CHARLES COUNTY

1948

DEPARTMENT OF GEOLOGY, MINES AND WATER RESOURCES STATE OF MARYLAND

STATE OF MARYLAND
BOARD OF NATURAL RESOURCES
DEPARTMENT OF GEOLOGY, MINES AND WATER RESOURCES
JOSEPH T. SINGEWALD, JR., *Director*

THE PHYSICAL FEATURES OF CHARLES COUNTY

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PREFACE

This report on Charles County is the thirteenth in a series of county reports that was started in 1900 and will ultimately include all of the twenty-three counties of the State. One of the published reports covers two counties, so that Charles County is the fourteenth county to be completed.

The county reports supplement and describe the four series of county maps that were initiated by the Maryland Geological Survey and continued by the Department of Geology, Mines and Water Resources. They are published on the scale of one inch equals one mile. The county topographic maps with a contour interval of 20 feet are the basic series on which the other three series of maps are overprinted. The latest edition of the Charles County topographic map was published in 1943. The Charles County soil map was published in 1922 and the geologic map in 1939. The forestry series was discontinued by the Maryland Geological Survey after 1914 before a forestry map of Charles County was published. The reader of this report will be aided greatly if he provides himself with the Charles County maps, which are now distributed by the Department of Geology, Mines and Water Resources.

These county reports are the most comprehensive and complete descriptions of the physical features and natural resources of the counties of Maryland that are available. The Charles County report describes the geography, physiography, geology, mineral resources, surface water resources, ground water resources, soils, forests, game, climate, and magnetic declination. The reports are encyclopedic in scope. Each section is written by an authority in the particular subject matter. Natural resources are included beyond the field of the Department of Geology, Mines and Water Resources. The authors of the sections in the Charles County report include not only personnel of the Department, but contributors from other State agencies and from Federal agencies. The Director expresses his deep appreciation to those who contributed to this volume both for their willing cooperation and for the excellence of their contributions.

The report is designed primarily as a geologic report to accompany the geologic map, so that the section on geology is, as in previous reports, the longest section. The discussion of the subsurface geology is more thorough than in any previous report because of its bearing on the ground water resources which are also more comprehensively discussed than in any previous report. The authors of the portion of the report dealing with the geology of Charles County are Dr. Lincoln Dryden of the Department of Geology of Bryn Mawr College and Dr. Robert M. Overbeck, Ground Water Geologist of the Department of Geology, Mines and Water Resources. Dr. Dryden prepared the geologic map of Charles County and a manuscript report on the areal geology of the county in 1939. Dr. Overbeck, as a member of the staff of the cooperative ground water investigations conducted jointly by the United States Geological Survey and the Department of Geology, Mines and Water Resources, interpreted the subsurface geology. The surface and subsurface geologic data have been integrated into the geologic section of the report jointly by Dr.

Dryden and Dr. Overbeck. An innovation in this report is a popular account of the geologic history of Charles County written in language devoid of technical and scientific terms that is readily understandable by the layman and which will be useful in the schools of the county.

The section on the mineral resources was written by Dr. Dryden.

The section on the surface waters was prepared by Mr. V. R. Bennion, District Engineer of the United States Geological Survey. The section on ground water was written by Dr. Overbeck. It is based on the ground water investigations conducted jointly by this Department and the United States Geological Survey and is made a part of this report with the permission of the Director of the United States Geological Survey. Its completeness results from the data collected from well drillers since July 1, 1945, under the 1945 Well Drillers law. This portion of the report is of immense practical value to the well drillers and all those depending on the ground water of Charles County for their water supply. It is the first of a series of detailed reports on the ground water resources of the counties of Maryland.

The section on soils is under the joint authorship of Mr. Merl F. Hershberger, State Soil Scientist, and Mr. E. Z. W. Compy, Soil Scientist, Survey Party Chief in Charge, Charles County, Soil Conservation Service, United States Department of Agriculture.

The section on forests is by Mr. Karl E. Pfeiffer, Assistant Director, Maryland Department of State Forests and Parks.

Another innovation in this report is the section on the wildlife resources of Charles County by Mr. Edwin M. Barry, Chief, Game and Fish Management, Maryland Department of Game and Inland Fish.

The section on the climate was prepared under the direction of Mr. G. N. Brancato, Meteorologist in Charge, Weather Bureau, Baltimore, United States Department of Commerce.

The section on magnetic declination was written by Dr. H. Herbert Howe, Mathematician, United States Coast and Geodetic Survey.

JOSEPH T. SINGEWALD, JR., *Director*

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BY

LINCOLN DRYDEN

Location and General Description

Charles County, lying west of Chesapeake Bay in that section of the State known as southern Maryland, is included between the parallels of 38°10′ and 38°43′ north latitude and between the meridians of 76°40′ and 77°20′ west longitude. The county has a land area of about 460 square miles.

The boundaries of Charles County are the Potomac River on the west and south, Prince Georges County on the north, and Prince Georges and St. Marys Counties on the east. A narrow strip of land extending between the two last-named counties reaches the Patuxent River and is the only frontage of Charles County on that river.

The original Charles County was essentially different in area and boundaries from that of the present day. In 1650, it consisted of a strip of land some few miles wide on the south bank of the Patuxent River in what are today parts of St. Marys and Prince Georges Counties. In 1654 the limits of the county were redefined and virtually the present boundaries established. At this time also the seat of government was moved from St. Marys City to La Plata, the present county seat.

The methods of transportation in Charles County show locally those changes which have been manifested in other tidewater parts of the State. From colonial times to within a few decades ago, the proximity of tidewater and the lack of other facilities resulted in the almost exclusive use of boats for moving goods to market. The mere name "Port Tobacco", as well as the large number of destroyed or abandoned wharves, bears mute testimony to a once thriving water commerce. The Popes Creek branch of the Pennsylvania Railroad, running through the center of the county, largely took the place of the Potomac River as the important route to Washington and Baltimore, and over this branch the greater part of the produce of the county was shipped for years.

Of late, competition offered by trucks, busses, and private automobiles over the improved highways of the county has led to a serious curtailment of both water and rail service. Every part of the county is accessible to trucks, and the central and eastern parts are connected by bus lines with nearby cities. A recently built bridge over the Potomac from near Morgantown to the Virginia shore affords a through route to the south which by-passes Washington.

Considering the numbers of persons engaged, farming is the foremost occupation of the residents of Charles County. Since earliest times the soil and climate have been found suitable for raising tobacco, and this crop today far surpasses in value all others combined. It is the "money crop" of the county. Considerable acreages of wheat and smaller areas of truck produce are sown.

Other types of employment are found at the Naval Powder Factory at Indian

Head, in the cutting and shipping of pulp wood, in the construction and maintenance of the many pleasure resorts, and in other less important fields.

The population of Charles County, according to the 1940 census, was 17,612. La Plata, the county seat, had a population of 488.

PHYSIOGRAPHY

The State of Maryland extends across five clearly defined physiographic provinces —the Appalachian Plateau, the Valley and Ridge, the Blue Ridge, the Piedmont, and the Coastal Plain Provinces, from west to east respectively.

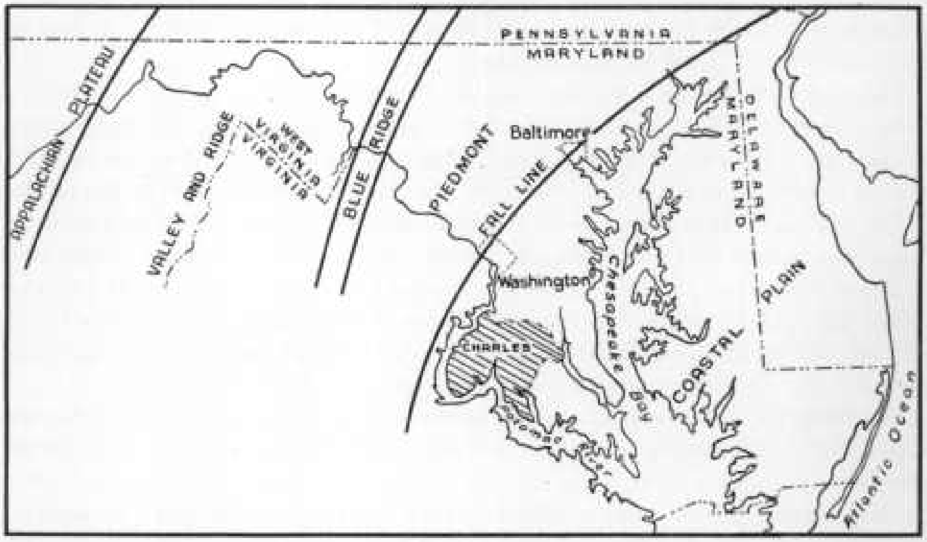

FIG. 1. Map of Maryland Showing Location of Charles County and the Physiographic Provinces.

The Appalachian Plateau in the western part of the State is a high region of nearly flat-lying Paleozoic rocks. It has at its eastern margin an almost unbroken steep escarpment, the "Alleghany Front," which has been throughout our history the chief obstacle to travel from the eastern seaboard to the interior of our country.

The Valley and Ridge Province is a region of long, ridge-like mountains and broad intervening valleys. The relief in this area is some 1000 to 1500 feet, and maximum elevations are near 3000 feet. The eastern boundary of this province is a roughly north-south line passing just west of Harpers Ferry.

The Blue Ridge and Piedmont Provinces offer some diversity of aspect both because of the variety of rock types present and because of their complex geologic history. Firm, crystalline rocks underlie most of this area and give to the surface a rolling, often rugged character; but over the greater part of the region deep weathering has provided an abundant soil and valuable farmlands are found in these Provinces. The eastern boundary of the Piedmont is marked by a more or less abrupt change of slope where the unconsolidated materials of the Coastal Plain abut against the firm rocks to the west. The transition belt where this change occurs is marked by the presence of falls and rapids in the streams.

The eastern part of Maryland—east of a line drawn through Wilmington, Baltimore, Washington, and Fredericksburg—lies within the Atlantic Coastal Plain. This Plain is of great extent. Near its northern limits it is only a few miles wide (southeastern New York), but it broadens gradually through New Jersey, Delaware, and Maryland. Farther south, in the Carolinas and Georgia it is more than a hundred miles wide; it continues (under other names) around the Gulf Coast and far south along the east coast of Mexico.

Throughout this great extent, the Coastal Plain is remarkably uniform. It is a comparatively low-lying region, with relief seldom exceeding a hundred or a few hundred feet. Large areas are exceedingly flat, with only the gentlest slope toward the sea, or toward the main drainage lines which cross it. Along its Atlantic portion the soils are sandy at many places, and it is characteristically the region of pine woods, peanuts, tobacco, and cotton; it is also the home of a large part of our negro population.

Though the Coastal Plain as a whole may be thought of as low and flat, there are significant minor differences in topography. This is particularly true in Maryland, the eastern part of the Coastal Plain contrasting with its western portion near the Fall Line. The Eastern Shore—east of Chesapeake Bay—is typical of the first. It is very low, often exceedingly flat, with local relief generally below 25 feet. Because of the slight elevation, erosion has been able to accomplish but little. Streams are swampy near their mouths, and even toward their headwaters they have wide open valleys. Many of the extensive flat surfaces are almost unbroken by stream channels.

The western portion is significantly different. This difference arises largely from the increase in elevation toward the west; this rise is scarcely noticeable, but over the width of the Coastal Plain elevations increase from near sea-level to more than 200 feet in the vicinity of Charles County. The rocks underlying this higher country are easily eroded clays, sands, and gravels, which have been extensively dissected by numerous streams, particularly the Potomac River and its tributaries. The work of dissection, however, is by no means complete. Flat areas several miles across have not as yet been reached by headward-cutting streams, but as a rule these high, flat areas are small, and they are separated from each other by rather narrow and deep stream valleys. Local relief of more than 100 feet is common.

Charles County has, in part, the kind of topography just described; this is especially true for the inland parts of the county, away from the Potomac and its larger tributaries. But in much of the western and southern parts of the county elevations range much lower—from 50 to 150 feet. With this decrease in elevation goes a decrease in erosive power of streams. Valleys are less steep and less deeply incised, and local relief is correspondingly low. Flat areas a mile or more across are largely undissected. Finally, along the Potomac and entering into its larger tributaries are lowlying flats no more than 10 to 25 feet above sea level. These areas (for example, Cedar Point Neck) are exceedingly flat and level, and a considerable part of the total area lacks surface drainage. The county, then, shows considerable diversity in its topography. The higher parts are typical of the western part of the Coastal Plain, the intermediate elevations are intermediate in topographic expression, and the low-lying flats are very similar to parts (particularly the southern part) of the Eastern Shore of Maryland.

Drainage

The whole Chesapeake Bay country, as well as most of the rest of the Atlantic Coastal Plain, has suffered recent submergence. Drowned topography is excellently developed; shorelines are crenulate and sinuous, and the larger streams are estuarine throughout a considerable part of their length.

Charles County shows these characteristic features, although not in such striking fashion as the lower, flatter Eastern Shore. The Potomac River is estuarine (tidal) from its mouth to some 15 miles above the county. Tidal currents are weak, and they probably play an unimportant role in eroding the shores. The river is wide enough, however, to provide fetch for the generation of waves of moderate height. Cliffs cut in the weak clays, sands, and gravels show that these waves are effective erosion agents; the sand beaches and underwater shoals are sites of deposition of much of this eroded material.

The Potomac—the master stream of the region—dominates the drainage of the county. Before submergence of the area, the Potomac must have cut down more deeply than any other nearby stream and most of the runoff was tributary to it. Submergence undoubtedly slowed the downcutting of all streams, but had little effect in changing the drainage pattern. Only two small streams—Swanson and Indian Creeks—are tributary to the Patuxent. Since both the Potomac and Patuxent are tidal, no particular advantage accrues to the tributaries of either river.

The larger streams of Charles County are Mattawoman, Nanjemoy, and Port Tobacco Creeks and the Wicomico River, which has its headquarters in Zekiah and Gilbert Swamps. Each of these streams is broadly estuarine at the mouth; above, there is an extensive swampy stretch, and then the non-tidal stream. All of them have southwest courses in their upper reaches, and all except Mattawoman Creek flow nearly southward as they enter the Potomac. All of them enter this river at a large angle.

A prominent feature of the drainage is the great extent and preservation of inter-stream areas. The western part of the county is drained mostly by small streams. The drainage pattern, however, is still very coarse; small lakes and swamps, indicative of poorly drained areas, are numerous. The eastern half, though traversed by Zekiah and Gilbert swamps, has broad undissected divides along which the principal roads have been built. The region north and northeast of La Plata has almost no surface drainage; swamps occur at elevations of over 200 feet. Steep-walled valleys and amphitheaters show, however, that erosion of such high-level flats is proceeding rapidly.

Another fact points to rapid erosion of the higher country: shoaling of estuaries during historical time. For example, Mattingly's, Proctor's, and Grinder's Wharves on Mattawoman Creek, long since abandoned, are mute evidence of earlier shipping;

today they are inaccessible to any but the smallest craft. Much better known is the history of Port Tobacco. In Colonial times, sea-going vessels docked regularly at Warehouse Landing; today the water is too shoal for all but the local small craft. In similar fashion, other landings had to be abandoned by steamboat lines which plied the Potomac not many years ago; in some cases, of course, other causes such as the growth of motor trucking led to disuse of water transportation. But there can be no doubt of the reality of the shoaling, which has gone on rapidly for the last hundred years or more.

SURFACE ELEVATIONS

The general topographic features of Charles County have been described. For many purposes, however, it is necessary to know the precise elevation of points on the land surface. This is particularly true for large scale engineering projects. A well driller, too, must know the approximate elevation of the point at which he is to drill his well. The elevation is his starting point for estimating the depth of the well, the points of shut-off for his casing; and for determining the type of pump he will need, and other factors that enter into the cost of drilling the well.

Precise elevations are given for a number of places in the county, and the points are indicated by small brass plates known as bench marks. The location of triangulation stations and bench marks are shown on the topographic maps. These bench marks are numbered and their elevation can be obtained from the Federal agency that installed them. Generally the local surveyor knows the location of all bench marks in his neighborhood and their elevation.

Approximate elevations can be obtained from topographic contour maps such as the county maps issued by the Maryland Department of Geology, Mines and Water Resources, the quadrangles of the War Department Corps of Engineers, U. S. Army, and of the U. S. Geological Survey, and the charts of the U. S. Coast and Geodetic Survey.

GEOLOGY OF CHARLES COUNTY

BY

LINCOLN DRYDEN AND ROBERT M. OVERBECK

General Geology

BY
Lincoln Dryden

INTRODUCTORY STATEMENT

The description of the geology of the county is intended primarily to accompany and describe the geologic map issued by the Department of Geology, Mines and Water Resources in 1939. Since many readers of this report will be unfamiliar with geology and geologic terms, the report is divided into two parts entitled General Geology and Detailed Geology. Under General Geology a section on a popular description of the geology of the county is included, and throughout it many of the geologic terms used are explained. Under Detailed Geology a more technical discussion of the geology of the county is given.

PREVIOUS WORK

Historical

General: In treating historically the growth of ideas concerning the physical features of Charles County, one can not set this region apart from the similar and larger area of which it is a unit. Thus, the earlier workers, who were, of course, interested almost wholly in the geography of this new region, expressed their investigations in the form of maps—maps which do not restrict themselves, as a general rule, to particular boundaries, but which extend to the limits of exploration. Later, when this period of pioneer work was drawing to a close, there appeared works—written and as maps—which today would be classed as geological. In these publications political boundaries have but little importance, and any area, such as Charles County, is treated as part of a larger region having similar origin, structure, and topography.

Several of the earlier, or geographical, works are of sufficient general importance to be considered here.

The maps of Ayllon, 1527, and of Ribero, 1529, are the two earliest which show the position of Chesapeake Bay. However, these maps but adumbrate the geography of the Atlantic coast, and are important here only in that they represent the earliest attempts to depict this region.

In 1612 there was published the famous "Smith" map, which grew out of the explorations led by Captain John Smith in 1608. This map was a remarkably accurate piece of work, if one considers the instruments, time consumed, and skill of the maker. All of the important land masses and streams are portrayed with a fidelity that evokes admiration. This map was followed and copied, in whole or in part, for some fifty years.

During these fifty years there appeared three maps worthy only of mention here: The Lord Baltimore map in 1635; the Farrer map in 1651; and the Alsop map in 1666. All three were much inferior in accuracy to the map of Smith.

In 1670 there was completed by Augustine Herman a map of the territory of Maryland, in which he attempted to portray the region in detail. The representation of parts of the area is superior to that of Smith, although the mapping of some sections was done, apparently, by hearsay and copying.

