Geology of the Brandywine Area and Origin of the Upland of Southern Maryland

GEOLOGICAL SURVEY PROFESSIONAL PAPER 267-A

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By John T. Hack

GEOLOGY AND SOILS OF THE BRANDYWINE AREA, MARYLAND

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A detailed study of the geologic history and origin of the surficial deposits of a small area on the Coastal Plain

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ILLUSTRATIONS

Only the upper 40 or 50 feet is exposed and this is restricted to the valley of Mataponi Creek and the deeper ravines tributary to it in the northeastern part of the map area, plate 1. Outcrops are few and expose only the upper sandy beds. They consist of greenish-gray glauconitic sand containing considerable clay. The contact between the Nanjemoy and the overlying Calvert is at an altitude of about 60 feet along Mataponi Creek. At Cheltenham the contact is at an altitude of 120 feet. According to the subsurface information in Charles and Calvert Counties (Dryden and Overbeck, 1948; Overbeck, 1951) the top of the formation is 20 feet below sea level in the southeastern part of the Brandywine area.

Summary of well log near Cheltenham

[Altitude, top of well, 240 feet]

	Approximate thickness (feet)
Brandywine formation (Pliocene?):	
Clay and silt, dark yellowish-orange in upper part. Lower part interbedded sand and gravel	30
North Keys sand (Miocene?):	
Silt and fine sand, dark yellowish-orange; some gravel	20
Calvert formation (Miocene):	
Silt and clay, olive-gray, interbedded with fine sand. Shell fragments and diatoms abundant	70
Nanjemoy formation (Eocene):	
Sand, medium greenish-gray, with glauconite; upper part. Lower part olive-gray to pale red clay	70
Aquia formation (Eocene):	
Sand, mostly olive gray, glauconitic; in part clayey	130
Monmouth and Matawan formations (Paleocene and Upper Cretaceous):	
Sand, dark-gray, glauconitic, generally clayey, micaceous	70
Magothy formation (Upper Cretaceous):	
Clay, light-gray, sandy, and clayey sand. Well penetrates clean pebbly sand at base	38+
Total	428

CALVERT FORMATION

The Calvert was named by Shattuck (Clark, Shattuck, and Dall, 1904) from the excellent exposures in the Calvert cliffs along Chesapeake Bay, a short distance east of the Brandywine area. At the type locality the formation is about 150 feet thick (Overbeck, 1950), but is only 70 to 85 feet thick in the Brandywine area. The upper part of the formation is not present. The top of the Calvert (fig. 2) is marked by a prominent bed of diatomaceous clay 15 to 30 feet thick, belonging to zone 12 of the type section. This bed is dark greenish gray massive and contains a few streaks of brown iron oxide, and fossil casts. In places it contains shells. The clay bed is overlain by the North Keys sand and is underlain by interbedded white to gray clay and medium-grained sand. The lower part of the formation contains several thick beds of diatomaceous earth. The contact between the Calvert and Nanjemoy formations was not seen within the area, but is well exposed on the east bank of the Patuxent River across from Nottingham at Kaylor's diatomite quarry, where a bed of clay 1 foot thick forms the base of the Calvert and rests with sharp contact on the greensand of the Nanjemoy formation. It is overlain by 3 feet of quartz sand which grades upward into 10 feet of diatomaceous earth.

Description of outcrops.—The most complete sections of the Calvert are exposed on the north side of Rock Creek where it is crossed by the road from Baden to North Keys. Another series of good exposures are on both sides of this valley on a branch of a road to Brookfield Church. A composite geologic section, made up of many outcrops at these localities, lacks only the lowest beds of the Calvert formation.

Section of upper part of Calvert formation at Rock Creek

	Feet
North Keys sand:	
Upper part of formation absent.	
Sand, silty fine, weathered light brown. Becomes yellowish-gray and more silty downward; grades into diatomaceous clay below	10
Calvert formation:	
Clay, yellowish-gray, fine, diatomaceous. The diatom flora correlates with zones 11, 12, and 13, in Calvert cliffs (Lohman, personal communication)	19
Sand, clean, fine, very pale orange	8
Sand, yellowish-gray, fine, silty, mottled with dark yellowish orange. An outcrop nearby in same bed contains bands of *Corbula elevata*	15
Clay, yellowish-gray diatomaceous, containing thin lenses of fine sand near base. Diatom flora correlates with zones 6, 7, and 8 of type section (Lohman, personal communication)	16
Sand, grayish-yellow, clean, fine	4
Sand, interbedded, fine; sandy clay, and clay, grayish-yellow	6
Sand, grayish-yellow with brown mottling, very fine micaceous mealy	7
Diatomaceous earth, pale greenish-yellow	10
Total	95

Base of Calvert formation concealed.

A complete section made up of many outcrops along 1.6 miles of road, was measured on U. S. Route 301 between the north edge of the Brandywine area and Charles Branch, south of Upper Marlboro. The lithology changes laterally.

Elsewhere in the Brandywine area only incomplete sections are exposed. In this area the Calvert formation is distinctive lithologically from the oxidized sand of the North Keys and is separated from it by the clay

FIGURE 2.—Outcrop near Brookfield Church in Brandywine area exposing lower part of North Keys sand and highest part of the upper clay bed in the Calvert formation. Hat is at contact.

marker bed. The contact is exposed in many road cuts, and where not covered by slope wash or younger deposits of transported material, is reflected by a sharp difference in soils. The lower beds of the Calvert differ markedly from the greenish glauconitic clayey sands of the Nanjemoy formation.

Generalized section of Miocene deposits along U. S. Route 301 immediately north of Brandywine quadrangle

[Altitude, top of section, 218 feet]

	Feet
North Keys sand:	
Sand, light-orange, fine and grading downward into mealy, loamy fine sand; gradational contact with Calvert formation	37
Calvert formation:	
Clay, gray diatomaceous. Lower 15 feet interbedded sand and clay	30
Clay, light-gray diatomaceous; richer in diatoms than beds above	12
Sand, light-gray to white, fine	18
Clay, diatomaceous or diatomaceous earth	6
Clay, black or dark-gray, weathered into large prisms separated by tongues of light-gray clay	7
Concealed	8
Nanjemoy formation (Eocene):	
Sand, dark greenish-gray, loamy glauconitic	10
Total	128

Mechanical composition and bedding.—The fine-textured material in the Calvert formation generally is clay. Because of the diatoms present, however, the material feels slippery and noncohesive when wet, more like silt than clay. The clayey beds are generally poorly sorted. The sand beds are light gray, almost white, and consist mostly of medium sand made of clear, angular quartz grains. Sand in these beds is well sorted and in mechanical composition resembles beach sand or shallow-water deposits. Figure 3 is a cumulative frequency diagram showing the mechanical composition of different beds in the Miocene, including a sample of diatomaceous clay of zone 12, and a sample of sand collected below zone 12.

As is strikingly shown at many places in the area along the Chesapeake Bay shore, bedding is thin and even. Individual thin beds of sand, fossil layers, or clay in some places extend for hundreds of yards along the cliffs without appreciable change in thickness or lithology.

Correlation with type locality.—The Miocene of Maryland has been subdivided into 24 zones by Shattuck (1904) on the basis of detailed work along the Chesapeake Bay shore. Although Schoonover (1941) has shown that some of the zones cannot be traced in the field beyond the type area, the major elements of Shattuck's subdivision have not been modified. The Calvert formation, according to Shattuck, is subdivided into the Fairhaven diatomaceous earth member, comprising zones 1–3, and the Plum Point marl mem-

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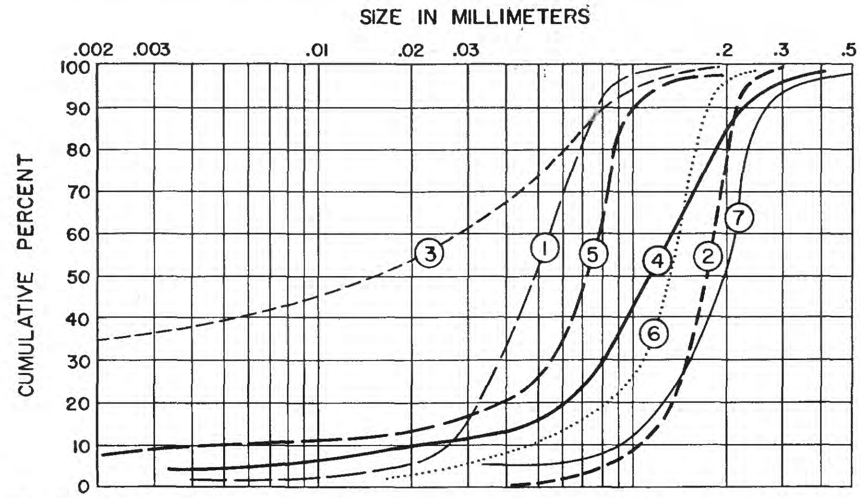

FIGURE 3.—Cumulative size-distribution curves of samples of Calvert formation and North Keys sand; compared with two samples of beach sand from southern Virginia. Analysis by Soil Survey, unless otherwise noted. (1) Quaternary beach sand from the Suffolk scarp, Nansemond County, Va. (2). Recent beach sand from Cape Henry, Princess Anne County, Va., analysis by C. K. Wentworth (1930). (3) Diatomaceous clay in Calvert formation (zone 12) from road cut on Maryland Route 382, near Brookfield Church, Brandywine area. (4) Sand in Calvert formation about 50 feet below top of formation; 0.7 mile west of North Keys. (5) Mealy, loamy sand in lower part of North Keys sand from road cut 1 mile west of North Keys. (6) Upper part of North Keys sand from 1.3 miles west of North Keys. (7) Upper part of North Keys sand, 1 mile north of Baden, Md.

ber, comprising zones 4–15. Fossil localities inland from the bay shore are rare, probably because fossils are preserved in stream banks and road cuts only where they are silicified, as they generally have been subjected to weathering at shallow depth. Collections of fossils have been obtained from a few localities in the Brandywine area, however, and the beds have been traced outside the area to correlate them with fossiliferous beds nearer the type Miocene section.

The correlations indicate that the Calvert formation in the Brandywine area includes at least zones 6–12. Zones 14–15 are not present, and zone 13 is probably not present. Diatoms and other fossils in the lowest of the Calvert beds have not been studied but it is possible that zones 1–5 are present in the Brandywine area.

The clay bed, which marks the top of the Calvert formation in the Brandywine area, has been traced over a wide area as shown in figure 4, and fossil evidence at several places indicates that it is probably correlative with zone 12 of the type section. The mollusk *Chione parkeria* has been found in this clay bed at locality 6, south of the Brandywine area, and at locality 8, near Owings in Calvert County. This mollusk was formerly thought to be restricted to zone 14, but according to Julia Gardner who has studied the type section, it is actually more abundant in zone 12. In a personal communication, Gardner states,

Very little collecting has been done in zone 12 except by the vertebrate paleontologists. I have not been to their localities north of Parker Creek and those south of Parker Creek are accessible only at low tide.

Glenn in his descriptions of the Bay sections (p. 1 of the Miocene volume) lists from 0.5 mile south of Parker Creek, *Ecphora quadricostata* var. *umbilicata*, *Venus mercenaria* and *Cytheria staminea*. *Cytherea staminea* is a trigonal shell similar in general outline to *Chione parkeria* but the concentric flanges are much more prominent than in *C. parkeria* and there is none of the radial grooving so characteristic of *C. parkeria*. The hinges are also very different but the interiors of both species are usually poorly preserved. However, *Cytherea staminia*, so abundant at Plum Point and widely distributed through the Calvert of Maryland was probably, in Glenn's list, a misidentification of *Chione parkeria* though in his large distribution table, he omits *C. staminea* and lists *C. parkeria* from "Parker Creek" a generalized locality. In his first description (Miocene volume, p. 310), Glenn lists *Chione parkeria* from "Parker Creek and 2 miles south of Parker Creek". "Parker Creek" is difficult to identify but "two miles south of Parker Creek" would doubtless fall in zone 14 of the Calvert formation. Glenn in his description remarks without further comment "This species seems to be related to *C. ulocyma* Dall." *Chione ulocyma* is a fairly common species in the Choctawhatchee formation of Florida but it is transversely ovate rather than trigonal as in *C. parkeria* and laterally the flanges are free, and upstanding and on the lateral areas, the radial lineation is almost or entirely obsolete. The Maryland and Florida species are doubtless related but they are easily separable.

Lois Schoonover Kent in her excellent report published as No. 94–B, vol. XXV of the Bull. Am. Paleontology, does not cover Zone 12 and cites *Chione parkeria* only from zone 14.

Two samples from the clay bed which marks the top of the Calvert formation in the Brandywine area have been studied by K. E. Lohman, one sample from locality 2, near Brookfield Church, in the Brandywine area, and one from locality 7 in Calvert County. Both samples contain a rich diatom flora which is correlative with the flora of zones 11, 12, and 13 of the type Miocene section. Because the mollusk *Chione parkeria*, abundant in zones 12 and 14, has been collected from

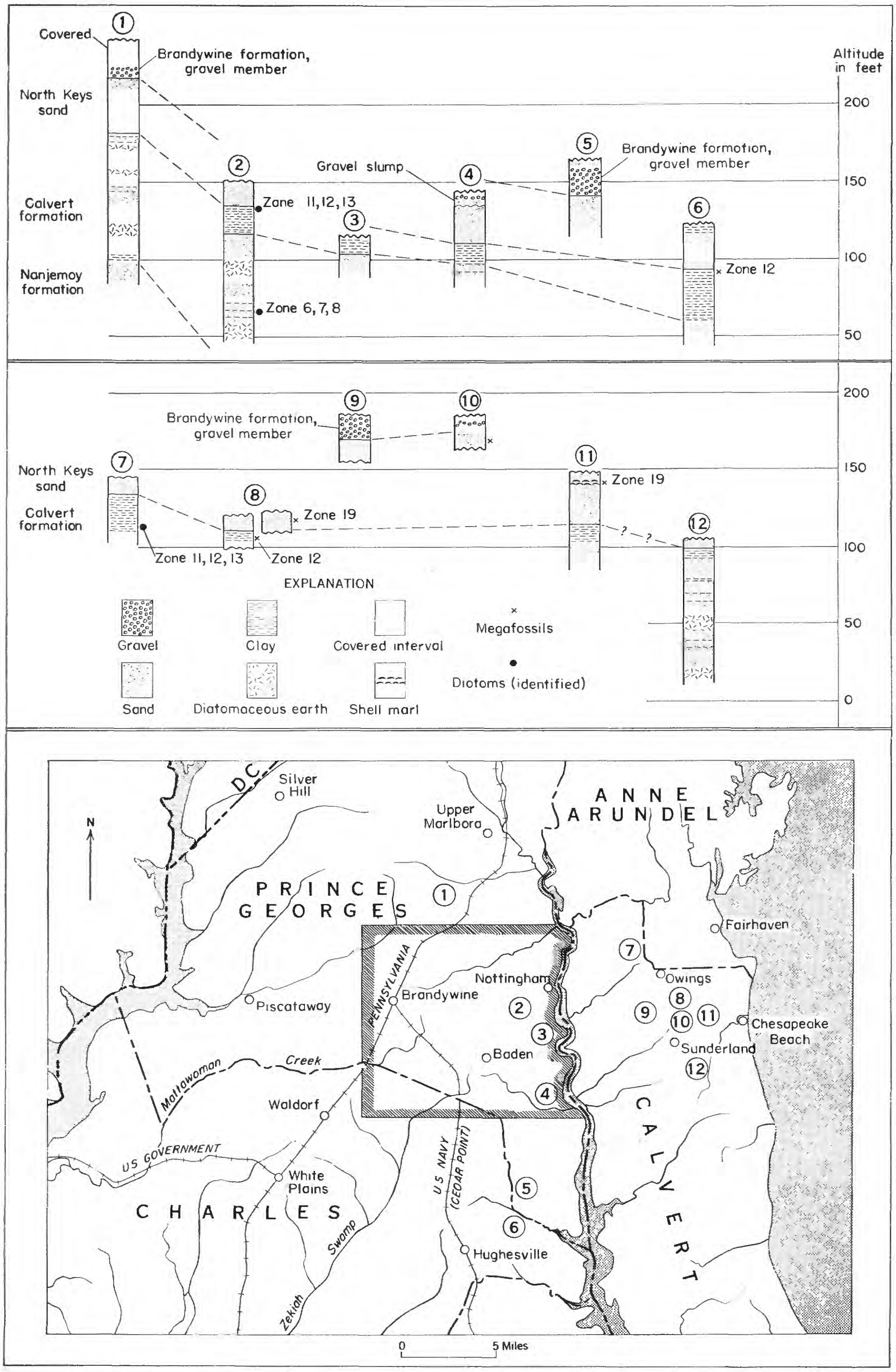

FIGURE 4.—Selected diagrammatic columnar sections in southeastern Prince Georges County and northern Calvert County showing lithology and principal fossil localities. The diagram summarizes the evidence by which the stratigraphic sequence in Calvert County described by Shattuck (1906) is correlated with deposits in the Brandywine area. Megafossils were identified by Julia Gardner, diatoms by K. E. Lohman. The Brandywine is outlined by hachured line on the index map.

the same bed it is concluded that the bed is the equivalent of zone 12 of the type section.

Diatoms have also been studied by Lohman from beds in the middle part of the Calvert formation, at locality 2 (fig. 4) near Brookfield Church, and indicate that these beds are correlative with zone 6, 7, or 8 of the type section.

NORTH KEYS SAND

The term North Keys sand, first introduced in this report, represents a bed of fine yellowish-orange sand which rests conformably on the top clay bed of the Calvert formation, and in the Brandywine area, underlies the gravel of the Brandywine formation (fig. 5). A sand similar to the North Keys sand in some places is interbedded with the Brandywine; in others the Brandywine is separated from the North Keys sand by a sharp, irregular erosional contact. The top of the North Keys sand is placed at the base of the lowest gravel in the local sequence. Thickness of the sand in the Brandywine area ranges from 20 to 60 feet, reaching its maximum in the central part of the area near Baden.

The North Keys sand was formerly mapped as part of the overlying formations and in the Brandywine area was included by Shattuck (1906) and Miller (1911) in the Brandywine and Sunderland formations. However the sand is at least in part Miocene in age, and in this area is equivalent to zone 19 in the Choptank, a sand and clay deposit overlying the Calvert along the Chesapeake Bay shore. The North Keys sand is traceable on the basis of lithology over a wide area in southern Maryland and may not be equivalent everywhere to zone 19. The writer believes that it may overlap the younger Miocene formations becoming younger to the south where it is equivalent to higher zones. For this reason, a new name defined on the basis of stratigraphic position and lithology is proposed even though in the Brandywine area fossil evidence nearby appears to identify the North Keys sand with the Choptank.

Description of outcrops.—The type locality is the vicinity of North Keys, a hamlet on the road from Brandywine to Naylor in Prince Georges County. The formation, which crops out on the eastern flank of the upland, caps many of the hills between the upland and the Patuxent River, and is exposed in many road cuts. The most complete exposures are on the road 1.4 miles northwest from North Keys. At this locality the base of the formation is at an altitude of 156 feet. It rests on the diatomaceous clay of zone 12 at the top of the Calvert. The contact is gradational and the greenish-gray clay merges upward through about 3 feet into yellowish-orange loamy fine sand. Farther up the hill another road cut exposes the upper part of the formation which is a fine sand well sorted and free of clay. The contact with the sand and gravel of the Brandywine formation at 198 feet, is irregular and sharp. Overlying sand and gravel is coarse textured and strongly crossbedded.

