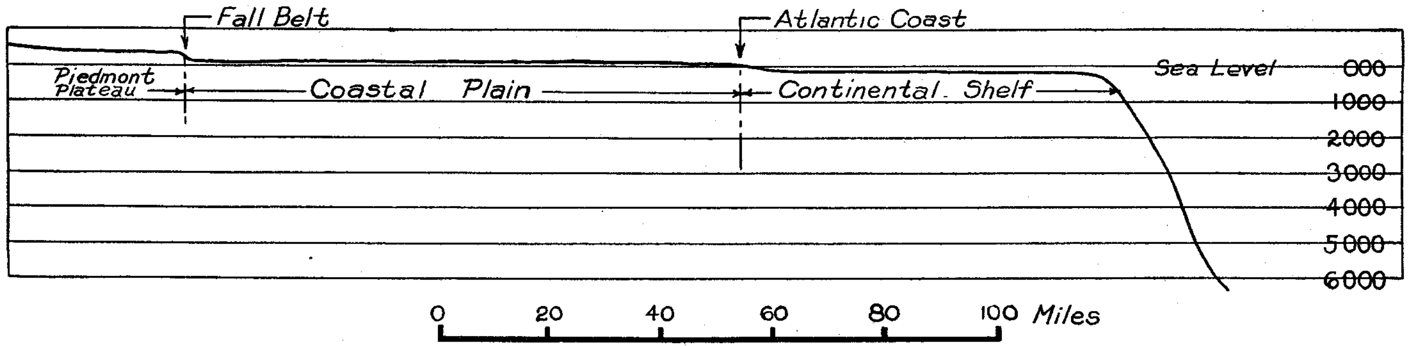


Figure 6.—Profile of the Coastal Plain of Virginia along parallel 36°40′ north. Vertical exaggeration about 32 times. The continuity of the Continental Shelf with the Coastal Plain and the trivial nature of the present coast-line as compared to the edge of the Continental Shelf are well shown.

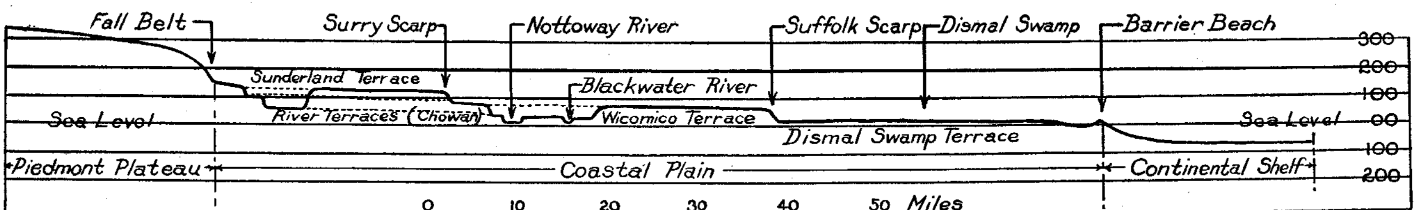


Figure 7.—Profile of the Coastal Plain of Virginia along parallel 36°40′ north, showing the terrace plains, some small areas of river terraces, and the scarps. Vertical exaggeration about 162 times.

The Continental Shelf adjacent to Virginia slopes seaward (1) about 6 or 7 feet per mile in the first 10 miles, (2) then gradually decreases to not over 2 feet to the mile in the next 20 to 30 miles, and (3) then increases slowly to an average of 50 feet per mile between depths of 50 and 100 fathoms. From depths of 100 to 1,200 or 1,500 fathoms the slope of the Continental Shelf is 250 or more feet per mile. Although this part of the shelf is distinctly steeper than the remainder of its surface, it is not a steep slope when compared with subaerial land surfaces. It is notable only in contrast to the extremely flat landward part of the shelf. Most of the bottom of Chesapeake Bay in Virginia is between 20 and 60 feet below sea-level. Depths of more than 100 feet are known in a few places. There are many areas of 20 to 30 square miles which show variations in depth of less than 10 feet. Local details of slope are not known, but slopes more than 15 feet to the mile are not sufficiently extensive to be indicated by soundings on the coast charts. Slopes approaching this steepness are found only on the flanks of sand spits and other depositional features just off shore.

Though there are many local variations in the form of the bottoms of the tidal channels of the rivers that cross the Coastal Plain, the channels conform rather generally to a typical cross-section. (See Figs. 8-10.) This consists of sub-aqueous shelves which slope gently toward a deeper middle channel with relatively steep sides. The submerged shelves are commonly 10 to 15 feet below the surface at a quarter to half a mile from shore though there are considerable variations in the depth of water at the margin. The middle channels range from 1,000 to 3,000 feet wide and from 20 to 60 feet deep. The slopes from the shelves into these middle channels are commonly very steep, being from 200 to 1,000 feet per mile. The deep channels are commonly midway between the shores, but they swing toward the outer shore of the sharper bends. Unlike most deep river channels there is a slight shelf on the outside of the curve, which indicates that wave erosion is here more effective than the river current. Profiles of several channels are shown in Figure 8.

DRAINAGE

GENERAL CHARACTERISTICS

Types of Streams

The Coastal Plain of Virginia is drained by three types of streams and their tributaries, namely, (1) trans-Blue Ridge, (2) Piedmont, and (3) Coastal Plain. The Potomac and the James

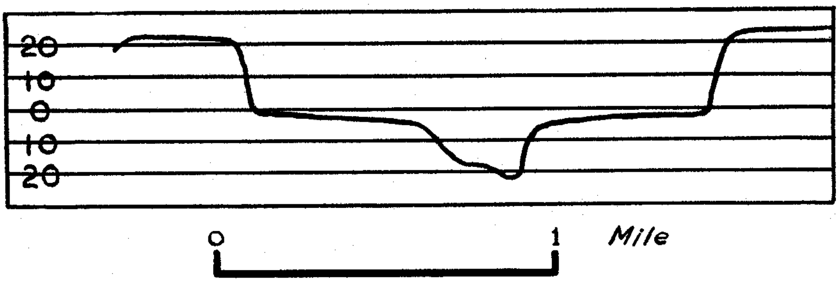


Figure 8A.—Profile across Nansemond River southeast from Cedar Point.

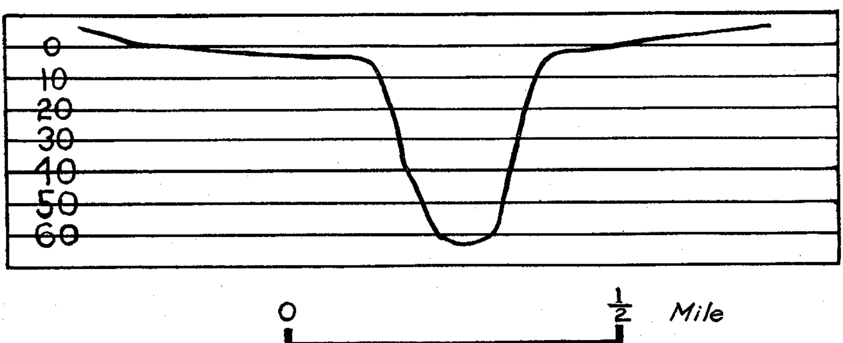


Figure 8B.—Profile across Potomac River southeast from Sheridan Point to Mockley Point.

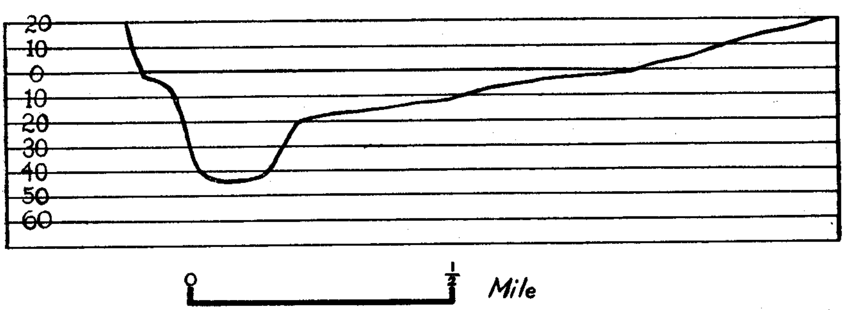


Figure 8C.—Profile across Potomac River southeast from Fort Humphreys. A shelf is found at the foot of the Fort Humphreys bluff even though the channel at this point is convex toward the bluff.

Profiles showing channel forms in tidal rivers of the Coastal Plain of Virginia. These profiles show the deep central channel and the submerged shelves which are formed partly by wave cutting and partly by wave deposition.

belong to the first type. As their headwaters are far to the west in the Appalachian Plateau and the Appalachian Valley provinces, they cross the Blue Ridge and Piedmont Plateau provinces before reaching the Coastal Plain. The Piedmont type, for example, Rappahannock and Meherrin rivers, heads on the east slope of the Blue Ridge or in the Piedmont Plateau. The third type, represented only by Piankatank River, is confined to the Coastal Plain province. The drainage and the three types of drainage basins of the Coastal Plain are shown in Figure 11 (p. 18).

DRAINAGE PATTERN

The drainage of the Coastal Plain is in the main dendritic[3] in pattern. There are no trellised or other patterns, due to structural control. The courses of major streams, and the minor details of the drainage pattern, show some departures from the dendritic pattern which are probably of great significance in interpreting the physiographic history of the region.

DRAINAGE ANOMALIES

The most important of these drainage anomalies is perhaps the southward turning of some of the master streams after crossing the Fall Belt, so that they flow more or less southwesterly for some distance before turning southeastward across the Coastal Plain by the shortest course to the ocean. The Delaware and Susquehanna rivers have this feature well developed. The Potomac shows it in less degree and the James, still farther south, has only a slight development of this type of course. None of the master streams south of the James show this feature.

The principal streams run nearly southeast from the Fall Belt, thus approaching Chesapeake Bay with an acute angle of about 45 degrees on their north sides. The James, York, Rappahannock, and Potomac rivers in Virginia and the Patuxent and other streams in Maryland are examples. Numerous streams of the Coastal Plain turn sharply to the east a few miles above their mouths, thus entering the bay at right angles. Such bends occur in the James at Newport News, in the York at Yorktown, and in the Rappahannock just west of Irvington. The Potomac does not have this type of bend, but it appears again in Patuxent River in Maryland.

Some of the master streams have other anomalous similarities. All except the Potomac have strongly meandered channels for 15

3 A drainage pattern which resembles the branching veins of a leaf. In contrast, is trellised drainage with its streams oriented along two sets of lines nearly at right angles to each other.

to 40 miles southeastward from the Fall Belt. The Rappahannock to Port Conway, the Mattaponi and Pamunkey to their junction at West Point, and the James to Bermuda Hundred have such courses. Eastward from these points the courses are of two types: (1) An almost straight drowned channel, such as York River below West Point, and (2) a succession of giant drowned meanders, such as those of lower James River. The Rappahannock shows both types, with meanders from Port Conway to Tappahannock, and a straight channel below Tappahannock. The Potomac, though not typical, belongs in the second class. Some other streams show characteristics in part similar to those described. The Piankatank-Dragon Run system has a sharp bend northwest of Cobb's Creek in Mathews County. The southeastward course of the upper Chickahominy and its sharp turn to the south several miles west of Toano (James City County) suggest piracy, but no other evidence is known. The Chickahominy has a meandered section corresponding to the meander phase of the other streams but at a point much lower in its course.

The major drainage pattern south of James River is sharply discordant with that to the north. West of Suffolk the headwaters of Blackwater and Nottoway rivers, which flow south to the Chowan, are within 10 miles of the James at many points. Moreover, the James has no southern branches of consequence between Appomattox and Nansemond rivers. To a limited extent a similar situation exists farther north where James and Potomac rivers and lower Chesapeake Bay have longer tributaries on the north or east side than on the opposite bank, which is more generally cut to a high, continuous bluff. There are also many places where the courses of smaller streams have been controlled by (1) the horizontal outlines of wave-cut cliffs, (2) meander-formed scarps or sloughs on river flats, and (3) bars and spits along the coast.

TRANS-BLUE RIDGE RIVERS

Potomac River System

The Potomac is one of the important rivers along the Atlantic Coast of the United States. Next to the Susquehanna with a drainage basin of 24,100 square miles above Harrisburg, the Potomac with a drainage basin of 11,460 square miles above Great Falls, Maryland, has the largest drainage basin of any Atlantic river south of the Saint Lawrence. The total area of the Potomac basin to Point Lookout is 14,550 square miles, with a mean elevation of 1,070 feet above sea-level. The mean discharge of 11,900 second-feet of Potomac River is exceeded by Susquehanna River with 36,300 second-feet, and Connecticut River with 13,500 second-feet.[4]

The Coastal Plain part of the Potomac drainage basin which lies in Virginia is a relatively narrow zone along the west and south sides of the river. A much larger area in Maryland drains into the Potomac from the north. The principal tributary in Virginia is Occoquan Creek, few of the other tributaries being over 10 miles long. The Potomac across the Coastal Plain is entirely in a drowned channel, in which the tide ebbs and flows. Near Washington the river is commonly about 1 mile wide and its central channel is scoured to depths of 25 to 60 feet. It gradually widens downstream until it is 6 miles wide at its mouth. Here it has an average depth of about 50 feet. This part of the river has a central channel which is deeper than it is farther inland. (See Fig. 9.)

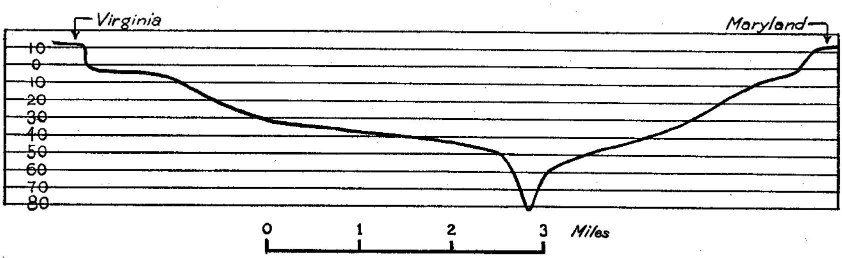


Figure 9.—Profile across the mouth of Potomac River between Cornfield Harbor, Maryland, and Presley Creek, Virginia. It shows one of the deepest parts of the central channel and hence is not typical. The average depth of the central channel is about 60 to 65 feet. The remainder of the channel configuration is approximately that shown here.

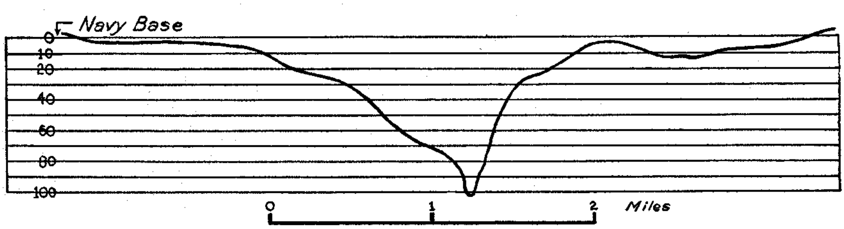


Figure 10.—Profile across Hampton Roads at mouth of James River. From the Navy Base northwest to a point east of Newport News.

JAMES RIVER SYSTEM

James River is part of the great Chesapeake system. (See Fig. 11.) Its basin is considerably smaller than the Potomac basin and its mean discharge is about two-thirds as great. The James drains parts of all the provinces which are drained by the Potomac. Its basin has a similar diversity of rocks, which have supplied sediments to the terrace formations of the Coastal Plain. The

4 Data from Water-Supply Papers and other records in the Division of Surface Water of the United States Geological Survey.

main tributaries in the Coastal Plain are the Chickahominy on the north and the Appomattox on the south. The latter, however, flows only a short distance in the Coastal Plain.

The tide reaches as far inland as Richmond in the Fall Belt. Below Richmond the channel of the James averages 1,000 to 1,500 feet wide, and it is generally not over 15 to 20 feet deep. At Hampton Roads the width is about 4 miles and the depth is seldom over 30 feet, though at a few points the natural central channel reaches depths of 60 to 100 feet. Dredging is necessary in places to maintain a depth of 30 feet.

RIVERS FROM THE PIEDMONT

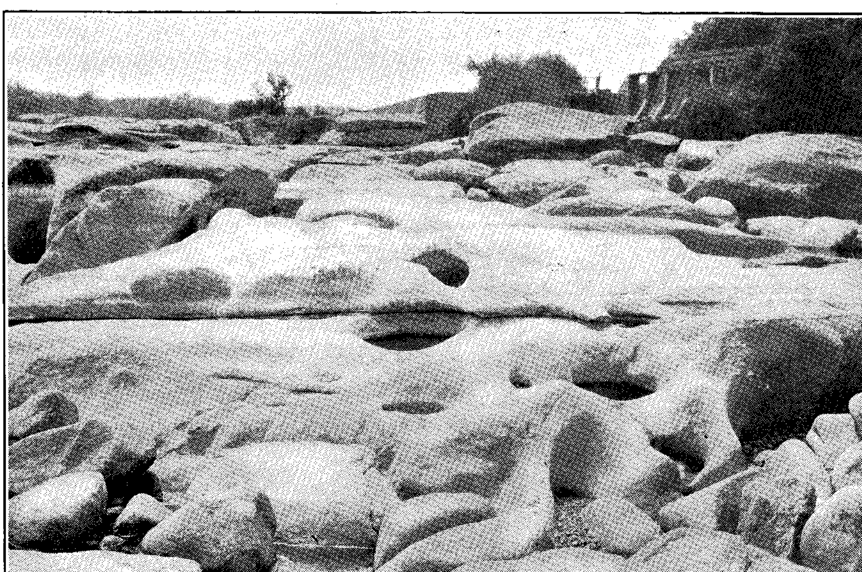
Almost the entire upland of the Coastal Plain between the Potomac and the James is drained by the Rappahannock and the York river systems. The only exception is the small Dragon Run-Piankatank drainage between the two major rivers. The Rappahannock is the largest of the rivers which rise in the Piedmont Plateau. It is the only one in which the tide flows inland to the Fall Line. Its tributaries in the Coastal Plain are small, being mostly 10 miles or less in length. York River is formed by the union of Mattaponi and Pamunkey rivers at West Point. Its entire course is an estuary. The tide is felt for some miles above West Point, but the extreme limit is not known to the writer. Mattaponi and Pamunkey rivers are notable for their well-developed meanders for many miles above West Point.

Most of the drainage of the western three-fourths of the Coastal Plain south of James River is tributary to Chowan River which flows into Albemarle Sound in North Carolina. So far as known, the tidewater part of the Chowan lies wholly in North Carolina. The Chowan has three branches which rise in the Piedmont Plateau, namely, Meherrin, Nottoway, and Blackwater rivers. A narrow strip of land south of Appomattox and James rivers drains into the James system.

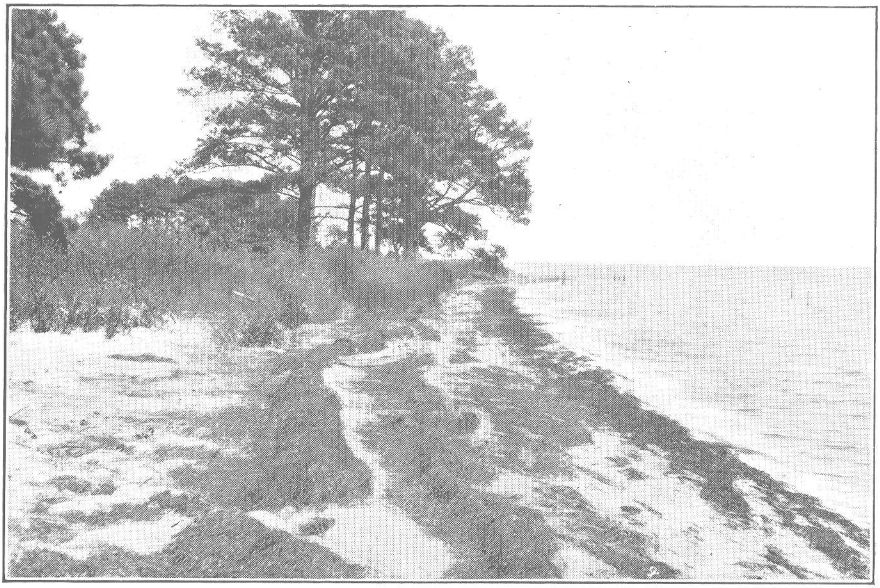
COASTAL PLAIN RIVERS

The largest river entirely in the Coastal Plain is the Piankatank which drains parts of Middlesex, Essex, King and Queen, Gloucester, and Mathews counties. The Great Wicomico of the Northern Neck and the Mobjack Bay system are others of this type. The drainage of the Eastern Shore consists of a few streams, mostly not over 5 miles long, which drain into the heads of small drowned palmate systems of streams. The drainage of the area around Norfolk is similar. Nansemond and Elizabeth rivers drain

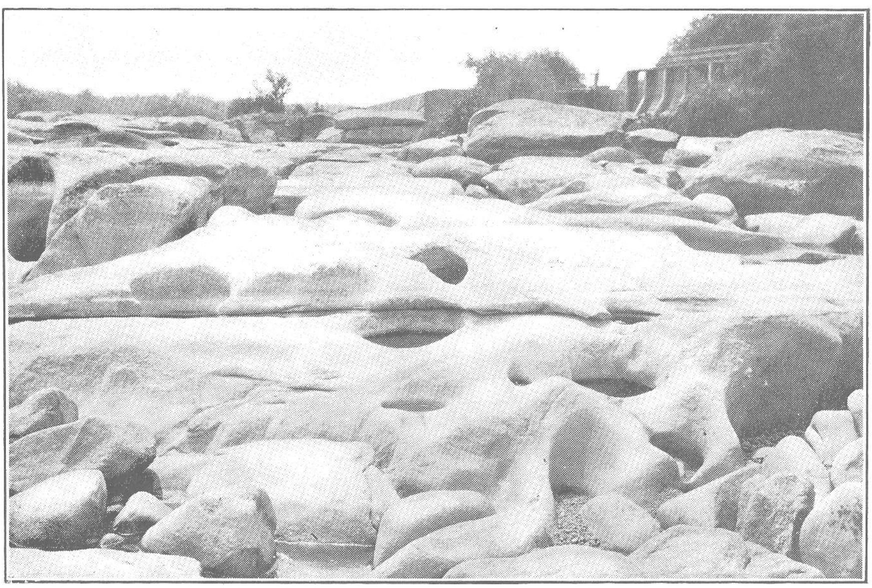
A. Low sandy shore adjacent to Princess Anne terrace 1 mile east of Quarter Point, Gloucester County. (See p. 7.)



B. Granite ledges and pot-holes in the channel of James River at the Fall Belt, Richmond. (See p. 7.)



A. Low sandy shore adjacent to Princess Anne terrace 1 mile east of Quarter Point, Gloucester County. (See p. 7.)



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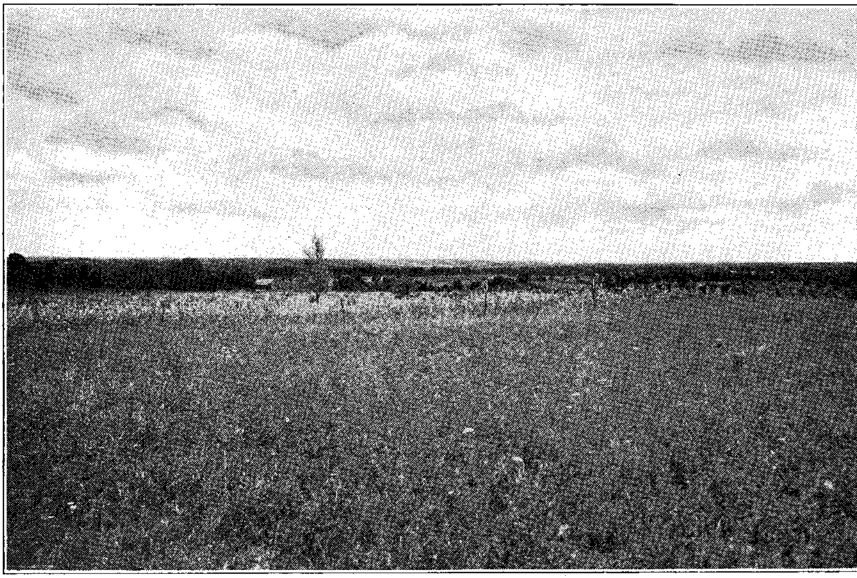
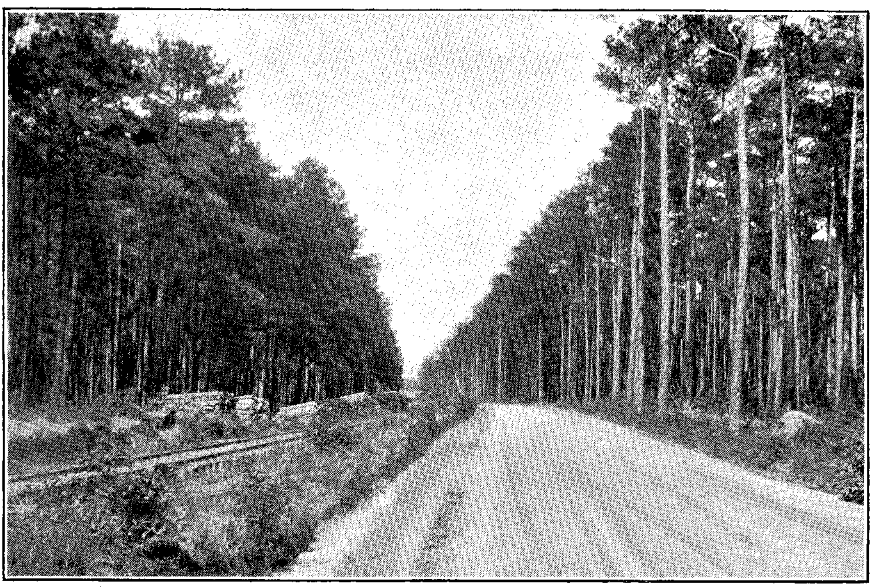
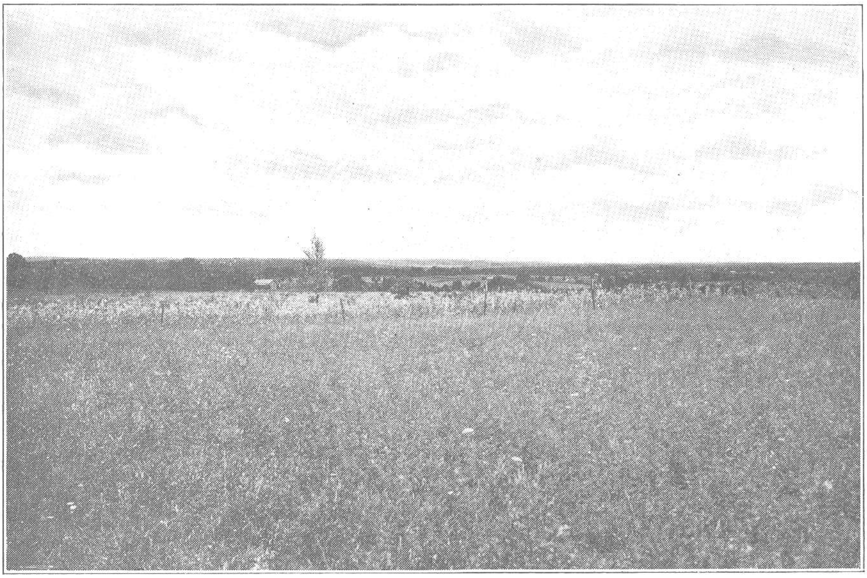


A. Brandywine terrace on the Coastal Plain near Potomac River. (See p. 8.)



B. Sunderland terrace, with pine forest, northeast of Surry, Surry County. (See pp. 8 and 43.)



A. Brandywine terrace on the Coastal Plain near Potomac River.
(See p. 8.)

B. Sunderland terrace, with pine forest, northeast of Surry, Surry County.
(See pp. 8 and 43.)

north from the Dismal Swamp area. North Landing and Northwest rivers drain southward to Currituck Sound.

TIDES ON THE VIRGINIA COAST

The tide is not ordinarily considered as part of the drainage system of a region but it seems desirable to consider it briefly in this report. On an embayed coast like that of Virginia the rise and fall of the tide are of great practical importance and also as an agent which modifies the form of the shoreline and the shallow bottom. Tidal currents are here included in the consideration of the tides.

TIDAL RANGE

On the outer coast of Virginia the mean tidal range varies from 4 feet at the north to slightly more than 3 feet at the south. Spring tide ranges are about 20 per cent greater. In the Chesapeake Bay system the mean tidal range at most points has values between 1.5 and 3.0 feet. At the entrance to the bay the mean tide range is about 3.0 feet. From this point the mean tide range decreases up the bay and up the principal rivers. It reaches minimum values of 1.2 feet in Potomac River near Maryland Point, 1.5 feet in Rappahannock River near Leedstown, 2.4 feet in York River near Yorktown, and 2.0 feet in James River near Claremont. Upstream from these places there is an increase in the mean tide range in each river, and values of 2.9, 2.8, 3.9, and 3.7 feet are reached respectively at Washington, Fredericksburg, Walkerton, and Richmond.

The decrease of tidal range inland in bays and estuaries is a common phenomenon. It is caused by the resistance of the restricted channel to the movement of the water necessary to raise the level of the inland portions. The extreme inland parts of the four long estuaries of Virginia have higher tidal ranges than points nearer the ocean. This seems to be caused by the piling up of the water in a narrowing channel which will not accommodate it without an exceptional increase in depth.

LAG OF TIDES

The movement of large quantities of water through narrow bays or estuaries takes considerable time. As the tide in Chesapeake Bay must enter through a single strait at Cape Charles, there is an important lag at any given place of high and low tides behind the corresponding times at Cape Charles. The amount of lag for any point depends on its distance by water from the strait

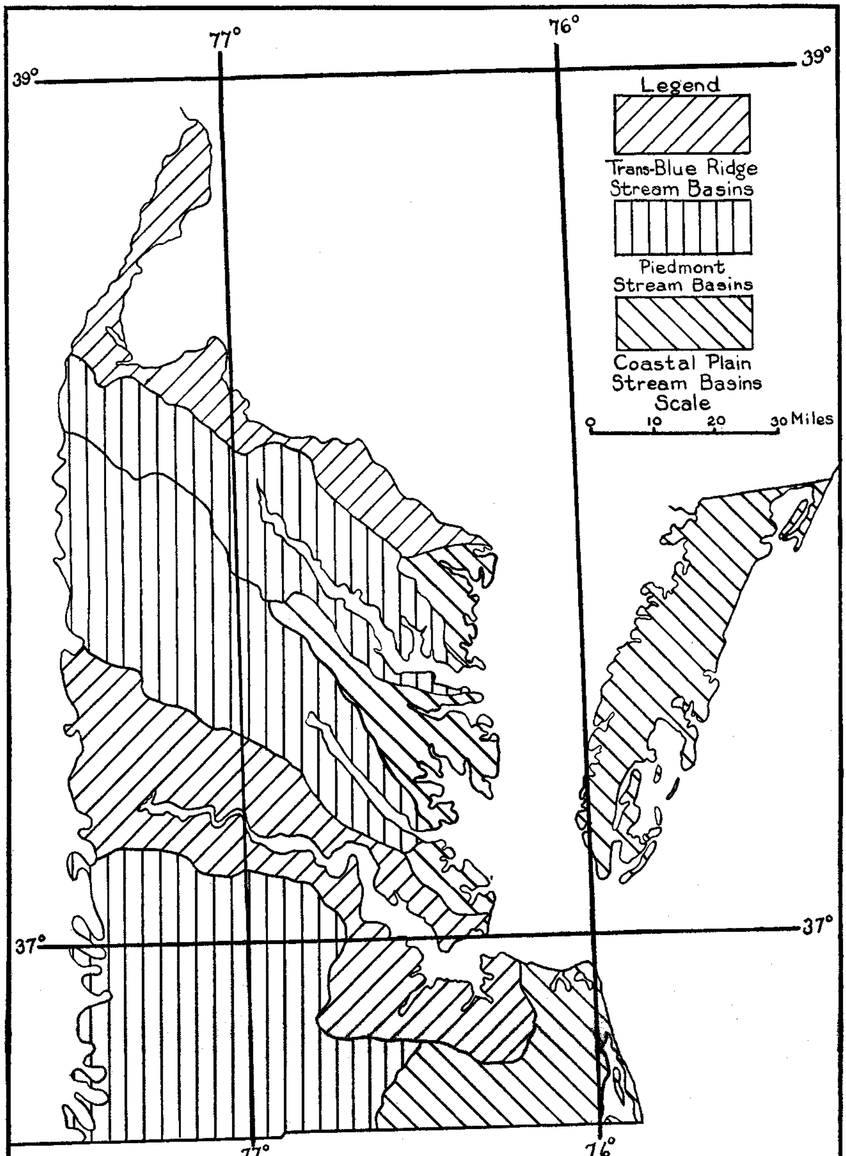


Figure 11.—Drainage map of the Coastal Plain of Virginia, showing basins of the trans-Blue Ridge, Piedmont, and Coastal Plain types of streams.

at Cape Charles and also on the average width and depth of the intervening channel. Owing to the fact that high tide, because of the deeper channel it occupies, is retarded less than low tide, the lag is less for high than for low tide. The approximate averages for both high and low tide lag for various parts of the tidewater region of Virginia are shown in Figure 12. This amounts to nearly 12 hours at Washington, 12 hours at Fredericksburg, 6 hours at Walkerton, and 10 hours at Richmond.

RELATION OF TIDAL AND DRAINAGE CURRENTS

At any point where the tide is strong, there is part of the day when the landward current of high tide is strong enough to reverse the normal seaward river current. During the remainder of the day the seaward movement of water includes the excess water carried in at high tide plus the normal river discharge. It is apparent then that at any point the excess of water which goes out during tidal ebb over that brought in during tidal flow will be equal to the discharge of the drainage systems involved. Using the known factors of areas of estuaries and bays and of tidal ranges, the writer has attempted to compute the amount of tidal ebb and flow past certain points and to compare this with the normal stream flow past the same points. The results are given below.

In round numbers the area of tidewater in Chesapeake Bay and its branches is 4,300 square miles, and the total land area which drains through the strait is 65,000 square miles. Data from 9 principal Atlantic Coast streams show an average discharge of 1.35 second-feet per square mile of drainage basin.[5] On this basis the daily discharge of land water through the Cape Charles strait is about 7,580 millions of cubic feet. During one semi-daily tidal period the amount is 3,790 millions of cubic feet. Distributed over the 4,300 square miles of tidewater this is equivalent to 0.033 feet of rise or about 2/5 inch. The tidal rise throughout Tidewater Virginia ranges from 1 to 4 feet, but it is equivalent to an average of about 2.0 feet. This rise and fall are accomplished in the same period as a run-off from the land of 0.033 feet and involve a to-and-fro movement of approximately 60 times as much water. During the ebb of tide for 6 hours, therefore, the strait carries about 120 times as much ocean water as land water.

Similar though less pronounced preponderance of ocean water over land water is shown in the flow past points on James and Potomac rivers. The land water delivered on the average to the tidal portion of the Potomac above Point Lookout in a semi-daily

5 op. cit.

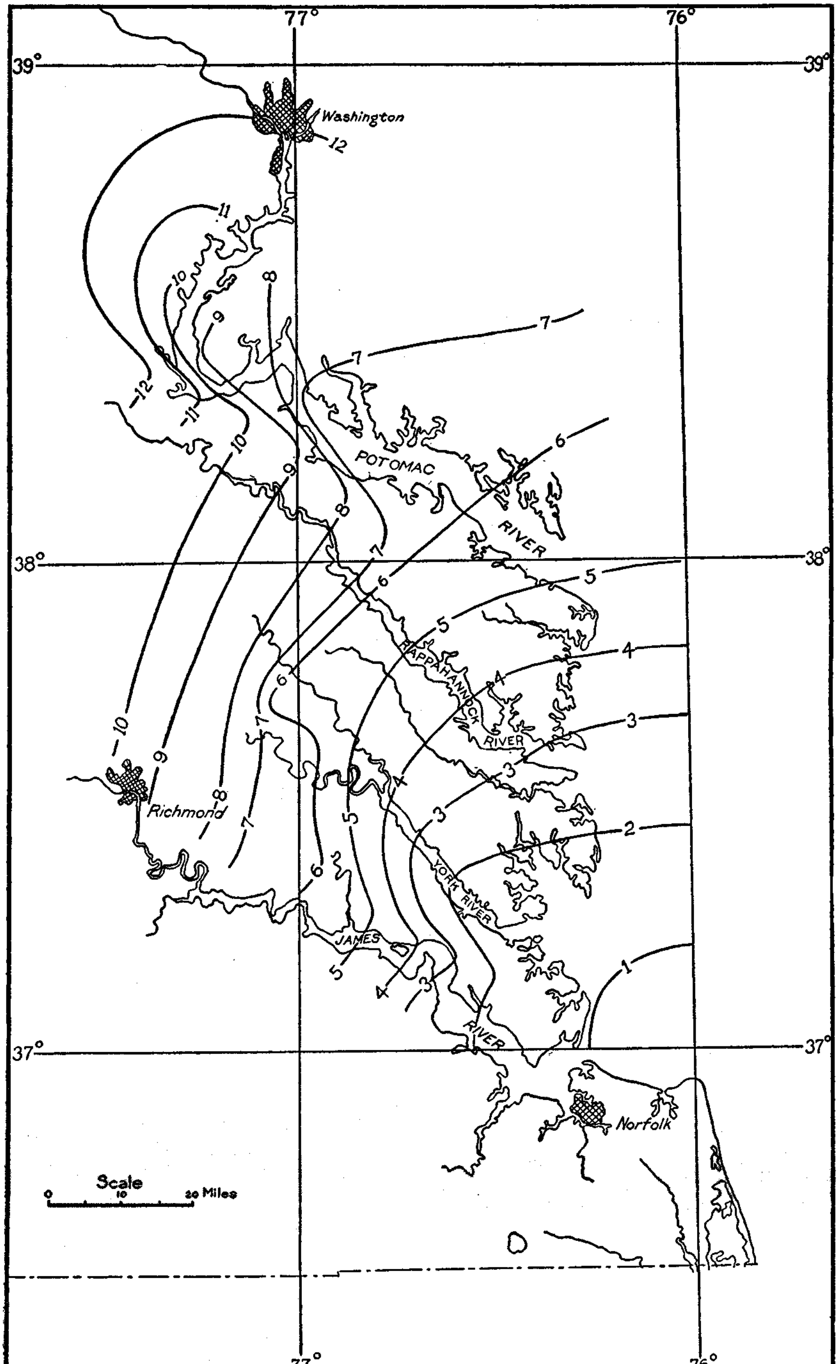


Figure 12.—Map of the Coastal Plain showing the lag of the tide in hours behind high tide in the strait between Cape Henry and Cape Charles. Figures are the average for high and low tides; low tide lags approximately an hour more than high tide at the most inland points.

tidal period is sufficient to raise its level 0.090 feet. The mean tide in this area is about 1.7 feet. Past Point Lookout there is, because of tides, therefore, a double movement of about 19 times as much water as is delivered by stream flow, and during the 6 hours of ebb the tidal part of the flow is 38 times the stream part. A similar computation for James River above Mulberry Point, Warwick County, shows a mean tidal fluctuation of 2.5 feet and a land water inflow of 0.233 feet during the same period. Thus the tidal water is about 11 times greater in amount than the land water and during the period of ebb the tidal part of the flow is on the average about 22 times as much as the stream part.

It is evident that over broad areas of the tidewater section tidal currents are of much greater volume and importance in shaping the land than are ordinary stream currents. This fact is well known to fishermen and others using boats on the rivers and bays. It is also shown by the shape of the central channels in some rivers. In places near bends in the rivers there are two deep channels. One shows linear continuity with the normal upstream channel of the river. The other shows similar continuity with the downstream channel and evidently is formed and kept open by tidal currents flowing up the river. The nearly equal prominence of these features testifies to the controlling importance of the alternating up and down tidal currents in the rivers.

HUMAN GEOGRAPHY

HISTORIC IMPORTANCE

The Virginia Coastal Plain is of especial interest as the site of the first English settlement in America in 1607. For more than 300 years Tidewater Virginia has seen the growth of American political and industrial institutions. Here was commenced that conquest of the natural resources of a new country which has culminated in the commanding position of America among the nations in the present age of technical and scientific achievement.

From the earliest days of Jamestown to the present time, Virginians have taken a prominent place in the civil and military activity which has made American history. In the earlier part of this history many of these leaders were born and reared in the tidewater section of the State where for many years were found the most important cities and towns. During the War between the States, because of its location along the ocean and near the border between the North and the South, the Coastal Plain of Virginia saw many of the military engagements which marked the struggle for States' Rights. Because of its harbors it remains today a district of great military and naval importance and is the site of important military and naval posts, munitions plants and ship-building yards.

There are valid reasons for stating these facts of colonization and human history in this report. The trend of human affairs and the patterns of transportation and industrial development are determined by the physical features and natural resources,[6] which are in part described below. Land-locked harbors, enormous resources of sea food, and a network of protected tidal waterways adjacent to a land of rich soils, abundant rainfall, and large resources of sand, clay, marl, and other mineral commodities made an almost ideal theater for the gradual conquest of a new land by settlers from overseas. Nor is it to be supposed that the influence of geographic factors in the affairs and outlook of man ceases at the close of pioneer days or is less real among civilized than among savage men. On the contrary, though the control becomes more complex and insidious, being exerted through the concealing fabric of economic and social forces, it is quite as strong and much more far-reaching in this industrial age than ever in the past. In the location of cities and routes of transportation, and in the determination of occupations and industries in relation to broad lines of national and international affairs, geographic factors are fundamental.[7]

DISTRIBUTION OF POPULATION

The total population of the Coastal Plain of Virginia is about 860,000, or 34 per cent of that of the State.[8] This is an average population density of 105 persons to the square mile as compared with 57 persons to the square mile for the entire State.[9] The most densely populated district is that around Hampton Roads, including the cities of Norfolk, Portsmouth, and Newport News.

The largest cities of the region are Richmond (182,929),[a] Norfolk (130,000),[a] Portsmouth (45,704),[a] Newport News (34,417),)[a] and Petersburg (28,564).[a]

Each of these cities is located at a focal point of important routes of transportation and at or near a boundary between two physiographic provinces.

TRANSPORTATION

Three principal kinds of transportation are important in the long distance movement of passengers or commodities on the

6 Semple, E. C., Influences of geographic environment, New York, 1911.
7 Bowman, Isaiah, The New World, New York, 1922.
8 Includes the population of Richmond, Petersburg, and Fredericksburg.
9 Census of 1920.
a Census of 1930.

Coastal Plain. In order of development they are, (1) by boats, (2) by railroads, and (3) by automobiles. The earliest traffic in Tidewater Virginia was by sailing boat and the natural conditions governing water traffic are today much the same as then, though here and there dredged channels and other improvements have made possible the use of larger vessels. With the introduction of steam vessels water transportation grew in importance and a system was developed which remains today the most important link between the eastern Coastal Plain and the outer world.

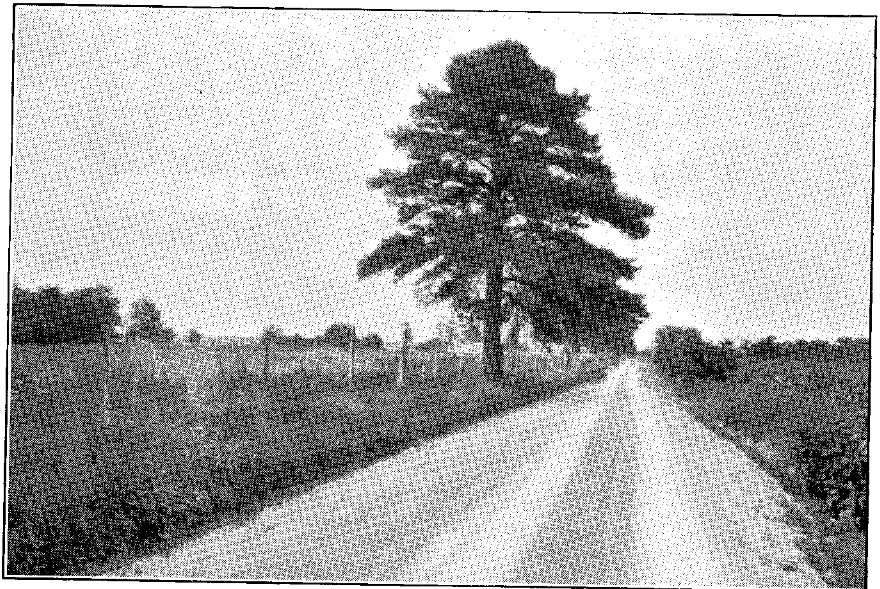
The western part of the Coastal Plain and the broad area included in the Sussex and Suffolk-Norfolk districts are served by a number of railroads. The Eastern Shore and the Williamsburg and Middle peninsulas are each served in part by a single line of railroad. The deep estuaries which divide the Coastal Plain into distinct districts have been an impassable barrier to north-south railroads east of the Fall Belt and have also greatly restricted the development of even the longitudinal railroads on the several peninsulas. As a result, in the eastern half of the Coastal Plain north of James River, water transportation has reigned almost supreme until the recent development of hard-surfaced roads and automobile travel. Until recently much of this part of the Coastal Plain has been tributary, economically and socially, to the port of Baltimore by reason of the greater ease of travel by river steamer to that city than by steamer or other means to any important metropolis in Virginia. South of James River, where there are fewer obstacles, several railroads cross the Coastal Plain, having straight lines for many miles. The head of tidewater in Nansemond River has produced an interesting railroad center at Suffolk, where several lines meet in passing around this obstruction to land traffic on their way to the great ports of Norfolk and Portsmouth.

Within the past few years Virginia has adopted a road-building program which has greatly increased the accessibility of the tidewater peninsulas to cities along the Fall Belt, and the use of motor vehicles has increased enormously. Bus lines now traverse each of the peninsulas from end to end and no part of the Coastal Plain of Virginia, except the Eastern Shore, is more than 4 hours' journey from Richmond. Another link has been wrought in the transportation system of this region by the establishment of passenger and mail service from Norfolk to Washington and Philadelphia by aeroplane.

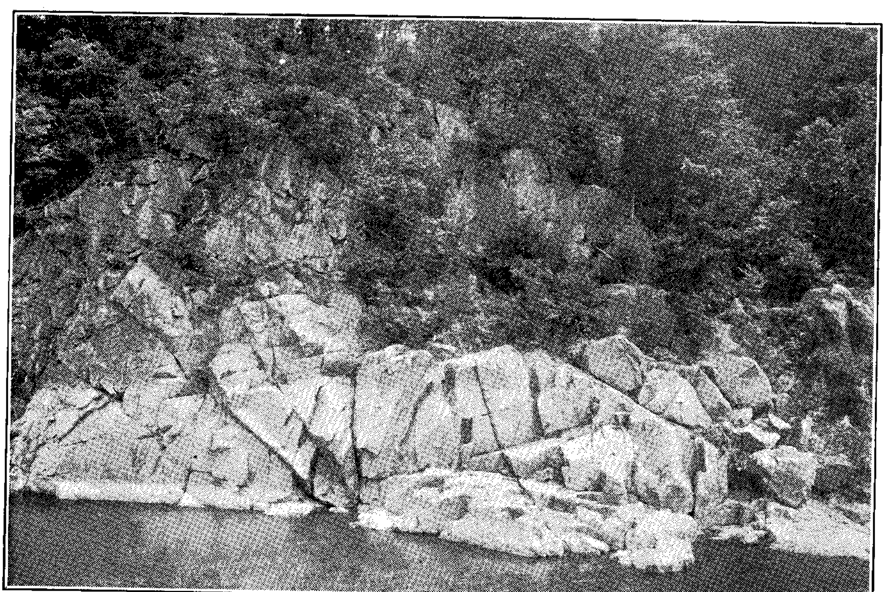
OCCUPATIONS AND COMMERCE

The principal industries on the Coastal Plain are agriculture, fishing, manufacturing, and shipping. The principal crops are cotton, peanuts, and truck garden vegetables. Cotton is grown extensively in the southern counties of the Sussex and Suffolk-Norfolk districts. There is a large production of peanuts in the Suffolk area, and Suffolk is said to be the largest peanut market in the world. Corn, alfalfa, clover, and cow peas are important forage crops. Hogs are raised extensively on the Coastal Plain. The sea fishery industry of Virginia ranks above that of any other Atlantic coast state.

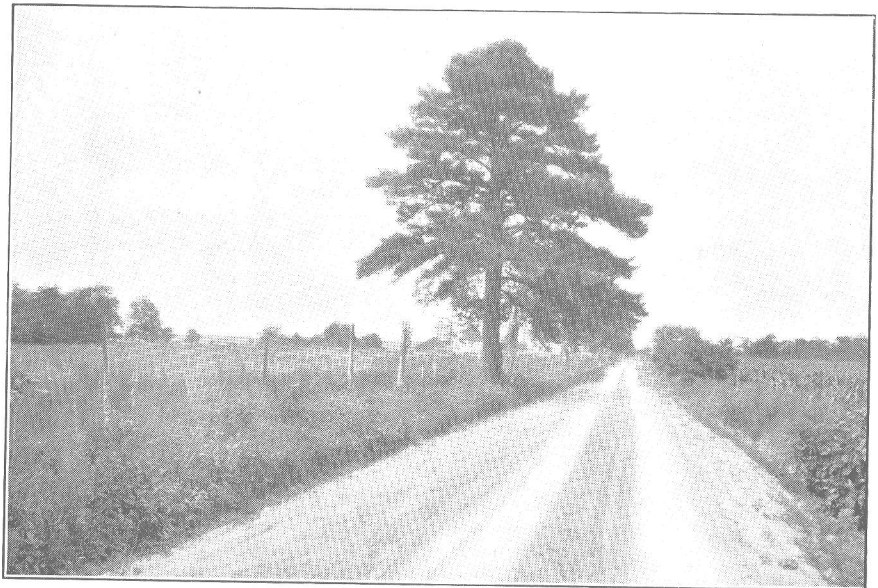
The principal manufacturing centers are the Fall Belt cities and the cities of the Hampton Roads area. Ship-building is an important industry in the latter district. More than 50 steamship lines control vessels sailing to European, Oriental, and southern hemisphere ports. The combined cities of Hampton Roads are second only to the port of New York among Atlantic Coast ports in the value of exports. Among the most important exports from this shipping center is coal.



A. Chowan-Dismal Swamp terrace 1 mile east of Bigler Mill, York County. (See pp. 9 and 75.)



B. West wall of Potomac gorge below Great Falls, showing jointed metamorphic rocks of the Piedmont Plateau. (See p. 25.)



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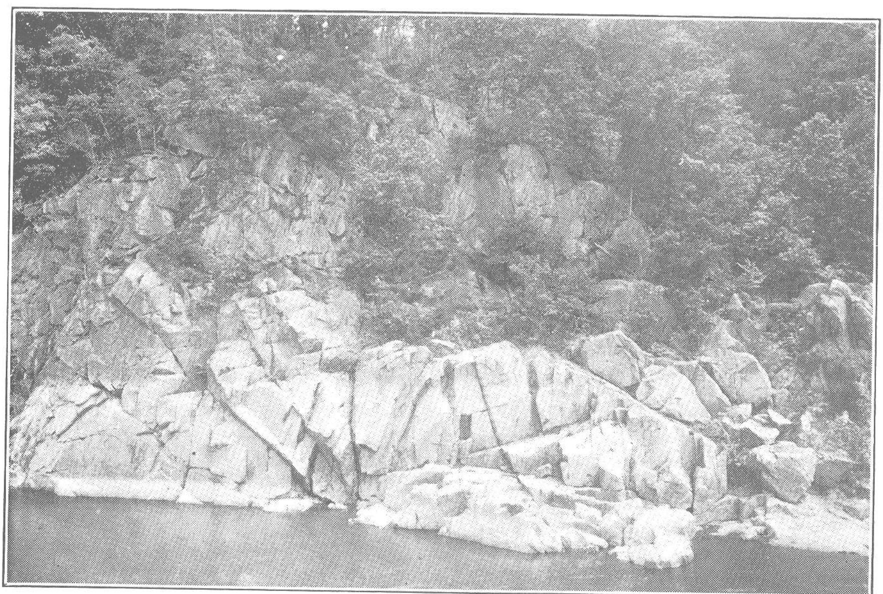
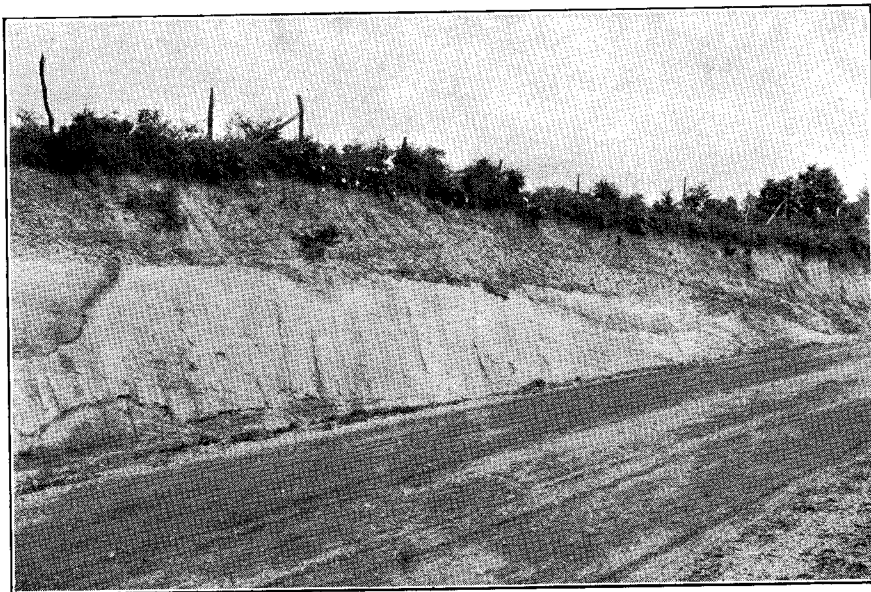
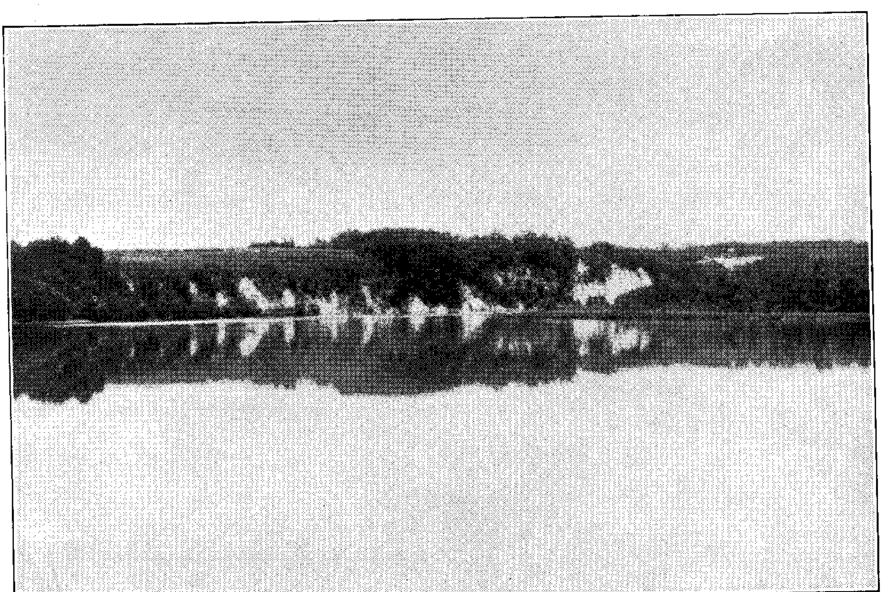


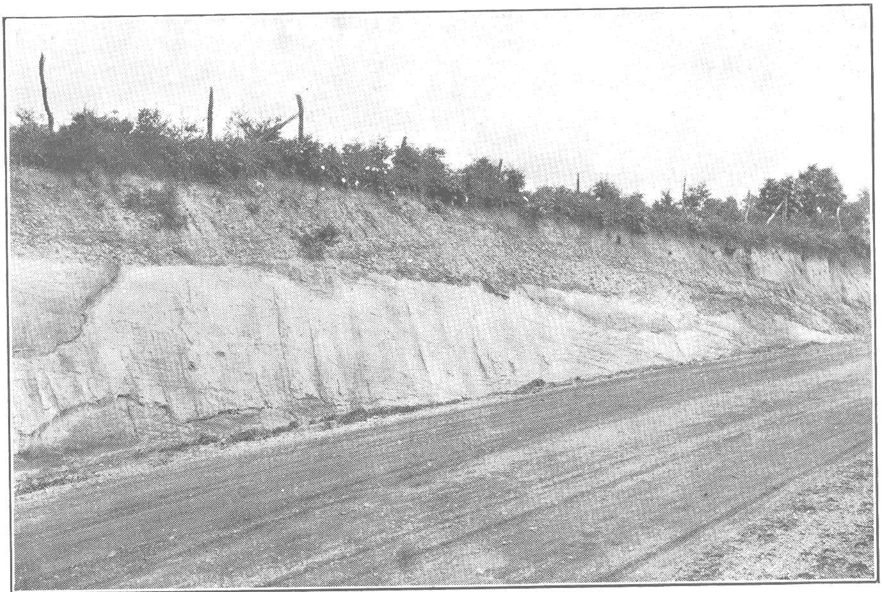
B. West wall of Potomac gorge below Great Falls, showing jointed metamorphic rocks of the Piedmont Plateau. (See p. 25.)