Dennis Griffith, resident in Philadelphia, published in 1794 a map of Maryland in which, at first glance, one has difficulty in descrying other than trivial errors. It may well be called the precursor of our "modern" State map.

In 1835 J. H. Alexander, working for the State, published two maps, one of which is a geological, contour map of St. Marys, Charles, and part of Prince Georges Counties. This map presented the topography of this region in much greater detail than had been heretofore attempted. The geology, as would be expected, is indicated here and there only by the name of a formation or type of lithology exposed in that area. This map represented the first effort at accurate portrayal of the topography of Maryland.

In 1843 the United States Coast and Geodetic Survey began work in Maryland. Although the work of this Survey is primarily that of charting the waters and delineating the coasts, still, in this State, with its relatively long shore line to area, this work, accurately done, provided a framework which later was filled in by the work of the United States Geological Survey in the interior. This branch of the Government began work in 1883, and has mapped the whole State. The topographic map of Charles County, made by the United States Geological Survey in cooperation with the Maryland Geological Survey (Edition 1914) was used as a base for the geological map of Charles County published in 1939.

If we turn to the history of geologic research, we find much the same conditions as have been briefly reviewed in the preceding sketch of cartographic development. The early works, in which that of Smith in 1624 is outstanding, have today but an antiquarian interest.

In 1809 William Maclure first published his observations on the geology of Eastern North America. This work is "modern" in the sense that it attempted a geologic division into formations on the basis of lithologic differences; it is not "modern" in that practically no references to specific localities or sections are adduced in support of the generalizations drawn.

J. T. Ducatel, State Geologist, furnished some detailed and definite knowledge of the geology of Charles County in the Annual Reports for 1834–1840. He was especially interested in the value of (Eocene) greensand marls for fertilizers. Included with Ducatel's work is the scheme of Alexander, Topographical Engineer, to drain Zekiah Swamp.

W. B. Clark, from 1887–1917, made several contributions to the local geology, as well as to that of the Coastal Plain in general.

In 1894 the Fredericksburg folio of the U. S. Geological Survey, and in 1896 the Nomini folio, both by Darton, were published. The two folios include the southern half of the county, and represent a great advance in the mapping of its geology.

The Patuxent folio, published in 1907 by Shattuck, Miller, and Bibbins, represents a further advance. It embraces the northeastern section of the county, and embodies the geologic classification used at the present time.

Cretaceous Rocks: The Cretaceous rocks are very poorly exposed in Charles County. As a result, the literature bearing on these beds is almost lacking in direct references to the county. Clark probably first made known the presence of Cretaceous strata by his work on the Fort Washington bluff, just a short distance above the boundary line of Prince Georges, although nothing is said as to the continuation of the Cretaceous into Charles County.

In 1895 Clark summarized the knowledge of the Cretaceous deposits of Maryland, giving a map of their distribution; on this map the parts of Charles and Prince Georges Counties lying just below Fort Washington bluff do not appear. The geologic map of Maryland, published in 1906, shows the distribution of Cretaceous strata in Charles County. In 1911 and 1916 there were published respectively the Lower Cretaceous and Upper Cretaceous volumes of the Maryland Geological Survey. These two volumes, with accompanying maps, represented the summation of knowledge concerning the Cretaceous formations of Maryland. The last geologic map of the State, 1933, epitomizes present knowledge of these formations.

Eocene Rocks: The Eocene rocks of Charles County have several good exposures along the Potomac River and its tributaries. The most famous of these is that extending from about a mile below Popes Creek to just below Chapel Point. Other well known localities are at Glymont and Port Tobacco. It is chiefly around the above three exposures that the literature on the Eocene has grown up.

Ducatel, in 1834, already knew of the existence of shell marl in Charles and the adjoining counties, and his map of 1836 shows the distribution of Eocene marls. Conrad described fossils from several localities in Charles County, contributing the most careful work of his time. Later Clark published several short notices referring specifically to the county in the Johns Hopkins University Circular. In 1901, there was published the Eocene volume of the Maryland Geological Survey by Clark and Martin. This publication is accompanied by a map of the Eocene formations.

Miocene Rocks: The Miocene rocks of Charles County are rather poor in exposures and fossils; as a result, the literature pertaining exclusively to the county is meager.

W. B. Rogers probably was the first to report Miocene deposits in Maryland. In 1837, the following year, Ducatel recognized that much of his "Eocene" in Charles County was actually Miocene blue clay (or marl). From 1830 to about 1850 Conrad published many important papers on the paleontology and correlation of the Maryland Miocene. Darton, in 1894, in the Fredericksburg folio, and in 1896 in the Nomini folio, gave the distribution of the Miocene of part of the county. In 1904 the Maryland Geological Survey published the Miocene volume. In 1907 the Patuxent folio was issued. This publication represents the most detailed mapping of geological formations which had previously been attempted in Charles County.

Pleistocene Rocks: Among the earlier workers in the Pleistocene series may be mentioned Conrad, W. B. Rogers, Lewis, Chester, and others. W J McGee, between 1886 and 1889, made very important contributions to the knowledge of the Lafayette (Brandywine) and Columbia formations. Darton later (1891–1901) extended and modified the work of McGee. Since Darton's work, that of Shattuck has taken first rank in the Maryland Pleistocene. In the Pliocene and Pleistocene volume of the Maryland Geological Survey (1906), Shattuck gave a summary of existing knowledge of these formations. Short articles have been contributed more recently by Clark, Bascom, Cooke, Wentworth, Campbell, Dryden, and others.

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PRESENT WORK

Surface. By Lincoln Dryden

Field work on the surface geology of the county was started in 1927 and was continued through the four summer months of that year, and a report was prepared in 1928. The county was revisited for short periods during the summers of the early 1930's, and a revised report was submitted in 1935. After several days of field work in 1947 the report was rewritten in its present form.

In 1935 a preliminary geologic map was submitted to the Maryland Geological Survey. Through a misunderstanding, this preliminary copy, without editing or corrections, was published in 1939. Some of the more obvious errors are the following.

In the body of the map, the Eocene series has not been subdivided, so that the pattern and the symbol "E" should stand for both the Aquia and Nanjemoy formations. In the legend and columnar section the Eocene is called "Nanjemoy" only; in the cross-section there is an additional unit, without pattern, marked "Ea." Further, although Cretaceous rocks are indicated on the map by the symbol "K," there is no mention of such rocks in the legend or columnar section, but they are shown on the cross-section.

Subsurface. By Robert M. Overbeck

Introductory Statement: The subsurface geology of Charles County is extremely difficult to decipher from surface exposures. Most of the county is covered by Pleistocene sand, clay, or gravel and by vegetation which effectively mask the older rocks lying beneath them. The older rocks, too, consist of sand, clay, and gravel—soft material that quickly disintegrates under the action of the weather where exposed along road-cuts or in the banks of streams. A few good exposures are found in the high bluffs of the Potomac River near Popes Creek, but these are the exception.

Since the basis on which geologic mapping rests is the measured geologic succession of rocks, the surface geologist in Charles County works at a great disadvantage. Nowhere in the county can he measure a continuous geologic section of the rocks in surface exposures.

In 1945, the Well Drillers Law was passed and its enforcement placed in the hands of the Department of Geology, Mines, and Water Resources. Among the features of this law was the requirement that drillers obtain permits to sink a well. Through these permits the Department knows where and approximately when wells will be drilled. A further provision of the law is that drillers are required to give samples of well cuttings from the wells they drill together with their drilling log, or description of the types of rock the drill passed through. Through this law, the Department obtains sections through the rocks at points where wells are drilled, and from these, a geologic map can be made of the subsurface of the county even though surface exposures are unsatisfactory.

Reliability of well samples: Limits are placed on the reliability of the samples taken from wells, and these will be discussed briefly by outlining the methods used in sinking drilled wells. Hand dug wells, which rarely go below 50 feet, will be discussed in another part of the report. In this report data are used from about 15 drilled wells, most of which are located in the southeastern part of the county. A more widely distributed group of wells would have given a more detailed map.

When a well is being drilled into the earth, the rock that comes out of the hole is called *well cuttings.* The amount of clay, sand, or gravel that comes out is comparatively small since in many drilled wells the diameter of the hole is only 2 inches. This material represents the rocks through which the drill has passed, and by its study much is learned concerning the subsurface geology.

Most of the wells in Charles County have been drilled either by the percussion method or by an adaptation of the rotary method called jetting. In the percussion method, hole is made by dropping at short time intervals a heavy bit at the end of a cable. The particles of rock broken off by the bit as it descends are brought out of the hole by a bailer. By simple measurement, the interval from which the sample came is known, and by getting samples from contiguous intervals one can build up a sample log that will give a very good picture of the rock section passed through. Samples obtained by this method are more reliable than those obtained by the rotary or jetting method. As with all well samples, contamination by rock from above the sampled interval is likely to occur, unless casing is put in as the well is being drilled.

The jetting method of drilling is carried out by means of a chisel-like bit at the end of a pipe rotated by hand which rises and falls as in the percussion method. The bit chops its way downward, and the material loosened by the bit is brought upward by hydraulic pressure. This pressure is supplied by a pump which forces a mixture of mud and water down through the drilling pipe, or stem, through the bit, and upward through the hole around the drill stem. The disintegrated rock and water pass out the top of the hole into a mud pit, and the water is returned again to the well. Samples are caught in pails as the drilling mud comes out of the well. A number of things can enter to change or contaminate the sample. For example, sorting may occur owing to the different sizes and weights of particles, to variations in hydraulic pressure, or to differences in the thickness of the mud in the water; or material may fall into the hole from above as most wells are drilled with only a portion of the hole cased off. Samples have to be studied, therefore, with the possibility of contamination always in mind; and the guiding principle used must be the first appearance of anything significant. Contamination, however, is less likely to occur in small diameter wells than in ones of large diameter. In spite of this contamination the samples do give a wealth of valuable information; and the above mentioned sources of error could be largely eliminated if drilling were closely supervised.

Preparation of the well cuttings for study: The well cuttings are obtained from the drillers in small sacks. The material is dried and separated into two parts. One part is filed for future reference; the other part is washed over a 200-mesh screen. This washing eliminates the silt and clay. The washed portion is immersed in carbon tetrachloride in order to obtain the foraminifera or other small organisms which may float on the carbon tetrachloride. The sand is then screened to get the relative amounts of different sized grains. Finally a microscopic examination is made of the material to see whether any peculiar minerals or mineral associations occur that might be used in correlation with other wells or outcrops. The organic remains are studied and described. These are of particular value since they can be used both for local correlation and geologic age determination.

Purpose of correlation: The purpose of correlation is to find common characteristics, physical or organic, that are of limited vertical extent in the wells and that can be easily recognized in the samples from other wells. If these characteristics can be shown to identify a particular bed, and if they can be found in a number of wells, the position of the bed can be indicated in a subsurface map. For example, the bottom of the "pink" clay bed (Marlboro Clay member) of the Nanjemoy formation is shown on Plate III with this report. A brief outline of what is looked for in the sample follows:

- A. Inorganic materials
  - 1. Physical characteristics
    - Kind of rock
    - Color
    - Mechanical composition
      - Grain sizes
      - Condition of grains
    - Minerals
      - General types
      - Heavy minerals
- B. Organic materials
  - 1. Microscopic
    - Foraminifera
    - Radiolaria
    - Ostracoda
    - Diatoms
  - 2. Megascopic
    - Sponge spicules
    - Echinoderm spines and parts
    - Shells and shell fragments
    - Wood

The kind of rock is the most abundant rock type in the specimen, such as clay, marl, gravel, and sand.

Approximately equal amounts of samples are washed through a 200-mesh screen, and the size of the residue noted as an indication of the relative amounts of sand and clay. The residue is then passed through a nest of screens for size grades, according to the classification shown in table I.

The most abundant size or sizes are noted. For example, if the grade is described as chiefly fine, it means that the sand residue is made of sand lying between 0.005 inch and 0.010 inch in diameter. By this method the size of the predominating material in the sand residue is made objective, although still qualitative, and comparisons can be made in a general way of the material in different wells, and in different formations.

TABLE I

Size Classification of Sand Grains

On Screen No.		Grain Size	Inch Grain Size
		mm.	*inch*
10	Granule size and up	2.00 mm and up	0.079 up
18	Very coarse sand	1.00 –2.00 mm	0.039–0.079
35	Coarse sand	0.50 –1.00 mm	0.020–0.039
60	Medium sand	0.25 –0.50 mm	0.010–0.020
120	Fine sand	0.125–0.25 mm	0.005–0.010
230	Very fine sand	0.062–0.125 mm	0.003–0.005

The mineral content of the sand is examined in only a very general way. Many more details could be worked out, such as the determination of heavy minerals, but this would require considerable additional study, since contamination would have to be guarded against by making complete runs of all the samples from a well. Two very important mineral constituents have been used to determine the extent of the Eocene formations. These are glauconite and mica. Yellow-stained quartz and "blue" quartz also have correlative value at places. In the description of the glauconite, the color and shape of the glauconite is given. So far these characteristics have not been found to have value for correlation, but may when more samples are available for comparison. Some work has been done on heavy minerals in outcrop samples, but, although a promising lead, has not yet been undertaken for the Charles County well cuttings.

Organic content: Most of the effort in the study of the data for subsurface correlation has been given to the collection and examination of the microorganisms. This approach is relatively new, and much more will have to be done before it is on a sound basis. It promises, however, a rather concise method for working the geology in detail and has already proved of great value in the determination of the broader geologic divisions. For example, the presence of microscopic algae, the diatoms, gives the location of the Fairhaven member of the Calvert formation and the base of the Miocene rocks. The microscopic animals, the foraminifera, indicate the Eocene series and its major subdivisions. Study has also been made of foraminifera characteristic of faunal zones within Miocene and Eocene formations.

Fragments of sea shells (few shells complete enough for determination are found in well samples) indicate the location of shell beds in the wells. Certain of these beds are of wide extent and can be found in the cuttings in a number of the wells and hence can be used for correlation.

Sponge spicules, ostracods, sea urchin spines and fragments, teeth, bone and other organic remains are found in the well samples and may prove to have considerable value in the future as collections are built up.

By use of the above data it is possible to make an underground or subsurface geologic map which shows, for example, just how deep one needs to drill to get water in almost any part of the county; or it tells where to find the "pink" clay bed, if this clay should prove useful for industrial purposes. A subsurface geologic map is particularly important for use in Charles County where outcrops are few and the older beds are covered with sand and gravel of much younger age.

POPULAR ACCOUNT OF THE GEOLOGY OF CHARLES COUNTY

BY

LINCOLN DRYDEN

You may be one of the Charles County residents who has noticed shells, such as oyster and clam shells, far from where they "ought to be." In the high bluff about a half mile above Glymont wharf you can dig out shells 40 to 50 feet above the Potomac River. More surprising than this, you can find the same sort of shells far inland in the county, away from any present-day river, and more than 100 feet higher than the bluff at Glymont. These shells are not just lying on the surface; they are buried in sand and clay, and have to be dug out. So it is clear that they have been there just as long as the sand or clay; they haven't been brought in and left by Indians or by your forefathers. (There *are* heaps of Indian shells *on the surface*, but these are not the ones we are talking about.)

People who have been around the water a good deal are quick to see that these shells are just like the ones that oysters and clams make today. But these animals live only where the water is salt—in the Potomac River (but not all the way up to Washington), in Chesapeake Bay, and along the shores of the Atlantic Ocean. When they die, their shells are left behind, lying on the bottom, and are later buried in mud or sand. So if you were to find shells like these near La Plata, far from any salt water, the natural thing to suppose would be that at one time the region around La Plata must have been covered by salt water, and that it was then that the shells got buried in the sands and clays where we now find them. You would be right, for that is exactly how they got there.

If you are like most people, you will immediately want to know how long ago it happened. There *is* an answer, but perhaps you won't like it, or believe it: It was several million years ago that Charles County was covered by salt water, when it was the bottom of an ancient sea.

You may not believe this answer, but unfortunately there is not enough time or space here to convince you that there are good sound reasons for believing it to be true. You may not like the answer because it has little meaning for you. If—you may say—it all happened that long ago, how can I possibly tie it up with anything that I can see or understand? Weren't things so different then that they have no connection with anything going on now?

There are connections between the remote past and now, because the same sort of things were happening then as at present. Let us take an example or two of some of the changes going on before our eyes.

Even in his own lifetime a man can see changes in the shape of the land. A new gulley may appear in his field during a heavy rainstorm. Unless he does something about it, the gulley may gradually cut back, and eat down, until it develops into quite a little valley, where before there was none. It may even develop little branches and side gulleys, and proceed to wash away the higher part of his land. Or take the opposite sort of case. A stream that was once used for transporting produce or for pleasure boating may become silted up and marshy, and thus lose any usefulness it once had. Indeed, the two are connected; the land eaten away from one man's field is washed down to fill up the next man's stream. Suppose that you give this long enough time—much more than one lifetime. Isn't it clear that much of the higher land will be washed away, and that the low places, like the low stream valleys, will be filled in?

The changes that have taken place in the county during these millions of years we speak of are like these changes going on now—it is just that there has been a lot more time for them to happen. There have been periods in the past when washing-away (erosion) went on for long enough to lower all the high parts, bringing the county all to the same low level. At the end of this erosion period it would be very easy for a slight rise of the sea (or an ancient Chesapeake Bay or Potomac River) to flood the whole county. At other times (for reasons we do not know), the county was raised again, the salt waters retreated, and erosion started all over. It may be that the county (and the surrounding country) is being lowered or raised today, but everything except erosion goes on so slowly that we perhaps will not be able to see the changes for several lifetimes. So some of the changes, like erosion of high lands and silting up of low places, are understandable because we see them happening. Others, like flooding by bodies of salt water, and like lifting the county up again out of the sea, are very hard to picture in our minds; but we know that they happened, because we have the evidence, like that of the shells of salt water animals, mentioned first. Some of the evidence, and the main things that happened to the county, will be related below.

Let us start by having a look at the surface of Charles County (Figure 2). Much of this surface is just "hills and valleys," but some parts of it are quite flat and level. For example, there are large, flat, low-lying areas which we know as "necks," like Cedar Point Neck. But the largest flat area of this kind is also the highest part of the county. It's the wide expanse in the central and northern parts, on which La Plata, Waldorf, Middletown, Mattawoman, Brice, Beantown and other places are situated.

Let us use the geologist's name for this high area—the "Brandywine surface"—so called from the village in Prince Georges County.