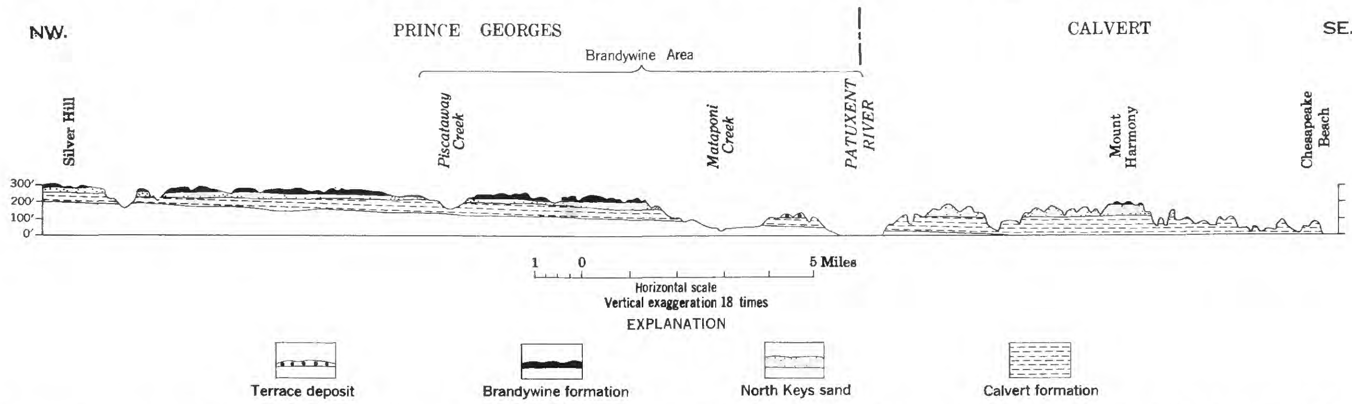

FIGURE 5.—Stratigraphic cross section across upland of southern Maryland through Brandywine area, showing the relationship between the Calvert formation, North Keys sand, and Brandywine formation. Based on reconnaissance by J. T. Hack and R. M. Lindvall. Vertical scale greatly exaggerated.

The lower part of the North Keys sand is loamy, and the upper part free of clay or silt. At only one place in the Brandywine area have fine-grained deposits been found in the North Keys. About 1 mile north from North Keys, west of the main road, is an outcrop of brown sandy loam at an altitude of 170 feet. As this outcrop is stratigraphically higher than the projected top of the Calvert the material is presumably a lens of fine-grained material in the North Keys. Poorly preserved fossils from this locality have been identified by Gardner (personal communication) as characteristic of the Choptank. At several places outside of the Brandywine area thin bands of clay of variegated color have been found in the North Keys sand.

Although the best exposures of the North Keys sand are in the eastern part of the area, outcrops occur on the upland surface wherever erosion has penetrated below the gravel of the Brandywine. One of the most accessible exposures is on U. S. Route 301 at the crossing of a south tributary of Piscataway Creek, 1 mile southwest from Cheltenham.

Composition and origin of sand.—The North Keys sand is remarkably well sorted. The loamier part of the formation encountered near the base, owes it relatively fine texture to an increase in clay content. The sand fractions are very well sorted, 80 percent being classed as fine sand. Cumulative frequency curves of representative samples are shown in figure 3, which also includes samples of two Recent beach sands from the Atlantic coast of Virginia. The characteristics of these curves are similar and indicate that the North Keys sand probably is a marine sand deposited in shallow water, on the shore, or as dunes behind the beach. Possibly it was deposited in all three environments and those parts of the formation which are free of clay or silt, and are devoid of fossils may represent a shore or shore-dune facies. The clear sharply angular nature of the individual sand grains also suggests origin along the shore. The origin of this deposit will be discussed more fully in a later section that deals with the upland deposits of southern Maryland.

Oxidation of sand.—The North Keys sand is conspicuously oxidized to a brilliant yellowish orange. Its hue contrasts with the olive or greenish-yellow hues of the underlying Calvert formation. Although clay lenses in the Brandywine area are rare they are common though very thin in areas to the south and east and are generally red. Oxidation has proceeded through the Brandywine formation to the depth of the highest thick impervious layer in the section, or to the permanent water table. In the Brandywine area, this depth is determined by the position of the thick clay bed at the top of the Calvert. The change from oxidized to unoxidized material is gradational but occurs within a few feet vertically in the clay. At a number of places the change is marked by joints in the top of the clay into which project narrow films of brown iron oxide. These joints form polygons several feet in diameter. Probably the oxidation of the sandy Miocene beds near the surface has in the past led geologists to group the orange sand with the overlying gravel deposits. It is the writer's belief that the color is entirely secondary and should not be a criterion for the separation of formations.

Treatment by previous workers.—On a map by Miller and Bibbins (1911), the outcrop area of the writer's North Keys sand is occupied approximately by the Sunderland formation, which was supposedly younger than the Brandywine formation. The report which accompanies the map describes the Sunderland formation in general terms but implies that its lithology is commonly interbedded sand and gravel. Many of the hills in the outcrop area of the North Keys sand are capped by gravel, either outliers of the Brandywine or by channel deposits and slope wash younger than the Brandywine. The slopes of the hills are commonly mantled by gravelly loam that has moved down by creep and slope wash. Presumably earlier workers misinterpreted these features for interbedded sand and gravel. Today the many deep road cuts in the area show clearly that the deposits mapped as North Keys are devoid of gravel and that they may be traced westward without a break and without change in stratigraphic position into deposits underlying the Brandywine formation. It is probable that the oxidized sand was not considered a part of the Miocene, for the Choptank formation, the youngest Miocene, is shown on the map of Miller and Bibbins (1911) as cropping out only in the extreme southeast corner of Prince Georges County. Shattuck in describing the Brandywine and younger coastal plain formations states that in many places they are entirely sandy, especially at the base. It is probable, therefore, that the North Keys sand was interpreted by Shattuck and his coworkers (Clark, Shattuck, and Dall, 1904) as a part of the Pliocene and Pleistocene sequence rather than of the Miocene.

Relationship of the North Keys sand to other Miocene deposits.—The Miocene deposits of Maryland are generally subdivided into three formations which contain 24 zones (Clark, Shattuck, and Dall, 1904, p. lxix), and are well exposed along the Chesapeake Bay shore in Anne Arundel and Calvert Counties. The deposits are sand, clay, and diatomaceous earth and along the shore are quite fossiliferous. They are classified as shown below.

Formation	*Zone*
Calvert	1–15
Choptank	16–20
St. Marys	21–24

In the Brandywine area the North Keys sand is younger than zone 12 of the Calvert and older than the Brandywine formation which overlies it. Fossil evidence as to its age in the area as shown on plate 1 is insufficient to date the deposit more precisely. The North Keys sand, however, has been traced into Calvert County east of the Patuxent River and near the village of Paris a shell bed or lens of marl occurs in the sand. The fauna in the shell bed has been studied by Gardner (personal communication) and is correlative with zone 19 of the Choptank formation.

The fossil localities in the Calvert formation and North Keys sand are shown in the correlation diagram (fig. 4). Fossil evidence in this area, therefore, identifies the North Keys sand with the Choptank formation. As fossils of zones 13–16 comprising the upper part of the Calvert and zones 17 and 18 of the Choptank were not found, presumably at least some of the Miocene beds in this area are missing and there is a hiatus or disconformity as recognized by Shattuck (Clark, Shattuck, and Dall, 1904, p. 1).

The North Keys sand is lithologically unlike the Choptank formation as it is exposed in the Calvert Cliffs, where it contains sandy clay and clay beds at several horizons (Clark, Shattuck, and Dall, 1904, p. 1). Two interpretations are possible. Either the North Keys sand represents an overlap of sandy beds of the Choptank, on the eroded Calvert formation, or the North Keys sand becomes younger to the south and overlaps the Choptank as well as the Calvert. The sandy nature of the North Keys, and the paucity of fossils suggest that it is a littoral or shore-dune facies of the Miocene. The latter possibility is discussed on page 30.

BRANDYWINE FORMATION

The name Brandywine formation was applied by W. B. Clark (1915) to the deposits in Maryland, formerly called the "Lafayette formation" (Shattuck, 1906). The type locality is the town of Brandywine. The formation consists of gravel, sand, and loam with gravel occurring in abundance at the base. The thickness ranges from 10 to 30 feet, but in places is as much as 50 feet. The original description contained no reference to the fine sand (North Keys) which underlies the gravel at the type locality, and presumably this sand either was not recognized or was included in the Calvert formation.

This report follows Clark's usage. The Brandywine includes the gravel and loam underlying the upland. The base of the formation is defined by the lowest gravel or coarse sand in the section, even though beds of fine sand identical with the North Keys sand occur in many places interbedded with the gravel. Although the formation as here defined may contain a disconformity and hiatus above the base it is believed that this definition is the only one practical in areal geologic mapping, and conforms closely to the original definition. The Brandywine formation has generally been considered to be Pliocene in age and is classified as Pliocene(?) in this report. The writer believes, however, that it may be in part Miocene in age and that the field evidence justifies only the statement that it may be Miocene, Pliocene, or Pleistocene.

The Brandywine formation may be divided into two members. The lower gravel member, ranging from 10 to 50 feet in thickness, is composed of interbedded sand and gravel, with a few lenses of clay and silt. The upper loam member grades upward from gravelly loam through sandy to silt loam and has a maximum thickness of 25 feet, but is generally about 15 feet or less. In large areas it is completely stripped from the lower gravel member by erosion.

FIGURE 6.—Typical outcrop of Brandywine gravel.

The Brandywine formation forms the surface of the uplands in the Brandywine area and has persisted in some places without appreciable erosion for a long geologic time interval. The formation contains well-developed soils and the original lithology of the loam member, particularly near the surface, is considerably modified by pedogenic processes.

Lower gravel member.—The gravel member is mostly interbedded sand and gravel. On slopes superficial examination gives the impression that gravel is the dominant constituent (fig. 6). This is because during the erosion of slopes the sand has been washed away and gravel has slumped over the interbedded sand. Fresh outcrops and auger holes, however, commonly show that the proportion of sand is higher than gravel. Borrow pits are numerous in the gravel member but in many places the proportion of interbedded sand is too high for the gravel to be usable.

The base of the lower gravel member in some places is a sharp contact with the North Keys sand and the change from well-sorted fine sand to poorly sorted coarse sand and gravel containing clay and silt is a sharp, irregular line. In other places the two deposits are interbedded, and beds of fine sand identical with the North Keys sand occur high in the gravel member. Where gravel and fine sand are interbedded, the bedding is generally very well developed. Thin bands of pebbles 1 to 2 inches thick extend long distances without change in texture or thickness. Such an occurrence is exposed in the Brandywine area on the road leading east from Duley at the point where it crosses the north boundary of the Brandywine quadrangle (latitude, 38°45′). Figure 7 shows the general stratigraphic relationship at this place. Figure 8 shows thin stringers of gravel in the sand.

This kind of bedding suggests deposition by shore currents. It is similar to the bedding in the underlying marine Tertiary deposits, and the sand is lithologically so similar to the North Keys that the two formations appear to be conformable.

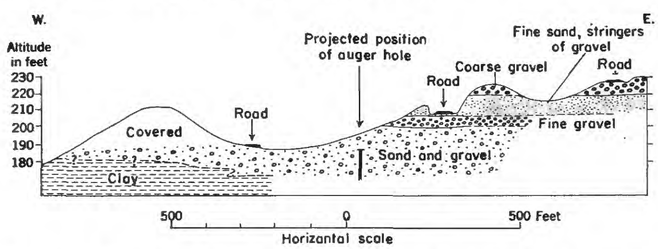

FIGURE 7.—Geologic cross section through Brandywine formation along winding road leading east from Duley to Croom at northern edge of Brandywine area. The village of Croom is about 0.2 mile east of the right end of the section. Shows position of thick bed of fine sand containing gravel stringers within Brandywine formation. The gravel member of the Brandywine is extraordinarily thick at this locality and the overlying loamy member is not preserved. Clay at base of section is in Calvert formation.

The gravel member of the Brandywine formation has a wide range in texture. Figure 9 shows typical cumulative frequency curves of the coarser beds and shows the wide variation from poorly sorted to well-sorted types. In many places the gravel is poorly sorted with a clay matrix, particularly at the top of the member. Figure 10 shows the composition of a variety of sand beds in the member. A sample of the North Keys sand is included for comparison.

The gravel member of the Brandywine is siliceous, the dominant constituents are vein quartz, chert, quartzite, and sandstone. Nonsiliceous pebbles are scarce, although a few pebbles of kaolin have been found. These are generally well rounded and in the Brandywine area few exceed 3 inches in diameter. Occasionally a cobble 8 inches or 1 foot in diameter is found.

Striated boulders and exceptionally large boulders more than 1 or 2 feet in diameter such as are common near the Potomac River and in many other parts of the Coastal Plain (Wentworth, 1928; 1930, p. 46) have not been found in the Brandywine area.

The gravel member of the Brandywine is restricted to the red and orange hues except where swampy condi-

FIGURE 8.—Exposure of Brandywine formation east of Duley, showing thin beds of gravel interbedded in fine, well-sorted sand. See figure 7.

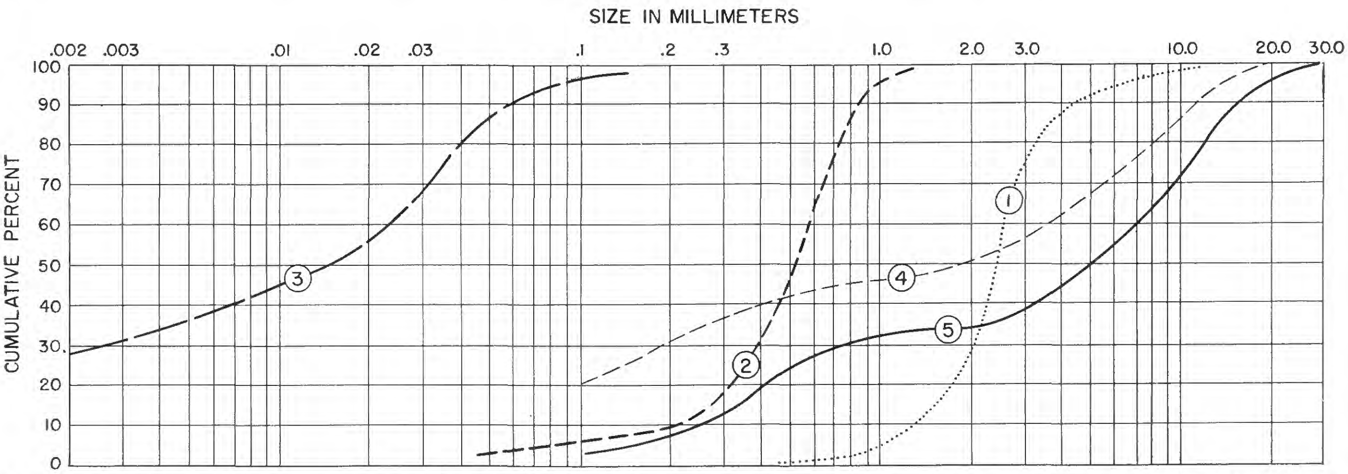

FIGURE 9.—Cumulative size-distribution curves showing the mechanical composition of several samples from the gravel member of the Brandywine formation. (1) Gravel bed 0.3 mile north of Bryantown, south of Brandywine area, Maryland; analysis reported in 1923 by C. K. Wentworth. (See footnote, 3, p. 27.) (2) Sand bed 4 feet above contact with North Keys sand, 4 miles east of Brandywine village; analysis by Soil Survey. (3) Lens of silt loam interbedded in gravel, 2 miles southeast of Brandywine village; analysis by Soil Survey. (4) Gravel 3 miles west of Upper Marlboro, north of Brandywine area; analysis by C. K. Wentworth. (5) Gravel 1 mile south of Gallant Green, south of Brandywine area; analysis by C. K. Wentworth.

tions have given the gravel immediately below the surface a bluish-gray color. Commonest colors of the gravel are pale yellowish orange (10 *YR* 8/6), very pale orange (10 *YR* 8/2), and dark yellowish orange (10 *YR* 6/6). In some places patches or pockets of gravel are reddish brown. Dark colors occur where the matrix is fine grained or clayey and it is the writer's impression that in the Brandywine area darker colors are associated with material of low porosity.

As described by Nikiforoff (1955) soils are weakly developed on the gravel especially where it is coarse textured and belong generally to the Evesboro (soil) series. They are loose and friable and have relatively inconspicuous profile development.

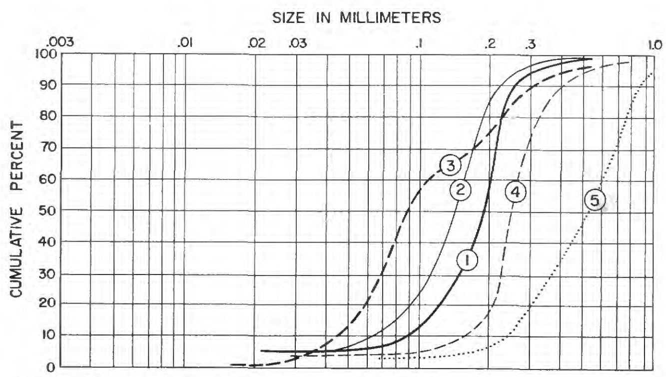

FIGURE 10.—Cumulative size-distribution curves showing mechanical composition of sands interbedded in the Brandywine formation, compared with the North Keys sand. (1) North Keys sand 1 mile north from Baden, Md. (2) Sand interbedded with gravel in the Brandywine on the road between Duley and Croom; locality same as figure 7. (3) Sand interbedded with gravel in the Brandywine on a road between Duley and Croom; this sample collected from road cut below sample 2, above. (4) Sand interbedded with gravel in the Brandywine formation from hole in floor of gravel pit west of Butler's Branch, Cedarville State Forest. (5) Coarse sand at base of the gravel member of the Brandywine formation, 4 miles east of Brandywine village. Analyses by Soil Survey.

No diagnostic fossil remains have been found within the gravel member in the Brandywine area. Near Baden, a pocket of dark-gray sand and gravel was found near the base of the gravel member containing small wood fragments, the largest less than 5 millimeters in length. The fragments have not been identified, but may be *Taxodium*.[1] In Calvert County, east of Sunderland, fossils similar to those in zone 19 of the Miocene and identical with those in the North Keys sand were found in fine sand at the contact between the North Keys sand and the upland gravel. A thin bank of quartzose pebbles was found below the fossil layer. The evidence at this locality is equivocal but suggests that some gravel as well as sand may have been deposited in the Miocene sea. On the other hand it is possible that the gravel at this place is much younger and that the fossils are reworked.

Loam member.—The upper loam member of the Brandywine formation has a large outcrop area and underlies most of the upland surface in the western part. It rests on the lower gravel member and has an irregular, but in many places, gradational contact. The maximum thickness of the upper member is probably about 25 feet but it is rarely this thick. The surface of the upland is erosional. Some or all the loam has been removed and it is carved into a gently undulating topography of broad shallow valleys and ridges. The average thickness is about 15 feet. Although the composition of the member has a wide range, silt loam is the most abundant material within 6 feet of the surface. The surface layer, the *A* soil horizon 15–20 inches thick, is mostly a very well sorted loesslike silt or fine sandy loam, but its presence is probably related to soil-

[1] R. W. Brown, oral communication.

forming processes either mechanical or chemical. Small pebbles ranging from about 3 to 5 millimeters in diameter are scattered through the loam but rarely comprise 1 percent of the deposit, except at the base where they may be as abundant as 10 or 20 percent. The sand grains in the loam are markedly different from those in the marine deposits below the Brandywine formation. Although some grains are angular, they are less sharp, and less fresh in appearance. There are few grains that are not etched, and rounded grains are abundant.

Mineralogically the loam member, like the gravel member, is highly siliceous, generally more than 90 percent silica. Heavy minerals comprise 2 to 5 percent (Nikiforoff, Humbert, and Cady, 1948).

Bedding is only rarely apparent, and the results of soil-forming processes are much more pronounced than the structural features of the parent material. In a few places lenses or pockets of sand are found in the silt loam, and in some places lenses or pockets of gravelly loam occur near the surface. The loam generally is uniform laterally and the vertical changes are gradational except for those that result from soil-forming processes. The characteristic soils of the loam member of the Brandywine belong to the Beltsville (soil) series.

Considerable data on the mechanical composition of the loam are available from analyses of samples of the Beltsville soil, taken at different places in southern Maryland. These include 57 analyses from 10 profiles; 6 are from the Brandywine area. The Beltsville soil is the most widespread soil developed on the loam member of the Brandywine formation and is coextensive with it. The deepest samples were collected only 88 inches below the surface. Nevertheless as the loam is thin the analyses probably are fairly representative of the entire upper member. The material ranges in texture from silt loam to sandy loam. In figure 11 graphs show median particle size, sorting coefficient [2] and percent clay for the 57 samples plotted against depth. The samples from one typical profile near the village of Brandywine are connected by lines. The notable features of the loam shown by these graphs are: (1) an apparent slight decrease in median particle size toward the surface. (2) at 14 to 20 inches a sharp decrease in median particle size and increase in clay content, (3) above 10 inches a much greater median diameter, lower sorting coefficient, and lower clay content. The second and third of these features occur in the *B* and *C* horizons of the soil and almost certainly are the result of soil-forming processes. If the effects of pedogenic processes are discounted, the graphs show the wide range in textural characteristics of the material. Sorting is characteristically poor, ranging from 2.6 to 20 and averages about 7, except in the *A* soil horizon. The line connecting the samples from one typical profile illustrates the marked change in texture attributable to soil-forming processes. Median particle size varies directly with clay content and sorting coefficient in the upper horizons. The hardpan described of Nikiforoff (1955) lies at depths between 18 and 50 inches. Note that the greatest change in textural characteristics occurs at the surface of the hardpan. A typical exposure of the Brandywine loam is shown in figure 12.