A. Pre-Brandywine gravel 4 miles northeast of Dumfries, Prince William County. (See p. 37.)



B. River bluff and Sunderland terrace south of Rollins Fork on Rappahannock River. (See p. 43.)



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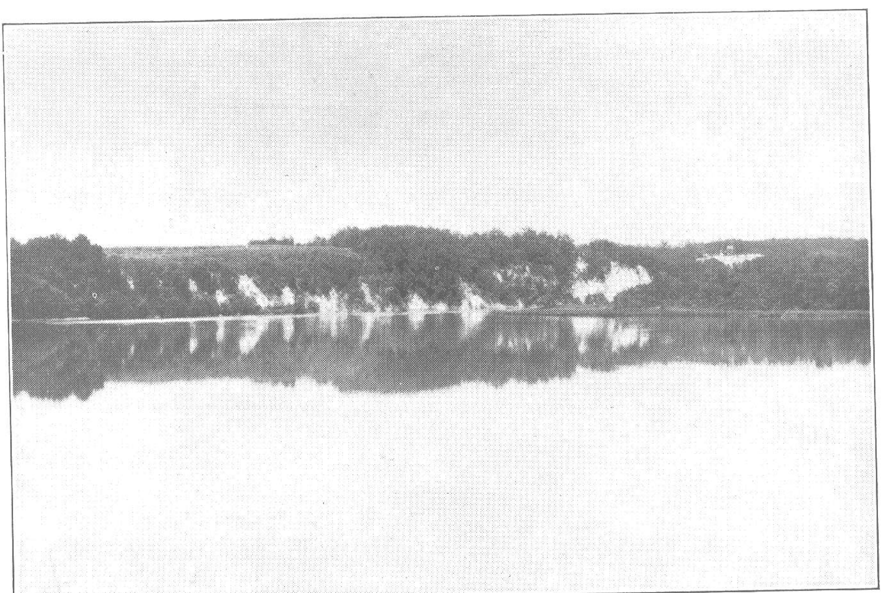

B. River bluff and Sunderland terrace south of Rollins Fork on Rappahannock River. (See p. 43.)

STRATIGRAPHY

GENERAL STATEMENT

In order to describe the features and the materials of the Coastal Plain it is necessary to discuss briefly the main groups of rocks involved. Rocks are divisible into three classes, igneous, sedimentary, and metamorphic. Igneous rocks are formed by the cooling and solidification of lava at the surface of the earth or beneath it. Examples are granite, syenite, and basalt. Sedimentary rocks are formed from particles of other rocks, which have been broken up by physical and chemical processes, and from chemical and organic sediments. Examples are sandstone, shale, limestone, coal, and salt. Metamorphic rocks have been derived from igneous or sedimentary rocks by the action of heat, pressure, and water. Examples are gneiss, schist, slate, and marble.

PRE-PLIOCENE FORMATIONS

ROCKS OF THE PIEDMONT PLATEAU

Crystalline rocks, mainly of pre-Cambrian age, form the foundation of much of the eastern United States and appear at the surface over much of the Piedmont Plateau. (See Fig. 13.) They dip seaward under the formations of the Coastal Plain, forming the complex basement on which the latter rest. The contact in a deep well at Fort Monroe is 2,246 feet below the surface.[10] A recent oil test boring in Mathews County, starting a few feet above sea-level, struck granite at a depth of 2,318 feet.[11]

The crystalline rocks of the Piedmont Plateau are composed of metamorphosed igneous and sedimentary rocks and relatively unaltered igneous rocks. The metamorphic rocks are generally rather closely folded. They trend as a rule northeast-southwest and dip at high angles. In some places the original bedding is the dominant structure, but in others the secondary planes of schistosity are more prominent. Joints are well developed in many places (Pl. 3, B).

Inasmuch as the crystalline rocks of the Piedmont region were the ultimate source of the sediments in the Tertiary and younger formations of the Coastal Plain, their composition is a fundamental factor in deciphering the complete history of the sedimentary formations. The lithology and mineralogy of the Pied-

10 Darton, N. H., U. S. Geol. Survey Geol. Atlas, Norfolk folio (No. 80), 1902.
11 Record in files of Virginia Geological Survey.

mont crystallines are, however, too imperfectly known to permit a detailed consideration of the sources of the rarer minerals in the coastal-plain sediments.

LOWER CRETACEOUS FORMATIONS

The crystalline rocks of the eastern edge of the Piedmont Plateau and the basement of the Coastal Plain are overlain immediately by sediments of Lower Cretaceous age.[12] The names and characteristics of the formations of the Coastal Plain of Virginia are given in Table 2.

The Lower Cretaceous rocks consist mainly of non-marine, unconsolidated sands and clays of highly varied character.[13] Cobbles and boulders occur in some beds. Many of the sands are arkosic. Plant fragments and lignitic material are common in some of the clays.

The known thickness of the Lower Cretaceous series ranges from about 500 feet at its western edge to about 1,300 feet in the deep well at Fort Monroe.

UPPER CRETACEOUS FORMATIONS

Although beds of Upper Cretaceous age do not crop out in the Coastal Plain of Virginia, they have been found in wells at Norfolk and at Fairport, Northumberland County.[14] The materials are gravel, sand, greensand, clay and shells, with an estimated thickness of 65 or more feet.

TERTIARY FORMATIONS (PRE-PLIOCENE)

The next younger group of rocks, closely related to the Coastal Plain, consists of a complex series of slightly cemented sedimentary rocks of Tertiary age. They were derived chiefly from the waste of Piedmont rocks and were deposited in the main east of the present Piedmont province. These beds dip seaward at low angles, with successively younger formations being exposed toward the coast.

The Brandywine and related terrace formations, formerly grouped as Lafayette, are thought to be of Pliocene age. Their mode of occurrence, lithologic character, and areal distribution are so similar to the Pleistocene deposits, known as the Columbia group, that they will be considered below as terrace formations.

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12 Triassic rocks (Newark series) are the next youngest above the crystalline basement in this region, but as they do not crop out on the Coastal Plain, they are not included in this brief summary.

13 Berry, E. W., The Lower Cretaceous [of the Coastal Plain of Virginia]: Virginia Geol. Survey, Bull. 4, pp. 61-69, 1912.

14 Darton, N. H., op. cit.

TABLE 2.—*Pre-Pliocene sedimentary formations on the Coastal Plain of Virginia*

System	Series	Formation	Thickness (Feet)	Characteristics
Tertiary	Pliocene	Brandywine		
		Unconformity		
	Miocene	Yorktown formation	125	Mainly beds of shell debris cemented by calcium carbonate. Contains in places large numbers of unbroken but somewhat worn shells. Bedding in places strongly undulatory, caused by solution of lower beds and unequal subsidence of higher beds.
		St. Mary's formation	150	Beds of sand, in places glauconitic, and dark blue to bluish-black clay. Some shell marl; most parts calcareous from disintegrated shells. Sands commonly yellow and buff.
		Unconformity		
		Calvert formation	200	Fine-grained, light-colored sands and dark blue to black sandy clay. Grades in places into diatomaceous earth. The blue clays contain abundant shells and casts of shells; glauconitic in places.
		Unconformity		
	Eocene	Nanjemoy formation	125	Largely greensand, in places argillaceous. Marked at base by a bed of white and pink compact clay.
		Aquia formation	100	Greensand and greensand marls with occasional interbedded layers of shells. Contains relatively little clay.
		Unconformity		
Cretaceous	Upper	(Not exposed)		
	Lower	Patapsco formation	150	Largely clays and sands with some beds of gravel and conglomerate. Beds are bright colored to variegated, cross-bedded, and arkosic. Indurated locally to a moderately strong rock.
		Unconformity		
		Patuxent formation	250-300	Variable beds of light colored sand, notably arkosic, with the feldspar much kaolinized. Beds of coarse gravel are not uncommon. Clay is interbedded with the sand. Lignite lenses occur in places. Cross-bedding is conspicuous throughout the formation.
		Marked unconformity		

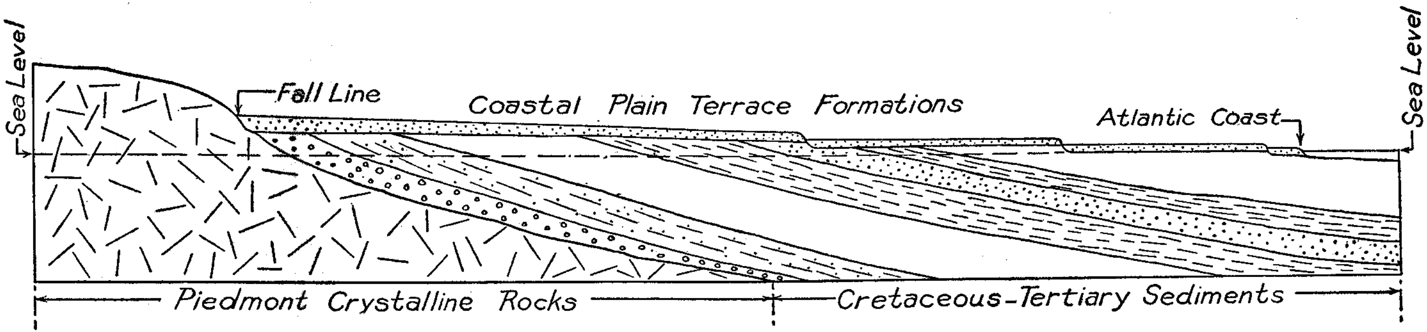

Figure 13.—Generalized section showing relations of the types of rocks in the Coastal Plain and adjacent provinces and the ideal relations of the terraces in the Coastal Plain.

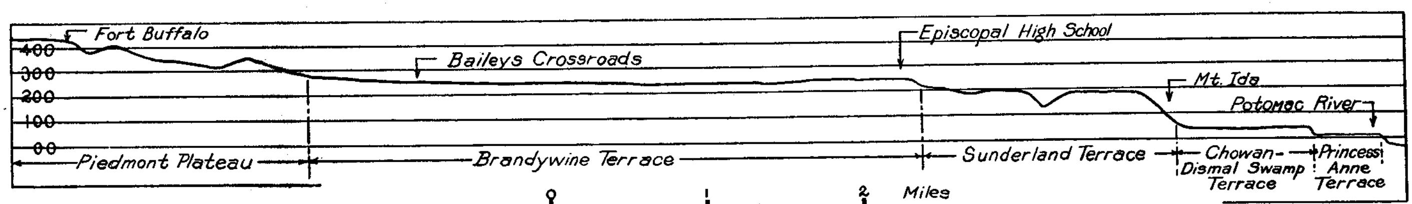

Figure 14.—Profile from Fort Buffalo, Fairfax County, southeast through Baileys Crossroads, Episcopal High School, and Mount Ida to Potomac River. It shows the Piedmont Plateau, the Fall Belt, and the Brandywine, Sunderland, Chowan-Dismal Swamp, and Princess Anne terraces. Vertical scale exaggerated about 8 times.

RELATIONS AND STRUCTURE

Though nearly all the contacts between these sedimentary formations are unconformable, the general attitude of the beds in the various formations is similar. The Yorktown formation, according to Clark and Miller, dips eastward at the rate of a few feet to the mile.[15] The St. Mary's and the Calvert formations dip almost east at about 10 feet per mile. The Nanjemoy and Aquia formations have an average dip of 12 to 15 feet to the mile. The Patapsco formation dips eastward at a rate about twice as great. The dip of the Patuxent varies from 50 feet per mile near the Fall Belt to about 30 feet per mile farther east.

PLIOCENE AND PLEISTOCENE TERRACE FORMATIONS

GENERAL STATEMENT

A complex series of largely unconsolidated gravels and loams, partly of marine[16] and partly of fluvial origin, covers the terraced surface of the Coastal Plain. The series is rarely over 50 feet thick; yet it is so intimately related to the present surface that the gravels and loams cover the entire area except in steep bluffs where active erosion exposes underlying formations. As these terrace formations are the principal subject of this report they are discussed in detail.

HISTORY OF THE TERRACE PROBLEM[17]

The history of geological study of the terraces and gravel formations of the Atlantic Coastal Plain dates from the first days of English colonization. It has been ably summarized by a number of geologists who have published their results since 1900 and who have prepared bibliographies on the subject. The important conclusions of some of the early workers is stated in this report and a bibliography is given of the notable contributions since 1905. A considerable part of this material refers directly to Virginia and much of the remainder is applicable to the problems in the State.

Many of the earlier references to the surficial materials of the Coastal Plain are brief notes about fossils or unusual mineral deposits at single localities. A few of the early workers gave some attention to the broader distribution of the materials and to the general problem of their origin. Among these was Willam Maclure

15 Clark, W. B., and Miller, B. L., Physiography and geology of the Coastal Plain province of Virginia: Virginia Geol. Survey, Bull. 4, p. 159, 1912.
16 See discussion of use of the term marine on page 100.
17 The writer is largely indebted to the work of Clark, Miller, Shattuck, and Stephenson, as cited in the bibliography, for knowledge of studies prior to 1890. He has examined but few reports of earlier work.

who published several papers between 1809 and 1818. He included all coastal-plain formations under "Alluvium" in his text and maps.

In 1832 there appeared the first of a number of papers by T. A. Conrad on the fossils of certain localities in the Coastal Plain. In his later work Conrad divided the surficial materials into the "Alluvium" above and the "Diluvium" below. Between 1842 and 1845, Charles Lyell contributed four papers on observations made during a trip in America, which dealt with Tertiary and Pleistocene formations of the Coastal Plain. Ebenezer Emmons, between 1856 and 1860, and W. C. Kerr, between 1869 and 1885, published important papers on coastal-plain geology.

Modern study of the coastal-plain terrace gravels commenced with the work of W. J. McGee. He was the first to interest geologists in the Lafayette formation and to bring into common use the name which had been previously proposed by Hilgard. In his monographic report McGee[18] describes the Lafayette formation with the clarity and charm of expression for which he was noted. He describes the formation over most of the Atlantic and Gulf coastal plains and attributes it to deposition in a sea which advanced so rapidly over the land as to alter only slightly its configuration. He considered the Lafayette formation to be mainly the result of reworking of residual material by the waves of an advancing sea.

He divided the Columbia formation into two phases: (1) The fluvial, a sub-aqueous delta deposit, and (2) the interfluvial, or littoral deposits, formed at the foot of the wave-cut bench along the coast. He recognized striated blocks and boulders in these deposits and considered them to be ice-borne and to indicate the Pleistocene age of the Columbia formation.

Earlier in his work McGee had used the name Appomattox for the oldest and highest gravel and loam formation of this region. Later the Appomattox was correlated with the Lafayette as described by Hilgard, and the name Lafayette was adopted by McGee. Later students have not agreed with McGee in his sweeping correlations of the supposed Pliocene and Pleistocene formations over broad areas nor have they in all cases accepted his conception of the origin of the deposits, yet all have recognized the fundamental character of his observations and felt the stimulating power of his original interpretations and inspiring descriptions.

Between 1891 and 1901, N. H. Darton made several contributions to our knowledge of the terrace formations. He traced the Lafayette northward from Virginia into Maryland, Pennsylvania, Delaware, and New Jersey. He also divided the Columbia forma-

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18 McGee, W. J., The Lafayette formation: U. S. Geol. Survey, Twelfth Ann. Report., pt. 1, pp. 347-521, 1891.

tion into an earlier and a later member. He considered that the Lafayette and Earlier and Later Columbia formations converged seaward from the Piedmont Plateau and that these horizons crossed in the vicinity of Chesapeake Bay so that the formations occurred in reverse vertical order on the Eastern Shore of Maryland. Here they were considered to be marine or estuarine, whereas the parts to the west were regarded as fluviatile.

In 1906 G. B. Shattuck published the results of his studies of the Pliocene and Pleistocene deposits of Maryland. He presented a historical summary of the terrace problem and an annotated bibliography. He believed that these deposits are wholly of marine origin and he prepared maps showing the extent of marine invasion during each of the epochs of terrace formation. He considered that the notable lack of sorting in most of the terrace materials was due to the rapidity of discharge of overloaded streams into the sea, which was unable to cope with such quantities of debris and hence deposited it on the bottom with little or no sorting.

The terrace formations of the Virginia Coastal Plain were described in 1912 by Clark and Miller.[19] No very detailed attention was given to the terrace formations in the study of the Coastal Plain by these authors and their conclusions as to the origin of the terraces are essentially those which Shattuck had reached in Maryland. In the same year a report on the Coastal Plain of North Carolina contains a description of the terrace gravels by L. W. Stephenson, who gives an extensive bibliography and a historical review of studies of the problem. The terraces of North Carolina, ranging in age from Pliocene to Recent, are believed by Stephenson to be chiefly of marine origin.

Salisbury has been recently the principal advocate of the fluviatile origin of large parts of the terrace formations. In 1917, he considered certain of the terrace materials to have been deposited as great alluvial fans not unlike certain Piedmont alluvial fans being formed at the present time.[20]

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19 Clark, W. B., and Miller, B. L., op. cit.
20 Salisbury, R. D., and Knapp, G. N., The Quaternary formations of southern New Jersey: New Jersey Dept. Cons., Div. Min. Geol., Final report series of the State Geologist, no. 8, 1917.

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Eng. Scholars Library No. 16. (For bibliography of Smith's works and their re-publication, see pp. cxxx-cxxxii.) This work contains many interesting notes on the physiography of Chesapeake Bay and its tributaries, and describes briefly the clays and gravels along their shores. This is the first known published reference to the geology of the Coastal Plain.

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METHODS OF INTERPRETATION

In accordance with previous custom, the names of the several terraces will be applied also to the corresponding terrace formations. Unless otherwise stated, the terrace will be understood to be the topographic surface of the formation of the same name. When the cut surface beneath the base of the formation is meant it will be specifically so designated. In some unpublished reports the term terrace-plain as originally proposed by Vaughan for the broader parts of the Coastal Plain terraces has been used, but since the use of both terms, terrace and terrace-plain, is somewhat confusing, the term terrace only will be used in this report.

The interpretation of the surficial formations of the Coastal Plain and of the corresponding terraces offers some difficult problems, for which there are several reasons. In the first place, the formations are thin, variable in character, unindurated, and practically devoid of fossils. There is slight opportunity to correlate formations from place to place by comparing standard sections because of the variability of the beds, the patchy character of outcrops, and the lack of distinctive horizons. In this respect they differ greatly from underlying Tertiary beds with their abundant fossils and rather distinctive sections.[21]

Moreover, the study of the terrace formations is a study in physiography as well as in stratigraphy. The problem of the post-Miocene physiographic history of eastern North America is a broad one which can not be solved within the limits of a single state. It needs to be considered not only from the standpoint of physiography but also from the standpoint of the correlation and significance of the various terrace formations. Neither the stratigraphic nor the physiographic post-Miocene history of this region can be worked out alone. Because the normal order of superimposition is reversed and the older deposits are at higher levels than the younger, many of the methods and assumptions of ordinary stratigraphy are not valid. This principle has not always been recognized in the past. The present report is a contribution to this problem with emphasis upon the economic importance of the gravel deposits of the Coastal Plain in Virginia.

GENERAL RELATIONS OF THE TERRACES

The terraces are of two different kinds. The main type consists of broad, gently sloping steps, which form the main area of the plain. In some areas much of the plain is contained in the upper step or terrace, as each of the lower steps is either relatively narrow or absent. In other places the several terraces are more nearly equal in width. The principal terraces of the Coastal Plain are interrupted by a few estuaries, or drowned valleys, some of which cut entirely across the plain. They correspond in number and elevation with those of the main Coastal Plain surface. The lower members only of this series are present along the smaller and younger channels. The ideal relations of the terraces to each other and to underlying formations are shown in Figure 13 (p. 27).

The relations of the terraces to each other make it clear that the higher terraces are older and the lower ones are younger. The older terraces are remnants of once continuous surfaces, around the margins of which younger benches have been formed by erosion and by deposition. These in turn have been cut away by later

21 As the study of the terrace formations has often been combined with the study of the underlying sedimentary series, students have given relatively slight attention to the surficial gravels.

erosion at still lower levels. In a few places the terraces are essentially the product of erosion, with little contemporaneous sedimentary material on them. This is especially true along the gorge of Potomac River in the Fall Belt, where each of the built terraces of the Coastal Plain has its representative in the rock benches which are conspicuously developed on the tops of islands and along the valley sides between Georgetown and Great Falls. In most places, however, the surface of the terrace is the same as the upper surface of the deposit on a bench previously cut by streams or waves. In many places the base of the gravels is a more valid horizon for the determination of grades and for correlation than is the upper surface of the deposit.

SUBDIVISION AND CORRELATION OF TERRACES

The origin of the coastal-plain terraces has not been essentially different from that of the much older peneplains of the Appalachian Mountains. The peneplains were formed by streams eroding broad areas of hard and soft rocks to plains of low relief, whereas the terraces are partial plains which have been formed only in the areas of weaker rocks along the sea and the main streams. Complete and gradual transition between terraces of limited area and extensive erosional plains exists in some regions. Well-developed peneplains are few, but remnants of partly developed erosion surfaces are numerous. Only the higher and older erosion surfaces of a region can approach a peneplain in extent, as lower erosion surfaces must be progressively restricted in their development. Central-eastern North America illustrates well this point. The accordant summits of the Appalachian Highlands are remnants of one or more extensive peneplains. The Coastal Plain province contains the remnants of not less than 10 erosion surfaces.

The terraces and gravel formations considered in this report belong to this series. Separation of the younger members on the Coastal Plain from the older inland erosion surfaces is somewhat arbitrary. Erosion may be regarded as a more or less continuous, though periodically stimulated, process which has affected the Appalachian Highlands since the end of Paleozoic time. Separation of recent from earlier events becomes increasingly difficult in the inland districts. Separation of Coastal Plain history from Piedmont and Appalachian history also becomes increasingly difficult as the older terraces are studied.

An attempt has been made in Table 3 to indicate the relationship between the several terraces which are discussed here and the progressive growth of the present terminology, as well as to outline the salient features of each terrace.

TABLE 3.—*Various classifications of the terraces of the Middle Atlantic Coastal Plain, and their characteristics*

	Darton[1] (District of Columbia)	Shattuck[2] (Maryland)	Clark and Miller[3] (Virginia)	Stephenson[4] (North Carolina)	Wentworth[5] (Virginia)	Characteristics
Pleistocene	Later Columbia	Talbot	Talbot	Pamlico	Princess Anne	Terrace and formation of marine origin.[6] Upper surface ranges from 10 to 15 feet above sea-level Occurs along shores of present tidewater.
					Dismal Swamp	Terrace and formation largely of marine origin. Fluvial portions not distinguished from Chowan. Upper surface of marine part ranges from 15 to 25 feet in elevation. Broad area south of Norfolk and elsewhere adjacent to tidewater.
				Chowan	Chowan	Almost wholly fluvial in Virginia. Ranges from 35 feet near coast to 80-90 feet in elevation near the Fall Belt. In valleys in Chowan River basin and adjacent to other main streams to the north.
		Wicomico	Wicomico	Wicomico	Wicomico	Chiefly of marine origin. Ranges from 60 feet at top of Suffolk scarp to 90 feet at foot of Surry scarp. In triangle between Surry and Suffolk scarps and North Carolina line; small fluvial remnants in James, Potomac, and Rappahannock valleys.
	Earlier Columbia	Sunderland	Sunderland	Sunderland	Sunderland	Upland terrace plain wholly of fluvial origin. Elevation of upper surface ranges from 100 feet at Surry scarp to 200 feet or more at Fall Belt. Principal upland surface between Fall Belt, Potomac River, and the Surry scarp.
Pliocene	Lafayette	Lafayette	Lafayette	Lafayette	Tertiary terraces (Brandywine, etc.)	Wholly of fluvial origin. Terrace remnants rising above Sunderland surface along Fall Belt, wider at north than at south. At elevations of 200 to 300 feet.

1 Darton, N. H., Jour. Geology, vol. 2, pp. 568-587, 1894.
2 Shattuck, G. B., Maryland Geol. Survey, Pliocene and Pleistocene, 1906.
3 Clark, W. B., and Miller, B. L., Virginia Geol. Survey, Bull. 4, pp. 48-51, 1906.
4 Stephenson, L. H., North Carolina Geol. Survey, Bull. 3, pp. 258-277, 1912.
5 This report.
6 Marine is used here in the broader sense discussed in the text, p. 100.

TERTIARY TERRACES

GENERAL STATEMENT

The term Lafayette originally included not only terraces and materials which are believed to be of Tertiary (Pliocene?) age but probably also considerable areas of Pleistocene terrace gravels. With the introduction of the term Columbia the Pleistocene gravels were separated from the Lafayette, which was then restricted to the supposed Pliocene deposits. It has long been felt, however, that the term Lafayette has been used in so many different ways that it is best to reject it altogether. In accordance with this view Clark[22] proposed the name Brandywine for the plain and the formation which are well developed on the upland near the town of Brandywine, Maryland. The term Brandywine as thus defined includes a considerable part of the terrace surface and deposits formerly called Lafayette in the Washington region. It has become apparent, however, that other parts of the former Lafayette formation could not be included in the Brandywine as that term was used by Clark.[23] As a result of field studies in 1921 and 1922 the writer divided the former Lafayette formation of the Washington region into (1) an older and higher terrace and gravel formation, the Tenley formation, from Tenleytown, D C., and (2) a younger and lower terrace and gravel formation, the Brandywine of Clark. As the Tenley terrace is not preserved on the Coastal Plain in the Washington area it will not be described in this report.

Two terraces have also been recognized in Pennsylvania as being probably equivalent to the older Lafayette terrace.[24] In North Carolina the Lafayette formation is thought to be of Pliocene age and the Coharie terrace is assigned to the Pleistocene.[25] The Coharie terrace has not been differentiated in Virginia.

All the pre-Sunderland gravels and terraces on the Coastal Plain of Virginia in the vicinity of Washington appear to be of Brandywine age. (See Table 3.) Hence the pre-Sunderland terrace materials of the western Coastal Plain of southern Virginia are tentatively considered to be of the same age, but considerable study of the gravel formations and terraces of the eastern margin of the Piedmont Plateau will be needed before they can be definitely correlated. (See Pl. 4, A.)

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22 Clark, W. B., The Brandywine formation of the middle Atlantic Coastal Plain: Am. Jour. Science, 4th ser., vol. 40, pp. 499-506, 1915.

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BRANDYWINE TERRACE AND FORMATION

Extent and topography.—The remnants of the Brandywine terrace in Virginia are confined to a narrow belt of the Coastal Plain adjacent to the Fall Belt. (See Fig. 24.) The best known and most sharply defined examples are found in the region northwest, west, and southwest of Alexandria. Here the Brandywine terrace forms the tops of several spurs which extend eastward from the Fall Belt, on which are the towns of Clarendon, Ballston, and Baileys Crossroads.[26] This flat upland forms a small part of the entire area between the Fall Belt and Potomac River but its exceptional flatness makes it a conspicuous feature of the region. (See Pl. 2, A.) This is well shown on the topographic map, Figure 15. Here the Brandywine terrace plain is represented by the flat areas west of Lincolnia, between Episcopal High School and Baileys Crossroads, and south and east of Garrison. A well-marked scarp, about 50 feet high, passing northwest of Penrose, west of Barcroft, and east of Episcopal High School, separates the Brandywine terrace from the younger Sunderland terrace. (See p. 43.) In the northern part of the district the Brandywine terrace has an elevation of 260 to 270 feet but it slopes southward at a rate of about 2 feet to the mile to an elevation of about 240 feet west of Mount Vernon. The northwest margin of the Brandywine terrace in this area coincides with the Fall Belt where the surface rises in half a mile to elevations of 300 feet or more.

The Brandywine upland to the east has been truncated in the development of lower terraces. It is in places cut off by scarps which descend at rates of 300 to 400 feet to the mile. (See Fig. 14.) In some places the Brandywine terrace is adjoined by remnants of the next younger Sunderland terrace. A fine example is the scarp along the inner margin of remnants of the Sunderland terrace near Arlington, which extends from the Theological Seminary northward along the Leesburg Road, through Barcroft, Penrose, and Hatfield. It is evidently a great meander scar cut by the river in Sunderland time. The scarp which surrounds the Mount Vernon cut-off is another fine example. (See p. 77.) In other places the Brandywine adjoins much lower terraces, as intermediate terraces of other areas either were not developed or they have been eroded away during the formation of the lower terraces.

Southwest for several miles from Mount Vernon the Coastal Plain is very narrow and the Brandywine terrace is restricted to very small remnants, which have not been mapped in detail. Several upland remnants in the Fredericksburg quadrangle, which rise

26 This terrace is exceptionally well shown, both in Virginia and Maryland, on the large scale map of Washington and Vicinity; scale 1/31,680, contour interval 10 feet.

somewhat above the known upper limit of the Sunderland horizon, are supposed to be parts of the Brandywine terrace. Because of the lack of good topographic maps, their relations are doubtful. These remnants are west of a line drawn from Mathias Point to Richmond. This same line bending slightly east as it crosses the Potomac defines the seaward limit of the much better discriminated Brandywine terrace of Maryland, and thus supports this interpretation.

In the vicinity of Richmond the highest gravel formations underlying the 200-foot plain do not appear to contain the large striated blocks which are characteristic of the Pleistocene formations. Hence they are probably of Pliocene age. From Richmond south to the state line irregular terrace remnants above the known Sunderland level are included in the Tertiary terraces as here mapped. It is probable that gravel formations of Mesozoic age (Patuxent formation, and others) have been mapped locally as Tertiary terraces, but it has been impossible to discriminate all of these in the available time.

Petrography.—The materials in the Brandywine formation are much more varied than those in the later terrace formations. This apparent variety is probably due in part to the fact that parts of several distinct terrace formations have here been grouped together. However, known Brandywine and other pre-Sunderland gravels show greater variation in composition from place to place than younger formations, because they have been largely derived from the diverse rocks of the Piedmont Plateau. Much essentially local material has been included, which does not appear so generally in the lower terraces. Deposits close to the main trans-Blue Ridge streams show, however, a similar lithologic heterogeneity.

Similar variety is found in the mechanical composition of the Brandywine terrace materials at different places. The Brandywine formation at the type locality in Maryland consists of quartzite, vein quartz, and chert pebbles in a red loamy matrix. About 15 to 25 per cent of the pebbles are chert that is typically light lavender-gray in color. The mechanical composition is similar to that of many moderately well sorted river gravels. It shows 2 maximum grades, about 5 grades apart. Only a very small part of the Brandywine formation of Virginia in and near Fairfax County resembles the type Brandywine. This gravel is described under samples 1444 and 1387-C below, and its size range is shown in Figures 16 and 17.

No gravel closely resembling this in lithologic character was found in James River basin near Richmond. Considerable areas in the western suburbs of Richmond at elevations of 200 to 230 feet are mantled by a red loamy gravel containing well-rounded cobbles up to 8 inches in diameter. Black chert cobbles 3 or 4 inches in diameter are fairly abundant. The finer gravel grades are variable, being composed in some places largely of slightly subangular quartz fragments from near-by rocks. Faceted or striated boulders or cobbles have not been found in the Brandywine formation. Several exposures in this area show that the Brandywine gravel is underlain by Patuxent gravel. The older gravel is generally distinguished by its arkosic composition, gray color, clay balls, and the clear, limpid appearance of most of the quartz pebbles.

Descriptions of representative samples of Brandywine and other pre-Pleistocene gravels are given below.

Between Fredericksburg and Washington some of the pre-Sunderland gravels resemble closely the type Brandywine and some are of distinctly local origin. Between Fredericksburg and Richmond, and south of Richmond and Petersburg, these gravels are arkosic and only slightly worn. Chert is rare or missing, being apparently confined to the ancient basins of trans-Blue Ridge streams.

Sample 1444. Brandywine gravel. Roadside pit on highway 1¼ miles west of Lorton, Fairfax County.

This is a poorly sorted gravel. The mechanical composition is shown in Figure 16. Chert fragments make up about 15 per cent of the pebble grades, the remainder being subangular vein quartz. The sand grades consist mostly of angular quartz with a few feldspar grains and fragments of kaolinized material. A large proportion of the finest grades consists of flakes of ferruginous kaolinized material.

Sample 1387-C. Brandywine gravel. From 4 feet below top of railroad cut at Franconia, Fairfax County.

The mechanical composition of this gravel is shown in Figure 17. The pebbles are somewhat rounded fragments of vein quartz and quartzite with about 25 per cent of chert in the finer grades. Most of the cherts are weathered to a chalky residue. The sand grades consist of angular or slightly rounded quartz fragments slightly stained with iron oxide and a few chalky cherts. Clay and silt grades of cream-buff color constitute a matrix of about 15 per cent.

Sample 1387-A. Pre-Brandywine (probably Patuxent) sand. From railroad cut at Franconia, Fairfax County, 10 feet below top of cut and 5 feet below base of Brandywine gravel.

This is a rather well sorted medium sand. Its composition is shown in Figure 18. It consists mainly of angular quartz fragments, but contains about 10 per cent of kaolinized feldspar and a few grains of mica, possibly of secondary origin.

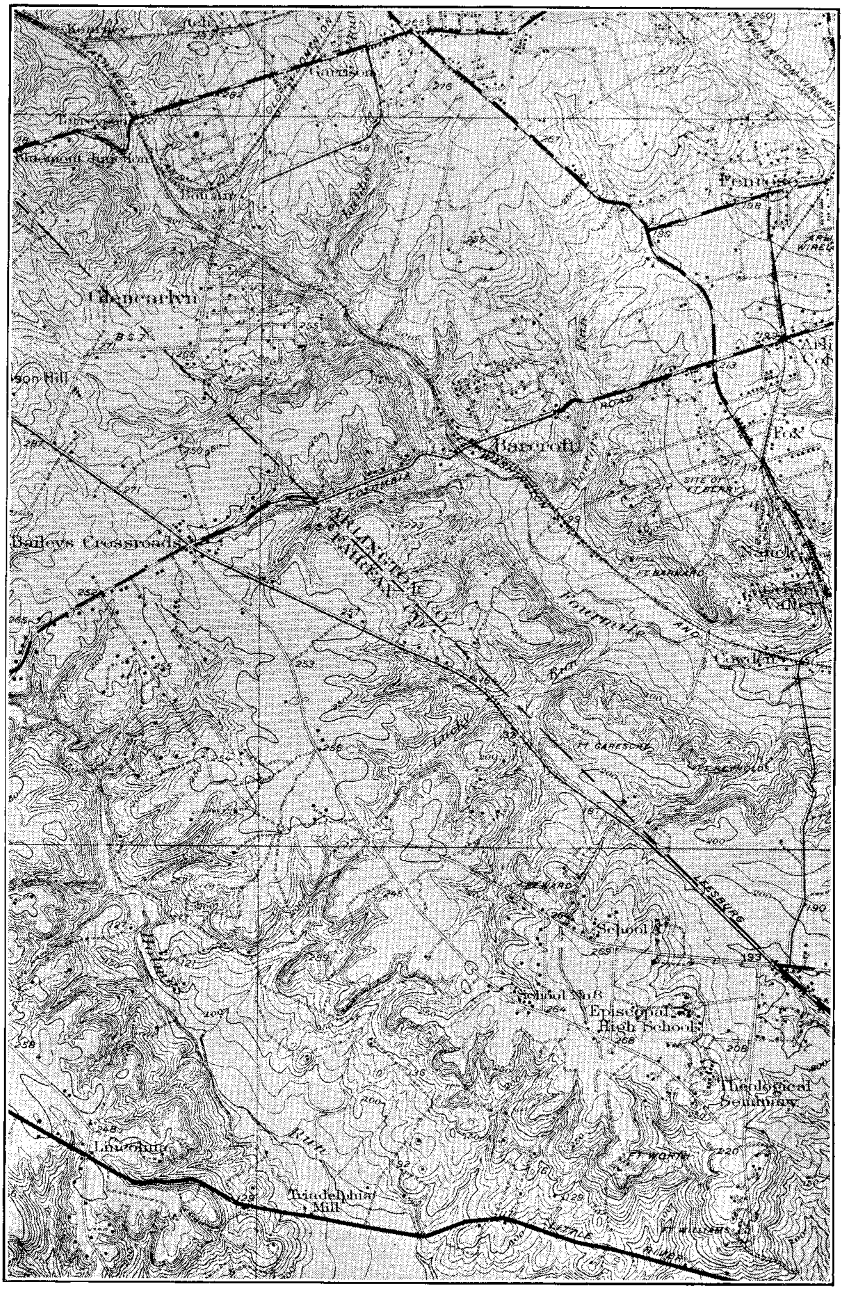


Figure 15.—Parts of the Brandywine and Sunderland terraces in Fairfax and Arlington counties. (Part of Washington and Vicinity map.) Scale, 1 inch equals 1.53 miles; contour interval, 10 feet. The Brandywine terrace is well shown between Baileys Crossroads and Episcopal High School, southwest of the county line. The Sunderland terrace is shown northeast of Episcopal High School and south of Penrose (northeast part of area). The scarp southwest of Penrose is an old meander curve. (See pp. 38 and 41.)

Sample 1387-B. Pre-Brandywine (probably Patuxent) gravel. From railroad cut at Franconia, Fairfax County, 20 feet below top of cut and 15 feet below base of Brandywine gravel.

This gravel shows maximum quantities in the plus 16 millimeter and plus ¼ millimeter grades, as shown in Figure 19. The pebble grades consist largely of subangular vein quartz with some quartzite and sandstone. Chert pebbles make up about 25 per cent of the finer pebble grades. The sand grades are composed chiefly of clean white and pink angular quartz showing very little rounding. A few grains of chert are present. In the finest sand grades there is a small percentage (about 0.1 per cent) of black sand, probably mostly ilmenite.

Sample 1434. Pre-Brandywine (probably Patuxent) gravel. From 5 feet below surface in railroad cut at Pohick, Fairfax County.

The mechanical composition of this gravel is shown in Figure 20. The pebbles are mostly clean subangular vein quartz, with small proportions of quartzite and chert. Numerous pellets of clay, possibly in part kaolinized feldspar, are present in the plus 4 millimeter and plus 2 millimeter grades. Sand grades consist in part of clean angular quartz but carry also limonite, cemented aggregates, and clay pellets. In the finer grades are numerous, much-weathered grains of feldspar (orthoclase, microcline and plagioclase) and much ferruginous kaolin residue from these feldspars.

Sample 1999. Brandywine gravel. From elevation of 250 feet, 1 mile southeast of Racume, Brunswick County.

A washed sample of this gravel showed the composition indicated in Figure 21. The pebble grades consist wholly of angular quartz debris from the weathering of a granite. The coarser sand grades are chiefly angular quartz, but in the finer grades ferruginous kaolin and feldspar become more abundant. In the minus 1/16 millimeter grade, feldspar composes possibly 60 or 70 per cent of the whole.

QUATERNARY TERRACES

SUNDERLAND TERRACE AND FORMATION

Extent and topography.—The Sunderland formation is the highest terrace formation in which large striated and supposedly ice-rafted boulders are found. The surface of this formation is the principal upland surface in the Coastal Plain counties west of a line drawn from Northumberland County to Southampton County. In the vicinity of Washington and Alexandria two parts of this terrace have been recognized, namely, an upper and a lower Sunderland terrace and formation, having elevations of approximately 200 and 150 feet, respectively. These divisions have not been made in the remainder of the Coastal Plain of Virginia and it is probable that they are not so distinctly developed elsewhere.

The name Sunderland was applied to this formation by Shattuck[27] in 1901 at the type locality in Maryland. The broad out-

27 Shattuck, G. B., The Pliocene and Pleistocene deposits of Maryland: Maryland Geol. Survey, Pliocene and Pleistocene, p. 85, 1906.

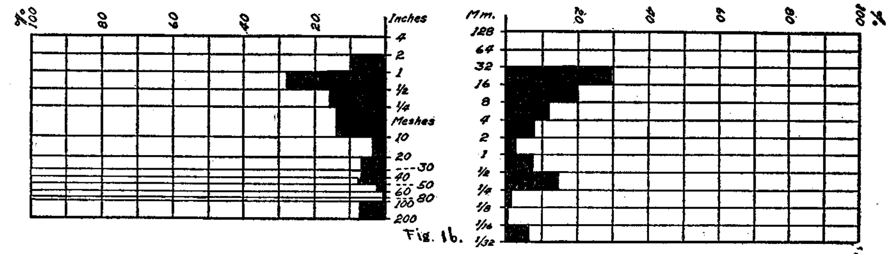


Fig. 16.

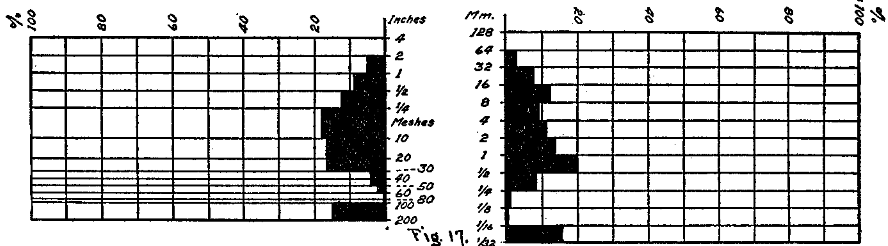


Fig. 17.

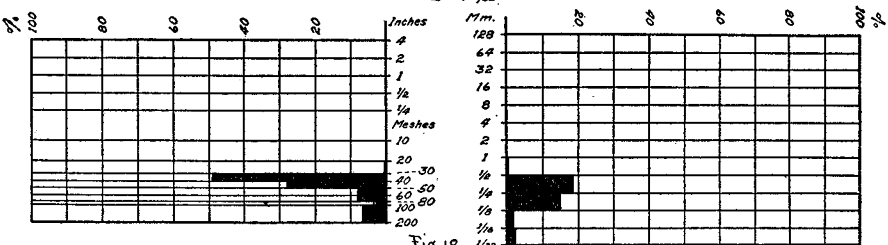


Fig. 18.

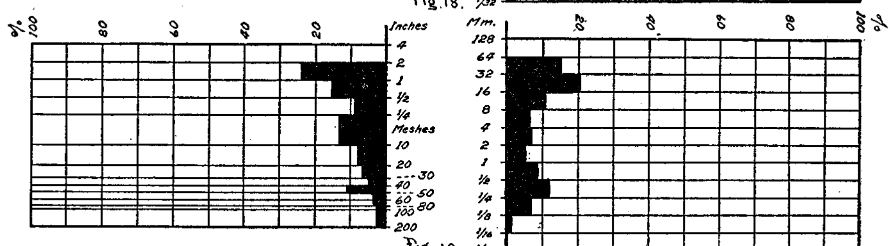


Fig. 19.

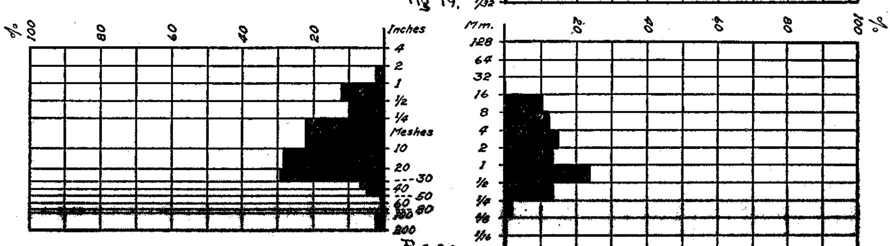


Fig. 20

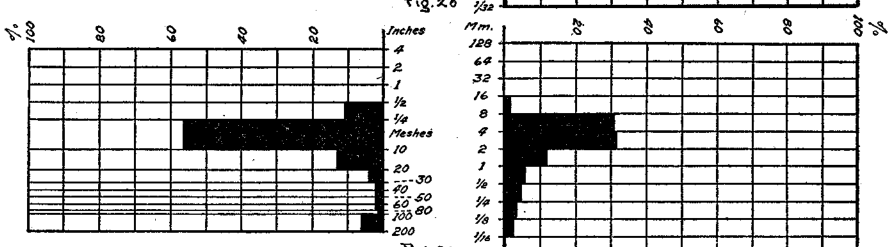


Fig. 21

Figures 16-21.—Diagrams showing mechanical composition of the Brandywine formation. Samples 1444, 1387-C, 1387-A, 1387-B, 1434, and 1999.

lines of the Sunderland terrace plain in Virginia are shown in Figure 24. The slope of its present surface is believed by the writer to be essentially the original slope of deposition of the Sunderland gravel by fan-building rivers. (See Pl. 2, B.)

The west limit of the Sunderland terrace is the frayed and commonly indistinct margin of the pre-Sunderland terraces. In a few places, such as the Washington-Alexandria area, the Sunderland terrace is separated from the Brandywine terrace by steep and distinct scarps. (See Fig. 15.) The Sunderland terrace is limited to the east by the steeper and strongly marked scarps that descend to the younger terraces, for example, the Wicomico terrace south of Piankatank River, and the Dismal Swamp and Princess Anne terraces in Middlesex, Lancaster, and Northumberland counties.

The Sunderland terrace is separated into several distinct parts by the main streams of the Coastal Plain (Pl. 4, B) and is still more minutely dissected in dendritic pattern by the numerous small tributaries of these streams. Few areas as large as a square mile remain undissected. On the other hand, somewhat in contrast with remnants of the Brandywine terrace, the Sunderland terrace is so clearly preserved over most of its original area that it is the most striking single element of coastal-plain topography. Much of its surface is so flat that, when viewed from its own level, the valleys are invisible and the region appears for miles in every direction as an unbroken plain.

Lithology and structure.—General statements only can be made about the sequence of beds in the formation as a whole. At the base, where it rests unconformably on older formations, there is commonly a cobble or pebble zone (Pl. 5, A). In a few places this zone is a continuous gravel layer 1 or 2 feet thick, but in most places far from the Fall Belt the cobbles are scattered along the contact. They grade through a few inches of slightly coarser gravel into the normal overlying loam or fine loam gravel. (See Pls. 5, B and 6, A.) Almost everywhere the upper 3 to 5 feet of the formation consists of fine sandy loam without pebbles.

The loam gravel between the basal and topmost layers of the formation varies greatly from place to place. There is no striking regularity or recognizable gradation from place to place in the details of the section and the distribution of pebble zones. In the coastward part of the formation a rude sequence of bedding, which is thought to be significant in interpreting the origin of the formation, has been deciphered. The buff sandy loam which composes the bulk of the formation grades downward in places to a series of alternating bands of buff loam and clean white sand. The individual beds commonly vary from less than 1 to 2 inches in thickness, and the entire zone is commonly not over 4 or 5 feet thick. Still lower are beds of clean white sand and gravel free from loam and clay.

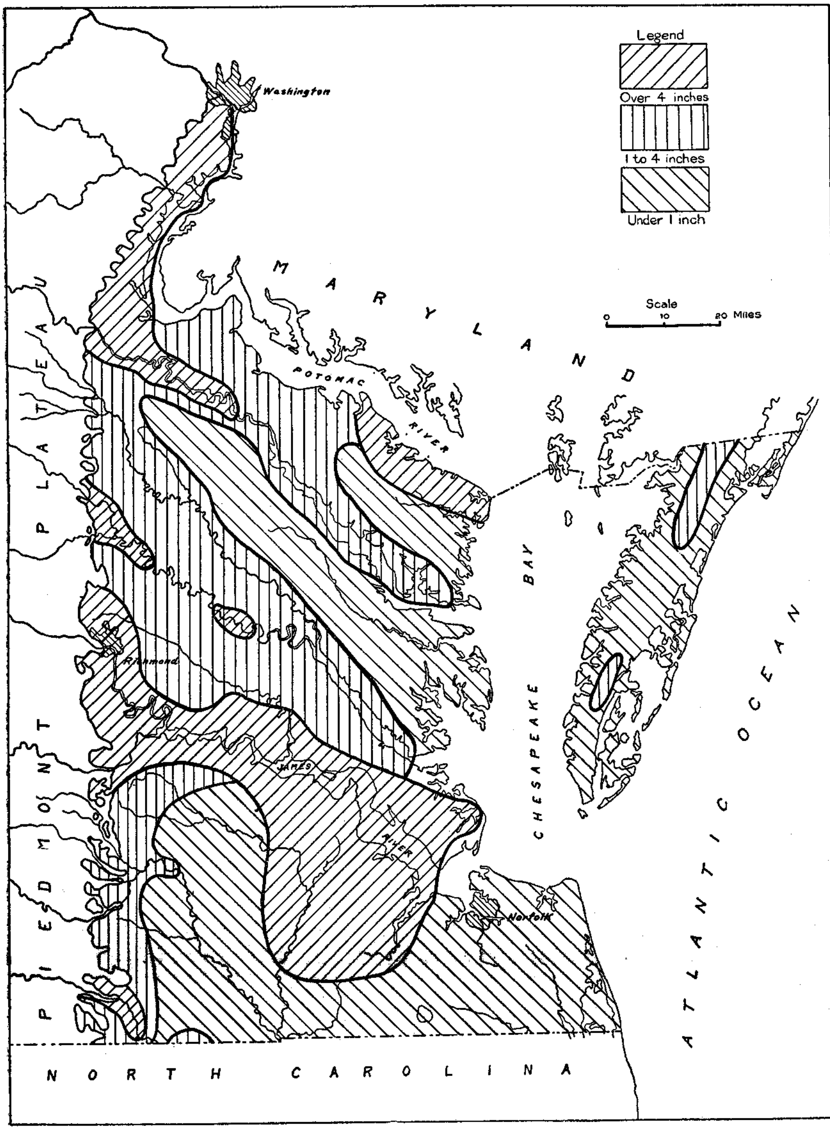


Figure 22.—Preliminary sketch map showing common size of the large cobbles in the coarsest gravel found in parts of the Coastal Plain. The sizes indicated are not those of occasional boulders of exceptional size, but are those which will be approximated by a fair number of cobbles in the coarsest gravel deposits.

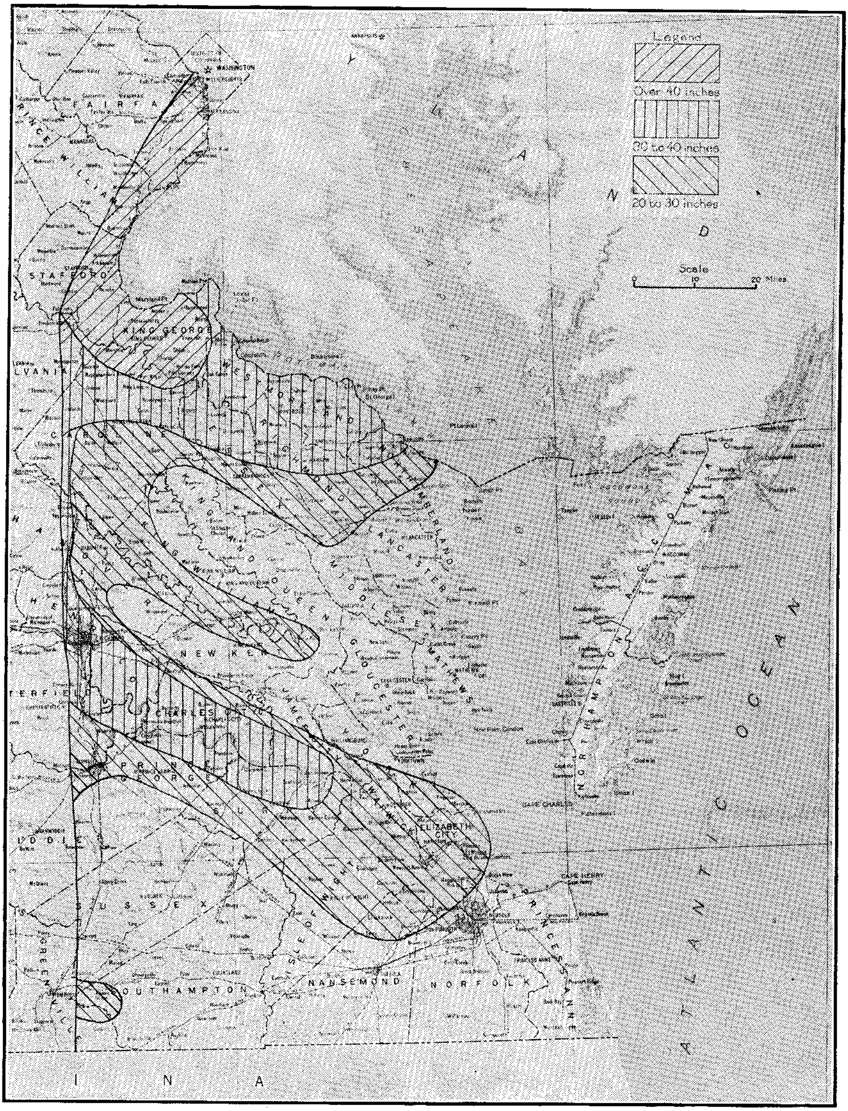


Figure 23.—Sketch map showing sizes of exceptional boulders on the Coastal Plain of Virginia. These boulders are believed to have been deposited by floating ice. Compare with Figure 22. (See pp. 46 and 59.)

This transition occurs at different elevations in the region, averaging about 0 to 50 feet, but there is rude local accordance. Transitions of this type appear to be confined to the seaward part of the Sunderland area.

Thickness.—The Sunderland formation varies from a thin mantle to 80 or possibly 100 feet thick. Most commonly it is 30 or 40 feet thick where it has been entirely preserved. Its bedding, like that of other terrace formations, is very poor, and is shown chiefly by strings of pebbles and cobbles and by a few fairly sharp contacts locally within the formation.

Petrography.—The mechanical composition of the Sunderland formation is typically that of a poorly sorted loam gravel extending over 9 or 10 grades and having 2 maximum grades about 5 grades apart. Neither of these maximum grades is more than 20 per cent. Some representative analyses are shown in Figures 26 to 48. The Sunderland formation along the Fall Belt contains some coarse gravel with cobbles ranging to 8 or 10 inches in diameter, and with a few blocks 4 or 5 feet in diameter. Toward the sea the gravel zones become thinner and less abundant, and are composed of finer material. The formation in the seaward half of its area is essentially a sandy loam having here and there a few small pebbles. It contains, however, some large blocks, a few of which are striated. (See Figs. 22 and 23.)

Clean, well-washed gravel, with low silt and clay grades, does not occur in the typical Sunderland formation except in small local pockets which are too small to be of economic value. Considerable quantities of clean sand and fine gravel occur to the east in the basal part of the formation.

The gravel grades of the Sunderland samples consist of subangular to moderately well rounded pebbles of vein quartz, quartzite, and chert. The chert is present almost everywhere, and varies from 1 to 20 per cent in amount. The sand grades consist predominantly of angular and subangular quartz grains with small quantities of other minerals in the finer grades. The matrix, which is commonly buff or red-brown, consists of quartz, iron oxide, and more or less completely decomposed residues of feldspars and other minerals. Samples are described on pp. 47-53.

Origin of sediments.—The formation is the product of long-sustained chemical weathering, as is shown by the highly siliceous character of its coarser grades and the almost complete absence of granitic or schistose pebbles even adjacent to a region replete with such rocks. On the other hand, the lack of sorting and the very imperfect rounding of either the larger or the smaller fragments point to a very moderate amount of mechanical milling as compared to that shown by most sand and gravel formations. This may have been due to the handling of large amounts of material, including much very fine material, by overloaded streams. Study of the Sunderland and other terrace formations and of the modern sands and gravels of the Atlantic beaches and Atlantic rivers leads the writer more and more to the conclusion, previously voiced by others,[28] that very great distances of transportation and very prolonged milling under favorable conditions are needed to produce well-rounded, generally spheroidal or ellipsoidal pebbles from hard rock fragments or similar sand grains from quartz. At a few places on sea beaches, where strong waves maintain an almost incessant milling of the coarse gravels, a general rounding of the cobbles and boulders is produced, which far surpasses that seen by the writer in any modern stream gravels. Disregarding such situations and confining attention to fluvial abrasion, it is exceedingly difficult to visualize, in terms of modern processes, the conditions under which the sand and gravel of certain formations were produced. The entire length of the longest rivers seems inadequate to produce the well-rounded forms. Comparison of the best rounded sand of the coastal-plain terraces with some fairly typical St. Peter sand suggests that the St. Peter sand has sustained possibly 10 times as much abrasion as the rounded sand of the Coastal Plain. This supports the conclusion that many formations contain much material which has been repeatedly transported and rounded as it passed through successive formations during geologic time.

Striated boulders.—The presence of large striated cobbles and boulders in the Sunderland and other Quaternary terrace formations constitutes a problem of considerable scientific importance.[29] Some of these boulders are much larger than is normal for these gravels. Boulders 2 feet or more in diameter have been found at several places not far from the western shore of Chesapeake Bay, and others up to 4 or 5 feet in diameter are more common along the Fall Belt and farther west up the Potomac Valley. During the present study these boulders have been found in the James River basin and south to the State line. Similar cobbles have also been found at many places in the basin of Tennessee River,[30] where they occur in groups.

Neither the striated nor the exceptionally large boulders seem to be closely related to the coarseness of the associated gravel because they are found at some places where the gravel is not coarse

28 Anderson, G. E., Experiments on the rate of wear of sand grains: Jour. Geology, vol. 34, p. 157, 1926.

29 Wentworth, C. K., Striated boulders on the southern Coastal Plain of Virginia: Geol. Soc. America Bull., vol. 38, pp. 150-151, 1927.