The flat Brandywine surface is being slowly but surely destroyed at the present time. It is being eroded by Gilbert and Zekiah swamps in the east, Kerrick swamp and Port Tobacco creek are cutting channels into it near La Plata, and Mattawoman swamp and its branches are attacking it in the north. We know that these streams are eroding and destroying it, because just after a heavy (or even a light) rain we see that they are colored with yellow and reddish particles washed down from its surface. Plowed fields in this area are being lowered rapidly enough for us to notice, but even the woodlands are being slowly worn down. Erosion is fast in one place and slow in another, but it is all going in one direction—toward erosional destruction of the flat, high Brandywine surface. Given enough time, erosion will lower this high area until it stands not far above sea level (the level of the Potomac River).

Suppose that instead of going forward in time, we picture the events going *backward* in time. The surface is being destroyed now, but there must have been a time when the destruction was less complete than at present. Still farther back, there must have been a time when streams had not even started to erode it—when it had its original extent and flatness. There were no Gilbert and Zekiah swamps, no Port Tobacco creek cutting through it, and the surface extended flat and unbroken from Prince Georges County on the north, across where the Potomac River now is, to Virginia on the south; and from Virginia on the west to Calvert County on the east.

Why do we think that this surface was once that extensive? Because we can find remnants of it, just as flat and at just about the same height above sea level, at many places outside the county. In your mind's eye, put back the material that the creeks and rivers have carried away to make their valleys—just as gulleys do in eroding your fields—and these now separate patches of the Brandywine surface can be seen to form a continuous, flat expanse. So Charles County was at one time as flat and featureless (and probably just as low) as parts of the Eastern Shore today. The county no longer looks like that because (probably after being lifted up) it was eroded by the Potomac River and its many branches. The Potomac River has been the chief agent in making the county look as it now does.

The Brandywine surface was destroyed more rapidly and more completely in some places than in others. There is no remnant of it left in the whole southwestern neck of the county—from Riverside to Doncaster to McConchie. For when the Potomac started to flow across the surface, this is the region it picked. The land was low, and a sluggish Potomac wandered (meandered) back and forth across the western part of the county, with its tributaries eroding the high land in and near its path (Figure 6). Across its belt of wandering it dropped some of its load of sand and gravel, covering this new belt of lowland it had eroded out of the Brandywine surface. The surface of much of the western part of the county is now made of this pebbly material, which you can see in gravel-pits and road-cuts almost anywhere in the area. The pebbles are rounded because the Potomac tumbled them about and knocked off their sharp corners and edges.

If it worries you to think of the Potomac flowing across country that is now more than 100 feet above the sea, remember that the county was not always as high as now. When the Potomac first started, the county, flat and featureless, probably lay not much above sea level. As it was lifted up, probably slowly and haltingly, the Potomac and its branches eroded the scenery we now know.

The county was raised about 100 feet or so, and then stood still for a good long time. During this time the river meandered back and forth over the western part, and deposited the sands and gravels we have already mentioned. Later, the county (and, of course, the surrounding country) was lifted still higher, almost to its present elevation. During this lifting, the powerful Potomac kept cutting down its bed and channel, keeping itself almost at the level of the sea. After the lifting stopped, the river again started wandering about, eroding not so much downward as sideward. But at this stage it did not wander so far, only over the area now making the low "necks" which border its present course. These necks, at that time, were under the river waters. Last of all, came an additional slight uplift, which raised these (Cedar

Point, Stump, and other) necks a few feet above the level of the Potomac. Today, the Potomac River is forming a number of flat, underwater, shallow shoals, which can be seen clearly on charts. If the land were to be uplifted again, these flat shoals would form another, and lower series of necks, lying below the necks named above.

So far in our geologic history of Charles County we have come a long way in time—from the time when all the county was part of the flat, low, and featureless Brandywine surface. We have seen that from this time to the present, two chief agencies have shaped the county: Uplift, from near sea level to more than 200 feet above; and erosion by the Potomac and its tributaries, during uplift and especially during those long periods when uplift was halted.

But so far we have gone only through the later part of the county's geologic history. We haven't even said how the Brandywine surface itself was formed; and the sands and gravels of that surface lie on something below, something still older. Let's now start with the oldest materials and the oldest events in the county, and come up to the time when the Brandywine surface was made. Then you can add on the part of the history we have already recounted, and you will have a complete geologic history for your county.

Somewhere down under Charles County there is old, hard rock, like the rock which you can see in Rock Creek Park, Washington. You don't see it because it is so deeply buried, but it was struck in a well at Indian Head, at a depth of about 750 feet; it is perhaps 1200 feet or more underground at La Plata. And on top of this hard rock is a thick series of sands and clays and gravels, which too are buried and out of sight over most of the county. But in a few places, at Indian Head, and in the bottom 20 feet of the bluff above Glymont, you can see these materials. Since they play such a small part, they will not be considered further, but it may interest you to know that they were formed at the same time that dinosaurs roamed our countryside.

The oldest widespread material is the greenish, sandy deposit that you can see at many places in the central and western parts of the county. It is known to geologists as "greensand," a very suitable name since you can distinguish little green grains in it if you look closely. Some other materials may look greenish, particularly if wet, but the others do not have these individual green grains; it is just that the whole mass looks greenish. The true greensand can be found from 21 feet above tide on upward in the bluff above Glymont, from tide to 20 feet above in the bluff just below Popes Creek, in road-cuts near Wards run, Mill run, Port Tobacco creek, and in a lot of other places.

This is a good place to stop for a moment in our history, to tell you how to find exact places where you can see greensand or any of the other materials which we have already discussed or which we will talk about below.

The greensand was formed during a time called "Eocene" by geologists. If you want to locate a place where greensand appears, look on page 77, where you see the statement: "Eocene beds will be found under the following:". Then follows a series of numbers in parentheses; on the following pages you will find these numbers listed in order. Each number is used for one place where greensand is found, and following the number is a description of just where the place is; following that is a brief description and the thickness of each layer of sand or clay occurring there; the oldest layers are at the bottom, the later ones at the top, just as they were originally formed. "Fossils" mean ancient sea shells buried in the sand or clay. So if we want to refer to a place where something particular appears, all we have to do is select a number, like (9); you can look up that number in its proper order, see where the place is, and what you can see there. With that information in mind, let's return to the geological history.

At quite a few localities, for example, (2), (5), (7), (9), (11), (20), (22), shells buried in the greensand show what kind of animals were living here when these materials were formed. Some of the shells will look strange to you, because many of these animals no longer live in this part of the world, and indeed some of them no longer live anywhere in the world. But there are oyster shells, and shells something like clam-shells of today. Such aninals must live in water, and more than that, in salt water. So the greensand must have been laid down on the bottom of the sea or some arm of it—perhaps an ancient Chesapeake Bay (Figure 3). The shell-forming animals lived on and in the bottom; when they died their shells remained, to be covered with more and more greensand.

The shore of this sea or bay lay somewhat to the west and north of Charles County, but possibly not very far away. Perhaps the high country in the western part of the District of Columbia and not far beyond Quantico was land at the time, and out from this land stretched a sea which covered all of Prince Georges, Charles, and the other counties nearby. Streams flowing from the land out to the sea brought down mud and sand which was washed around by waves and currents and in this way spread more or less evenly over the bottom. That is how "beds" or "layers" of sand or clay are formed. We know that the same sort of thing is going on today, though since it takes place under water, it is difficult to watch. For example, we are getting layers of the same sort (but without greensand) in the shallow waters of the Atlantic, just off from the Maryland shore. So there is nothing mysterious about the *way* the Charles County greensand was formed, but it is surprising to know that the county was once the sea bottom.

Layer after layer of greensand was deposited in this sea, until the total thickness was more than 200 feet. Then there was a change. The kind of material which was brought in and laid down was now mostly light-colored, so that where you see the two different kinds of material together there is a marked contrast. At (8), (13), (19), (29), (30), and (31) you can see the change from one kind of material to the other, called by geologists the "contact" between them. In all cases, the greensand lies below, being the older, and the lighter material above, where it was deposited later. The contact is often so sharp that it is only about the width of your finger.

Not only do the light-colored sands and clays differ in color, but they contain a different assortment of fossil shells. It is true that we can still recognize oysters and clams, but the types are slightly or greatly different from those in the greensand below. You can prove this fact for yourself if you make collections from some of the greensand localities and then compare these shells with those from the lighter-colored material above. Shells are not so common in the younger materials, but at locality (38) they are abundant, and you can easily get a large number to take home and study.

Other places are listed under the name "Miocene" on page 77; in most places the shell material itself has been dissolved away, leaving only a shape or impression.

Let us be sure that we have a clear picture before we go on. The shore of an ancient sea lay just to the west of Charles County, probably extending roughly through Baltimore, Washington, Alexandria, and Fredericksburg. To the east of this shoreline lay a bay or ocean. For a long time, rivers brought down sand and clay from the land to the west, and waves and currents spread it around over the bottom. In the earlier stages, this material was greensand, which grew to be more than 200 feet thick. Then over the top of this was spread a sheet of lighter-colored sands and clays containing a different group of shells. At the end of this time, then, Charles County lay beneath a body of shallow salt water; underneath the bottom of this water lay (below) the greensands, and on top of these more than 100 feet of the lighter material (Figure 3).

Then came a gradual movement which brought the bottom up to and above sea level, the waters retreating from the county (Figure 4). As the land was raised, it was also tilted to the east, so that the beds of greensand and lighter materials, which once were flat and horizontal, were now tilted down toward the east. Therefore, they now show up at the surface in Charles County but disappear underground to the east, under St. Marys County and under the present Bay.

The newly upraised sea-bottom was immediately attacked by streams, which began to erode the soft materials of which it was composed. They cut into it, destroyed the high parts, and brought all of it down to near the new sea level, making all of it flat like Cedar Point or Stump Neck. In this flat land the greensand showed in the west and the lighter sands in the east, just like shingles overlapping each other toward the east.

Then there was a marked change in conditions (Figure 5). Before, streams coming from the land to the west had carried only sands and clays. Now, they began to bring down pebbles and cobbles, mixed with sand and clay, and they spread a sheet of this material (often reddish in color) over the flat surface cut on top of the greensand and lighter sands. This sheet of pebbly material, ten to fifty feet or so thick, is like a veneer applied to the older materials. The upper surface of this veneer we call the Brandywine surface.

From this point in time, we return to the first part of our description. When the "veneer" was formed, Charles County was probably above, but quite close to sea level. The next step was uplift of the land and beginning of stream erosion on the Brandywine surface (Figure 5). Where the Brandywine pebbly layers have been stripped away, greensand and light-colored sands and clays appear; where it still remains, as north of La Plata, you see the original flat Brandywine surface, and the older layers are completely hidden. The greensand is more commonly seen in the western part of the county because, having been tilted down toward the east, it gets deeper and deeper underground in that direction. The lighter sands and clays occur just above it; they can be seen in many stream valleys and road-cuts in the central and eastern parts of the county.

One final word of warning: No human being was present to *see* the events described above. All of our knowledge comes from piecing together bits of evidence—like the kind of sand or gravel, or the kinds of fossil shells—and you can easily see that not every geologist would read the evidence in the same way. The history as outlined above is one possible interpretation, but it is not meant that you should take every detail of it as definitely proved.

Suggested Reading

If after reading this account, you are interested in finding out more about geology, you might try some of the books listed below. But you should be warned that most geology books are intended for college classes, to be used in connection with lectures, laboratory work, and field trips. You may have to dig deeply to understand them.

Some books treat only of the processes that act on and within the earth—such as erosion, deposition of materials to make rocks, volcanoes and earthquakes, and the formation of mountains. Of this group, the first is comparatively simple in its treatment; the third is the most complete, perhaps too complete and detailed for your needs.

Longwell, Knopf, and Flint: "Outlines of Physical Geology," 2nd edition. John Wiley and Sons, New York, 1941.

Longwell, Knopf, and Flint: "Textbook of Geology. Part I, Physical Geology," 2nd edition. John Wiley, New York, 1941.

Arthur Holmes: "Principles of Physical Geology." The Ronald Press Company, New York, 1945.

Other books treat only of earth history, the chief events being arranged in order from the oldest to the most recent. The first book is probably sufficient for your needs; the second is much fuller, but it may be so detailed as to be confusing.

Schuchert and Dunbar: "Outlines of Historical Geology," 4th edition. John Wiley and Sons, New York, 1941.

Schuchert and Dunbar: "Textbook of Geology. Part II, Historical Geology," 4th edition. John Wiley, New York, 1941.

Several books take up both the processes and earth history. These two are written in rather simple fashion.

Croneis and Krumbein: "Down to Earth." University of Chicago Press, Chicago, 1936.

Victor T. Allen: "This Earth of Ours." The Bruce Publishing Company, Milwaukee, 1939.

If none of these books is available, try your local library for anything they may have on geology or the history of the earth.

Figure 2 shows Charles County and the nearby region as you might see it from an airplane. The county boundaries are shown by dashed line; "LP" is La Plata, and the river flowing from the upper center, down the left margin, and into the foreground is the Potomac. The "roughness" of the landscape has been exaggerated a little to bring out the points made in our discussion.

This diagram (and the others which follow) shows more than just the landscape. The whole area has been, as it were, lifted up out of the earth so that you can see the various layers of sand, clay, and gravel that underlie the county. Different patterns of dots mark off different layers along the edges of the diagram. What these layers are, and how they were formed, is told you in the following diagrams, and in the text of the geologic history.

After you have gone through the other diagrams, and have read the text, return to this one. In that way, you will come to realize that any landscape, like that of the present Charles County, has perhaps had a long and complicated history. Indeed, the history of the county began many millions of years ago, and there were many different landscapes before the present one.

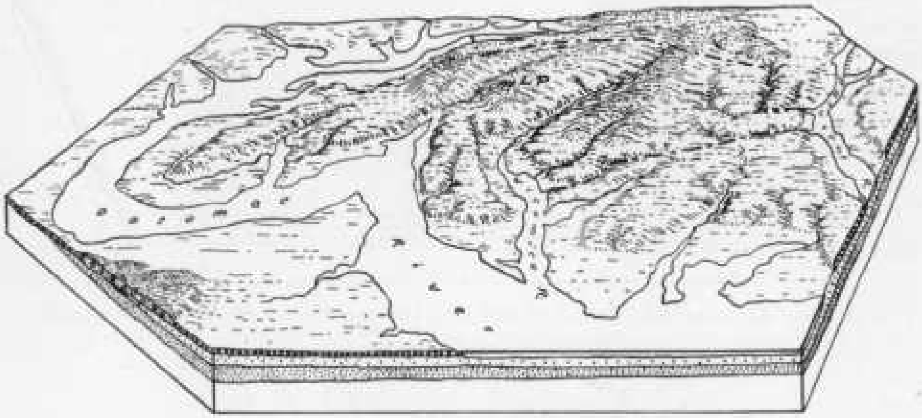


FIG. 2. Block Diagram Showing Recent Stage in the Physiographic Development of Charles County

Essentially, the surface of the county is made of several layers of gravel, lying at different elevations. Where erosion has cut through these gravels—chiefly along the Potomac and its tributaries—we see the older sands and clays which underlie the whole county, but which are hidden from sight over most of its area.

For a long time, (Fig. 3) Charles County lay beneath the salt water of a sea or large bay, with the shoreline not very far beyond the county, to the west and northwest.

Exactly where the shore was, we do not know. Perhaps there was a beach at one time, but if so it has long since been destroyed by erosion. And though the land shoreward from the beach must have changed greatly since the time shown in this diagram, we have a method of telling what this old land was like. We know that it must have been comparatively low and undergoing erosion by rather sluggish streams. For these streams did not being pebbles and cobbles down to their mouths, but only fine material like mud and sand. This material was dropped where the streams entered the sea, that is, at or near the shoreline, beyond which streams have no "carrying power." But at this point a new carrying agent comes into play: moving water, in the form of waves and currents, in the shallow sea itself. Waves and currents remove material as it is dropped by streams at their mouths, shift it about, rework it again and again, and finally spread it more or less evenly over the sea-bottom.

During this long time, the present county was covered by two layers of clay and sand—the Eocene greensand (closely spaced dots) and the Miocene lighter sands and clays (widely spaced dots)—which in turn were under a body of shallow salt water (above, without dots). Animals that lived on this sea-bottom left their shells to be buried and to be found today as fossils.

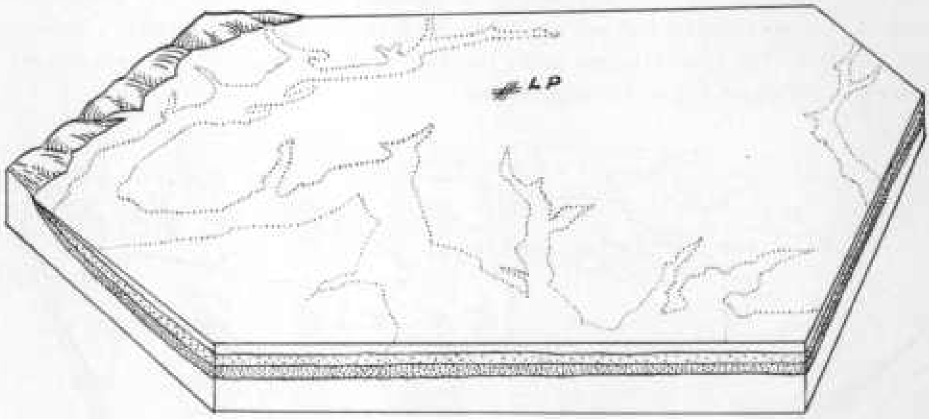


FIG. 3. Block Diagram Showing Late Miocene Sea Covering Present Site of Charles County

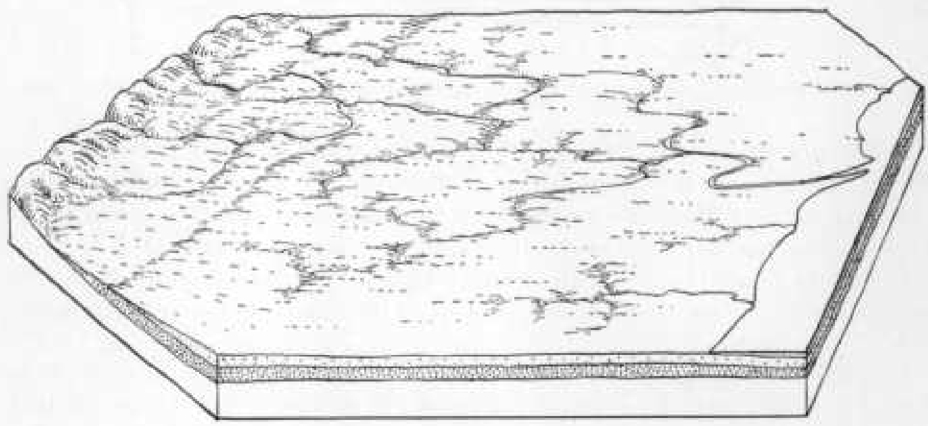


FIG. 4. Block Diagram Showing Early Pleistocene Stage in the Physiographic Development of Charles County.