The loam member has a range in color similar to that of the gravel member. The common colors are dark yellowish orange (10 *YR* 6/6) near the surface, and at depth, moderate yellowish brown (10 *YR* 5/4), light brown (5 *YR* 5/6) or mottled reddish brown (10 *R* 4/6).

[2] Sorting coefficient is defined as $\sqrt{Q_3/Q_1}$ after Trask, 1932.

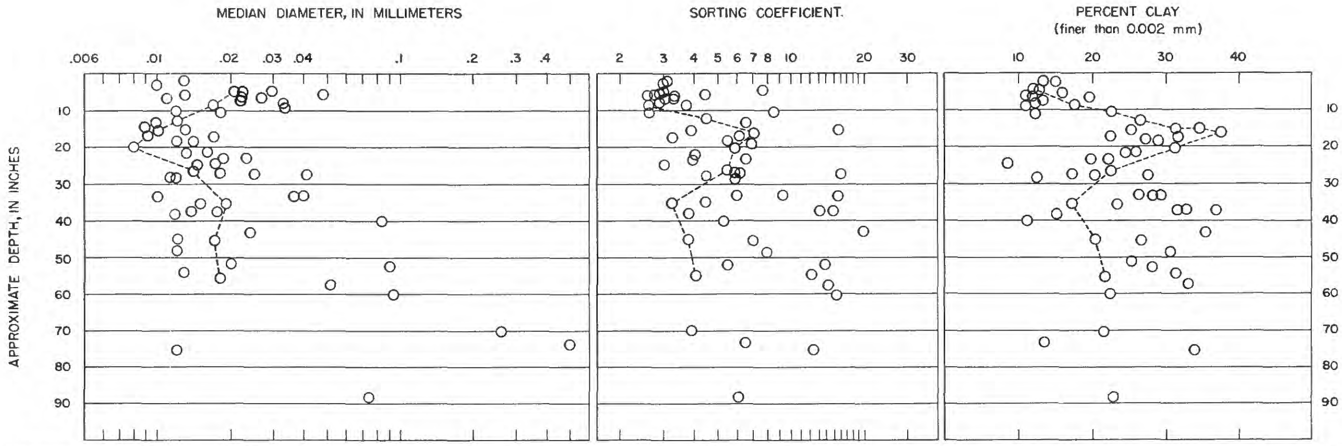

FIGURE 11.—Graphs showing variation in mechanical composition with depth in the loam member of the Brandywine formation. The graphs illustrate the wide range in texture of the material and the uniformly sharp decrease in clay content in the upper 15 inches. The dashed line connects samples from one characteristic profile. The graphs are based on analysis of 57 samples from 10 soil profiles. Analyses by Soil Survey.

FIGURE 12.—Outcrop on U. S. Navy (Cedar Point) Railroad in Brandywine area; typical exposure of the loam member of the Brandywine. Pick is at top of hardpan layer.

Fossils have not been found in the loam member in the Brandywine area. Surface finds of the remains of extinct terrestrial mammals have been reported by Hay (1923) from other localities in southern Maryland.

Eolian silt.—The upper member of the Brandywine formation has been referred to by Shattuck (Clark, Shattuck, and Dall, 1904) and by other geologists as loesslike. It is yellow, lacks bedding, and has a tendency to form steep slopes that give the upper part of the loam a loesslike appearance, but no geologist, to the writer's knowledge, has ever proposed that any of the material of the southern Maryland upland actually might be either loess or eolian silt. The finding of sandy eolian deposits (described on page 17) raises the question whether finer grained eolian deposits also occur and it is appropriate here to consider the possibility of eolian origin for at least some of the loam. It should be emphasized, however, that there is no a priori reason that eolian silt must occur on the upland because eolian sand is present. Eolian silt, for example, generally does not occur downwind from coastal dunes because the source material of the dunes is entirely sand. The source of the eolian deposits of the upland of southern Maryland is probably the sandy lower gravel member of the Brandywine formation which contains little material finer than sand. It is quite conceivable that gullying of the silty and clayey deposits of the loam member above would not make silt available for transportation by the wind because these finer materials are more likely to be fixed by vegetation than the sand. Nevertheless, some transportation of silt by the wind under the circumstances postulated is a probability.

No field evidence has been found favoring an argument for the occurrence of windblown silt, and it is probable that eolian silt does not make up an appreciable quantity of the loamy member. The composition of the loam has a wide range, and most of it is poorly sorted. Only the upper 10 to 15 inches is relatively well sorted. The possibility of the remainder being eolian is unlikely because it is too heterogeneous in texture, having sorting coefficients generally higher than 4.0. Material of even the upper, relatively well sorted layer has an average coefficient of sorting of 3.0 and the best sorted samples have an average coefficient of 2.6. This coefficient compares favorably with that of many water-laid deposits but not with typical eolian silts. Loess samples from Illinois, for example, described by Smith (1942) have a sorting coefficient ranging from 1.3 to 1.8. Samples of Peorian loess in Kansas, reported by Swineford and Frye (1951, p. 311) have sorting coefficients between 1.3 and 1.7.

If an appreciable quantity of the loam were eolian in origin one would expect that the deposit would thicken toward its source area and also become coarser in that direction. The entire loam member, however, although it has a wide range in thickness locally, has no systematic regional change in thickness. On the basis of many mechanical analyses it can also be stated that the material has no systematic regional variation in texture. It is as well sorted at Brandywine as it is near the Potomac River. Perhaps the most compelling evidence against an eolian origin for the loam member is that the well-sorted material rarely occurs except in the upper 10 to 15 inches of the soil profile, and furthermore the corollary is true, the upper 10 to 15 inches of the soil throughout the area shows a marked decrease in the sorting coefficient. This suggests that the loesslike appearance of the surface layers of loam is due to a soil-forming process either mechanical or chemical rather than to eolian deposition.

YOUNGER LOAM DEPOSITS

The lower gravel member of the Brandywine formation acts as a resistant bed protecting the Miocene sediments beneath. The overlying loamy member is in many places stripped off and broad valleys and stripped surfaces are cut on the gravel. The walls of these valleys of the upland commonly are very steep and mantled with loam that has moved downslope either by washing or mass sliding. Where steep slopes are cut into the gravel, the slope mantle is usually a mixture of gravel and loam. It has crude stratification consisting of pebble bands parallel to the slope, mixed in a massive loam.

The valley floors on the upland are generally flanked by terraces composed of gravel and loam, if cut into the gravel member and of clay or loam if cut into only the loamy member. In places even small valleys contain more than one terrace above their swampy flood plains. No attempt to correlate or map these terraces was made. Certainly, however, more than one cycle of cutting and filling has taken place on the upland since original deposition of the Brandywine formation. In consideration of the great length of time which has elapsed it may be assumed that much of the material mapped as loam has been moved from its original place of deposition, by sheet wash and transportation in small rills. In some places, especially on slopes of small ridges or valleys the soil profile is truncated, indicating relatively recent erosion.

STRUCTURE OF BRANDYWINE FORMATION

The average dip of the Brandywine formation is about 5 feet to the mile to the south. This degree of slope is gentle enough so that no deformation of the land is implied and the gravel and loam members which make up the formation could have been deposited with such an initial dip. The areal geologic mapping, however, demonstrated that the structure is not that of an even incline but is more complex. The inclined surface of the upland is broken by low topographic unconformities, which are probably associated with unconformities in the Brandywine formation. Examples of such topographic breaks were found on the margins of the upland facing the Patuxent River as well as on the upland itself. These breaks with associated unconformities probably represent structures resulting from the scour and fill action of the rivers which deposited the Brandywine formation and are not marine terraces. The origin of the upland deposits is discussed more fully on page 33.

Although the average dip of the Brandywine formation in the Brandywine area is south or slightly west of south, on the margin of the upland facing the Patuxent River, and in the outliers of the Brandywine in the Patuxent River valley, the average dip is east. As is shown on page 20 the surface of the Brandywine is erosional, and although the general slope of the surface conforms to the dip of the two members of the formation, the details are unrelated. For this reason level lines were run with plane table and alidade along the county roads on the eastern margin of the upland connecting exposures of the base of the Brandywine formation, and at a few other places in the quadrangle to determine, if possible, the shape of this contact. Figure 13 shows the results of the traverses. Accuracy of the altitudes obtained is within 2 feet. It was the writer's impression while making the traverses,

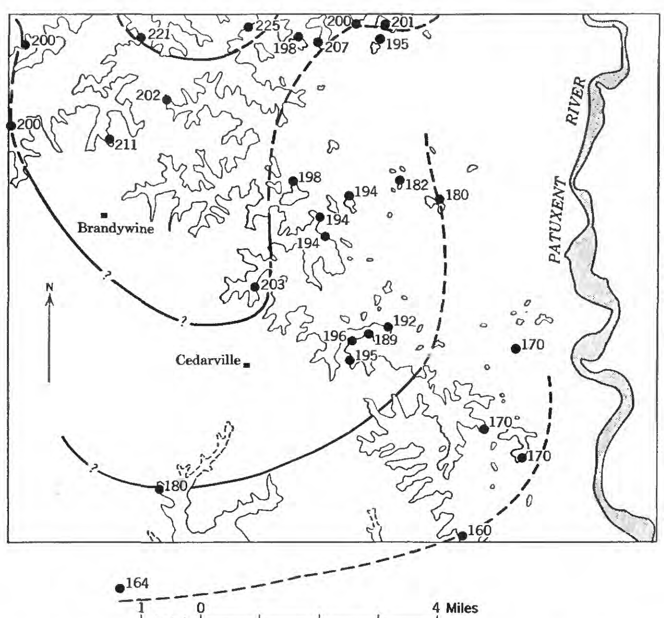

FIGURE 13.—Generalized contours on base of Brandywine formation in Brandywine area. Contour interval, 20 feet. Fine line indicates trace of base of Brandywine formation. Figures show altitudes of exposures at the base of the formation, measured by stadia traverse and are accurate within 2 feet.

that the dip of the formation toward the river in the eastern part takes place in terracelike steps rather than as an even incline. Outcrops exposing the base of the formation are not numerous enough to reveal the steps and risers clearly, but they are strongly suggested at a number of places. The base of the gravel member is well exposed 1.25 miles north along the road from Baden to Brookfield Church on the northeast side of a hill 200 feet in altitude, shown on plate 1. East of this hill the member drops 10 feet in a horizontal distance of 200 feet. Beyond this drop the gradient to the east is 10 feet in 2,000 feet. A cross section drawn through several exposures of the base of the Brandywine in the central part of the area is shown in figure 14.

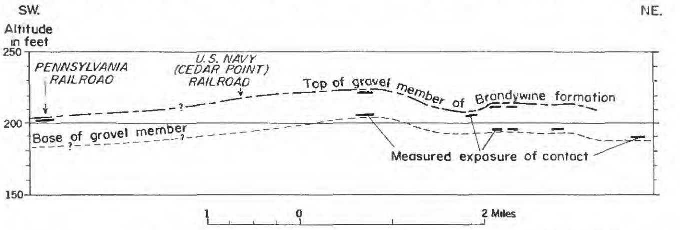

FIGURE 14.—Estimated position of horizons of top and bottom of lower gravel member of Brandywine formation in the Brandywine area. The profile connects measured outcrops along a northeast-southwest line in the central part of the mapped area, plate 1. The profile shows the steplike structure of the formation on the eastern edge of the upland.

This section shows a steplike change in dip on the margin of the eastern upland surface.

The significance of this feature perhaps can be understood by comparison with a similar steplike change in dip, which was exposed in a series of road cuts on the southern Maryland upland overlooking the Potomac River. One and two-tenths miles north of Piscataway Creek, on the highway from Indian Head, Md., to Washington, D. C., the surface of the upland drops abruptly about 15 feet in a gentle scarp. In 1948, road cuts, one of which is shown in figure 15, disclosed the underlying Brandywine formation for a considerable distance. The relationships are shown in a much-reduced sketch, figure 16. The drop in the upland surface corresponds with a drop in the base of the gravel, and in the base of the loam, and also corresponds with a marked change in lithology. The gravel north of the topographic unconformity is massive coarse grained and contains little sand. It is overlain by a thin deposit of silty loam. South of the break, crossbedded sand is the dominant constituent of the lower part of the deposit. A layer of coarse boulders a few feet thick forms the base. The loam is much thicker and consists of sandy clam loam overlain by silt loam. Clearly this group of outcrops discloses an unconformity between two terrace deposits each of which is locally flat lying. Probably the dip of the Brandywine formation toward the Patuxent River on the east side of the upland can be accounted for in the same manner. The apparently gentle slope of the base of the formation to the east is

FIGURE 15.—Exposure of terrace deposits near Potomac River; eolian sand lentil resting on gravel member in the Brandywine formation on upland surface.

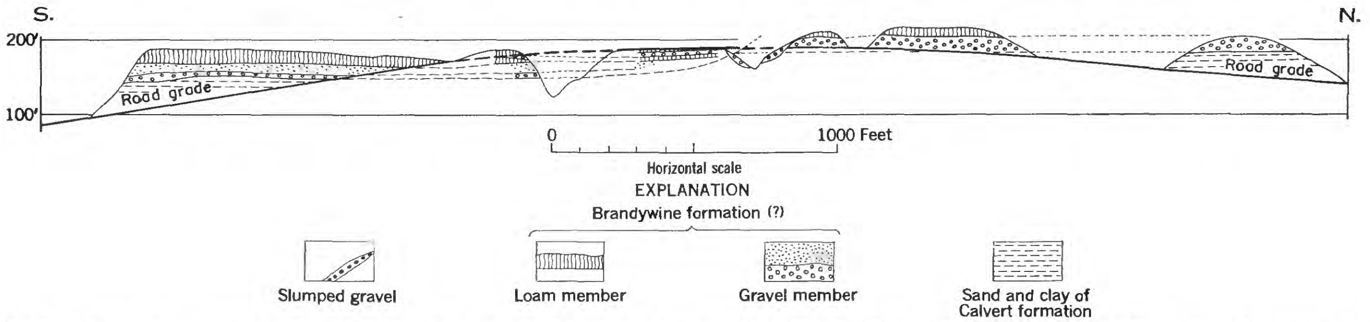

FIGURE 16.—Geologic cross section along road cuts on highway from Indian Head, Md., to Washington, D. C., north of Piscataway Creek. Shows unconformity separating two terrace deposits on the western margin of the southern Maryland upland.

in reality a series of terraces, and unconformities separate the deposits overlying them.

Similar unconformities in the Brandywine formation, expressed topographically as terraces probably occur on the surface of the upland and account for some of the 5 foot per mile slope to the south. The writer believes that such an unconformity occurs in the Brandywine area about 1.2 miles west-southwest from Cedarville, in the southern part of the area, plate 1. It was suspected during the mapping that a sharp drop in the contact between the upper loam and the lower gravel member occurred here, and a detailed survey of about 100 acres of farm and woodland was made with contours plotted at 2-foot intervals. Geology was mapped along a north-south profile across the map area by means of shallow borings averaging about 3 feet in depth. The resulting topographic map and geologic cross section are shown in figure 17. In the center of the cross section the base of the loam descends to the south about 10 feet within a horizontal distance of less than 600 feet, which is a slope ratio greater than 1 in 60. In the area as a whole the average slope ratio of the formation and of this contact is about 1 in 500. In the time available and because the surrounding terrain is heavily wooded it was not possible to trace this relatively sharp drop across the upland. In the area shown in figure 17, however, it trends a few degrees north of east, parallel to the 200-foot contour which apparently lies on the surface of the lower gravel member. It was the writer's impression that a similar drop, or possibly a continuation of the same drop is observable on the west side of the U. S. Navy (Cedar Point) Railroad 1.05 miles southeast of Cedarville (pl. 1). This impression has not been verified by leveling and borings.

Evidently the Brandywine formation at the type locality does not have a uniform gentle dip, but is broken in some places by low topographic breaks, steeper than the average dip of the formation. By comparison with a locality to the west where exposures are better, it is inferred that unconformities are probably present at the topographic breaks. The terrace-like slope toward the Patuxent River can be explained as the remains of stream terraces which marked the incipient trenching of the Patuxent River valley.

EOLIAN DEPOSITS AND ORIENTED TOPOGRAPHY

Sandy eolian deposits are widespread in the Brandywine area. There is abundant evidence that the movement of sand by the wind has been a recurring phenomenon for a long geologic period of time, probably representing the entire Pleistocene. On the map, plate 1, eolian sands are shown only where they overlap the Brandywine formation. These deposits are mostly ancient, are considerably eroded and probably of local origin. Eolian sands also occur in other parts of the area, overlapping the Miocene sediments and in some places the terraces of the Patuxent River. They have been delineated in mapping only where they rest on the Brandywine formation because they can be readily differentiated from the underlying material only where there is contrast in composition at the contact, as that with the loam member of the Brandywine. Sand deposits, too thin to be mapped, occur on the terrace surfaces. On the east side of the Patuxent River outside the mapped area the lower terraces are covered by a thick mantle of dune sand, which has a well-developed eolian topography.

The eolian sands of the upland have clearly influenced the development of the topography, and are eroded into elongate subelliptical bodies without characteristic dune topography. The northwest-trending topographic features so conspicuous in the area are interpreted as having been sculptured by minor streams controlled by and consequent on a surface covered by low dunes.

Loess or eolian deposits other than sand have not been identified, but may be too inconspicuous to be recognizable.