30 Wentworth, C. K., Striated cobbles in southern states: Geol. Soc. America Bull., vol. 39, pp. 941-953, 1928.

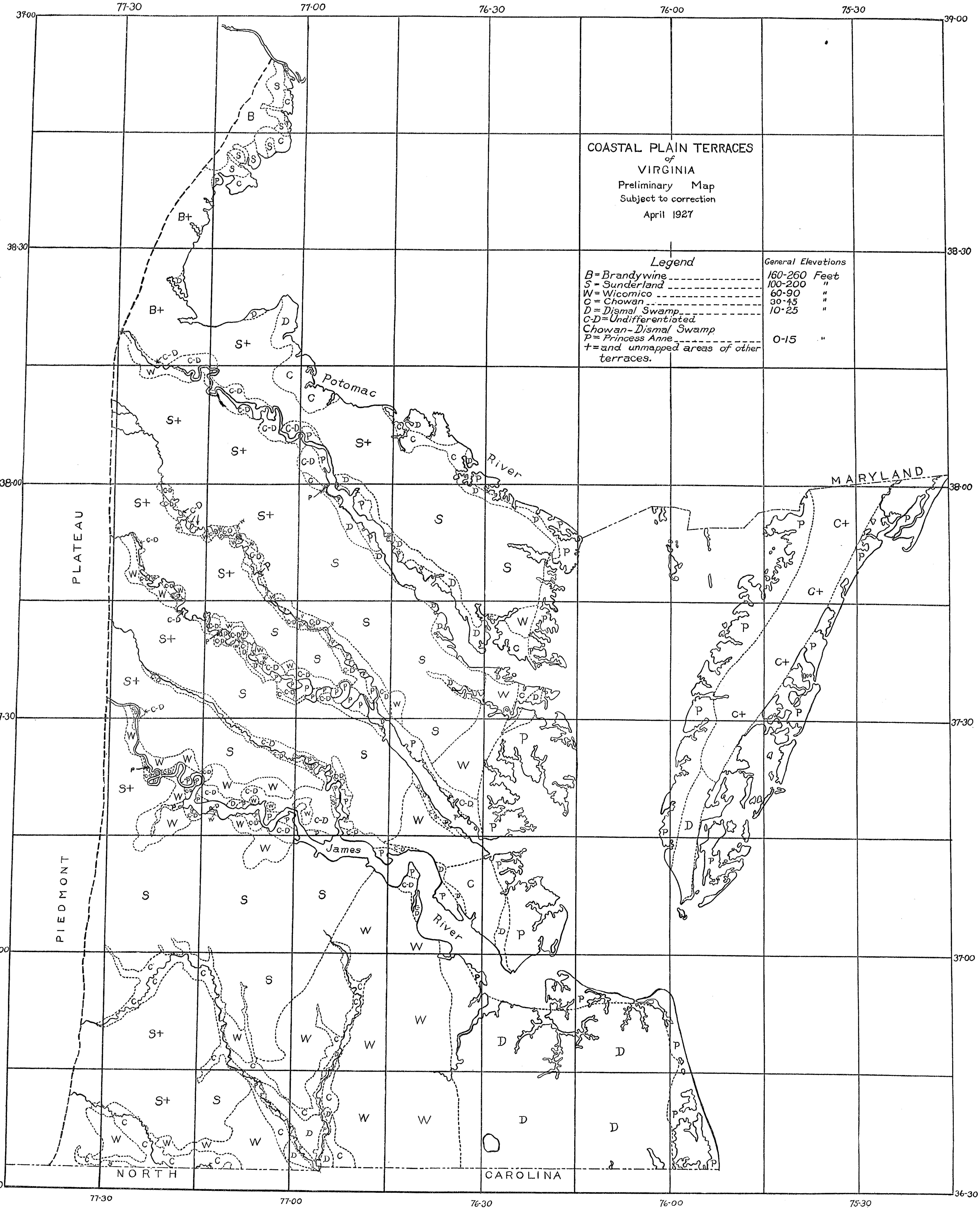


Figure 24.—Areal map of the terraces of the Coastal Plain of Virginia.

and they are missing at other places where the main deposit is very coarse. Their sporadic occurrence is thought to indicate ice flotation and stranding of ice blocks. (See Fig. 25.)

The striated blocks consist mainly of two kinds of material: (1) Dominantly hard, fine-grained quartzite, and (2) some dark-red quartzitic and somewhat micaceous sandstone. The sandstone blocks may have come from the Juniata formation.

The striations on these boulders and cobbles vary from rude gouges to well-defined systems of scratches on nearly plane facets. It is clear that the gouges and scratches have been produced by the same agent. These facets and striations are not essentially different from those of true glacial origin. More than half of the markings are of this type. Faceted and striated materials have not been found in the modern gravel of the Potomac or the James river basins.

These boulders have clearly been transported down Potomac and James rivers. They are absent or extremely rare in coastal-plain terraces not formed by these rivers. One well-striated boulder of vein quartz more than 3 feet across was found in the Sunderland formation in the District of Columbia. It was derived probably from the Potomac Basin east of Blue Ridge because such large masses of vein quartz are not known west of the Blue Ridge.[31] Striated materials may also occur, therefore, along other streams on the east slope of the Blue Ridge, but only doubtful and inconclusive data have been discovered.

No final conclusion can be reached at present as to the origin of these striated materials. They do not differ in any essential way from true glacial materials. On the other hand, in the absence of true erratics, till, and other direct evidence of glaciation in the Appalachian Mountains in Virginia, these boulders alone are insufficient evidence of glacial action. The writer suggests tentatively that they may be the result of intensive local action of river ice during colder climates than at present. Similar striated pavement materials are being produced in the channels of Mackenzie and Yukon rivers.

Sample 1364. Sunderland pebbly sand. From the upper 6 feet of the terrace at Arlington wireless station, Arlington County. Sample shows finer part of gravel only; plus 4 millimeter part of material in section estimated at 30 per cent. Fines washed out.

This sample is a rather well sorted coarse sand containing a few pebbles. See Figure 26. The larger pebbles consist mainly of fairly well rounded quartz and chert. The smaller pebbles and the quartz grains of the sand grades are angular or only slightly rounded. The medium and fine sand grades contain con-

31 Stose, G. W., personal communication.

siderable feldspar, mostly orthoclase and microcline. Feldspar and its kaolinized residue constitute more than 50 per cent of the finer grades.

Sample 1686. Sunderland gravel. From half a mile southwest of King George, King George County.

This is a poorly sorted fine loam gravel. See Figure 27. The pebble grades consist of rough angular masses of quartz from schist and granite. No chert is present. One or two per cent of blue quartz is found in these grades. The sand

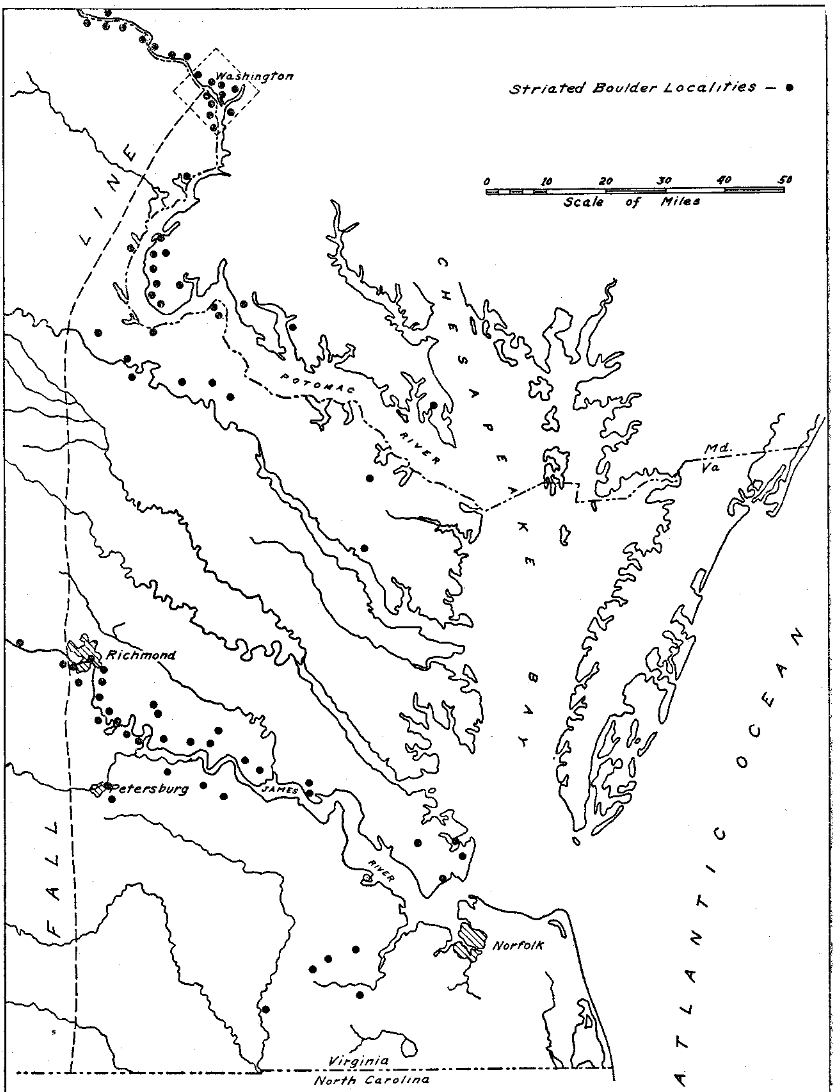
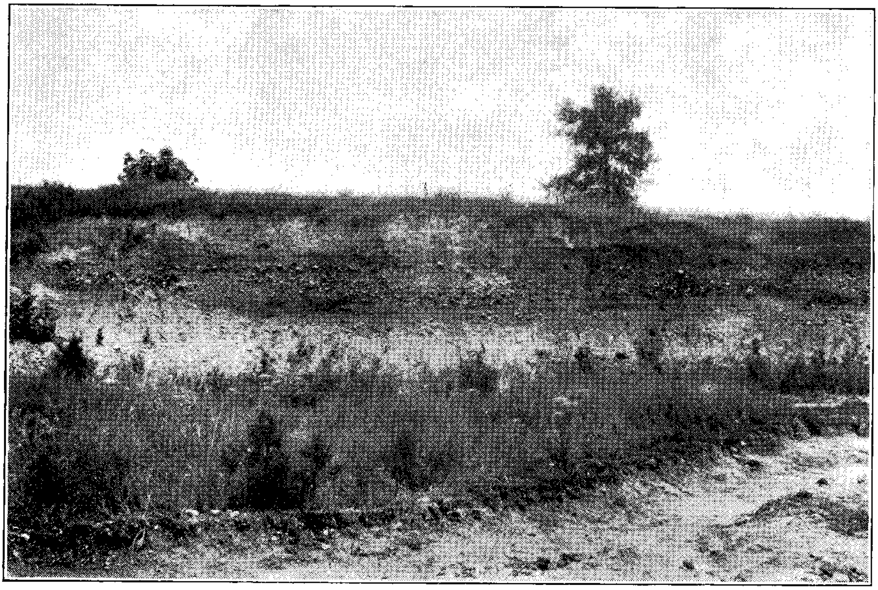
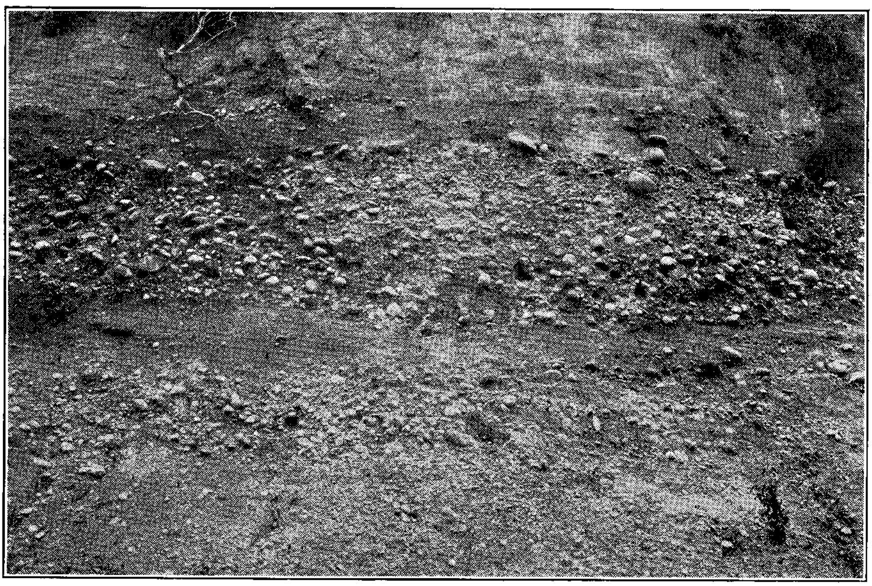


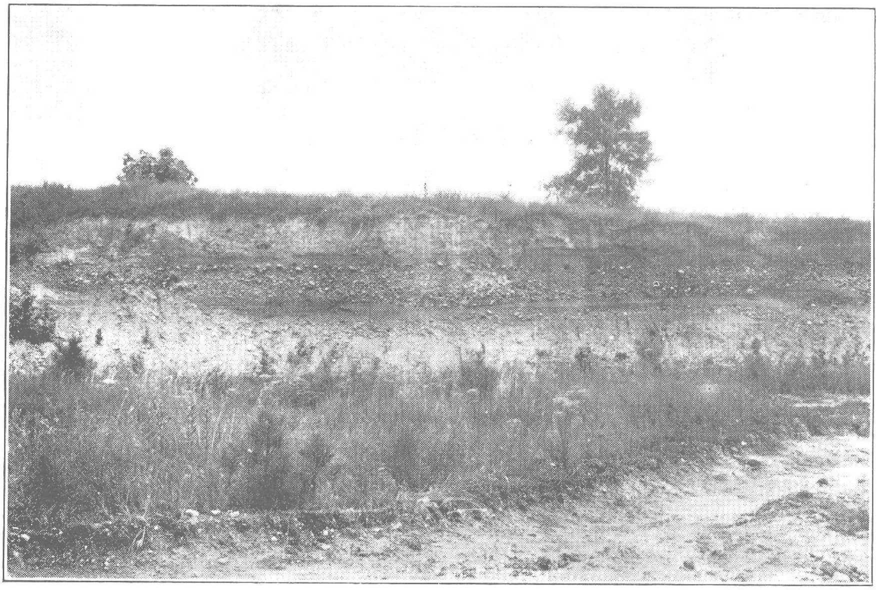
Figure 25.—Localities where striated boulders have been found on the Coastal Plain of Virginia.



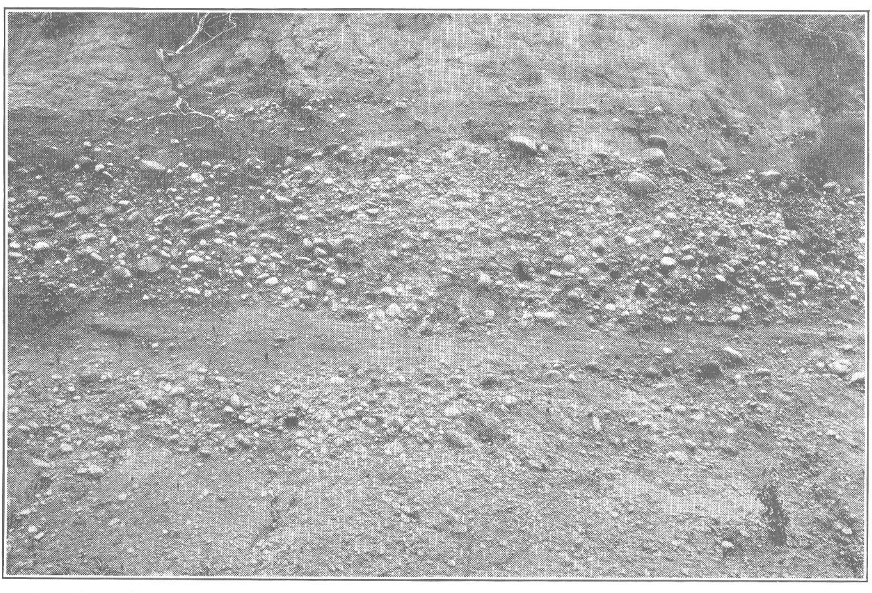
A. Basal gravel of the Sunderland formation west of Camp Lee, Prince George County. (See p. 43.)



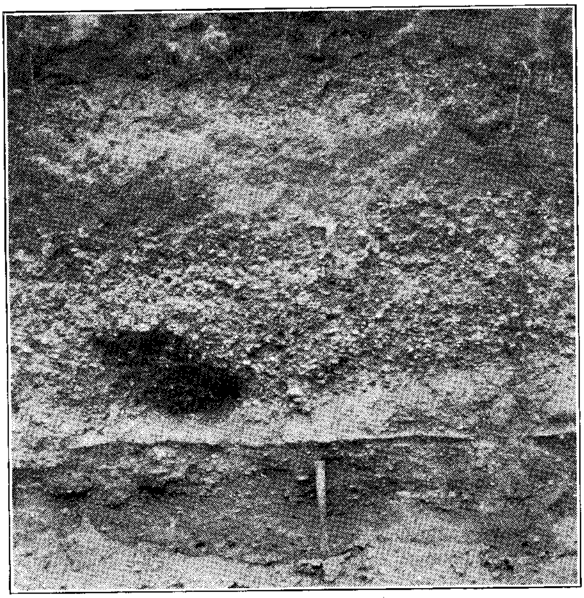
B. Detail of gravel in the lower part of the Sunderland formation west of Camp Lee, Prince George County. (See p. 43.)



A. Basal gravel of the Sunderland formation west of Camp Lee, Prince George County. (See p. 43.)

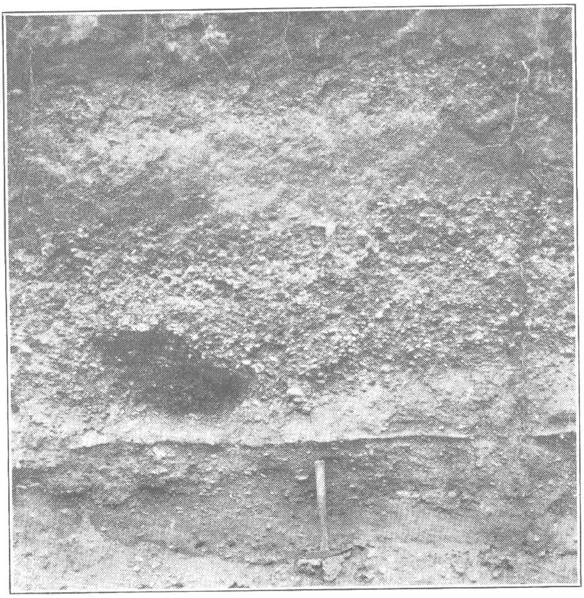


B. Detail of gravel in the lower part of the Sunderland formation west of Camp Lee, Prince George County. (See p. 43.)

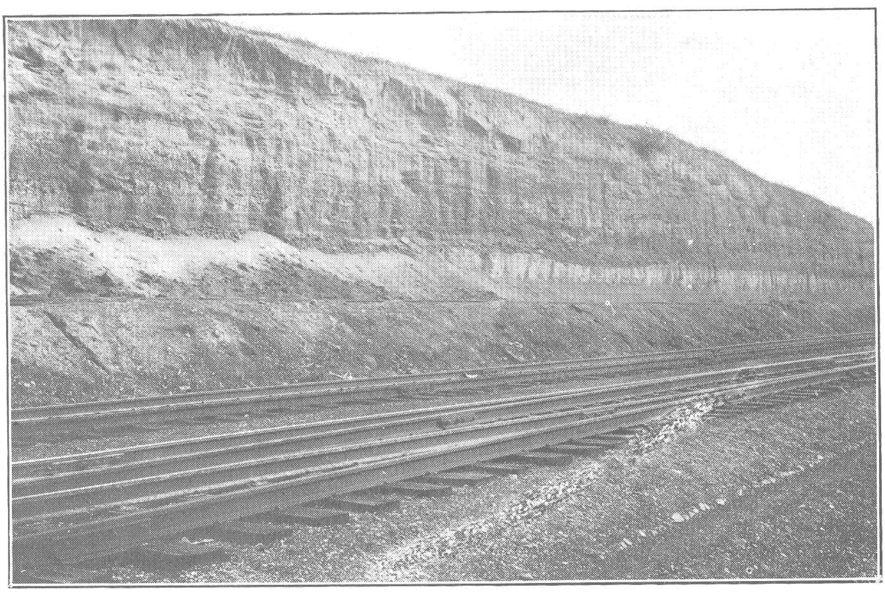


A. Fine loam gravel of Sunderland formation in road cut 1½ miles southwest of Dogged Forks, Caroline County. (See p. 43.)

B. Wicomico gravel on the northeast side of Rappahannock River opposite Fredericksburg. (See p. 58.)



A. Fine loam gravel of Sunderland formation in road cut 1½ miles southwest of Dogged Forks, Caroline County. (See p. 43.)



B. Wicomico gravel on the northeast side of Rappahannock River opposite Fredericksburg. (See p. 58.)

grades consist largely of angular quartz grains somewhat coated with arkosic material. In the finer grades a majority of the grains is composed of feldspar and ferruginous kaolinized residues.

Sample 1735. Sunderland loam. From upland terrace half a mile north of Macedonia Church, Essex County.

This is a sandy loam of which 75 per cent passes the 1/16 millimeter sieve. See Figure 28. The sand grades of this loam are similar in composition to the normal upland material.

Sample 1736-B. Sunderland sand. From an elevation of about 80 feet, half a mile east of Church View, Middlesex County.

This is a well-sorted coarse sand. See Figure 29. The coarse sand grades consist mostly of angular quartz grains, some of which are blue quartz. The fine grades contain much ferruginous kaolinized residue.

Sample 1736-A. Sunderland pebbly sand. From an elevation of about 80 feet, half a mile east of Church View, Middlesex County.

This is a fairly well sorted coarse sand containing a few pebbles. See Figure 30. A few cherts are present in the pebble grades, the remainder being angular and subangular quartz. The finer sand grades contain a large proportion of ferruginous kaolinized feldspar residues.

Sample 1739. Sunderland gravel. From an elevation of about 90 feet at Streets, Middlesex County.

This is a fine-grained, poorly sorted loam gravel. See Figure 31. The pebbles of this gravel are mostly sharply angular and rough fragments of quartz and quartzite. No chert is present. The sand grades are mainly angular quartz, with a very few heavy mineral grains and possibly 20 per cent of feldspar and kaolinized residues in the finest grades.

Sample 1555. Sunderland sand. From an elevation of 185 feet, half a mile west of Edna, King and Queen County.

This is a well-sorted medium sand. See Figure 32. It consists almost wholly of subangular, clear quartz grains. In the plus ⅛ and plus 1/16 millimeter grades there is less than 1 per cent of ilmenite and other heavy minerals. Feldspar is more abundant.

Sample 1557. Sunderland gravel. From an elevation of 100 feet, 2 miles west of St. Stephens Church, King and Queen County.

This is a fine-grained gravel which is fairly well washed of the loam grades, but is otherwise only moderately sorted. See Figure 33. The pebble grades contain 1 or 2 per cent of chert and possibly 10 per cent of fairly well rounded quartz and quartzite fragments. The remainder is subangular. The sand grades consist of subangular quartz grains with considerable quantities of feldspar and kaolinized residues in the fine grades.

Sample 1556. Sunderland sand. From an elevation of 170 feet, half a mile west of St. Stephens Church, King and Queen County.

This sample is a well-sorted medium sand. See Figure 34. The coarser grades consist mainly of subangular quartz grains somewhat coated with kaolin residues. Weathered feldspar grains make up 20 or 30 per cent of the finer grades. This

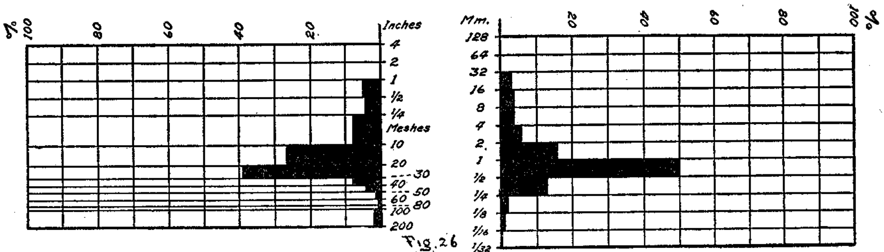


Fig. 26

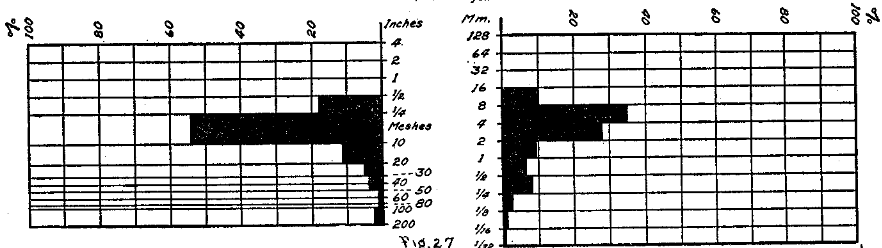


Fig. 27

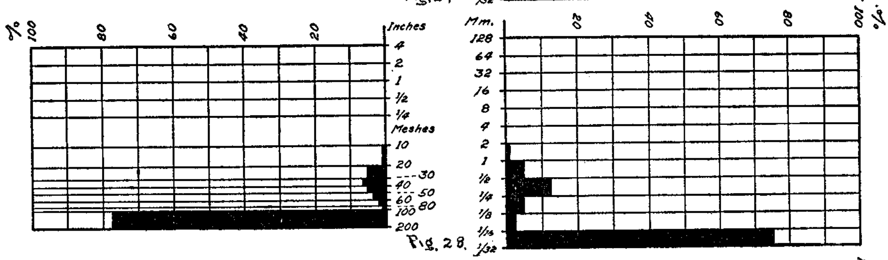


Fig. 28.

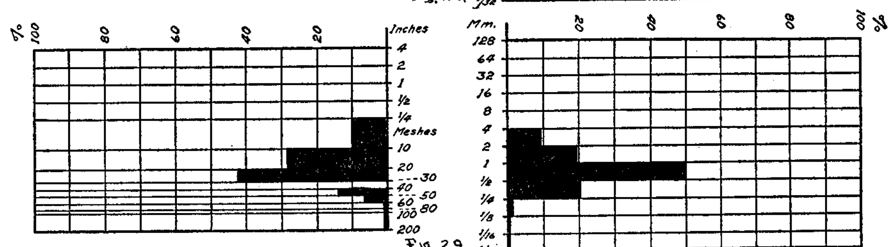


Fig. 29.

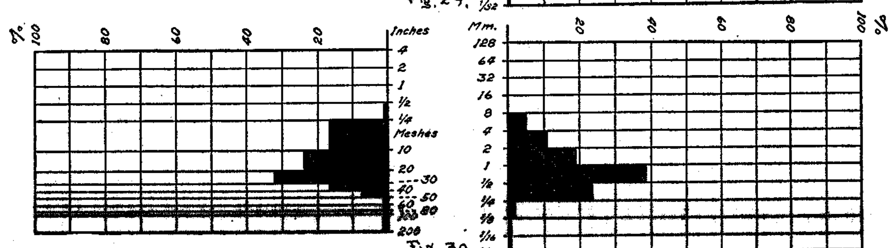


Fig. 30.

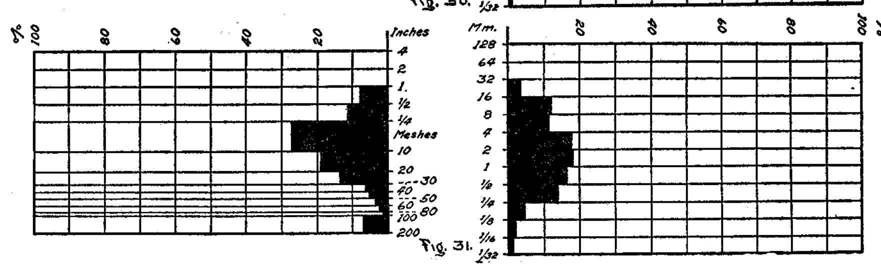


Fig. 31.

Figures 26-31.—Diagrams showing mechanical composition of the Sunderland formation. Samples 1364, 1686, 1735, 1736-B, 1736-A, and 1739.

sample, while classed as Sunderland, appears to be derived, with little resorting, from some underlying arkosic formation.

Sample 1762-B. Sunderland pebbly sand. From pit at Ephesus Church, King William County.

This is a pebbly coarse sand, fairly well sorted. See Figure 35. The coarser grades are composed of clear, slightly rounded quartz grains. In the finer grades are exceptional quantities of white, almost completely non-ferruginous, kaolinized feldspar debris, with considerable feldspar.

Sample 1762-A. Sunderland gravel. From pit at Ephesus Church, King William County.

This is a fairly well sorted fine loam gravel. See Figure 36. The pebbles are mainly subangular vein quartz with no chert. The coarser sand grades are of the same material. Considerable quantities of kaolinized feldspar residues are present in the finer sand grades.

Sample 1561. Sunderland gravel. From an elevation of 100 feet, 1 mile southwest of Manquin, King William County.

This is well-sorted gravel ranging to 16 millimeters. It consists mainly of subangular quartz fragments and contains about 1 per cent of chert pebbles.

Sample 1782. Sunderland sand. From 1 mile south of Signpine, Gloucester County.

This is a well-sorted fine sand carrying about 20 per cent of silt grades. See Figure 37. This sand is mainly composed of subangular and moderately rounded quartz grains. The finer sand grades contain few heavy mineral grains and feldspar and feldspar residues.

Sample 1967. Sunderland gravel. From an elevation of 150 feet, 1 mile east of Mechanicsville, Hanover County.

This is a rather well sorted gravel with double maximum grades. See Figure 38. The pebbles are mainly moderately well rounded quartz with 3 or 4 per cent of chert pebbles. Small quantities of feldspar and heavy minerals are present in the finest sand grades, the remainder of the sand being clean subangular quartz grains.

Sample 1974. Sunderland gravel. From an elevation of 150 feet, 2 miles southeast of Brookland, Henrico County.

This is a fairly well sorted, moderately coarse gravel. See Figure 39. The pebbles consist mainly of subangular and slightly rounded vein quartz and quartzite. A very few chert and about 15 to 20 per cent of moderately rounded quartz pebbles are present. The sand grades consist mainly of clean, angular and subangular quartz grains, with a few heavy minerals and a considerable proportion of feldspar grains in the finest sand grades.

Sample 1961. Sunderland gravel. From an elevation of 160 feet near Brookland, Henrico County.

This is a poorly sorted gravel with a sticky clay and sand matrix (not shown in analysis of washed sample). See Figure 40. There is 2 or 3 per cent of chert. Pebbles are mostly subangular quartz. The finest sand grades contain considerable feldspar and kaolinized residues.

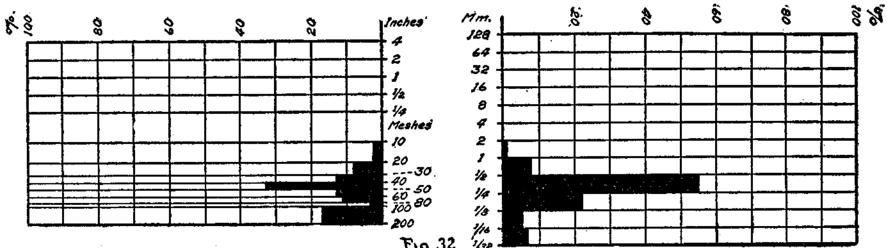


Fig. 32

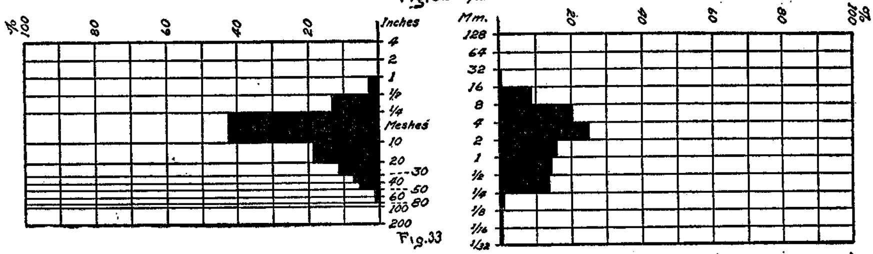


Fig. 33

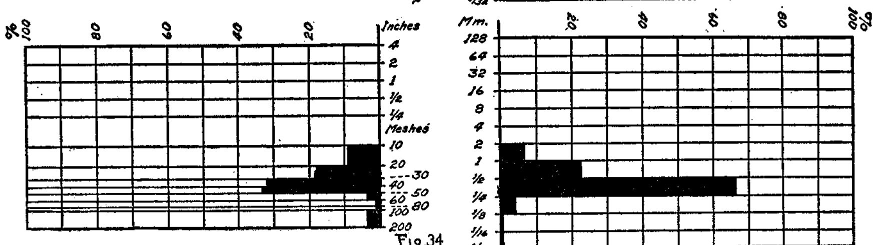


Fig. 34

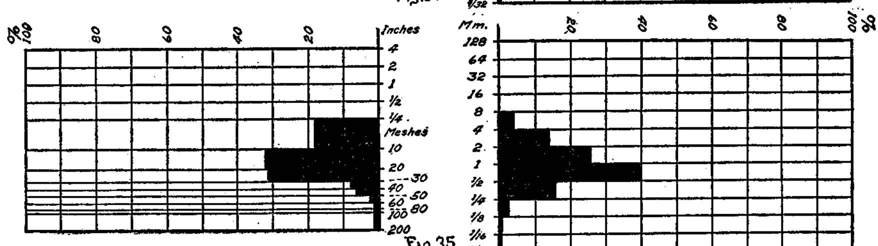


Fig. 35

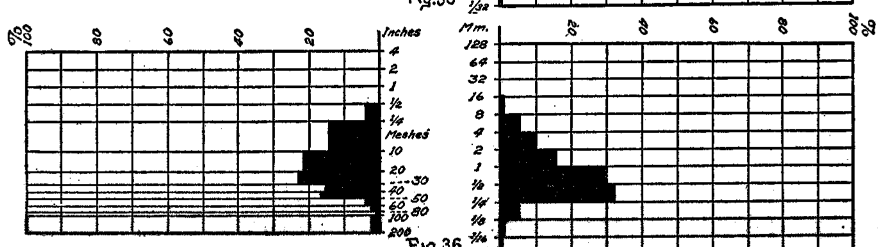


Fig. 36

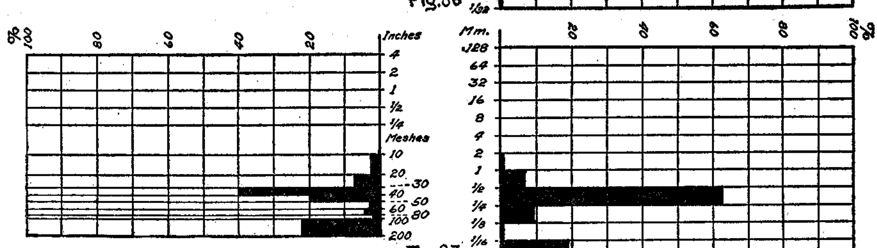


Fig. 37

Figures 32-37.—Diagrams showing mechanical composition of the Sunderland formation. Samples 1555, 1557, 1556, 1762-B, 1762-A, and 1782.

Sample 1985. Sunderland gravel. From an elevation of 90 feet, half a mile north of Perkins Crossing, Dinwiddie County.

This is a moderately well sorted loam gravel showing maxima in the plus 2 and the plus ¼ millimeter grades. See Figure 41. The pebble grades consist of angular vein quartz, fragments of weathered granite, and quartz from schist and granite. No chert was found. The coarser sand grades are mostly very angular quartz showing reentrants and indicating its derivation from a granite. In the finer grades the proportion of ferruginous kaolin increases to a large fraction of the whole, and considerable feldspar is found in addition to angular quartz grains.

Sample 2152. Sunderland gravel. From an elevation of 150 feet, 2 miles southeast of Blandford, Prince George County.

This is a fairly well sorted loam gravel. See Figure 42. The pebble grades are about half moderately rounded and half angular light cream-colored vein quartz and quartzite pebbles. No chert was seen. The finer sand grades contain a considerable percentage of feldspar and kaolinized residue grains. Quartz makes up the larger part of the sand grades.

Sample 2153. Sunderland gravel. From an elevation of 170 feet, south of Camp Lee, Prince George County.

This is a poorly sorted gravel containing about 30 per cent of material passing the 1/16 millimeter sieve. See Figure 43. The pebble grades consist of subangular quartz fragments. The sand grades are mainly of quartz, except in the finest grades which contain considerable feldspar and a few heavy mineral grains.

Sample 2145. Sunderland loam. From an elevation of 113 feet, 2½ miles north of Waverly, Sussex County.

This loam contains more than 93 per cent of material which passes the 1/16 millimeter sieve. An analysis of the remaining sand grades is shown in Figure 44. The coarser sand grades consist of angular quartz and ferruginous aggregates in equal amounts. The finer grades carry small quantities of these aggregates and a few heavy mineral grains in addition to the clear angular quartz grains.

Sample 1990. Sunderland pebbly sand. Washed sample from an elevation of 150 feet, 1½ miles southwest of Tyus Store, Sussex County.

This is a moderately well sorted sand containing a few pebbles. The fines were removed by washing before the analysis was made. See Figure 45. Considerable quantities of fairly fresh feldspar grains are found in the finest sand grades. Otherwise the sample consists of clear angular quartz grains.

Sample 2149. Sunderland sand. From an elevation of 115 feet, 1¼ miles west of Cook's Bridge, Sussex County.

This sand carries about 30 per cent of fines which pass the 1/16 millimeter sieve. See Figure 46. The coarser grades consist mainly of clear angular quartz grains, but a considerable proportion of kaolinized feldspar residues is present in the finer grades.

Sample 2146. Sunderland sandy loam. From an elevation of 110 feet, 4 miles northwest of Waverly, Sussex County.

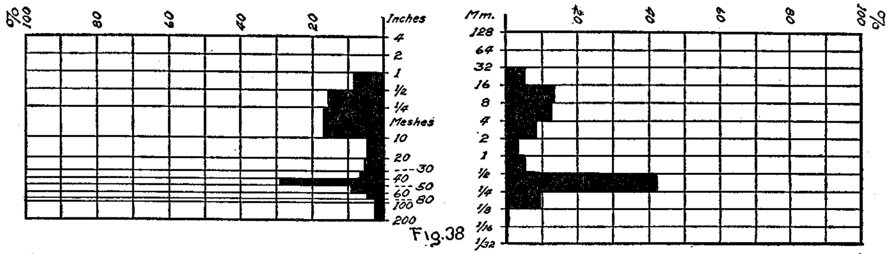


Fig. 38

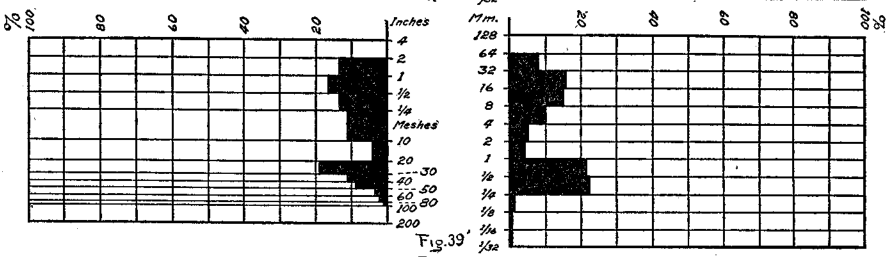


Fig. 39

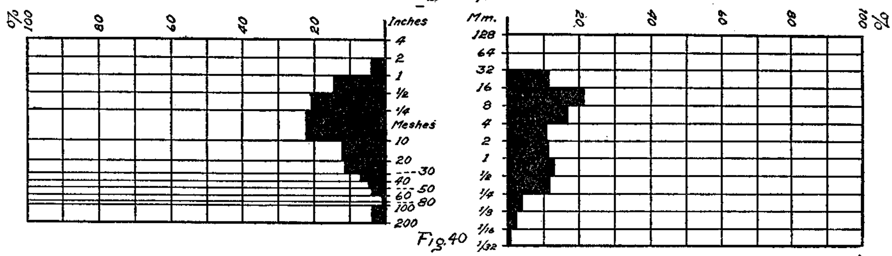


Fig. 40

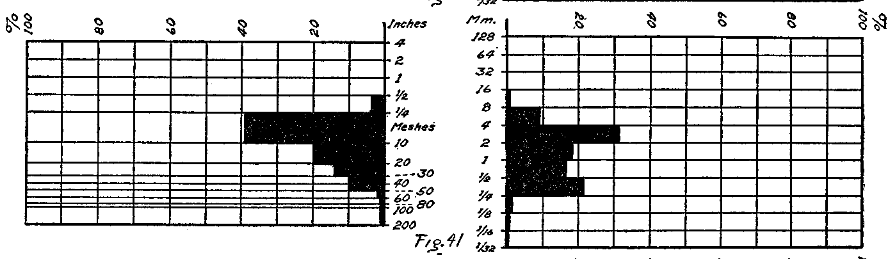


Fig. 41

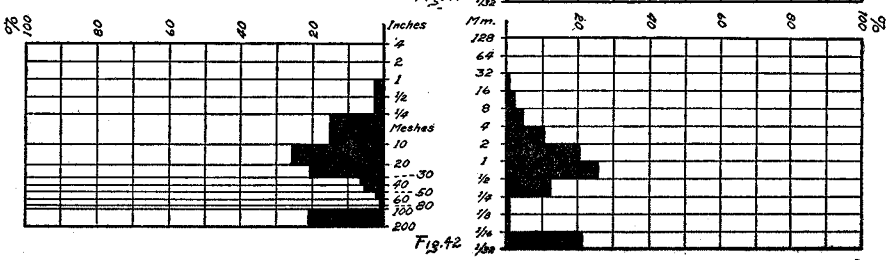


Fig. 42

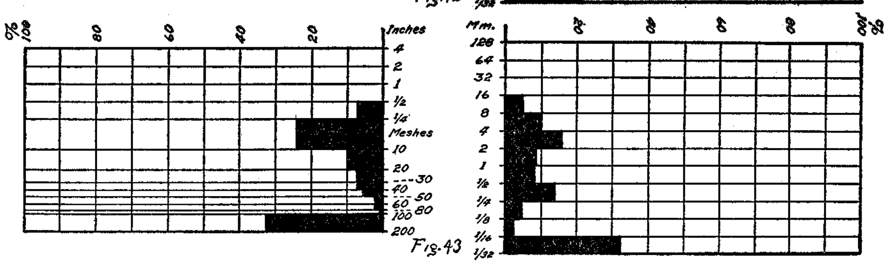


Fig. 43

Figures 38-43.—Diagrams showing mechanical composition of the Sunderland formation. Samples 1967, 1974, 1961, 1985, 2152, and 2153.

This loam contains over 60 per cent of material which passes the 1/16 millimeter sieve. An analysis of the remainder is shown in Figure 47. The sand grains are dominantly clear angular quartz, but small quantities of several heavy minerals are present in the minus 1/16 grade.

Sample 2103. Sunderland sand. From an elevation of 95 feet, one-fourth mile east of Shiloh, Southampton County.

This is a moderately well sorted coarse sand containing a few pebbles. See Figure 48. The pebbles consist of angular clear and blue quartz. The sand grains are mainly clear angular quartz, with a few heavy minerals and a considerable amount of feldspar and kaolinized debris in the finest grades.

WICOMICO TERRACE AND FORMATION

Definition.—The Wicomico terrace and formation were named by Shattuck[32] from Wicomico River in St. Marys and Charles counties, Maryland. According to his description the best development of the Wicomico formation is on the Eastern Shore of Maryland. Most recent students of the terrace problem have agreed that the remnants of the Wicomico formation on the western shore of Maryland, especially in the vicinity of Wicomico River, are so sporadic that they do not adequately represent the formation. In view, however, of the extensive use of this term, it seems best to retain it for the Coastal Plain in Virginia with an attempt to present a clear understanding of the meaning of the term.

Extent and topography.—The Wicomico terrace of this report is the main terrace which lies east of the Surry scarp on the southern part of the Coastal Plain of Virginia (Fig. 24). It forms a large part of the upland of the Eastern Shore of Maryland. Lesser terrace remnants which are accordant with it in the valleys of the principal streams west of the Surry scarp are included. Its elevation varies from about 90 feet at the foot of the Surry scarp to about 60 feet at its eastern margin. (See Fig. 62.) The best development in Virginia of the terrace and of the formation which underlies it, is at Ivor, Southampton County. Here the terrace is a conspicuously flat surface at an elevation of about 90 feet.

Several remnants of the Wicomico formation and terrace are present at various points north of Potomac River between Washington and Point Lookout, Maryland, especially at Indian Head and near Nanjemoy. Remnants are scarce in Virginia, due generally to the greater erosion on the south and west banks of the Potomac during some of the later Pleistocene epochs; hence high bluffs reach in many places to the Sunderland terrace level.

The areas of Wicomico terrace in the District of Columbia and along the Maryland side of the Potomac are believed to be

32 Shattuck, G. B., op. cit., p. 92.

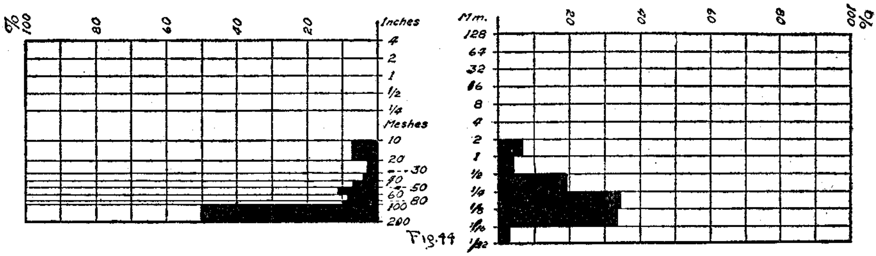


Fig.44

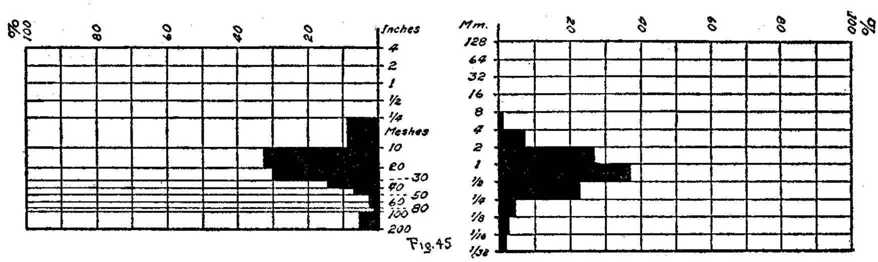


Fig.45

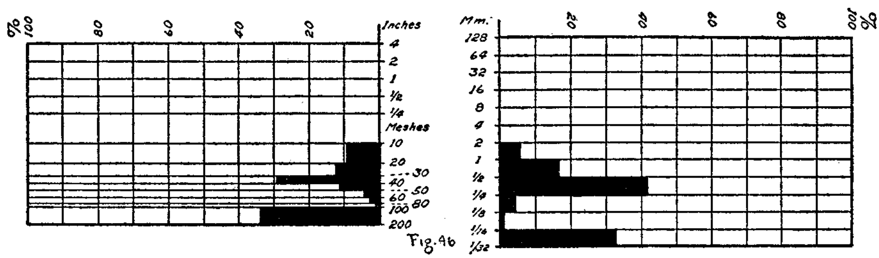


Fig.46

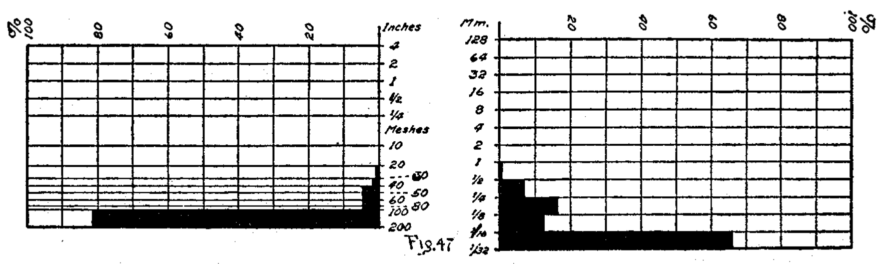


Fig.47

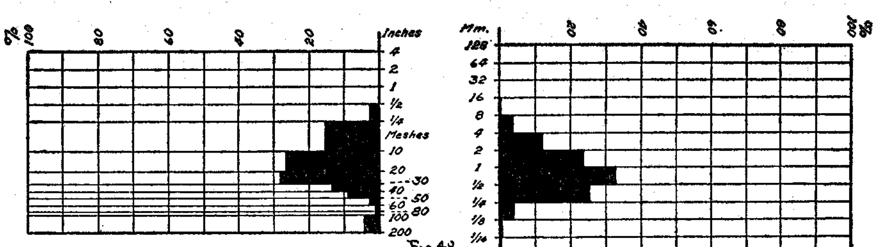
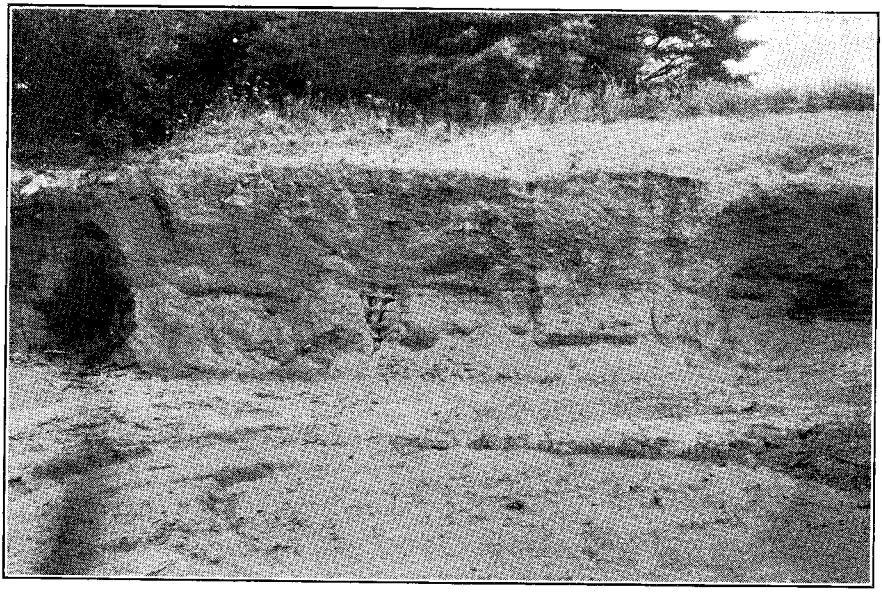


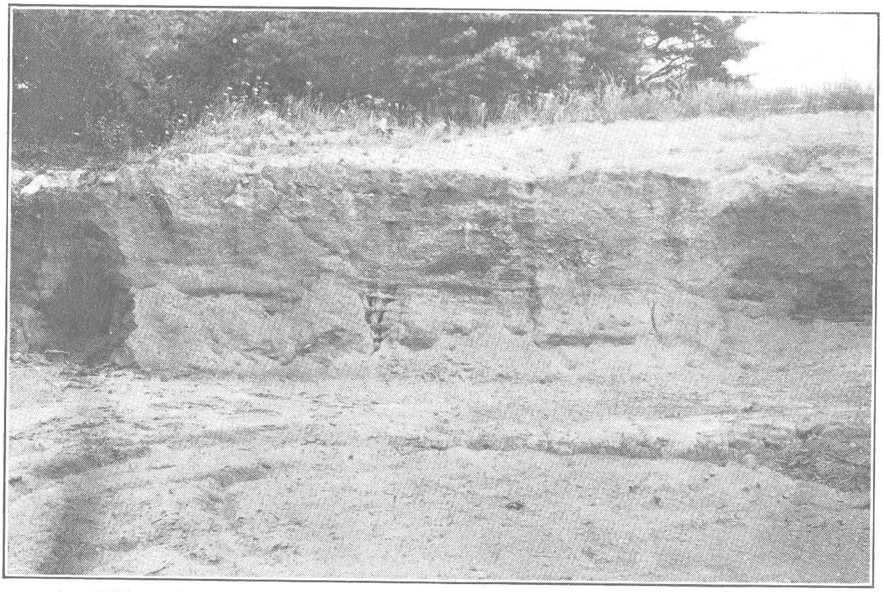
Fig.48

Figures 44-48.—Diagrams showing mechanical composition of the Sunderland formation. Samples 2145, 1990, 2149, 2146, and 2103.



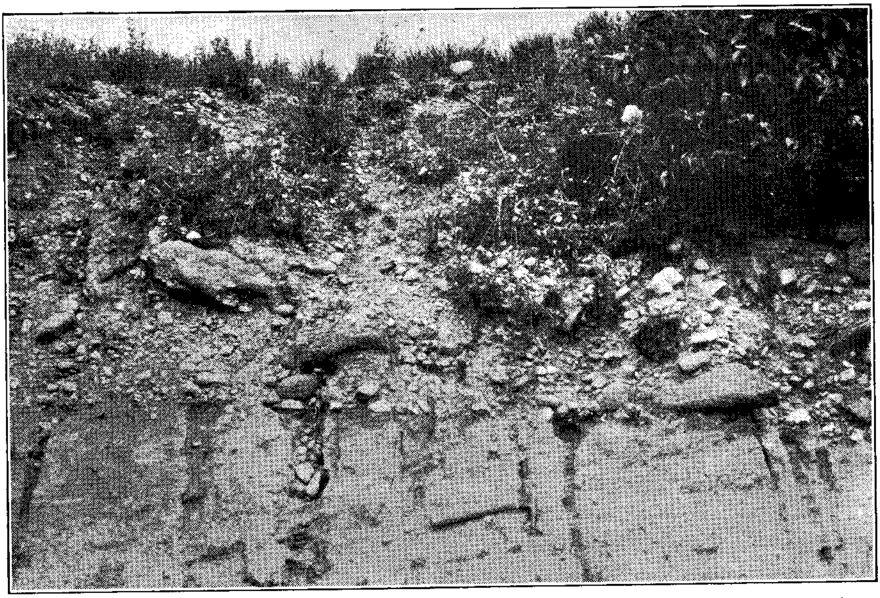
A. Wicomico gravel in roadside pit three-fourths of a mile east of Charles City, Charles City County. (See p. 58.)

B. Detail of Wicomico loam gravel in bank three-fourths of a mile east of Charles City, Charles City County. (See p. 58.)

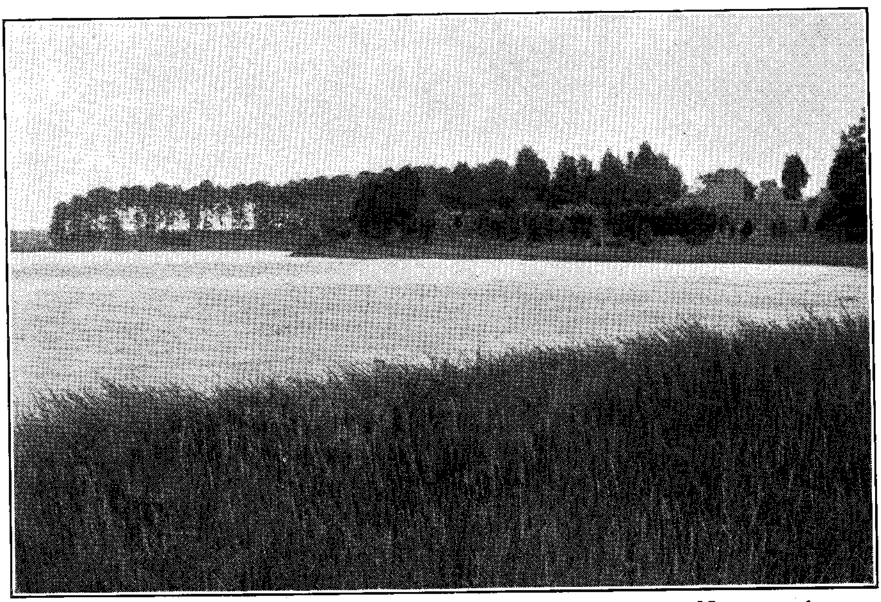


A. Wicomico gravel in roadside pit three-fourths of a mile east of Charles City, Charles City County. (See p. 58.)

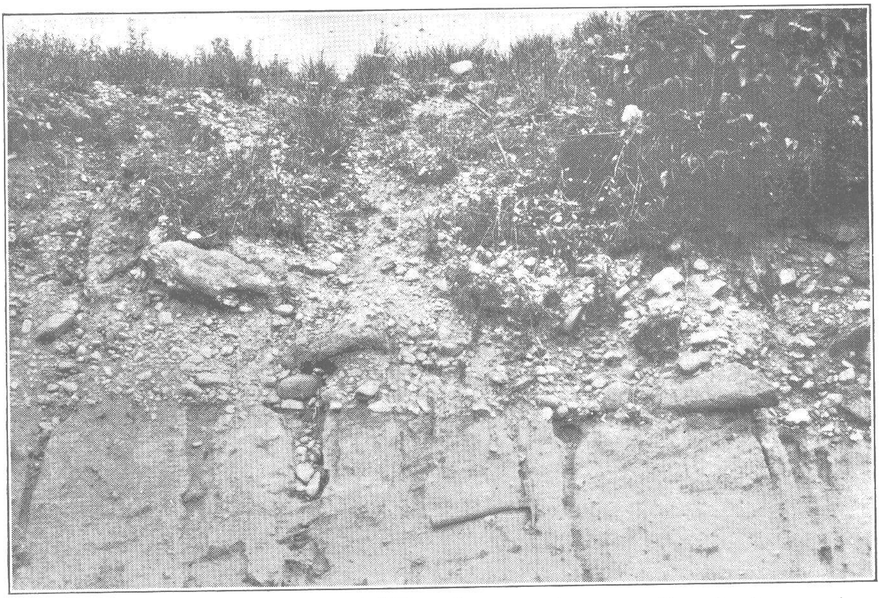
B. Detail of Wicomico loam gravel in bank three-fourths of a mile east of Charles City, Charles City County. (See p. 58.)



A. Unconformable contact of Wicomico gravel on pre-Brandywine sand northwest of Massaponax Creek bridge, Spotsylvania County. (See p. 59.)



B. Shore of Nansemond River in Dismal Swamp terrace, Nansemond County. (See p. 69.)



A. Unconformable contact of Wicomico gravel on pre-Brandywine sand northwest of Massaponax Creek bridge, Spotsylvania County. (See p. 59.)

B. Shore of Nansemond River in Dismal Swamp terrace, Nansemond County. (See p. 69.)

of fluvial origin. Their physiographic and petrographic similarity to the Sunderland formation, which has been interpreted as fluvial, as well as the continuity of the Wicomico terrace and formation of the Potomac west of the Fall Line, leads to this conclusion.

The principal development of the Wicomico in Virginia is as a marine terrace which forms the seaward part of the Coastal Plain upland on all the peninsulas from the Northern Neck south to the North Carolina line. It is not more than 2 or 3 miles wide in Lancaster County at the north, but it is nearly 20 miles wide at the North Carolina line. The landward margin of this terrace is an escarpment, or sea-cliff, which extends across the Coastal Plain from Kilmarnock, Lancaster County, to Boykins, Southampton County. It separates the marine Wicomico terrace from the fluvial Sunderland terrace. Because of its well-marked development just east of the town of Surry this feature will be here called the Surry scarp. (See Fig. 63.)