The present-day relations of land and water are shown in dotted lines. To help you locate yourself, "LP" is La Plata.

After a long time under the sea of Figure 3, the county and the old land to the west and northwest rose slightly (Fig. 4). Just what brought this about we can't say, though we have evidence of such changes in elevation in many parts of the United States, at many different times in their history.

The cause of the land's rising is unknown, but its effects are clear. First, there was a slight tilting, so that previously flat and horizontal layers of clay and sand now tilt downward toward the east and southeast—the amount of tilt so slight that it cannot be shown on the diagram. Second, erosion began to act on the newly emerged land. This erosion was neither rapid nor deep, since the land was still at but a slight elevation above the sea, but it was sufficient to erode some of the Miocene layer and to

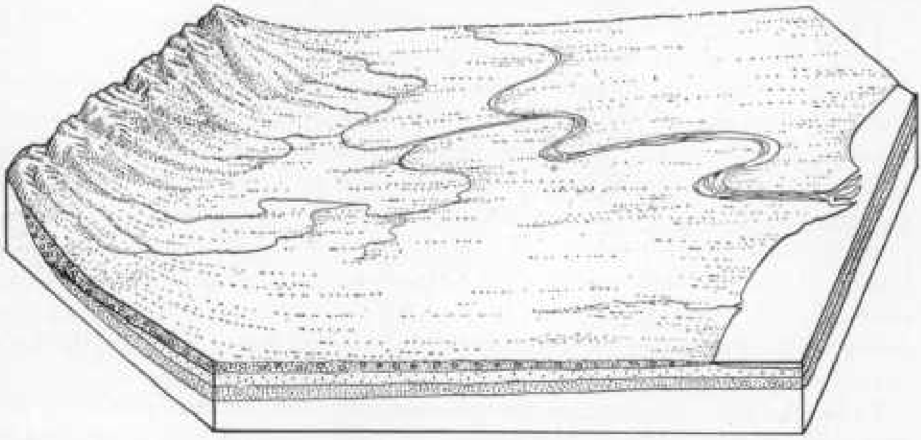


FIG. 5. Block Diagram Showing Brandywine Stage in the Physiographic Development of Charles County.

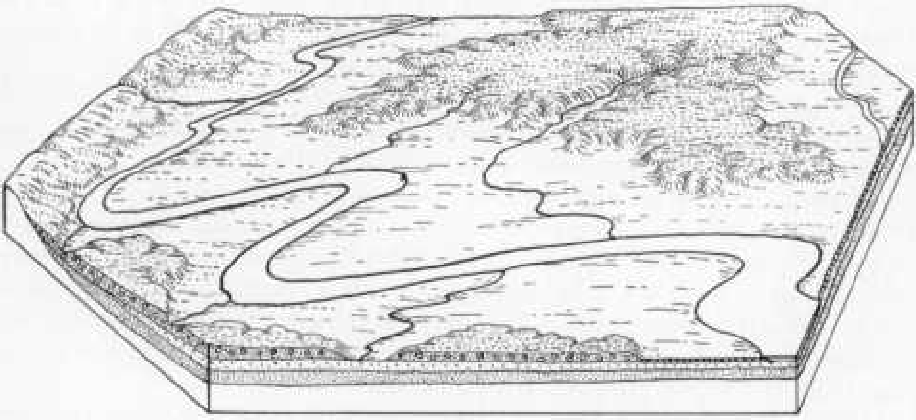


FIG. 6. Block Diagram Showing Late Pleistocene Stage of Development of Charles County

expose the Eocene greensand in the northwestern part of what is now Charles County. This is shown in the left front of the diagram, where you can see that the greensand now appears at the surface. And third, the sea was "pushed" back to the east and southeast, over what are now Calvert and St. Marys Counties. In these counties, layers of sand and clay continued to form, so that we have there younger layers, containing salt-water fossils, lying on top of our Miocene layer of Charles County. These younger layers are beautifully exposed in the Calvert Cliffs, along Chesapeake Bay.

Though erosion did not cut deeply, it went on for a long time, until the county was beveled and smoothed off to an almost flat surface, the surface on which our next deposits were laid down.

At the end of the erosion shown in Figure 4, the land was flat and low, and not very much was happening (Fig. 5). But this period of quiet was brought to a close by a fundamental change in conditions.

The old land to the north and west seems to have become "active." Instead of yielding only fine materials, it now became the source of pebbles and cobbles. Clearly, the streams that brought this coarse material must have been flowing rapidly; their beds must have been steep to give them enough speed. To have steep courses and rapid streams we must have rather considerable differences in elevations—the old land must have been newly elevated and "rejuvenated." Numerous newly-formed and swift streams began to cut into this high land, and to bring their coarse burdens to the low land that is now Charles County. At first they dumped much of their load near the borders of the old-land, but as time went on they gradually extended a sheet of pebbly material out across the low, flat plain. All parts of the plain were covered as the streams shifted their courses from time to time. The top of this layer of sand and gravel (small circles and dots) is the "Brandywine surface."

Two things about this diagram are rather unsure. First, the high part of the old-land might well have been farther beyond the county than is shown here, and its surface need not have been quite so high or rough. Second, whether or not there was a sea or other large body of water in the position shown (right margin) is a matter on which geologists do not agree. At least, we find no fossil shells in the gravels of Charles County, and the shoreline at the time of this diagram might well have been much farther to the east and southeast.

Some time after the Brandywine surface had been formed, (Fig. 6) the whole countryside was uplifted again, and erosion started anew. Most of the erosion was done by the ancestor of the present Potomac River, and its tributaries.

After cutting down for some distance—perhaps a hundred feet or so—the river eroded its bed so close to sea level that it stopped cutting down, and began to widen its valley. Wandering back and forth over this wide valley, it laid down a new and lower layer of gravel (heavy dots, right front and right side of diagram). Over much of the county this gravel lies on the Miocene sands and clays, but in the northwest it may lie on the greensand. The top of the gravel now makes much of the surface around Doncaster, McConchie, Faulkner, Dentsville, and Stilltown.

After the formation of this gravel, there came another uplift, the river cut down further, and again wandered back and forth for a while, forming one or more lower gravels. The lowest gravel (not shown in the diagram) forms the surface of the low necks, like Cedar Point neck. Finally, the last down-cutting of the river left these necks slightly above the river level, as shown in Figure 2.

In Figure 6, there is a sharp break from the top gravel to the level over which the river has been meandering. But as time went on, this steep slope was smoothed down by erosion, so that today (Figure 2) the break between the two levels of gravel is scarcely noticeable. But the steep slope up from the lowest gravel is still strongly marked, as at Brentland and at Wayside.

DETAILED GEOLOGY

BY

LINCOLN DRYDEN AND ROBERT M. OVERBECK

General Features

In this section the geology will be discussed in more detail and in less popular style than in the preceding section. The data on which the general conclusions are based will be presented, so that these conclusions can be evaluated and checked.

The detailed geology is given under two general heads—Surface Geology and Subsurface Geology, the first having to do with the rocks in surface exposures and the second with rocks obtained as samples from wells.

The geologic formations mentioned in this report have already been described systematically and in detail in reports issued by the Maryland Geological Survey (see Bibliography). Those who are interested in the general discussion of the formations and particularly of their paleontology should refer to those volumes.

Charles County lies within the Atlantic Coastal Plain and exhibits geologic features common to many other parts of that province. Several of the formations found within the county extend almost continuously across to the northeastern part of the State; and to the south and west, the Potomac River forms but a small break in their continuity from Charles County into Virginia.

In some respects the county differs in geologic character from the nearby counties —Prince Georges, Anne Arundel, Calvert, and St. Marys. The first two extend to and beyond the Fall Line, and in their northern and western parts they display a much more complete series of Cretaceous rocks than are found in Charles County. At least in surface exposures, Charles County is almost lacking in older rocks of the Coastal Plain. Calvert and St. Marys Counties lie to the east and southeast, and they in turn are almost completely lacking in exposures of the Eocene rocks, so well developed in Charles County. On the other hand, they have a much fuller development of the upper deposits of the Miocene, particularly the Choptank and St. Marys formations. These latter two counties also have but slight development of the topographically highest and oldest deposits of the Pleistocene series.

The following is a tabular arrangement of geologic formations found in Charles County:

Geologic Age	*Period*	*Formations*	*Members*
Pleistocene	—	Talbot	
	—	Wicomico	
	—	Sunderland	
	—	Brandywine	
Miocene	Middle	Choptank (?)	
	Middle	Calvert	
Eocene	Middle and Lower	Nanjemoy	Woodstock Potapaco
	Lower	Aquia	Paspotansa Piscataway

Geologic Age	*Period*	*Formations*	*Members*
Upper Cretaceous[1]		Monmouth (?)	
		Magothy (?)	
		Raritan (?)	
		Patapsco[1]	

Cretaceous System: Cretaceous rocks, although well exposed in the more northern counties of Maryland, are poorly exposed in Charles County. Exposures are confined to the northwest section of the county. The Cretaceous rocks are present, of course, in depth throughout the county, and have been penetrated by several of the deepest wells in the central part.

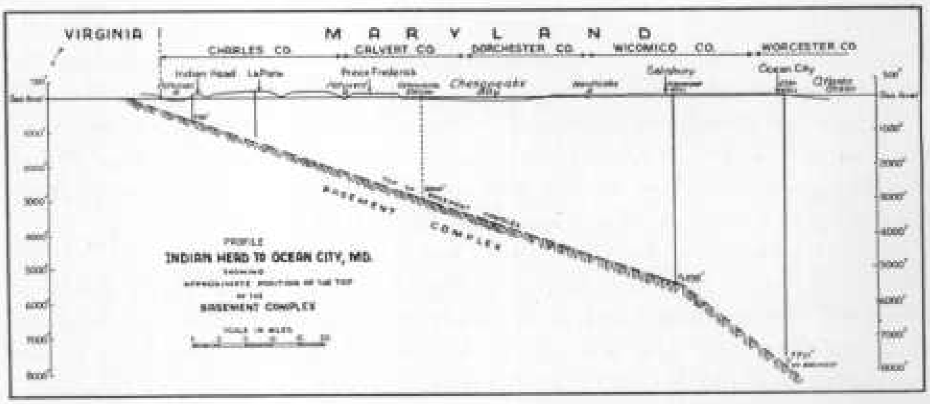


FIG. 7. Cross-Section Indian Head to Ocean City Showing Probable Position of the Top of the Basement Complex.

Eocene Series: The Eocene rocks are exposed in part along the Potomac River above and below Popes Creek. The lower part of the Aquia formation in contact with the Cretaceous rocks can be seen at Glymont. The best exposures of the Eocene rocks, however, are found along the Potomac River on the Virginia side at Aquia and Potomac Creeks.

Eocene rocks are present in all the well samples examined from the county.

Miocene Series: Miocene rocks are poorly represented in outcrop in Charles County, but are found in most of the deep wells. The Choptank formation is not known definitely to be present, although it probably occurs in wells in the Hughesville area. The Calvert formation has been recognized both in outcrop and in wells.

BASEMENT COMPLEX

The Basement complex is not exposed at the surface within the limits of the county. It has, however, been penetrated for nearly 500 feet by a well at Indian Head. Since this well was drilled many years ago, no samples from it are now available. The well driller's log describes the rocks as "hard green rock" and "hard red and gray rock."

[1] The Patapsco Formation is now considered to be Upper Creaceous in age. See Anderson, Judson L., Cretaceous and Tertiary Subsurface Geology. Department Geology, Mines and Water Resources, Bull. 2, 1948.

The profile drawn across the State, Fig. 7, gives one a general idea of the subsurface position of the Basement complex under the county.

The points used to sketch in the approximate top of the Basement complex are based on information from (1) well log data at Indian Head; (2) geophysical data from two stations in the Chesapeake Bay a little north of the mouth of the Patuxent River; (3) the core record from the Hammond oil test well near Salisbury, Wicomico County; (4) well cuttings from the Esso oil test well near Ocean City.

Although on the profile the surface of the Basement complex is shown as a straight line, this representation is only approximately true. The surface is more probably an undulating one. The average inclination of the plane is about 43 feet to the mile toward the southeast.

CRETACEOUS SYSTEM

SURFACE GEOLOGY

Upper Cretaceous—Patapsco formation:[2] The Patapsco formation outcrops only in the northwestern part of the county, in the vicinity of Glymont, Indian Head, and on Stump Neck. Only superficial examination of these deposits was made, and no persistent units were recognized. The variable nature of the formation is shown by the sections below, taken from the Lower Cretaceous Volume, Maryland Geological Survey, 1911, page 80.

Section at High Point, ½ to ¾ mile below Glymont:

Geologic Age		*Thickness in feet*
Pleistocene		
Talbot	Loam and gravel	15
Cretaceous		
Patapsco	Interbedded buff and more or less arkosic sand, loose and cross-bedded, with light drab clay, iron crusts at base	20
	Irregularly interbedded brown and light drab clay, grading down to brown sandy clay	7
	Brown sandy clay, with greenish-drab, chloritic, sandy clay at tide	55
	Total	97

Section on Stump Neck:

Geologic Age		*Thickness in Feet*
Pleistocene		
Talbot	Brown, gravelly loam	3
	Sand, gravel, and cobbles	12
Cretaceous		
Patapsco	Cross-bedded, compact sand, slightly arkosic	8
	Massive, green, chloritic clay to tide, with lenses of drab clay carrying leaf impressions	4
	Total	27

[2] See footnote, page 30.

A Lower Cretaceous age of some of these beds was suggested by fossil plants. At the Stump Neck locality, the position of the plants is clearly indicated, but below Glymont there is no mention of what bed or beds yielded fossils. This omission is important in that the upper part of this section belongs to the Upper Cretaceous, as discussed in connection with heavy minerals, below.

Upper Cretaceous—Raritan and Magothy formations: The presence of the Raritan and Magothy formations in Charles County has not been confirmed. In the Upper Cretaceous Volume of the Maryland Geological Survey, 1916, these two formations are mapped (Plate 1) as extending from Prince Georges County to the vicinity of Glymont. In the table of fossil occurrences (pp. 102–104), under the Raritan formation there is a locality called "Glymont"; from this locality (not described further) there is reported one fossil plant, which is found at a few other places in the Raritan of Maryland. On this evidence, the Raritan may be present at the surface in Charles County, but until the exact locality and horizon of the fossil plant are determined no further information can be given.

The occurrence of the Magothy formation in outcrop is supported only by the geologic map (Plate 1); it has not been recognized in the field work on which this report is based.

The possible presence of the Monmouth formation is suggested by the following. In the Lower Cretaceous Volume, p. 79, the section at Fort Washington, a few miles north of the Prince Georges County line, includes 20 feet of sandy material called "Matawan," of the Upper Cretaceous. Three fossils are listed as occurring in this horizon. In the Upper Cretaceous Volume, one of these fossils, *Cyprimeria densata*, is not listed; another, *Cucullaea vulgaris*, is said to occur in both the Matawan and Monmouth formations; and the third, *Crassatella vadosa*, is reported to occur only in the Monmouth formation. Further, on the geologic map and in the text (Plate 1, and pp. 66–67), the Matawan formation is said to extend southwestward only as far as the northern part of Prince Georges County. Presumably the material at Fort Washington should have been called Monmouth. The thickness of the formation here—20 feet—implies that it may extend over into Charles County. Heavy minerals suggest the presence of Upper Cretaceous rocks in the Maryland State Police well at Mattawoman.

Mechanical analysis: Four samples of the Cretaceous rocks from the wells at Spring Hill and La Plata have been analyzed mechanically. These samples were picked because of their coarse, sandy nature; this selection is therefore *not* intended to give an average or typical mechanical composition of the mostly fine-grained, clayey Cretaceous sediments. Three of these four samples have also been analyzed for heavy mineral content. These four selected samples range in composition from very coarse to very fine sand, with little or no finer-grained material. Except for Sample 2, sorting is poor (Table II).

Heavy minerals: Seven subsurface samples and one surface sample of the Cretaceous sediments from Charles County have been examined for heavy mineral content. From this small number no exact correlations can be expected; however, comparison of the local suites with those found in nearby parts of the Coastal Plain is suggestive. A summary of the results obtained with samples from New Jersey to Virginia follows.

Twenty-five samples—14 from the Patuxent formation, 5 from the Arundel formation, and 6 from the Patapsco formation—contain abundant staurolite, common kyanite, tourmaline, and zircon, and rare sillimanite and epidote. The grains are large, fresh, and angular. Garnet and chloritoid are conspicuous by their absence.

Eleven samples from the Raritan and Magothy formations show rather striking differences. The grains are small and worn, and the suites are much smaller than those of the underlying rocks, and in some samples there are almost no minerals except opaques. The composition is somewhat variable, but staurolite is the most persistent and abundant species. In addition, zircon, kyanite, and tourmaline may be present. There is practically no garnet, no sillimanite, and no chloritoid. One conspicuous exception is the marine Magothy formation from Cliffwood Beach, New Jersey, which has the composition of the marine Upper Cretaceous rocks described below.

TABLE II

Mechanical Analysis of Coarse-Grained Cretaceous Sediments

Sample No. and Percentage	Size in mm.					
	2	1	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{16}$
1	14	37	40	6	2	1
2		9	67	21	2	1
3	12	24	36	20	8	
4	8	13	35	32	12	

Sample 1: Southern Maryland Cleaners Well, Spring Hill; depth 460–462 feet.
Sample 2: Southern Maryland Cleaners Well, Spring Hill; depth 512–519 feet.
Sampel 3: La Plata town well; depth 600–610 feet.
Sample 4: La Plata town well; depth 630–640 feet.

The marine Upper Cretaceous rocks, beginning with the Matawan formation, contain heavy mineral suites different from either of the types described above. Heavy minerals are usually abundant, the grains appear to be fresh, and may be either angular or rounded. All of the species cited above as present are likewise present here, and in addition, garnet, sillimanite, and chloritoid are persistent. Epidote and hornblende are present in some samples.

The following samples from Charles County have been examined:

Surface exposure, N. of Glymont, locality (2)
La Plata town well; depths: 380–390 and 600–610
Southern Maryland Cleaners well, Spring Hill; depths: 420–430, 460–462, and 512–519
Sullivan well, Nanjemoy; depths: 41–55 and 189–210
Maryland State Police well, Mattawoman; depth: 410–420

All these samples, except the last one, agree in heavy mineral character with the Raritan and Magothy formations. Crops are very small, grain-size is small, and the individual grains are worn and rounded. Two of the samples contain little or nothing except opaques; four have nothing but zircon; and two contain zircon and staurolite. This agreement is remarkable in the case of the sample from north of Glymont, which is supposedly from Lower Cretaceous rocks.