Eolian sand on the Brandywine upland.—The elongate bodies of sand traversing the upland in the Brandywine area range in length from insignificant areas too small and too thin to map, to an area east of Brandywine 1.4 miles long with a maximum thickness

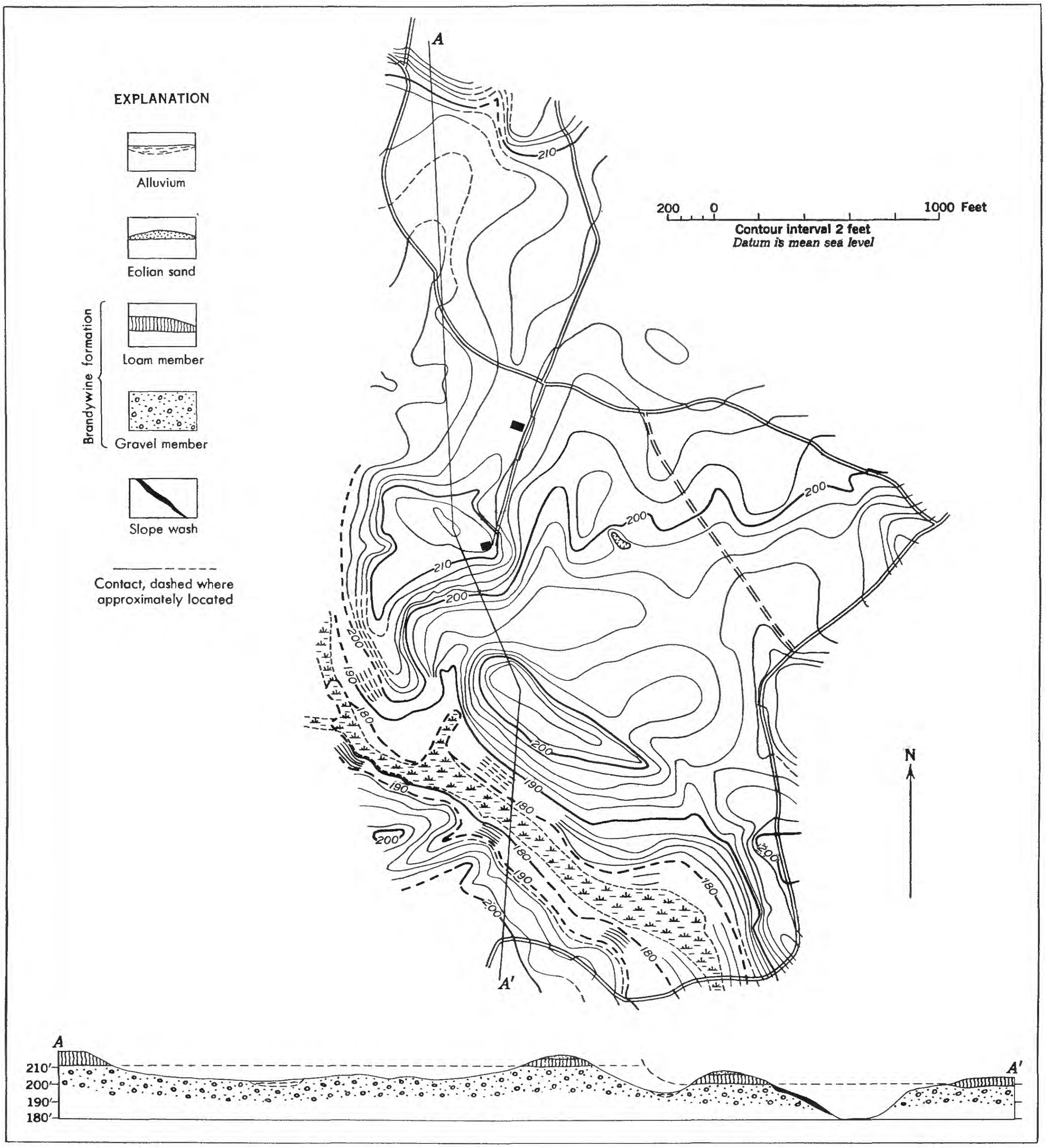

FIGURE 17.—Topographic map of area near Cedarville in Brandywine area showing a sharp drop in the upland surface and the associated drop in the base of the upper loam member of the Brandywine formation. Contour interval, 2 feet. Based on plane table survey.

of 15 feet. The number and thickness of sand bodies shown on the map is somewhat limited by the practical problem of mapping them. Some bodies other than those shown on the map probably exist but were not encountered in the traverses during the field work. Many of the sand areas are less than 2 feet in thickness and because they are covered with trees and forest litter cannot be seen without sampling the ground either with a shovel or auger. Furthermore, the bodies are often not mappable where they rest on the gravel mem-

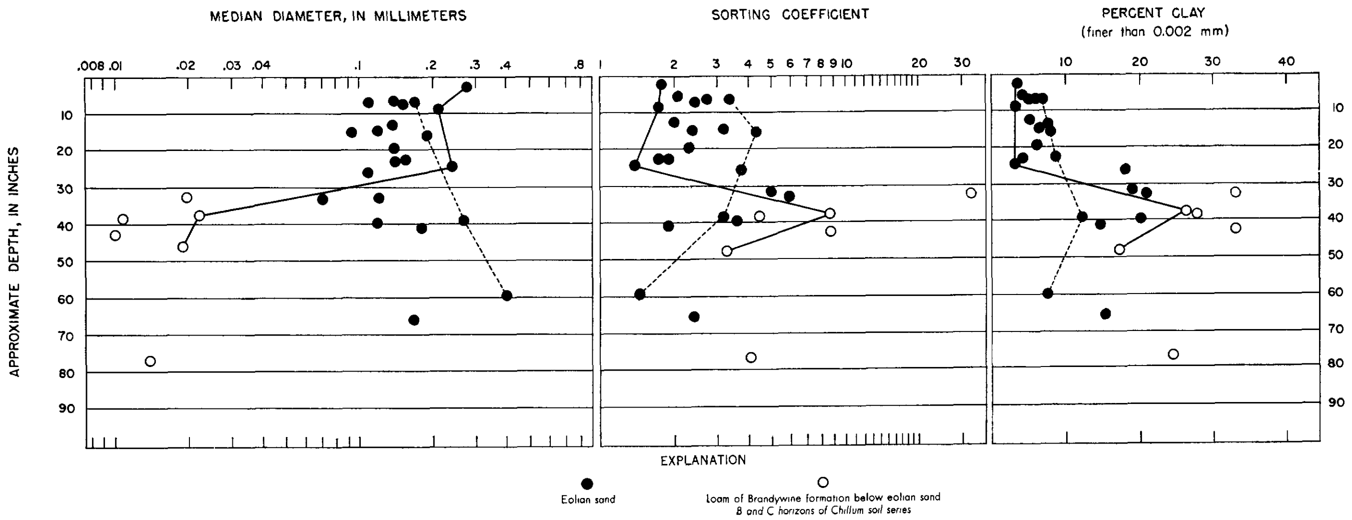

FIGURE 18.—Variation in texture with depth of soil profiles in eolian sand. Data based on analyses of 28 samples from 5 soil profiles in eolian sand bodies resting on the loam member of the Brandywine. Dashed and solid lines connect the analyses from two characteristic profiles to show characteristic changes in texture with depth. Analyses by Soil Survey.

ber of the Brandywine, because they cannot be differentiated from the sandy portions of the gravel member of the Brandywine unless they are thick enough to form a conspicuous topographic rise. The eolian sand has a well-developed soil, described by Nikiforoff (1955). In places where the sand is thin and the *C* horizon is within the underlying loam member of the Brandywine, these soils are classified as Chillum series.

Analyses of five soil profiles developed on the eolian sand show the textural characteristics of the material. In figure 18, median particle size, sorting coefficient, and clay content for these profiles are plotted against depth. As the lower horizons of the soil in several profiles are developed in the upper loam member of the Brandywine rather than in the sand, samples of loam are shown by circles. Thus in several profiles the sand resting on the loam member of the Brandywine is only 30 inches thick; in others it is more than 65 inches thick. As in the case of the loam member the eolian sand has been greatly modified by pedogenic processes. The clay content in the *B* horizon is remarkably high and has the effect of increasing the sorting coefficient and decreasing the median particle size. The average sorting coefficient is between 2 and 3 for the sandier parts of the profiles.

The bodies of sand on the upland, where they are best exposed are crudely elliptical in shape. The surface topography is erosional and does not suggest an eolian origin. An eolian origin, however, is indicated by three observations:

(1) Bodies of sand having a dune form occur on the lower terraces of the Potomac and Patuxent Rivers. Two places where such deposits are conspicuous are on a low, 10-foot terrace of the Potomac River south of Marshall Hall and on the east side of the Patuxent River across from Nottingham on a terrace 60 feet above sea level. At these places the sand is formed in elongate parabolic ridges having northwest axes.

(2) The sand in the bodies on the upland has a mechanical composition similar to the sand in the dunes at Marshall Hall. As shown in figure 19, the sand on the Brandywine upland is totally unlike the marine sand interbedded in the gravel member of the Brandywine formation.

(3) The long axes of the sand bodies have a pronounced northwest trend identical with the trend of the dunes of the lower terraces referred to above. Furthermore, the same trend is found in sand bodies in widely scattered areas on the upland throughout southern Maryland.

The eolian sand must be younger than the Brandywine formation because it rests on top of the two members and nowhere has been interbedded in them. The

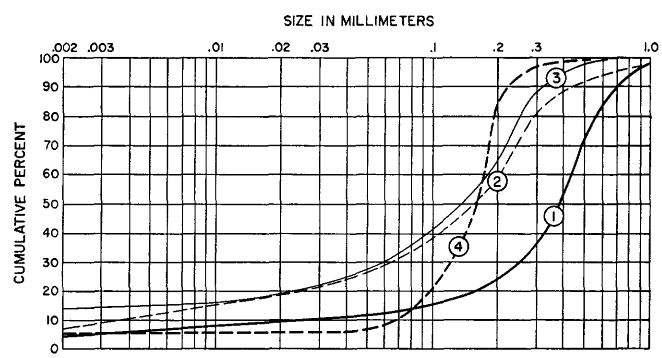

FIGURE 19.—Cumulative size-distribution curves showing mechanical composition of eolian sands, comparing sand in sand bodies in the Brandywine area with dune sand from Marshall Hall, Md., above a low terrace of the Potomac River. (1) Dune sand at Marshall Hall, (2) and (3) Sand from sand bodies in Brandywine area. (4) Interbedded sand in Brandywine formation, east of Duley, Md. Analyses by Soil Survey.

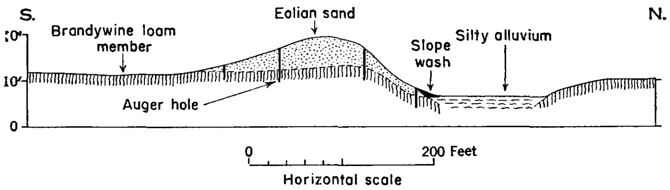

FIGURE 20.—Geologic cross section showing small sand body resting on loam member of the Brandywine southeast of Brandywine village. Explored with auger. Note the filled gully north of sand body. The eolian sand was presumably derived from this gully during its erosion and before filling.

stratigraphic relationships tested in many places by auger holes are generally similar to those shown in figures 20 and 22. The sand lentils, also, must be related to the erosion of the upland for their distribution shown on the geologic map is closely related to gullies or valleys which cut through the loam. The largest sand areas occur in the vicinity of Brandywine at the head of a gully which drains into Piscataway Creek and southwest of the head of Mataponi Creek. The most numerous bodies of sand occur in the southern part of the area where the Brandywine formation is being minutely dissected by Butler's Branch and other headwater ravines of Zekiah Swamp. Even the small sand beds that appear to rise directly above the loam member and have apparently no source ravine can be shown in some cases to head southeast of an ancient filled gulley. The writer bored a series of auger holes through the small isolated lentil at the Brandywine railroad junction. This bed (fig. 20) rests directly on the loam member but heads at a small scarp which marks a filled ravine formerly tributary to Timothy Branch. The ravine is now filled with reworked loam, indistinguishable at a field mapping scale of 1:25,000 from the surrounding loam member of the Brandywine but once must have exposed sandy beds in the Brandywine formation.

The sand bodies, then, are remnants of dunes and are younger than the Brandywine formation. The source of the sand must have been the lower gravel member of the Brandywine, at times when it was exposed by the erosion of ravines and gullies. There is little evidence of present-day wind action in the area. Except for areas actively farmed the region has a thick vegetation cover. Trees and shrubs cling to the walls of the steepest ravines. Even the sandy shores of the Potomac and Patuxent Rivers are devoid of active dunes and in most places vegetation grows to the water's edge. Present-day farming activity cannot account for the eolian sands because their antiquity as shown by their relationship to the parallel drainage pattern of the area is obviously too great. The deposition of eolian sand must be related to a period or periods of time climatically different from today. It may be postulated that at several times during the Pleistocene epoch conditions may have been warm and dry enough to restrict the vegetative cover and cause relatively rapid erosion of the area and the blowing of sand downwind from the sand and gravel banks thus exposed. On the other hand rapid erosion and blowing of sand might have occurred during the coldest times of the Pleistocene if the climate became cold enough to weaken the vegetation cover or cause a change in vegetation to an assemblage of plants more susceptible to erosion. Farther north, on the coastal plain of New Jersey dunes are far more extensive, larger, and are associated with ventifacts. It might, therefore, be argued that southern Maryland is within a zone of periglacial dune formation which was more pronounced farther north. Enough evidence is not at present available to permit a choice between these hypotheses.

Linear hills and trellised drainage.—Only a part of the problem of the origin of the sand bodies is revealed by study of the bodies themselves. The topographic expression of the sand bodies on the upland surface is clearly erosional. In addition low linear ridges occur on the upland that are underlain by the loam or gravel member. Such ridges are conspicuous on the geologic map, plate 1, in the area southwest of Cedarville where most of the loam is stripped from the underlying gravel and remains only in a few low ridges. Northwest-trending ravines are numerous throughout the map area. A topographic map of an area of open fields was made at Malcolm, 1 mile south of the Brandywine area along the U. S. Navy (Cedar Point) Railroad. This map (fig. 21) shows the longitudinal pattern of ridges and valleys better developed than in most areas. Although the topography, superficially at least, resembles constructional dune topography, it is actually erosional for the ridges are composed of the upper loam member capped by less than 3 feet of sand and the valleys are underlain by the lower gravel member.

Another common relationship is illustrated by figure 22, a geologic cross section southwest of Cedarville along the trail leading west from the west fork of Butler's Branch to spot altitude 203. As shown here thin lenses of sand rest on either slope of the small loamy upland at the west end of the section. Such bodies of sand seem to occur on the northeast-facing slopes of many ridges underlain by loam, especially in the southern part of the area shown on plate 1.

The sand bodies and the linear topography were probably formed in the following manner: During recurring periods in the Pleistocene when erosion was more rapid than now, gullies were cut into the Brandywine

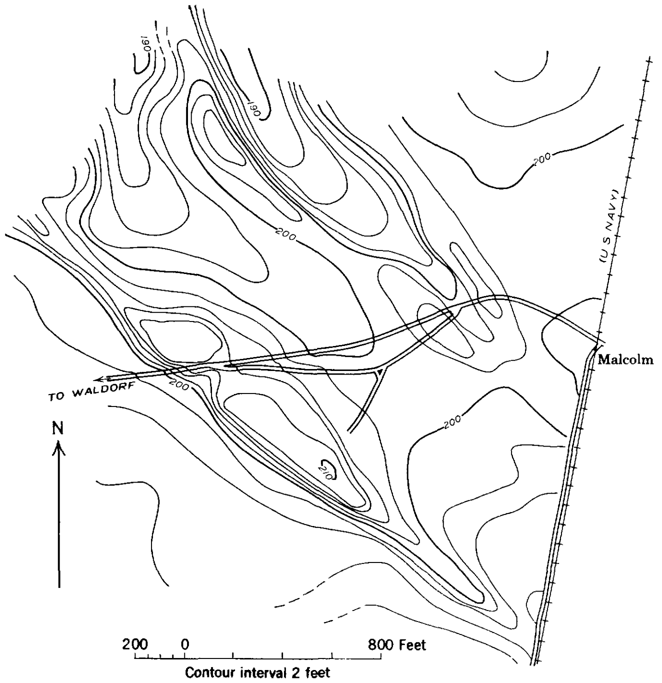

Figure 21.—Topographic map of area near Malcolm on upland surface south of the Brandywine area on U. S. Navy (Cedar Point) Railroad. Shows linear erosional topography. Ridges are capped by thin lenses of sand resting on the loam or gravel members.

exposing and concentrating sand in the gully bottoms. The sand was then carried by the wind to the area immediately leeward from the gully and was molded into dunes of parabolic shape with pronounced northwest axes. Eventually the surface of the upland was covered by enough small, thin elongate dunes so that the minor drainage ways became confined between the interdune areas. As erosion proceeded, the northwest drainage alinement became superimposed on the Brandywine formation, and incised. During recurring periods of erosion and eolian deposition some of the older dune sand was reworked by the wind and by running water and a northwest pattern of linear hills and valleys formed, underlain partly by eolian sand, partly by waterlaid sand and by the exposed Brandywine formation. The present pattern of surficial deposits is complex consisting of eroded loam or gravel and of reworked thin bodies of sand found on the hilltops where they might be the residue of a former dune, on the flanks of the ridges and on the valley floors where reworked by wind or water.

Geographic distribution of linear ridges and valleys.—Linear ridges and valleys similar to those near Brandywine are found throughout southern Maryland in the area between Chesapeake Bay and the Piedmont. Furthermore, close inspection of topographic maps of areas in the Piedmont west of Washington, D. C. reveals many northwest-trending ravines in the areas where the regional structure of the bed rock trends northeast. It is the writer's opinion that the process described above was active over a very wide area. The linear pattern of the topography is particularly noticeable between Washington, D. C. and Annapolis, Md., where the underlying deposits are Eocene and Miocene. In a few places southwest of Annapolis actual dunes have been observed on the erosional, hilly upland surface. Figure 23 shows well-developed oriented topography in an area near Collington, Prince Georges County, Md. In the area shown on figure 23, no vestige of the eolian sand remains.

Similar drainage alinement has been reported in the western Great Plains and is ascribed to similar causes (Russell, 1929).

TERRACES AND GRAVELS OF THE PATUXENT RIVER VALLEY

The eastern part of the Brandywine area, shown on plate 1, is occupied by the Patuxent River valley. At least four prominent terraces have been identified and mapped in this area, at altitudes ranging from sea level to 140 feet. The well-developed terraces are confined to a belt less than 1½ miles wide on the west side of the river. As described on page 24, the outer walls of

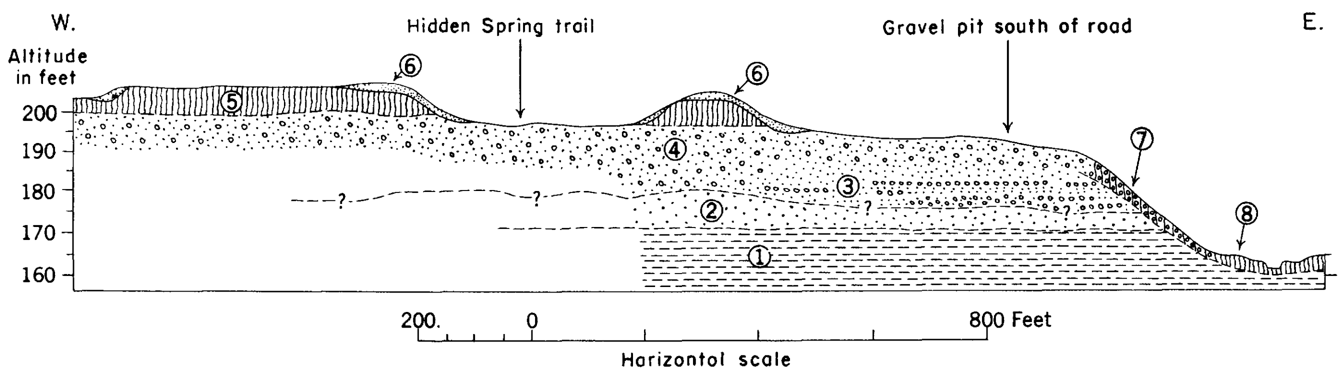

FIGURE 22.—Geologic cross section in Cedarville State Forest along forest road west from the west fork of Butler's Branch, Brandywine area, plate 1. (1) Miocene Calvert formation. (2) Miocene(?) North Keys sand. (3) Interbedded sand and gravel in lower part of Brandywine formation, explored with auger. (4) Sandy lower gravel member of Brandywine formation. (5) Loam member. (6) Eolian sand bodies. (7) Slope wash and creep of loam and gravel. (8) Alluvium in west fork of Butler's Branch.

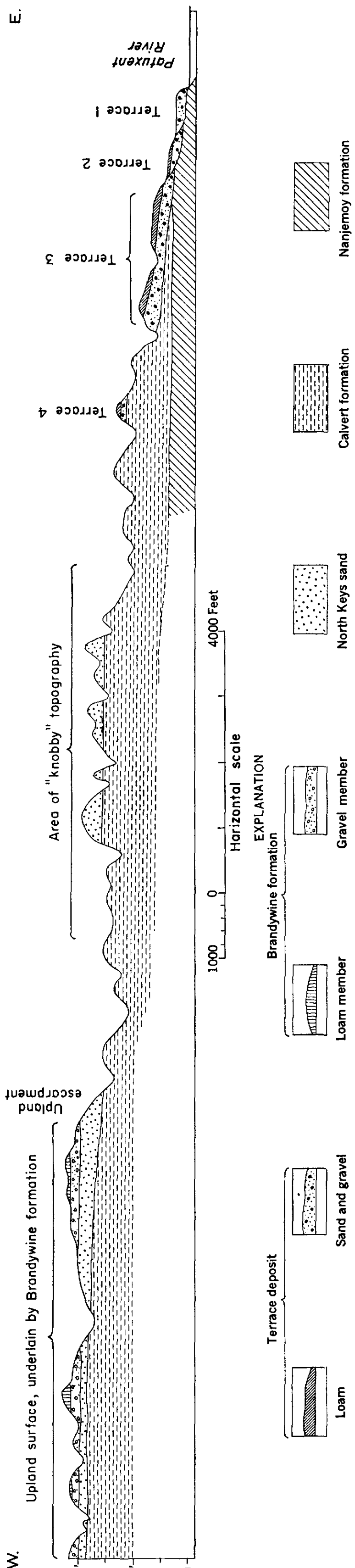

FIGURE 24.—Generalized geologic cross section across eastern part of Brandywine area from the upland near Brandywine to the Patuxent River. The section shows the terraces of the Patuxent River valley and the area between them and the upland in which many hills, though underlain by Miocene deposits are capped with patches of gravel too thin to be shown.