The elevation of the Wicomico terrace is approximately 90 feet at the foot of the Surry scarp along its entire length in Virginia. This elevation is identical with that given by Shattuck[33] for the Wicomico terrace at the point where it abuts against the Sunderland terrace in Cecil County, Maryland, and further confirms the correlation of the Wicomico of this report with the terrace named by Shattuck. Within the limits of accuracy of the existing topographic maps there is no evidence of differential uplift along the line of this emerged scarp. The Wicomico terrace slopes eastward from the Surry scarp to elevations of about 60 feet along the top of the southern part of the Suffolk scarp which is above the Dismal Swamp terraces south of James River. (See Figs. 62 and

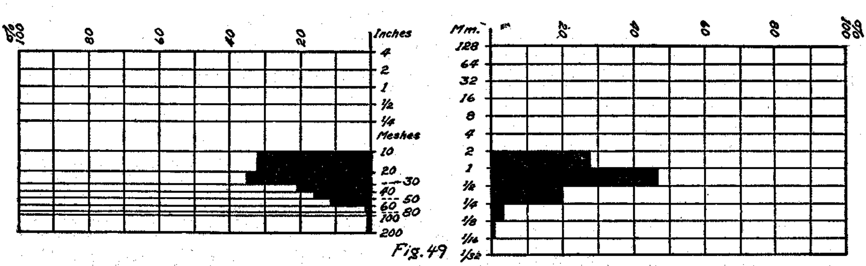


Figure 49.—Diagram showing mechanical composition of Wicomico (?) sand. Sample 1744-A.

63.) In Maryland the Wicomico is said to slope to elevations of 60 feet at shore lines, and to have an elevation of 45 feet south of Salisbury.

These slopes are believed to be the off-shore slopes of the sea-bottom at the time the marine terrace was formed. They are simi-

33 Shattuck, G. B., op. cit., p. 73.

lar to existing off-shore slopes and are not believed to indicate tilting or differential uplift.

Shattuck,[34] in his report on the Maryland terraces, states that the Wicomico terrace at Ridge, St. Mary's County, has an elevation of 45 feet at the Sunderland margin and slopes to an elevation of 15 feet at Point Lookout. Inasmuch as Shattuck in the same report states that the younger Talbot terrace almost everywhere has a very constant landward elevation of 40 to 45 feet, it is difficult to understand why the terrace between elevations of 15 and 45 feet at Point Lookout has been regarded as Wicomico. From field evidence and from general accordance with elevations elsewhere, the writer believes that the terrace having its landward margin at 45 feet at Ridge is part of the Chowan terrace of this report and that the Wicomico terrace is missing at this particular place. As the Wicomico terrace becomes progressively narrower north of James River, the elevation of its east margin increases because of its almost uniform seaward slope of about 1 foot to the mile.

The surface of the much dissected Wicomico terrace shows the same general flatness and accordance of levels as do remnants of the Sunderland terrace. In the area north of the James, which is generally dissected by large streams, the Wicomico terrace is less well marked and less easily separated from the Sunderland terrace. The difference in elevation between the two along the Surry scarp is not more than 20 to 25 feet. In places the scarp is fairly well marked and recognizable, though it nowhere has the distinctness of the younger and lower scarps. The westward trend of the Surry scarp in Virginia carries the limit of marine terraces from Chesapeake Bay almost across the Coastal Plain to the Fall Belt. Some of this widening has possibly been caused by crustal movements. A local cause has been probably the great alluvial fan of the Sunderland formation which was far better developed in the Potomac region than further south.

Fluvial parts of the Wicomico terrace are found along the James, Nottoway, Meherrin, York, and Rappahannock river systems, though they are mostly small remnants. (See Pls. 6, B, 7, A, and 7, B.) They are especially well developed adjacent to the James where several large meander scars, with bottoms at the Wicomico level, are cut in the Sunderland upland. They are shown on the Charles City and Disputanta topographic sheets.

Thickness.—Very few direct measurements of the thickness of the Wicomico formation were made. The thickness of the marine part is probably about 25 feet. In some places near the Surry

34 Shattuck, G. B., op. cit., p. 73.

scarp it is not over 15 or 20 feet thick; farther away it was found to be as much as 30 feet thick. As the underlying Miocene formations appear not to have been eroded generally to altitudes less than about 40 feet, it is possible that in places the Wicomico formation rests on uneroded remnants of the Sunderland formation, but no demonstrable instance was noted. The thickness of the fluviatile parts of the Wicomico formation is probably similar to that of the marine part, but few data are available.

Structure.—The structure of the fluvial parts of the Wicomico formation is similar to that of the Sunderland formation. The bedding is poor and individual beds are lenticular and rarely traceable for any considerable distance. Some zones are generally more pebbly than others, and the large striated boulders tend to be somewhat concentrated in certain bands. The marine part of the Wicomico is rarely well exposed and systematic structure was not made out. The bedding varies from place to place. Considerable loamy material differing only slightly from that of the Sunderland is present in places. It has similar structure. Much of the formation consists of sand which shows fairly well marked bedding in well-sorted layers. Just west of Suffolk, beds of clean, well-sorted sand and gravel lie unconformably on a buff loam which may be a Sunderland remnant. The elevation of the contact is about 35 feet. The structure and relations are shown in Plate 8, A.

Fossils.—Fossil plants have been found in this formation in North Carolina, but so far as known no fossils have been found in the Wicomico of Virginia.[35]

Petrography.—The Wicomico formation differs only slightly from corresponding parts of the Sunderland formation. (See p. 45.) The fluvial Wicomico consists of ferruginous red loamy gravel carrying in places large boulders. It is poorly sorted, ranging over eight or ten grades in its mechanical composition. In places near Washington, the Wicomico formation carries exceptional numbers of large striated boulders. (See Pls. 9, A and 9, B.) There is little doubt that these boulders were brought from the upper Potomac basin during the Wicomico epoch, though it is probable that the Wicomico terraces at other places were built in part of reworked material from the adjacent Sunderland upland.

The fluviatile parts of the Wicomico formation along the James and other rivers in Virginia are similar to those of the Potomac

35 Stephenson, L. W., The Coastal Plain of North Carolina; the Cretaceous, Lafayette, and Quaternary formations: North Carolina Geol. Survey, vol. 3, p. 281, 1912.

basin, except that the striated boulders are not so numerous or so large. The formation in the valleys of some of the Piedmont rivers is also more completely sorted and has also a smaller proportion of loam matrix.

The marine Wicomico east of the Surry scarp consists in part of well-washed sand and gravel, but it contains considerable buff-colored pebbly loam. The basal part of the formation, as a rule, is more perfectly sorted and the overlying beds are more loamy.

Detailed descriptions of samples of the Wicomico formation are given below.

Sample 1744-A. Wicomico (?) sand. From base of 90-foot terrace one-fourth mile north of Locust Hill, Middlesex County. As the Wicomico and Sunderland terraces merge almost imperceptibly in this region, this sample may be basal Sunderland sand.

This is a well-sorted coarse sand. See Figure 49. Coarser grades consist of subangular, well-smoothed, clean quartz grains, in part blue quartz. The finer grades contain uncommonly large quantities of very slightly weathered feldspar debris, largely plagioclase and microcline.

Sample 1779. Wicomico sand. From an elevation of 60 feet, 1 mile north-east of Glenns, Gloucester County.

This is a fairly well sorted fine sand carrying about 25 per cent of material passing the 1/16 millimeter sieve. See Figure 50. The finer grades of this sand contain considerable ferruginous kaolinized residues, a few fairly fresh feldspar grains, and a few heavy mineral grains. The remainder of the sand consists of angular or slightly rounded quartz grains.

Sample 1831. Wicomico gravel. From roadside pit at an elevation of about 50 feet, Charles City, Charles City County.

This is a fairly well sorted medium loam gravel. An analysis of this gravel, made after the fines had been removed by washing, is shown in Figure 51. The fines amounted to about 2 per cent of the whole. Chert makes up 1 to 2 per cent of the pebble grades. One-third or more of the remainder consists of fairly well rounded quartz pebbles; the others are rough and angular. Considerable feldspar and feldspathic weathered debris are present in all the sand grades and increasingly in the finer grades. Angular quartz makes up the bulk of the sand grades.

Sample 2107. Wicomico pebbly sand. From an elevation of 50 feet, 2 miles north of Haley's Bridge, Southampton County.

This is a moderately well sorted coarse sand containing a few pebbles. See Figure 52. The pebble grades consist wholly of angular and subangular quartz, quartzite, and blue quartz. No chert is present. The sand grades are mainly of the same materials. Feldspar increases in amount from the medium sand grades downward. A few heavy mineral grains are present in the finest grades.

Sample 2168. Wicomico sand. From an elevation of 30 feet in base of bluff 1 mile north of Chuckatuck, Nansemond County.

This is a fairly well sorted coarse sand. See Figure 53. It contains a few chert pebbles, but the larger part of the pebble grades consists of yellow and brown quartz and quartzite pebbles. The sand grades are mainly subangular quartz, but there are a few heavy mineral grains in the finest grades.

Sample 2087. Wicomico sand-loam. From an elevation of 50 feet, east of Crismond, Nansemond County.

This is a fairly well sorted sand-loam, with more than 30 per cent passing the 1/16 millimeter sieve. See Figure 54. A few heavy mineral grains occur in the plus 1/16 millimeter grade; otherwise the sand grades are wholly slightly rounded quartz grains.

Sample 2088. Wicomico sand-loam. From an elevation of 60 feet, half a mile south of Franklin Grove School, Nansemond County.

This loam contains slightly more than 40 per cent passing the 1/16 millimeter sieve. See Figure 55. A few ferruginous aggregates are found in the coarsest grade. The finest sand grade contains 5 to 10 per cent of heavy minerals. The remainder of the sand consists of clean, subangular quartz grains.

Sample 2132. Wicomico loamy sand. From an elevation of 75 feet, 2 miles northwest of Windsor, Isle of Wight County.

This is a well-sorted fine sand carrying 25 per cent of material passing the 1/16 millimeter sieve. See Figure 56. This sand carries a moderate percentage of heavy mineral grains and feldspar and feldspar residues in the finest grades. It is composed mainly of subangular clear quartz grains.

Sample 2128. Wicomico loamy sand. From an elevation of 65 feet, 3 miles southwest of Windsor, Isle of Wight County.

This is a fairly well sorted medium sand carrying a loam matrix of about 20 per cent. See Figure 57. The coarser grades consist of slightly iron-coated subangular quartz grains. The finer grades contain considerable feldspar, ferruginous kaolinized feldspar residues, and heavy mineral grains.

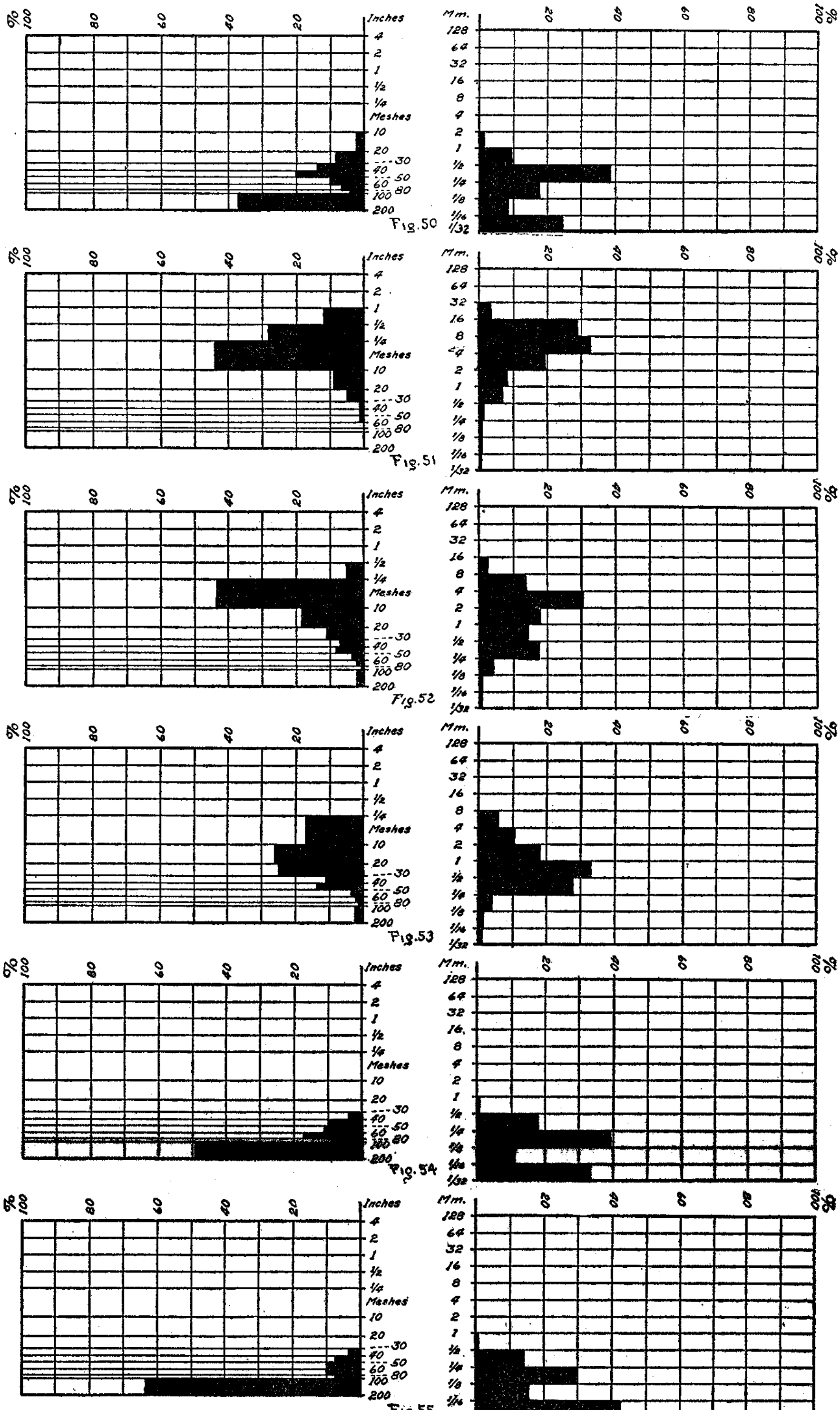
Sample 2126. Wicomico sand. From an elevation of 50 feet, 2½ miles northeast of Carrsville, Isle of Wight County.

This is a fairly well sorted fine sand. See Figure 58. This sand is almost wholly composed of conspicuously clear subangular quartz grains showing very little abrasion. A few heavy mineral grains are found in the finest sand grade.

Sample 2290. Wicomico gravel. From edge of upland east of Wattsville, Accomac County.

This is a fairly well sorted sandy gravel containing nearly 10 per cent of gravel grades. See Figure 59. The pebble grades consist of slightly iron-stained quartz fragments, of which two-thirds or more are rather well rounded. The sand grades are of iron-stained quartz, with a few heavy mineral grains in the finest grades.

Sample 2287. Wicomico gravel. From 3 feet below the surface at News Town, Accomac County.



Figures 50-55.—Diagrams showing mechanical composition of the Wicomico formation. Samples 1779, 1831, 2107, 2168, 2087, and 2088.

This is a fairly well sorted sandy gravel. See Figure 60. The pebbles are partly well rounded and partly subangular quartz fragments. The sand grades are mainly iron-stained quartz grains, with considerable ferruginous kaolinized residues in the finest grades.

Sample 2260. Wicomico gravel.[36] From road cut 1 mile southeast of Gilden Post Office, Northampton County.

This is a well-sorted sandy gravel containing about 35 per cent of pebble grades. See Figure 61. About 15 per cent of the pebbles is chert, and the remainder is well-rounded to angular quartz. The sand grades consist of iron-stained quartz grains, with a moderate amount of ferruginous kaolinized residue fragments in the finest grades.

CHOWAN TERRACE AND FORMATION

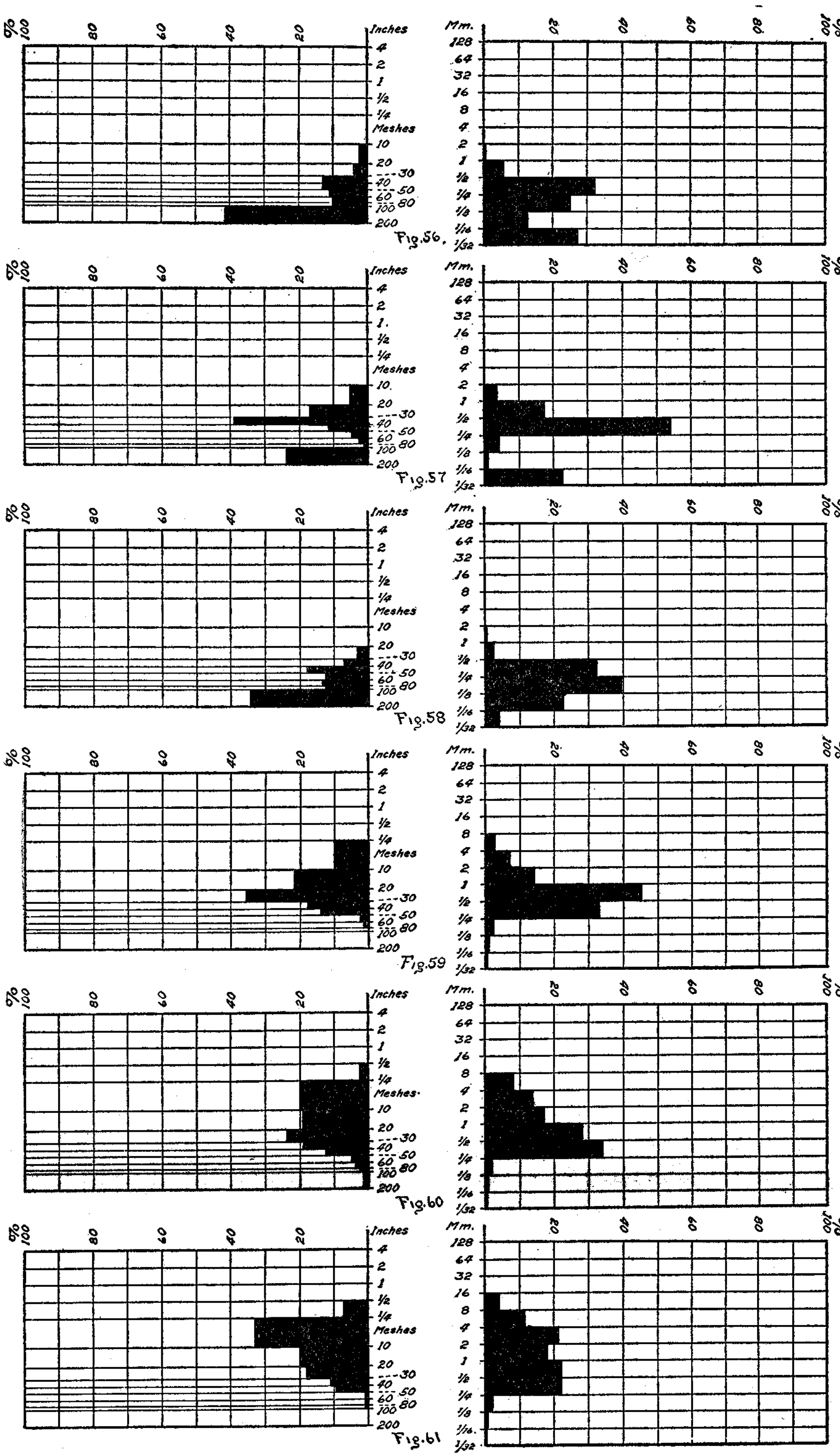
Definition.—The Chowan terrace was first named by Stephenson[37] in 1912 from its development south of Chowan River in North Carolina. He states that this terrace rises from elevations of 25 to 40 feet along its eastern margin to an elevation of 50 feet at its western margin. He further states that the eastern margin of the terrace is a well-marked sea-facing scarp, above the Pamlico terrace, that continues from Virginia into the eastern part of Gates County, North Carolina. The map shows that this scarp is in line with the Suffolk scarp of Virginia, which separates the Dismal Swamp and Wicomico terraces west of the Dismal Swamp. Small but well-marked remnants of the Chowan terrace are shown on the North Carolina portion of the Suffolk topographic sheet, where they are separated from the Wicomico terrace by a clearly defined scarp southeast of Hazleton, but the terrace is not developed on this quadrangle in Virginia. (See Figs. 62-64.)

Extent and topography.—The Chowan terrace is missing from the state line to James River because the younger Dismal Swamp terrace has been cut against the older Wicomico terrace. Only very small and somewhat doubtful remnants of the Chowan terrace are found along Chesapeake Bay north of James River. It is probable that considerable areas of the Eastern Shore upland in Virginia belong to the Chowan terrace, but lack of topographic maps has made it difficult to discriminate the Chowan and Dismal Swamp terraces in the time available for field work. The Chowan terrace is a well-developed river terrace along several tributaries of Chowan River which head in Virginia. It rises up-stream to elevations or 80 to 90 feet near the Fall Belt. (See Fig. 24, p. 48.)

Similar terraces are found in the valleys of the James and the other main coastal-plain rivers in Virginia. The lack of well-devel-

36 This gravel is doubtfully referred to the Wicomico formation. Until topographic maps are available and more field studies are made, the details of these terrace formations must remain obscure.

37 Stephenson, L. W., op. cit., p. 282.



Figures 56-61.—Diagrams showing mechanical composition of the Wicomico formation. Samples 2132, 2128, 2126, 2290, 2287, and 2260.

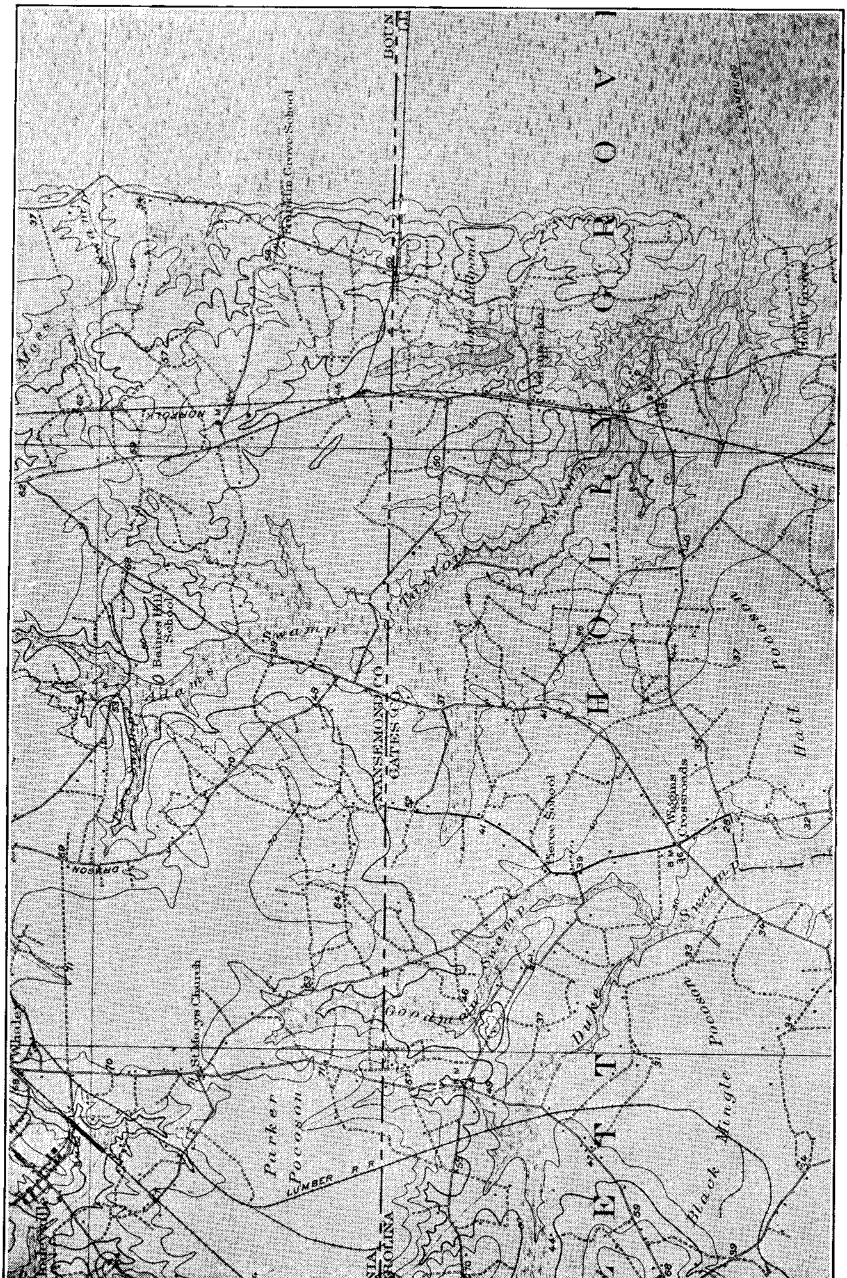


Figure 62.—Parts of the Dismal Swamp, Chowan, and Wicomico terraces in Nansemond County, Virginia, and Gates County, North Carolina. (Part of the Suffolk sheet.) Scale, 1 inch equals 1.48 miles; contour interval, 10 feet. The Dismal Swamp at the east is part of the Dismal Swamp terrace. The semicircular area at elevations of 30 to 45 feet, mainly in North Carolina, is Chowan terrace. The area at elevations of 60 to 70 feet is Wicomico terrace. (See pp. 55, 63, and 69.)

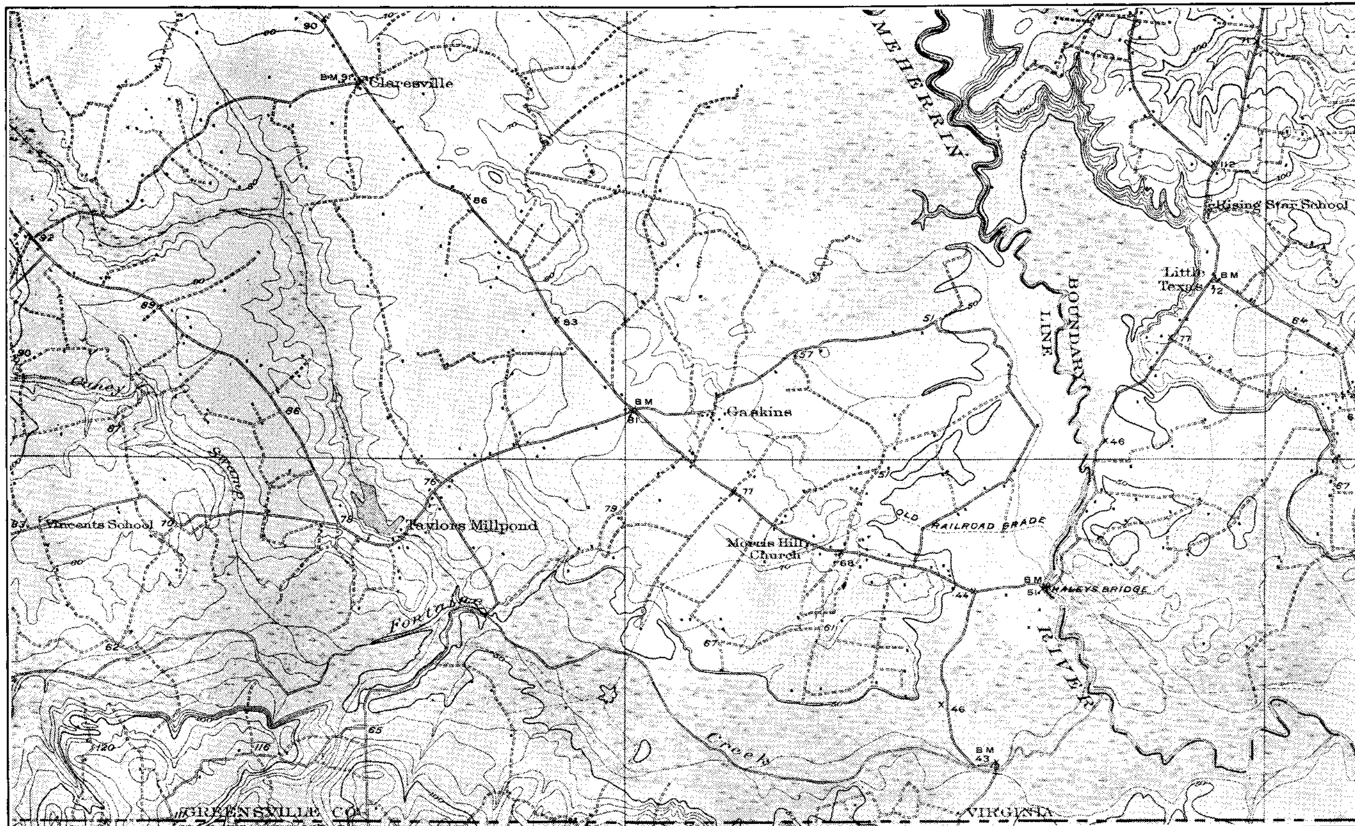


Figure 63.—Parts of the Sunderland, Wicomico, and Chowan terraces in Greensville and Southampton counties, Virginia. (Part of the Arringdale sheet.) Scale, 1 inch equals 1.4 miles; contour interval, 10 feet. Areas above 100 feet elevation at the northeast and southwest corners are on the Sunderland terrace plain. The flat area between Meherrin River and Fontaine Creek at elevations of 70 to 90 feet is Wicomico terrace. The lowland at 40 to 55 feet is part of the Chowan terrace. (See pp. 43, 55, and 63.)

oped marine Chowan at the mouths of these streams makes it impossible to carry continuous correlations into the valleys. Moreover, the fact that the fluvial parts of both the Chowan and Dismal Swamp terraces rise upstream with grades which possibly differ for the two terraces, and which certainly differ in the valleys of different streams, makes it impracticable to discriminate their remnants north of the Chowan River drainage. Inasmuch as erosion may have been continuous in the upstream parts of the Coastal Plain from Chowan time into Dismal Swamp time, it is possible that the Chowan and Dismal Swamp surfaces are not everywhere distinct.

Because of this uncertainty only the known Chowan fluvial terraces of the Chowan River system are here considered. The remainder of the possible Chowan terraces is considered later under the heading Chowan-Dismal Swamp terraces and formations (pp. 75-81).

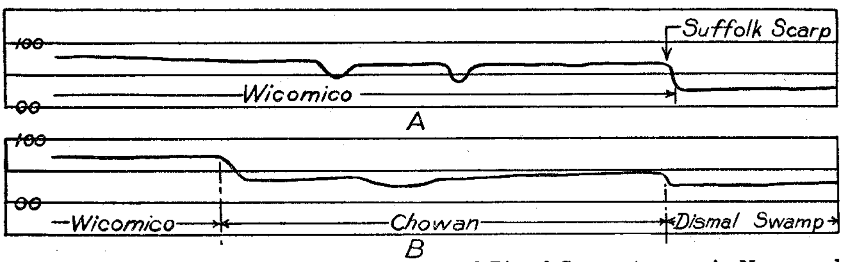
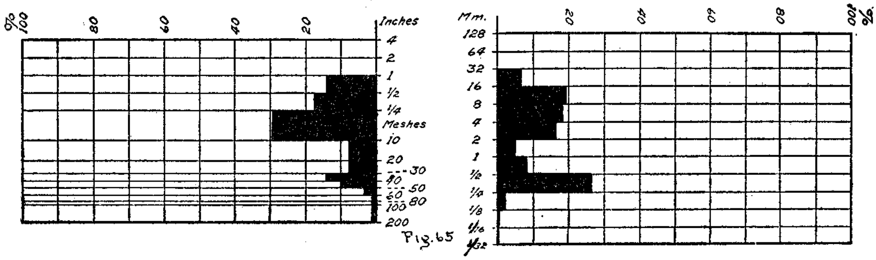


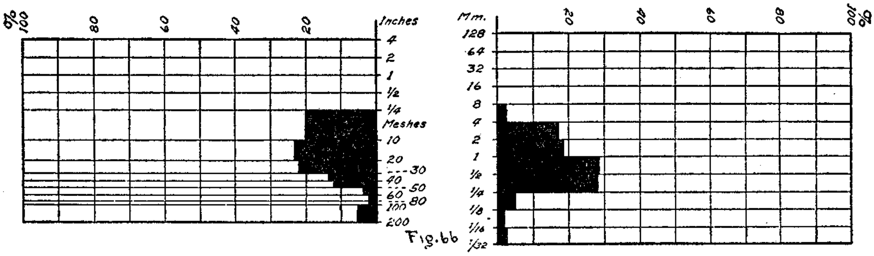
Figure 64.—Profiles showing Wicomico, Chowan, and Dismal Swamp terraces in Nansemond County, Virginia, and in Gates County, North Carolina. A, Profile southeast from Purvis Station to Dismal Swamp showing the prominent Suffolk scarp; B, Profile through Hazleton and Holly Grove, Gates County, North Carolina, showing the Chowan terrace between the Wicomico and Dismal Swamp terraces.

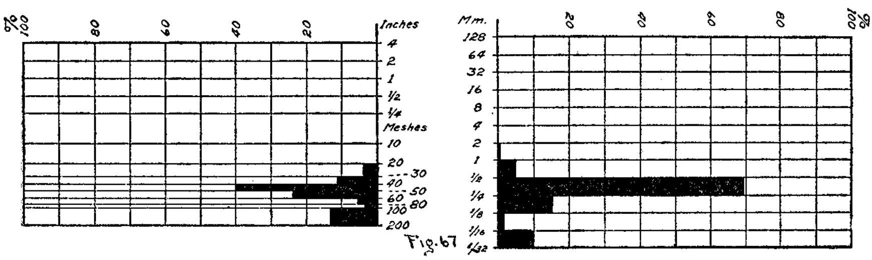
Thickness and structure.—The lower terrace formations could be measured inland at only a few places. Along the banks of various estuaries the Chowan-Dismal Swamp formations commonly are 20 to 30 feet thick. It is probable that the fluvial Chowan south of James River is not thicker; in many places it is much thinner. The bedding of the Chowan formation is similar to that of modern river flood-plain sands and gravels. It is more distinct and sharply marked than that of the very loamy upland gravels. In a few places loamy beds, thought to be of fluviatile origin, overlie better assorted sands and gravels which are probably of marine origin. (See Pl. 10, A.)

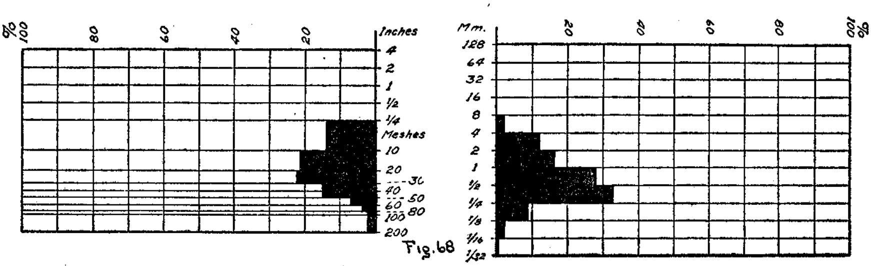
Fossils.—A few species of fossil marine invertebrates and more than 40 species of plants have been found in the Chowan formation of North Carolina.[38] None have been found in Virginia.

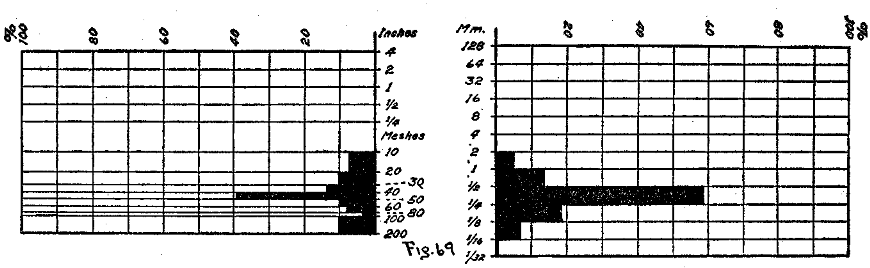
38 Stephenson, L. W., op. cit., pp. 284-286.











Figures 65-69.—Diagrams showing mechanical composition of the Chowan formation. Samples 2109, 2139, 2142, 2108, and 2094.

Petrography.—The Chowan formation in Nottoway and Meherrin valleys consists of moderately well sorted sand and gravel. The material is mainly quartzose, but it contains considerable other debris from the disruption of crystalline rocks. The particles are generally less well rounded than those in the gravels of the James and Potomac basins and in some places they are rough and angular.

Detailed descriptions of samples from the Chowan formation are given below.

Sample 2109. Chowan gravel. From an elevation of 45 feet, one-fourth mile west of Haley's Bridge, Greensville County.

This is a fairly well sorted gravel. See Figure 65. The pebble grades consist of 90 to 95 per cent angular and subangular quartz pebbles, with the remainder somewhat smoothed and rounded. No chert was found. The sand grades contain considerable feldspar and various heavy minerals.

Sample 2139. Chowan sand. From an elevation of 43 feet, half a mile south of Burt, Sussex County.

This is a moderately well sorted coarse sand. See Figure 66. The composition of this sand is similar to that of sample 2108.

Sample 2142. Chowan sand. From an elevation of 60 feet at Lambs, Sussex County.

This is a well-sorted medium sand. See Figure 67. The coarser grades contain a few grains of feldspar and mica, which, with heavy minerals, are more abundant in the finer grades.

Sample 2108. Chowan sand. From an elevation of 46 feet, 1½ miles north of Haley's Bridge, Southampton County.

This is a fairly well sorted coarse sand. See Figure 68. The coarser and medium grades consist of rough angular quartz grains and a few grains of feldspar. Feldspar, mica, and various heavy mineral grains are abundant in the finest grades.

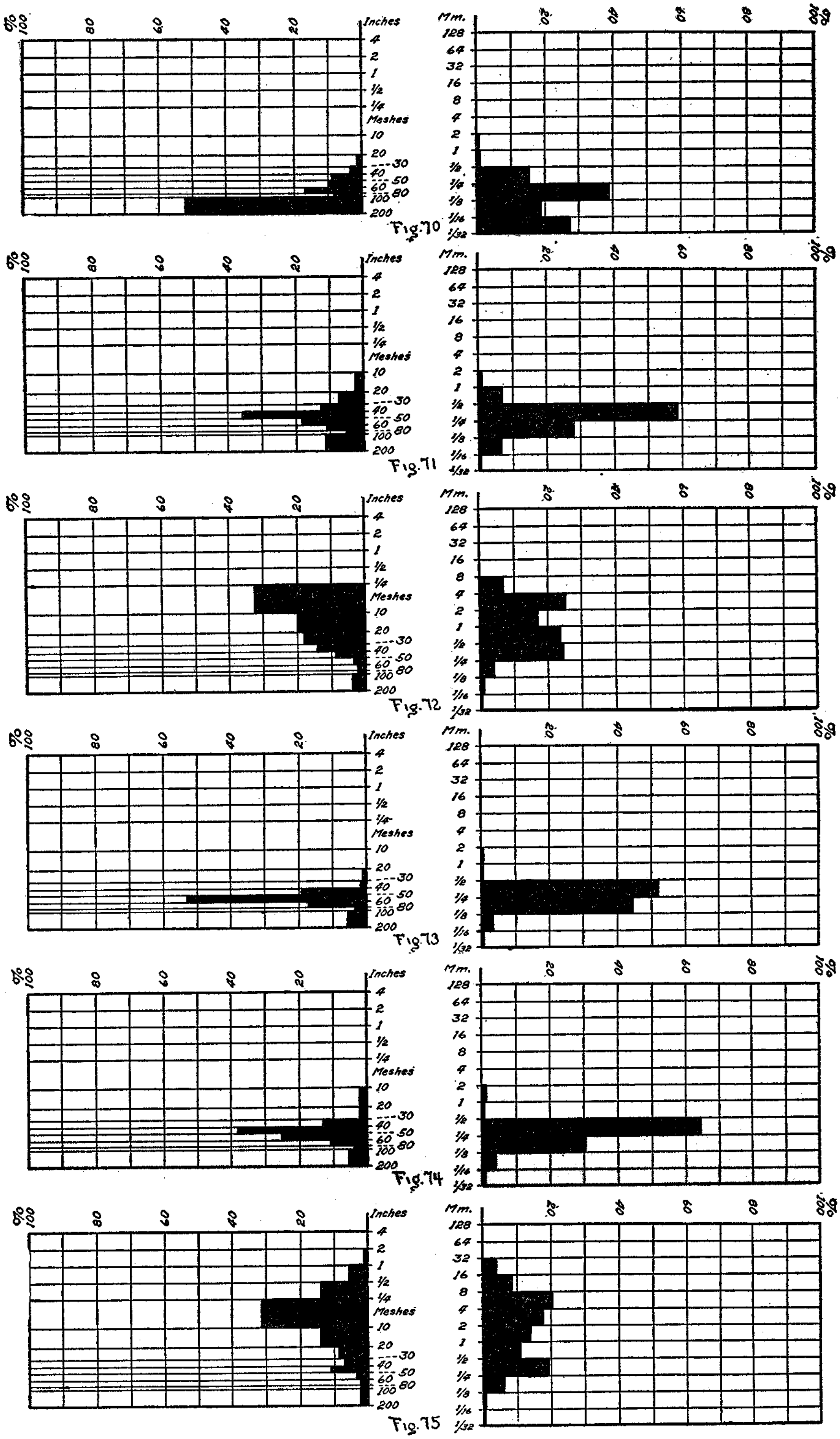
Sample 2094. Chowan sand. From an elevation of 25 feet, 1 mile south of Franklin, Southampton County.

This is a well-sorted medium sand. See Figure 69. The coarser sand grades are wholly quartz, mostly clear and subangular, but with a few milky grains. A few heavy mineral grains are found in the finest grades.

DISMAL SWAMP TERRACE AND FORMATION

Relation to the Pamlico terrace.—The name Pamlico, derived from Pamlico Sound in eastern North Carolina where the terrace is well marked, was applied in 1912 by Stephenson[39] to the terrace and formation which are east of the Chowan formation and which are separated from the Chowan by a well-marked sea-facing scarp.

39 Stephenson, L. W., op. cit.



Figures 70-75.—Diagrams showing mechanical composition of the Dismal Swamp formation. Samples 1540-A, 1540-B, 1540-C, 1741, 1748, and 1788-A.

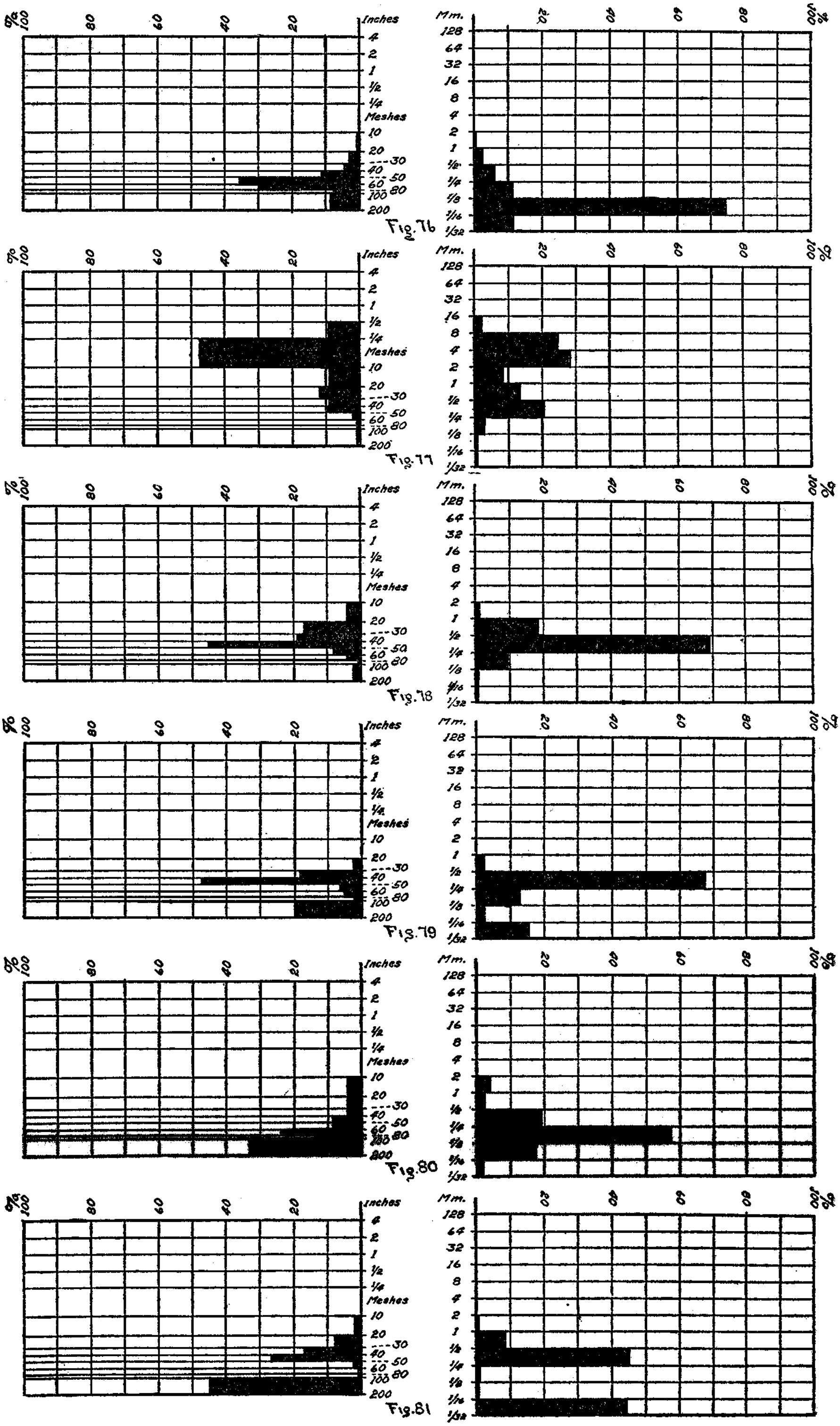
This scarp trends almost north and south through eastern Gates County, North Carolina, and is continuous with the Suffolk scarp in Virginia. The marine part of the Pamlico terrace has a maximum elevation of about 25 feet at the foot of the Suffolk scarp. It slopes gently seaward to elevations of 15 to 18 feet along the coast.

Stephenson included in the Pamlico terrace the entire Coastal Plain lowland east of the Pamlico-Chowan scarp (Suffolk scarp in Virginia). The field work in Virginia proves that two terraces lower than the Chowan occur on the Coastal Plain. These terraces are clearly shown on the recent topographic maps of the Coastal Plain in Virginia. The lack of such maps in North Carolina makes it still impracticable to discriminate the two terraces there. In this report the Pamlico terrace and formation are subdivided into the Dismal Swamp and Princess Anne terraces and formations as defined below.

Definition.—The Dismal Swamp terrace and formation are named from the Dismal Swamp district, east of the Suffolk scarp, where they are excellently developed. (See Figs. 62 and 63.) The type area of the Dismal Swamp terrace is separated on the north from the lower Princess Anne terrace by a low, distinct scarp which trends almost east and west south of Oldtown in Norfolk County and Bayville in Princess Anne County.

Extent and topography.—Dismal Swamp in Norfolk and Princess Anne counties is the largest single area of this terrace. It covers several hundred square miles in North Carolina and Virginia along the western margin of the terrace. Its great size results from (1) the gentle slope, in part reversed, of the sea floor that emerged at the close of Pamlico time, and (2) the lack of tidal channels across the area between James and Roanoke rivers. North of James river small areas of the Dismal Swamp terrace are found west of Chesapeake Bay. It is extensively developed on the Eastern Shore. (See Fig. 24.) The elevation of the terrace varies from 15 to 25 feet. (See Pl. 11, A, and Fig. 5.) Lower areas may have been developed in Dismal Swamp time and have been only slightly modified in Princess Anne time. However, as the Princess Anne and Dismal Swamp formations are physically alike, such low areas are mapped as Princess Anne terrace.

Terrace remnants at constant elevations of about 25 feet along the main tidal channels are believed to have been developed by wave work during Dismal Swamp time. (See Pl. 11, B.) They indicate that deep channels which had been cut during an earlier stage had become drowned tidal channels by Dismal Swamp time.



Figures 76-81.—Diagrams showing mechanical composition of the Dismal Swamp formation. Samples 1788-B, 1788-C, 2096, 2050, 2052, and 2066.

Remnants of fluvial terraces which merge with the wave-cut Dismal Swamp terraces extend up the valleys of the principal streams. There are few, if any, places where Dismal Swamp fluvial terraces are sharply cut against Chowan fluvial terraces with a distinct intervening scarp. It is hardly to be expected that a change of the strand line from the 40-foot level to the 25-foot level would produce a complete series of river terraces accordant with the new strand line and distinct from the earlier terraces. Hence the fluvial parts of the Dismal Swamp and Chowan terraces have not been separated in mapping. They are designated as Chowan-Dismal Swamp terraces and are so described in a later section.

Thickness.—The Dismal Swamp formation probably is rarely more than 20 feet thick. The thickness ranges from 10 to 25 feet on benches cut at many places in Miocene formations. These benches occur from tidewater to 10 feet above sea-level. The uniform elevation of this contact over broad areas is strong evidence for the marine origin of the formation. The formation thins inland.

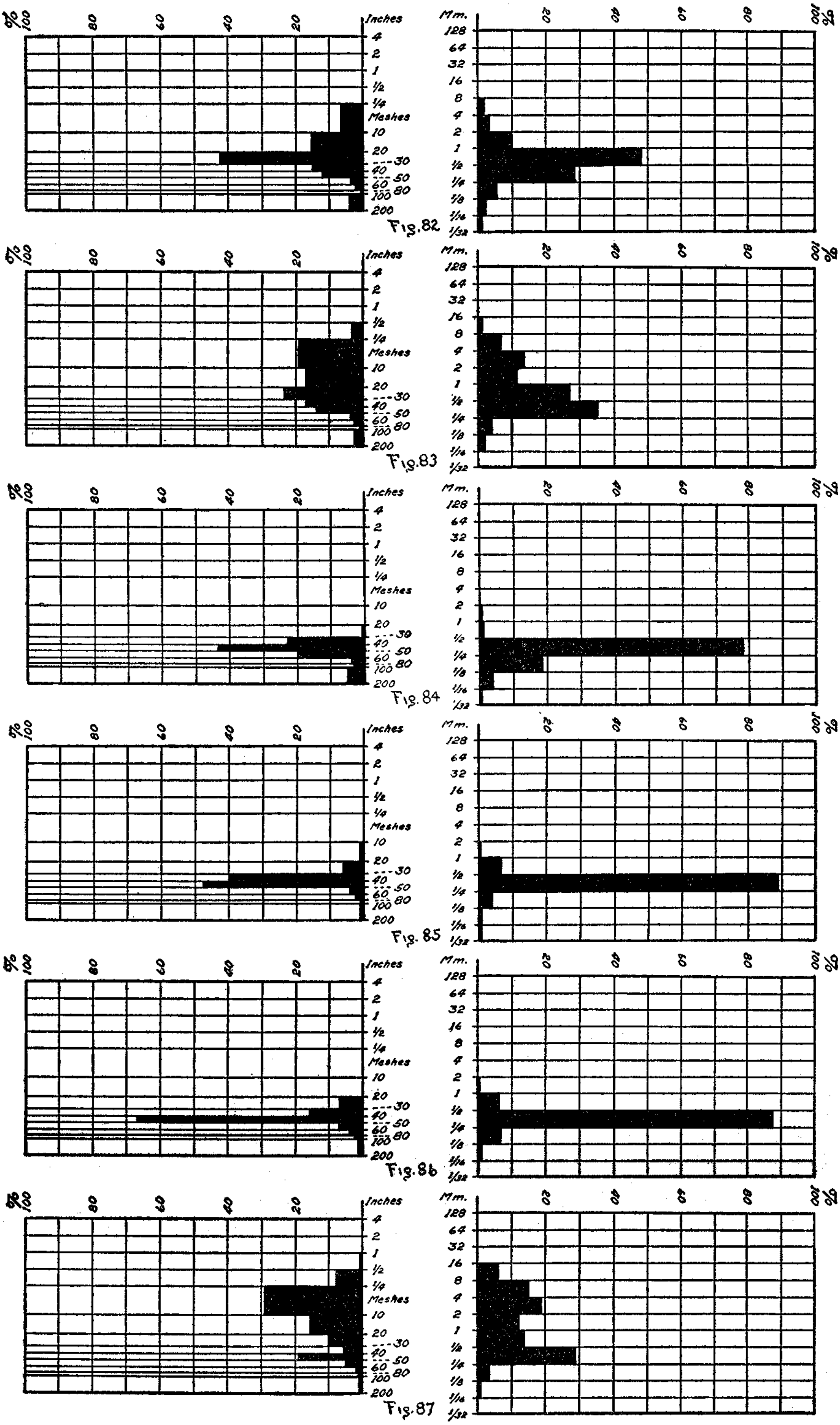
Structure and relations.—The bedding of the Dismal Swamp formation is commonly well marked by beds of sand and gravel. Although the bedding in any outcrop is much more regular than that of the upland loam gravel formations, no regularity of vertical sequence can be distinguished. Thin zones of pebbles and gravel are common at the base of the formation. The basal contact is generally marked by a ferruginous crust in the terrace formation and by a ferruginous impregnation of the Miocene clay to a depth of a few inches. The upper part of the formation is composed of fine sand or loam and not uncommonly contains a layer of oyster shells 1 to 2 feet thick.

Fossils.—The Dismal Swamp terrace and formation are of marine origin over considerable areas. It is the only terrace formation on the Coastal Plain of Virginia in which marine fossils have been found. South of Portsmouth 26 species of mollusks have been identified from Dismal Swamp deposits.[40]

The Talbot formation, which is subdivided in this report into the Chowan, Dismal Swamp, and Princess Anne formations, has yielded plant remains (Pl. 12, A) at several localities as reported by E. W. Berry.[41]

Petrography.—The Dismal Swamp formation is composed mainly of sand. It is, as a rule, clean, white, yellow, or light cream,

40 Clark, W. B., and Miller, B. L., op. cit.
41 Berry, E. W., op. cit.



Figures 82-87.—Diagrams showing mechanical composition of the Dismal Swamp formation. Samples 2069, 2079, 2254-A, 2254-D, 2256, and 2254-C.

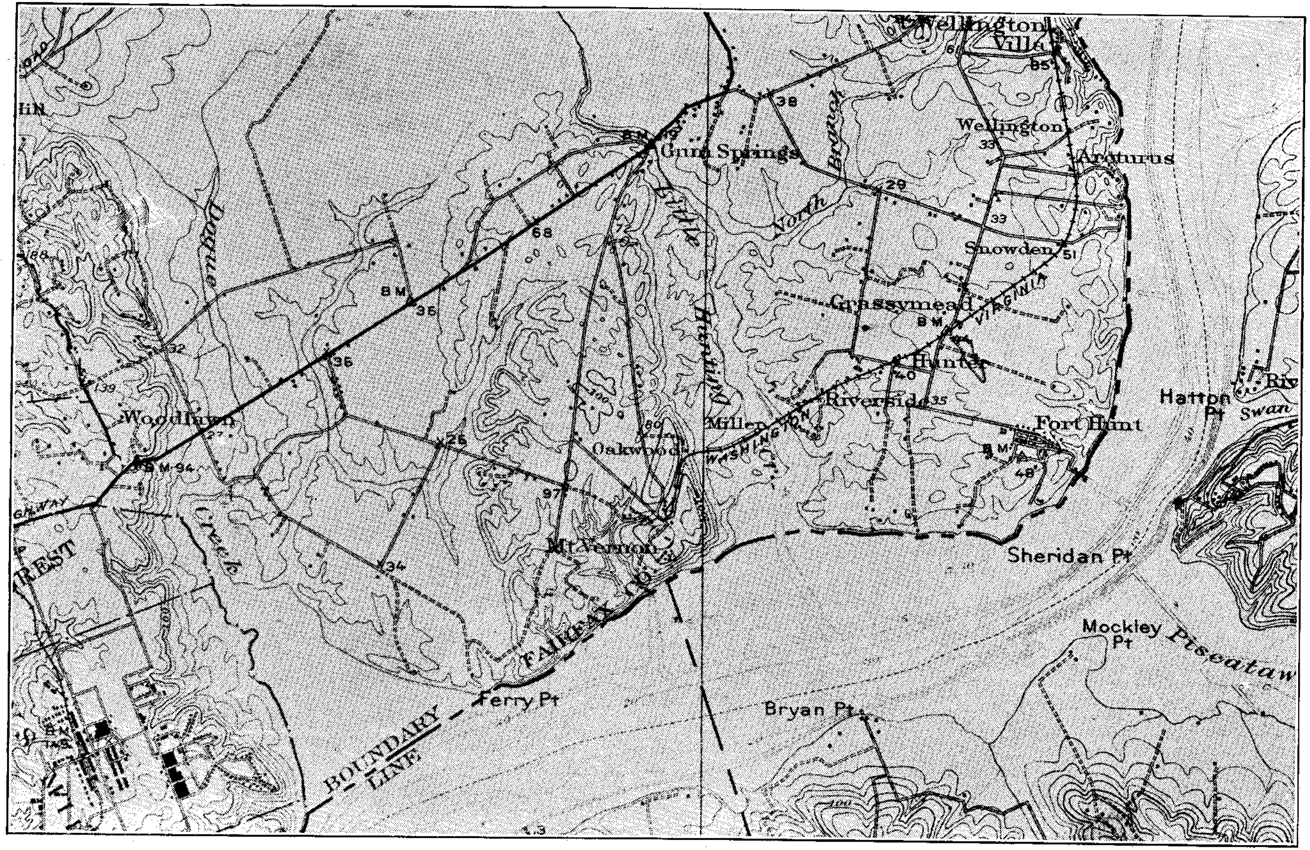


Figure 88.—Topographic map of the area in the vicinity of Mount Vernon. (Part of Indian Head sheet.) Scale, 1 inch equals 1.04 miles; contour interval, 20 feet. The 140-foot highland at the southwest is part of the lower Sunderland terrace. The upland at Mount Vernon, probably of Wicomico age, is encircled by a meander channel which is believed to have carried the main river during much of Chowan-Dismal Swamp time. (See p. 77.)