The last sample, at Mattawoman, has a considerably larger percentage of transparent grains. It contains significant quantities of zircon, tourmaline, staurolite, garnet, and chloritoid, with smaller amounts of kyanite, sillimanite, and epidote. This suite suggests correlation with the marine Upper Cretaceous or younger beds. Differentiation of the marine Upper Cretaceous from Eocene or Miocene deposits may be possible, but at the present stage of heavy mineral work it has not been clearly demonstrated.

SUBSURFACE GEOLOGY

General statement: In the section on Surface Geology it was stated that exposures of Cretaceous rocks were limited in number, and were generally unsatisfactory for study and age determination. Four wells in the county from which samples were obtained were drilled definitely into Cretaceous rocks and one into probable Cretaceous rocks. The Indian Head Naval Powder Plant wells are all drilled into Cretaceous rocks, and at least one of them was drilled through the Cretaceous rocks into the Basement complex. Indian Head wells were completed a long time ago and samples from them are no longer available. The La Plata well, which was drilled to a depth of 1094 feet, passed through a little more than 700 feet of Cretaceous rocks. A complete suite of samples from this well was, however, not obtained. One well at Piscataway in Prince Georges County not far from the Charles County line definitely reached marine Upper Cretaceous beds.

The contact between the non-marine Cretaceous rocks and the Eocene Aquia rocks above them is easily recognized in the water well samples. Lithologically the rock is sandy clay or argillaceous sand both above and below the contact. The Aquia, however, is characterized by the presence of much glauconite and of marine organic remains, such as shell fragments and foraminiferal tests, and its color is weak olive or olive-gray. The Cretaceous cuttings, on the other hand, show no glauconite or organic remains, and the dominant colors are brown, yellow, and red. The few sand beds found in the Cretaceous section are arkosic and carry noticeable amounts of gray ("blue") quartz. Carbonaceous and lignitic materials are abundant in some samples. The separation between the Eocene rocks and the underlying marine Upper Cretaceous (Monmouth) rocks can be made definitely only if foraminifera are present in the samples to indicate Cretaceous age. In the Kierstead well in Prince Georges County, Cretaceous foraminifera are found in rocks that could be mistaken lithologically for Eocene rocks.

Distribution: Cretaceous rocks are found in the Kierstead well (Prince Georges County), Maryland State Police well, La Plata Town well, Southern Maryland Cleaners well, I. & P. Company well, and in the Sullivan well in the southwestern part of the county. The Indian Head wells all start in Cretaceous rocks.

Lithology: Only pertinent comments on the lithology will be made here since a rather complete description of the samples is given later.

No samples were obtained from the Indian Head wells, but drillers logs show the rock to be chiefly sandy clay—blue, gray, green, red, and brown in color. One well shows a total of only 69 feet of sand in 741 feet of rock; the rest of the material is clay or sandy clay.

In the La Plata Town well it was necessary to drill to 1094 feet (over 700 feet of this in the Cretaceous) before a sand sufficiently pervious to carry water was found. The samples from this well are clay or sandy clay of brownish, yellowish-brown, or yellowish-orange color; the little sand found is arkosic and chiefly of fine grain. The complete absence of marine fossils and the generally rather bright coloration of the rocks (iron oxides and hydroxides) suggest non-marine deposition.

The Sullivan well was started in the Eocene Aquia formation about 41 feet above its contact with the Cretaceous. The base of the Eocene series in this well is marked by a little gravel followed in depth by brown clay. Cretaceous rocks were penetrated 154 feet before a water sand was found. The well cuttings show sandy clay and argillaceous sand, light brown and light yellowish-brown in color. The sand portions are arkosic, and carry commonly gray ("blue") quartz.

The Southern Maryland Cleaners well went through 222 feet of Cretaceous rocks before finding a water-bearing sand. Samples were obtained of only the upper half of the Cretaceous rocks cut in this well. The well penetrated chiefly brownish and yellowish-brown clay. The little sand found is arkosic.

The I. & P. Company well went into Cretaceous rocks only about 25 feet before finding a water-bearing sand. The sand is arkosic and carries "blue" quartz. A moderate yellowish-brown clay lies above the sand.

The Maryland State Police well went about 20 feet into what are probably marine Cretaceous rocks. Below this lay 18 feet of arkosic sand containing "blue" quartz. These supposed marine Cretaceous rocks are lithologically similar to exposed sections of known marine Upper Cretaceous rocks, and to known Upper Cretaceous rocks in the Kierstead well. A heavy mineral separation of this material showed significant quantities of zircon, tourmaline, staurolite, garnet, and chloritoid, with smaller amounts of kyanite, sillimanite, and epidote. The suite suggests correlation with marine Upper Cretaceous or younger beds, although definite separation by heavy minerals of the Upper Cretaceous rocks from the Eocene rocks is not yet possible.

In the Kierstead well the marine Upper Cretaceous rocks are represented by dark glauconitic micaceous sandy clay which has a thickness of about 38 feet. Under this are pink clay and streaks of lignite, and arkosic sand containing "blue" quartz.

Organisms and Age: No shells or the remains of microscopic animal organisms were found in any of the Cretaceous well samples except in those from the Kierstead well in Prince Georges County. Lignite, however, is rather abundant at places. In the Kierstead well at elevation −78 feet, foraminifera occur that are unlike those found in the Eocene Aquia formation, but are like those found in nearby outcrops of Upper Cretaceous Monmouth rocks at Friendly in Prince Georges County.[3] The foraminifera, then, determine the age of the rocks in the samples in the Kierstead well from elevation −78 to −116 feet to be Upper Cretaceous, probably Monmouth in age. Lithologically similar cuttings are found in the Maryland State Police well from elevation −195 to −225 feet. No fossils, however, were obtained from the State Police well.

[3] Shifflett, Elaine. Eocene Stratigraphy and Forminifera of the Aquia Formation. Maryland Department of Geology, Mines and Water Resources, Bull. 3, p. 6, 1948.

Just under the marine beds in the Kierstead well at elevation −116 feet, an abundance of lignite was found associated with pink clay and gravel. An abundance of lignite was found also in a well at Pomonkey, a town in Charles County a few miles southwest of the Kierstead well. The Magothy formation of Upper Cretaceous age and the Patapsco formation are both characterized by lignite. These samples possibly indicate the presence of Magothy beds as surface work in the adjacent Prince Georges County shows Magothy underlying Monmouth at Friendly. Near Glymont, however, the Aquia is said to be resting on the Patapsco (see p. 31) although without supporting evidence.

Thickness: No definite data on the thickness of the Cretaceous rocks are available for the central and eastern part of the county. A very rough approximation can be made, however, because the depth to the Basement complex is known to be about 3000 feet under the Chesapeake Bay near the mouth of the Patuxent River. (See Figure 7.) By connecting this station with a point in well 15 at Indian Head which is known to be the top of the Basement there at an elevation of about −700 feet, we arrive at the average slope of the top of the Basement under Charles County. Figure 7 shows that at La Plata the thickness of the Cretaceous rocks is about 1100 feet and at the eastern edge of the county at the Patuxent river about 1800 feet. At Indian Head a thickness of about 741 feet was penetrated, but it is estimated that 30 to 50 feet of Cretaceous rocks have been eroded at the place well 15 was drilled.

The Upper Cretaceous Monmouth (?) formation is about 38 feet thick in the Kierstead well, and about 30 feet thick (if correctly identified) in the Maryland State Police well.

As stated above, heavy minerals suggest the presence of Magothy and Raritan formations in the La Plata, Southern Maryland Cleaners, and Sullivan wells. No estimate, however, can be made of the thickness of the individual formations.

Structure: The contour map (Plate I), depicts the contact surface between Eocene and Cretaceous rocks. The strikes and dips of this surface are not necessarily, however, the strikes and dips of the beds or formations that make up the Cretaceous. Other surfaces of unconformity within the Cretaceous may likewise be different from that shown on the map. The study of heavy mineral distribution may give a means whereby the non-marine formations of Upper and of Lower Cretaceous age can be differentiated by well cuttings. By this method it would be possible to draw contours on the surfaces between the marine Cretaceous formations. Because of the lenticularity and discontinuity of the lithologic units within the non-marine formations, it is doubtful that satisfactory contour maps will ever be made of them.

The contours of the map of Plate I represent the surface at the bottom of the Aquia formation. The Cretaceous rocks underlying this surface are of different age in different parts of the county. In the north the underlying rocks are probably Monmouth in age, and in the southwestern part, Patapsco in age.

The map shows the general overall strike of the contact plane within the county to be about N 35° E. There is a westward bulge of the contours in the central part of the county.

The most significant feature of the map is the marked flattening of dip near the east border of the county. To the west of the line of change the average dip is about 20 feet to the mile, and to the east about 6 feet to the mile to the southeastward.

TERTIARY SYSTEM

EOCENE SERIES—SURFACE GEOLOGY

General Features: After the deposition of the Cretaceous formations the Maryland area was emergent for a long time. Probably the land did not stand high for there was no extensive destruction of Cretaceous deposits, but at least in the area of outcrop within the county there is no sedimentary representation of Paleocene (Midway) time. (See p. 45.)

During a considerable part of Eocene (Wilcox and Claiborne) time the Maryland region lay beneath shallow seas, in which the Aquia and Nanjemoy formations were deposited. Perhaps these seas were inconstant, extending for a while to or near the Fall Line, then retreating eastward to some as yet undetermined shoreline. The Aquia formation may represent a deposit laid down more or less continuously, but the overlying Eocene beds probably show several retreats of the sea (Cooke et al., 1945, Chart No. 12). Similar deposits extend northward into New Jersey, although the actual connection of the rocks of the two areas is now hidden; to the south, the Maryland Eocene extends without break at least as far as Virginia. (See p. 30.)

The greatest shoreward extent of the Eocene seas is a matter of speculation. In Prince Georges County, rocks of this age have been mapped almost as far inland as the District of Columbia line. Near the base of the formation, pebble layers may indicate near-shore conditions (Miller, 1911, p. 101), but in general the Eocene series retains its typical lithology throughout the area of outcrop. Whether it once extended onto or over the Piedmont cannot be decided, but a previously greater extent is considered likely. Pre-Miocene erosion may be responsible for the destruction of such deposits. At present, the Eocene series is overlapped by the Miocene Calvert formation, this relationship being particularly clear in Virginia, where at places the Calvert formation lies directly on rocks of Cretaceous age or even on the crystalline rocks of the Piedmont (Clark and Miller, 1912, p. 126).

The sediments deposited in the shallow Eocene seas have a rather remarkable uniformity. Sands, sandy clays, and argillaceous sands—often containing fossils—make up almost the entire thickness; glauconite, usually in considerable amount, is an invariable constituent. Only one bed, the clay (Marlboro clay member) at the base of the Nanjemoy formation, shows a conspicuously different composition. In Charles County the presence of glauconite is an almost infallible criterion for recognition of Eocene deposits.

The thickness of Eocene rocks in the county is about 250 to 300 feet. The beds dip slightly to the east and southeast, being exposed chiefly in the west and northwest parts of the county; in the central and eastern portions they are encountered in deeper and deeper wells. At Salisbury, on the Eastern Shore, Eocene rocks, but of Jackson age, are almost 1200 feet underground.

Eocene rocks outcrop chiefly in bluffs along the Potomac River and in the valley walls of several tributaries. They nowhere form any considerable part of the surface, and they have but little influence on the topography of the county.

Aquia formation

Lower boundary: The base of the Aquia formation is exposed at only one locality in the county, in the bluff above Glymont (2). At this place the Eocene lies unconformably on Upper Cretaceous Patapsco rocks although only a few miles away, at Fort Washington in Prince Georges County, the upper 20 feet of Cretaceous rocks are considered to be Matawan[4] in age (Clark, et al., 1911, p. 79). In well P. 1548 (Sullivan), near Liverpool Point, the contact lies only 12 feet below tide, so that the Cretaceous-Eocene boundary follows approximately the course of the Potomac River along the northwestern border of the county. The basal Eocene beds are exposed in the low bluff on the Potomac about 50 yards west of the Sullivan well. About 5 feet of a very heavy shell bed carrying *Turritella mortoni* is present. The shells are soft and much decomposed. Under this is a dark, micaceous, glauconitic sandy clay, containing scattered fossil shells. Sullivan well samples show a dusky yellow-green glauconitic sandy clay followed in depth by a six-foot bed of gravel and shell fragments. Under the gravel is 4 feet of moderate yellowish-brown clay and then 10 feet of weak yellow, somewhat argillaceous arkosic sand. The gravel and shell bed is believed to be basal Eocene because of the sharp lithologic change in the material under it; particularly the absence of glauconite, and the presence of arkosic sand carrying "blue quartz." That this contact is not exposed northward is doubtless due to concealment by low-lying river terraces.

Distribution: The area of outcrop of the Aquia formation has not been precisely determined. As stated above, its base is visible in outcrop at only one place. Its upper limit is marked by the bottom of the pink clay bed (Marlboro clay member) of the Nanjemoy formation. This clay is exposed at several places outside the county,[5] and is clearly recognized in well samples from many parts of the county. But surprisingly, it has not been possible to identify this clay in outcrop, and although its approximate position is known, no exact boundary between the Aquia and Nanjemoy can be mapped on the surface. For that reason, on the geologic map of the county the Eocene series is mapped as a single unit (but see corrections to the map, p. 13).

The Aquia formation is exposed at numerous places along the Potomac from about a mile above Liverpool Point to near Smith Point (Clifton Beach). Indurated layers containing *Turritella mortoni* are well developed; these beds are probably to be correlated with similar indurated layers at Aquia Creek, Virginia, a few miles to the southwest. Inland, the Eocene-Miocene contact is found near Hilltop (12) and near Pomonkey (7) (8); presumably this contact lies above the Nanjemoy formation, so that the Aquia-Nanjemoy boundary should outcrop in about the westernmost one-quarter of the county. But since the Marlboro clay member of the Nanjemoy formation has not been found, and since the inland exposures are usually small and unfossiliferous, no more exact delimitation of the Aquia formation distribution is possible at this time.

Well logs from the central and eastern parts of the county show that Aquia rocks are present underground; its top lies at a depth of about 200 feet below La Plata

[4] Probably should be Monmouth (see p. 32).

[5] Darton, N. H., The Marlboro Clay. Econ. Geol., vol. 43, pp. 154–155, 1948.

and 440 feet below Hughesville. The only well log recorded from the western part of Charles County (Sullivan well) begins near the base of the Aquia formation and passes into Cretaceous rocks.

Lithology and Thickness: The Aquia formation consists essentially of unconsolidated materials ranging in size from sand to silt and clay. In no case is there very good sorting; beds of "pure" sand are lacking, and the same is true for beds made dominantly of silt or clay sizes. In all cases, there seems to be a considerable admixture of several size fractions, but at some localities or horizons the materials appear to be more sandy, at others to consist largely of fine sand sizes and smaller. From the viewpoint of grain size and sorting, there seem to be no distinctive beds within the Aquia formation. A typical mechanical analysis is given as sample No. 1, on p. 43.

Glauconite is an almost invariable constituent of the Aquia rocks. The grains of this mineral are generally irregular in shape or commonly are botryoidal; color ranges from dark to light green, with a larger proportion of olive and light green grains than in the Nanjemoy rocks. Red glauconite is found in some samples. In a number of well samples from near the base, the materials are a dusky yellowish-green.

On exposure and weathering, the typical "greensand color" of the Aquia may change to lighter hues. Sometimes almost all traces of green disappear, and the materials take on the usual brown and yellow colors of iron compounds. Usually, however, there is some trace of green, which may be bleached to a yellowish tinge. In this case the exposure may be a "dirt-brown" with a greenish and yellowish hue. The yellow color is often segregated in roundish patches a few inches or a foot or so across, giving a spotted appearance to the outcrop. Inspection of such material with a hand lens usually reveals a few grains of glauconite. Yellowish or whitish grains with the botryoidal shape of glauconite may be a stage in the alteration of this mineral (Gildersleeve, 1932, p. 101).

Quartz grains make up a variable but large percentage of the Aquia. More than half of these are clear and transparent; the rest may be translucent or "milky." Yellow staining is fairly common in some samples, and there are more yellow grains than in the Nanjemoy formation.

Surface exposures of the Aquia formation are inadequate for measuring its thickness. The greatest thickness measured at any one locality is in the bluff near Glymont (2), where 45 feet at the base of the formation are exposed. Calculations of the thickness, based on surface mapping, are likewise unreliable; it is seldom possible to correlate small, isolated exposures, and the dip and strike of the formation cannot be assumed to have constant values. Several wells (see p. 49) pass through the Aquia formation and give reliable figures of thickness.

Subdivisions and Paleontology: In the Eocene volume of the Maryland Geological Survey (Clark and Martin, 1901, pp. 58-64) the Aquia formation has been divided into two members, and these in turn into nine "zones." Faunal lists are given, together with lists of species restricted to each of the members and to the formation as a whole.

The units so delimited can probably be recognized in the area adjacent to the Potomac River, where they were established and named. Inland, much poorer exposures and leaching out of fossils make recognition difficult or impossible, so that for the most part the subdivisions of the formation are known only at the type sections or nearby. A restudy of the Aquia and Nanjemoy fossils is needed.

Upper boundary: The Aquia-Nanjemoy contact is marked by an abrupt change in lithology, from greensand to the "Marlboro" or "Potapaco" clay. At Upper Marlboro, Prince Georges County, there are no evident signs of erosional unconformity. However, correlation of the fossils of the clay seems to show a lost interval between the Aquia and Nanjemoy formations. (Cooke et al., 1943, Chart No. 12). This indicates a probable retreat of the sea after deposition of the Aquia rocks, and a readvance at the beginning of Nanjemoy time. How much of the Aquia formation was eroded during that interval is not known.

Nanjemoy formation

Lower boundary: The most distinctive lithologic unit in the Eocene of Maryland is the "pink" or light brown clay which lies at the base of the Nanjemoy formation. This bed is most clearly exposed near Upper Marlboro, in Prince Georges County, where it lies on the Aquia greensands and is known as the Marlboro clay member of the Nanjemoy formation. But although it has been known from a few other localities, and its approximate area of outcrop can be calculated, it has not been found at the surface in Charles County. Until a few years ago, its presence in the county was doubtful, being suggested only on verbal accounts of well drillers and from a few doubtful well logs.

Within the last few years, with more careful supervision of well drilling and sample collection, the presence of the clay has been definitely established. Indeed, it seems to be everywhere present except in the western part of the county, where it has been removed by Pleistocene or pre-Pleistocene erosion.