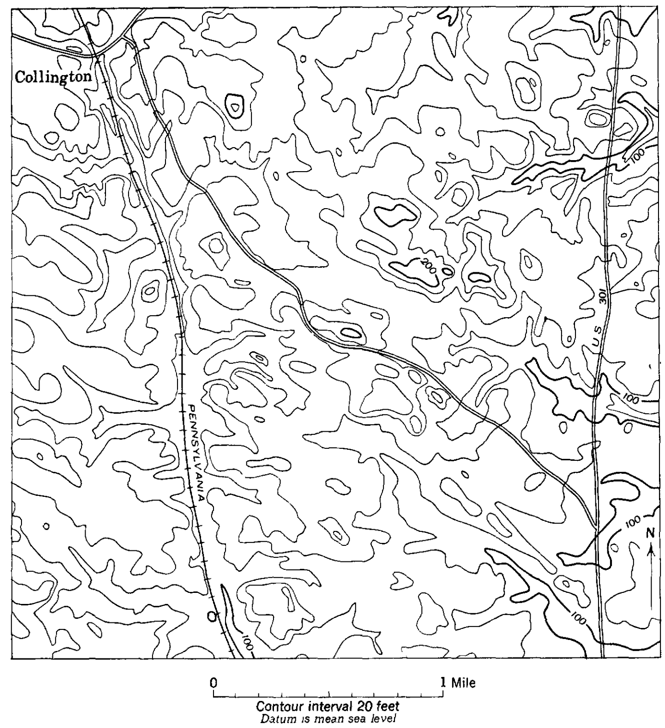

FIGURE 23.—Area near Collington, Prince Georges County, Md., showing linear pattern of topography presumably superimposed from surfaces covered with patches of eolian sand. Redrawn from Lanham and Davidsonville 7½ minute quadrangles of Army Map Service. Drainage and culture omitted.

the valley east of the upland escarpment, have a knobby topography with many of the hills capped by gravel mapped as part of the Brandywine formation. The gravel knobs, however, decline in altitude toward the east as the river is approached, and probably represent two or more very ancient higher terraces formed during the initial stages in the cutting of the Patuxent River valley. Many hills and slopes covered or veneered with thin deposits of gravel are too low to be included in the Brandywine formation, and too high or too far removed to be included as remnants of the lower terraces. These are channel gravels deposited by side streams during stages in the cutting of the valley. The divisions of the valley are shown graphically in the geologic cross section, figure 24.

Inasmuch as the altitudes and outcrop patterns of these deposits as mapped by the writer and Lindvall do not conform exactly to any previous descriptions their nomenclature is a problem. The highest deposits of the valley occupy the eastern spurs and knobby outlying hills of the upland. It is not feasible to separate these deposits from the Brandywine formation. They are therefore included in that map unit already described. The four well-developed terraces along the river are given the name Nottingham terraces, and are numbered from lowest to highest, as shown.

Terrace	*Altitude of surface at Nottingham (feet)*
Nottingham 1	12–20
Nottingham 2	20–40
Nottingham 3	60–80
Nottingham 4	80–140

The many small gravel deposits that veneer hill tops and slopes in the valley between the terraces and the upland are not shown on the map, but are described in the pages following under the heading "Channel gravel."

Nottingham terrace 4.—At altitudes ranging from 80 to 140 feet are several flat surfaces underlain by gravel, sand, and loam similar in lithology to the Brandywine formation. Generally, however, these deposits are less than 20 feet thick. The basal portion is commonly gravel, and the upper portion a silt loam similar in composition to the Brandywine loam. An auger hole in one of these deposits southwest of White's Landing revealed the section shown below.

Section of deposit on Nottingham terrace 4 from auger hole southwest of White's Landing

[Altitude, top of section, 129 feet]

	Feet
Terrace deposit:	
1. Silt loam, yellowish-orange	3.5
2. Loam, sandy, slightly darker with fine pebbles and coarse granules	2.0
3. Sand, pebbly, dark yellowish-orange	2.5
4. Sand, grading downward into mottled gray and red loam	4.0
5. Clay, mottled gray and reddish	1.0
North Key sand (?):	
Sand, orange, fine clear angular grains	1.0
Total	14.0

No systematic change in altitude of these terrace deposits downstream was observed within the area mapped. They probably occupy larger areas than shown on the map but except where they underlie a flat surface they cannot always readily be distinguished from pockets of loamy and gravelly surficial material that has been let down by the erosion of the Brandywine formation. The terrace deposits between 80 and 140 feet probably represent remnants of a single terrace or system of several stream terraces. They are the highest recognizable terrace remnants below the Brandywine formation.

Nottingham terrace 3.—This terrace is very well developed on both sides of the Patuxent River. The best exposures and largest area are west of Nottingham, where the terrace deposits occupy a wide ancient meander scar carved in the Calvert formation. The deposits near Hotchkins' Branch are at least 20 feet thick. They consist of interbedded sand and quartzose gravel grading upward into sandy loam and silt loam. The surface material of the terrace is identical with the silt loam which occupies the largest part of the surface area of the Brandywine formation. No systematic change in altitude of the terrace was observed. The area of the map (pl. 1) is perhaps not large enough to enable an estimate to be made of the regionable slope. Presumably, however, the materials of the terrace deposit are of fluviatile origin and the form of the outline of the terrace indicates that it was stream cut.

Nottingham terrace 2.—This terrace is the best developed terrace in the area and can be traced a long distance downstream. It is much less dissected than the higher terraces. It is, however, broken by low swales, has well-developed drainage network and in places is dissected by wide tidal tributaries and swamps of the Patuxent River. Lithologically, terrace 2 differs from the higher terraces. In the few exposures where the underlying material is exposed the terrace deposit appears to contain less gravel, and more sand. It is also less siliceous and grains of glauconite are a common constituent. The soil is markedly different from the soil of the higher terraces and generally belongs to the Sassafrass series, whereas soils of the higher terraces belong to the Beltsville or Chillum series. The surface horizons are darker, contain no hardpan and the profile is thinner. Whereas the soil and parent material of the higher terraces contain reddish mottlings, the soil of terrace 2 seems to contain none. An incomplete section of this terrace deposit was obtained in an auger hole on the north bank of Hotchkins' Branch southwest of Nottingham:

Incomplete section of deposit on Nottingham terrace 2 from auger hole on north bank of Hotchkins' Branch

[Auger hole did not penetrate base of terrace deposit]

	Feet	*inches*
Terrace deposit:		
1. Clay loam, sandy at surface, becomes mottled toward base	3	4
2. Sand, very fine containing a few coarse granules		6
3. Clay, heavy gray		6
4. Clay, gray, thinly interbedded and orange sandy loam	1	0
5. Sand, fine white with some pebbles. Contains thin lenses of orange clay loam	4	11
6. Sand, coarse interbedded with fine white sand and sandy clay	3	3
7. Sand, greenish fine containing abundant glauconite. Probably reworked from Nanjemoy formation	1	1
Total	14	7

Terrace 2 has a distinct slope downstream. North of Mataponi Creek the surface of the terrace in places is at an altitude more than 40 feet. At the extreme south margin of the quadrangle no point on the terrace is higher than 25 feet. The same terrace has been traced downstream to Benedict, 7 miles south of the area mapped, where the altitude is only 10 feet.

Nottingham terrace 1.—On the geologic map (pl. 1), terrace 1 is subdivided into two parts, designated 1*a* and 1*b*. The unit 1*a* is separated from 1*b* by a low scarp averaging about 7 feet high. North of Nottingham these terraces are at altitudes of 12 and 19 feet in the Patuxent estuary. Exposures of the material in the terraces were not observed, but their surfaces are strewn with gravel and cobbles. The soil is heavy gravelly loam. It is not evident that terraces 1*a* and 1*b* are underlain by two distinct terrace deposits and it is possible that terrace 1*a* is merely an erosional surface cut into 1*b* either by the Patuxent River or by wave action during a higher stand of sea level.

Channel gravel.—Between the Brandywine upland and the well-developed Nottingham terraces is an area of rough, knobby topography cut on the Miocene Calvert formation and North Keys sand (fig. 24). Nearly every hill or flat area has some gravel on its surface. The highest hills, rising to altitudes of 170 to 180 feet, are commonly capped by thick gravel deposits which are indistinguishable in stratigraphic position and composition from the Brandywine gravel. The lower deposits of gravel are commonly irregular and relatively thin. Nevertheless they are abundant. In field mapping a thick deposit of gravel lying near the altitude of the Brandywine gravel was mapped as Brandywine. A thin gravel mantle, or a thicker deposit at lower altitude was considered younger and omitted from the map. The altitudes of the smaller gravel deposits have no systematic pattern. Figure 25 is a geologic sketch map of a sample area near Baden, in which all the gravel-covered areas were mapped, and altitudes were taken with plane table and alidade on the base of the gravel wherever they could be located even approximately. These altitudes illustrate the unsystematic pattern of occurrence of these bodies. Furthermore in some places gravel mantles have been encountered in channels and pockets on slopes.

The widespread occurrence of channel gravel having an irregular pattern of distribution may be the result of inversion of topography, an hypothesis suggested by MacClintock and Richards (1935) to explain large-scale features of the Pensauken formation of New Jersey. As already stated on page 16, the Brandywine formation along the margin of the Patuxent River valley slopes gently toward the river in a series of low steps that represent the first stages in the cutting of the valley. The period of valley cutting which followed was presumably more rapid, and side streams etched back the older gravel deposits exposing soft Miocene sediments in their floors and walls. Those side streams which headed in the Brandywine were laden with gravel, and hence their beds, terraces, and banks became mantled with thin deposits of gravel.

Presumably the gravel mantle on the stream beds and terraces was more resistant to stream erosion than the interfluve areas underlain by fine-grained Tertiary deposits, and encouraged lateral migration. Erosion by

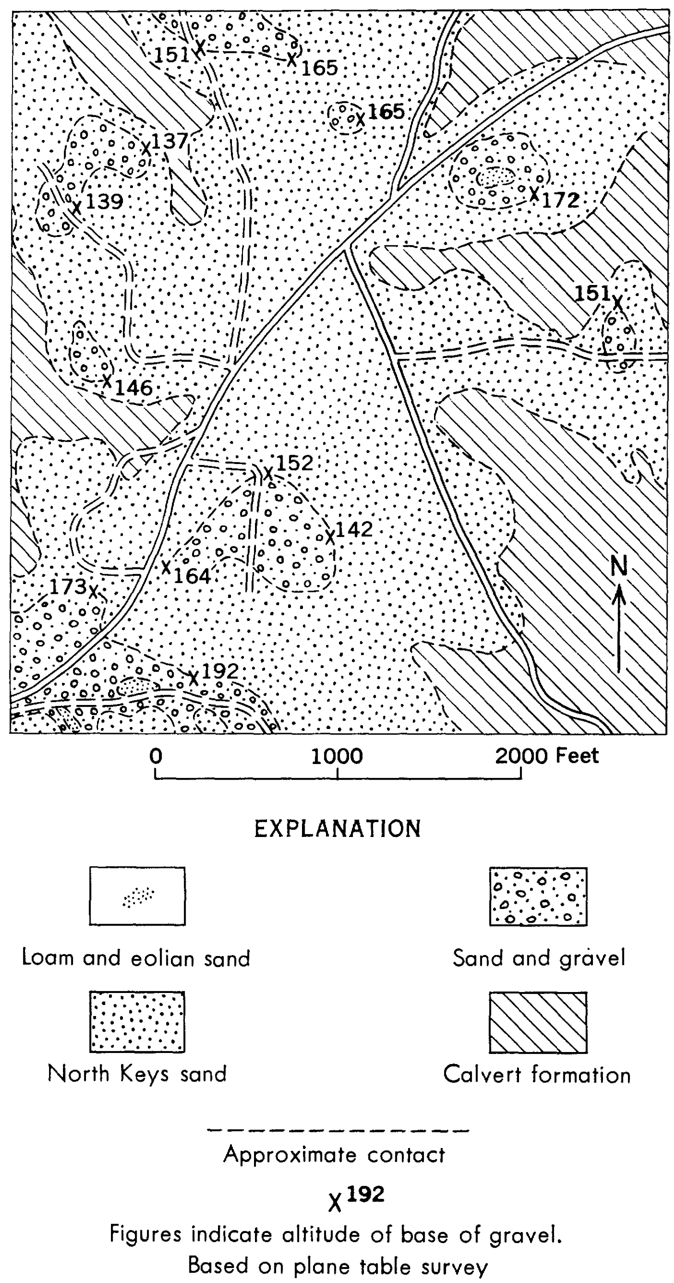

FIGURE 25.—Geologic sketch map of area northeast of Baden, Md., showing deposits of gravel resting on the North Keys sand. Figures indicate altitude of base of gravel. Based on table survey by J. T. Hack and R. M. Lindvall.

smaller streams which did not head on the upland and which therefore had no gravel in their drainage basins was more rapid. The smaller streams may therefore have grown headward rapidly and captured the larger through-flowing streams. This process of piracy by streams heading in the soft Tertiary deposits, in addition to the tendency of the larger streams heading on the upland to migrate laterally, directed the drainage toward the gravel-free areas leaving a discontinuous mantle of gravel on the higher slopes, abandoned by the through-flowing streams. The resulting mature topography may be called "inverted" for the former stream beds and terraces have become the resistant deposits which mantle many hill tops. The present complex distribution of thin gravel bodies could have developed in this way. The process is not unlike the process of gully gravure, described by Bryan (1940) that occurs during the retreat of slopes when a mantle of porous, resistant material rests on a more readily eroded material.

Conclusion.—The mapping in the Brandywine area shows that the Patuxent River valley was excavated in stages that produced a complicated system of gravel deposits and terraces. Too small a segment was mapped to permit determination of regional gradients or correlation of the terraces with those of other areas. The soils developed on the terraces may provide a clue to their age. The soils on Nottingham terraces 3 and 4 are similar to the soils on the Brandywine formation, that is they resemble the Beltsville and Chillum series. The soils on terrace 2 are distinctly different, belonging in part to the Sassafrass series. Notably they lack the reddish mottling characteristic of *C* horizons of the soil on the higher terraces. It is argued by Nikiforoff (1955) that the reddish color of the *C* horizon in the Beltsville soils may be a relict feature of the warm climate of the Sangamon interglacial period. Presumably therefore terraces 3 and 4 are Sangamon in age or older and the lower terraces are post Sangamon. The soils of the lower terraces also lack the hardpan and polygonal cracks found on the higher terraces. If these features are correlative with the maximum advance of the Wisconsin ice as proposed by Nikiforoff, then terraces 1 and 2 must be late Wisconsin or Recent in age. This reasoning may not be applied to the terraces without qualification, however, for drainage conditions on the lower terraces presumably differ from those on the higher terraces and may have differed even more in the past. Change in drainage conditions could have destroyed or modified some of the relict features of the soil profile.

The terrace levels mapped by Lindvall and the writer do not appear to fit an interpretation that they are in part estuarine or marine (Cooke, 1952). The estuarine hypothesis supposes that the terraces of the Patuxent valley, although cut by streams, are covered by estuarine deposits limited at their highest points by shorelines at altitudes of 6, 25, 42, 70, 100, 140, and 170 feet. As shown on plate 1, the terraces of the Patuxent River valley are rather well defined and do not appear to conform to this interpretation. Terrace 2 slopes in a downstream direction for a considerable distance.

TERRACES OF MINOR STREAMS

Terraces are well developed along several of the minor streams including Piscataway, Mataponi, and Rock Creeks. At Rock Creek, for example, where crossed by the road from Baden to Naylor, terraces lie at heights of 6, 15, and 25 feet above stream grade. As the terraces of these streams are generally heavily wooded and mapping would be excessively time consuming, no attempt to differentiate them was made. They are generally gravelly, however, and in their lower courses are commonly covered by thin deposits of sand rather than loam.

ALLUVIUM

Most stream valleys are floored with alluvium. In the lower courses of the streams these deposits are probably quite thick. Data interpreted from test piles in the Patuxent River at the site of the Benedict-Hallowing Point Bridge indicate that the river is underlain by Pleistocene fill to a depth of about 100 feet (Maryland State Roads Commission, 1949). This location is only 7 miles south of the Brandywine quadrangle, and presumably, therefore, the Patuxent River valley is drowned and underlain by considerable fill for a long distance up the river. In the Brandywine area valleys tributary to the Patuxent River are probably also drowned and underlain by as much as 25 to 50 feet of fill where they enter the river. How far upstream this fill extends is not known, but on Rock Creek, bedrock is exposed in the stream banks 2 miles upstream from the mouth. The stream banks in the alluvial area are generally low, and sandy or gravelly. The flood plains are broad and swampy and traversed by a network of flood channels. They are underlain by clay and silt.

GEOLOGY AND DEVELOPMENT OF THE SOUTHERN MARYLAND UPLAND

The mapping of the Brandywine area uncovered new data on the stratigraphy of the late Tertiary formations of southern Maryland. A limited amount of reconnaissance work was, therefore, undertaken in the area between the Potomac River and Chesapeake

Bay to determine the relationship of the Brandywine formation at the type locality to other similar deposits in southern Maryland and to examine the terraces in this part of the Coastal Plain. Most of the work was done in northern Calvert County but several weeks were spent in visiting road cuts and studying topographic maps of southern Prince Georges, Calvert, Charles, and St. Marys Counties.

The hypothesis is advanced that no high-level seaward-facing marine terraces exist on the surface of the Maryland upland west of Chesapeake Bay and that the sand, gravel, and loam that veneer the upland are in part deltaic and in part fluviatile in origin. They are primarily the deposits of a degrading stream, or stream system, which debouched from the Piedmont onto the Coastal Plain during the retreat of the Miocene sea and the subsequent period of subaerial erosion. The earliest deposits, of Miocene or Pliocene age, were deltaic, and include some shore and nearshore deposits. During Pliocene and early Pleistocene time when sea level retreated below the upland surface at its lowest point, and perhaps at times below the present sea level, the Potomac River and other streams debouching from the Piedmont eroded the soft sediments of the Coastal Plain, gradually carving the topography to its present form. As the Potomac shifted its course and widened and deepened its valley the stream left behind in the abandoned parts of the valley those deposits which formerly occupied the bed and flood plain. The original deltaic deposits were reworked and in places removed entirely. The gravels, continually being added to by the new bed load of the stream were shifted as it meandered and changed its course. In most places the river excavated a new channel in the soft Miocene marine or shore deposits but did not cut through the resistant gravel of its own bed. The valley bottom as it deepened migrated to the side and southward, forming a broad, southward-sloping, and gently terraced plain.

In the discussion which follows the equivocal term "upland deposits" is used to refer to the gravels and loams resting on the southern Maryland upland. It does not include the terrace deposits which border the rivers at altitudes below the upland level. It includes the Brandywine formation as defined in this report and as originally defined by Clark. It also includes those parts of the Sunderland and Wicomico formations originally defined by Shattuck, which are lithologically similar and continuous in outcrop with the Brandywine.

PREVIOUS WORK

The first definitive work on the upland deposits, by McGee (1891) and Darton (1894) subdivided the post-Miocene into two formations, the Lafayette and the Columbia. The Lafayette comprised gravel and loam deposits that occurred in the Mississippi embayment and in the entire Atlantic Coastal Plain. In southern Maryland this formation constituted essentially what is referred to herein as the upland deposits. The Lafayette formation was mapped as the gravel and loam resting on Miocene or older deposits and capping the uplands of the inner or higher parts of the Coastal Plain. The Lafayette was thought to be marine in origin and of Pliocene age. Its type locality was in Mississippi. The Columbia formation comprised the gravel and loam deposits of the outer, or lower parts of the Coastal Plain and the terrace deposits bordering the streams which cut through the Lafayette upland. The Columbia was regarded by McGee and Darton as part marine and part nonmarine and of Pleistocene age. Its type locality is the District of Columbia.

Later the Maryland coastal plain was surveyed in relatively great detail by the Maryland Geological Survey and a series of excellent detailed county and systematic reports resulted. G. B. Shattuck was the principal student of the deposits of the Miocene, Pliocene, and Pleistocene and his work and interpretations are fully expressed in the volume on the Miocene (Clark, Shattuck, and Dall, 1904) and in the volume on the Pliocene and Pleistocene (Shattuck, 1906) issued by the Maryland Geogloical Survey. Shattuck believed that the upland of southern Maryland was broadly terraced by wave action and that both the deposits of the upland and the younger terraces could be subdivided into four terraces, each one sloping seaward and toward the stream valleys. The term Lafayette was retained by him to describe the highest of these formations. The terms Sunderland and Wicomico were applied to the upland deposits at lower altitudes and the term Talbot to lower terraces included by McGee (1891) entirely in the Columbia formation. In southern Maryland the upland deposits of this report correspond in a general way with the Lafayette and Sunderland formations as the extent of the Wicomico formation is very limited except on the Eastern Shore. Shattuck believed that the terraces of southern Maryland were wave cut and that the gravels and loams resting on them were laid down entirely in the sea, although near the mouths of large streams. The Lafayette was regarded as Pliocene in age; the three younger formations as Pleistocene, because they contained striated boulders thought to be ice borne. The term Columbia group was retained to include the Pleistocene formations.