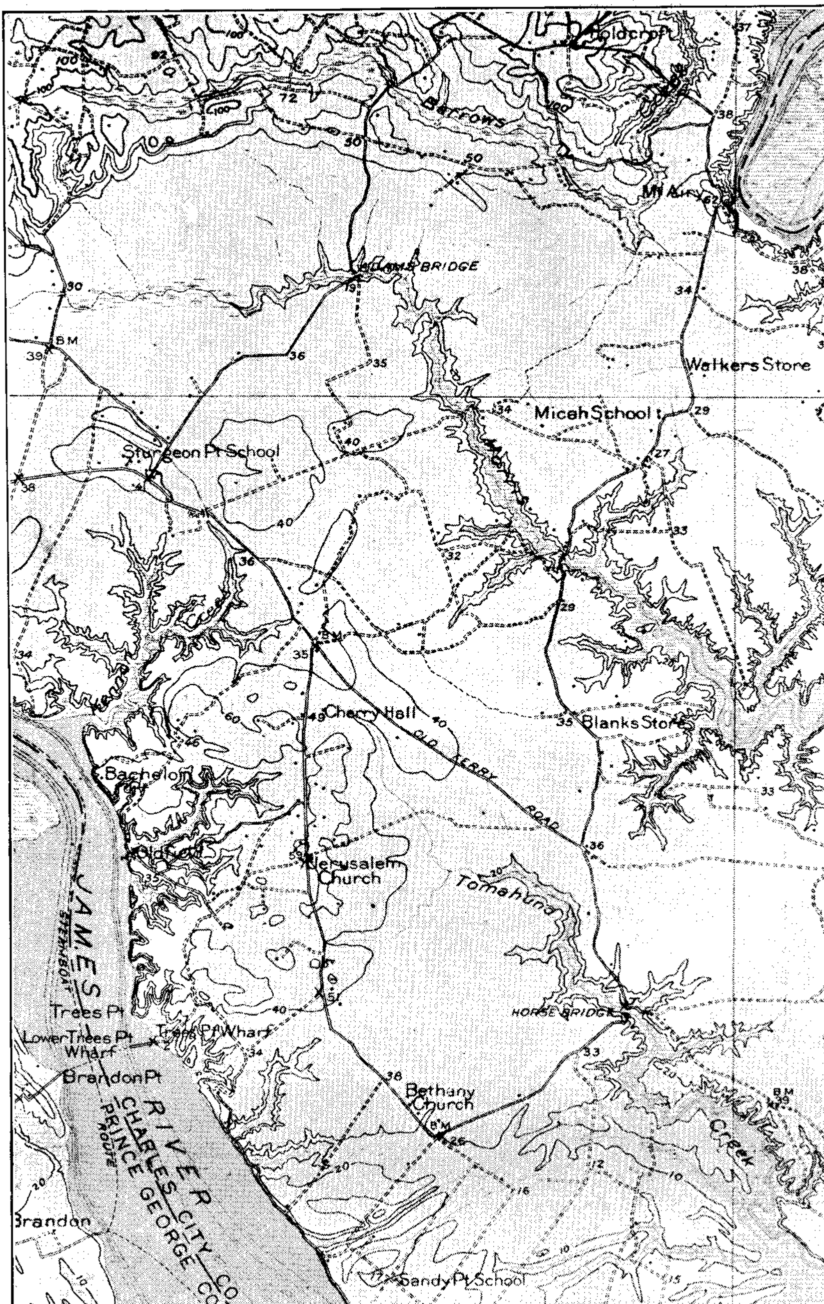


Figure 89.—An abandoned meander of James River in Charles City County. (Part of Toano sheet.) Scale, 1 inch equals 1.25 miles; contour intervals, 10 and 20 feet. James River cut a broad meander in Wicomico time, which was entrenched in Chowan-Dismal Swamp time to the principal flat area at an elevation of about 35 feet, and then cut off. (See p. 77.)

well-sorted material. Moderately coarse well-sorted gravel is not uncommon in the inland part of the formation, but this gravel becomes finer and less abundant toward the coast.

Detailed descriptions of samples from the Dismal Swamp formation are given below.

Sample 1540-A. Dismal Swamp loam. From an elevation of 25 feet, half a mile west of Tappahannock, Essex County.

This is a fine sandy loam with almost 30 per cent passing the 1/16 millimeter sieve. See Figure 70. The sand grades are mainly subangular, slightly iron-stained, quartz grains. Heavy mineral grains are rare in the finest sand grades. This material overlies samples 1540-B and 1540-C.

Sample 1540-B. Dismal Swamp sand. From an elevation of 25 feet, half a mile west of Tappahannock, Essex County.

This is a well-sorted medium sand. See Figure 71. It consists chiefly of clear, slightly smoothed and slightly rounded quartz grains, with a few heavy mineral grains in the finest grades.

Sample 1540-C. Dismal Swamp pebbly sand. From an elevation of 25 feet, half a mile west of Tappahannock, Essex County.

This is a pebbly coarse sand. See Figure 72. The coarsest grades consist of clear white quartz grains, with a few gray chert grains. These are mainly subangular and somewhat smoothed. The finest grades contain a few heavy mineral grains.

Sample 1741. Dismal Swamp sand. From a 20-foot bank, half a mile north of Urbanna, Middlesex County.

This is well-sorted fine sand. See Figure 73. It consists of slightly iron-stained yellow grains of quartz, which are angular and subangular. A few grains of heavy minerals occur in the finest grades.

Sample 1748. Dismal Swamp sand. From an elevation of 25 feet, half a mile north of Amburg, Middlesex County.

This is well-sorted medium sand. See Figure 74. It consists almost wholly of clear, well-smoothed, moderately rounded quartz grains. There are a few heavy mineral grains and feldspars in the finest grades.

Sample 1788-A. Dismal Swamp gravel. From an elevation of about 10 feet at Capahosic, Gloucester County.

This sample is fairly well sorted sandy gravel. See Figure 75. The pebble grades contain a few chert fragments, the remainder being angular quartz and quartzite fragments. The sand grade consist mostly of clear and yellow slightly rounded quartz grains, with a considerable fraction of heavy minerals and feldspars in the finest grades.

Sample 1788-B. Dismal Swamp sand. From an elevation of about 10 feet near Capahosic, Gloucester County.

This is a well-sorted, very fine sand. See Figure 76. It is composed of exceptionally clear, slightly rounded quartz grains, with small quantities of heavy minerals.

Sample 1788-C. Dismal Swamp gravel. From an elevation of about 10 feet near Capahosic, Gloucester County.

This is a well-sorted, fine, sandy gravel. See Figure 77. A few chert pebbles are present, the remainder being mainly somewhat rounded quartz and quartzite. The sand grades are similar to those of sample 1788-A.

Sample 2096. Dismal Swamp sand. From an elevation of 25 feet, half a mile south of Wiggins' School, Southampton County.

This is a fairly well sorted medium sand. See Figure 78. It consists chiefly of iron-stained, subangular quartz grains, with a few heavy mineral grains and feldspars in the finest grades.

Sample 2050. Dismal Swamp sand. From an elevation of about 15 feet, south of Portsmouth, Norfolk County.

This is a slightly loamy fairly well sorted sand. See Figure 79. The sand grades consist chiefly of quartz. The silt grades carry a variety of minerals which have not been identified.

Sample 2052. Dismal Swamp sand. From canal bank 1½ miles south of Deep Creek, Norfolk County.

This is a well-sorted, fine sand. See Figure 80. The coarsest grades consist of quartz grains, quartz aggregates, and shell fragments. The finest grades contain considerable heavy mineral grains.

Sample 2066. Dismal Swamp terrace loam. From half a mile southeast of Oldtown, Norfolk County.

This is a sandy loam of the composition shown in Figure 81. The sand grades consist of angular and slightly rounded quartz grains, with a few grains of heavy minerals in the plus 1/16 millimeter grade. The clay and silt matrix is light buff in color. It was not analyzed.

Sample 2069. Dismal Swamp pebbly sand. From an elevation of about 20 feet near Lake Smith, Princess Anne County.

This is a moderately well sorted coarse sand carrying a few pebbles. See Figure 82. The pebble grades contain a few chert fragments and consist mainly of white, yellow, and pink quartz fragments. The sand grades consist mostly of quartz, but a small proportion of kaolinized residues and a few heavy mineral grains are found in the finest grades.

Sample 2079. Dismal Swamp pebbly sand. From an elevation of about 20 feet, 1 mile south of James Fishery, Princess Anne County.

This sample is a moderately well sorted medium sand containing a few pebbles. See Figure 83. Chert makes up some 10 per cent of the pebble grades. The remainder is composed of rather well rounded and smoothed quartz fragments. The sand grades are mostly subangular, clear quartz. A few heavy mineral grains are found in the finest grades.

Sample 2254-A. Dismal Swamp sand. From shore bluff 1 mile south of Kiptopeke, Northampton County.

This is a well-sorted medium sand. See Figure 84. The coarser grades are composed wholly of slightly rounded well-smoothed and polished quartz grains. A moderate proportion of heavy mineral grains and feldspars is found in the finest sand grades.

Sample 2254-D. Dismal Swamp sand. From shore dune 1 mile south of Kiptopeke, Northampton County.

This is a well-sorted medium sand. See Figure 85. The composition is similar to that of sample 2254-A.

Sample 2256. Dismal Swamp sand. From shore dune on Bay shore south of Old Plantation Creek, Northampton County.

This is a very well sorted medium sand. See Figure 86. The coarser grades are mostly of well-polished and slightly rounded quartz. Relatively small quantities of heavy mineral grains occur in the finest grades.

Sample 2254-C. Dismal Swamp gravel. From shore bluff 1 mile south of Kiptopeke, Northampton County.

This is a well-sorted sandy gravel containing 40 per cent of gravel grades. See Figure 87. A few chert pebbles are present, but the pebbles are mainly white and cream-colored, somewhat smoothed, subangular quartz. The sand grades are similar to those of sample 2254-A, except that they are somewhat iron-stained. The finest grades contain large quantities of ferruginous kaolinized residue from feldspars.

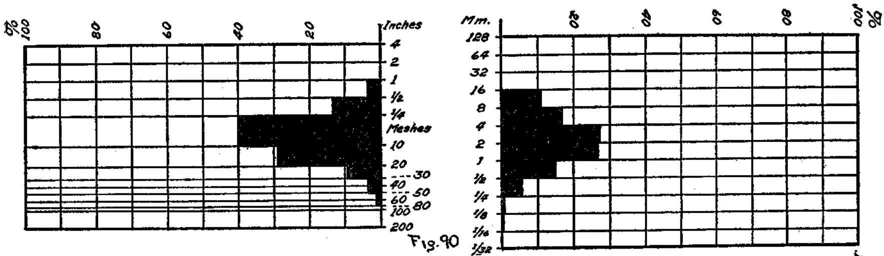
UNDIFFERENTIATED CHOWAN-DISMAL SWAMP FORMATIONS

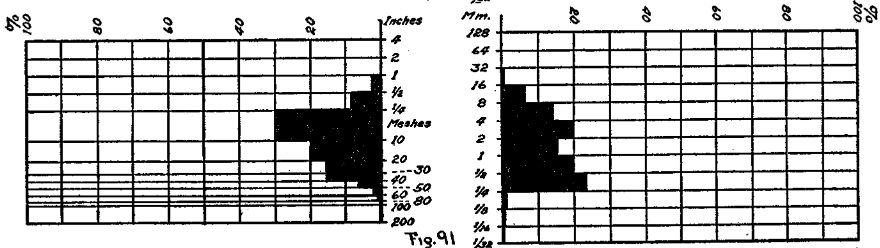
General statement.—The fluvial terraces and formations in the valleys of streams between James and Potomac rivers, which may be either Chowan or Dismal Swamp, are considered in this section. It is thought that most of the terrace cutting in these valleys was done during Chowan time, and that in the larger valleys, at least, the fluviatile phase gave way to the marine phase during most of Dismal Swamp time.

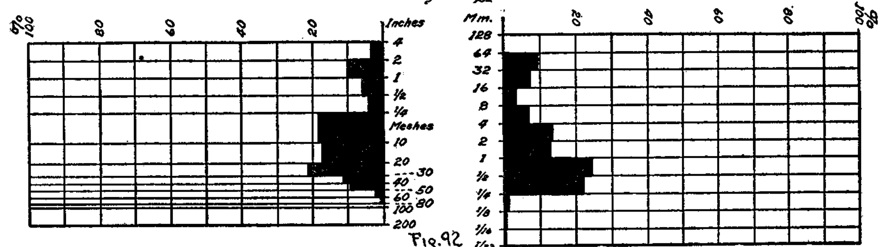
Extent and topography.—The principal areas of Chowan-Dismal Swamp terraces are found (1) along James River from Charles City to Richmond, (2) along York River and its tributaries, the Mattaponi and the Pamunkey, (3) along the Rappahannock above Tappahannock, and (4) at scattered localities along the Potomac from Westmoreland County to the Fall Belt. (See Pls. 3, A, 12, B, 13, A, and 13, B, and Fig. 24, p. 46.)

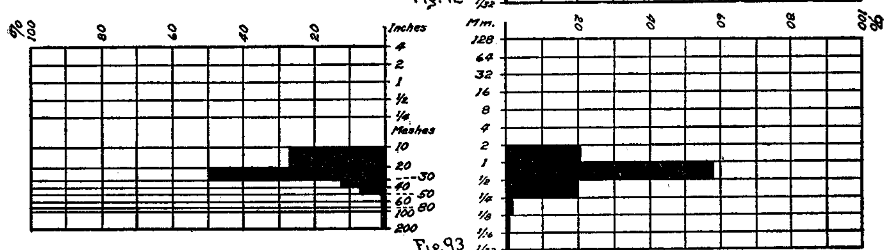
These terraces rise from elevations of 30 to 40 feet near Chesapeake Bay, to elevations of 70 to 80 feet near the Fall Belt, except along Potomac River where they are only slightly higher at the Fall Belt than at the coast.

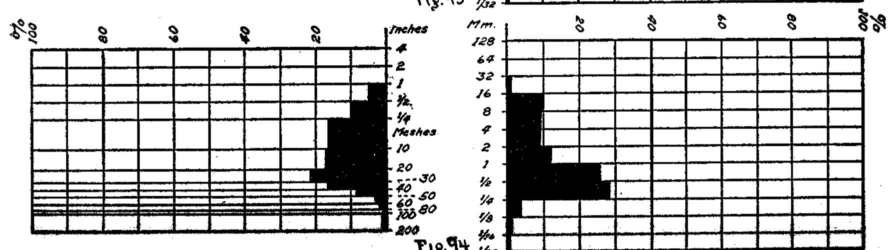
This series of terraces has strongly developed meanders. (See Pl. 14, A.) Some of these meanders were assumed on higher terraces and were entrenched to the Chowan level. Others may have developed only at the Chowan level. Fine examples of entrenched meanders which were cut off late in Chowan time occur at Mount Vernon and near Charles City on James River.

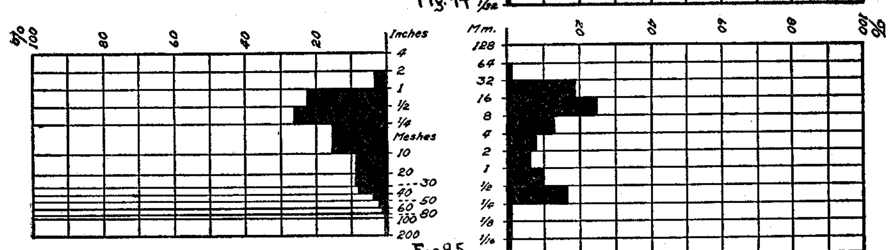












Figures 90-95.—Diagrams showing mechanical composition of undifferentiated Chowan-Dismal Swamp formations. Samples 1530, 1500, 1534, 1558, 1761, and 1522.

Figure 88 shows conditions in the vicinity of Mount Vernon. The upland at Mount Vernon is probably a remnant of Wicomico terrace. It is encircled by a meander channel, less than 40 feet above sea-level, which is believed to have been the course that the Potomac assumed in late Sunderland or Wicomico time and continued to follow during much of Chowan-Dismal Swamp time. Late in Chowan time this ox-bow appears to have been cut off and in part silted up. The ridge extending south from Wellington Villa is probably a long bar formed at the junction of the river and slack water in the cut-off ox-bow.

Figure 89 shows a small area, at the north, of Sunderland upland into which James River cut a broad meander in Wicomico time. In Chowan-Dismal Swamp time this meander was entrenched to the principal flat at an elevation of about 35 feet. It was then cut off in a manner similar to the cut off at Mount Vernon.

Thickness and lithology.—The thickness of the undifferentiated Chowan-Dismal Swamp deposits is rather variable, and averages possibly about 15 to 20 feet. In places these deposits are probably 30 to 40 feet thick. The sequence of beds varies from place to place. The basal part of the formations is commonly coarser than the upper part, where loam is abundant, but the sections are irregular from place to place. (See Pl. 14, B.) In the Washington area the formations carry considerable fine loam with large boulders, which indicate conditions of river transportation similar to those of earlier Pleistocene epochs. (See Pl. 15, A.)

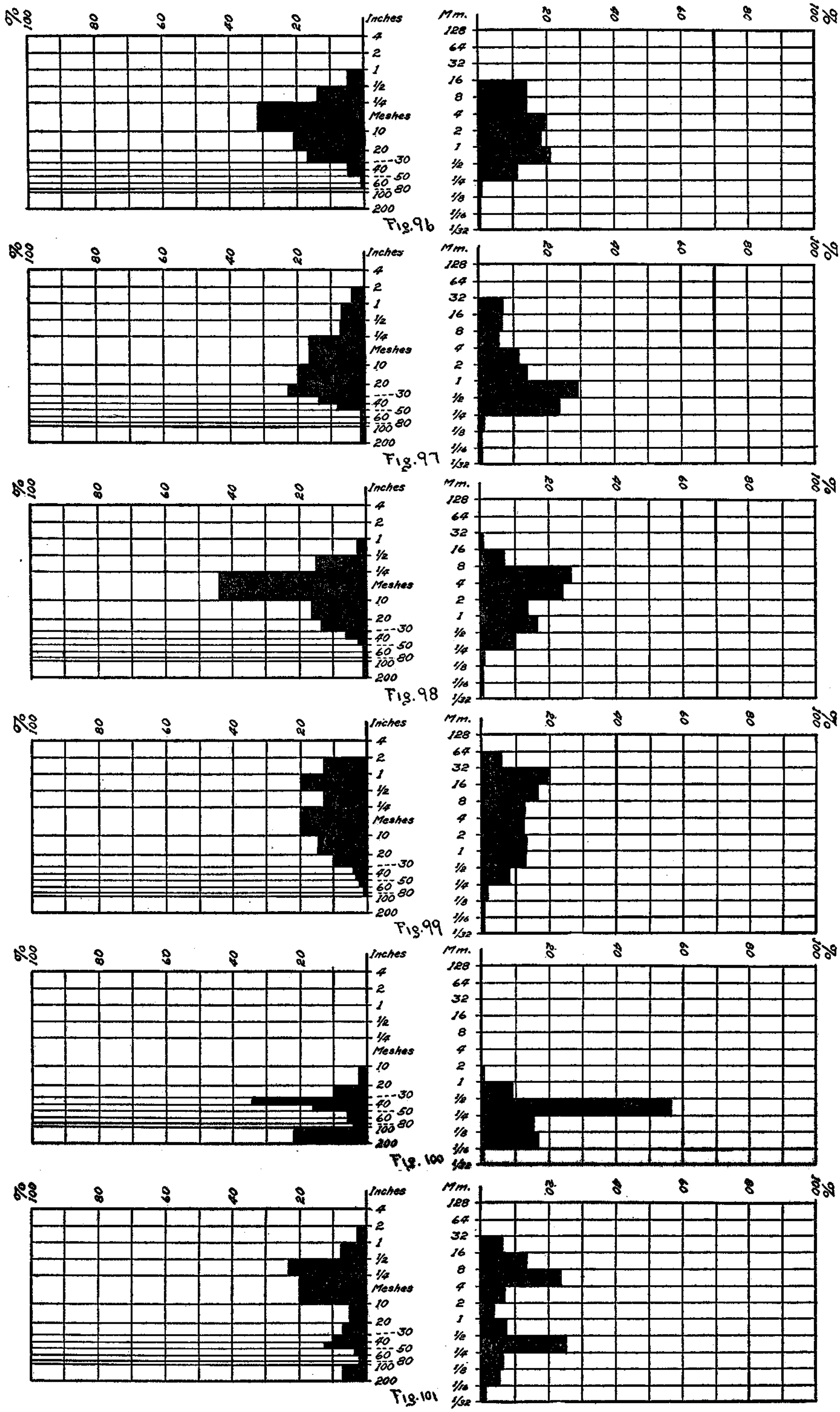
Petrography.—The Chowan-Dismal Swamp terrace deposits consist in general of moderately well sorted river gravel. They differ from the upland loam gravel in having less fine-grained material in the matrix, and from typical marine gravel in being less perfectly sorted and more heterogeneous. Fewer of the sand grains and pebbles are quartzose than in the upland loam gravel or most of the marine terrace formations.

Detailed descriptions of samples from the undifferentiated Chowan and Dismal Swamp deposits are given below.

Sample 1691. Chowan-Dismal Swamp pebbles. From an elevation of 43 feet, Port Conway, King George County.

These pebbles are almost wholly angular and subangular vein quartz and quartzite. Chert is negligible. Almost no crystalline rock fragments, other than quartz, are present.

Sample 1530. Chowan-Dismal Swamp sandy gravel. From an elevation of 60 feet, 1 mile northeast of Gether, Caroline County.



Figures 96-101.—Diagrams showing mechanical composition of undifferentiated Chowan-Dismal Swamp formations. Samples 1525, 2049, 1820, 1829, 1795, and 1796.

This is a fairly well sorted gravel with coarse sand grades. See Figure 90. Half of the pebbles are well rounded and the remainder are subangular quartz and quartzite fragments. A few chert pebbles are present. The sand grades consist of slightly iron-stained, mostly subangular quartz grains, with a small proportion of heavy mineral grains in the finest grades.

Sample 1500. Chowan-Dismal Swamp gravel. From roadside pit at an elevation of about 95 feet, half a mile west of Burkes Bridge, Caroline County.

This is a moderately well sorted gravel, with a small amount of fine material. See Figure 91. The pebble grades consist mainly of subangular and rough vein quartz fragments. No chert pebbles were found. The coarser sand grades are almost wholly slightly iron-stained angular quartz.

Sample 1534. Chowan-Dismal Swamp sandy gravel. From an elevation of 35 feet, half a mile north of the mouth of Gravel Run, King and Queen County.

This is fairly well sorted sandy gravel. See Figure 92. The pebble grades consist mainly of vein quartz and quartzite, with a few chert pebbles. In the very coarsest grades some of the pebbles are well rounded, but they are chiefly subangular. The sand grades are mainly slightly iron-stained, subangular quartz grains, with a few heavy minerals and feldspar grains in the finest grades.

Sample 1558. Chowan-Dismal Swamp sand. From an elevation of about 40 feet, at Aylett, King William County.

This is a well-sorted coarse sand. See Figure 93. The coarser grades consist of clear, slightly smoothed quartz grains. A few heavy mineral grains and feldspar grains are found in the finest grades.

Sample 1761. Chowan-Dismal Swamp gravel. From an elevation of 20 feet at West Point, King William County.

This is a fairly well sorted, sandy gravel. See Figure 94. Chert constitutes a fraction of 1 per cent of the pebble grades, which are mostly of angular and subangular quartz and quartzite. The sand grades are mainly iron-stained subangular quartz. The finest grades contain numerous grains of heavy minerals and feldspars.

Sample 1522. Chowan-Dismal Swamp gravel. From an elevation of 40 feet, 1½ miles northeast of Hanover Courthouse, Hanover County.

This is a rather well sorted sandy gravel. See Figure 95. Few of the pebbles are well rounded, but most of them are subangular. Almost no chert is present. The sand grades consist largely of rough angular quartz, with considerable feldspar, mica and heavy minerals.

Sample 1525. Chowan-Dismal Swamp gravel. From an elevation of 45 feet, 2 miles east of Hanover Courthouse, Hanover County.

This is a poorly sorted, coarse, sandy gravel. See Figure 96. The sand grades contain considerable feldspar, mica, and various other minerals from crystalline rocks. The proportion increases in the finer grades.

Sample 2049. Chowan-Dismal Swamp gravel. From an elevation of about 35 feet, 1½ miles northeast of Dutch Gap, Henrico County.

This sample is a well-sorted sandy gravel. See Figure 97. The pebble grades consist mainly of quartz and quartzite fragments, with a considerable variety of other rocks, such as schist, chert, and granite. The sand grades consist largely of iron-stained quartz grains, but they contain other minerals, such as feldspar, ferromagnesian minerals, mica, and heavy minerals.

Sample 1820. Chowan-Dismal Swamp gravel. From an elevation of about 25 feet, half a mile west of Boulevard, New Kent County.

This is a well-sorted sandy gravel. See Figure 98. Chert pebbles make up 1 or 2 per cent of the pebble grades. The remainder is well smoothed, slightly rounded quartz. The coarser sand grades are mainly quartz. The finest grades consist almost wholly of ferruginous kaolinized residues, with a few feldspar grains.

Sample 1829. Chowan-Dismal Swamp gravel. From an elevation of 15 feet, Charles City, Charles City County.

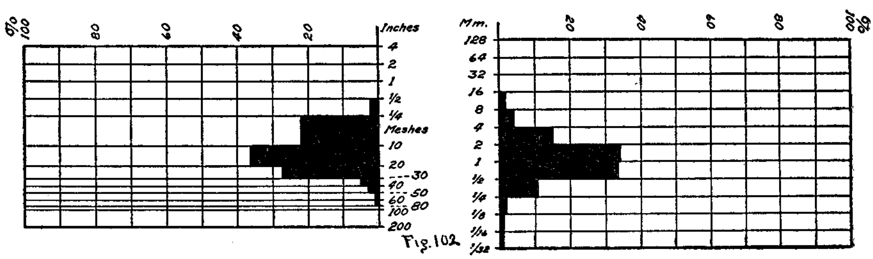


Figure 102.—Diagram showing mechanical composition of undifferentiated Chowan-Dismal Swamp gravel. Sample 2003.

This is a rather well sorted sandy gravel. See Figure 99. The pebble grades contain 10 to 15 per cent of chert, the remainder being mostly subangular quartz. The sand grades are mainly clear, slightly rounded quartz grains. Feldspars and various heavy minerals are increasingly abundant in the finer grades.

Sample 1795. Chowan-Dismal Swamp sand. From an elevation of 35 feet, half a mile southeast of Harris Grove, York County.

This is a well-sorted medium sand containing about 15 per cent of material passing the 1/16 millimeter sieve. See Figure 100. The sand grades are almost wholly composed of subangular slightly smoothed quartz grains. A considerable proportion of heavy mineral grains is present in the finest sand grade.

Sample 1796. Chowan-Dismal Swamp gravel. From an elevation of 35 feet, 2 miles south of Grafton, York County.

This is a rather well sorted sandy gravel. Its composition, exclusive of about 15 per cent of silt and clay grades, is shown in Figure 101. It consists mainly of subangular vein quartz and quartzite, with a few chert pebbles. About 10 per cent of the pebbles and cobbles is fairly well rounded. The sand grades consist mainly of subangular and somewhat smoothed quartz grains. Small amounts of feldspars and heavy mineral grains are found in the finest grades.

Sample 2003. Chowan-Dismal Swamp gravel. From an elevation of 40 feet, Blandford, Prince George County.

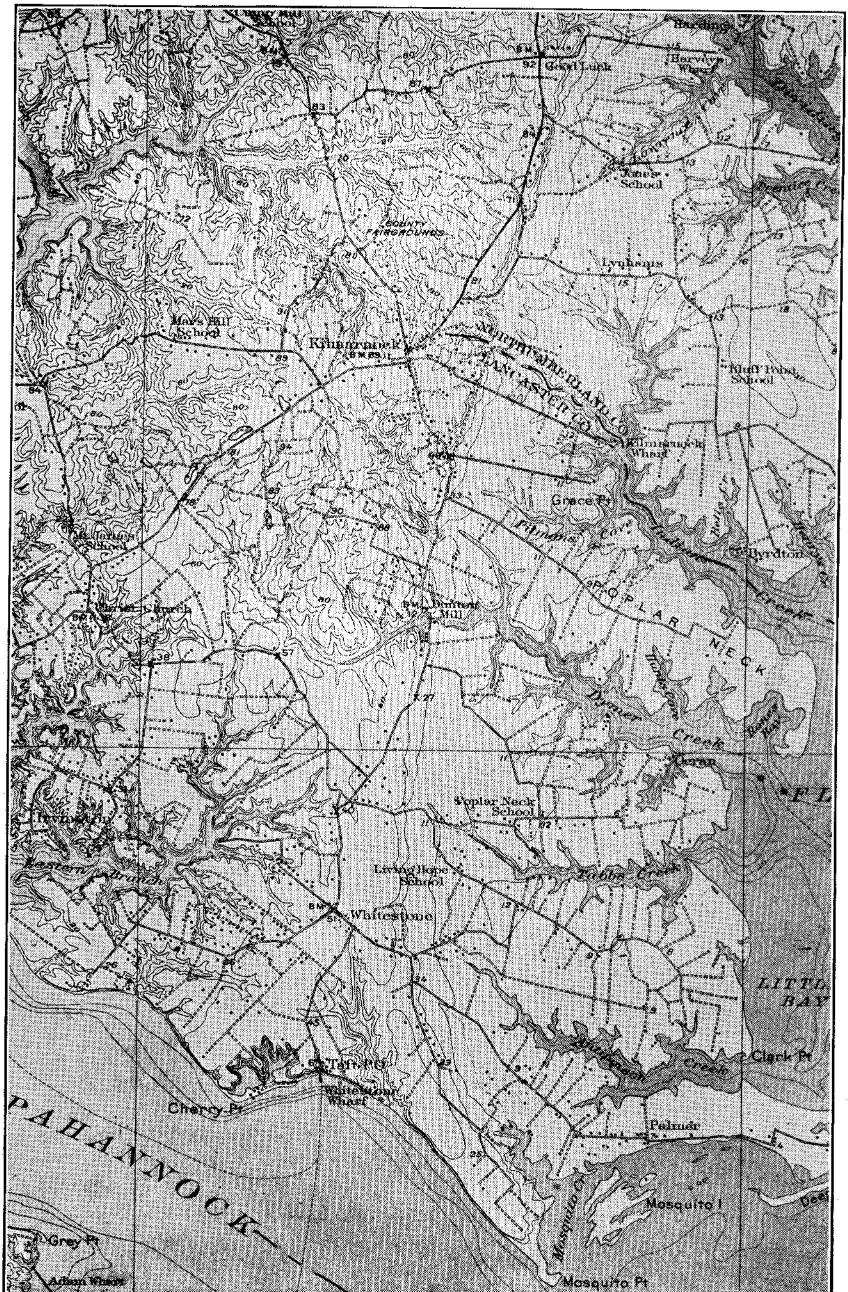


Figure 103.—Parts of the Princess Anne terrace in Northumberland and Lancaster counties. (Part of Kilmarnock sheet.) Scale, 1 inch equals 1.45 miles; contour intervals, 10 and 20 feet. The terrace is east of the prominent scarp between Good Luck and Mosquito Point. The upland between 80 and 90 feet is thought to be part of the Wicomico terrace.. (See pp. 55 and 81.)

This sample is a fairly well sorted, coarse sand containing about 20 per cent of pebbles. See Figure 102. The pebbles are mostly angular and subangular quartz. The sand grades are chiefly clear subangular quartz, but they contain white feldspar grains. Heavy mineral grains and other minerals from crystalline rocks are somewhat abundant in the finest grades.

PRINCESS ANNE TERRACE AND FORMATION

Definition.—Stephenson,[42] in 1912, included in the Pamlico terrace the whole area of the Coastal Plain in North Carolina east of the Chowan-Dismal Swamp scarp and below 25 feet in elevation.

From recent topographic maps of the Coastal Plain of Virginia, it is clear that there is a distinct terrace about 12 feet above sea-level, which is separated from the 25-foot terrace by a well-marked scarp. This scarp is prominent in the Cape Henry quadrangle east of Norfolk. It appears from maps to be well developed on the seaward side of the Eastern Shore. This low terrace and formation are here designated the Princess Anne terrace and formation because of their typical occurrence at the village of Princess Anne in Princess Anne County. Here the terrace forms a rounded reentrant extending into the type area of the Dismal Swamp terrace. The scarp which separates the Princess Anne and Dismal Swamp terraces is well developed east and southeast of Barney's Corner in Princess Anne County. (See Pls. 15, B and 16, A.)

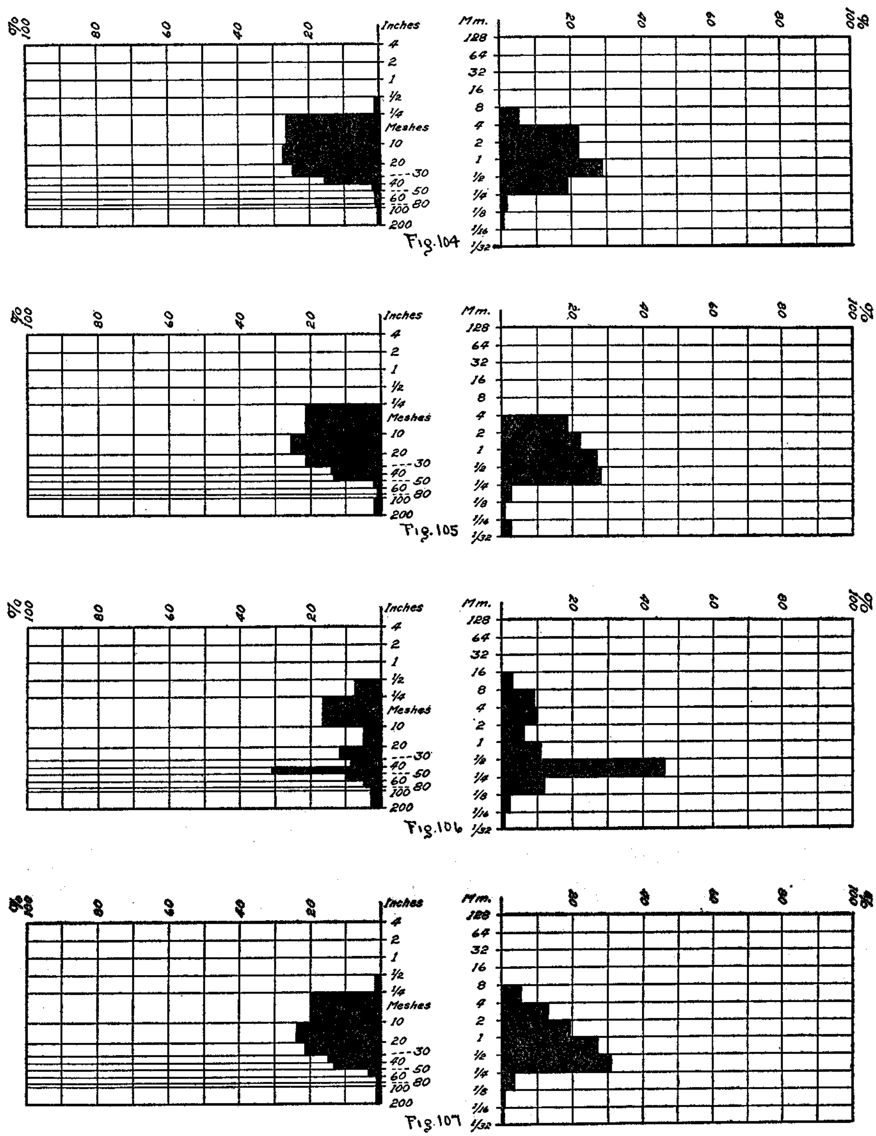
Extent and topography.—The Princess Anne terrace occurs as a narrow fringe around the margin of the Dismal Swamp terrace of the Norfolk-Cape Henry area. It forms also the greater part of the lowland east of the scarp which extends from Newport News north to the mouth of Potomac River. This lowland and the bordering scarp are well shown on the topographic map, Figure 103. The prominent scarp between Good Luck, at the north, and Mosquito Point, on the Rappahannock, separates the Princess Anne lowland from remnants of Wicomico (?) terrace, at elevations of 80 to 90 feet. The Princess Anne terrace is found also in large areas on both sides of the Eastern Shore peninsula, which can not be mapped with confidence because of the lack of topographic maps. (See Fig. 24, p. 46.)

The surface of the Princess Anne terrace is in general extremely flat and only a small part has been modified by subaerial erosion. (See Pl. 17, A.) It has, however, been dissected by small streams which have cut entirely across it to the scarp at its landward edge. Subsequently the land has been depressed relative to the sea, so that the margin of the Princess Anne terrace is tat-

42 Stephenson, L. W., op. cit., p. 286.

tered by numerous drowned channels. Indeed, the detailed coastal irregularity of much of the Chesapeake Bay region is formed by the drowning of the dendritic topography developed by post-Princess Anne erosion on the Princess Anne terrace.

Thickness and structure.—The base of the Princess Anne formation is exposed in very few places above sea-level. In such places



Figures 104-107.—Diagrams showing mechanical composition of the Princess Anne formation. Samples 1711-A, 1711-B, 1775, and 1577.

the thickness of the exposed formation is not more than 12 to 15 feet. It seems likely that the formation is somewhat thicker, but not more than 15 to 20 feet. Where the formation is well exposed the bedding is sharply marked and continuous. The basal part generally is somewhat coarser than the upper part, which is composed as a rule of fine sand or loam.

Origin.—The Princess Anne terrace is of marine origin. Small areas of marine Princess Anne terrace are found along the principal tidal channels as far west as the Fall Belt. These merge imperceptibly with fluvial terraces in such streams as the Mattaponi and Pamunkey, where tidewater does not reach the Fall Belt. It is impracticable to separate fluvial parts of the Princess Anne terrace from modern flood-plain terraces or to distinguish fluvial Princess Anne sands and gravels from similar recent sediments.

Petrography.—Most of the Princess Anne formation is well-sorted fine sand. Some gravel occurs in lenses or as a basal layer, but the total amount of such material is small.

The samples collected from outcrops of the Princess Anne are described below. Much of the modern sands described in a subsequent section are reworked from Princess Anne terrace outcrops along modern shores.

Sample 1711-A. Princess Anne pebbly sand. From river bank 2½ miles northwest of Smith Mount Landing, Westmoreland County.

This is a moderately well sorted, coarse sand. See Figure 104. The pebble grades are composed of rough subangular quartz fragments. Moderate amounts of heavy minerals and somewhat larger quantities of feldspar grains are present in the finer sand grades.

Sample 1711-B. Princess Anne sand. From river bank 2½ miles northwest of Smith Mount Landing, Westmoreland County.

This is moderately well sorted sand slightly finer in grain than sample 1711-A. See Figure 105. The mineral composition is similar to sample 1711-A.

Sample 1775. Princess Anne terrace sand. From an elevation of 8 or 9 feet about 1½ miles southeast of Remo, Northumberland County.

This is a pebbly sand carrying about 20 per cent in the plus 2 millimeter grades. See Figure 106. The sand grades consist almost wholly of quartz. A few grains of feldspar are found in the finest grades.

Sample 1577. Princess Anne terrace sand. From 10-foot terrace at Wares Wharf, Essex County.

This is a poorly sorted, pebbly, coarse sand. See Figure 107. The pebbles are mostly slightly iron-stained angular and subangular quartz fragments. The sand grades contain angular quartz with a few heavy mineral grains in the finer grades.

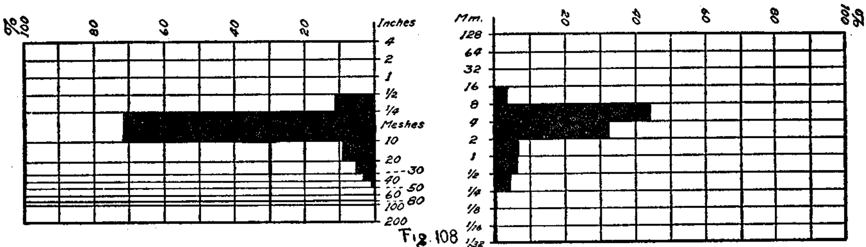


Fig. 108

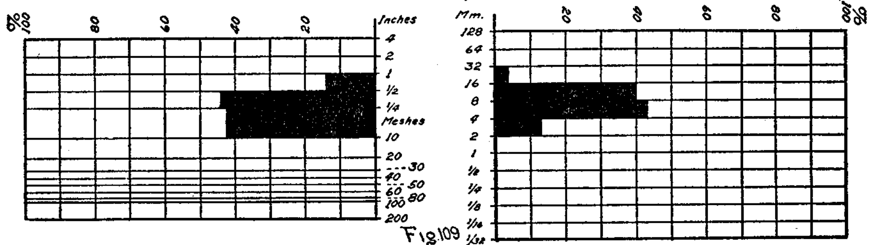


Fig. 109

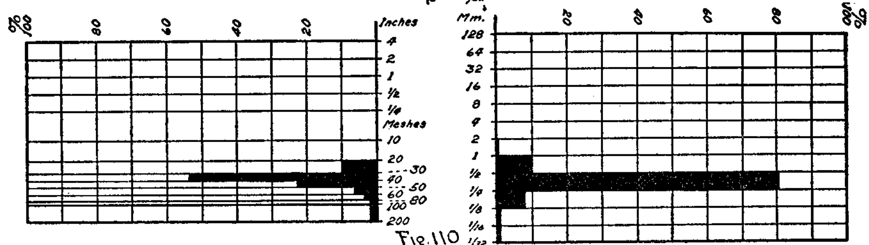


Fig. 110

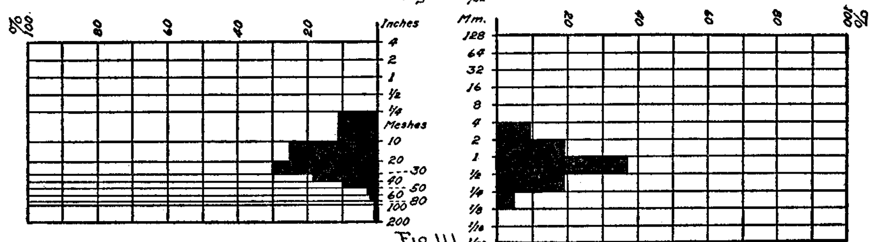


Fig. 111

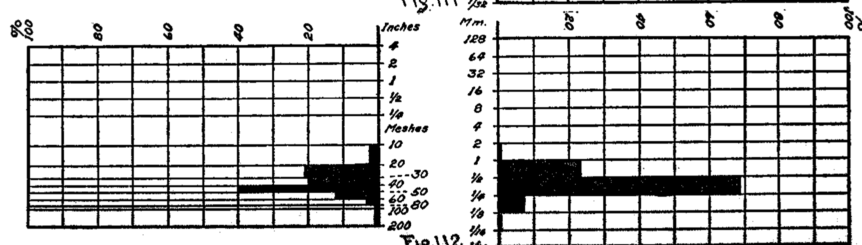


Fig. 112

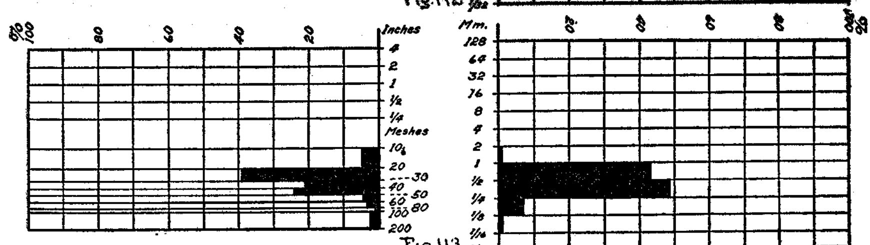


Fig. 113

Figures 108-113.—Diagrams showing mechanical composition of Recent deposits. Samples 1951-B, 2061-A, 2063, 2065, 2076, and 2074-C.

THE RECENT TERRACE AND FORMATION

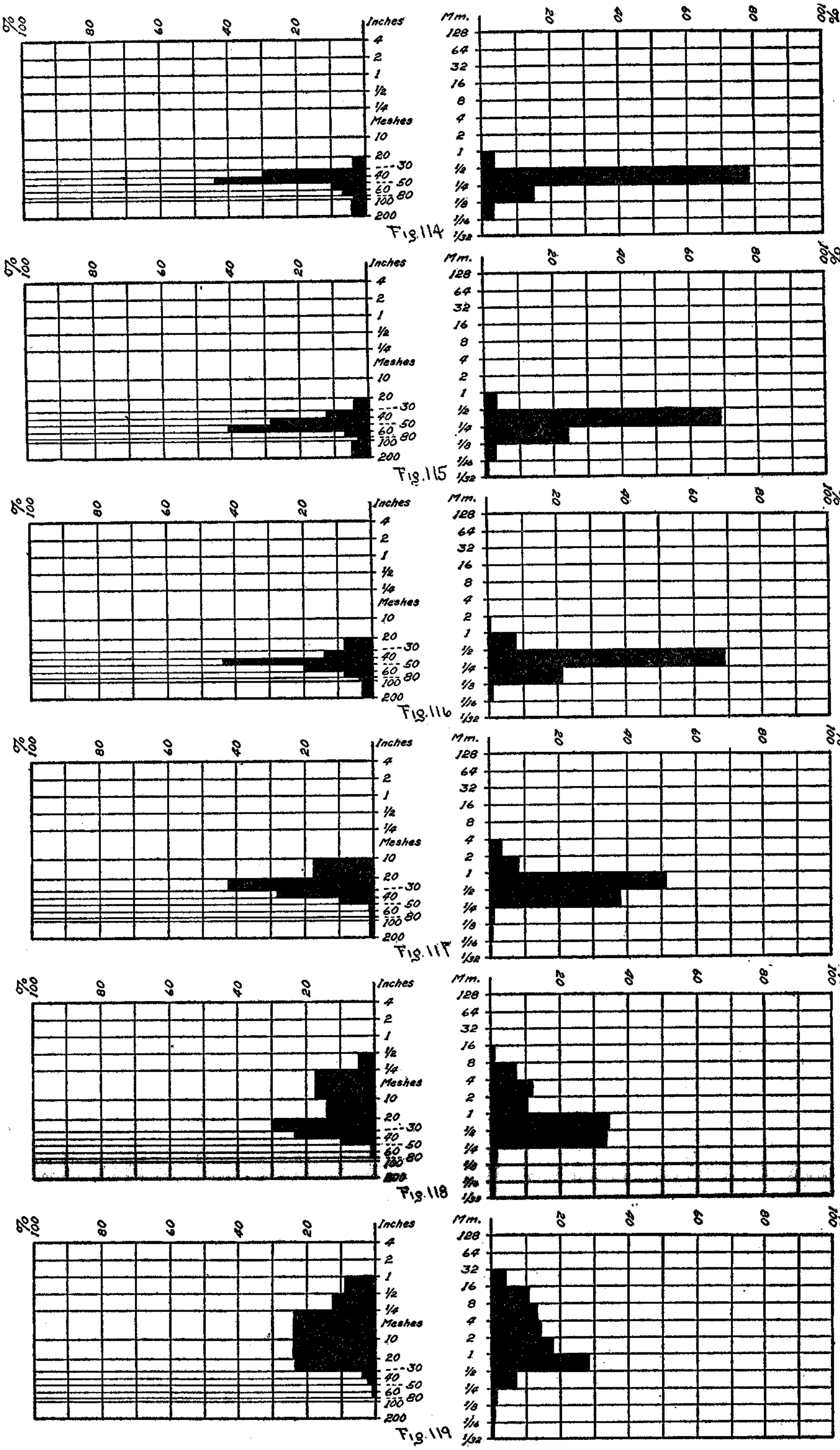
Extent and character.—In the preceding description each terrace formation has been described as though its upper surface were developed as a simple physiographic surface of fluvial or marine origin. The simplicity of this concept is unfortunately the result of ignorance of the detailed configuration of ancient formations. At present sediments are being deposited in places (1) over much of the land, (2) along the shores of the ocean and of estuaries, (3) off shore to great depths in the ocean, and (4) at least sporadically in all streams. Many of these deposits are meager and last for a short time only. Nevertheless, small parts of them are preserved in many places. The great similarity of the successive terrace formations and the lack of definitive fossils prevent, in general, the recognition of deposits not made in topographic accordance with the greater part of the same formation. Such deposits are recognized mainly among the modern sediments.

Information about modern sediments which are being deposited under water is very meager. Most of our information concerns beach or flood-plain sediments. Sand beaches are found along much of the Virginia sea-coast (Pls. 16, B and 18), and to some extent along Chesapeake Bay, and also along the broader tidewater rivers. Where the shores are attacked by strong waves, the beaches are built 5 to 10 feet above sea-level. In many places on-shore winds build shore dunes from beach sands. Some dunes are 100 or more feet high. The Cape Henry region is notable, in eastern North America, for dunes and dune topography. (See Pl. 17, B.)

A few samples indicate that fine black or gray silty mud is being deposited in much of Chesapeake Bay, and throughout the chief estuaries. Along beaches where the waves are vigorous or off spits where currents are strong, sand or fine gravel extends several hundred feet from shore. Mud bottoms generally are present, however, in water more than 5 feet deep, and there are large areas where the muddy bottom extends almost to the shore.

Because the topmost deposits in tidal rivers are almost everywhere black mud, it does not follow that all of the material is so fine. The preponderance of mud bottom indicates rather that the deposits during most of the year consist of fine material. Either fluviatile or marine scour and fill may be of sufficient vigor during short intervals to leave considerable sand on parts of the bottom, which is soon covered with mud. Only cut sections or samples taken with a tube sampler will show the proportions of coarse and fine materials that are being deposited at present.

From observation of small and changing deposits of coarse debris in the Potomac gorge below Great Falls, it is believed that



Figures 114-119.—Diagrams showing mechanical composition of Recent deposits. Samples 2074-A, 2074-B, 2072-B, 1729-A, 1729-B, and 1729-C.

considerable sand and fairly coarse gravel are carried through the rapids of the Fall Belt and deposited in the inland stretches of the tidewater channels. No evidence is at hand to show that the major streams now carry appreciable amounts of material coarser than fine sand far into the tidewater zone. It is believed that substantially all the coarser sand and gravel which are being worked on the beaches and along the lower estuaries are derived from the adjacent terraces. The lack of fan building by modern streams, even in the narrow heads of such tidal channels as the Potomac with its abrupt change of competence, suggests that the Potomac is now carrying very little clastic debris through the Fall Belt, as compared to the amounts it must have carried when the great Sunderland and Brandywine alluvial fans were being deposited.

Nothing is known of the thickness of modern terrace deposits, except what can be deduced from the known depth of water and depth of scour. It is likely that deposits 15 to 20 feet thick are being formed in some places. The bedding and sequence of beds are probably similar to those of recent terraces.

Petrography.—No modern fluvial loam deposits are known in this region. The deposits of the present rivers in the Fall Belt consist of moderately well sorted sand and gravel. The sand grains and pebbles are mainly quartz, but the percentage is not nearly so large as in the Pleistocene formations. The fragments are mostly angular and slightly smoothed.

Modern marine deposits are little known, with the exception of beach sands and gravels and the associated dunes. The beach sand is as a rule fine- or medium-grained and consists of clear, polished, subangular quartz grains. From 60 to 90 per cent of the materials is in one grade. The finer grades contain small percentages of heavy minerals.

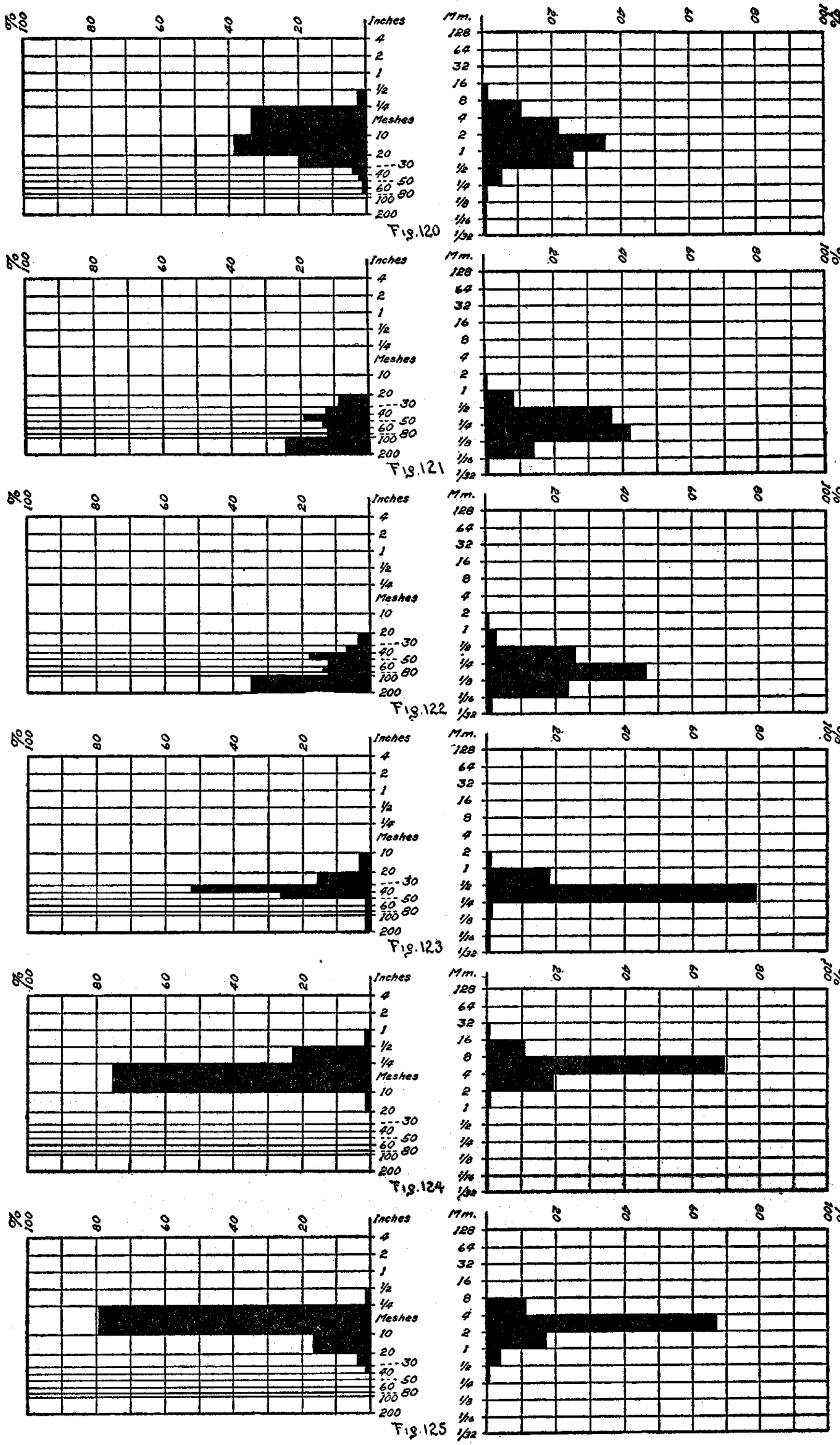
Detailed descriptions of the recent deposits are given below.

Sample 1951-B. Recent lag gravel. Gravel skimmed from windswept beach surface, north end of Rigby Island, Mathews County.

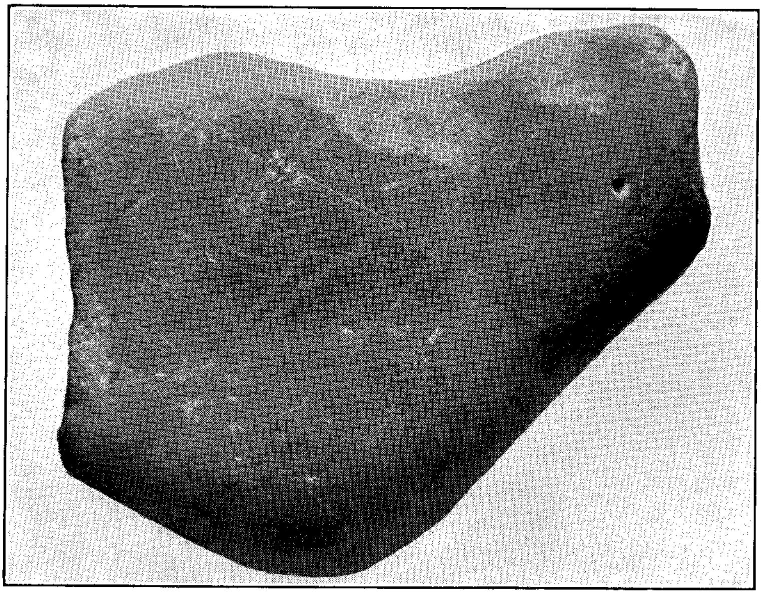
This is a well-sorted gravel from which most of the sand has been removed by the wind. See Figure 108. About 25 per cent of the larger pebbles is chert. Most of the remainder is fairly smooth white and pink quartzite and quartz pebbles, with about 10 per cent well rounded. Sand grades are composed of somewhat smoothed, but very slightly rounded, clear quartz grains.

Sample 2061-A. Recent lag gravel. From west end of Willoughby Beach, Norfolk County.