The clay marks a sharp change in lithology from the argillaceous greensands of the Aquia to a pinkish or brownish material that seems to be all of silt or clay size. As mentioned previously, the contact between the Aquia rocks and the Marlboro clay is thought to be an unconformable one.

Environmental conditions during deposition of the clay are at present almost unknown. However, that they were uniform over a wide area is shown by the great extent of this comparatively thin bed (maximum about 25 feet), for it probably extends over much of southern Maryland. Whatever these conditions were, they were different from those of the beds above and below, for the clay, unlike the rest of the Eocene, contains no glauconite.

Distribution: From well logs, it is known that the Nanjemoy formation is present underground in central and eastern Charles County, its top being about 75 feet below the surface at La Plata and 200 feet at Hughesville. A short distance west of La Plata, in the valley of Port Tobacco Creek, Nanjemoy rocks are found at the surface; the southeasternmost outcrop is in the vicinity of Popes Creek. West of Port Tobacco Creek and Popes Creek, the formation outcrops at numerous places.

At most of the western localities, the Eocene greensands are overlain by light-colored, non-glauconitic sands and clays of the Miocene series. In such cases, the greensands below are assumed to belong to the Nanjemoy formation. This assumption is based largely on negative evidence: on lack of any proof that the Miocene rocks overlap the Nanjemoy rocks and lie directly on the older Aquia formation. That this assumption is possibly incorrect is suggested by a section along the new road to Indian Head, 2.1 miles southwest of Bryans Road post office, at an estimated elevation of about 150 feet; Miocene sands and clays exposed here are the most northwesterly known in the county. The section at Glymont (2) nearby shows the base of the Aquia formation at an elevation of about 20 feet; taking the thickness of the Aquia formation at 140 feet and allowing for a slight eastward dip, there can be but a small vertical interval occupied by the Nanjemoy rocks, known elsewhere to be at least 100 feet thick. Either the Nanjemoy is absent, or it is thinner than in wells drilled in the central part of the county.

Since most of the critical exposures are small and have apparently been leached of their fossil content, solution of the problem of Nanjemoy formation distribution will have to await either recognition of the basal clay at the surface or carefully supervised drilling of wells in the western part of the county. Analysis of micro-fossils in well samples is regarded as the most promising line of attack.

In summary, the Nanjemoy formation seems to be present in full thickness in the central part of the county; at Popes Creek, for example, the Miocene series lie unconformably on the highest beds of the formation. To the west, the base of the Nanjemoy formation has not been recognized, and its extent in that direction is largely unknown.

Lithology and Thickness: In outcrop, Nanjemoy sediments are almost indistinguishable from those of the Aquia sediments. Both contain glauconite and mica; both are mixtures of medium or fine sand with silt or clay fractions. Weathering is similar, with change from a typical greensand color to yellows and browns.

In well samples, the Nanjemoy is seen to be somewhat finer-grained than the more sandy beds of the Aquia. Most of the quartz grains are clear, without staining, and the glauconite grains are more commonly botryoidal and dark green in color. Hydrologic data indicate the absence of any very persistent beds of sand. Mechanical and heavy mineral analyses are given on a later page.

The basal clay (Marlboro clay) is distinct in lithology and appearance from any other bed of the Eocene series. Though it has not been analyzed mechanically, throughout its total thickness of 10 to 30 feet it looks and feels like a "pure" clay. In outcrop, as at Upper Marlboro, it is a pink-brown, and it has been known as the "pink clay." In well samples, it is typically light or pale brown in color. Glauconite seems to be completely lacking; macro-fossils are scarce, or lacking.

The distinctive appearance of this clay makes it all the more remarkable that nowhere in the county has it been recognized at the surface. There are at least three possibilities why this should be the case. First, some of the beds near the base of the Miocene series, especially when they are wet, have an appearance not unlike that of the Marlboro clay; the two may have been confused in small exposures. Second, some of the Pleistocene terrace beds include local beds of clay; these are ordinarily pink or red in color, and the chances of mistake are obvious. Third, the clay, on prolonged exposure, may weather and so change its appearance as to be unrecognizable; new, artificial exposures may show its presence in areas where it has not yet been found.

No more than about 25 feet of Nanjemoy greensands are well exposed at any one locality in the county. This fact, together with a lack of information as to the base of the formation makes it impossible to determine its thickness from surface studies. A number of wells pass through the formation, its upper and lower limits clearly marked by abrupt changes in lithology. The maximum thickness shown in wells is 233 feet at Hughesville; the minimum is 115 feet at Waldorf; and there is an average of about 170 feet in the southeastern part of the county. Whether these differences in thickness are to be ascribed to original deposition or to subsequent erosion has not yet been determined.

Subdivisions and Paleontology: The Nanjemoy formation has been divided into two main members, and these in turn into a total of eight "zones" (Clark and Martin, 1901, pp. 64–72). As in the case of the Aquia formation, these subdivisions have not been recognized inland, away from the localities for which they were established. It is believed that a restudy of the Nanjemoy micro-fossils may permit tracing of small units by means of well samples.

Upper boundary: The top of the Nanjemoy formation can be easily recognized both on the surface and in subsurface samples. In some of the low bluffs along the Potomac the formation is overlain directly by Pleistocene rocks; in this case there is a marked change from greensands below to brown or reddish sands and clays and pebble beds of the Pleistocene series. The overlying materials contain no glauconite, are usually coarser in grain, and show much greater variation in the kinds and sizes of constituent particles, so that there is seldom any uniformity through more than a few feet of thickness. The underlying greensands are seldom coarse, and almost never contain pebbles.

Elsewhere, the Nanjemoy formation is overlain by the Calvert formation of the Miocene series. In this case the lithologic change is perhaps less striking, though just as distinct. The most diagnostic change is from glauconitic materials below to non-glauconitic sands or clays above; this change is reflected in the color difference, the Miocene rocks above always being whitish or light tan or gray, the Nanjemoy rocks a typical green when fresh and a yellow or brownish-green when weathered. In addition, the Nanjemoy rocks contain an appreciable amount of muscovitic mica, the Miocene rocks, little or none. In most wells and in a few exposures the diatomite of the Calvert formation is present; in this case the top of the Nanjemoy formation is to be expected some 10 or 20 feet below this bed.

In Charles County, no large scale features of erosion can be seen at the Eocene-Miocene contact. At some localities there are small irregularities and "waves" a few inches in amplitude; at others, irregular and tube-like penetrations into the Eocene rocks suggest the action of burrowing animals. In neither case is there any indication of the long lost interval marked in other areas by deposition of Oligocene sediments. However, in the large exposure near Orth, Anne Arundel County, in an exposed length of about 180 feet, the Eocene rocks (presumably the Nanjemoy formation) are truncated to the extent of about 6 feet of stratigraphic thickness by the Eocene-Miocene contact. This remarkably large difference in dip of the two formations may be only a local feature, but it is to be expected that the Eocene and Miocene beds differ slightly in the amount and perhaps in the direction of dip.

Mechanical composition: Four samples of Eocene rocks, one from the Aquia formation and three from the Nanjemoy formation have been analyzed; the results are given in the table below. As in the case of the samples from other stratigraphic units, no special precautions were taken to disaggregate the materials thoroughly; usually the coarser fractions contain a considerable proportion of aggregates, made commonly of grains of fine sand held together by material of silt or clay size.

TABLE III

Mechanical Analyses of Eocene Sediments

Sample No. and percentage	Size in mm.					
	2	1	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{16}$
1	2	3	11	62	17	5
2	1	5	20	48	16	10
3	1	4	7	11	51	26
4	4	6	10	28	41	11

Sample 1: Locality (2) near Glymont, about 3 feet above the Cretaceous contact. Two coarsest fractions largely aggregates; $\frac{1}{4}$ mm sieve: about 60 per cent glauconite; quartz grains rounded to well-rounded; $\frac{1}{8}$ mm sieve: 85 per cent quartz grains, somewhat rounded by solution (?).

Sample 2: Just under Miocene contact at locality (7) near Pomonkey. Similar to sample 1 except that quartz grains on $\frac{1}{4}$ mm sieve mostly angular.

Sample 3: Near Miocene contact at Mill Run, locality (13). On $\frac{1}{4}$ mm sieve about 75 per cent are aggregates or light-colored grains which may be weathered glauconite; considerable mica throughout.

Sample 4: Near Miocene contact, Popes Creek, locality (30). Aggregates on 1 mm sieve consist of small quartz grains, mica flakes and light brown or gray matrix. Quartz grains on most sieves show pitting and rounding by solution (?). On $\frac{1}{4}$ mm sieve about 60 per cent quartz grains, 40 per cent glauconite with smooth, rounded shape.

The following remarks apply in general to all samples. Quartz grains: no fine pitting or frosting; all except finest sizes have broad, smooth, shallow depressions and pits suggesting solution. Aggregates: two largest fractions consist largely of aggregates made of quartz grains, glauconite grains, mica flakes, and fine matrix; may be confused with light-colored grains which are not aggregates. Glauconite: the greenness of the sample is an indication of the amount present; usually botryoidal or mammillary in shape; size different in different samples; may give rise to "light-colored grains" by weathering.

Heavy minerals:

TABLE IV

Heavy Mineral Suites of Eocene Sediments

Sample No.	Zircon	Staurolite	Garnet	Rutile	Epidote	Tourmaline	Kyanite	Chloritoid	Sillimanite
1	28	18	25	7	13	3	3	3	0
2	14	42	8	4	7	8	8	3	5
3	42	20	2	8	16	4	3	3	0
4	34	33	2	13	6	6	2	4	1

The sample numbers refer to the same samples as those used for mechanical analysis.

Samples from Charles County and nearby areas show that the Eocene sediments differ radically in heavy mineral composition from Lower Cretaceous or Upper Cretaceous non-marine rocks. Differences between the Eocene rocks and the overlying Miocene rocks are less striking; average compositions have been given elsewhere (Dryden, 1932). In neither case, however, is this differentiation of great use. Both the Cretaceous rocks and the Miocene rocks can be easily distinguished from the Eocene rocks on other criteria, particularly by the presence or absence of glauconite; this is the case both in surface exposures and in well samples.

The presence of marine Upper Cretaceous rocks in Charles County has not been proved, although the lithology and heavy mineral content of one sampled interval in the State Police well at Mattawoman suggest correlation with these rocks. In areas outside Charles County, differentiation of the Eocene sediments from marine (often glauconite-bearing) Upper Cretaceous rocks is at present not well established by heavy mineral analysis. Further investigation may show that these rocks have different percentage compositions or that they contain different varieties of the common heavy mineral species.

EOCENE SERIES—SUBSURFACE GEOLOGY

General statement: The surface exposures of the Eocene rocks having been described above, we shall now see what a study of the water-well cuttings can add to our knowledge of their distribution and character. The Eocene series will be discussed under the formational headings, Aquia and Nanjemoy.

The collections of well cuttings give excellent well sections of the Eocene rocks, particularly those of the Nanjemoy formation, at widely separated places in the eastern part of the county where surface exposures are not possible; and enable us to determine the thickness of the formations, their strike and dip, and their lithologic character.

The generalized Maryland section of the Eocene series is:

	Eocene Series
Pamunkey Group	Nanjemoy Formation
	Woodstock member (Zones 16–17)
	Potapaco member (Zones 10–15)
	Aquia Formation
	Paspotansa member (Zones 8–9)
	Piscataway member (Zones 1–7)

Correlation of the Maryland section with the Standard American section is.

Eocene—Standard	*Eocene—Charles County*
Jackson—Upper Eocene	Absent
Claiborne—Middle Eocene	Woodstock member of Nanjemoy formation
Wilcox—Lower Eocene	Potapaco member of Nanjemoy formation
Wilcox—Lower Eocene	Aquia Formation

The study of well cuttings and core samples from Coastal Plain water wells and oil test wells is giving a very different picture of the occurrence of the Eocene series in the state from that given from surface exposures alone. In Charles County the Eocene series is about as indicated by the surface exposures, and it rests normally on the Cretaceous. In Prince Georges County, and possibly in eastern Charles County, the Eocene series lies on the Paleocene.[6] Before the subsurface work was begun, the presence of the Paleocene was unsuspected. Well cuttings also show the presence of Upper Eocene Jackson[7] formation in wells in Calvert County to the east. On the Eastern Shore of Maryland the Middle and Lower Eocene seem to be absent, and only the Upper Eocene is present.[8] Much work must still be done to delimit the Eocene formations in the subsurface.

Aquia Formation

Distribution: The Aquia formation appears in all the wells from which samples were obtained.

Lithology:

Mica is somewhat less noticeable in the Aquia samples than in the Nanjemoy well samples. Glauconite occurs throughout. The presence of hard lime-cemented beds near the top of the formation is shown by fragments of "rock" in the well cuttings. In outcrop on the south side of the Potomac River near the mouth of Potomac Creek indurated beds are found commonly in Zone 9, the top faunal zone of the Aquia formation, and about 15 feet below the top of this zone. There is some variation, however, in position and horizontal extent. At Marlboro a heavy limestone fossil bed outcrops 30 feet below the top of the Aquia formation. In the Goldstein well in Calvert County, hardshell and sea shells were found just under the base of the Nanjemoy formation.

Another feature of the lithology (one that is used by some of the well drillers to locate themselves underground) is the presence of conspicuous yellow, iron-stained quartz grains. Some yellow grains are found in the Nanjemoy formation, but are not nearly so common as in the Aquia, where they are sufficiently abundant to give a dusky yellowish-green tinge to the rock. The dusky yellow green color was not seen at any place in the Nanjemoy formation. It is particularly noticeable in the color of the drilling mud, but may not always show up in the samples.

In the Police well at Mattawoman the samples of the upper 40 feet of the Aquia formation are greensand and marl. Pieces of hardshell were noted at 30, 50, and 170 feet from the top. Yellow grains occur at 80–90 feet. The samples are somewhat less sandy toward the bottom. The size of the washed sand grains is generally medium, but this grades off into fine.

The Parlett well shows marl at the top and sandy clay and clayey sand through the rest of the section. Most of the washed samples carry much sand of medium size grading to fine. Hardshell was found at 12, 20, 26, 85, and 139 feet below the top of the formation. Yellow grains are found rather generally below 60 feet from the top. A peculiar feature of this section is the occurrence of a coarse to medium-grained gray sand at 139 feet below the top. This sand is feldspathic and looks much like the Cretaceous sand. An analysis of the water, presumably from this sand, is of Eocene type. This sand is therefore called tentatively Eocene in age.

[6] Shifflett, op. cit., p. 36.
[7] Shifflett, op. cit., p. 27.
[8] Anderson, op. cit.

In the Southern Maryland Electric Cooperative well at Hughesville the washed samples show considerable sand, most of it medium grade. Yellow-stained quartz grains are found throughout. The only hardshell noted was 48 feet below the top of the formation. A color change from olive-green to yellowish-green takes place 54 feet below the top. In the Goldstein well in Calvert County rock of this same color lies directly under the Marlboro "pink" clay of the Nanjemoy formation.

The Aquia formation in the La Plata well is a little less sandy than in the previously described wells. A little lime-cemented material was found at 30 feet below the top. A color change to weak yellow-green occurs at 30 feet and another to dusky yellow-green at 96 feet below the top of the Aquia formation.

In the Southern Maryland Cleaners well, the washed residue indicates a considerable amount of sand that is medium to fine in grain. A little hardshell was found at 23 and 38 feet below the top of the formation. A color change to yellowish-green takes place at 38 feet but does not continue in depth.

In the I. & P. well the first 25 feet are chiefly greensand marl. Indurated pieces occur at 25 feet. Yellow grains are common throughout, but particularly near the top.

In the Pace well the rock is sandy clay. A color change to dusky yellow-green takes place at 30 feet below the top. Yellow grains are very common at 40 feet below.

In the Orth well marl occurs at 20 feet below the top, and a color change to dusky yellow-green at 40 feet. Yellow grains are particularly abundant from 50 feet below to the bottom.

In the Menders well, hardshell is found 13 feet below the top, and a color change to yellowish-green occurs at 14 feet.

The Norris No. 2 well is interesting because of the rather common presence of brick-red glauconite.

Resumê: A comparison of the occurrence of heavy fossil shell beds and hardshell shows a close relationship between them. In those wells in which few shell fragments were found, no indurated beds were recognized.

Rocks of a dusky yellow color seem to be a characteristic of part of the Aquia formation as they have not yet been noted in samples from any of the other formations. This color was not found in all well samples from the Aquia formation. Its first appearance below the top of the Aquia formation varies from 40 feet in the Orth well to 80 feet in the Maryland State Police well. In the Goldstein well at Prince Frederick, Calvert County, the dusky yellow rocks lie directly under the Marlboro pink clay.

Organisms: Remains of organisms are much more common in the Aquia formation than in the Nanjemoy formation. This is true of both mega- and microfossils.

Table V indicates the distribution of shell fragments and brings out the fact that in all the western wells a heavy shell bed occurs directly under the Nanjemoy. In the southeast portion of the county the shells are not so abundant, and begin, if present, about 20 feet below the Nanjemoy contact.

In the Maryland State Police well shell fragments are abundant from the top of the Aquia formation to 40 feet below the top. They are common at 130 feet from the top, and are abundant again at 160 feet. Foraminifera are abundant from 60 to 90 feet below the top.

In the Parlett well shell fragments are common to abundant from 5 to 27 feet below the top of the Aquia formation and again at 74 feet. A few fragments appear at 134 feet below the top. The well bottoms at 153 feet below the top of the formation and hence does not penetrate far enough to reach the shell bed at 160 feet below the

TABLE V

Marine Shells in Aquia Formation

	Md. State Police	Parlett	So. Md. El. Coop.	La Plata	So. Md. Cleaners	I. & P. Co.	Hayden	Pace	Orth	Menders	Norris 2	Williams	
	Top of Aquia Formation								Top of Aquia Formation				
0													0
	x	x	x	x		x	x						
	x	x	x	x	x	x	x						
20	x	x		x		x			x	x			20
	x	x		x		x				x			
	x		x	x				x		x			
40	x				x					33	36		40
			x		x							41	
					x				x				
60						x	x		60				60
							66						
		x											
80			x	x				80					80
			x										
100													100
			103	x									
			BA										
120													120
	x												
		x			135								
140					BA								140
		153				152							
160	x					BA							160
	170			170									
180	BA			BA									180
200													200

BA—indicates well was drilled through the Aquia formation

top in the Police well. Foraminifera are abundant from 20 to 60 feet and are common toward the bottom of the well.

In the Southern Maryland Electric Cooperative well shell fragments are abundant at the top of the formation and at 83–88 feet below the top. Foraminifera[9] are abundant at 46 feet below the top.

[9] For a list of the foraminifera found see Shifflett, op. cit., p. 19.