Shattuck believed that each terrace deposit terminated in a wave-cut scarp at its upper edge which was essentially horizontal. The scarps were well developed in the walls of the estuaries, but on the upland each terrace deposit was overlapped by the next lower one, and because of the gentle gradient of the surface, the scarps were only poorly developed or preserved.

Early work in New Jersey resulted in a different concept for the origin of similar uplands in that state. Salisbury and Knapp (1917) concluded that the gravels and loams of New Jersey, though divisible into several formations, were primarily of nonmarine origin. Chamberlain and Salisbury (1906) in a summary discussion of the entire Coastal Plain interpreted the Maryland upland deposits as nonmarine also, although they recognized that marine deposits occurred at lower levels on the Coastal Plain.

Because the deposits at the type locality of the Lafayette formation in Mississippi had proved to be Eocene in age, W. B. Clark (1915) suggested that the name Brandywine formation should be substituted for the Lafayette formation as mapped by Shattuck. Clark supported Shattuck in the belief that the upland deposits are marine in origin.

Wentworth undertook extensive petrographic studies of the gravel deposits of the upland of southern Maryland and of the peninsular area of Virginia, as well as the gravel of the Potomac river terraces upstream from Washington. He did not remap nor reclassify the deposits in Maryland but retained Shattuck's terminology so far as the high-level deposits were concerned. He concluded, largely on the basis of petrographic data, that the Brandywine, Sunderland, and Wicomico formations in southern Maryland were stream deposits on broad fluviatile terraces or alluvial fans except that he recognized the deltaic character of the Sunderland formation in Calvert County. Wentworth did not retain the term Talbot but subdivided the lower terraces close to the streams into 3 new units, each of which was interpreted as part estuarine and part fluviatile in origin. Wentworth also contributed to our knowledge of the upland deposits by his classic work on striated boulders. Through this work he confirmed Shattuck's ideas on the age of the upland deposits, assigning the Brandywine to the Pliocene and the Sunderland and later deposits to the Pleistocene. Wentworth (1930) discusses the origin of the Pliocene and Pleistocene deposits of the Coastal Plain. His doctorate thesis,[3] however, not published in full, contains a more complete account of his work and conclusions as they apply to southern Maryland.

Wentworth prepared a diagram (fig. 26) showing the grade lines of the terraces bordering the main stem of the Potomac River. As this diagram shows, the three lowest terraces are essentially horizontal in their lower courses. These terraces are in part estuarine in origin. The higher terraces (Sunderland, Brandywine, and Wentworth's Tenley) which correspond to subdivisions of the upland deposits of this report, slope seaward for their entire length and are interpreted by Wentworth as fluviatile.

Wentworth's conclusion that the upland deposits of southern Maryland are largely nonmarine was supported by work of M. R. Campbell (1931). Campbell found no evidence that the upland deposits could be subdivided into formations separated by wave-cut scarps. He studied critical localities described by Shattuck and concluded that the upland deposits represent erosion remnants of an alluvial fan deposited by the ancestral Potomac River, entirely above sea level. These deposits may have been graded to a marine shoreline at an altitude of about 100 feet, corresponding to Wentworth's Surry scarp, now preserved in southern Virginia (Wentworth, 1930). As the entire upland of southern Maryland lies above this altitude the shoreline during the deposition of the Potomac alluvial fan must have been farther eastward in the area now occupied by Chesapeake Bay and the younger deposits of the Eastern Shore.

C. W. Cooke (1930, 1931, 1932), who has made extensive studies of the Coastal Plain in the southeastern States, reaffirmed the marine origin of the upland deposits. He believed that the gravel and loam of Maryland as well as in the southeastern States could be subdivided into at least 7 terrace formations, separated from each other at some places by low scarps. From highest to lowest these terrace formations and the altitudes of the shorelines at their inner edge are listed below.

Terrace deposit	*Altitude of shoreline (feet)*
Brandywine	270
Coharie	215
Sunderland	170
Wicomico	100
Penhaloway	70
Talbot	42
Pamlico	25

Cooke believed that these formations could be traced northward and southward from Maryland to Florida and that the shorelines which separated them were essentially horizontal. All were interpreted as Pleistocene in age. In southern Maryland the contacts between them are obscured by the advanced stage of dissection of the region. In a recent paper Cooke (1952) abandoned the 270-foot shoreline and believes that the gravel of the Brandywine of the upland of southern

[3] Wentworth, C. K., 1923, The petrology and origin of the post-Miocene terrace gravels of the middle Atlantic slope. Unpublished doctorate thesis in files of the State Univ. of Iowa, 2 v.

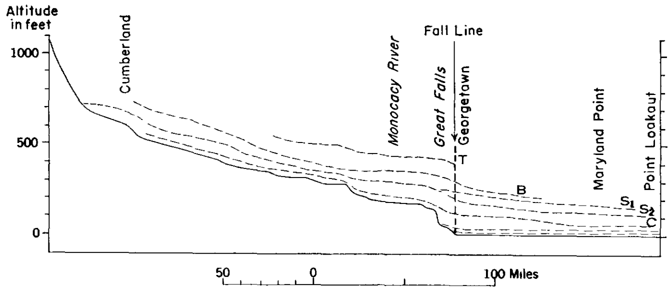

FIGURE 26.—Longitudinal profile showing altitude of terraces along Potomac River from Cumberland, Md., to Point Lookout, after C. K. Wentworth. Redrawn, with some information omitted from text figure in doctorate thesis at State University of Iowa. (See footnote 3, p. 27.) *T*, Tenley terrace: *B*, Brandywine terrace: S_1 and S_2, higher and lower Sunderland terraces; *C*, terrace in part estuarine, designated "*C*" terrace by Wentworth.

Maryland represents a pre-Pleistocene alluvial fan deposit as proposed by Campbell.

The Pleistocene deposits of Prince Georges County and the District of Columbia are now divided into three formations (Cooke, 1952), the Sunderland, the Wicomico and the Pamlico. Each formation in this region is composite, partly fluvial, partly estuarine, comprising all the deposits of a complete oscillation of sea level. The river gravels accumulated during the glacial stages when sea level was low and are overlain unconformably by estuarine interglacial deposits which accumulated when sea level was high. The estuarine deposits represented in the southern Maryland formations may be correlated with the eight interglacial formations of Pleistocene age recognized in the southeastern States. The Sunderland formation of southern Maryland includes the Coharie and Sunderland of the South; the Wicomico includes the Okefenokee (shoreline 140 feet), the Wicomico, the Penholoway, and the Talbot of the South; the Pamlico includes the typical Pamlico and the Silver Bluff (shoreline 6 feet) of the South.

During the thirties Darton (1939) made new detailed studies of the upland deposits of sand and gravel resources. He believed as did Campbell that the upland deposits were deltaic in origin, and could not be subdivided into several formations, the only terraces in the area being those along the streams at lower levels than the upland. In a report by Darton (1951), all the higher gravel and loam deposits are included in the Brandywine, whose area of outcrop in a general way agrees with the outcrop area of the upland deposits under consideration in this paper.

Dryden and Overbeck (1948), who mapped Charles County in southern Maryland, follow Shattuck's (1906) classification of the upland deposits but believe that they are largely nonmarine. Their conclusions agree closely with those of Wentworth (1930) and Campbell (1931). They found no basis for separating the Sunderland formation from the Brandywine.

As the above brief account indicates, there has been little agreement among previous workers as to the origin of the upland deposits of southern Maryland or as to the manner in which they should be classified or subdivided in mapping. Even the presence of scarps on the upland surface has been questioned. The evidence available in the literature relating to the problem over a wider area than included in this study has been discussed by R. F. Flint (1940). The reader is referred to his paper for a more complete review of the problem. Similar problems in New Jersey have been reviewed by MacClintock and Richards (1935).

GEOLOGY OF UPLAND DEPOSITS

Separation into formations.—One of the major problems involves the classification of the deposits immediately underlying the upland. Can they be subdivided into formations separated by scarps (Shattuck, 1906 and Cooke, 1952), or must they be treated as a single unit (Campbell, 1931 and Darton, 1951)? The upland itself, excluding terrace surfaces bordering the adjacent streams, rises to an altitude of about 300 feet at Good Hope Hill in the District of Columbia and slopes gently to an altitude of about 90 feet near the mouth of the Potomac River. In most of this area the uplands deposits were included by Shattuck in his Lafayette and Sunderland formations. The mapping of the Brandywine area shows that the surface of the upland and the deposits under it are complex and that a separation of them into mappable units may be possible. It has not been possible, however, as yet to trace lithologic boundaries, or topographic features which might mark such boundaries for any distance in the field, and the validity of the subdivisions and boundaries marking shorelines or terraces is questionable.

The separate identity of the Sunderland formation was questioned in considerable detail by Campbell (1931) who reexamined several of the localities cited by Shattuck (1906) where evidence existed of wave-cut scarps at the inner edge of the Sunderland formation. Campbell showed that at Charlotte Hall, for example, the scarp described by Shattuck as wave-cut was in reality produced by subaerial erosion. Dryden and Overbeck (1948), working in Charles County, also question the separation of the upland deposits into Brandywine and Sunderland formations. They state that apparently gradational changes occur in the lithology of the gravels. At higher altitudes the gravels are fine grained. No mappable scarps, however, or sharp changes in lithology were found on the upland.

The writer's work supports these conclusions and furthermore shows that the stratigraphic sequence of deposits at the type locality of the Sunderland formation is identical with the sequence at the type locality of the Brandywine formation. As shown by the detailed study of the Brandywine area the geologic column below the upland in that area may be subdivided on the basis of lithology into 3 units, (1) the Calvert formation, a succession of thin-bedded clays and sands, (2) the North Keys sand, a bed of fine sand poor in fossils and generally oxidized, and (3) the upland deposits consisting of an upper gravel and a lower loam member. The upland deposits, locally called the Brandywine formation, in places are quite sandy and interbedded with the underlying North Keys sand. Miller and Bibbins (1911) mapped the North Keys sand in this area as Sunderland, a formation supposedly younger than the Brandywine. It was shown, however, that the North Keys sand extends under the Brandywine formation and therefore must be older. Furthermore the North Keys has been shown to be Miocene(?) in age.

Similar relationships exist in Calvert County at the type locality of the Sunderland formation. Examination of Shattuck's (1903) map of Calvert County shows that the horizon representing the base of the Sunderland is equivalent to the base of the North Keys sand. For example, between Owings and Chesapeake Beach near locality 11 (fig. 4), Shattuck drew the base of the Sunderland formation just above the 100-foot contour, at about 110 feet. In this area the lowest gravel bed in the section is at about 170 feet. The gravel is underlain by 55 feet of oxidized sand, in which Miocene zone 19 fossils were found at an altitude of 140 feet. The base of the sand is at 115 feet and rests on a clay bed of the Calvert formation.

The horizon marking the base of the gravel mapped throughout Calvert County was far less extensive than Shattuck's Sunderland formation.[4] Therefore it seems clear to the author that the lower part of Shattuck's Sunderland formation at the type area is a Miocene deposit. As shown in figures 4 and 5 the gravel which forms the upper part of the Sunderland lies at altitudes comparable with the gravel member of the Brandywine east of Brandywine, and there is no apparent basis for mapping it separately as a younger formation. Similar relationships have been found at many places in Prince Georges, Charles, and St. Marys Counties. Figure 27 is a map showing localities in southern Maryland, where sandy deposits, lithologically similar to the North Keys sand, some of them containing zone 19 fossils, have been found beneath the upland gravel.

Although there is no practical basis for separation of the upland deposits, it is clear as stated by Dryden

[4] Compare plate 2 of this report with Shattuck (1906, pl. 1).

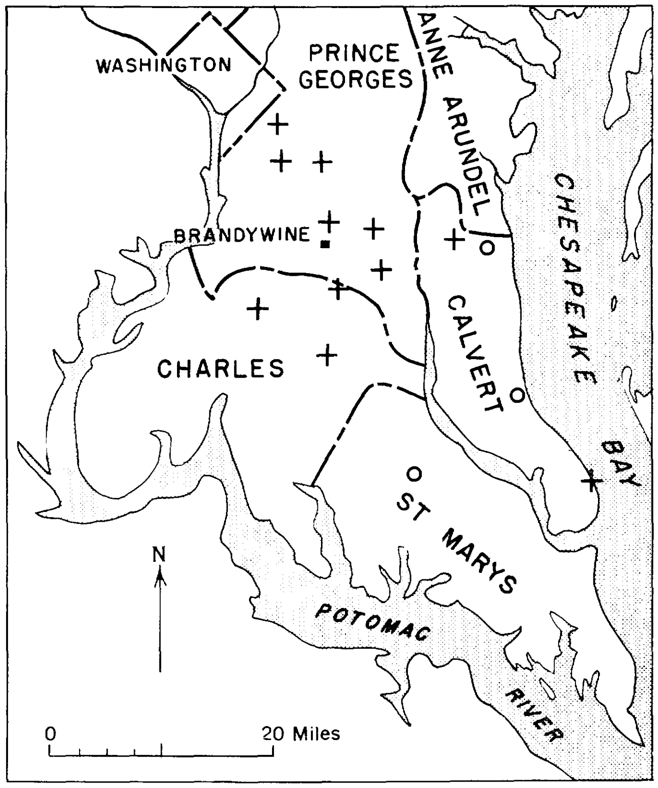

FIGURE 27.—Map of southern Maryland showing localities at which upland lower gravel member and the underlying sand of Miocene age are essentially conformable. Circles indicate localities at which fossils of zone 19 have been found in fine sand within 20 feet below the base of the upland gravel. Crosses indicate some of the localities at which the North Keys sand or a deposit similar in lithology has been identified beneath the upland gravel.

and Overbeck (1948) that broad changes in lithology occur. In most places where the entire sequence of deposits is preserved the upland deposits consist of sand and gravel overlain by loam, the two rarely reaching a combined maximum thickness of 50 to 60 feet. In the eastern and southeastern parts of southern Maryland, the gravel is commonly sandy and rests on fine sand of marine aspect, that is, remarkably well sorted and with clear angular grains. The gravel is highly siliceous, containing few constituents other than quartz, quartzite, or chert, and is medium grained. Near the Potomac River large boulders, some exceeding 2 feet in diameter are common in the gravel, many of which are igneous and metamorphic rocks. Also, especially in the southwestern part of the upland where the altitude is less than about 160 feet, the gravel rests directly on the Calvert formation or on the Eocene Nanjemoy formation.

The conclusion to be drawn from this evidence is that the lithology of the upland deposits varies. The lowermost deposits near the Potomac River are less siliceous and possibly, therefore, younger than those farther east. Unconformities probably also exist and the grade lines of separate terraces such as those recognized by Wentworth [5] may be valid.

Relationship between the upland deposits and the Miocene marine deposits.—The discovery in the Brandywine area of a Miocene(?) marine deposit (North Keys sand) between the upland deposits (Brandywine formation) and the Calvert formation has an important bearing on the origin of the upland. The lower gravel member of the Brandywine in some places is interbedded with sand similar to that in the underlying North Keys, as shown in figure 28. The gravel member probably contains two kinds of gravel deposits, an upper one, which is poorly sorted, with irregular structure; and a lower one consisting of well-defined evenly bedded well-sorted sand and gravel. The contact between the two kinds of gravel is in some places sharper than the contact between the lower gravel member and the North Keys sand and may represent an important stratigraphic break. It is not feasible to map the two kinds of gravel deposits separately and they are therefore both included in the lower gravel member of the Brandywine formation.

Relationships between the upland and the underlying marine deposits are similar over a wide area in southern Maryland. The upper poorly sorted gravel, shown in figure 28 is interpreted as a terrestrial deposit, composed of gravel deposited in channels, either deltaic or fluvial. Some of it may be much younger than the North Keys sand. The well-sorted material below as well as the North Keys sand is interpreted as littoral or nearshore and may be as old as Miocene. Presumably the relationship indicates that the upland deposits were deposited along a retreating shoreline and southeastward they overlap younger marine sediments.

This interpretation, that the North Keys sand and a part of the upland deposits represent a regressive overlap of shore, nearshore, and deltaic deposits beginning in the Miocene is suggested also by evidence in Calvert County and northern Virginia. In southern Maryland and in the peninsular area south of the Potomac River the Miocene marine deposits form a wedge-shaped body of thin-bedded siliceous sediments which dip southeast. The Calvert formation forms the base of the Miocene sequence throughout this area, and the uppermost Miocene becomes progressively younger southeastward. Thus in northern Calvert County the Calvert is overlain by the Choptank formation. In southern Calvert County the Choptank is overlain by the St. Marys formation and in Virginia the St. Marys is overlain by the Yorktown formation so that the Miocene of Virginia is customarily subdivided into four formations. The North Keys sand, a nearshore or littoral deposit, may overlap these formations and become progressively younger southeastward. An alternative hypothesis is that the overlap is more complicated and involves several advances of the sea in late Miocene and Pliocene time.

In northern Calvert County the North Keys sand contains fossils from zone 19, the equivalent of a sandy horizon in the Choptank formation. Farther south where exposed in the Calvert Cliffs, the sandy bed of zone 19 is interbedded in fine-grained clay and marl. Shattuck's work (1906), however, shows that in most, or in many places in Calvert County, the gravel of the upland is underlain by fine sand, which he included in the upland deposits (Sunderland). See the section on the Sunderland formation at Cove Point (Shattuck, 1906, p. 88) and the description of the Pleistocene deposits (Clark, Shattuck, and Dall, 1904, p. lxxxvi–xcii).

The reconnaissance work in Calvert County indicates that the gravel on the upland is far less thick and extensive than Shuttuck's Sunderland formation and is generally underlain by fine sand. This suggests that sandy deposits like the North Keys sand may rest on Miocene marine deposits throughout Calvert County and overlap younger and younger beds and formations.

Relationships described by Stephenson and MacNeil (1954) in southern Calvert County, Md., and in Virginia have a bearing on this hypothesis. They found a fine gravelly sand of marine and probably nearshore origin containing *Halymenites major* between the gravel of the upland deposits (upper part of Shattuck's Sunderland formation) and the St. Marys formation.

[5] Wentworth, C. K., op. cit.

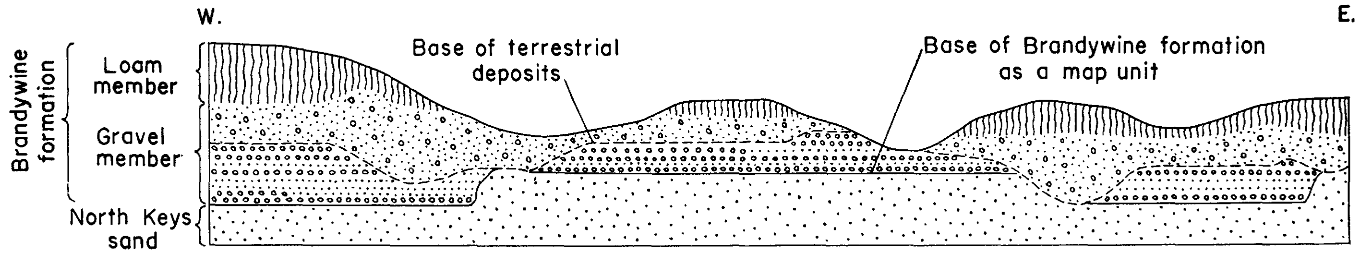

FIGURE 28.—Hypothetical cross section of an area on the upland of southern Maryland illustrating the writer's ideas concerning the relationship between the marine and terrestrial deposits of the upland. In the Brandywine area the gravels are all included in the Brandywine formation, whether their origin is marine or nonmarine. The dashed line indicates base of terrestrial deposits.