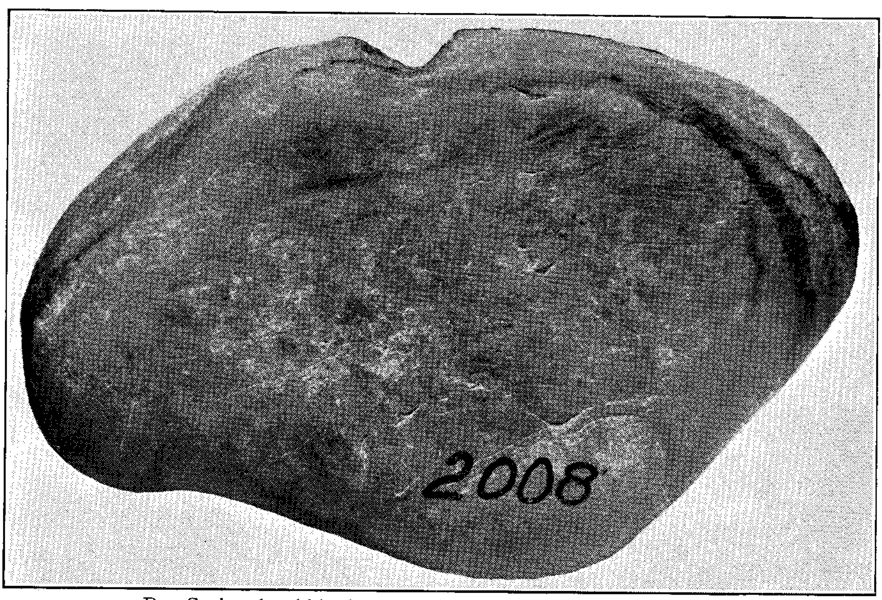
This is a fairly well sorted gravel ranging mostly from 4 to 16 millimeters. See Figure 109. About 20 per cent of the pebbles is chert. The remainder includes quartzite, vein quartz, schist, granite, and other igneous and metamorphic



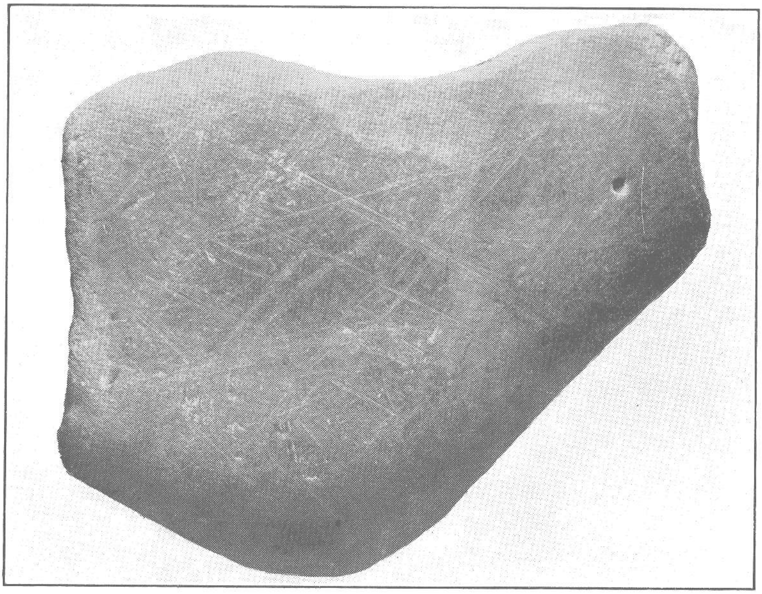
Figures 120-125.—Diagrams showing mechanical composition of Recent deposits. Samples 1729-D, 1543, 1578, 1738, 2296, and 1930-E.



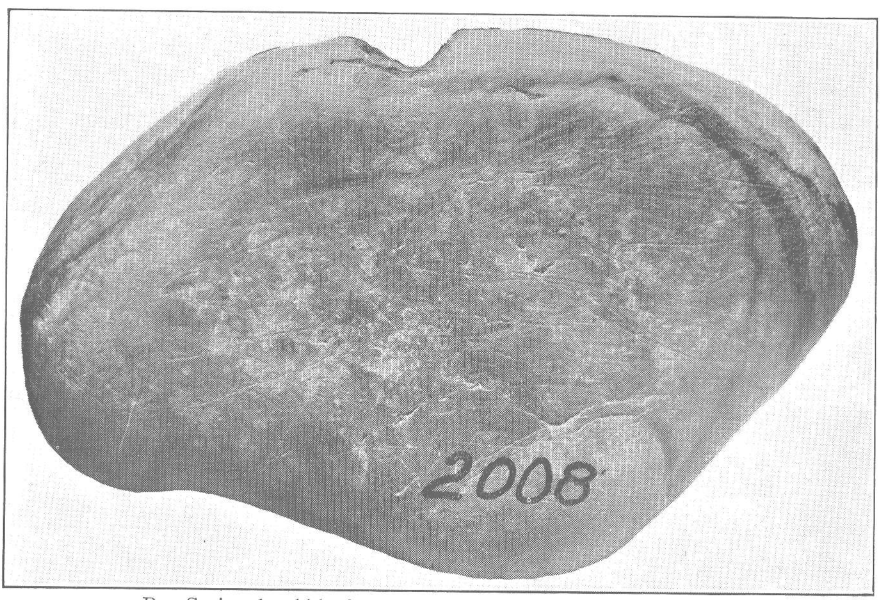
A. Striated cobble from the Wicomico formation. (See p. 59.)



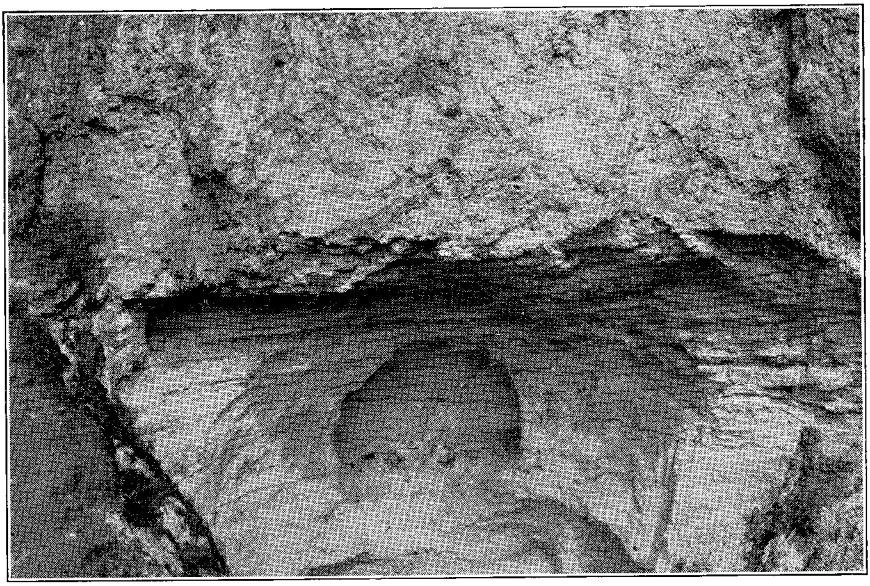
B. Striated cobble from Wicomico gravel. (See p. 59.)



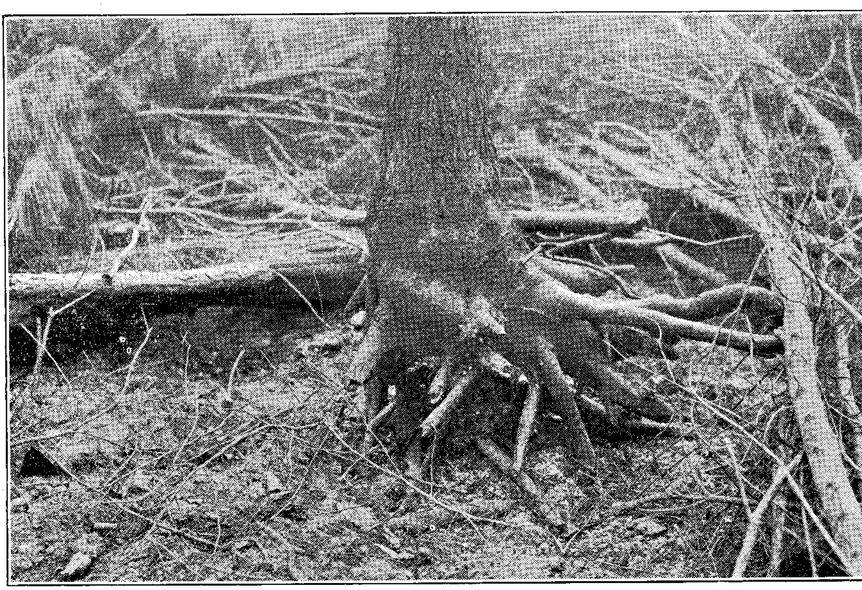
A. Striated cobble from the Wicomico formation. (See p. 59.)



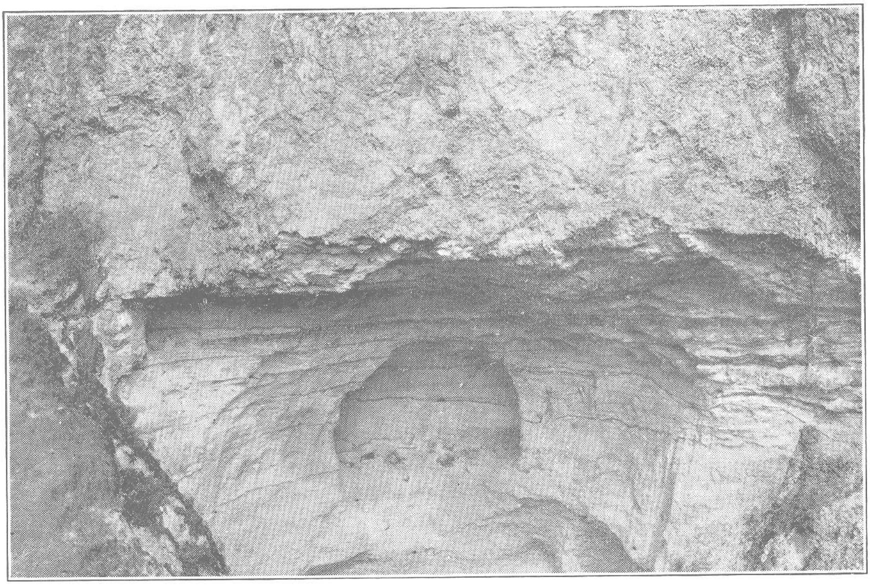
B. Striated cobble from Wicomico gravel. (See p. 59.)



A. Chowan buff loam overlying sand-loam banding and clean sand beds, Southampton County. (See p. 65.)



B. Base of tree about to fall after roots had been burned in peat surface fire, Dismal Swamp, Norfolk County.



A. Chowan buff loam overlying sand-loam banding and clean sand beds, Southampton County. (See p. 65.)

B. Base of tree about to fall after roots had been burned in peat surface fire, Dismal Swamp, Norfolk County.

rocks. The pieces are angular to well rounded. This gravel probably contains several types of natural gravel.

Sample 2063. Recent dune sand. From 1 mile east of Ocean View, Norfolk County.

This is a very well sorted medium sand. See Figure 110. Its composition is similar to sample 2061-B. The finest grades have a much smaller percentage of heavy minerals.

Sample 2065. Recent lag sand. From dune mounds 3 miles east of Ocean View, Norfolk County.

This is moderately well sorted coarse sand. See Figure 111. The coarser grades consist of somewhat smoothed, slightly rounded quartz grains. The finer grades are similar with a very small proportion of heavy grains, chiefly ilmenite.

Sample 2076. Recent dune sand. From point west of Cape Henry, Princess Anne County.

This sand is medium-grained and well sorted. See Figure 112. It is similar in mineral composition to sample 2072-A.

Sample 2074-C. Recent lag sand. Collected from ripple crests, at an elevation of 40 feet, near Cape Henry.

This sand is moderately well sorted and coarse. See Figure 113. It closely resembles sample 2074-A in composition.

Sample 2074-A. Recent dune sand. Vicinity of Cape Henry, Princess Anne County.

This is a rather well sorted medium sand. See Figure 114. The coarser grades consist of moderately rounded quartz grains. In the finer grades there appears progressively a considerable proportion of heavy minerals, with possibly 10 per cent in the plus 1/16 and still more in the minus 1/16 grade.

Sample 2074-B. Recent dune sand. From section of dune near Cape Henry, Princess Anne County.

This sand is slightly less well sorted than sample 2074-A and slightly finer grained. See Figure 115. Its mineral composition is almost identical with sample 2074-A.

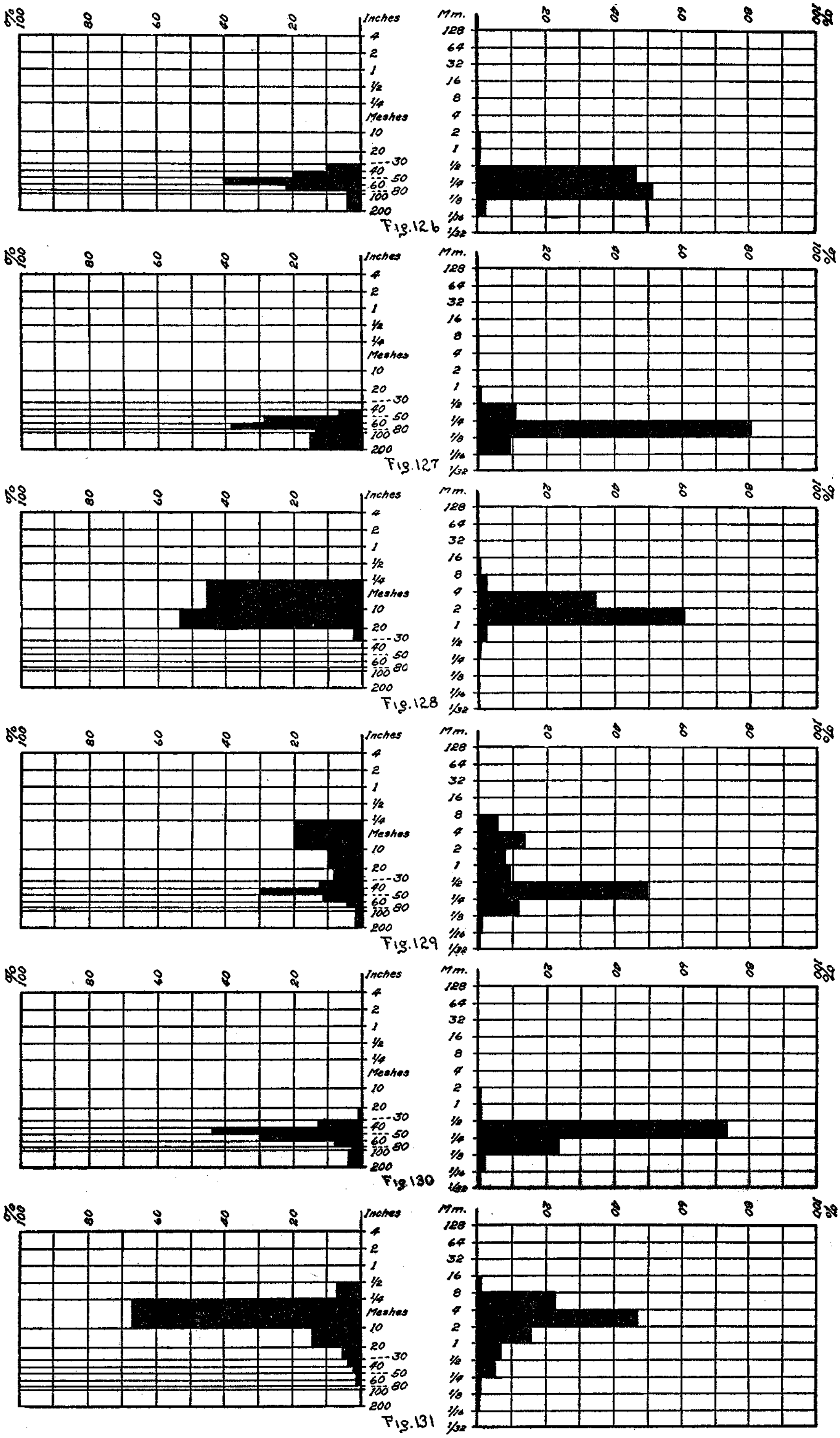
Sample 2072-B. Recent dune sand. One hundred yards inland from the site of sample 2072-A, 4 miles north of Virginia Beach, Princess Anne County.

This is a well-sorted dune sand, slightly finer grained than the beach sand from which it is derived. See Figure 116. It is similar in composition to sample 2072-A.

Sample 1729-A. Recent river sand. From Rappahannock River flood plain at Falmouth, Stafford County.

This is a moderately well sorted coarse sand. See Figure 117. Both the coarse and fine grains consist mainly of quartz, but contain abundant grains of feldspar, mica, hornblende, and various other minerals from granites and schists.

Sample 1729-B. Pebbly river sand. From Rappahannock River bar at Falmouth, Stafford County.



Figures 126-131.—Diagrams showing mechanical composition of Recent deposits. Samples 1579-B, 1579-A, 1749, 1747-A, 1747-C, and 1747-D.

This sample is predominantly a fairly coarse, well-sorted sand, with the plus 2 millimeter grades about 20 per cent. See Figure 118. The pebble grades consist of rough angular fragments of vein quartz, schist, granite, and similar debris. The sand grades are mainly quartz, but contain other granite and schist minerals.

Sample 1729-C. Recent river gravel. From Rappahannock River bar at Falmouth, Stafford County.

This sample is considerably coarser than sample 1729-B. See Figure 119. Its composition is almost the same as that of sample 1729-B.

Sample 1729-D. Recent river gravel. From downstream point of Rappahannock River bar at Falmouth, Stafford County.

In both mechanical and mineralogical composition this sample is similar to sample 1729-C. See Figure 120.

Sample 1543. Recent rill sand. From roadside at an elevation of 100 feet, 2 miles west of Tappahannock, Essex County.

This is a moderately well sorted fine sand. See Figure 121. The coarser grades of this sand consist chiefly of clean, angular and subangular quartz grains. Grades from ¼ millimeter downward carry increasing quantities of heavy minerals, such as ilmenite, zircon, and feldspars.

Sample 1578. Recent rill sand concentrate. From roadside southeast of Dunnsville, Essex County.

This is a well-sorted fine sand. See Figure 122. The coarser grades consist mostly of quartz, but the finer grades contain up to perhaps 75 per cent of heavy minerals, which are chiefly ilmenite.

Sample 1738. Glauconitic sand on modern beach. Derived from shore bluff in Aquia formation 1 mile north of Marlboro Point, Stafford County.

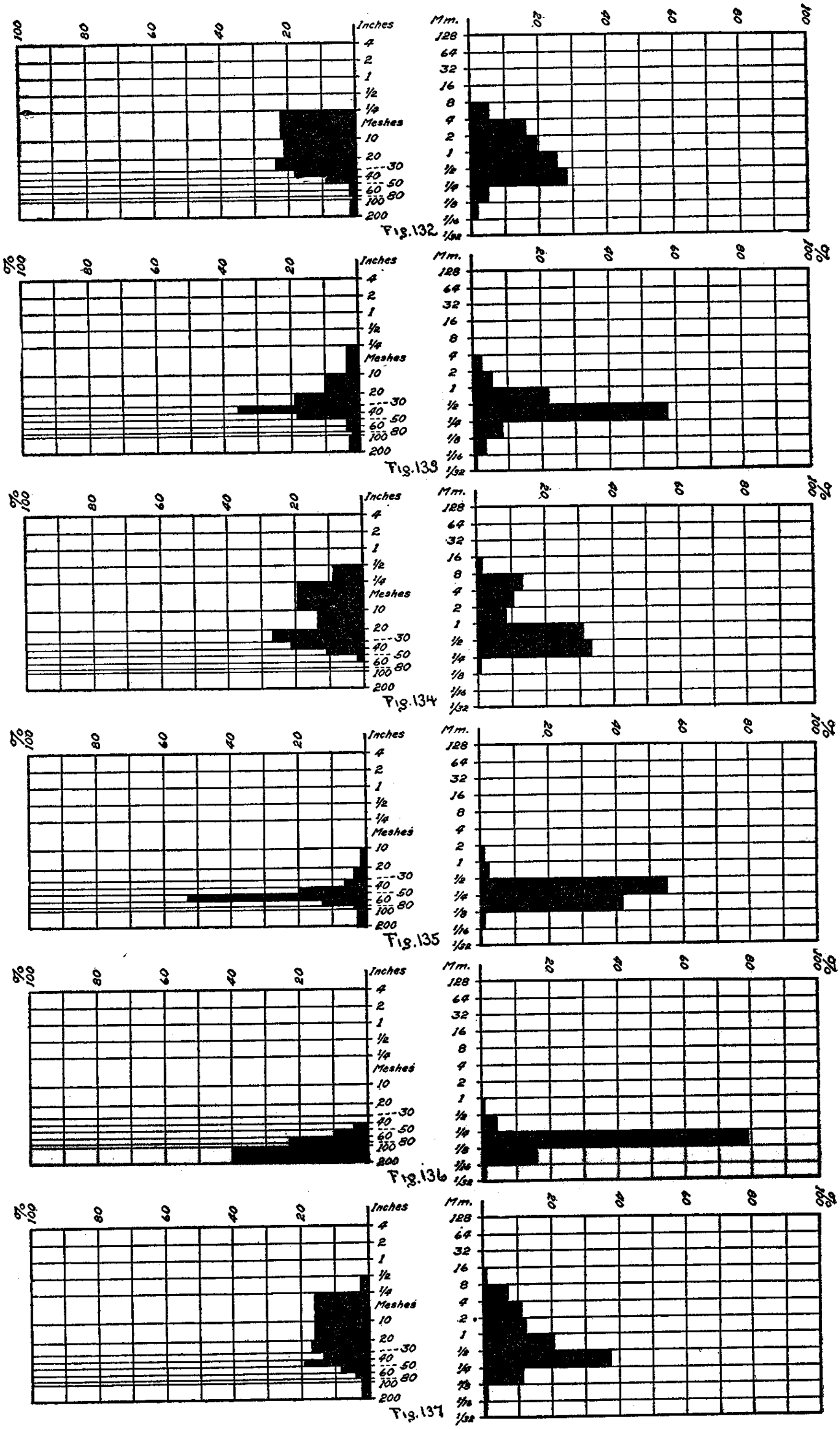
This is a very well sorted medium sand. See Figure 123. The coarser sand grades are composed dominantly of shell fragments, with minor amounts of clear, fairly well rounded quartz grains. The medium grades contain perhaps 30 per cent of botryoidal and mammillary aggregations of glauconite grains, the remainder being chiefly quartz with a few shell fragments. A small proportion of the quartz grains are well rounded and somewhat frosted. The finer grades are similar, but with a few feldspar grains.

Sample 2296. Recent beach sand. From the Potomac shore north of Stratford, Westmoreland County.

This is a well-sorted medium sand. See Figure 124. The sand consists mainly of subangular clear quartz grains. There are a few heavy mineral grains in the finest grades.

Sample 1930-E. Recent beach gravel. From beach 1½ miles southeast of Whitestone Wharf, Lancaster County.

This is a well-sorted fine gravel. See Figure 125. The coarser grades of this gravel consist of moderately rounded, somewhat smoothed, clear, white, yellow and pink quartz fragments and a few gray chert fragments. The sand grades are mostly of clear quartz, with a few shell fragments.



Figures 132-137.—Diagrams showing mechanical composition of Recent deposits. Samples 1950-A, 1950-B, 1951-A, 1951-C, 1799 and 1874-A.

Sample 1579-B. Recent beach sand concentrate. From beach half a mile north of Bowlers Wharf, Essex County.

This sand was collected to show natural sorting. It is a well-sorted fine sand. See Figure 126. The plus ¼ millimeter grades carry not over 10 per cent, and the plus ⅛ millimeter grade probably not over 1 per cent of quartz. The bulk of the sand is ilmenite and other heavy minerals.

Sample 1579-A. Recent beach sand concentrate. From half a mile north of Bowlers Wharf, Essex County.

This is a well-sorted fine sand. See Figure 127. The grades down to ¼ millimeter are dominantly quartz. Those below ¼ millimeter are mainly ilmenite, with small amounts of other heavy minerals. The plus ⅛ millimeter grade is probably more than 90 per cent ilmenite. The plus 1/16 millimeter grade carries less ilmenite, but larger amounts of zircon. The quartz in the plus ¼ millimeter grades is largely due to contamination in collecting. See sample 1579-B.

Sample 1749. Recent beach sand. From a point half a mile east of Grinels Post Office, Middlesex County.

This is a well-sorted pebbly coarse sand. See Figure 128. The coarser grades consist mainly of clear subangular quartz grains, a few chert fragments, shells, and iron crusts. Quartz is the principal constituent in the finer grades.

Sample 1747-A. Recent beach sand. From 6 inches below surface of upper beach, one-third of a mile southwest of Stingray Point, Middlesex County.

This is a fine pebbly sand having a secondary maximum in the plus 2 millimeter grade. See Figure 129. The pebble grades are composed mainly of slightly smoothed subangular quartz and quartzite. A few chert pebbles are present. The plus 1/16 millimeter grade includes nearly 50 per cent of heavy minerals.

Sample 1747-C. Recent beach sand. From one-third of a mile southwest of Stingray Point, Middlesex County.

This sample is a well-sorted medium sand. See Figure 130. Its composition is similar to that of other ocean beach sands of this region.

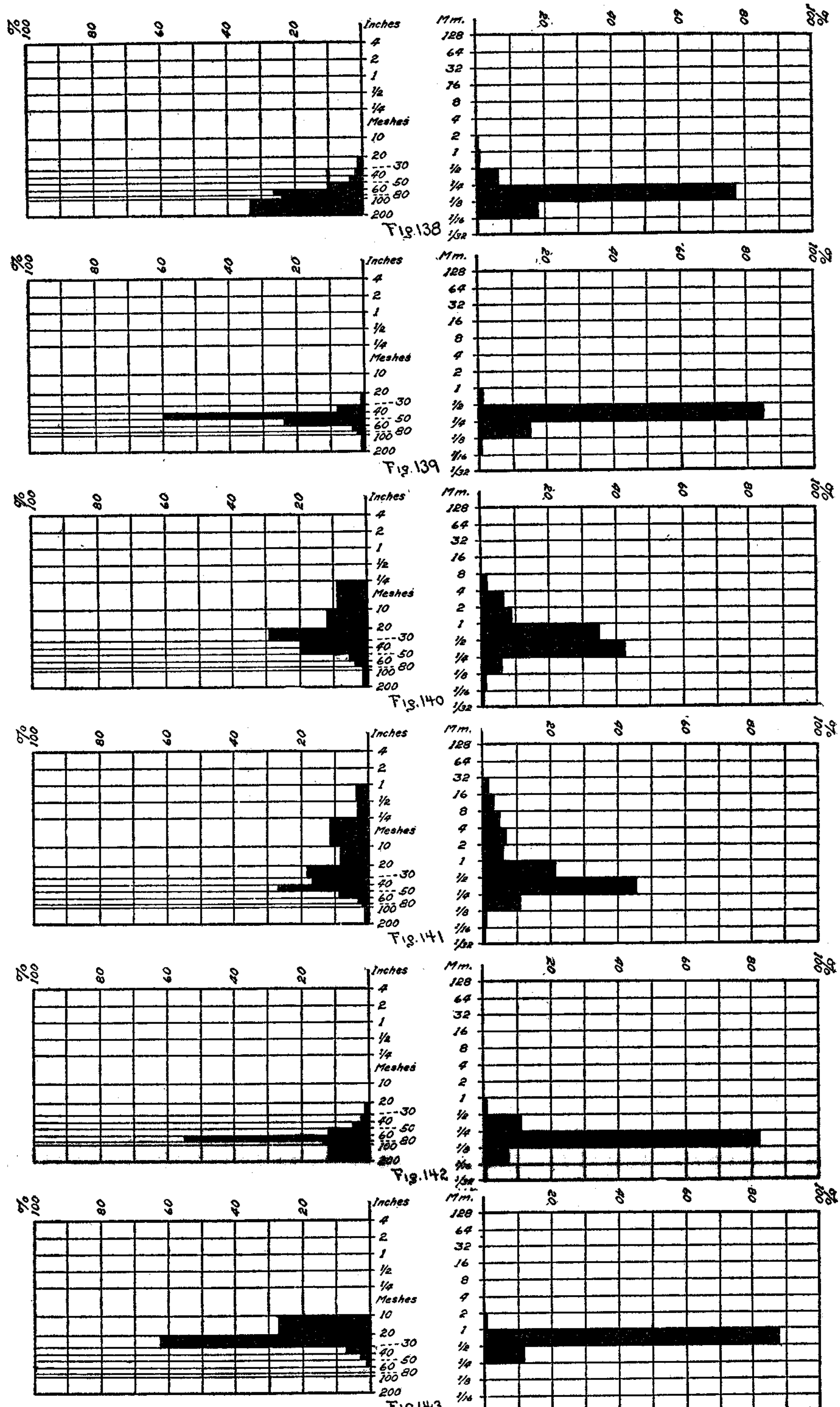
Sample 1747-D. Beach pebbles. From low water beach zone, one-third of a mile southwest of Stingray Point, Middlesex County.

These pebbles are mostly subangular with a few moderately rounded. See Figure 131. They are clean, well smoothed, and consist mainly of vein quartz, with about 1 or 2 per cent of chert.

Sample 1950-A. Recent beach gravel. From upper storm beach where wind has removed some of sand. Half a mile south of Iron Point, Mathews County.

This is a fairly well sorted sandy gravel. See Figure 132. The pebble grades include a few chert fragments and iron crusts, in addition to the dominant white, yellow, and blue quartz grains. The sand grades are mostly angular quartz, with a moderate amount of heavy minerals and some feldspars in the finest grades.

Sample 1950-B. Recent beach sand. From half a mile south of Iron Point, Mathews County.



Figures 138-143.—Diagrams showing mechanical composition of Recent deposits. Samples 1874-B, 1874-C, 1874-D, 1874-E, 2012, and 2061-B.

This is a well-sorted medium sand. See Figure 133. The mineral composition is similar to that of sample 1950-A.

Sample 1951-A. Recent beach gravel. Random sample from upper 1½ feet of beach at north end of Rigby Island, Mathews County.

This is essentially a pebbly sand. See Figure 134. The lithologic composition is similar to sample 1951-B.

Sample 1951-C. Recent beach sand concentrate. From beach near north end of Rigby Island, Mathews County.

This a fairly well sorted fine sand. See Figure 135. Its two coarsest grades consist mainly of clean somewhat smoothed quartz grains. The finer grades are progressively composed of larger proportions of heavy minerals, including ilmenite, magnetite, and zircon. The plus ⅛ millimeter grade contains probably not more than 25 per cent quartz.

Sample 1799. Recent beach sand. From beach half a mile west of Boat Harbor, Newport News, Warwick County.

This sample is a well-sorted fine sand. See Figure 136. Its coarsest grade consists mainly of quartz grains, but the medium and fine grades contain a considerable proportion of heavy minerals.

Sample 1874-A. Recent beach gravel. From ocean beach at Northend Point, Elizabeth City County. This gravel is somewhat concentrated by removal of sand by wind.

This is a moderately well sorted pebbly sand. See Figure 137. The pebble grades consist of slightly rounded, somewhat smoothed, clear, yellow and pink quartz fragments. A few pieces of chert are present. The sand grades are chiefly clear subangular quartz grains, with a moderate amount of heavy mineral grains in the finest grade.

Sample 1874-B. Recent beach sand concentrate. From Northend Point beach, Elizabeth City County.

This is a well-sorted, fine black sand. See Figure 138. The coarsest grades consist mainly of quartz and ilmenite aggregates. The plus ⅛ and plus 1/16 millimeter grades consist almost wholly of ilmenite, with subordinate amounts of other heavy minerals.

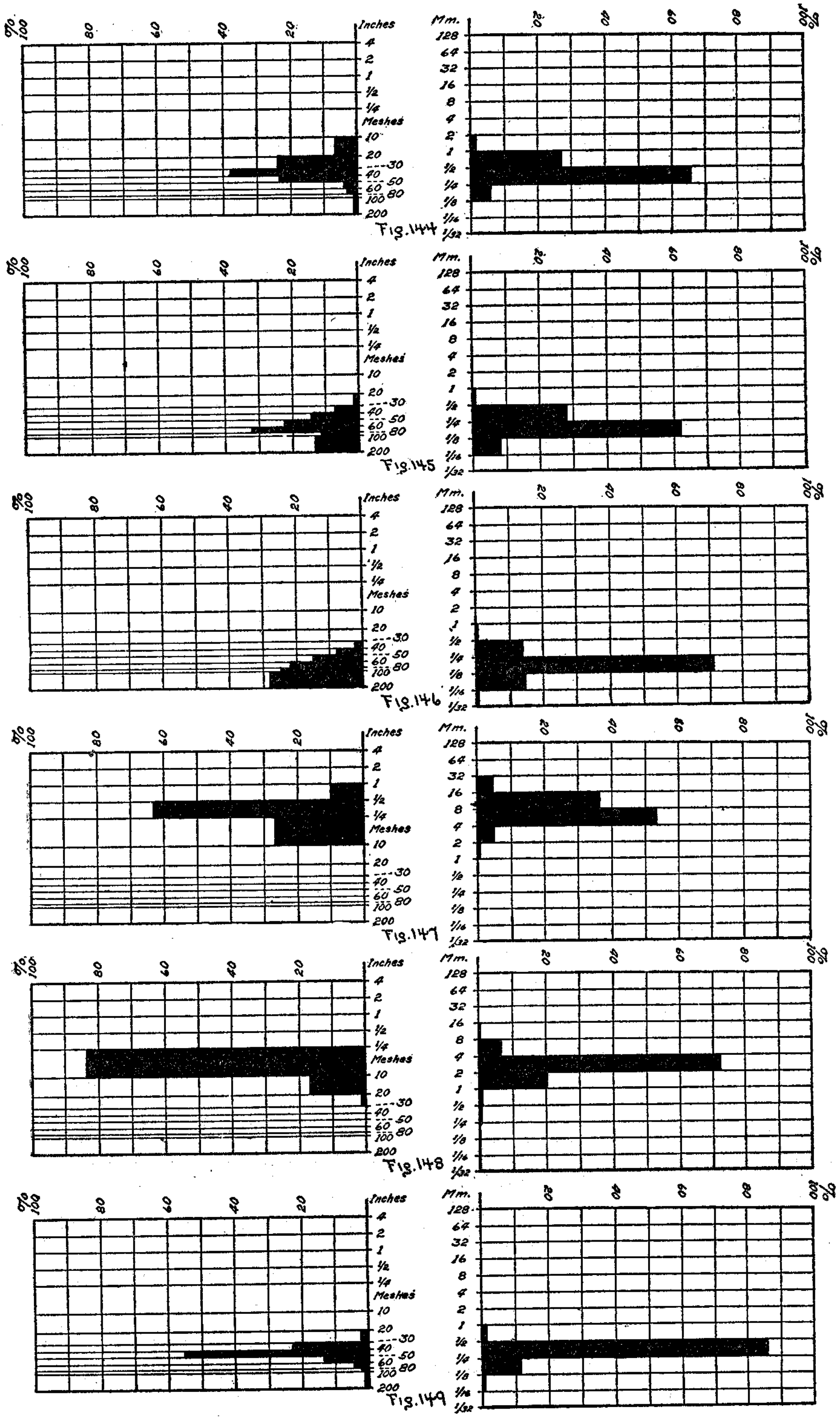
Sample 1874-C. Recent beach sand. Normal sand of beach at Northend Point, Elizabeth City County.

This is an exceptionally well sorted medium sand. See Figure 139. It consists of clear subangular, somewhat smoothed quartz grains, with a few heavy mineral grains in the finest grades.

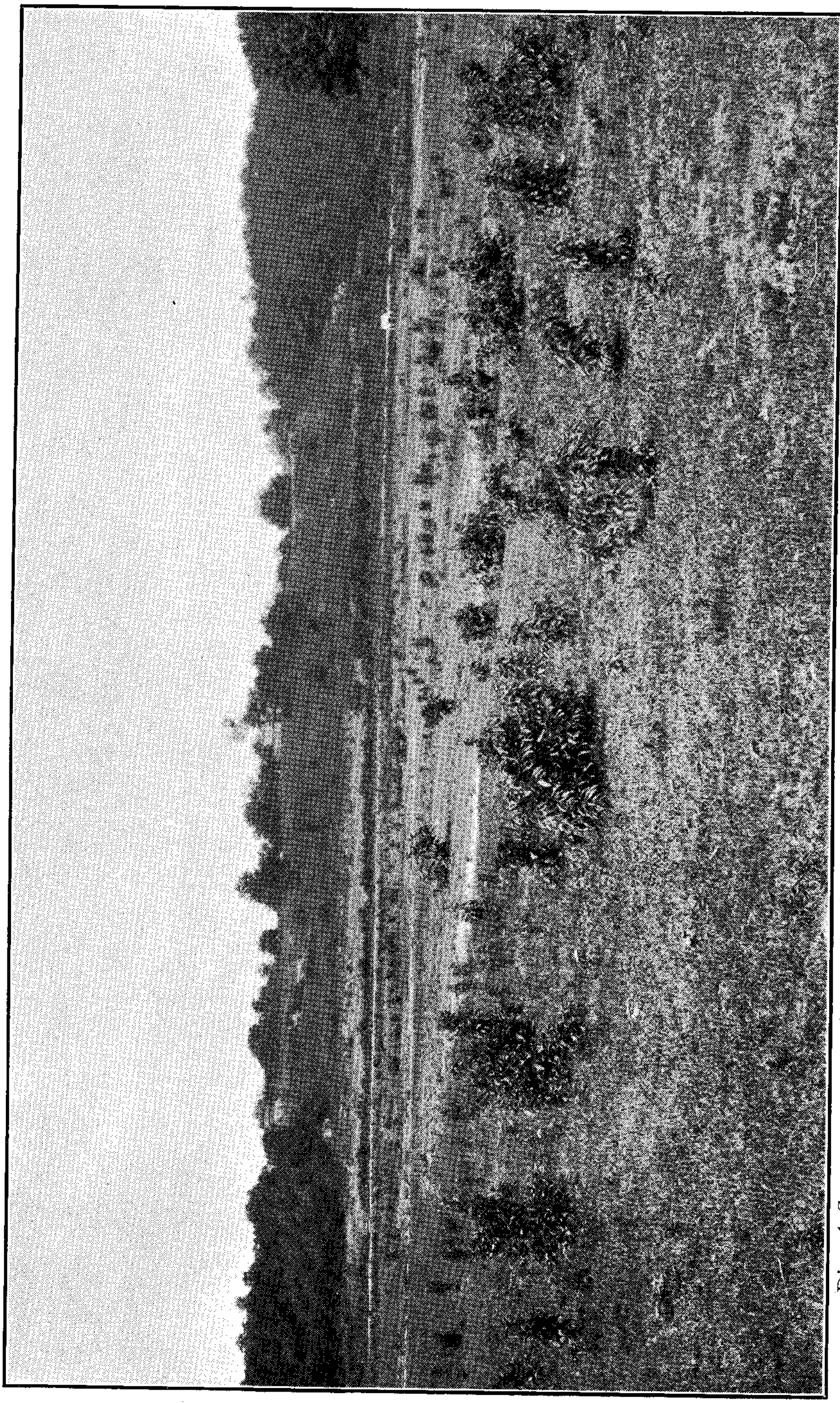
Sample 1874-D. Recent beach sand. From high tide breaker zone, Northend Point beach, Elizabeth City County.

This is a moderately well sorted coarse sand containing a few pebbles. See Figure 140. The composition is similar to that of sample 1874-A.

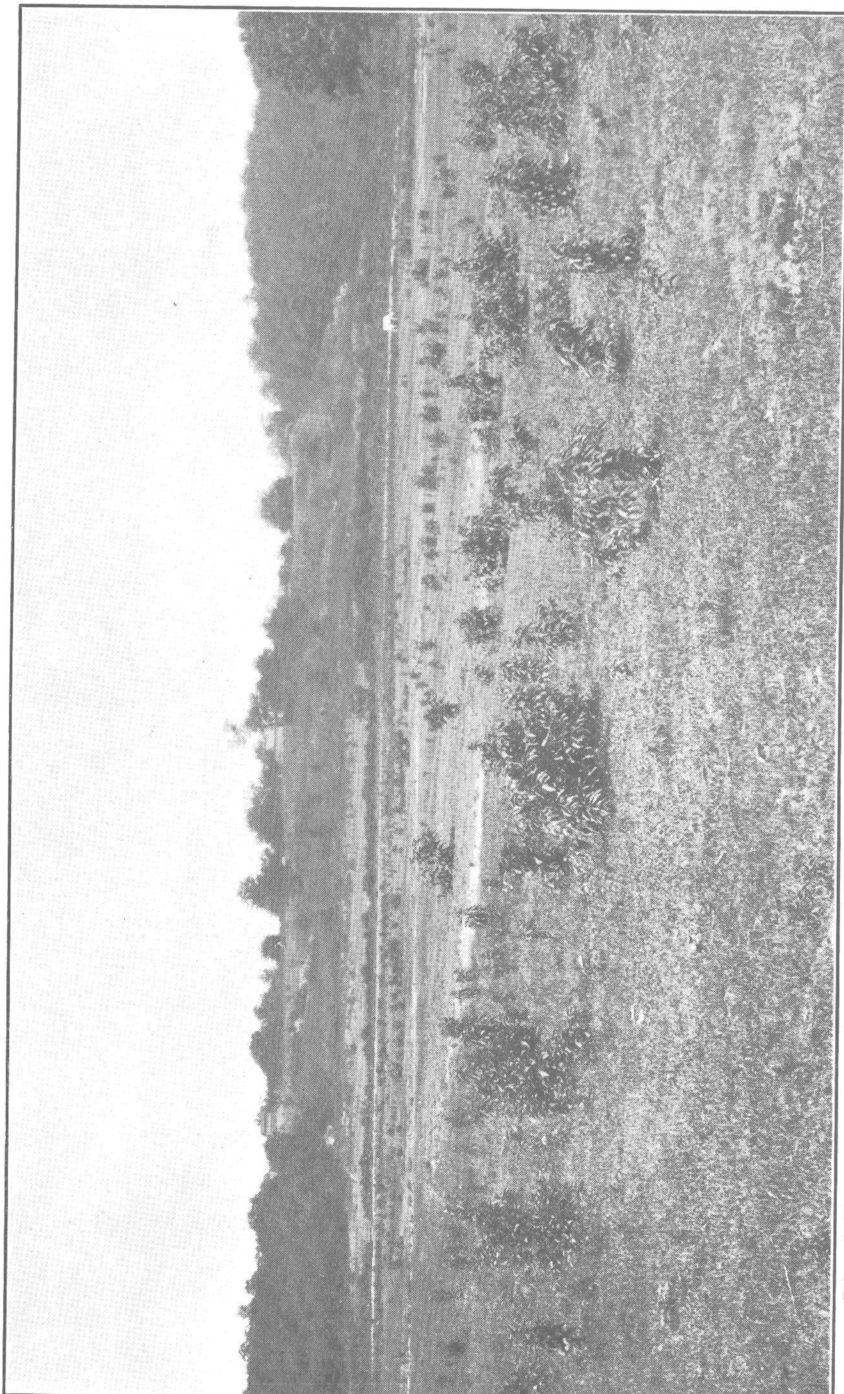
Sample 1874-E. Recent pebbly beach sand. From low water mark on Northend Point beach, Elizabeth City County.



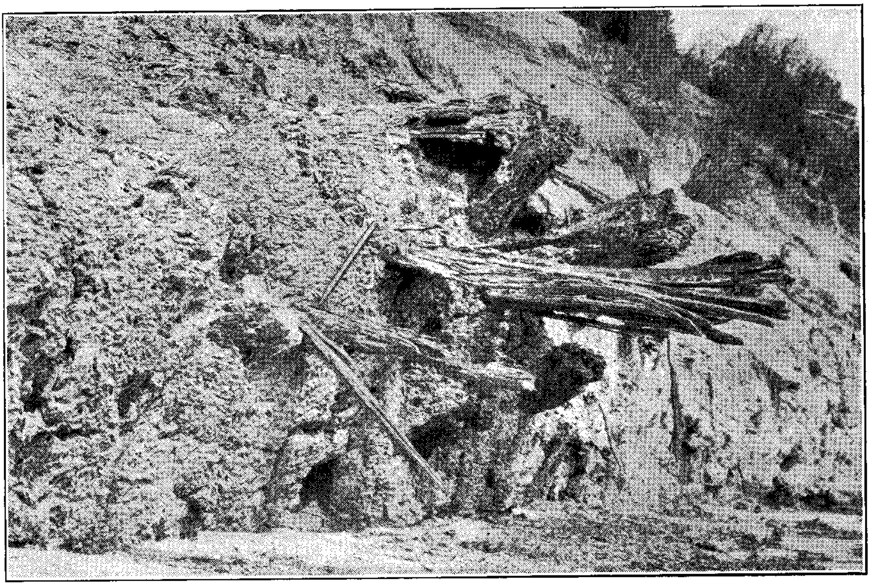
Figures 144-149.—Diagrams showing mechanical composition of Recent deposits. Samples 2072-A, 2075, 2073, 2071-A, 2071-B, and 2071-C.



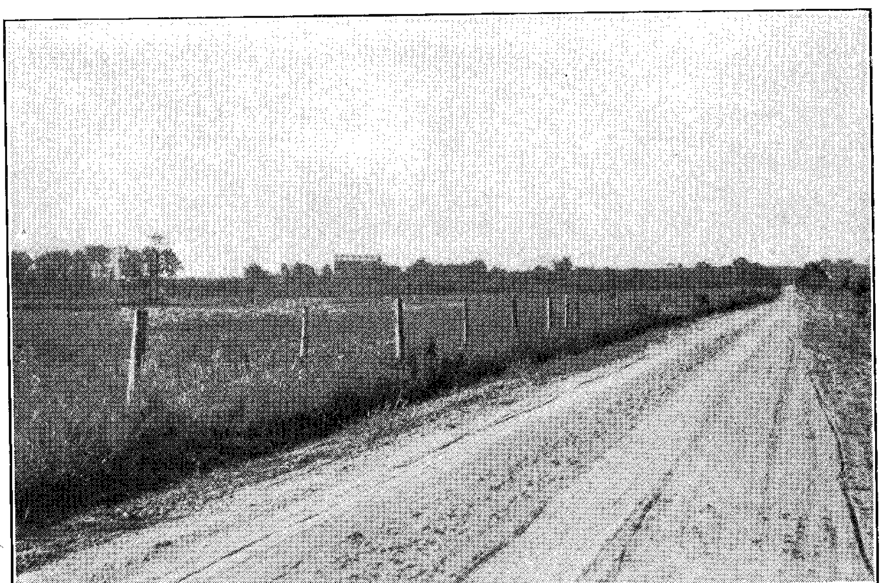
Dismal Swamp terrace and scarp leading to Sunderland level, west of Tappahannock, Essex County. (See p. 69.)



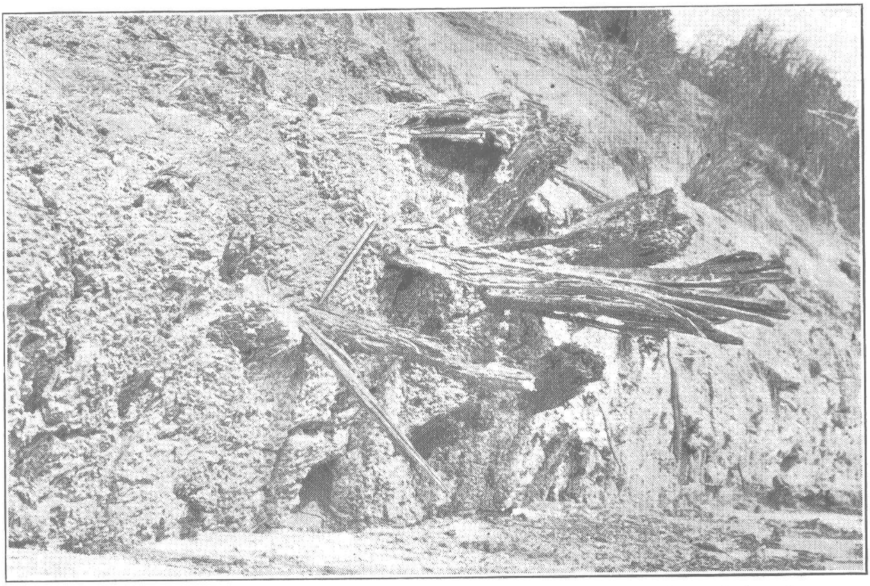
Dismal Swamp terrace and scarp leading to Sunderland level, west of Tappahannock, Essex County. (See p. 69.)



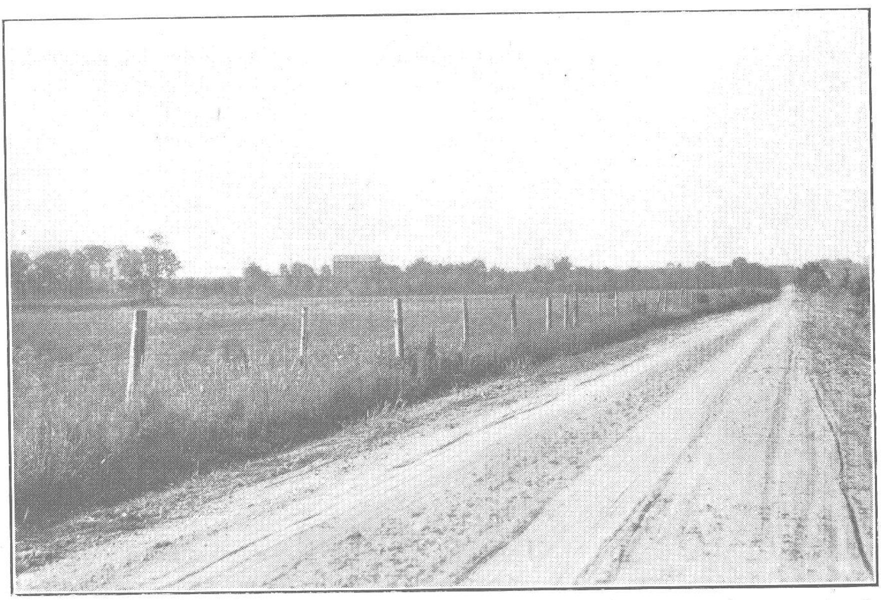
A. Cypress logs in bluff cut in Dismal Swamp formation, 1½ miles southeast of Taft, Lancaster County. (See p. 71.)



B. View over Chowan-Dismal Swamp terrace toward scarp and remnant of Wicomico terrace, 3 miles west of Charles City, Charles City County. (See p. 75.)



A. Cypress logs in bluff cut in Dismal Swamp formation, 1½ miles southeast of Taft, Lancaster County. (See p. 71.)



B. View over Chowan-Dismal Swamp terrace toward scarp and remnant of Wicomico terrace, 3 miles west of Charles City, Charles City County. (See p. 75.)

This is a moderately well sorted medium sand containing a few pebbles. See Figure 141. The composition is similar to that of sample 1874-A.

Sample 2012. Recent beach sand concentrate. From beach at Jamestown, James City County.

This is a well-sorted fine sand. See Figure 142. The plus ¼ millimeter grades of this sand consist largely of quartz grains, mainly angular and iron stained. The minus ¼ millimeter grades are composed almost wholly of heavy minerals, of which ilmenite is the most abundant constituent.

Sample 1956. Recent gravel. From depth of 3 feet on shoal above lighthouse off Fergusons Wharf, Isle of Wight County.

This sample consists almost wholly of entire and broken oyster shells showing considerable wear and rounding. This material contains a few rock fragments but almost no sand or finer material.

Sample 2061-B. Recent beach sand. From west end of Willoughby Beach, Norfolk County.

This is an exceptionally well sorted coarse sand. See Figure 143. It consists chiefly of angular and subangular, slightly smoothed quartz grains. Most of the grains are clear and colorless, but a few are yellow or pink. A trace found in the plus ⅛ millimeter grade is more than 50 per cent heavy minerals, including magnetite, garnet, and ilmenite.

Sample 2072-A. Recent beach sand. From a point 4 miles north of Virginia Beach, Princess Anne County.

This is a well-sorted medium sand. See Figure 144. It consists chiefly of moderately rounded, somewhat polished, grains of clear, white, yellow, and brown quartz. The finest grade contains a considerable proportion of other minerals, including zircon, feldspar, and hornblende. This is a typical beach sand of this region. See sample 2072-B.

Sample 2075. Recent beach sand. From beach 1 mile west of Cape Henry, Princess Anne County.

This is a fine-grained, well-sorted sand. See Figure 145. It is composed mainly of slightly rounded, clean quartz grains. A small percentage of dark, heavy minerals is found in the finest grade.

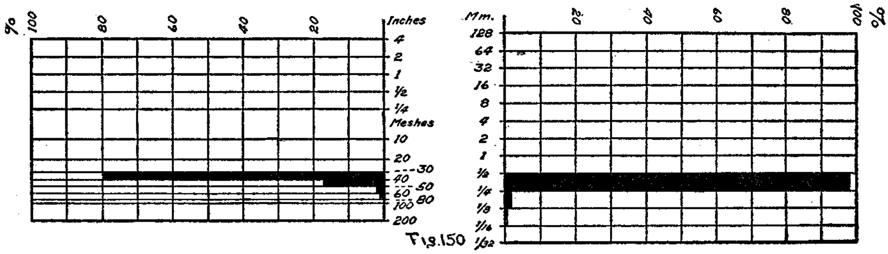
Sample 2073. Recent beach sand. From beach north of Cape Henry lighthouse, Princess Anne County.

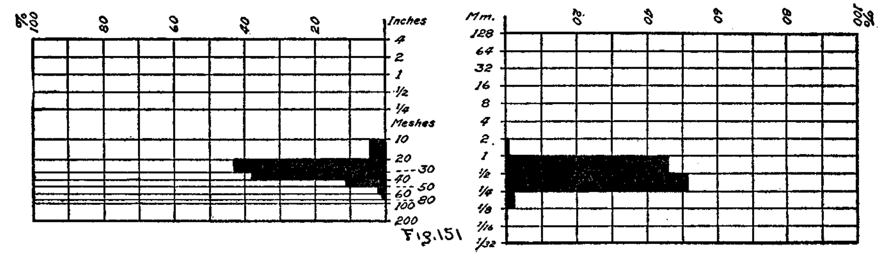
This is a well-sorted fine sand. See Figure 146. Its finer grades carry increasing quantities of heavy minerals, the minus 1/16 millimeter grade containing not more than 25 per cent of quartz.

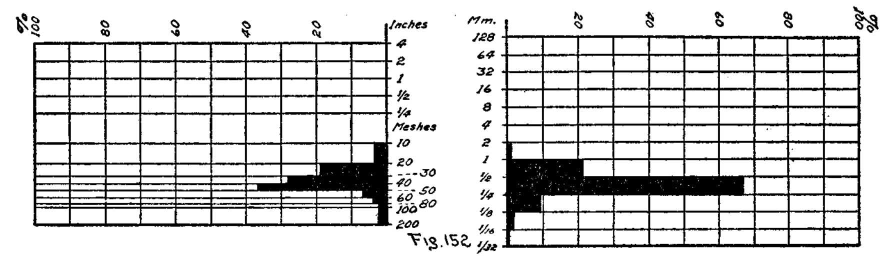
Sample 2071-A. Beach gravel. From beach surface at low water zone, 2 miles north of Virginia Beach, Princess Anne County.

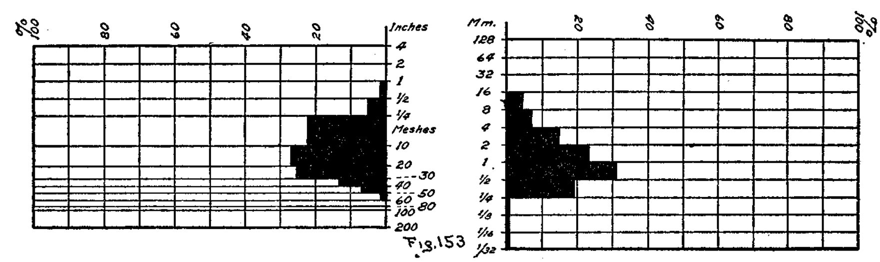
This gravel is well sorted and consists of about 20 per cent each of shell fragments and chert pebbles. The remainder is well-rounded to angular clean white vein quartz and dark brown quartz and quartzite pebbles. See Figure 147.

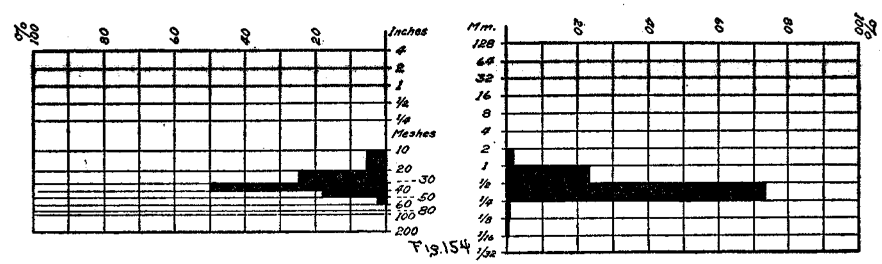
Sample 2071-B. Recent lag gravel. From upper beach back of storm crests 2 miles north of Virginia Beach, Princess Anne County.











Figures 150-154.—Diagrams showing mechanical composition of Recent deposits. Samples 2254-B, 2277-B, 2288, 2286-B, and 2286-A.

This is a well-sorted fine gravel. See Figure 148. Its coarser grades carry a considerable percentage of shell fragments. Splinters of shells appear in all the grades. The bulk of the material of the more abundant grades consists of a heterogeneous mixture of well-rounded to angular fragments of white to dark brown quartz, with a few fragments of chert.

Sample 2071-C. Recent beach sand. From 2 miles north of Virginia Beach, Princess Anne County.

This is an exceptionally well sorted medium sand. See Figure 149. It is similar in mineral composition to sample 2072-A.

Sample 2254-B. Recent beach sand. From beach 1 mile south of Kiptopeke, Northampton County.

This is a remarkably well sorted sand, 98 per cent being in the medium sand grade, ¼ to ½ millimeter. See Figure 150. The mineral composition is similar to that of sample 2254-A.

Sample 2277-B. Modern beach sand. From Battle Point, Northampton County.

This is a moderately well sorted coarse sand. See Figure 151. Besides the dominant well polished, slightly rounded quartz grains, there is a moderate amount of heavy mineral grains in the finest grades.

Sample 2288. Modern beach sand. Commercial pile sample from Fishing Point, Assateague Island, Accomac County.

This is a fairly well sorted medium sand. See Figure 152. The coarsest grades are mainly quartz grains, with a few shell fragments. A considerable percentage of heavy mineral grains is found in the finest grades.

Sample 2286-B. Recent lag gravel. From shore flat on Bailey's Neck, Accomac County.