In the La Plata well shell fragments occur fairly abundantly from the top of the Aquia formation to 30 feet below the top. A few fragments also were found at 80 and 110 feet below the top. Foraminifera are scarce.

In the Southern Maryland Cleaners well shells occur at the top of the formation and are abundant 8 feet below the top. A fair number of fragments are found at 40 feet below the top and a few at 49 and 57 feet. Foraminifera[10] are scarce.

The I. & P. samples show very abundant shell fragments from 7 to 27 feet below the top of the Aquia formation. Foraminifera are common at 27 and at 57 feet below the top.

The Hayden samples are incomplete. Shell fragments occur abundantly at 0 to 10 feet below the top of the formation, but between this and the bottom of the well only a single sample was taken.

In the Pace well shell fragments were found in only one sample, at 30 feet below the top of the Aquia formation. Foraminifera are rather common from 50 feet from the top to the bottom of the well.

In the Orth well shell fragments are not abundant. A few occur at 20 feet and at 57 feet below the top of the formation. Foraminifera are rather abundant in the lower part of the formation.

In the Menders well shell fragments were found at 18, 26, and 32 feet below the top, but in only very small amounts.

No shell fragments were found in the Norris No. 2 well, the Williams well, the Hill well, the Simms well.

Resumé: The heavy shell beds at the top of the Aquia suggest those found at the top of the Aquia in the Potomac Creek bluff in Virginia. Fossils there come in very abundantly below 12 feet from the top, but a few occur above this also. The heavy fossil bed at 160 feet near the bottom of the Aquia formation in the Police well may be zone 2 of the Potomac Creek section, which occurs about 48 feet above the base of the section there.

The fact that a heavy shell bed is found in practically all the wells at the top of the Aquia indicates that no very extensively angular unconformity exists between the Aquia beds and those of the Nanjemoy formation.

Thickness: The Aquia formation was drilled completely through in only five of the wells from which samples were obtained. In all the other wells it was penetrated only in part.

Table VI shows the thickness of the Aquia formation in those wells in which it was drilled completely through, and the distances penetrated in the other wells.

Plate II is an isopach map which by means of contour lines shows the changes in the thickness of the Aquia formation. The map indicates a thinning of the Aquia formation toward the east, and this conforms to the fact that the Aquia formation is missing on the Eastern Shore of Maryland.

The thickness of the Aquia formation runs from 86 feet to 170 feet.

Structure: Plate III (in pocket) represents by means of contours the contact surface between the Aquia formation and the Nanjemoy formation. This surface is

[10] Shifflett, op. cit., p. 18.

believed to be one of unconformity and hence is not necessarily parallel to bedding in the Aquia. Correlation based on the position of the heavy shell bed indicates, however, that there is no great angular difference between the intra-formational beds and the contact surface.

The contour map shows a surface having many changes in strike and dip. Aside from these changes the most noticeable feature is the flattening of the dip at the St. Marys County border.

The strike of the surface varies from N-S to N 80°E and the average strike is about N 42°E.

The average dip in the central part of the county is about 15 feet to the mile to the southeast; in the northern part it is 19 feet to the mile to the south. In St. Marys County the dip is about 5 feet to the mile to the southeast.

TABLE VI

Thickness of the Aquia Formation

Well	Thickness Aquia Formation	Elevation top	Elevation bottom	Elevation bottom of well	Distance in Aquia Formation
Md. State Police	170	−25	−195	−235	Through
Parlett	—	−25	—	−177	153
Southern Md. Elec. Coop	86	−262	−348	−369	Through
La Plata Town	170	−50	−220	−934	Through
Southern Md. Cleaners	135	−110	−245	−467	Through
I. &. P. Co	133	−120	−253	−280	Through
Hayden	—	−180	—	−246	66
Pace	—	−190	—	−250	80
Orth	—	−232	—	−286	60
Menders	—	−228	—	−261	33
Norris No. 2	—	−218	—	−250	36
Williams	—	−224	—	−265	41

Nanjemoy Formation

Distribution: Rocks of Nanjemoy age were found in all the wells from which samples were obtained.

Lithology: Both the top and bottom of the Nanjemoy formation are clearly defined by lithologic changes which are easily recognized in the well samples. A pale-brown clay bed (Marlboro clay member) is the basal member of the formation. The criteria for recognizing the top of the Nanjemoy formation are the disappearance of diatoms, the change in color from yellowish-gray to olive-green, the appearance of glauconite and coarse muscovite, and a marked change in foraminifera types.

A detailed description of the Nanjemoy well cuttings is given below (see p. 97).

The rocks composing the Nanjemoy formation are predominantly micaceous sandy clay or very argillaceous sand. Glauconite is everywhere present. Residual sand from cuttings is generally fine or very fine, and in a few wells, medium in grain. The absence of any well-defined sand beds is indicated by the absence of aquifers in the Nanjemoy formation.

In the Maryland State Police well there is a fairly well-defined change in depth from more sandy to less sandy. This change takes place about 65 feet above the base of the formation. A similar change was noted in the Parlett well at 55 feet above the base, but could not be recognized in any of the other wells. In the Parlett well the sand of the upper portion is somewhat finer than that in the State Police well.

The Southern Maryland Electric Cooperative well at Hughesville offers a confusing feature at the bottom of the formation. Whereas in all the other wells of the county the contact of the Marlboro clay member with the underlying Aquia formation is sharp, in the Hughesville well it appears to repeat. That is, the "pink" clay of 20 feet thickness is followed by several feet of sand and shell fragments, and then is followed by another foot of "pink" clay. This could, of course, be due to contamination, and, consequently, the base of the Nanjemoy formation is placed at the bottom of the first clay.

The top of the Nanjemoy formation in the Southern Maryland Electric Cooperative well is also somewhat uncertain. Glauconite and mica appear at elevation −29, but the glauconite is very scarce, and the rest of the material with which it occurs is definitely Miocene in age. Samples from elevation −66 carry some rock fragments, indicating that the drill passed through indurated beds.

The most noticeable feature of the La Plata well sample is the great abundance of glauconite in the upper part of the formation. The sand in this well is on the whole a little coarser than in the Parlett and Police wells.

In the Southern Maryland Cleaners well the upper 30 feet of the formation are somewhat less sandy than the lower portion. This is the reverse of what was found in the Parlett and Police well. The heaviest glauconite is in the central part of the formation.

In the Pace well at Wayside the clay is less sandy for the first 50 feet, and in this respect it checks with the Southern Maryland Cleaners well. Glauconite is abundant all through, but diminishes somewhat toward the bottom of the formation.

In the Orth well the top 50 feet are less sandy than the lower portion. Glauconite is abundant all through.

Resumé: No zonal differentiation could be made on lithology. The principal regional change seems to be that the top part of the formation is somewhat less sandy in the south portion of the county than it is in the north. Likewise the wells in the south seem to carry somewhat more glauconite than in the north. Neither of these differences appears to be significant.

Organisms: Organic remains are found in many of the samples. These consist of bone fragments, teeth, shell fragments, foraminifera, and radiolaria. Of these the foraminifera will undoubtedly prove to be most important in future correlations.

The occurrence of sea shell fragments is shown in Table VII. The table brings out rather strikingly the existence of a shell bed in most of the wells in the neighborhood of 40 feet from the top of the formation. This fossil zone may represent the Woodstock member.

The foraminifera of the Nanjemoy formation have not been studied in detail, but a general comparison with the Aquia types shows little difference between the two.[11]

[11] Shifflett, E., op. cit., p. 16.

TABLE VII

Distribution of Abundant Marine Shells in Nanjemoy Formation of Charles County Water Wells

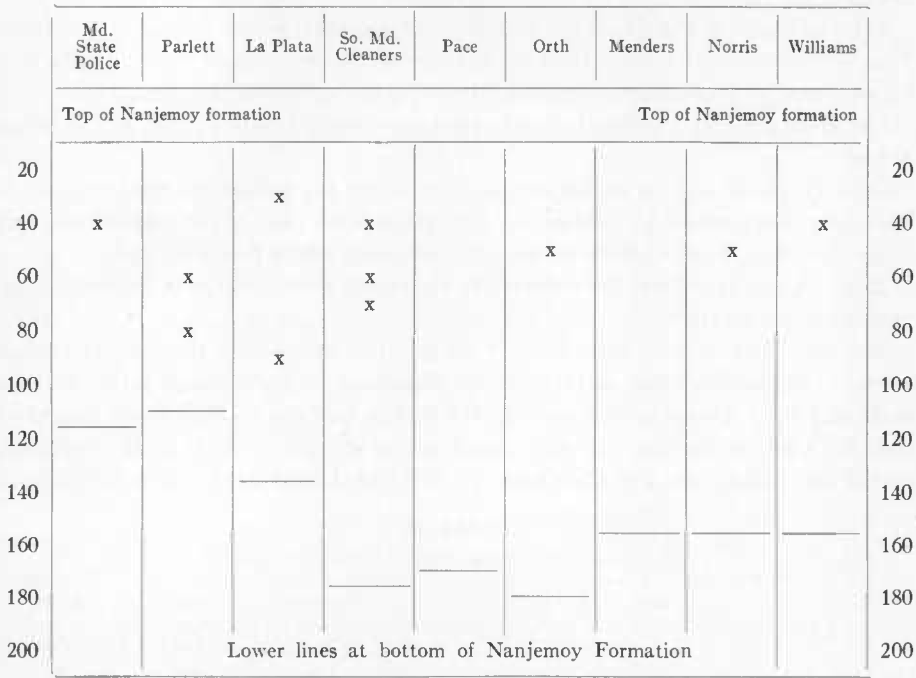


TABLE VIII

Thickness of Nanjemoy Formation and Marlboro Clay Member of the Nanjemoy Formation

Well	Elevation Top	Elevation Bottom	Thickness Nanjemoy	Thickness Pink Clay
Md. State Police	+95	−25	120	20
Parlett	+90	−25	115	28
Southern Md. Elec. Coop	−32	−262	234	17
La Plata Town	+85	−50	135	20
Southern Md. Cleaners	+65	−110	175	31
Hayden	+6	−180	186	30
Pace	−20	−190	170	20
Orth	−52	−232	180	20
Menders	−66	−228	162	18
Williams	−45	−217	172	12
Norris No. 2	−62	−218	156	5
Goldstein, Calvery County	−103	−329	226	7
Marlboro, Prince Georges County				22

Thickness: Table VIII gives the thickness of the Nanjemoy formation in the wells in which it was found. There is a considerable thickening of the Nanjemoy formation toward the eastward, as shown in the Hughesville well and in the Goldstein well in Calvert County.

The table shows that the Nanjemoy formation varies in thickness from 115 feet to 234 feet.

The thickness of the Marlboro "pink" clay member is also shown in the table. This bed is somewhat thicker than the average in the central part of the county near Popes Creek, and somewhat thinner in the southeast corner of the county.

The Marlboro clay member ranges in thickness from 5 feet to 31 feet, and averages 20 feet.

Plate IV (in pocket) is an isopach map on which the subsurface thickness of the Nanjemoy is expressed by contours. This map shows plainly the marked thinning of the Nanjemoy toward the west and its thickening in the Benedict area.

Table IX gives the total thickness of the Eocene series in those wells in which it was completely penetrated.

Structure: The contour map, Plate V (in pocket), shows that the contact surface between the Miocene series and the Eocene Nanjemoy formation has a rather uniform strike and dip. This is in contrast with the surface between the Nanjemoy formation and the Aquia formation. A slight bend in the structure occurs in the northeast part of the county and a sharper bend in the Cobb Island Area. The flattening of the dip in St. Marys County is interesting because it is just there that the probable Upper Eocene Jackson formation appears first in the well samples.

TABLE IX

Thickness of the Eocene Series in Charles County

Well	Nanjemoy	Aquia	Eocene
	Feet	*Feet*	*Feet*
Md. State Police	120	170	290
La Plata Town	135	170	305
Southern Md. Cleaners	175	135	310
So. Md. El. Coop	234	86	320

The average strike of the Nanjemoy-Miocene contact surface is N 38°E, and its dip is about 12 feet to the mile. In St. Marys county the dip is about 7 feet to the mile.

MIOCENE SERIES—SURFACE GEOLOGY

General features: Miocene deposits have wide distribution in the Atlantic Coastal Plain, being almost continuous from New Jersey to Florida. They are found, at the surface or in wells, from near the Fall Line to the present coast, and they extend out under the continental shelf.

In middle Miocene time the eastern part of Maryland was covered by the sea. The first sediments deposited in this sea (Calvert formation) are the most extensive; they lie nearest the Fall Line and probably continue across northeastern Maryland into Delaware. As time went on, the sea was more restricted, its shoreline moving south and east, so that the limits of the Choptank and St. Marys formations lie progressively farther in those directions. Indeed, the surface exposures of the St. Marys are essentially confined to the county for which it was named. A still younger formation, the Yorktown, is found only to the south, in Virginia and North Carolina.

The Maryland Miocene formations have a total thickness of a few hundred feet in the area of outcrop. In lithology, they range from medium-to-fine sands to materials largely in the clay size. The average dip is very gentle, to the east and southeast. Almost everywhere the rocks are unconsolidated. In most of their area of outcrop they are covered by Pleistocene gravels or "terrace" deposits, so that they are nowhere responsible for the topography of any extensive areas; where they form the surface, the resulting topography is very similar to that on other pre-Pleistocene Coastal Plain sediments.

Calvert formation

With the possible exception of certain deposits in the easternmost part of the county, all known Miocene rocks can be assigned to the Calvert formation; with the same exception, they can be further assigned to the Fairhaven diatomaceous earth member of the Calvert.

Lower boundary: Though there is little physical sign of any major unconformity between the Eocene Nanjemoy and the Miocene Calvert formations, the lost interval includes part of the Eocene series, all of the Oligocene series, and possibly part of the Miocene series. The top of the Nanjemoy formation shows no signs of subaerial weathering or soil formation; pre-Miocene erosion appears only in small-scale features, such as channels a few inches in amplitude and irregular holes and hollows made by burrowing animals (?). At one locality outside the county (see Nanjemoy formation, upper boundary) the Eocene-Miocene contact truncates the beds below.

The lithologic change at this contact has been described previously. It is marked particularly by a sharp boundary between greensands below and non-glauconitic, light-colored sands and clays above. Quartz or phosphatic pebbles half an inch or smaller in size are common just above the contact; elsewhere, pebbles are extremely rare in the Miocene deposits.

Fairhaven Diatomaceous Earth: The lower member of the Calvert formation was named for the town of Fairhaven, Anne Arundel County. As described in the Miocene volume of the Maryland Geological Survey (Shattuck, 1904), the member consists of three beds: the lowest, or "zone 1," of brownish sand, about six feet thick; "zone 2," a sand or sandstone about one foot thick; and "zone 3," forming the rest of the member. This last zone is characterized as follows: "This stratum when freshly exposed consists of a greenish-colored diatomaceous earth which, on weathering, bleaches to a white or buff-colored deposit breaking with a columnar parting and presenting perpendicular surfaces. It is very rich in diatomaceous matter, the mechanical analysis of specimens yielding more than 50 per cent of diatoms. The thickness of this bed varies from place to place, but where it is penetrated at Chesapeake Beach by an artesian well it has a thickness of about 55 feet."

"Zones" 1 and 2 have not been identified in Charles County. The one consistent feature in the lower beds of the Calvert is a stratum containing a large proportion of diatoms. Whether this layer is found everywhere at the same distance above the Eocene contact is doubtful, but in general the interval is about 10 to 20 feet. Below this diatomaceous bed there seem to be no persistent units. At some localities, the Miocene rocks are indurated just above the contact; at others, there may be an indurated bed a few feet above, and at still others there is no sign of induration near the base of the Miocene series. On the other hand, the Eocene series below may or may not be indurated at different localities. The variable nature of the Miocene indurations makes it impossible to recognize "zone 2", and it is believed that this "zone" has no stratigraphic significance.

"Zone 1" was described as "a bed of brownish sand carrying *Phacoides contractus*. This stratum varies somewhat in thickness from place to place, but does not depart widely from six feet on the average." It is impossible to say where this "zone" can be found, since no localities are given. In Charles County, the lowest part of the Miocene series is variable in lithology. At some places, there is a bed of clay just above the Eocene series contact; at others there is a whitish sand and at others a brownish sand; at no one of these places has *Phacoides contractus* been found. "Zone 2" then is believed to be equally invalid as a stratigraphic unit.

However, the Eocene-Miocene contact is always sharp and definite. At all localities, the Eocene beds are glauconitic below, but the Miocene beds above are conspicuously lacking in this mineral, even though the over all color may be green at some localities. In addition, the Eocene rocks are commonly micaceous, the Miocene rocks, very slightly so. The actual contact is sharp and clean, although there may be interpenetrations of Miocene materials in irregular small holes and hollows (borings ?) in the Eocene greensands below. Almost the only pebbles ever seen in the Calvert formation are found occasionally just above the contact; these pebbles may be quartz or phosphatic, and may range up to one-half inch or so in size. Commonly, they are associated with bone fragments.

"Zone 3," as described in the quotation above, was established to include the rest of the Fairhaven diatomaceous earth member. The name "diatomaceous earth" for this member is somewhat confusing and ambiguous since the greater part of its thickness is no more "diatomaceous" than are other beds of the Calvert formation.

In Charles County, there is one bed, 17 feet thick at Popes Creek, which may properly be called "diatomaceous earth" or "diatomite." This corresponds with a thickness of 8½ feet at Ferry Landing, 14 feet at Hollin Cliff (both in Calvert County), and about 10 feet at Wilmot Wharf (Virginia). In well samples, this richly diatomaceous layer can be recognized readily, although because of the comparatively large sampling interval its thickness cannot be fixed accurately. On the average, diatoms make up at least 50 per cent of this bed.

Above this bed, the Fairhaven member is dominantly fine-grained sand with an admixture of fines (mechanical analyses given below). Diatoms may be present, but they constitute an insignificant proportion. These silty or clayey sands furnish most of the exposures of Miocene rocks in the county.

The only locality in the county where the Fairhaven member is exposed in full thickness is at and near Popes Creek (30). Lying above the diatomaceous bed are about 40 feet of silty or clayey fine-grained sand. When dry, this material is loose and friable, but it does not run freely, as pure sand does; the writer used the term "mealy" to describe it. When damp, it will ball up in the hand, but the ball can be easily broken apart. In color the sand varies from a dirty white to a brownish;

color changes seem to correspond to bedding, although this was not clearly established. This kind of material makes up most of the natural and artificial exposures of Miocene rocks in the county.