Stratigraphic work by them in Virginia suggests a correlation of this deposit with the Yorktown formation of Miocene age. It is, therefore, possible that the fine sand and at least some of the gravel interbedded with it, in the Brandywine area and in the area described by Stephenson and MacNeil is entirely Miocene, and represents an overlapping deposit resting on and intertonguing with the more fossiliferous facies of the type section exposed in the lower part of the cliffs along the Chesapeake Bay shore. To the north the deposit may be correlative with the Choptank formation, and to the south with the Yorktown formation. The top of the deposit has an altitude of about 240 feet near Washington, D. C., and only 100 feet in southern Calvert County. Whether the deposits are actually continuous or whether the relationship is far more complex and they are separable into several units at different levels, is of course not known. They have been separated in stratigraphic work only by the writer and Lindvall in the Brandywine area and the region nearby, and in the southernmost part of southern Maryland by Stephenson and MacNeil. Although the hypothesis of a regressive overlap appears to explain the facts thus far observed, fossil localities are few. It is possible that the North Keys sand may be in part much younger than the Choptank formation and that outliers of Choptank age have been buried by similar nearshore deposits of Yorktown or even post-Yorktown age.

Stephenson and MacNeil noted a sharp contact at the top of the marine gravelly sand which indicated that it is separable from the gravelly deposits above (Sunderland formation). Exposures along the Chesapeake Bay shore are excellent at many places and continuous enough so that this contact can be seen. In some places a disconformity can be plainly seen, and prominent channels filled with sand, gravel and clay cut into the deposit below, as shown in the photograph (fig. 29), taken at Point of Rocks, Md.

The poorly sorted gravel overlying the disconformity as has been suggested already may be much younger. It is presumably fluvial and in many places may have been laid down on the upland during the Pleistocene when the sea stood far to the southeast.

In some places in southern Maryland deltaic and other terrestrial sediments may never have been deposited. Locally in northern St. Marys County the surface deposits on the highest points of the upland consist entirely of fine sand or loamy sand, containing occasional thin pebble bands. The usual combination of relatively coarse sandy gravel and overlying loam may be lacking.

Topography of the upland and structure of the deposits.—A generalized contour map of the upland of southern Maryland has been constructed from the 20-foot contour topographic maps of the Maryland Department of Mines and Water Resources, and is superimposed on the geologic map of the upland deposits, plate 2. The upland generally slopes southward. Its backbone is a broad ridge that extends southeast from Washington, D. C., to Ridge, Md., near the mouth of the Potomac River, and which is now the drainage divide between the Potomac and Patuxent Rivers. A profile (fig. 30) along the crest of the backbone reveals no prominent scarp or terrace but has a low gradient concave upward, becoming gradually flatter to the southeast. The upland in Calvert County as well as the upland near the Potomac River are both slightly lower. It is also evident from the contours of plate 2 that the upland surface and the deposits under it slope toward all the major drainage lines. This is a phenomenon noted by many previous workers; Dryden (1935) attributes it to deformation.

FIGURE 29.—Exposure of Miocene and overlying upland deposits on Chesapeake Bay shore near Point of Rocks, Calvert County, Md. Note channel at extreme right margin of cliff.

In the eastern part of the Brandywine area the upland slopes toward the Patuxent River valley. The easterly dip of the upland deposits, though imperceptible without careful measurements, takes place in a series of broad shallow steps, with probable stratigraphic breaks between them. Similar breaks or unconformities may be present in the upland farther south.

Northeast of Oraville where the altitude of the upland ranges from 160 to 180 feet, the U. S. Geological Survey topographic map shows a small hill rising to

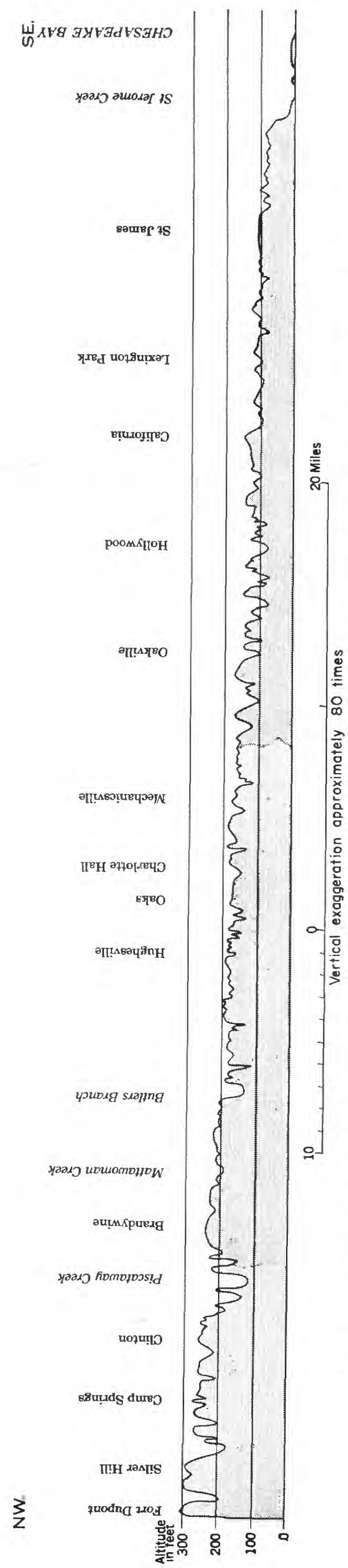

FIGURE 30.—Longitudinal profile along crest of upland of southern Maryland from Washington, D. C., to Chesapeake Bay near Point Lookout.

an altitude of more than 200 feet.[6] The altitude of the hill in relation to the surrounding terrain is shown on the projected profile of figure 31. The existence of this isolated hill has been verified in the field. It is underlain by about 20 feet of mottled red sandy loam which rests on gravel more than 40 feet thick. The base of the gravel is covered but its altitude is between 80 and 140 feet. The adjacent, and lower upland is also underlain by loam and gravel and the altitude of the base of the gravel ranges from 120 to 140 feet. This unusual hill must be an erosion remnant of a once more extensive gravel and loam deposit older and higher than the gravel and loam of the surrounding upland. An unconformity presumably exists between the two deposits. Because the high area is small and circular the possibility of deformation can be discounted.

The existence of other terracelike scarps of other outliers of older deposits, or of unconformities is suggested by study of topographic maps or by casual field observations. There are a number of places where the upland surface as well as the deposits under it drop more steeply than the average slope. The profile of figure 32, for example, drawn across the Port Tobacco Creek to the big bend of the Potomac River suggests that the southwest slope of the upland is broken by broad terraces that in a general way parallel the major rivers.

The writer believes that unconformities, low terracelike scarps and outliers of old gravels and loams which rise almost imperceptibly above the dissected surface of the upland are actually generally recurring phenomena characteristic of the upland deposits. If the lithology could be seen in continuous outcrop it probably would be broken by unconformities such as were observed near the Potomac River (fig. 16), or in the Brandywine area.

FOSSILS IN THE UPLAND DEPOSITS

The few fossils reported from the upland deposits are terrestrial types. Hay (1923) reports bones of terrestrial mammals from many localities on the upland. None, however, was found in place. The writer found wood fragments in a coarse sand at the base of the Brandywine formation near the hamlet of Baden in the area shown on plate 1. Shattuck (1906) reports two localities in Calvert County where plant fossils were found, one near the headwaters of Island Creek, and one at Point of Rocks. The localities described by Shattuck were visited in the field and although the exact strata probably were not recovered, R. W. Brown of the Geological Survey and the writer made a collec-

[6] The location of the feature described is on the U. S. Geological Survey's Leonardtown, Md., quadrangle, 1939. Scale, 1 : 62,500; contour interval, 20 feet. It lies 1.4 miles north-northeast of Oraville in St. Marys County, lat, 38°26'15; long, 76°41'18).

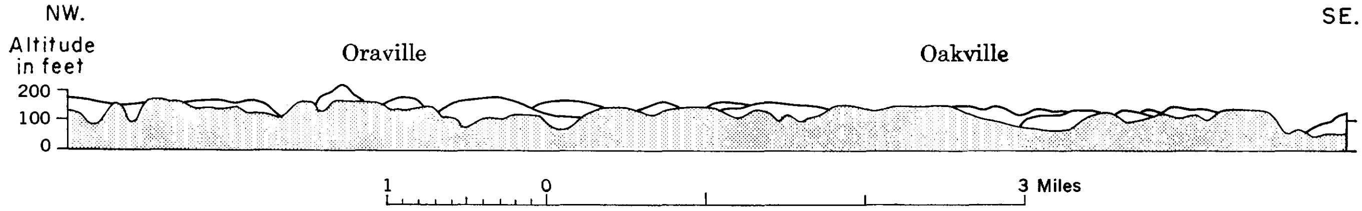

FIGURE 31.—Projected profile drawn along crest of upland from northwest to southeast near Oraville in St. Marys County, showing unusual topographic high area.

tion containing seven species from a new road cut near Island Creek. The locality lies 1.15 miles south of Mutual and 1.2 miles northeast of the village of Island Creek on a county road connecting State Routes 264 and 265. The section is shown below.

Section of upland deposits at fossil locality near Island Creek, Calvert County

[Altitude, top of section, about 150 feet]

	(Feet)
Gravel, coarse and sand, interbedded, grading upward into sand and sandy loam. Upper 10 feet mostly sandy loam	20
Loam, hard sandy	5
Clay, sandy, dark-yellowish-orange, containing plant fossils; pinches out to west	6
Sand and gravel, crossbedded	20
Base covered.	
Total	51

The fossils occur near the base of the clay lens. The deposit apparently is a channel deposit similar to the one illustrated in figure 29 on the Chesapeake Bay shore. The collection was studied by R. W. Brown, who prepared the following report:

Taxodium distichum (Linnaeus) Richard (bald cypress)
Populus deltoides Marshall (cottonwood)
Salix sp. (willow)
Alnus rugosa (DuRoi) Sprengel (alder)
Platanus occidentalis Linnaeus (sycamore)
Ulmus sp. (elm)
Quercus spp. (oak)

The specimens in this collection are for the most part fragmentary and some are not susceptible of specific identification, as for example, the willow, elm, and oaks. So far as I can tell, the components of this collection do not differ noticeably from the species living at or near the locality today. The aspect of the collection also is the same as that of the living flora there. Thus there seems to be nothing in the collection to indicate climatic change, evolutionary change, or migratory movement of species. I conclude that the deposit containing the plants most likely accumulated anywhere from the Pleistocene on, and at a time when the climate was like that of today at the same locality.

The very limited occurrence of fossils confirms the suggestion that most of the gravel in the upland deposits is terrestrial or deltaic in origin, was deposited in channels, and is separated by a disconformity from marine sands and gravels below. Apparently in places at least, there is considerable difference in time of deposition between the deposits above and below the disconformity.

ORIGIN OF UPLAND DEPOSITS

The development of the upland was complex and occupied a long period of geologic time. The Miocene marine sequence which underlies almost the entire area is overlain by nearshore and shore deposits of sand and

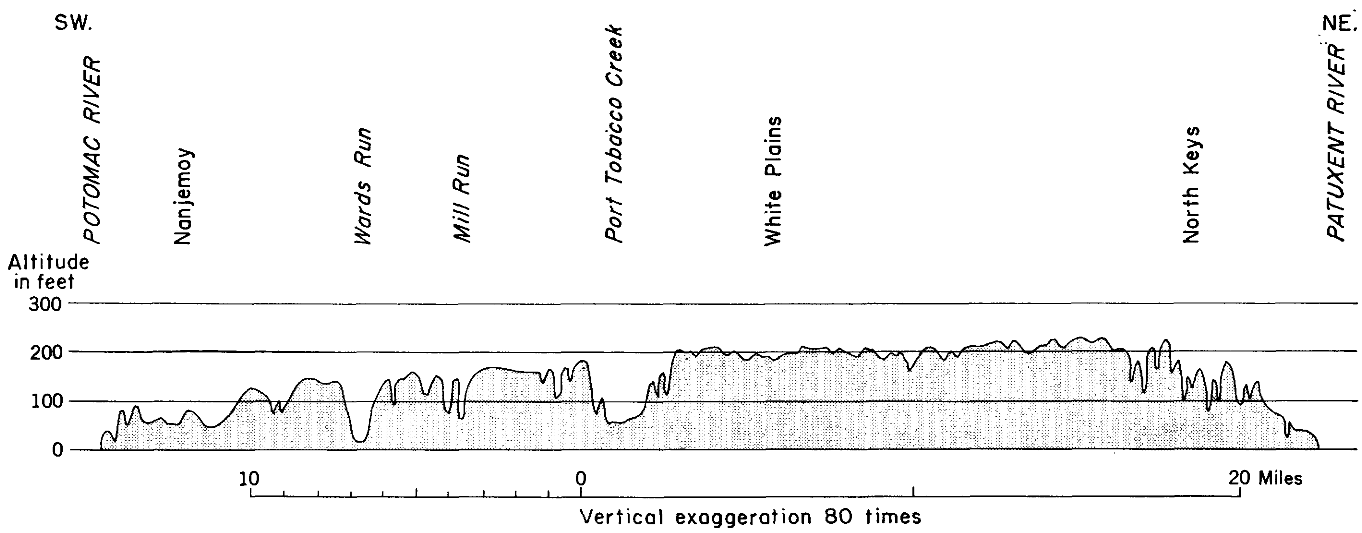

FIGURE 32.—Transverse profile northeastward across upland of southern Maryland from Potomac River to Patuxent River.

interbedded gravel which appear to be younger to the southeast than to the northwest. These nearshore or shore deposits are overlain by gravel and loam that contain terrestrial fossils and are less regularly bedded than the shore and nearshore deposits. The terrestrial deposits cut the shore deposits in channels and are themselves broken by unconformities. The upland deposits are broadly terraced, parallel to the main rivers. At one locality an outlier of older gravel is preserved on the upland surrounded by younger gravel at a distinctly lower altitude. The upland deposits, change broadly in lithology, becoming markedly coarser and less siliceous toward the Potomac River where they contain large boulders as much as 3 feet in diameter.

Origin.—One of the most notable features of the upland deposits is the association between the gravel and the overlying loam. Both deposits have the same areal distribution, and as noted in the Brandywine area, similar deposits occur on the higher terraces of the Patuxent River. Similar loams and gravels are found on the Potomac River terraces in the Piedmont and the Appalachian Mountains. Specific localities examined by the writer are near the village of Martinsburg in western Montgomery County, Md., at an altitude of 480 feet where the Potomac River valley widens to about 4 miles and at Moorefield, W. Va., along the South Branch at an altitude of 825 feet. Because gravel and loam are characteristic of the flood plains and terraces of many streams, some workers in the Coastal Plain have regarded the gravels and loams as river deposits. Campbell (1939) believed that the upland deposits were originally a single great alluvial fan or apron spreading out from the confined channel of the Potomac River at the edge of the Piedmont. Wentworth (1930)[7] regarded the upland deposits as a series of alluvial fans of different ages, each one now constituting a separate terrace. The fact that the upland deposits are a single lithologic pair consisting of a relatively thin sheet of gravel overlain by loam makes it unlikely that they could have been laid down by aggrading streams. If they represent alluvial fans, complex interbedding of gravel and flood-plain silts would be expected. The lithology of the upland deposits resembles closely the terrace deposits of streams that are at grade or are degrading. Examples of such deposits occur in many places. Mackin (1948, p. 472) describes the terraces of the Shoshone River as being covered by gravel and fine-grained material. The mechanism of deposition is described as follows:

> As each meander shifts it leaves behind a gravelly surface exposed at low-water stage—it is safe to infer that the thickness of this channel gravel is at least equal to the depth of the channel. It is evident that the gravel deposit grows by lateral accretion as the stream shifts, and if, as seems likely, it rests on a rock floor, then this rock floor must have been cut by the shifting stream, pari passu, with the deposition of the gravel. The gravel sheet represents the bed load; it is soon covered by fine silt and sand representing the finer fractions of the suspended load deposited by slow-moving or ponded overbank waters, and later by slope wash and side stream alluvial fans.

The Clark Fork and Spokane Rivers in the Columbia Basin are flanked by postglacial stream terraces which have an alluvial cover consisting of channel gravel 10 to 30 feet thick overlain by silt, loess, and slope wash (Mackin, 1948, p. 474).

Jahns (1947) in a detailed study of the flood deposits and recent terraces of the Connecticut River describes the mechanism of flood-plain deposition and the formation of terraces by this downcutting stream. The flood-plain and terrace deposits consist of gravel and sand overlain by finer deposits. The flood plain normally consists of an upper flood-plain sequence of deposits which is quite loesslike, massive, structureless and much modified by soil-forming processes. This sequence overlies a lower flood plain or "banded" sequence consisting of markedly banded silts and sands. The lowest or "bar and bottom" sequence, consists of bedded and crossbedded sand and gravel. The flood-plain and terrace deposits have a wide range in thickness. One measured section has a total thickness of 42 feet (Jahns, 1947, p. 48). The Connecticut River has been cutting and widening a valley in glacial sediments throughout postglacial time. In doing so it has formed and occupied at least five successively lower plains each one capped with fine-grained sediments. As the newer flood plains are built the higher ones are abandoned and become terraces. There are two flood plains above the present low-water channel; the higher one has been nearly abandoned by the river as a flood plain and is on the point of becoming a terrace. It is overtopped by only the highest floods.

Figure 33 shows a comparison of the mechanical composition of recent flood deposits from (3, 4) the Potomac River flood plain above Washington, D. C., (1) a surface silt loam of the 60-foot terrace of the Patuxent River in the Brandywine area and (2) a typical surface silt loam from the upland at Brandywine. The remarkable similarity in size distribution between these samples is compatible with the hypothesis that they have a common origin. The samples from the Brandywine formation differ only in that they have a slightly higher clay content.

The few examples cited indicate that the lithology of the upland deposits is similar to the lithology of graded river deposits. The Shoshone and Connecticut Rivers occupy relatively narrow valleys and the

[7] See also Wentworth, C. K., 1923, The petrology and origin of the post-Miocene terrace gravels of the middle Atlantic slope. Unpublished thesis in files of the State Univ. of Iowa, 2 v.

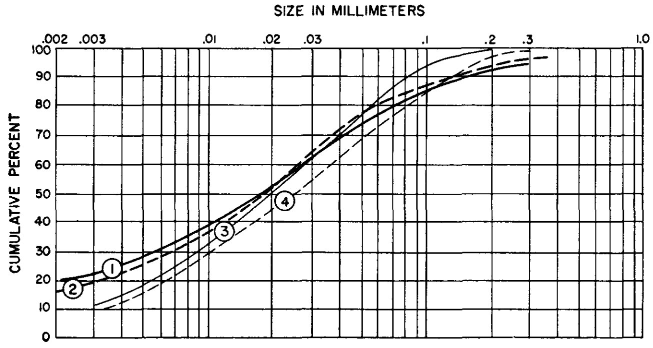

FIGURE 33.—Mechanical composition of loams on upland of southern Maryland compared with recent flood deposits of Potomac River. (1) Silt loam from the upland at Brandywine, collected 40–50 inches below the surface. (2) Silt loam from terrace 60 feet above the Patuxent River, collected 10–15 inches below the surface. (3–4) Recent flood deposits from the flood plain of the Potomac River above Washington, D. C. (Seneca quadrangle), collected by Mansfield (1939).

streams have formed increasingly narrow terraces as the valleys deepened. On the other hand the upland deposits of southern Maryland have a wide lateral extent. Both the Shoshone and Connecticut are confined in rockwalled valleys as is the Potomac above Washington. In the Coastal Plain, however, the ancestral Potomac flowed in soft sediments, less resistant to erosion than the gravelly bed load of the river. For this reason, as the river meandered across the Coastal Plain, continually lowering its channel, it had a tendency to cut and erode the bank composed of Miocene sand more rapidly than the bank composed of gravel. As a result, in the Coastal Plain the river has eroded a wide valley and kept it gently terraced and veneered with abandoned flood-plain and channel deposits. The development of such a broad, gently terraced valley is illustrated diagrammatically in figure 34, consisting of a series of hypothetical profiles illustrating stages in the development of an upland formed by lateral migration of degrading streams on a plain underlain by soft material, such as that of southern Maryland. The end result (profile F) is to produce a plain which slopes toward the major streams, and which is gently terraced by low scarps parallel to them. The diagram illustrates the writer's conception of the formation of the higher terraces of southern Maryland. The presence of deep alluvial and submarine fill and other complexities caused by changes in sea level which affected the lower terraces in southern Maryland are not indicated.