This is a fairly well sorted sandy gravel. See Figure 153. The pebble grades consist in part of very well rounded, somewhat lozenge-shaped, quartz pebbles, and in part of angular fragments of chert, iron crusts, quartz, etc. The sand grades are similar to those of sample 2277-B.

Sample 2286-A. Recent beach sand. From shore of Bailey's Neck, Accomac County.

This sample is a well-sorted medium sand. See Figure 154. The mineral composition is similar to that of sample 2277-B.

GEOLOGIC HISTORY OF THE TERRACES

STATEMENT OF PROBLEM

The Coastal Plain terraces have been interpreted as of marine origin and of fluviatile origin. Some, especially Shattuck[43] in his studies of the Maryland terraces, have considered the entire series to be the result of successive marine invasions, each of less extent than the preceding one, with each terrace indicating the net change of sea-level. Others, especially Salisbury,[44] who studied the terraces of New Jersey, have considered many, if not all, the formations to be parts of great alluvial fans built out over the low-lying lands east of the Fall Belt by heavily laden streams which were aggrading their shifting channels. During study of the terraces and gravel formations of this region for several years, it has become apparent to the writer and to others that neither hypothesis may be applied alone to the origin of these terrace formations. Field study shows that terraces along the seaward margin of the Coastal Plain are so related to the present coast line, and show so clearly wave-cut features that they must be regarded as of very recent marine origin. Contrariwise, there are many inland terraces whose position, form, and materials prove that they are of fluvial origin.

It is evident that both types were formed contemporaneously in appropriate situations. Hence, one must be on guard to recognize the transition between marine and fluviatile terraces and formations. Virginia is in a peculiarly favorable location for such discrimination. It is believed that most of the terrace surface in the northern part of the State is of fluvial origin and that most of it in the southern part is of marine origin. In Virginia the marine terraces extend gradually farther inland to the south. These conditions enable one to elaborate the criteria by which the marine and fluviatile terraces may be separated. These criteria are outlined below.

SEPARATION OF MARINE AND FLUVIATILE TERRACES

It will be necessary in this paper to use the terms marine and fluviatile somewhat arbitrarily and to draw the line between the two types of processes and products as distinctly as possible where there is the greatest break in the coordinate series. There is a

43 Shattuck, G. B., op. cit.

44 Salisbury, R. D., The Quaternary formations of southern New Jersey: New Jersey Dept. of Conservation and Development, vol. 8, 218 pp., 1917.

very gradual transition from purely marine to purely fluviatile conditions across an embayed coastal plain, as in Virginia. Salt water extends, with decreasing salinity, far into the drowned channels of the tributaries of Chesapeake Bay. It has been shown previously that in the tidal channels the movement of seawater is far more important quantitatively than the seaward flow of land water. (See pp. 19-21.) This indicates that the upstream movement of water is nearly as important as the seaward flow. At the broad mouths of such streams as Potomac River, shore features, either beaches or cut bluffs, and the bottom are being modified almost wholly by waves rather than by shore currents. The cross profiles of most of the streams, the bottom materials, and the movement of water in the channels show (1) a preponderance of longitudinal current work, mostly by tidal forces, in the central deeper channels and (2) a dominance of wave work along the shelving shores, whether flanked by high bluffs or low sandy beaches. Wave work dominates over river work at the shore and foot of the shore bluffs in the present Potomac River upstream to Georgetown. Thus it appears that whereas fluvial processes may extend in mid-channel far downstream into the tidal part of a river, wave action on the shores and shallower bottom extends inland to the head of tidewater.

The scarcity of fossils makes paleontologic discrimination of marine and fluviatile terrace deposits impracticable. Hence they must be distinguished by topographic form and position and the character of the formations. The writer believes from observation of modern processes, terraces, and deposits in these estuaries that wherever wave work dominates in shaping the shore cliff and in making a built terrace, the resultant topography and deposits are more closely related to marine than to fluvial conditions. He believes also that the most significant break in physical conditions, assuming that only one break is to be recognized, comes at or very near the head of tidewater and that the chief discrimination should be made between fluvial and "standing water" conditions and deposits.

More detailed study of the formations, as well as more intimate knowledge of present conditions, would permit a more graded and less arbitrary consideration of the transitional embayed zone where fluviatile and marine processes mingle. Inasmuch as terrace deposits rather than deep channel deposits dominate at present, as well as in the deposits of each past epoch, the characteristics of the terraces must be used largely in interpreting the geologic history of the region. Use of these criteria places the line of demarcation at the head of tidewater. For greater simplicity and brevity the term marine in this report will henceforth include the whole embayed realm in which tidal fluctuation is or has been felt.

PHYSIOGRAPHIC CRITERIA

Marine terraces commonly have a gentle seaward slope from a distinct wave-cut cliff. The horizontal plan of this cliff may be of two kinds. If the cliff has been formed wholly by marine agents it will be straight or gently curved with the smooth outlines characteristic of shore features. If slight sapping by waves has sharpened and modified a cliff previously formed by stream erosion and since drowned, the wave-cut cliff will retain, for a long time, the broad outlines of the river-formed scar. The surface of the bench in this case, instead of having a gentle seaward slope, may show alternating bars and sloughs like those of river flood plains. Bars, spits, and barriers showing characteristic shore relationships will be associated with marine cliffs and terraces.

River terraces, as considered in this report, are of two kinds: (1) The alluvial fan surface which is not necessarily limited by a cliff at its inland margin, and (2) the flood-plain terrace which has its broader outlines formed by stream erosion, but is considerably modified by the deposition of sediments. The alluvial fan terrace in this region has a seaward slope of 1 to 2 feet a mile, this being the original slope of deposition. Its upper surface is not flat, because it had variations in elevation which, in some places, amounted to 10 to 20 feet, due to cutting and filling as the stream channel migrated across its surface. Typically, such a fan is a low-angle cone with appreciable lateral as well as seaward slopes. Adjacent fans, however, merge, as in the cases being considered, to form a nearly continuous alluvial plain of more or less uniform slope.

Flood plain terraces have seaward slopes similar to those of alluvial fans. Their horizontal patterns are generally distinctive. In general, they are parallel to and adjacent to stream courses, which gives them a linear arrangement. In detail, their boundaries are largely meander curves, each of which is successively cut off by later meanders. The landward boundary is concave toward the terrace and the streamward boundary, if sharp, is convex toward the terrace. The surfaces of many flood plain terraces have sloughs and bars with meander patterns, some of which are shown on contour maps but on most maps they are indicated only by the courses of minor streams, the outlines of marshes, or contrasts in the vegetation.

The most conclusive evidence of the fluvial origin of a terrace is, perhaps, an island of high land, which has been developed as a terrace, enclosed within a cut-off ox-bow. The significance of this feature and the conclusion that the ox-bow could be cut off only in a stream above sea-level have recently been described by Campbell.[45]

PETROGRAPHIC CRITERIA

The features by which rocks may be interpreted are of three orders of magnitude, namely, microscopic, megascopic, and formational. Some rocks may be identified and their origins determined by microscopic examination alone, whereas others must be considered as formations before even the elements of their history can be told. The gravels and sands of the coastal-plain terraces are in general so similar that the fluvial and marine phases can not commonly be separated with confidence by examination of small units. Although, in some instances, this can be done, in others the characters are so indefinite that even in extensive exposures no conclusion can be reached in the light of present knowledge.

Nevertheless, viewing the formations in a broad way, there are fairly constant and definable differences in petrographic character between the higher and landward terraces on the one hand and the lower and coastward terraces on the other. Perhaps the most important of these differences is that of mechanical composition. The typical fluvial material is a poorly sorted pebble-bearing loam which consists of material ranging from fine clay particles through the silt and sand grades to cobbles of moderate size. There is commonly a maximum grade in the sand grades and another in the gravel grades. These maxima are four or five grades apart and they do not, as a rule, exceed 20 per cent each in amount. As many as 9 or 10 grades commonly contain 2 or 3 per cent each. The fluvial gravels contain, in places, exceptionally large boulders, up to 3 feet or more in diameter. These boulders can scarcely be considered as part of the normal composition though, in some cases, they grade into the upper limit of the other cobbles.

In contrast to the fluvial gravels, the marine materials are much better sorted. In some cases they also have two maxima, but with a much smaller percentage of clay and silt or larger pebbles. In other cases the marine materials in a given stratum consist of clean sand or gravel, with from 50 to 90 per cent in one grade. The marine and fluvial materials are by no means so sharply separated everywhere as the types described above; rather they grade into each other locally, so that it is commonly difficult to distinguish them in a single exposure.

45 Campbell, M. R., Meaning of meanders in tidal streams: Geol. Soc. America Bull., vol. 38, pp. 537-555, 1927.

There is no essential difference in the lithologic and mineralogic composition of the sediments of the fluvial and marine terraces. The most important distinction is the more common lack of a fine matrix and the lack of ferruginous and kaolinitic material in the marine sediments. The fluvial materials with a fine matrix are generally buff to dark red, whereas the marine materials vary from white to cream or yellow because of slight ferruginous coatings on the grains. Clay beds associated with the marine formations are generally cream-colored or gray, except where much organic material makes them black.

The fragments in the marine beds are commonly cleaner, lighter colored and smoother, even somewhat polished, as compared with those in the fluvial formations. There is little, if any, difference in rounding, although because of their cleaner, smoother appearance, one gains the impression that the marine materials are better rounded.

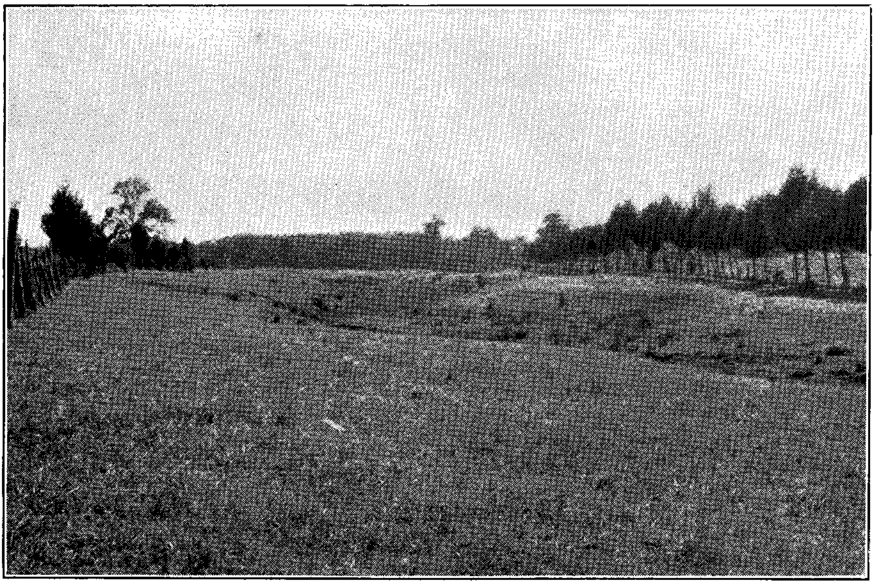
There are some general differences in the structure and bedding of the two types. The marine beds are more sharply defined, with more abrupt changes in coarseness and with steeper and more sharply truncated cross-bedding. The cobbles and pebbles in the marine beds are commonly in contact and, where present, they make up a larger part of the deposit. The fluviatile formations often appear massive, almost till-like, with the pebbles and cobbles scattered throughout the loam matrix or only rudely concentrated string-like in certain zones. Well-defined gravel beds are found in places, but, on the whole, the massive loam with scattered pebbles and strings of pebbles is more abundant and typical. The beds, indicated by the strings of pebbles and other slight contrasts in composition, are thicker and more lenticular than beds of the marine deposits. Cross-bedding in fluvial deposits consists of lenticular bedding, channel filling, etc., instead of the well-marked marine cross-bedding described above.

ORIGIN OF THE TERRACES

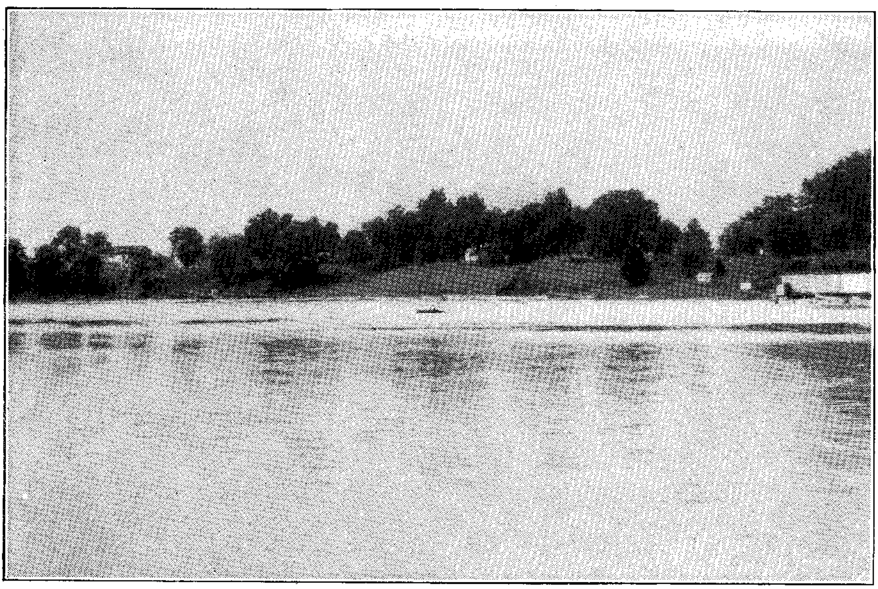
In applying these considerations the following conclusions are reached for the Coastal Plain of Virginia:

Brandywine terrace.—The entire Brandywine formation and other pre-Sunderland terrace formations which have been included with it, are of fluvial origin, being mainly of the alluvial fan type.

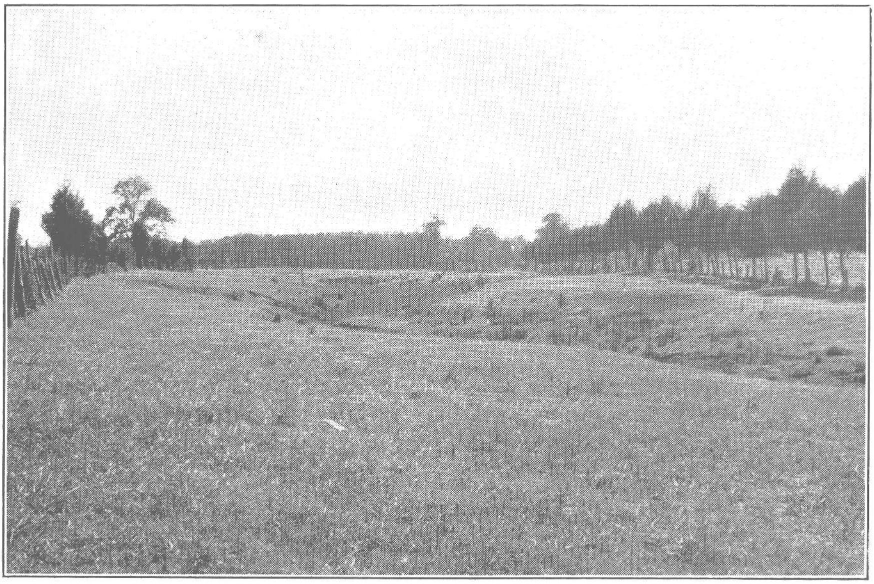
Sunderland terrace.—The Sunderland terrace and most of the formation are of fluvial origin. The only exception is that part lying generally below an elevation of 50 feet and within 10 to 15 miles of the present eastern edge of the formation, which appears



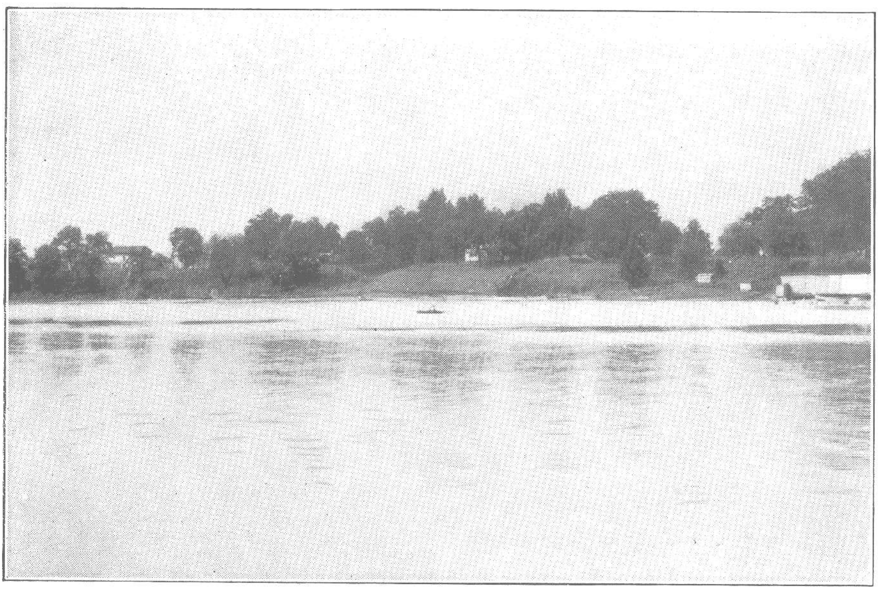
A. Small recent valley cut in surface of Chowan-Dismal Swamp terrace north of Lester Manor, King William County. (See p. 75.)



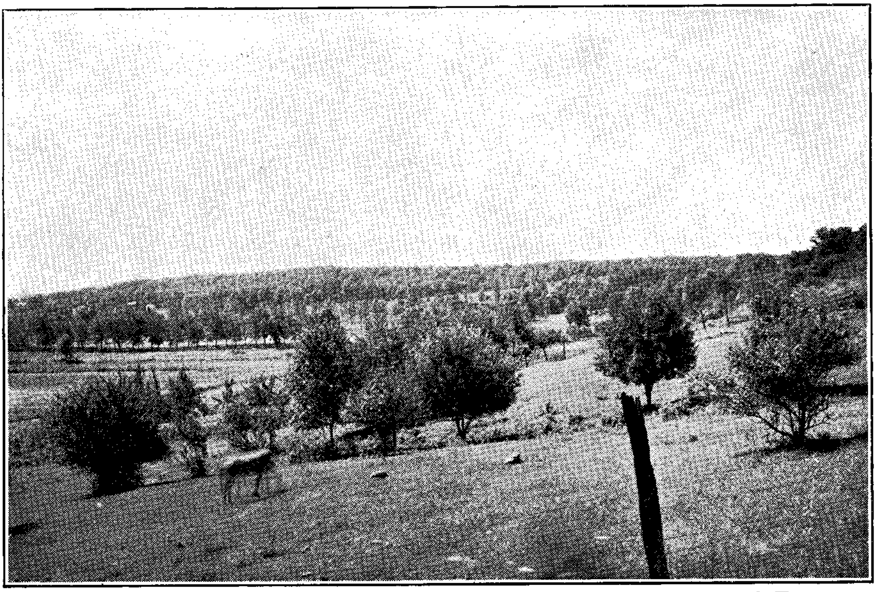
B. Chowan-Dismal Swamp terrace opposite Port Conway on Rappahannock River, Caroline County. (See p. 75.)



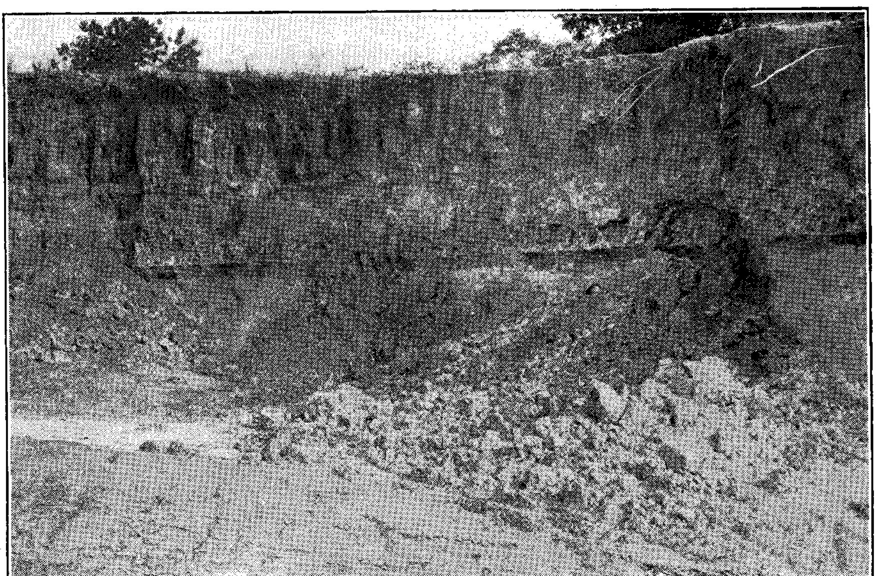
A. Small recent valley cut in surface of Chowan-Dismal Swamp terrace north of Lester Manor, King William County. (See p. 75.)



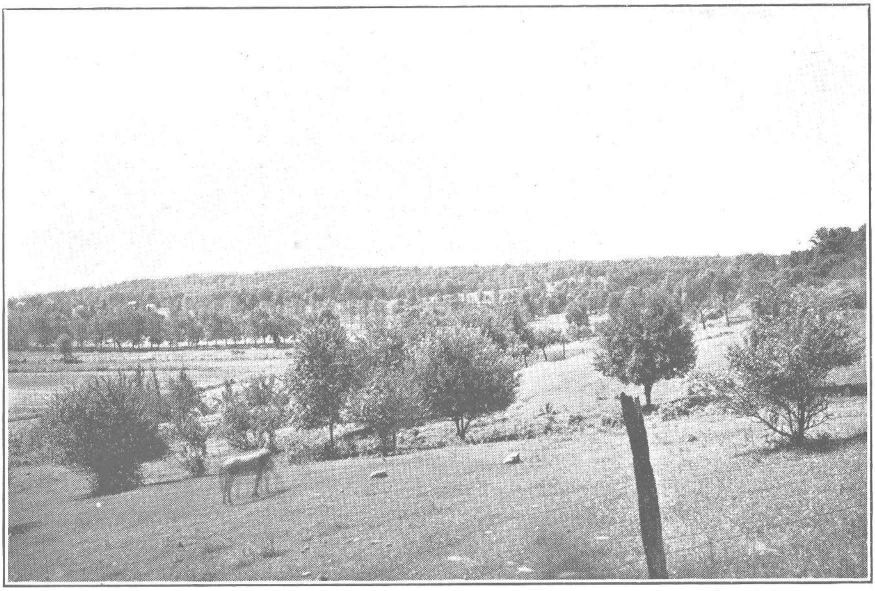
B. Chowan-Dismal Swamp terrace opposite Port Conway on Rappahannock River, Caroline County. (See p. 75.)



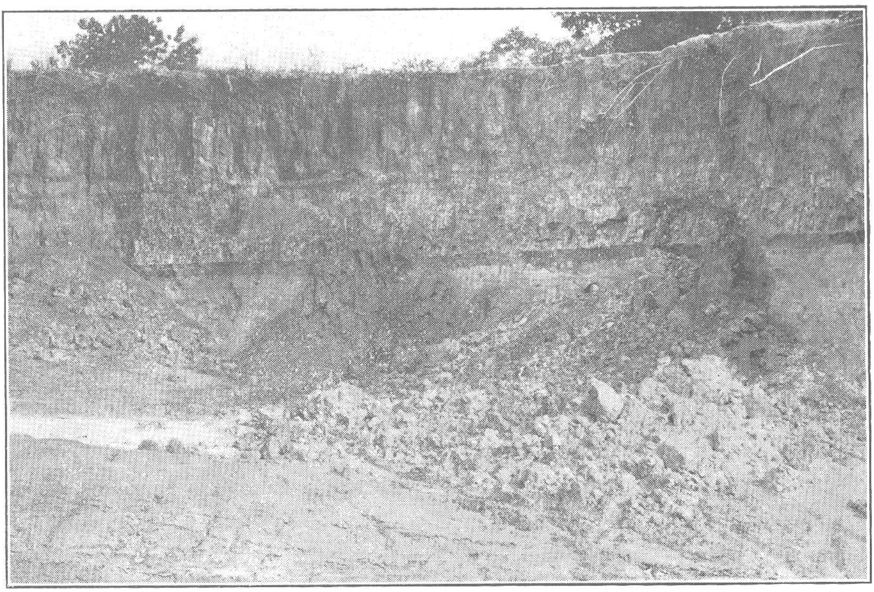
A. Chowan-Dismal Swamp terrace and ox-bow scarp south of East Arlington, Arlington County. (See p. 75.)



B. Chowan-Dismal Swamp formation at West Point, King William County. (See p. 77.)



A. Chowan-Dismal Swamp terrace and ox-bow scarp south of East Arlington, Arlington County. (See p. 75.)



B. Chowan-Dismal Swamp formation at West Point, King William County. (See p. 77.)

to be of marine origin. This basal part of the formation is overlain by 30 to 50 feet of typical fluvial Sunderland material. Inland from this marginal belt the entire formation, so far as known, is of fluvial origin.

Wicomico terrace.—The greater part of the Wicomico formation in Virginia is of marine origin. This includes the entire terrace east of the marine scarp which extends in a nearly straight line from Kilmarnock, Lancaster County, to Boykins, Southampton County. A few small areas of fluvial Wicomico terrace are found along the James, the Potomac, and other rivers which cross the Coastal Plain. Their typical fluvial patterns are shown in Figure 24 (p. 46).

Chowan and Dismal Swamp terraces.—The true relations between the Chowan and Dismal Swamp terraces are not yet known. As correlated with the type area, remnants of Chowan fluvial terrace and gravel are numerous along Blackwater, Nottoway, and Meherrin rivers. Similar remnants are abundant along rivers farther north. If marine areas of Chowan be present along the Virginia coast, they are very small, having been largely cut away in the development of the Dismal Swamp terrace. Fluvial terraces of Dismal Swamp age are well developed along several of the principal streams. Marine Dismal Swamp terrace forms the larger part of the land area east of the Suffolk scarp. Considerable areas of fluvial terrace formations, which are clearly either Chowan or Dismal Swamp, but which can not be discriminated with confidence, are known in the upper parts of valleys. Some of the Dismal Swamp terrace remnants in the lower parts of the tidal channels are of marine origin.

Princess Anne terrace.—The larger part of the Princess Anne terrace adjacent to Chesapeake Bay is composed of marine sand and gravel. Marine Princess Anne terrace remnants are numerous along the deeper tidal channels, and fluvial remnants of this terrace extend considerably farther upstream. (See Figure 22.)

SEQUENCE OF POST-MIOCENE EVENTS

LATE TERTIARY EROSION

Following the deposition of the youngest marine Miocene formations the Coastal Plain was uplifted and subjected to long-sustained erosion. Little is known of the arrangement of drainage lines at this time. There is no evidence that the Potomac or any other river had cut a valley through any of the Tertiary formations to a depth below the general level on which the terrace gravels were deposited. The drainage lines of the Coastal Plain are believed to have been formed after the close of Miocene time.

During the period of erosion which followed the uplift of the Miocene formations, the Coastal Plain was reduced to a surface of low relief which is now preserved in a few places beneath the gravels of the Brandywine fan. This surface was separated from the surface of the Piedmont Plateau by a Fall Belt somewhat less pronounced than at present. The surface of the Piedmont Plateau, at that time, was similar to the present surface except that 100 feet of the larger valleys, the deep trenches of the tributary streams, and the narrow gorges of the master streams in the Fall Belt, had not yet been cut.

The land area of the Coastal Plain probably did not extend farther east than, and possibly not so far as, the present coast. After this surface of low relief had been produced, there was apparently a long period during which streams were sluggish and the products of weathering accumulated over much of the area.

BRANDYWINE STAGE

Cause of Fan Building

This time of the dominance of weathering over transportation was brought to a close by events which commenced the building of the Brandywine alluvial fan. It is not known whether the increased stream competence which enabled Potomac River to carry out to the Coastal Plain enormous quantities of fine and moderately coarse debris was caused by eastward tilting of the land or to an increase in the rainfall. There is considerable circumstantial evidence for accepting the latter interpretation. The deposition of the Brandywine fan materials took place under fluvial conditions similar to those existing during the several stages of terrace building in Pleistocene time. Although the detailed correlation of the terrace-building stages with the several glacial stages has not been accomplished, it seems highly probable that the alternation of terrace building at one extreme with the erosion of valleys at the other was causally related to the periodic alternation of glaciation and deglaciation. It has been recognized in Europe and in North America that streams immediately beyond the margin of the ice had periods of increased competence which led to the building of extensive terraces and fans during the time of maximum glaciation. In view of these parallelisms, it appears more plausible to suppose that the fundamental cause of successive Pleistocene terrace forming epochs was climatic rather than due to crustal movements; by analogy that the same was true of the Brandywine fan-building epoch.

Any interpretation based on crustal movements involves numerous difficulties. The lower terraces of Potomac River, especially west of the Fall Belt, show very little departure from parallelism between the gradients of the several terraces and the gradient of the river. For example, the Sunderland terrace is approximately 100 feet above the present level of Potomac River above Great Falls and about 80 feet above the river just below Cumberland. Similarly, the Brandywine terrace, as correlated, is about 170 feet above the river at these points. Hence, within a possible error of 10 to 20 feet, the ancient and the modern grades are parallel. The present grade of Potomac River, for the most part, is just sufficient to prevent great deposition at any point, but it does not, under present climatic conditions, render the river competent to deliver debris at the head of tidewater in kind or amount which accumulates in recognizable deposits above water level. Considerable quantities of sand and gravel are dredged from the upper estuary of the Potomac at the present time. Nevertheless it is not believed that the replenishment of these materials is comparable in a geologic sense with the rates of accumulation during the stages of terrace building. If Brandywine or other fan building be regarded as the result of eastward tilting, there must have been a return movement at the close of each stage which restored the land to its former attitude. Moreover, from Brandywine time to the present there has been no appreciable net increase of eastward tilt.[46]

It is not asserted that such an alternative of positive and negative tilting in post-Miocene time, with no net change in the altitude of the land, is impossible. It does, however, seem improbable that it could have been the major cause of the alternations in stream competence under discussion. It is believed also that differential crustal movements were negligible and were subordinate to climatic factors in producing the changes in stream competence.

It should be noted here that, though increased erosion and reduction of land areas are properly ascribed to uplift of the land without tilting, such features as those under discussion can not be so explained. Response of the streams of a low coastal area to an uplift of 100 to 200 feet will be almost immediate at the coast and trenching will commence at once. On the other hand, an uplift of 100 or even 1,000 feet in the Potomac Basin would have little or no effect in the upper part of the basin until long after trenching and other recognizable changes had taken place in the lower valley. Even when the pulsation of increased grade had reached

46 It must not be understood that the writer denies pre-Brandywine arching and tilting of the Appalachian tract. Although the details of this tectonic history have not been deciphered, the evidence of differential warping of the area in Mesozoic and early Tertiary time is indisputable.

the headwater areas, there is little likelihood that so gradual a change in competence would show itself in clear defined fan building such as took place in Brandywine time.

Whatever may have been the cause, it is evident that during Brandywine time Potomac River and other streams brought vast quantities of material to the western margin of the Coastal Plain. As they were unable to transport this material across the plain, most of it was deposited in a series of alluvial fans which, merging, formed a great alluvial plain. The Potomac fan, which begins at Washington and extends south and east for at least 40 to 50 miles, was deposited on the relatively flat surface which had been cut on the edges of the Miocene and pre-Miocene formations. As sediments were deposited, the channel of the Potomac migrated over the surface of the fan, thus building it gradually broader and higher. At this time there was probably no deep Potomac gorge across the formations of the Coastal Plain, such as the present gorge from Washington to Point Lookout. Sections of deep filled valleys are not exposed in the area and no other evidence is known to indicate that such a gorge had been previously cut and filled.

VOLUME OF THE FAN

The total volume of material in the original Brandywine fan may be roughly estimated. Assuming a total area of 1,000 square miles and an average thickness of 25 feet, the result would be 25,000 mile-feet.[47]

The area of the Potomac drainage basin west of the Fall Belt is roughly 13,000 square miles. The volume of the fan, therefore, corresponds to a depth of about 2 feet throughout the entire basin. Possibly less than half of the entire amount of sediment brought down the river was deposited in the fan. Various other unknown factors enter the problem, but, in spite of them, it is useful to assume that 5 or possibly even 10 feet of material were eroded on the average from the drainage basin of the Potomac during the building of the Brandywine fan. Estimates of the rates of continental denudation vary between 3,000 and 10,000 years for the removal of 1 foot of material from the whole continent. Assuming that the removal during Brandywine time was exceptionally rapid, largely because the rocks were deeply weathered, the duration of Brandywine time may be estimated as perhaps 25,000 to 50,000 years. This estimate is not accurate, but it is probably of the right order of magnitude. Attention must be called here to the fact that, though the amount of deepening of the Potomac valley bottom be-

47 A mile-foot is the volume of 1 square mile filled to a depth of 1 foot.

tween successive terrace stages is greater than 5 to 10 feet, in some instances ten times as great, it by no means follows that the average removal is nearly so great; the amount of 5 to 10 feet is thus inherently reasonable.

Establishment of Stream Courses

At the close of Brandywine time, Potomac River assumed a course at the extreme southwestern margin of the fan and commenced cutting down through the materials of the fan and the underlying Tertiary and Mesozoic formations. This new course, which differed but slightly in a broad way from the present course, was notable in its similarity to the courses of several other master streams of the Atlantic slope. The Delaware, Susquehanna, Potomac, and James rivers turn sharply south at the Fall Belt and flow for a considerable distance in a southerly or southwesterly direction at the foot of the Fall Belt before finally turning eastward to flow across the Coastal Plain to the sea. There is considerable evidence that this type of course was assumed by each river at the close of Brandywine time, before the deposition of the Sunderland formation.

No generally accepted explanation of these anomalous courses has been offered. McGee[48] considered them to be the result of crustal movements producing a trough at the east foot of the Fall Belt, along which each stream took its post-Brandywine course. Darton[49] expressed the view that these south-turned courses were not caused by crustal movements, but were due to the original configuration of the Lafayette deposits, including such irregularities as submarine bars and intervening sloughs, which determined the courses of the streams when uplift occurred. The writer favors Darton's interpretation. It is thought, however, that the original configuration of the Brandywine formation was due to fluvial rather than to marine agencies.

It seems probable that the extensive alluvial fans were most important in determining the present stream courses. There is abundant evidence that fans deposited by the master rivers were larger and higher at the margin of the Piedmont Plateau than were those formed by the smaller streams in the intervening areas. The fans were formed when streams were most competent to carry coarse debris to the Piedmont margin. When fan building ceased and down-cutting commenced, the streams assumed courses to one side of the axis of the fan because of the general dissection of the

48 McGee, W. J., The geology of the head of Chesapeake Bay: U. S. Geol. Survey, Seventh Ann. Rept., pp. 537-646, 1888.

49 Darton, N. H., Outline of Cenozoic history of a portion of the middle Atlantic slope: Jour. Geology, vol. 2, p. 581, 1894.

fan at its narrow apex. This interpretation explains the abrupt turning of the courses of streams at the west margin of the Coastal Plain, but it does not explain why that turning was uniformly toward the south. Whether this is to be explained (1) by a slight differential tilting, which is not clearly indicated by other evidence in the Potomac area, or (2) possibly by successively thicker and higher fan and terrace deposits to the north, is not known. Comparison of the fan deposits around the Potomac and James rivers lends some slight support to the second view, but neither of the above possibilities can be regarded as more than suggestions to be tested by study in a wider area.

During the post-Brandywine stage of down-cutting the Potomac entrenched itself in substantially its present course from Washington to Maryland Point, and the James likewise to the vicinity of Dutch Gap. East of these points both rivers probably flowed in general southeasterly, but they migrated sufficiently to erode the entire Coastal Plain to the surface of slight relief which underlies the Sunderland formation. The sea shore at this time probably extended obliquely across Virginia from the mouth of Potomac River to the western edge of the Coastal Plain in Southampton or Greensville counties. Nothing is known of the courses of the other streams. The course of Susquehanna River along the Fall Belt as far southwest as Annapolis was probably the same as at present. Whether the river flowed nearly east from this point, or down the present south course of Chesapeake Bay, is not evident, though the former seems more probable.

SUNDERLAND STAGE

The Sunderland stage was heralded by an increase in competence in the upper courses of streams relative to their capacity to carry debris across the Coastal Plain. During this stage a mantle of loam and gravel, which is now known as the Sunderland formation, was deposited over 3,000 to 4,000 square miles of the Virginia Coastal Plain. This formation was deposited (1) partly as terraces in the valleys which Potomac and James rivers had cut in the Brandywine and older formations, and (2) in much larger part as a broad plain of coalescing fans. Most of the Sunderland formation consists of materials transported by Potomac and James rivers, but minor streams contributed considerably to it. The streams meandered broadly on both the terraces and the plain, as is shown by (1) the great curved scarps in the adjacent highlands, and (2) by ox-bows in the valleys. Although these ox-bows have been cut off in later time, their courses must have been established on the Sunderland plain because they enclose remnants which rise to the full height of the Sunderland upland.

The basal part of the Sunderland formation to the east consists of beds of well-sorted sand and gravel, which are thought to be of marine origin. It is believed that the sea shore at this time was along a line from the mouth of Potomac River to the vicinity of Boykins in Southampton County. Sea-level was about 50 feet higher than at present. The fans were probably built out to the shore and somewhat beyond, being deposited over the marine beach and off-shore materials of earlier Sunderland age. According to this view none of the present Sunderland surface is of marine origin. It is evident that such marine sediment was deposited in Sunderland time, but in Virginia it was buried under Sunderland fluvial or under marine Wicomico deposits. As the width and thickness of the fluvial Sunderland seem to have decreased notably from Potomac River southward to the State line, it is not improbable that considerable areas of marine Sunderland, which may never have been covered by later fluvial beds, now form the present surface of the Coastal Plain of the Carolinas. This conjecture is based wholly on the apparent trends of the several terraces and formations in Virginia.

ICE-RAFTING OF BOULDERS

During the Sunderland stage numerous large blocks, boulders, and cobbles, some with striae like those of glacial origin, were transported for the first time down Potomac and James rivers as far as the limits of the Sunderland formation.[50] It is not known whether they were the product of true glacial action. It is believed, however, with considerable assurance, that they were transported by floating ice, and that they are evidence of a climate more rigorous than the present one. They thus afford additional evidence for considering the several stages of terrace building to be the analogues of the stages of glacial advance in the northern part of the United States. The Sunderland stage is considered, therefore, to correspond to the earliest glacial stage.

WICOMICO STAGE

The Sunderland stage was followed by a stage of erosion in which the waves and currents were active. The sea was probably 50 to 60 feet above its present level at the close of Sunderland time. During much of the Wicomico stage, it was about 90 feet above its present level. There is no clear evidence to show that

50 Wentworth, C. K., Striated cobbles in the southern states: Geol. Soc. America Bull., vol. 39, pp. 941-953, 1928.

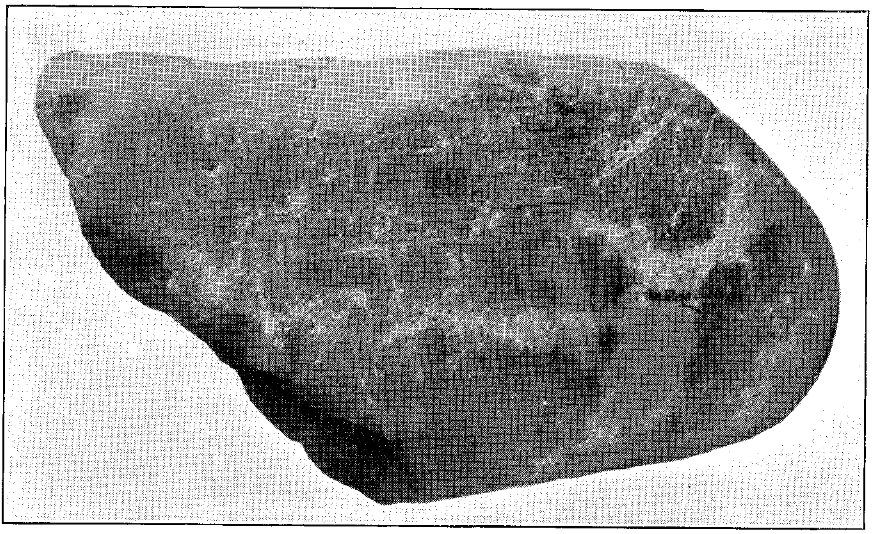
the sea withdrew to a lower level before its advance on the land in Wicomico time. The streams in post-Sunderland time entrenched themselves on the Sunderland plain down to the level of the Wicomico surface. Deep channels cut into the Sunderland surface and filled with Wicomico materials are not known to the writer. Until such evidence is found it must be assumed that, if the land rose after Sunderland time, the rise was moderate or of too slight duration for deep channels like those of the present tidal rivers to be formed.

The courses of the coastal-plain streams west of the Surry scarp between the Potomac and the North Carolina line appear to have been determined by the slope of the surface of the Sunderland plain. This plain slopes southeast almost at right angles to the shore-lines of Sunderland and Wicomico time, and at an oblique angle to the present coast or to the shore of Chesapeake Bay. The courses of the coastal-plain streams are likewise uniformly southeast across this part of the plain. Such courses are more striking where they are discordant with courses of the same streams farther east, as in the case of the headwaters of Blackwater, Nottoway, and Meherrin rivers.

In the renewed cutting of post-Sunderland time, the larger streams, such as the Potomac and the James, entrenched themselves in meandering courses, which in some cases survived to be cut off as ox-bows in later time. The smaller and less vigorous streams assumed almost straight consequent courses down the slopes of the surface fan, which have been maintained to the present time.

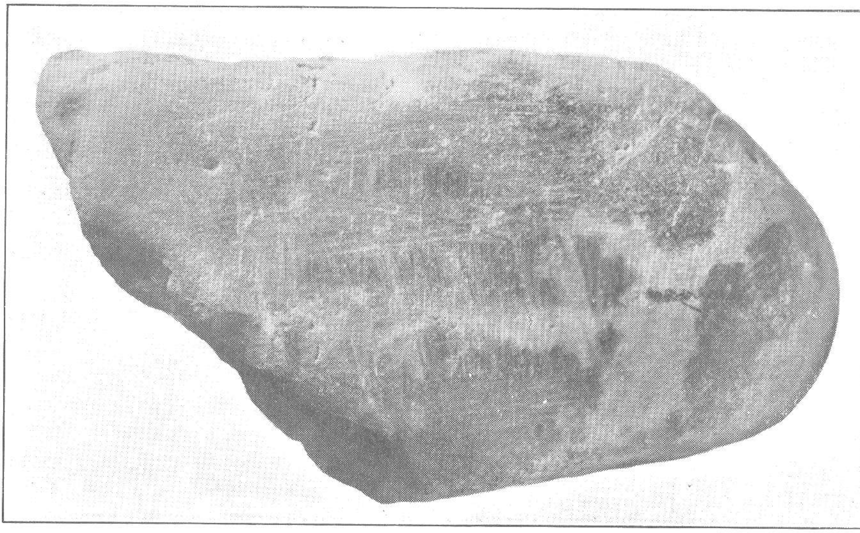
It is not believed that Chesapeake Bay below the mouth of Potomac River existed at this time, but it is thought rather that the Atlantic shore-line trended in a southwesterly direction from the vicinity of Pocomoke Sound to the head of Albemarle Sound. Whether the Susquehanna drainage entered the Atlantic in the region of Pocomoke Sound or farther north is not certainly known, but it is thought probable that it was in the Pocomoke area because no deposits or buried channels suggesting a course across the Eastern Shore of Maryland are known. This view is supported by the distinct discordance at this point between the narrow Eastern Shore of Virginia, with its minute drainage pattern, and the broader Eastern Shore of Maryland with its more mature and broadly developed drainage pattern. This fact suggests that the combined Potomac and Susquehanna drainage may have entered the sea at Pocomoke Sound.

The drainage patterns of the major streams east of the Surry scarp have several features which bear on the drainage history.



A. Cobble from the Chowan-Dismal Swamp formation showing two systems of striae at right angles. (See p. 77.)

B. Sunderland-Princess Anne scarp southwest of Brents Point, Stafford county. (See p. 81.)



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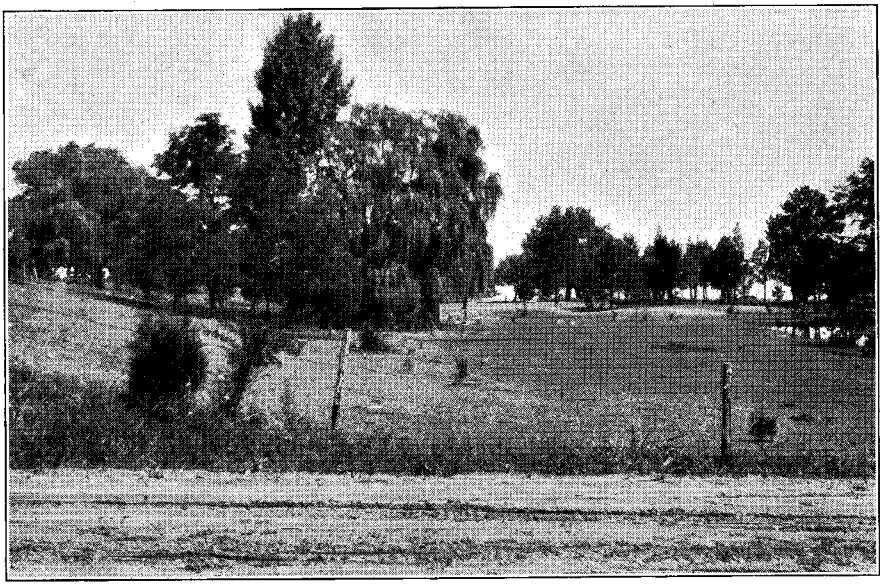
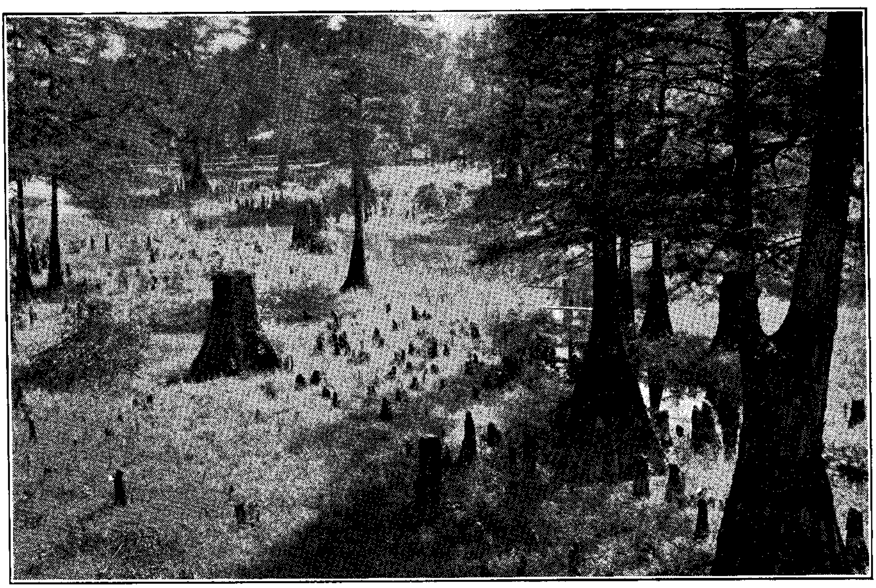
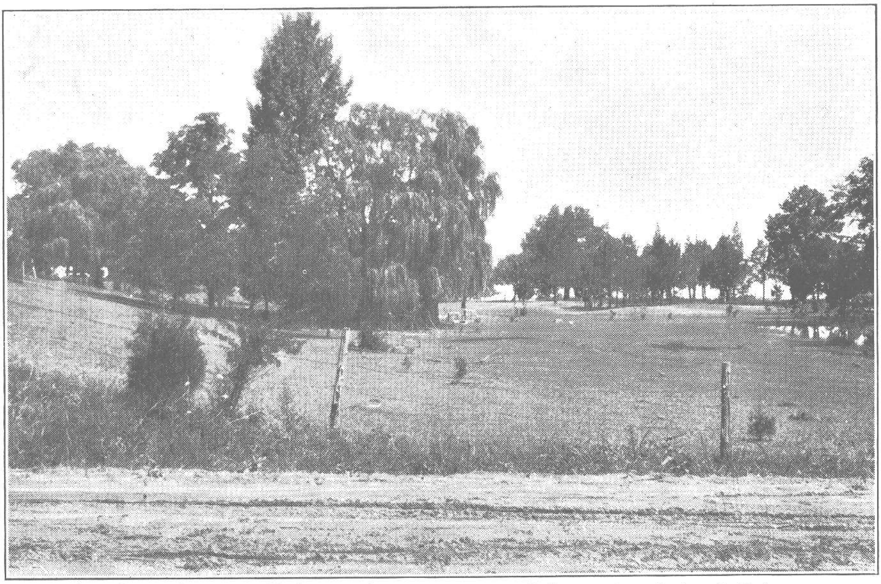


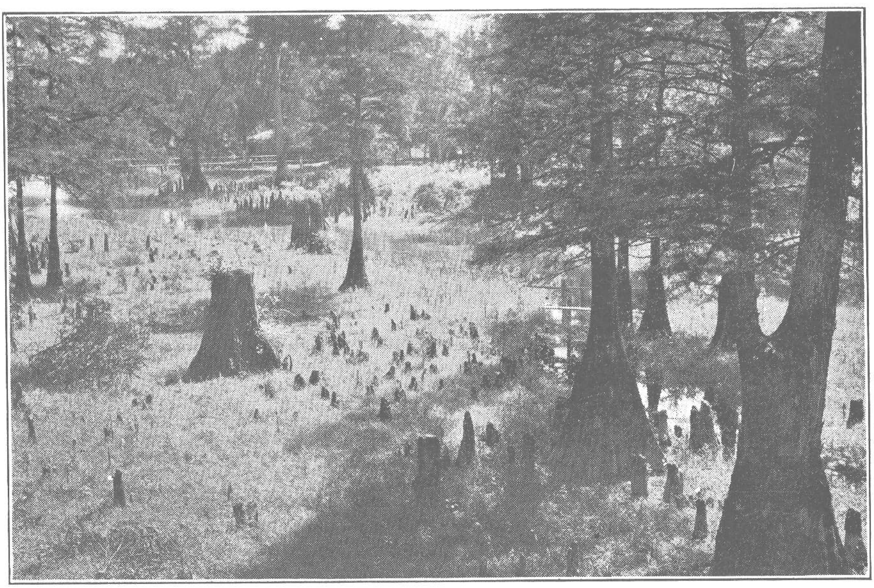
A. Scarp between Princess Anne terrace and flat at beach level Princess Anne County. (See p. 81.)



B. Cypress bottom on Nottoway River near Courtland, Southampton County. (See p. 81.)



A. Scarp between Princess Anne terrace and flat at beach level Princess Anne County. (See p. 81.)



B. Cypress bottom on Nottoway River near Courtland, Southampton County. (See p. 81.)

The most striking feature is the sharp south-turning of branches of the Chowan system, with their lack of drowned channels in Virginia, as compared with the direct courses of the James and the York eastward past the Surry scarp. The lower courses of the Chowan system were certainly assumed anew on the emerged Wicomico surface. This suggests that the straight course of the York past the Surry scarp and the course of the James, whose meanders do not show any systematic similarity to the Chowan pattern, may have been sufficiently fixed as deep channels in post-Sunderland time to survive after the post-Wicomico emergence. The Surry scarp intersects the course of the Rappahannock too far to the east to provide an analogy to these features.

So far as known, no sharp separation can be made between the erosional stage, during which streams were entrenched on the Sunderland plain, and the presumably Wicomico stage of stream deposition and fan building. Only relatively small areas of fluvial Wicomico formations, chiefly in the vicinity of Washington and along James River above Charles City, are known. These deposits represent conditions very similar to those of Sunderland time, except that the quantities of material transported by streams must either have been much less or else the great bulk was carried out to sea where it was so reworked as not to be recognizable. The existing fluvial deposits of this age are confined within relatively narrow limits by the uneroded Sunderland upland and nowhere, so far as known, did they form typical alluvial fans.

During Wicomico time the sea advanced over the land for at least 40 to 50 miles in the Suffolk area. In places materials of the Wicomico plain lie 15 to 35 feet deep on a bench eroded on Tertiary beds. Deposits of possible Sunderland age are preserved in places under the Wicomico formation, but these remnants can not be positively identified.

At the close of Wicomico time, the sea withdrew and rivers advanced over the emerged areas of sea bottom close to the land. The rivers south of the James, namely, the Chowan headwaters, the Roanoke, and the Tar, turn at the Wicomico-Sunderland scarp to courses more southerly than those upstream. This feature is more marked to the north. The lack of such a turn in York River, where it crosses the Surry scarp, and the rather irregular course of the James lead to the belief that these streams were entrenched to such an extent in pre-Wicomico time that their courses were again assumed after the post-Wicomico emergence. The southward turning of the streams south of the James may have been caused by a slight southwestward tilting of the land at the time it emerged. The pronounced elbow of Blackwater River southeast of Dendron may be the result of piracy, a tributary to the James having been diverted by a south-flowing stream whose course is now that of lower Blackwater River.

CHOWAN STAGE

The Chowan terrace is so slightly developed in Virginia that few details of Chowan history can be determined. Some general interpretations can be made from the general relations of the Chowan and the Dismal Swamp scarps in North Carolina. The Chowan cliff resembles the Wicomico cliff in its oblique southwesterly trend. On the other hand, the cliff above the Dismal Swamp terrace trends almost south from Smith Point across Virginia and North Carolina to a position west of Cape Lookout. It is thought that this change of direction in the Virginia-North Carolina shore-line is related to the development of lower Chesapeake Bay and the Eastern Shore of Virginia south of Smith Point.

FORMATION OF THE EASTERN SHORE PENINSULA

It is believed that little or no land existed in the area of the Eastern Shore of Virginia before the beginning of Chowan time. During Chowan time the combined action of waves and shore currents built spits and barriers across the shore reentrant from the vicinity of Snow Hill, Maryland, to eastern Gates County, North Carolina, thus forming an enclosed area of lagoons and marshes similar to Pamlico and Albemarle sounds. After the Chowan emergence this barrier was sufficiently continuous to force the combined Potomac and Susquehanna drainage southward to its present outlet into the ocean. Much of the deep cutting of Chesapeake Bay and its tributaries may have taken place in post-Chowan time. The present width of lower Chesapeake Bay is not, however, necessarily the result of the drowning of a deeply eroded valley. Its form is as well explained as the bottom of the bay which was enclosed behind the Chowan shore barrier.

DISMAL SWAMP STAGE

Dismal Swamp time commenced with a relative depression of the land to a position about 25 feet lower than at present, as is shown by buried swamp deposits in several places. The waves advanced on both sides of the long narrow Eastern Shore, on the western edge of the bay, and along such built land in the vicinity of Norfolk as was formed in Chowan time. A terrace of increasing width from Smith Point southward, was formed along the shore. Apparently the Chowan barrier in the Norfolk area was cut entirely away. The sea of the Dismal Swamp stage extended westward to the Suffolk scarp along its entire length of about 200 miles. A few island remnants of the Chowan barrier on the Eastern Shore protected the northern part of the mainland which possibly accounts for the narrowness of the Dismal Swamp terrace in this district.

The Dismal Swamp terrace and formation are of marine origin west to the Fall Belt along the Potomac and almost as far west along the James. Strong evidence for this interpretation is found in the great number of places west to the Fall Belt where the Dismal Swamp formation is composed of well-sorted and evenly-bedded material which rests on a sharply cut bench in Tertiary beds, at elevations varying from sea-level to 8 or 10 feet above the sea. The general uniformity of these variations over the entire area is difficult to explain on any other basis than that of strong wave-cutting in a wide estuary. Some of these inland terrace remnants have the form of meander curves, but it is thought that this form has been inherited. No ox-bows are known to have been cut off in Dismal Swamp time.

At the close of Dismal Swamp time the land emerged and the streams flowed across the newly exposed terrace in easterly courses, in contrast to their southeasterly direction farther inland. Sharp eastward turning at the Dismal Swamp scarp occurs in Patuxent River at Solomon's Island, Maryland, the Rappahannock near Irvington, the Piankatank near Cobb's Creek, the York at Yorktown, and the James south of Newport News. This feature is also strikingly shown in the course of the lower Roanoke and the Chowan in Albemarle Sound and in the Pamlico and Neuse rivers farther south. These streams apparently assumed consequent courses across the eastward slope of the Dismal Swamp terrace.

Evidence is lacking to show whether any of the streams which began to dissect the Dismal Swamp terrace upon its emergence cut their channels below the level reached by the later Princsss Anne sea. It is therefore impossible to determine whether there were both emergence and submergence, or only the former, between Dismal Swamp and Princess Anne time.

OUTLINE OF THE COAST

After Dismal Swamp emergence, the outline of the North Carolina-Virginia coast was markedly different from that of earlier times. The principal difference was in the great width of the emerged Dismal Swamp terrace from Cape Henry south to Cape Lookout. The continuity of this terrace to the north is broken by Chesapeake Bay. The terrace is narrower north of the Virginia line. This change in the outline of the east coast of North America is a problem of considerable interest which has not been wholly solved.

According to the interpretation given in a preceding paragraph, Potomac and Susquehanna rivers first entered the sea at the present outlet after the post-Chowan emergence. This merging of the drainage of a considerable part of the Atlantic slope at the same time that erosion was renewed because of emergence, caused large quantities of sediment to be deposited off the southern coast of Virginia. This material was probably reworked by shore currents and built into the exceptional Cape Hatteras projection during Dismal Swamp and later times.

The total area of land made in this district since Dismal Swamp time is in round numbers about 12,000 square miles. The average depth of the fill is, roughly, perhaps 100 feet. This makes a total fill of 1,200,000 mile-feet. The area which drains through the Cape Charles outlet is approximately 65,000 square miles. In order to obtain the amount of material in this fill, the drainage basin would have to be eroded, on the average, about 18 feet. This erosion would require approximately a period of an order of magnitude of possibly 100,000 to 150,000 years.