Development of the upland.—The development of the upland of southern Maryland began in late Miocene time when the Atlantic shoreline lay somewhere near or west of the Piedmont border. At this time the Coastal Plain was completely submerged and was the site of slow deposition of diatomaceous and highly fossiliferous sands and clays. Uplift of the land or lowering of the sea exposed the nearshore portion of these sediments to wave attack and transport by shore currents. Simultaneously the base level of erosion of the land was lowered, causing the streams and particularly the Potomac to trench their valleys and to enter the sea on the surface of the former submarine plain. As the sea retreated further, the Potomac cut a shallow valley through the plain and may have built a thin cuspate delta into the sea. The coarse river sediments entering the sea were rapidly dissipated by attack by the waves of the open Atlantic and were distributed along the shore and bottom by currents. As retreat continued the site of deposition shifted downslope with the shore to the southeast and the subaerial portion of the valley widened and lengthened. The river at times cut in the deltaic top-set beds, or because of the lateral growth of the valley, cut into the sandy shore deposits which flanked the delta. Eventually, in Pliocene time, when sea level stood not far from its present position, or was somewhat higher, the river flowed across the Coastal Plain in a southeasterly direction. It had a broad valley underlain by flood-plain deposits and deltaic deposits, some of which were reworked or removed by the lateral migration and downcutting of the streams. The broad valley was flanked by and only slightly entrenched in a swampy plain whose interfluve areas were underlain by sandy littoral deposits left behind by the sea.

The events of Pliocene and early Pleistocene time cannot be outlined in any detail because fossils, or other means of identification of the particular deposits laid down are wanting. Nevertheless the region presumably was above the sea at this time and the reworking of older sediments by fluviatile processes continued. Doubtless much of the original mantle of Miocene or Pliocene deltaic and nearshore sediment was eroded, but remnants of it were left on the gently sloping plain. By the end of Pliocene time, presumably the area east and southeast of Washington was mantled by a thick deposit of gravel and loam. The area adjacent to the Piedmont, however, north and south of Washington was covered by less extensive deposits. When further downcutting and channel migration ensued in the Pleistocene, perhaps at a more rapid rate, the river tended to migrate away from the area covered by the apron of heavy gravel and began cutting in a narrower, terraced valley between the older gravels and the Piedmont border, in the manner illustrated in sections D, E, and F, of figure 34. Migration and lowering of the axis of the valley continued until it was inhibited by contact of the river with more resistant deposits.

Immediately south of Washington the west side of the Potomac River valley is now abrupt and high and the river impinges on coarse-grained Cretaceous de-

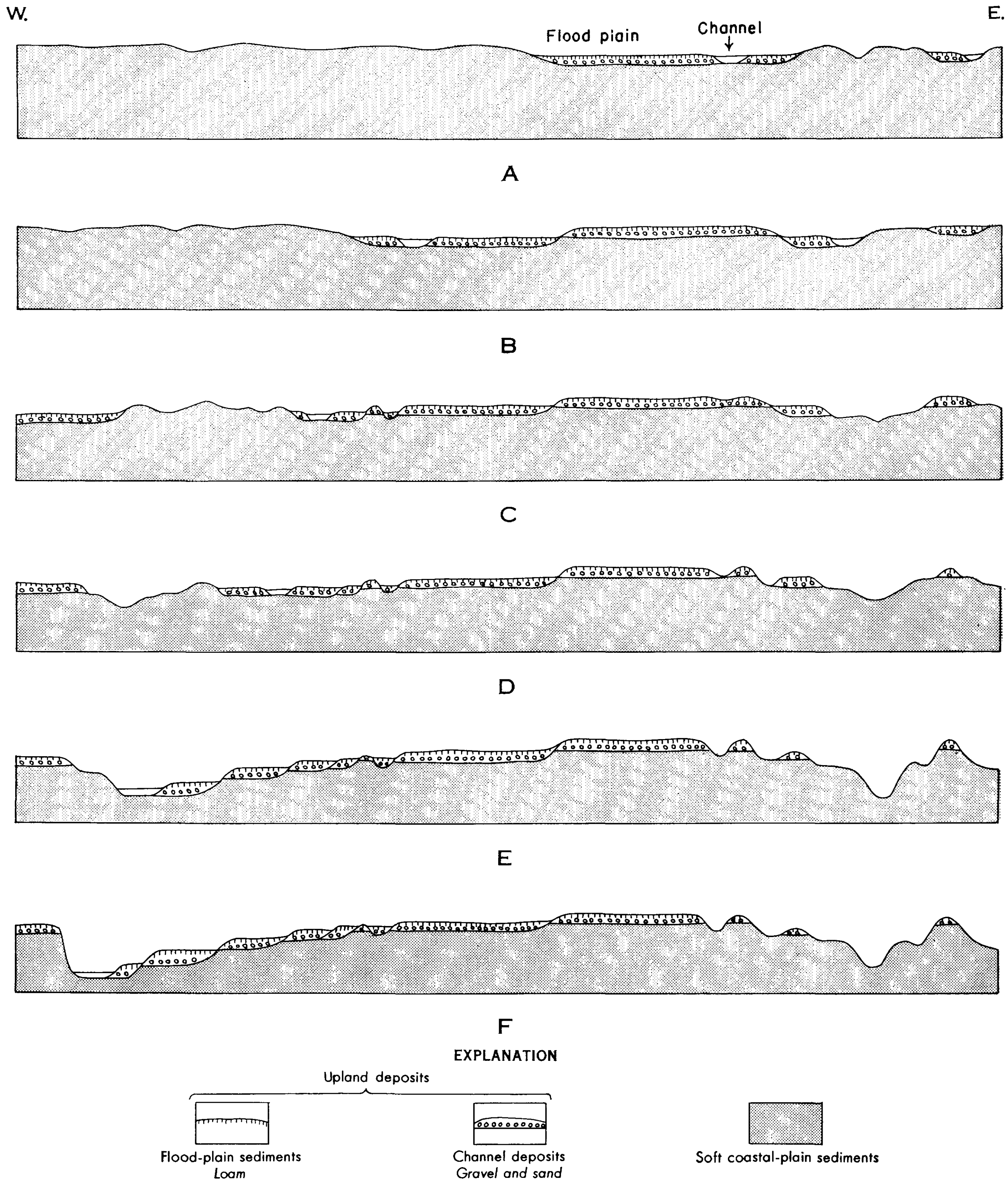

FIGURE 34.—Hypothetical diagram illustrating development of an upland such as that of southern Maryland by lateral migration of degrading streams.

posits and resistant rocks of the Piedmont. East of the big bend, where the river turns east, its south bank is capped by channel gravels probably laid down in the same manner by the ancestral Rappahannock which may to some extent retard further migration of the valley toward the right bank. Probably the Potomac River became confined against the Piedmont border at an earlier time in the upstream portion than in the downstream portion, for the east valley wall is much steeper and higher near Washington than it is farther south and east. The higher terraces in the valley immediately below Washington, therefore, are probably contemporaneous in origin with the upland itself farther downstream (Wentworth, 1930).[8]

The area north of Washington, where gravel occurs only in rare outliers on the highest hills, presumably was never entirely covered by gravel and loam as was the upland of southern Maryland. The northern area, therefore, was more easily eroded because unprotected by a continuous gravel capping and is now a lowland area.

The hypothesis just outlined requires that the Potomac River and its tributaries on the Coastal Plain were continuously meandering on and channelling the Coastal Plain from Miocene or early Pliocene time until the major outlines of the present topography were formed, that is, during the entire period of deposition of the upland deposits. The rate of downcutting must have varied because it was affected by changes in load due to climatic changes as well as by changes in base level at the seaward end of the river. Downcutting may have been interrupted from time to time, but little, if any, evidence of aggradation since Miocene time has been found except in the lower terraces. After the present valley of the Potomac River was well established, the history of deposition was affected by rises in sea level sufficient to form estuaries, and the Pleistocene deposits of southern Maryland at lower altitudes are clearly in part estuarine in origin (Wentworth, 1930). This phase of the problem, however, is outside the scope of the present report.

The hypothesis outlined, implies that the upland deposits were formed over a period of time beginning in the Miocene or Pliocene, and ending in the Pleistocene. The deposits that lie at higher altitudes generally are older than those at lower altitudes. The deposits of the central and higher part of the upland are older and more nearly conformable with the underlying Miocene sediments, whereas the younger deposits on the lower part of the upland, as for example those bordering the Potomac River, overlap onto older Miocene deposits, or even Eocene and Cretaceous deposits. The upland deposits are broken by unconformities and in places contain gravels that have been reworked many times. The deposits dip toward the major drainage lines because they were deposited as part of the process of downcutting and valley formation. The Potomac River was the principal stream involved in the deposition of the upland deposits in southern Maryland, but it is probable that the gravels east of the Patuxent River in Calvert County were deposited by the Patuxent River, or even by the Susquehanna. Tributaries of the Potomac, some of them originating entirely within the Coastal Plain must also have contributed debris and figured in the development of the upland.

Striated boulders.—Shattuck (1906) and Wentworth (1930) have stated that striated boulders, worn by ice, occur in the Sunderland and younger formations but not in the Brandywine formation. Similarly, large boulders (more than 1 foot in diameter) that may have been transported by floating ice are not reported from the Brandywine formation. Wentworth states that he found striated boulders only near the present streams. His map showing distribution of these finds (Wentworth, 1930, fig. 25) shows that none have been made in the high central part of the upland of southern Maryland, regardless of the formation name used for the deposit in which they occur. According to casual field observations of the writer, the striated boulders and those of exceptional size are restricted to the lower and, therefore, younger parts of the upland and to the terraces bordering the streams. It is likely therefore that the lower parts of the upland and the stream terraces are of Pleistocene age and that the boulders were transported by river ice during glacial stages.

Terraces of the Garonne River, France.—In the Aquitanian Basin of southern France, the geologic environment and process of valley development are similar in many respects to southern Maryland (Chaput, 1927). The Garonne River emerges from the Pyrenees onto a gently sloping dissected upland underlain by marine Miocene sediments and flows in a great arc in a terraced valley to its junction with the Dordogne River, below Bordeaux. In the middle course of the Garonne, near Toulouse, the valley has a maximum width of 18 miles. The river flows against the right valley wall which is abrupt and steep in comparison with the gently sloping left valley wall. The left wall slopes toward the river at about 27 feet per mile and is veneered by deposits of gravel and overlying silt (limons). These deposits have a combined thickness that ranges from 15 to 25 feet and are broken by a series of discontinuous terraces. Chaput shows that the terraces were formed by a continuously meandering and

[8] Wentworth, C. K., op. cit.

degrading stream which widened its valley as it became further incised below the surface of the upland. In the case of the Garonne, the process had its beginnings before the Pleistocene as shown by remnants of river deposits of supposed Pliocene age of the upland surface. The middle course of the Garonne was not enough affected by glacially induced changes in sediment load or base level to interrupt the process of degradation. Fill terraces, however, which represent change in conditions from degradation to aggradation occur in the upper Garonne River valley as well as in the lower valley where the river joins the Dordogne to form the Gironde Estuary.

The process of terrace formation and valley development by the Potomac River envisaged by the writer is identical with the concept of Chaput except that the terraces of the Potomac are perhaps in places considerably older than those of the Garonne and more reworking of older gravels has occurred.

Discussion of fluviatile terrace hypothesis.—The history of development of the southern Maryland upland outlined in the preceding pages differs only in detail from the hypothesis of origin of the Virginia uplands developed by Wentworth (1930). Wentworth believes that the upland surfaces above the Surry scarp of Virginia, at an altitude of 100 feet and above, are entirely nonmarine except that he recognizes the deltaic character of some of the deposits. He refers to the fluviatile deposits as the deposits of an alluvial fan whereas it is probable that they represent the bed, bank, and flood deposits of degrading streams or streams at grade. Wentworth divides the upland deposits into the Brandywine and Sunderland formations, whereas in southern Maryland such a subdivision may not be warranted. On the other hand it is acknowledged that the upland deposits corresponding to Wentworth's Brandywine must, for the most part, be older than the deposits that correspond to his Sunderland and so far as the uplands above 100 feet are concerned, Wentworth's conclusions about the adjacent area in Virginia are strongly supported by the writer's work in Maryland.

Discussion of marine terrace hypothesis.—The concept that the entire Coastal Plain has been notched by a succession of high stands of the sea whose levels were controlled by Pleistocene glaciation has long been of interest (Cooke, 1930, 1952). The shorelines probably are horizontal along the Atlantic coast at least as far north as Maryland. This horizontality requires that the Coastal Plain province has remained rigid and undeformed since the beginning of the Pleistocene. Thus the consequences are of widespread interest, but seem implausible to some geologists. For example, it is generally accepted that the Gulf Coastal Plain has undergone considerable deformation during the Pleistocene and the profound changes of level in the glaciated tract of the eastern seaboard are well known. By comparison it is questionable whether the Atlantic Coastal Plain from Maryland to Florida could have remained stable during the same period. The great difference in distance to head of tidewater in the different drowned valleys of the Coastal Plain are suggestive of relatively recent, and certainly Pleistocene deformation. Nevertheless deformation of the Atlantic Coastal Plain has not been demonstrated, and the horizontality of the lower terraces has been supported by the tracing of two shorelines in the field (Flint, 1940). The hypothesis of horizontality throughout the Pleistocene is based on the reported occurrence of abandoned shorelines at the same altitudes for long distances. The existence of such horizontal shorelines above altitudes of 100 feet has been questioned by Flint (1940).

It is therefore pertinent to discuss further the evidence for Pleistocene marine transgressions on the Coastal Plain of southern Maryland. One concept is that it is not possible to map all the Pleistocene shorelines in this region because of its great dissection (Cooke, 1952, p. 44). Nevertheless several marine and estuarine shorelines presumably crossed the upland of southern Maryland at least at levels below 215 feet, the Coharie shoreline. The altitudes of these shorelines are placed at 215, 170, 140, and 100 feet. Lower shorelines are at levels below the upland, and in southern Maryland would have been entirely estuarine. The four shorelines cited above, however, would have been exposed to attack by the waves of the open Atlantic Ocean for at least a part of their course across the upland, or at a prominent headland, and for many miles would have bordered an estuary as wide as the present Chesapeake Bay. The entire upland of southern Maryland below an altitude of 215 feet would have been submerged at least once and part of it several times during the Pleistocene, and presumably the depositional features preserved on the surface of the upland would be of marine origin.

In my opinion, if the marine terrace concept is correct and the upland of southern Maryland was submerged in the Pleistocene we should expect to find (1) terraces bordering the Potomac and Patuxent Rivers whose inner surfaces approximate horizontally, and (2) corresponding terraces or depositional features on the upland surfaces at about the same levels.

A study of the terraces bordering the Potomac and Patuxent Rivers is outside the scope of this investigation. Nevertheless, terraces bordering the Patuxent River were mapped in detail in the Brandywine area. The surfaces of these terraces do not correspond in number or in altitude with the postulated shorelines.

The shorelines are 8 in number and are presumed to lie at altitudes of 6, 25, 42, 70, 100, 140, 170 and 215 feet. In the Brandywine area only 4 terraces below the Brandywine formation were distinguished. None correspond to the levels at 6, 170, and 215 feet. Nottingham terraces 1 and 2 appear to slope in a downstream direction, and the other two correspond only approximately in altitude with the postulated shorelines. Local irregularities in terraces so broad as these may be very great and the apparent slope of the terrace surface might be related in part to its distance from the channel, to slope wash, and to other factors causing irregularities. Nevertheless the Patuxent River terraces in the area mapped offer no evidence in support of horizontal terraces at eight levels.

Estuarine terraces approaching horizontality might be better preserved in the Potomac estuary, which was considerably wider than the Patuxent. Many places on the Maryland shore of the Potomac River were examined by the writer. Broad terraces are exposed at many levels in different degrees of preservation. In several places below an altitude of 80 feet there are well-developed terraces which probably are horizontal for long distances and which might be estuarine, either because they are underlain by a thick fill of silty deposits differing somewhat from the upland deposits or because they contain marine fossils. Nevertheless the writer is unable on the basis of reconnaissance work or study of topographic maps to correlate the terrace remnants from one area to another. The writer believes that such correlations can be made only on the basis of the kind of detailed work expressed in the map of the Brandywine area (pl. 1), or the use of techniques of petrography or soil science which were not applied to the problem.

Others who have studied the terraces bordering the Potomac estuary do not regard all of them as either horizontal or estuarine. Wentworth (1930) believes that the higher terraces slope in a seaward direction (see fig. 26). Terraces at 15 and 23 feet, however, are estuarine. Darton (1951, p. 778) expresses the belief that the terraces bordering the Potomac were cut subaerially by shifting stream so that the present terraces do not necessarily represent remnants of larger continuous terraces, in other words that they are like the terraces of the Garonne (Chaput, 1927).

If marine shorelines cross the upland as they must, according to the marine terrace hypothesis, no evidence has as yet been discovered of their former presence. The following statement concerning the lack of evidence on the upland for the Sunderland formation, and the shoreline above it has been made (Cooke, 1952, p. 46).

> Few, if any, recognizable deposits of the Sunderland sea are to be expected along this part of the seashore, for there were no running streams to bring in sand, and most of the silt and mud carried in suspension was dropped in the estuaries before reaching the ocean. Moreover the land in this region, being an old alluvial fan that sloped gently out beneath the sea, offered no banks from which sand and gravel could be readily mined by the waves.

The writer does not agree with this statement. This is a situation where there should be the most abundant evidence of wave action. Such a shoreline would have been a depositional shoreline, similar to the Atlantic shore of Maryland and New Jersey today, along which there should have been an extensive barrier beach having lagoon deposits inshore, dunes on the beach, sandy bottom deposits offshore, and a depositional scarp beneath the shoreline. However no trace of such deposits has been found. The surface of the upland is underlain in part by silts identical with the silts of the Brandywine formation, which in turn are similiar to flood-plain silts of the modern Potomac River. Scattered on the eroded surface of the silts are small, discontinuous sandy ridges oriented in a northwest direction, which as has been argued on page 20, are terrestrial features related to stages of erosion of the land. Beneath the upland gravels, however, sands of marine or littoral origin do occur, and they are lithologically unlike the surface deposits, being markedly even bedded and well sorted.

Part of the argument for marine Pleistocene invasions of the southern Maryland upland rests on the assumption that the Coastal Plain has not been deformed since Pliocene time and that shorelines observed in the southern States may be extended northward. Unfortunately there appears to be no reliable evidence bearing on this question. The presence of shorelines cannot be used as evidence because in southern Maryland they are not discernible. Nor does the lack of proof of crustal deformation prove crustal stability. Probably all the sediments in southern Maryland could have been deposited in their present attitude. On the other hand they could also have been deposited on gentler gradients and have been tilted in a seaward direction, or otherwise warped. The Brandywine formation, for example, which now has a slope of 5 feet to the mile, generally is a finer grained deposit than the gravels of the Sunderland formation as mapped by Cooke (1952) in the vicinity of the Potomac River. According to any interpretation or mapping of these younger deposits, they must rest on a gentler gradient, since they unconformably overlie the seaward margin of the Brandywine formation and are lower in altitude upstream. Records of borings show that the present submerged thalweg of the Potomac River valley, which is overlain by gravel, is at least 100 feet below sea level at Anacostia and 170 feet at the Potomac River bridge, near Dahlgren, Virginia, a drop of only 1.3 feet per mile. This valley and presumably the gravel therein must have been formed subaerially. However, no conclusion can be drawn from these observations, except the obvious one that the gravels on the upland could have been deposited on gradients gentler than the present one. The size and amount of gravel which a river can carry is probably dependent on many factors other than gradient.

Conclusion.—The hypothesis of marine terracing of the Coastal Plain cannot at present be demonstrated on the upland of southern Maryland. On the contrary, the evidence suggests that no Pleistocene marine transgressions have occurred at altitudes above 100 feet at a date later than the deposition of the upland deposits. We are not yet able to correlate with the stages of glaciation. If Pleistocene marine terraces exist, they must be masked under a blanket of terrestrial deposits and have not been discovered.

On the other hand the marine terrace hypothesis may be perfectly valid for lower surfaces on the Coastal Plain of southern Maryland or for other areas of comparable altitudes farther south. Indeed, the character of the Coastal Plain surface appears to change markedly in southern Virginia.

It is hoped that the present report demonstrates a greater complexity in the geologic history of the region than has hitherto been evident, and that it may help us eventually to harmonize some of the diverse ideas that have been argued. Certainly there is an abundant need for further research on the Pleistocene geology of the Coastal Plain and the question of Pleistocene deformation is still open. We are far from having developed a theory of origin which will explain the geologic facts of the whole Atlantic Coastal Plain section.

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