PRINCESS ANNE STAGE

After the post-Dismal Swamp emergence the sea remained for a long time at a level about 15 feet higher than at present. The Princess Anne terrace was cut at this level. During Princess Anne time the sea advanced moderately to form a wave-cut and wave-built terrace from 1 to 10 miles wide. The greater width of the Princess Anne terrace on the shores of Chesapeake Bay, as compared with that on the Atlantic coast of the Cape Henry district and the Eastern Shore, is possibly due as much to more extensive deposition by waves in the quieter water of the Bay as to greater wave erosion. During this stage, tidewater conditions prevailed over practically the same area as at present. Fluvial conditions of deposition did not differ, so far as known, from those of the present day. No large striated boulders are known to have been transported down the principal rivers at this time, although some have been incorporated in the Princess Anne deposits by the reworking of older formations.

RECENT STAGE

Princess Anne time was brought to a close by a marked emergence of the land to a position probably at least 50 feet higher than at present. Stream erosion was renewed and the margins of the land were trenched everywhere. The surface of the Princess Anne terrace was dissected by many small streams, many cutting their valleys well below present sea-level. Some of these streams came into existence with the emergence of the Princess Anne terrace and developed by headward growth on its nearly level surface. Other streams continued across the Princess Anne terrace as it became land. The small drowned valleys which everywhere fray the edge of the Princess Anne terrace furnish abundant evidence of (1) emergence of the land after Princess Anne time to a position considerably higher than now, and (2) later submergence of the dissected margin land to form the present minutely embayed shore-line.

SHIFT OF STRAND-LINE

The evidence bearing upon recent movement of the land is conflicting. (1) Roads which were once passable are reported to be sinking relative to the surfaces of adjacent marine marshes. (2) On the other hand, many old river ports which were reached by salt water craft are now inaccessible because of the shoaling of the smaller tidal rivers. The first line of evidence is vitiated by the possibility of local subsidence into the spongy mass of the bogs, and the second may be explained wholly by excessive sedimentation in the tidal courses of streams, since the land has been extensively cultivated and erosion greatly increased.[51] The last recorded shift seems to have been the submergence which drowned the numerous stream valleys cut in the Princess Anne terrace.

Attention has been called to widespread evidences of a negative shift of the strand-line in Recent time.[52] The apparently world-wide distribution of wave-cut benches about 15 feet above sea-level has been considered as evidence that the strand line shift was eustatic and resulted from a change in sea-level. Local evidence bearing on this hypothesis is not available; indeed from the nature of the problem, positive local evidence can scarcely be expected.

Evidence of differential crustal movements resulting in tilting, as well as submergence and emergence of the Atlantic coastal

51 Studies are in progress under the direction of a committee of the National Research Council to determine the rate and direction of change in the sea-level relative to the land along the eastern coast of the United States, but evidence now available does not justify positive conclusions.

52 Daly, R. A., Pleistocene changes of level: Am. Jour. Sci., 5th ser., vol. 10, p. 313, 1925.

Johnston, W. A., Lack of evidence on the Pacific coast of Canada for a recent sinking of ocean level: Am. Jour. Sci., 5th ser., vol. 12, pp. 249-253, 1926.

Buddington, A. F., Abandoned marine benches in southeast Alaska: Am. Jour. Sci., 5th ser., vol. 14, pp. 45-52, 1927. Several earlier papers are cited here.

region, is abundantly recorded in the Tertiary and late Mesozoic sediments. Similar movements unquestionably took place after the deposition of the last Miocene formations and before the deposition of the Brandywine fan deposits.

According to the above interpretations, there is no clear evidence of tilting or differential crustal movement in the present positions of the several terrace formations from the Brandywine down to the present. Such departures from the horizontal, as characterize these formations, are well within the limits of the original slopes of alluvial fans or of marine terraces. The directions of slope are in each case consistent with this postulate of original form and position. In view of the extensive areas which are mapped topographically and over which the forms of well-preserved terraces are known within limits of 5 to 10 feet, it does not seem valid to use departures from strict horizontality as evidence of tilting expressly to explain the recurrent changes in stream competence. The writer believes that the departures are so slight and so accordant with the probable original slopes of the terraces as to be strong evidence that no tilting of importance has occurred during post-Miocene time. The simpler and more valid interpretation is to ascribe the changes in stream competence to climatic fluctuations.

If the hypothesis of tilting be dismissed as unproved, the successive emergences and submergences may be regarded as due either to crustal movements or to fluctuations in sea-level. So far as the local evidence is concerned, either cause is as valid as the other. It is probable, however, that, when detailed studies are made along the entire Atlantic Coastal Plain, using topographic maps of small contour intervals, some of the terraces will be found to rise or fall from north to south and proof of crustal movement will be obtained. It seems probable that there has been recently a world-wide eustatic emergence of about 15 feet. The Princess Anne terrace may have emerged with this shift. There are some who would ascribe all the other relative shifts to fluctuations of sea-level, especially the conditions of greatest emergence when the deepest valleys were trenched. The present study affords no observational data on this problem, and it is beyond the scope of this paper to consider further the theoretical aspects of the problem.

ECONOMIC GEOLOGY

CLASSIFICATION OF SAND AND GRAVEL

Sand in a commercial sense somewhat loosely means a material consisting of the rock particles which are larger than 1/200 inch and smaller than ¼ inch in diameter. Gravel consists of somewhat rounded fragments which are larger than ¼ inch in diameter and which may range to 2 or 3 feet or more in diameter. Because these terms and related terms have been used in various ways, the writer in 1922 reviewed their usages and formulated a systematic scheme which would not depart widely from the average usage of geologists.[53] The table of terms given below is adapted from that scheme, using English in place of metric units.

TABLE 4.—*Terms applied to grades of rock fragments*

Material		Size (inches)
Boulder gravel		More than 10
Cobble gravel		2 1/2 to 10
Pebble gravel		1/6 to 2 1/2
Granule gravel		1/12 to 1/6
Sand	Very coarse	1/400 to 1/12
	Coarse	
	Medium	
	Fine	
	Very fine	
Silt		1/6,500 to 1/400
Clay		Less than 1/6,500 inch

USES OF SAND AND GRAVEL

The principal commercial uses of gravel are (1) for road building, (2) for a self-draining sub-base, and (3) as the coarse constituent or aggregate in concrete. Sand is used in many ways. Clean sand without special chemical peculiarities is extensively

53 Wentworth, C. K., A scale of grade and class terms for clastic sediments: Jour. Geology, vol. 30, no. 5, pp. 377-392, 1922.

used in mortar and concrete and as a sub-base for paving. Fine sand having special properties is used in various ceramic arts, as in the manufacture of refractory bricks, ordinary bricks, and tile. Molding sand, which must have definite physical and chemical properties, is of great importance in the foundry industries. Almost pure silica sand is used in the manufacture of glass. Sand is used in the manufacture of abrasive materials or in abrasive operations such as sandblasting. It is also used in filtering water and in some of the chemical industries. Minor uses are: (1) As an absorbent for corrosive liquids, (2) for covering hot metals in annealing, (3) as an anti-skid on steel rails, and (4) in fillers and adulterants.

An extreme range in the utilization of sand may be seen in the large variation in the economic value of different types of sand, and hence in the distances to which sand is carried from its sources. Ordinary building sand is available in nearly all parts of the world. Local sand, though not ideal, is used instead of shipping better materials great distances. Building sand is probably not transported on the average more than 10 to 20 miles. Sands for special purposes are not uncommonly shipped some hundreds or thousands of miles, and a few sands are shipped in small amounts to all parts of the civilized world.

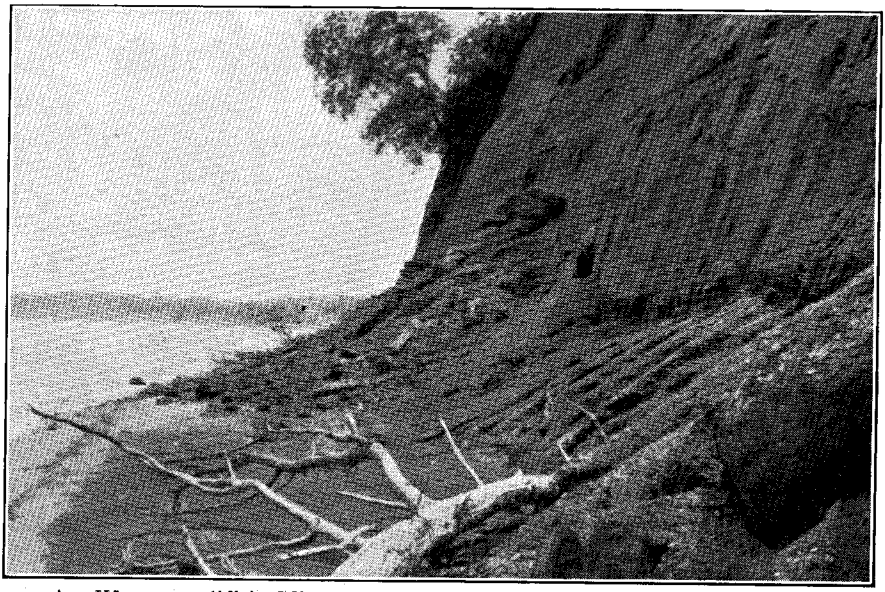
Gravel for grading the sub-base of highways is used in such quantities and is of such slight intrinsic value that it can not be hauled more than 5 or 10 miles before the haulage cost equals the cost of digging and the gross cost becomes so great that a new pit is opened, or less suitable but more accessible material is substituted.

The sand and gravel deposits described in this report have few unusual properties, and their applicability to any of the special uses named above was not studied. Bricks, tile, and other ceramic products are being produced at various points on the Coastal Plain, and sand in some instances is used in their manufacture. Considerable sand in this region, though probably not of the highest quality for such purposes, could, with sufficient demand, be used in filtering and abrasive industries. There is little doubt that molding sand could be produced at several places. This type of material was not specially studied.

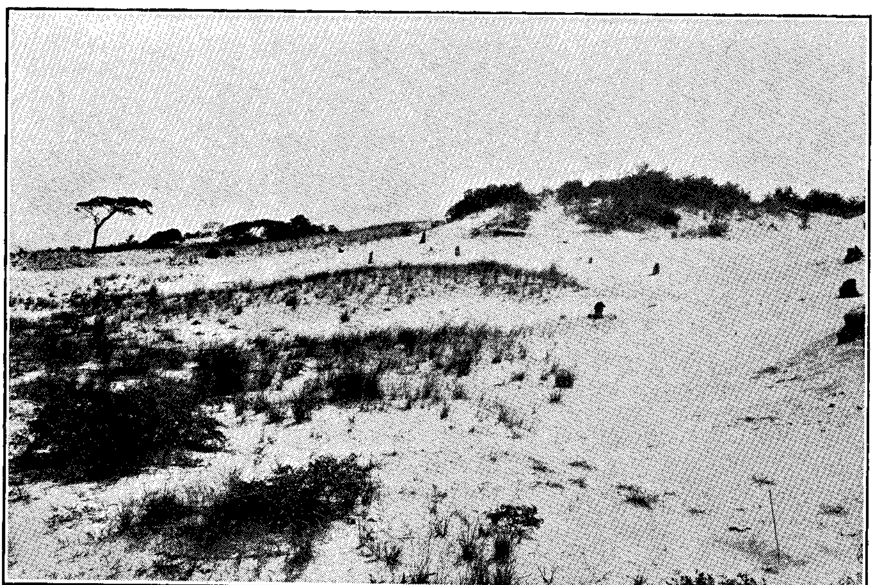
GENERAL FEATURES OF SAND AND GRAVEL

PRINCIPAL CHARACTERISTICS

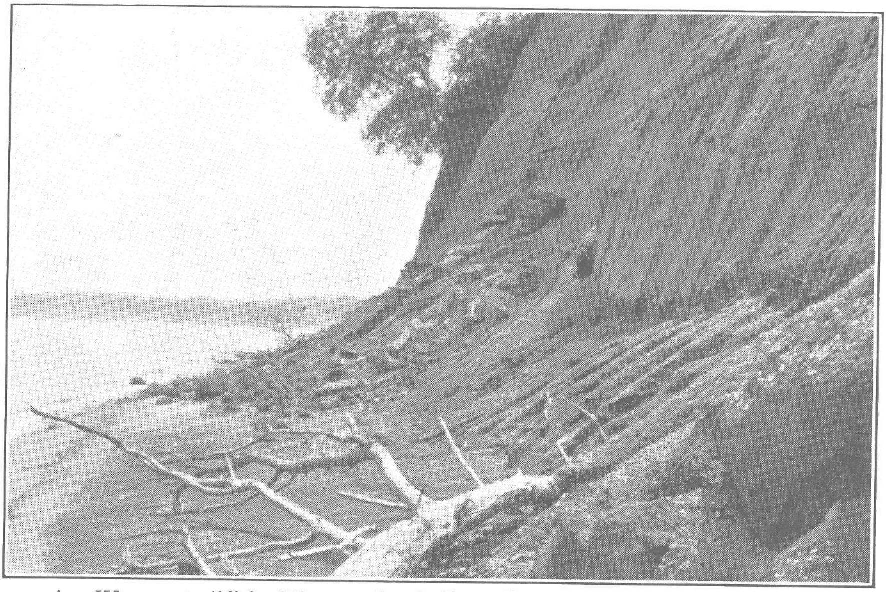
The primary character of sand and gravel is their mechanical composition. This is determined by passing a sample of the ma-



A. Wave-cut cliff in Miocene clay half a mile south of Jones Point, Essex County. (See p. 85.)

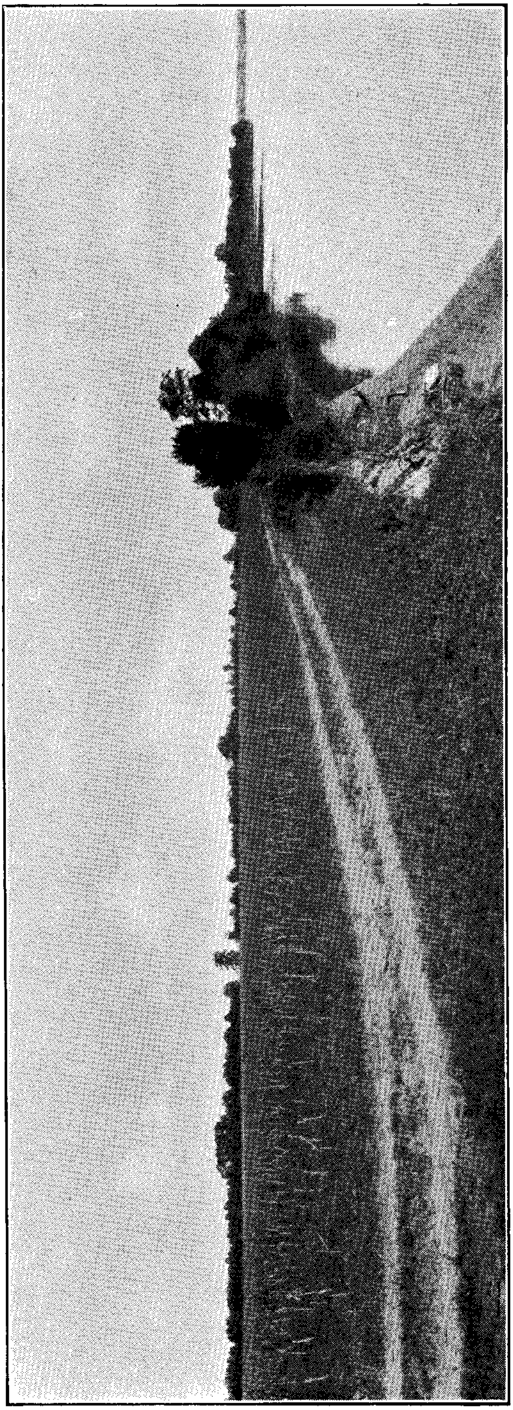


B. Dunes and dune vegetation at Cape Henry, Princess Anne County. (See p. 85.)

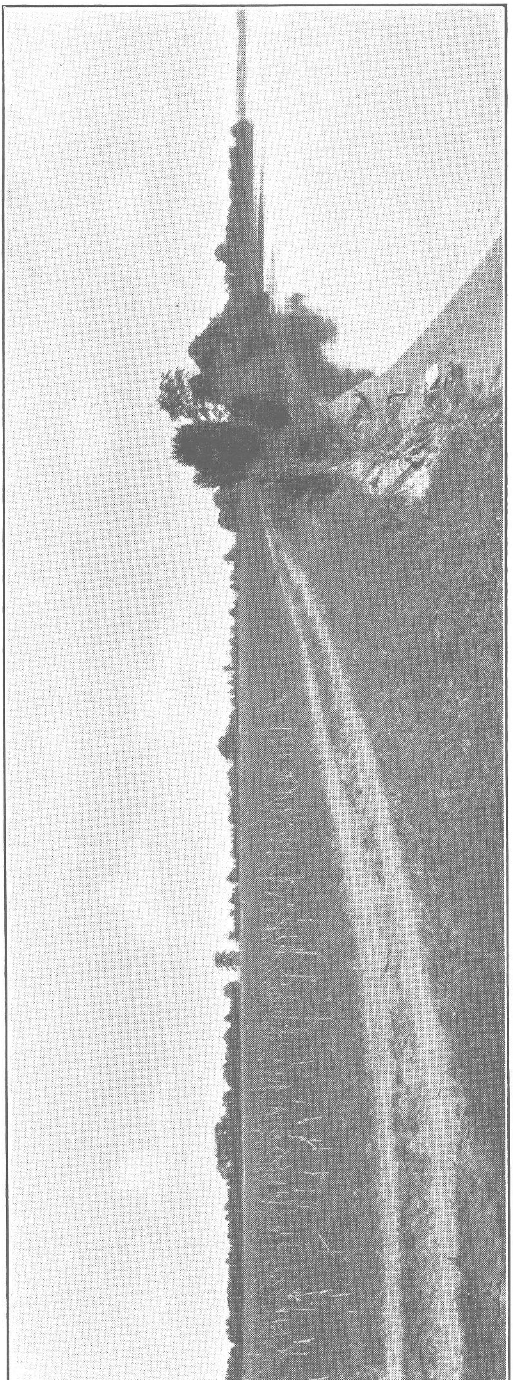


A. Wave-cut cliff in Miocene clay half a mile south of Jones Point, Essex County. (See p. 85.)

B. Dunes and dune vegetation at Cape Henry, Princess Anne County. (See p. 85.)



Princess Anne terrace and recent wave-cut cliff on the shore of Rappahannock estuary, Westmoreland County. (See p. 85.)



Princess Anne terrace and recent wave-cut cliff on the shore of Rappahannock estuary, Westmoreland County. (See p. 85.)

terial through a series of sieves, weighing the amounts retained on the several sieves, and then expressing these fractions in percentages of the whole. The result of such a test indicates (1) the size of grain present in the largest amount, (2) the range of sizes present, and (3) the cleanness or perfection of sorting by which the dominant size has been freed from other material. The methods of making mechanical analyses have been described elsewhere.[54]

The next most important characteristic of sand or gravel is the lithologic or mineralogic composition. The grains in sands consist mostly of particles of quartz, whereas the pebbles of a gravel are generally rock fragments which may be largely of one mineral or may contain several. For most engineering purposes it is important that a sand or gravel consist almost wholly of hard, durable constituents, as a rule mostly one rock or one mineral. Another important feature is the chemical condition, such as (1) the degree of weathering, (2) the amount of iron stain on the grains, (3) the amount of cementation, and (4) the presence of material which might aid compacting or bonding in a road surface under the traffic conditions.

TYPES OF SAND AND GRAVEL

Description, even in a brief manner, of the properties and methods of testing all the kinds of sand and gravel now used commercially, is beyond the scope of this report. Somewhat extended treatment of these subjects is given by Dake, Teas, Searle, Hodkin and Cousen, and Lamar.[55]

It is sufficient here to indicate the variation in type of the principal sand and gravel deposits of the Coastal Plain. The most abundant type may be called upland loam gravel. This is a poorly sorted material, containing particles ranging in size from clay to boulders, and having a sticky, ferruginous, clay-loam matrix. If sufficient pebble and cobble grades are present, it makes a very good sub-base for highways. This material in its typical form is of slight or no use in the production of washed sand or gravel for concrete or other building operations, as the matrix can not be economically removed. The greater part of this gravel consists of pebbles and sand grains which are mostly nearly pure

54 Wentworth, C. K., Methods of mechanical analysis of sediments: Univ. of Iowa Studies in Nat. Hist., vol. 11, no. 11, 1926.

55 Dake, C. L., Sand and gravel resources of Missouri: Missouri Bur. of Geol. and Mines, 2nd ser., vol. 15, pp. 1-86, 1918.

Teas, L. P., Preliminary report on the sand and gravel deposits of Georgia: Georgia Geol. Survey, Bull. 37, pp. 1-144, 1921.

Searle, A. B., Sand and crushed rocks, London, 1923.

Hodkin, F. W., and Cousen, A., A textbook of glass technology, New York, pp. 61-84, 1925.

Lamar, J. E., Geology and economic resources of the St. Peter sandstone of Illinois: Illinois State Geol. Survey, Bull. 53, pp. 99-142, 1928.

silica. Very few pebbles of granite or other crystalline rocks are present. Grains of feldspar and other crystalline rock minerals may be present in the finer sand grades. A sub-type of this gravel is found in places near the Fall Belt, where deposition by Piedmont streams or by the trans-Blue Ridge streams has produced a gravel containing more crystalline rock material, which may be called arkosic loam gravel.

Washed terrace sand and gravel of both marine and fluvial origin are found in various parts of the Coastal Plain. This gravel is naturally sufficiently free from clay or loam matrix so that moderately clean sand and gravel grades for concrete can be produced by screening. The total amounts of such gravel are very much less than of the upland loam gravel.

Modern marine sand and fine gravel which are found at various places along the coast are commonly the cleanest materials in this region. They are most completely sorted and contain the smallest percentage of non-siliceous materials.

The modern river gravels differ from the upland loam gravels in the better mechanical sorting and in the larger percentage of crystalline rock fragments. They are lithologically the most heterogeneous materials in the region. The larger part of the washed sand and gravel used in this region comes either from recent river gravels or gravels in some of the low, recent terraces which are mined by underwater methods.

AREAL OCCURRENCE OF DEPOSITS

GENERAL DISTRIBUTION

The general distribution of gravel of varying coarseness is shown on the map, Figure 22. (See p. 44.) Practically all the upland loam gravel is in counties west of the Surry scarp and the coarser grades occur only in counties not far from the Fall Belt or near the larger rivers. The modern river gravel is found mostly in the inland reaches of the larger streams. Marine sand and washed terrace sand are found in the shore districts, and washed river terrace sand and gravel are found mainly in the low river terraces. Coarse washed gravel occurs chiefly in the low terraces of the principal rivers. Gravel is very scarce in the eastern third of the Coastal Plain.

DISTRIBUTION BY COUNTIES

ACCOMAC COUNTY

Accomac County, on the Eastern Shore, lies almost wholly in the area of the Dismal Swamp and Princess Anne marine terraces.

It is not certain whether remnants of the Wicomico terrace are represented in the higher land in the northern part of the county. No true upland loam gravel is found, but sandy gravel with a slightly sticky ferruginous matrix occurs in places in the higher parts of the county. At the site of sample 2290 this gravel probably is 8 to 10 feet thick over an area of several acres, and it will average 10 to 15 per cent larger than 10 mesh. (See sample 2290, p. 61.) An abundance of clean medium sand can be had from the ocean beach. The sand of the lower terraces is well sorted in places but is, on the whole, too fine for commercial use. No washed beach or low terrace gravel is found in the county, though in a few places pebbles ranging to ½ inch mesh are concentrated in trivial quantities by the action of wind on the beach sands. (Samples 2286-A and B, 2287, 2288, and 2290, pp. 61 and 99.)[a]

ARLINGTON COUNTY

Arlington County is on the west side of Potomac River, within the Fall Belt. Most of its Coastal Plain consists of remnants of the Brandywine and Sunderland terraces, but considerable areas of the Chowan-Dismal Swamp and Princess Anne terraces are present along the river.

Arkosic loam gravel occurs in some of the pre-Brandywine formations. Typical upland loam gravel, with abundant coarse pebble grades, is found in the Brandywine and Sunderland terraces. The lower terraces are composed mainly of loamy material containing cobbles and scattered boulders, but they contain locally small quantities of well-washed sand and gravel. Much clean sand and gravel can be obtained by underwater methods from the low terraces and modern river gravels. (See sample 1364, p. 47.)

Some of the low terrace materials are being used in the manufacture of brick and tile.

CAROLINE COUNTY

The larger part of Caroline County is on the Brandywine and Sunderland terraces. The east and southeast parts of the county are on the Sunderland terrace. Remnants of the Brandywine terrace are believed to be widespread in the western part of the county, but the boundary of these terraces has not been sharply drawn in this area. Small areas of the Wicomico and Chowan-Dismal Swamp terraces are present along Rappahannock, Mattaponi, and Pamunkey rivers.

Most of the upland terraces are underlain by red loam gravel suitable for road building. Pebbles and cobbles are neither large

[a] Samples are listed serially in the index.

nor abundant, because the county was not crossed by a large stream when the terrace formations were deposited. Large quantities of rather well sorted arkosic gravel are found in the Wicomico terrace along the southwest side of Rappahannock River. This gravel contains abundant coarse grades and it can be screened without washing. Moderately well sorted gravel, ranging to 1 inch mesh and carrying 20 per cent of material larger than ¼ inch mesh, is found at various places in the Chowan terrace along Mattaponi and Pamunkey rivers. It is chiefly hard, fresh quartzose material which may be screened without washing. (See samples 1500 and 1530, pp. 77 and 79.)

Charles City County

As this county is between James and Chickahominy rivers, its area is well divided between the Sunderland, the Wicomico, the low Chowan, Dismal Swamp, and Princess Anne terraces. The terrace formations, with the possible exception of the Dismal Swamp and Princess Anne terraces, are of fluvial origin. Large quantities of coarse loam gravel of excellent quality for road building are found in the Wicomico terrace. Parts of the Sunderland terrace are underlain by moderately coarse gravel. (See sample 1831, p. 60.) Large amounts of well-washed sand and gravel can be obtained from the Chowan and lower terraces along James River. (See samples 1829 and 1831, pp. 60 and 80.)

Chesterfield County

This county is chiefly an upland area partly on the Piedmont Plateau and partly on the Brandywine and Sunderland terraces. A small area of lower terraces is found along the James and Appomattox rivers. An abundance of coarse loam gravel occurs in the upland area, and large quantities of clean river gravel and low terrace gravels are to be had along James and Appomattox rivers. A large fraction of the commercial gravel and sand produced in the Coastal Plain is dug in this county or in adjacent counties.

Dinwiddie County

The Coastal Plain part of this county is along the Fall Belt south of Petersburg. Much of the area is mantled with fine loam gravel of the Brandywine and Sunderland formations, but in most places the percentage of pebbles is too small to make good road gravel. Pebbly phases may be found in a few places. (See sample 1985, p. 53.) The pebbles in these gravels are only slightly rounded and considerable weathered debris from crystalline rocks is present.

ELIZABETH CITY COUNTY

This county consists wholly of Princess Anne terrace with a small remnant of the Dismal Swamp terrace. It contains no upland loam gravel. The surface of the terraces consists mainly of fine, light loam and fine sand. Coarse gravel is found in places at the base of the Princess Anne terraces, and large boulders are found in digging ditches at Langley Field. Considerable quantities of coarse gravel were dredged from Back River some years ago and used by the Pennsylvania Railroad Company for ballast on the Eastern Shore. Unlimited amounts of medium, clean sand are available along the present beach. Material containing 5 to 10 per cent of pebbles larger than 10-mesh is found in small quantities on the beach, but no large deposits of washed coarse gravel are known in the county. (See samples 1874-A, B, C, D, and E, p. 95.)

ESSEX COUNTY

The greater part of Essex County is on the Sunderland upland terrace. Small areas along Rappahannock River consist of Chowan-Dismal Swamp and Princess Anne terrace remnants. Great quantities of slightly pebbly loam are found in most of the upland but the pebbles are small, commonly not being as large as 2 inch mesh, and relatively scarce. The lowland terraces consist in part of fine sandy loam and in part of cleanly washed sand and fine gravel. In a few places gravel carrying 25 per cent of material larger than the 10-mesh sieve may be dug, but the quantities are probably limited. Good clean building sand is found in large quantities. (See samples 1540-A, 1540-B, 1540-C, 1543, 1577, 1578, 1579-A, and 1579-B, pp. 71, 83, 91, and 93.)

FAIRFAX COUNTY

This county includes a segment of the Fall Belt about 15 miles long on the west side of Potomac River. The area in the Coastal Plain is roughly divided between Brandywine, Sunderland, and Chowan-Dismal Swamp terraces with a few small remnants of Princess Anne terrace. Large quantities of Brandywine loam gravel containing abundant pebbles and well suited for road construction are found in the upland area of this county. (See samples 1387-C and 1444, p 40.) Considerable gravel from pre-Brandywine formations is found also in the county, though this gravel is usually more arkosic and less suitable for road work. (See samples 1387-A, 1387-B, and 1434, pp. 40 and 41.) The low terraces are in part composed of loam gravel and in part of somewhat assorted material from which sand and gravel may be obtained by screening.

They may be produced more economically by dredging operations in the channel of Potomac River.

GLOUCESTER COUNTY

The area of this county is about equally divided between (1) the Sunderland and Wicomico terraces and (2) the lowland Chowan-Dismal Swamp and Princess Anne terraces adjacent to York River and the Mobjack Bay shore. The upland formations consist almost wholly of loam and fine sand which contain a few thin pebbly lenses. Very few, if any, deposits of loam gravel suitable for road sub-base are present. Large quantities of well-washed sand and fine gravel are found in parts of the lowland terraces. In places gravel carrying 50 per cent over 10 mesh and 15 per cent over ¼ mesh can be had in considerable quantity. (See samples 1779, 1782, 1788-A, 1788-B, and 1788-C, pp. 51, 60, 71, and 74.)

GREENSVILLE COUNTY

A small part of this county lies east of the Fall Belt north and south of Emporia. Most of this part consists of Sunderland and remnants of older terraces. Small areas of Chowan and Wicomico terraces are found along Meherrin River. The Sunderland and older terrace formations are variable, but they consist mainly of loam gravel. The pre-Sunderland formations have not been satisfactorily discriminated. There are probably some pre-Tertiary gravels which in general are less suitable for road building than the terrace gravels. Large quantities of gravel carrying a considerable percentage of cobbles up to 3 or 4 inches in diameter occur along the Fall Belt. Considerable amounts of somewhat angular, heterogeneous washed gravel and sand are found in parts of the lower terrace along the river. (See sample 2109, p. 67.)

HANOVER COUNTY

About half the area of Hanover County is in the Coastal Plain between Chickahominy and Pamunkey rivers. The Sunderland terrace occupies the southern part of this area, but there appear to be remnants of higher terraces toward the Fall Belt. There are small areas of Wicomico, Chowan, and lower terraces along both rivers. Large amounts of fairly coarse loam gravel are found in the upland terrace formations in the western part of the Coastal Plain. Moderately well washed sandy gravel occurs locally in considerable quantities in the lower terraces. (See samples 1522, 1525, and 1967, pp. 51 and 79.)

HENRICO COUNTY

Three-fourths of this county is in the Coastal Plain along the north side of James River. The area consists largely of Sunderland upland, but small areas of pre-Sunderland terraces are found in the western half and small patches of lower terraces are found along James and Chickahominy rivers. Coarse gravels, with loam matrix, are very abundant in the higher parts of the county. An abundance of well-washed coarse gravel and sand in the lower terraces make this county one of the richest in these resources in this part of the State. Large quantities of commercial sand and gravel are produced from the channel and low terrace of James River at Dutch Gap, and are shipped in barges to the Hampton Roads area. (See samples 1961, 1974, and 2049, pp. 51 and 79.)

ISLE OF WIGHT COUNTY

With the exception of a few small areas of low terrace along James and Blackwater rivers, this county is wholly on the Wicomico terrace. Loam gravel, with a few pebbly zones, is found in a few places in the Wicomico formation, but the formation consists here mainly of loamy sand. Suitable road gravel is scarce. Washed sand and fine gravel are found in the upland and lower terraces, but no large deposits suitable for development are known. (See samples 1956, 2126, 2128, and 2132, pp. 61 and 97.)

JAMES CITY COUNTY

James City County consists largely of Sunderland upland terrace, with a small area of Wicomico terrace in the southeast corner and numerous remnants of Chowan, Dismal Swamp, and Princess Anne terraces along James and Chickahominy rivers. There is a relatively slight development of low terrace along York River. Moderate quantities of coarse loam gravel are found in the Sunderland formation in the southwest side of the county near James River, but such gravel is much less abundant in the northeast part. Moderate amounts of sand and washed gravel are found in places in the lower terraces. (See sample 2012, p. 97.)

KING AND QUEEN COUNTY

This county consists of a long narrow strip of Sunderland terrace plain on the northeast bank of Mattaponi River. Small patches of all the lower terraces occur along the river. Loam gravel, even with a small percentage of small pebbles, is known in but few places, and commercial deposits are practically absent. The Sunderland formation consists very largely of fine and sandy loam. Moderate amounts of sand and fine gravel are found in places in the lower terraces. (See samples 1534, 1555, 1556, and 1557, pp. 49 and 79.)

KING GEORGE COUNTY

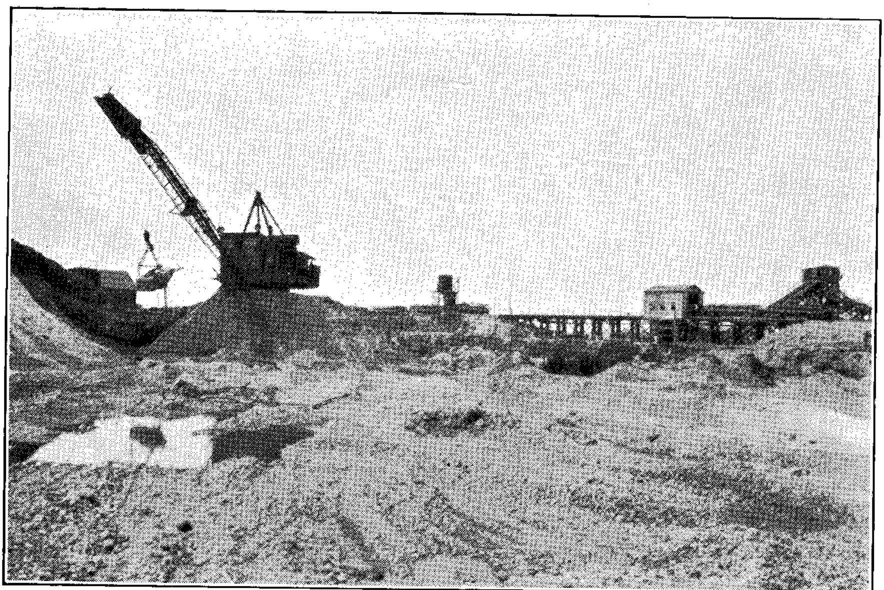
The larger part of this county is on a high level plain which is in part Sunderland, but it probably has also some unreduced patches of higher terraces. Discrimination of these terraces was impracticable because of the lack of accurate large scale topographic maps. Moderate areas of lower terraces are adjacent to Rappahannock and Potomac rivers, but these likewise are only roughly mapped. Loam gravel containing fair percentages of pebbles and some fair-sized cobbles are found in many places in the Sunderland and the older formations, but in other places these deposits consist largely of sandy loam with relatively few larger fragments. The lower terraces contain fairly well sorted lenses of sand and medium to coarse gravels in places. (See samples 1686 and 1691, pp. 48 and 77.)

KING WILLIAM COUNTY

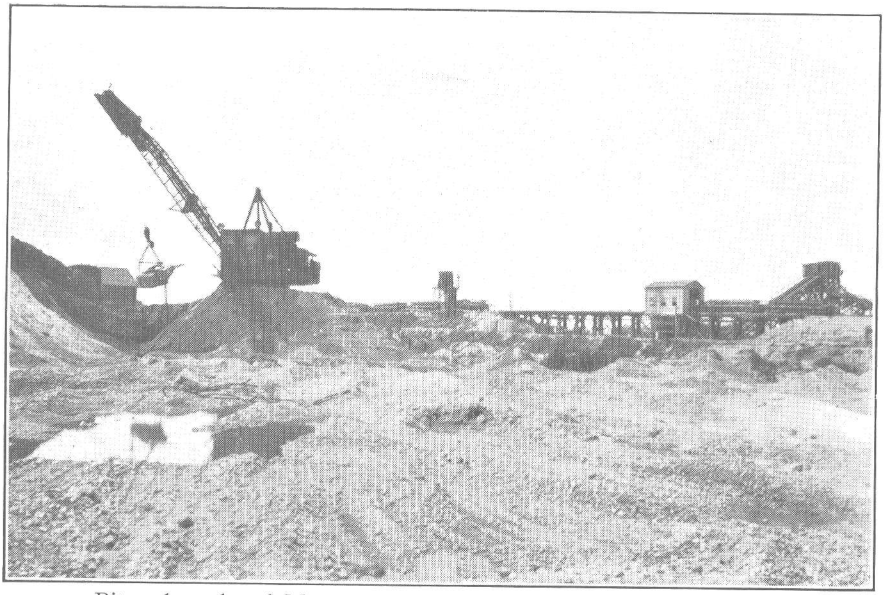
This county comprises the long narrow peninsula between Mattaponi and Pamunkey rivers northwest of West Point. Somewhat over half the area consists of Sunderland terrace and the remainder consists of small patches of Wicomico, Chowan, and lower terraces. Loam gravel, with some pebbles, is somewhat abundant in the northwest part of the county, but the percentage and size of pebbles decline rapidly seaward. Moderate amounts of material which may be used in road building occur at the tip of the upland at Ephesus Church. Sand and gravel of good quality for building purposes and concrete are found in various places in the lower terraces. These are especially conspicuous in the vicinity of Aylett. (See samples 1558, 1561, 1761, 1762-A, and 1762-B, pp. 51 and 79.)

LANCASTER COUNTY

About half of the area of Lancaster County is Sunderland terrace and the remainder is divided between small areas of Wicomico, Chowan, Dismal Swamp, and Princess Anne terraces. A few thin pebbly zones are known in the Sunderland formation, but it is mainly sandy loam. No extensive deposits of good road gravel are known. Large quantities of well-sorted, clean sand and fine washed gravel are found in various parts of the lower terrace formations. Considerable quantities of sand occur off Windmill Point in water 5 to 15 feet deep and, in places, gravel ranging to ½ inch mesh



Pit and works of Massaponax Sand and Gravel Company, in the Wicomico formation, Spotsylvania County. (See p. 132.)



Pit and works of Massaponax Sand and Gravel Company, in the Wicomico formation, Spotsylvania County. (See p. 132.)

forms the surface of the underwater spit. The thickness of such gravel deposits is not known. (See sample 1930-E, p. 91.)

MATHEWS COUNTY

With the exception of small areas of Dismal Swamp and Chowan terrace in the northwestern corner, the entire county is on the Princess Anne terrace. No loam gravel suitable for road building is known in the county. Sand is present in places in the Princess Anne formation, but this consists for the most part of fine sandy loam. Small amounts of fine washed gravel are found in the Dismal Swamp formation in the northwest part of the county. Large amounts of medium to coarse sand of excellent quality are available on the modern beaches of the east coast. In a few places wind scour has concentrated the few pebbles in the sand and small amounts of gravels ranging to ½ inch mesh occur a few inches below the surface. Deposits of commercial value are not known. (See samples 1950-A, 1950-B, 1951-A, 1951-B, and 1951-C, pp. 87, 93, and 95.)

MIDDLESEX COUNTY

This county is between Rappahannock and Piankatank rivers. Somewhat over half the area is Sunderland terrace plain. The remainder includes small areas of each of the lower terraces. The greater part of the Sunderland formation in this area consists of mottled sandy loam. Loam gravel consisting of relatively thin fine pebbly zones between beds of sandy loam is found in places in the Sunderland formation. It may be used for road building, but the deposits are scattered and limited in amount. Considerable amounts of washed sand and fine gravel are present in the lower terraces along Rappahannock River and locally in the modern beaches. Practically no coarse gravel is known in the county. (See samples 1736-A, 1736-B, 1739, 1741, 1744-A, 1747-A, 1747-C, 1747-D, 1748, and 1749, pp. 49, 60, 71, and 93.)

NANSEMOND COUNTY

Nansemond County includes large areas of Wicomico and Dismal Swamp terraces, with small areas of Chowan and Princess Anne terraces along Blackwater and James rivers. Small amounts of cobbly loam suitable for road work are found in a few places in the Wicomico formation west of the Suffolk scarp, but these deposits are variable. They will not justify exploitation on a large scale. Well-washed and fairly coarse gravel suitable for concrete aggregate is found in the base of the Wicomico formation near

Suffolk and elsewhere. Sand of good quality is abundant at places in the lower terraces. (See samples 2087, 2088, and 2168, pp. 60 and 61.)

NEW KENT COUNTY

The larger part of this county is on the Sunderland plain between Pamunkey and Chickahominy rivers. Small areas of lower terraces are also found along these rivers. The Sunderland formation is in places moderately pebbly, and it is the source of small amounts of good road gravel. Moderate amounts of coarse well washed gravel are found in parts of the lower terraces. They contain abundant deposits of sand and fine gravel. (See sample 1820, p. 80.)

NORFOLK COUNTY

This county probably contains the largest unbroken area of one terrace, the Dismal Swamp, of any county in the Coastal Plain. A fringe of Princess Anne terrace is developed along the northern shore. Much of the western part of the county is in the great Dismal Swamp of Virginia and North Carolina, and its surface is covered with peat. No loam gravel of the upland type is present. Much of the area is underlain by fine sand and sandy loam with marine shells in places. Large amounts of well-washed sand are found on the modern beaches and in the shore dunes. (See samples 2050, 2052, 2061-A, 2061-B, 2063, 2065, and 2066, pp. 74, 87, 89, and 97.)

NORTHAMPTON COUNTY

This county comprises the southern half of the Eastern Shore of Virginia. It consists of a narrow axis of Dismal Swamp terrace and possibly small remnants of Chowan terrace, with considerable areas of Princess Anne terrace on either side. No true upland loam gravel is found in the county. There are abundant resources of well-sorted sand in the terrace formations, as well as on some of the modern beaches. The beaches in places furnish the coarsest sand. There are here and there zones of gravel 2 or 3 feet thick which carry 20 to 30 per cent of grades over ¼ inch mesh. These deposits are not extensive nor exposed at many points, but it is thought that with careful prospecting local supplies of considerable value may be found. (See samples 2254-A, 2254-B, 2254-C, 2254-D, 2256, 2260, and 2277-B, pp. 63, 74, 75, and 99.)

NORTHUMBERLAND COUNTY

The greater part of this county lies on the Sunderland terrace south of the mouth of Potomac River. Smaller areas of lower terraces are developed along the river and along the shore of Chesapeake Bay. The Sunderland formation consists in the main of sandy loam with a few thin zones of pebbles ranging to 1 inch or uncommonly 2 inches in diameter. Considerable amounts of well-washed medium and coarse sand and very fine gravel are found in the lower terraces. (See sample 1775, p. 83.)

PRINCE GEORGE COUNTY

This county includes a large area of Sunderland terrace south of Appomattox and James rivers, and smaller areas of Wicomico and lower terraces adjacent to the rivers. There are possibly small remnants of pre-Sunderland terraces and formations in the western part of the county. Large quantities of typical upland loam gravel are found in the Sunderland formation and parts of the base are very coarse. The Wicomico formation of this county contains large amounts of coarse loam gravel. Considerable quantities of well-washed sand and gravel are present in parts of the lower terraces. (See samples 2003, 2152, and 2153, pp. 53 and 80.)

PRINCESS ANNE COUNTY

This county consists of a large area of Dismal Swamp terrace and a somewhat smaller area of Princess Anne terrace on the extreme eastern shore of the main part of the Coastal Plain of Virginia. No loam gravel is found. The Dismal Swamp formation consists chiefly of fine sandy loam. Large supplies of well-washed sand are present in the Dismal Swamp and Princess Anne formations and still more accessible deposits of sand are found in the modern beaches and dunes along the coast. (See samples 2069, 2071-C, 2076, and 2079, pp. 74, 89, and 99.)

PRINCE WILLIAM COUNTY

A strip of this county 2 or 3 miles wide and 10 miles long, lies east of the Fall Belt. Small remnants of all the terraces from the Brandywine to Recent probably occur in this area, but they have not been discriminated because of the lack of detailed topographic maps. Moderate amounts of good road gravel are found in some of the terrace remnants, but they do not constitute very large supplies. Clean sand and gravel suitable for use in concrete are found in the lower terraces along the rivers and also in places in the flood-plains of the streams of the Fall Belt.

RICHMOND COUNTY

Richmond County is on the north bank of Rappahannock River. It consists of a large area of Sunderland terrace with a fringe of lower terrace areas along the rivers. The Sunderland formation is in places moderately pebbly, but the formation is too largely loamy in most places for the best road material. Large amounts of well-washed sand and gravel are found in some of the lower terrace formations and somewhat loamy, moderately coarse gravel suitable for road work is found in a few places in these terraces.

SOUTHAMPTON COUNTY

Large areas of the Sunderland terrace exist in this county and the areas of Wicomico terrace are of only slightly less extent. There are also in the aggregate considerable areas of Chowan, Dismal Swamp, and Princess Anne terrace which occur in numerous elongate areas along Blackwater, Nottoway, and Meherrin rivers. For the most part the Sunderland formation consists of slightly pebbly loam. Material sufficiently coarse to be most useful for road building is not abundant except in the extreme western part of the county. Considerable amounts of moderately well sorted sand are found in some of the lower terrace formations. (See samples 2094, 2096, 2103, 2107, and 2108, pp. 55, 60, 67, and 74.)

SPOTSYLVANIA COUNTY

A small corner of this county lies east of the Fall Belt south of Rappahannock River. This area is largely on Sunderland and pre-Sunderland terrace remnants, but small areas of lower terraces are found along the river. Considerable amounts of loam gravel are found in the Sunderland and older terrace formations, and large quantities of fairly well sorted sand and gravel suitable for concrete and other construction purposes are found in lower terraces. These deposits are being extensively worked southeast of Fredericksburg. (See Pl. 8, B.)

STAFFORD COUNTY

Somewhat less than half of Stafford County lies on the Coastal Plain. It is mostly Sunderland terrace with remnants of higher terraces along the Fall Belt and remnants of lower terraces along the river. They have not been mapped in detail because of the lack of modern topographic maps. Considerable amounts of loam gravel are available in the Sunderland terrace. Such material is also found in the higher terrace remnants, but these appear to be small and somewhat variable. Clean sand and gravel are found in places in the low terraces along the river. Well-washed sand and gravel are also present in considerable amounts in the modern plain of Rappahannock River near Falmouth. (See samples 1729-A, 1729-B, 1729-C, 1729-D, and 1738, pp. 89 and 91.)

SURRY COUNTY

This county is at the eastern margin of the Sunderland terrace south of James River. It is mostly on this terrace but a small part is on the Wicomico terrace, and small areas of several lower terraces occur along the river. There are large quantities of coarse loam gravel in the Sunderland formation in this county. Gravel sufficiently well sorted to permit screening for concrete aggregate is found in places in this formation. Moderate amounts of sand and clean fine gravel are present in the lower terraces.

SUSSEX COUNTY

This county lies immediately east of the Fall Belt. It is composed of Sunderland terrace, with a few small areas of higher terraces along the Fall Belt and some low terraces along Nottoway River. The Sunderland formation is fine-grained and consists mainly of slightly pebbly loam. It is sandy in places. Considerable amounts of well-sorted, coarse sand and fine gravel are found in the low terraces along Nottoway River. The pebbles and sand grains in these sediments are rough angular fragments weathered from the crystalline rocks of the Piedmont Plateau. (See samples 1990, 2139, 2142, 2145, 2146, and 2149, pp. 53 and 67.)

WARWICK COUNTY

This county is just north of James River, and is east of the Surry scarp. It contains small areas of Wicomico, Chowan, Dismal Swamp, and Princess Anne terraces. Moderate amounts of coarse, somewhat loamy gravel are found in places in the Wicomico terrace. Large quantities of clean sand and some fine gravel are present in the lower terraces. (See sample 1799, p. 95.)

WESTMORELAND COUNTY

This county consists largely of Sunderland terrace, but it has moderate areas of lower terraces along Potomac River and, to a less extent, along the Rappahannock. Considerable quantities of moderately pebbly loam gravel are found in the Sunderland formation. Large amounts of sand and gravel suitable for concrete can be produced from the low terraces along the rivers. (See samples 1711-A, 1711-B, and 2296, pp. 83 and 91.)

YORK COUNTY

This county contains a small area of Sunderland terrace, a somewhat larger area of Wicomico terrace, and considerable areas of each of the lower terraces adjacent to York River and Chesapeake Bay. The Sunderland and Wicomico formations, so far as known in this area, consist mostly of loam. Abundant resources of washed sand and gravel can be had from the lower terraces. Coarse gravel, which may be basal Wicomico or Wicomico reworked into Chowan terrace, is exposed in the scarp 2 miles south of Grafton. Considerable coarse material has been dredged from Back River for use on the Eastern Shore, but little is known of the relations and amount of this material. (See samples 1795 and 1796, p. 80.)

SUMMARY

In the foregoing descriptions, it is shown that moderate quantities of washed sand and gravel are found in nearly all the counties of the Coastal Plain of Virginia. Moderately coarse loam gravel is found in perhaps half of the counties of the Coastal Plain, chiefly in counties near the Fall Belt or near one of the principal streams.

As extremely large quantities of washed sand and gravel are not needed, the demand for them can be more readily met by shipment overland or by water than in the case of the loam gravel which is needed in great quantities in building highways. There seems little prospect that large resources of pebbly loam gravel will be found in the eastern counties of the western shore, or in the counties of the Eastern Shore. Since the quality of this material may be somewhat flexible, small amounts suitable for local use will doubtless be found in practically all of the counties.

As loam gravel suitable for roads is found in increasing amounts northward along the Eastern Shore of Maryland, it is possible that this may be the most economical source for the counties of the Eastern Shore in Virginia.

In order to supply the need of parts of the eastern Coastal Plain for large quantities of road gravel for important projects, it is thought that the most economical plan, in the long run, would be to open pits in suitable loam gravel of the high terraces at some point on the James or Potomac rivers where this material could be loaded by gravity onto barges. It is believed that a portable pontoon pier could be used for the delivery of gravel by truck at a permissible cost to various points in Tidewater Virginia.

APPENDIX A

*Strength tests of certain samples of Coastal Plain sand and gravel**

Number	Days	Pounds per square inch†			Average	Same cement with standard sand	Strength ratio	Water in sand mortar Per cent
1444	7	3100	3100	3400	3200	2733	115	11.0
	28	5000	4700	4850	4850	3947	123	
1469	7	1400	1500	1500	1466	2866	51	14.0
	28	2200	2190	2200	2197	3810	58	
1483	7	3650	3800	3350	3600	2566	140	11.0
	28	4560	4690	4790	4680	3710	126	
1522	7	3100	3050	2900	3016	2866	105	11.3
	28	4800	4660	4940	4800	3810	126	
1531	7	2550	2300	2550	2466	2866	86	10.4
	28	4130	4080	4130	4113	3810	108	
1558	7	2650	2650	2700	2666	2866	93	11.3
	28	4410	4110	4000	4173	3810	109	
1566	7	3200	3200	2900	3100	2866	108	12.0
	28	4890	4940	4840	4890	3810	128	
1686	7	4550	4550	4550	4550	2733	164	10.0
	28	6390	6440	6290	6373	3947	162	
1739	7	3330	3120	3160	3203	2557	125	11.0
	28	4410	4630	4310	4450	3480	128	
1748	7	1730	1720	1760	1737	2557	68	12.0
	28	2410	2460	2540	2470	3480	71	
1796	7	3230	3140	3000	3123	2557	122	12.0
	28	4360	4400	4440	4400	3480	126	
1831	7	3460	3600	3740	3600	2557	141	11.0
	28	5410	5560	5530	5500	3480	158	

*Tests made by the State Department of Highways, Mr. Shreve Clark, Assistant Engineer of Tests.

†One part of cement to three parts of sand.

APPENDIX B

*Mechanical analyses of certain samples of Coastal Plain sand and gravel**

On mesh	No. 1444	No. 1469	No. 1483	No. 1522	No. 1531	No. 1558
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
(Gravel)						
2½ inches.....	....	4.5	6.3	....	....	....
2 "	....	3.4	7.1	3.1	....	....
1½ "	....	10.3	5.6	4.9	....	....
1 "	2.4	7.4	11.2	5.5	....	....
1¼ "	11.8	9.9	13.2	9.2	1.9	....
¾ "	16.2	15.7	12.7	15.3	1.4	....
½ "	31.0	22.0	19.0	28.7	17.2	....
¼ "	38.4	24.2	23.7	31.9	76.8	....
¼ "	.2	2.6	1.2	1.4	2.8	....
(Sand)						
No. 10......	18.5	19.8	23.9	22.5	25.4	3.7
No. 20......	11.3	15.1	14.4	18.6	26.3	12.3
No. 30......	21.7	25.6	21.5	21.2	25.2	26.9
No. 40......	14.7	10.0	12.2	12.5	11.6	15.8
No. 50......	13.8	5.9	8.8	10.0	7.8	15.4
No. 60......	8.0	2.5	6.0	4.7	2.2	8.0
No. 80......	3.5	1.0	3.1	1.5	0.4	3.2
No. 100......	4.0	2.0	4.0	1.8	0.4	3.9
No. -100......	4.5	18.1	6.1	7.2	0.7	10.8
Silt in sand....	0.2	6.2	....	4.7	0.2	2.1

***Tests made by the State Department of Highways, Mr. Shreve Clark, Assistant Engineer of Tests.**

APPENDIX B

Mechanical analyses of certain samples of Coastal Plain sand and gravel

On mesh	No. 1566	No. 1686	No. 1739	No. 1748	No. 1796	No. 1831
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
(Gravel)						
2½ inches	...	...	...	...	18.8	...
2 "	...	...	...	...	9.0	...
1½ "	...	...	...	...	7.2	...
1¼ "	...	...	...	...	10.2	...
1 "	...	...	...	...	7.5	5.5
¾ "	(a)	(a)	...	...	7.9	7.7
½ "	...	...	...	...	15.4	26.8
¼ "	...	...	3.3	...	24.0	60.0
−¼ "	...	...	...	...	...	...
(Sand)						
No. 10	14.4	39.4	9.8	1.3	20.8	34.3
No. 20	20.0	34.4	26.5	3.6	15.4	31.6
No. 30	27.1	11.6	28.0	6.0	15.0	18.8
No. 40	14.1	3.3	10.8	3.6	6.6	3.2
No. 50	14.2	4.0	14.0	24.4	11.0	4.2
No. 60	4.9	2.8	6.5	32.8	8.2	2.2
No. 80	1.7	1.3	2.0	6.3	4.9	0.8
No. 100	1.4	1.6	1.1	16.8	8.9	1.6
No. −100	2.2	1.6	1.3	5.2	9.2	3.3
Silt in sand	3.5	0.3	...	...	...	...

(a) All passing ¾" mesh.

APPENDIX C

Remarks on samples listed in Appendices A and B

Sample 1444: Lab. No. G4313. Locality, 1½ miles west of Lorton, Fairfax County. Sand 40.5 per cent, gravel 30.7 per cent, clay 28.8 per cent. Colorimetric test, 1. Water in sand mortar, 11.0 per cent.

Sample 1469: Lab. No. G4307. Locality, road cut ¾ mile west of Stafford, Stafford County. Sand 36 per cent, gravel 64 per cent. Colorimetric test, 6. Water in sand mortar, 14.0 per cent.

Sample 1483: Lab. No. G4312. Locality, on property of John Ayers, north of Mt. Vernon, Fairfax County, 1/10 mile southwest of bridge on Little Hunting Creek. Sand 42 per cent, gravel 56 per cent, clay 2 per cent. Water in sand mortar, 11.0 per cent.

Sample 1522: Lab. No. G4310. Locality, ½ mile west of Pamunkey River bridge, 2 miles east of Hanover, Hanover County. Sand 41.8 per cent, gravel 58.2 per cent. Colorimetric test, 4. Water in sand mortar, 11.3 per cent.

Sample 1531: Lab. No. G4314. Locality, ¾ mile northeast of Gether, Caroline County. Sand 75.7 per cent, gravel 24.3 per cent. Colorimetric test, 9. Water in sand mortar, 10.4 per cent.

Sample 1558: Lab. No. G4311. Locality, west end of Mattaponi River bridge at Aylett, King William County. Colorimetric test, 3. Water in sand mortar, 11.3 per cent.

Sample 1566: Lab. No. G4308. Locality, on 45-foot terrace 1½ miles south of Manquin, King William County, and ¼ mile north of the road corner. Sand 92.6 per cent, gravel 7.4 per cent. Colorimetric test, 3. Water in sand mortar, 12.0 per cent.

Sample 1686: Lab. No. G4309. Locality, ½ mile southwest of King George, King George County. Sand 73.0 per cent, gravel 10.1 per cent, clay 16.9 per cent. Colorimetric test, 1. Water in sand mortar, 10.0 per cent.

Sample 1739: Lab. No. G5069. Locality, 200 feet west of Streets P. O., Middlesex County. Gravel 2.9 per cent, sand 83.7 per cent, clay 13.4 per cent. Colorimetric test, 1. Water in sand mortar, 11.0 per cent.

Sample 1748: Lab. No. G5070. Locality, ½ mile north of Amburg, Middlesex County. Sand 97.2 per cent, clay 2.8 per cent. Colorimetric test, 1. Water in sand mortar, 12.0 per cent.

Sample 1796: Lab. No. G5067. Locality, northwest of Tabb, York County, on road ½ mile south of Poquoson River.

Sample 1831: Lab. No. G5068. Locality, Charles City, Charles City County, 1/6 mile west of Parrish Hill Creek crossing. Gravel 25.5 per cent, sand 70.5 per cent, clay 6.0 per cent. Colorimetric test, 1. Water in sand mortar, 11.0 per cent.

INDEX