Apparently this same material takes on a quite different appearance when fresh and when wet. At one locality (26) it was found impossible to match the fresh and weathered (dry) materials, although the same units were examined. When fresh, the color is greenish, and one gets the impression of a much higher content of clay. To a certain degree, this is the same difference that is found in the case of the wet and dry diatomaceous material. This difference is strikingly shown where the diatomite is being excavated (as formerly, at Ferry Landing in Calvert County). When fresh, the material looks and even feels like almost pure clay, green in color. When allowed to stand and dry, it turns almost pure white, becomes friable, and feels like pure very-fine-grained sand. The change in the case of the sand above the diatomite is less striking, but it is of the same general type. The fresh material may even be confused with glauconitic sand or clay unless carefully examined.

In addition to the Popes Creek locality, the "mealy" sands are well exposed at several other places in the county. Two of the best exposures are on the hills on either side of Zekiah Swamp, on the Newtown-Dentsville road (42) and (43). On the west side, about 55 feet are exposed, the lower 10 feet being correlated with the white sand at Popes Creek. Above a wavy, irregular contact are 45 feet of brown sand, believed to be a greater thickness of the brown sand at the top of the Miocene beds at Popes Creek, perhaps including younger beds at the top. The same relations are found on the east side of the swamp although a smaller section is exposed.

In both cases, there are indurations below the wavy contact; these indurations here and at other localities, contain the only fossils seen in the Fairhaven "mealy" sands. About 75 per cent of the forms are *Turritella*, about 20 per cent are *Pecten*, and other forms, represented chiefly by fragments, suggest *Astarte*, *Calyptraea*, *Nucula* or *Yoldia*, *Polynices*, and *Cadulus*.

This same contact has been found in a few places outside Charles County. One is on the east side of Budd Creek, near the town of that name, in St. Marys County. Below the contact, indurations contain a fauna similar to that found at Zekiah Swamp. Another locality is in Calvert County. The contact therefore may represent a minor unconformity of more than local significance. Fossils are present only because they have been preserved in indurated material; perhaps they were once widespread in the sands, but have been removed by subsequent leaching.

Other exposures of the sands, usually showing a smaller thickness, are found on the west side of Budd Creek, both sides of Clark Run near La Plata (25), on the hill just west of Bryantown (44), at locality (17), on the south side of Swanson Creek (45), and in many smaller exposures (chiefly road-cuts) in the central and eastern parts of the county.

The ambiguity in calling this member "Fairhaven diatomaceous earth" can be seen from the description above. The member has a thickness of about 75 feet at Popes Creek. Of this total, only one bed, 17 feet thick, contains more than an insignificant proportion of diatoms. Elsewhere the relative thicknesses seem to be about the same. For this reason, it is suggested that the term "Fairhaven member" be used for the lower part of the Calvert formation, and that "diatomaceous earth" or "diatomite" be reserved for the one bed containing a high percentage of diatoms.

The maximum thickness of the Fairhaven member in the county is that given for the Popes Creek locality. A nearby well shows 70 feet. Other wells seem to show a thickness of as little as 40 feet, but it is difficult to establish the precise limits of the member from well samples. The thickness may be expected to vary from place to place. The member lies unconformably on the Eocene series, and although exposures show no sign of channeling or large-scale irregularities, the surface of unconformity might well have had some initial relief. Above, the member is overlain unconformably by Pleistocene sands and gravels. Again, exposures show few signs of local erosion, but it is certain that the member must be quite thin in the western part of the county, where it is overlain by the low-lying Pleistocene terraces. In the eastern part of the county the member is probably present in full thickness (Southern Maryland Electric Cooperative well at Hughesville), but it is impossible to separate it from higher beds of the Calvert formation (but see correlations suggested below). The thickness can be given only approximately, as about 50 to 75 feet.

The western limit of the Miocene rocks lies approximately along a north-south line through Hilltop and Mason Springs. West of that line the formation was probably removed before deposition of the Pleistocene terrace deposits. To the east, practically all of the Miocene exposures in the county are of the "mealy" sands of the Fairhaven member; the diatomite is recognized definitely only in the vicinity of Popes Creek. In the easternmost part of the county, Plum Point marls and perhaps beds younger than the Calvert formation are exposed or encountered in wells.

Plum Point marls: The Plum Point marls were named from the locality on Chesapeake Bay, Calvert County. For some miles north and south of this locality the beds which make up the member are almost continuously exposed along the high cliffs—"Calvert Cliffs"—which border the Bay.

The original description of the member gives no locality where the contact between it and the Fairhaven beds below can be seen; the implication is that it was unknown. Likewise, the contact with the Choptank formation above is described only as shown along the Cliffs. The writer has given reasons for believing that the lower contact occurs just below the oyster bed near the north end of the Cliffs (Dryden, 1936 and 1933). The upper contact has not been definitely recognized; it lies somewhere between Shattuck's "zones" 13 and 17, but no clear signs of unconformity have been seen (Dryden, 1936; Schoonover, 1941, pp. 14, 15). The thickness of the member is surely as much as 50 feet, and may be as much as 75 feet.

Essentially, the Plum Point marls have been known only from the immediate vicinity of the Calvert Cliffs, and their extent inland and to the north beyond the Cliffs has remained completely unknown. This fact is the more remarkable since "zone 10" of this member is the thickest and most prolific fossil bed of the Calvert formation. Consequently, in attempting to trace the member from the Cliffs to Charles County, little or no stratigraphic information was available.

The section at Hollin Cliff (46) on the Patuxent River in Calvert County is of great value in this respect. The lower 52 feet of this section belong almost certainly to the

Fairhaven member. An irregular and extensively bored upper surface of the Fairhaven deposits is overlain by 18 feet of sand including a 7-foot fossil bed, which in turn includes a 2½-foot layer of oysters at its base. The oyster bed is assumed to be the same as that exposed along the Calvert Cliffs ("zone 4"), and the rest of the fossil bed above to be "zone 10." The clay at the top of the section may be "zone 11" of the Cliffs. This interpretation means that "zones" 5 to 9, some 15 to 20 feet or more thick along the Bay shore, have disappeared in the Hollin Cliff section. These "zones" however show unusual thinning even along the Bay exposures.

The Hollin Cliff section, only a few miles from Benedict in Charles County, almost surely proves the existence of the Plum Point marls in the county, but the final proof is afforded by locality (38). In this section the lowest unit is probably the top of the Fairhaven member. Its upper surface is bored in the same fashion as at Hollin Cliff and along the north end of the Calvert Cliffs, but the oyster bed above is not clearly developed. The main fossil bed at this locality is reported to be definitely "zone 10", and to contain several species restricted to that "zone" (Schoonover, 1941, pp. 81–83, 99). Both this section and that at Hollin Cliff show 28 feet of probable Plum Point marls.

Correlation with the Hughesville well (well P. 850) cannot be surely established. In that well the Miocene series has its greatest known thickness for the county—about 170 feet. Assuming a thickness of 70 feet for the Fairhaven member, there remain about 100 feet of Plum Point marls or younger Miocene beds. Since the position of the diatomite is only approximately fixed—within the interval 151–189 feet—it is impossible to measure intervals from this persistent horizon. At Hollin Cliff the fossil bed is about 25 feet above the diatomite; in well P. 850 abundant shell fragments at 121–128 feet depth may represent the same fossil bed ("zone 10") found at Hollin Cliff, and at locality (38) a few miles east of Hughesville.

Fossils and Correlations of the Calvert Formation: Although the Miocene deposits are very fossiliferous and easy of access along the Calvert Cliffs, since the Miocene volume of the Maryland Survey in 1904 there has been very little published on these fossils until recent years. References to fossils in Charles County in that volume are limited to collections made by Cope, listed as "near the Patuxent River"; it is possible that this locality is the same as (38) of the present work.

Schoonover made a restudy of certain genera of pelecypods from the Calvert Cliffs in 1941 and included in her paleontologic and stratigraphic studies a collection from locality (38). She reports the following from this locality (Schoonover, 1941, pp. 81–83):

Nucula proxima
Leda liciata
Leda liciata var. amydra
Glycymeris parilis
Anadara subrostrata
Pedalion maxillata
Chlamys madisonius
Amusium cerinum
Anomia sp. indet.
Modiolus ducatellii
Astarte cuneiformis
Astarte cuneiformis var. obesa
Astarte cuneiformis var. calvertensis
Astarte exaltata
Astarte thomasii
Eucrassatella melina
Venericardia granulata
Saxolucina (Megaxinus) foremani
Saxolucina (Megaxinus) anodonta
Phacoides crenulatus
Phacoides trisulcatus
Phacoides prunus

Erycina sp. indet.
Cardium craticuloide
Cardium laqueatum
Isocardia markoei
Isocardia mazlea
Dosinia acetabulum
Macrocallista marylandica
Callocardia subnasuta
Antigona staminea
Chione latilirata
Venus rileyi
Tellina declivis
Tellina sp. indet.
Semele carinata
Mactra clathrodon
Corbula idonea
Corbula elevata
Corbula inaequalis
Saxicava arctica
Panopea whitfieldi

Acteon shilohensis
Retusa conulus
Retusa calvertensis
Pleurotoma communis var. protocommunis
Surcula rugata
Mangilia parva
Drillia pseudeburnea
Marginella calvertensis
Scaphella typus
Scaphella solitaria
Fulgur coronatum var. rugosum
Siphonalia devexa
Ptychosalpinx lienosa
Ecphora tricostata
Ecphora quadricostata var. umbilicata
Scala sayana
Scala prunicola
Scala pachypleura
Eulima migrans
Odostomia conoidea
Turbonilla gubernatoria
Cerithiopsis calvertensis
Vermetus graniferus
Vermetus virginicus
Turritella indenta
Turritella plebeia
Turritella variabilis var. exaltata
Turritella variabilis var. cumberlandia
Crucibilum costatum
Calyptraea aperta
Crepidula fornicata
Xenophora conchyliophora
Polynices heros
Calliostoma philanthropus
Teinostoma calvertense
Teinostoma liparum
Fissuridea marylandica

Dentalium attenuatum
Dentalium danai
Cadulus thallus

This rich fauna of 42 pelecypods, 37 gastropods, and 3 scaphopods compares favorably in variety and number of individuals with the most prolific localities of "zone 10" along the Calvert Cliffs. The following forms at (38) are reported to be confined to zone 10: *Antigona staminea*, *Isocardia markoei*, *Isocardia mazlea*, *Glycymeris parilis*, *Anadara subrostrata*, and *Turritella indenta*. *Astarte cuneiformis* is said to be common only in this bed.

Microfossils are scarce at other horizons and localities within the Miocene series of this county. For the most part, they come from the Fairhaven member. Since the paleontology of this member has never been adequately studied, it is doubtful that the fossils in Charles County can at present be used for stratigraphic purposes.

Recently, a restudy of the foraminifera of the Calvert formation has been made by Ann Dorsey (Dorsey, 1940).[12] This study is being extended to the well samples from Charles County; surface exposures are much less promising, since fossils seem to have been leached wherever the beds approach the surface. Fresh samples from wells offer the best chance for exact correlation of the Charles County Miocene.

Upper Boundary: Over most of the county, the upper boundary of the Miocene series is the contact between the Fairhaven member and the overlying Pleistocene

[12] Anderson, J. L., op. cit., pp. 268–321.

deposits. The nature of this contact has been described in the discussion of the Pleistocene deposits. It is usually marked by a sharp change from fine-grained sands below to pebble beds, coarse sands, and clays above.

Mechanical Analyses: Only a few mechanical analyses of Calvert sediments have been made. No especial precautions were made to disaggregate the finer material, and in all cases except sample 6, material on the coarser sieves contains a large percentage of aggregates. Fractions below $\frac{1}{16}$ mm in size were not separated.

The method of performing the mechanical analyses, and the inherent difficulties of interpreting such analyses, however performed, makes it impossible to tell much about the origin of the Calvert sediments from their mechanical composition. The

TABLE X

Mechanical Analyses of Calvert Formation Sediments

Sample No. and percentage	Size in mm.					
	2	1	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{16}$
5			12	14	24	50
6		1	30	60	6	3
7			1	2	52	45
8			2	37	55	6
9			2	56	37	5

Sample 5: From the supposed diatomite layer of locality (26). Practically all of material on $\frac{1}{4}$ and $\frac{1}{8}$ mm sieves is aggregates, and half that on $\frac{1}{16}$ mm sieve. Material less than $\frac{1}{16}$ mm is more than 50 per cent diatoms.

Sample 6: From middle of highly fossiliferous layer at locality (38). Coarsest material is largely shell fragments. Chiefly quartz grains in finer grades, all except finest sizes showing solution (?) effects on surface.

Sample 7: From just under the Pleistocene contact, locality (30), along bluff at Popes Creek; in the field the lithology was called a very-fine-grained sand. All sizes except that below $\frac{1}{16}$ mm contain a large proportion of aggregates.

Sample 8: From just under the Pleistocene contact, locality (30), along north road leading into Popes Creek. On the $\frac{1}{4}$ mm sieve: about 60 per cent aggregates, 40 per cent quartz grains; some grains cemented with black material which is visible on outcrop. Finer sizes chiefly angular quartz grains.

Sample 9: From locality (43), road-cut on hill east of Newtown. Sample taken from around the indurations just below contact between white and brown sands. Aggregates common in coarsest size, mostly angular quartz grains in finer sizes.

sands are dominantly fine or very fine, with a considerable admixture of silt or clay sizes. The Plum Point marls sample, No. 6, is coarser than the others, which come from the Fairhaven member; prolific fossil beds in the Calvert formation are usually made of shells and coarse sediment of this character. In none of the samples is there much evidence of mechanical rounding, pitting or frosting.

Heavy Minerals: The heavy mineral suites of the Miocene deposits differ but slightly from those of the Eocene rocks in mineral species, but they are significantly different in proportions; this fact has been pointed out in general (Dryden, 1932) for these beds in southern Maryland, and in detail for one locality (Dryden, 1935B). Table XI shows the composition of heavy mineral suites from a few samples of the

Miocene rocks of Charles County; the figures are percentages based on a count of about 200 grains in each sample. Only transparent grains were considered.

Suites from samples taken near the Eocene contact have close resemblance in percentages to suites of the underlying Eocene rocks. This is shown by samples 1 and 2, which may be compared with Eocene suites on page 43. In both of these samples there is an unusually small amount of zircon, an abnormally high percentage of staurolite, and a comparatively large amount of garnet. However, this resemblance is not due to reworking of Eocene materials into the base of the Miocene series (Dryden, 1935B). For although the percentages are similar, the mineral varieties on the two sides of the contact are quite different. The absence of Eocene greensand in the Miocene rocks supports this conclusion.

Though only sample No. 5 of Table XI is from the Plum Point marls, additional work shows there is comparatively little difference in heavy mineral suites between this and the Fairhaven member (if the first foot or two above the Eocene contact be

TABLE XI

Heavy Mineral Suites of Miocene Sediments

Sample No.	Zircon	Staurolite	Garnet	Rutile	Epidote	Tourmaline	Kyanite	Chloritoid	Sillimanite
1	35	29	13	6	6	7	2	1	2
2	40	29	10	4	6	4	3	2	1
3	69	10	—	7	4	3	1	4	—
4	52	13	2	6	11	5	5	2	2
5	55	13	12	2	7	4	—	2	2

No. 1 is from locality (30), just above Eocene contact.
No. 2 is from locality (13), just above Eocene contact.
No. 3 is from locality (30), about 37 feet above Eocene contact.
No. 4 is from locality (34), near base of section.
No. 5 is from locality (38), fossil band.

excluded from consideration). In general, then, heavy minerals have not as yet proved useful in differentiating units within the Calvert formation.

Perhaps one difference in mineral content can be used to separate different beds of the Miocene series as a whole. In the Fairhaven member no hornblende has been seen. It is very rare in the Plum Point marls, but becomes more common toward the top; in the Choptank formation it often makes up as much as 5 per cent of the suite, and is even more abundant in the St. Marys. It may be significant in this connection that the whitish material at the base of the section at (39) contains 5 per cent of hornblende. In the field, this material resembles diatomite in its mode of weathering, but from a consideration of the elevations of the diatomite at locality (46) and of the Plum Point marls fossil band at (38) correlation with the diatomite was thought to be impossible. The hornblende content makes it seem likely that the material is the upper part of the Plum Point marls or part of the Choptank formation, which quite probably is present in well P. 850 at Hughesville.

A sample from this well, depth 65–80 feet, was too small to yield a good heavy mineral crop, the total being only 47 transparent grains. Percentages based on such a small count are not trustworthy, but it is suggestive that this suite contains 13 per cent of hornblende. This indicates correlation with the material at locality (39) and with the Choptank formation along the Calvert Cliffs, in Calvert County.

A short description of each mineral species is given below, the sizes being as follows: small, .05–.08 mm; medium, .08–.12 mm; large, .12–.20 mm.

Zircon: Grains always small, even when grains of other minerals are unusually large; almost always rounded, broken, and worn; about 10 per cent in a few samples show some preservation of faces, but otherwise the elongation is the only clue to original shape; probably not in first cycle, but derived from pre-existing sediments.

Tourmaline: Over 90 per cent are fragments of once larger grains which were originally as long as 0.2 mm; all show some signs of wear and attrition; colors, dominantly some shade of brown, sometimes with a purplish tinge; few grains of deep indigo blue; most common shape has length about twice the width.

Staurolite: Generally medium to large; lemon-yellow to orange-yellow color; irregular shape, often "worm-eaten"; varies from dirty (from inclusions ?) to clear; grains with lighter color show weaker pleochroism.

Sillimanite: Shape varies from long and narrow, to bladed, to tabular; most common shape has length two to three times width; generally striated parallel to elongation; clear, transparent; ends rounded.

Garnet: Usually large, irrespective of size of other grains; wide range of colors from pink to colorless; surface smooth to "speckled" or "knobbly"; apparently certain types restricted to one or more horizons, so that detailed work may show value of garnets for distinguishing different beds or localities.

Epidote: Rather consistent in character; usually light yellow-green to colorless, rounded and dirty in appearance, so that it resembles small dirty zircon grains; pleochroism weak to almost absent; grain size small.

Kyanite: Two well-defined shape types, with length-width ratios of about 3:1 and 1:2; most samples contain mixture of the two types but some contain only one; grain size large; corners and edges rounded.

Rutile: Both honey-yellow or yellow, and the "foxy-red" types present; honey-yellow type more elongated; crystal form preserved only as elongation.

Chloritoid: Typical "smoky-blue" grains with medium to strong pleochroism in blue and light olive-green.

Choptank and St. Marys Formations

The presence of the Choptank or St. Marys formation has not been proved in the county. In the central and western parts they are almost certainly lacking, but in the Hughesville well some part of the unusually thick Miocene section probably belongs to the Choptank formation. This assumption is supported by two heavy mineral analyses, discussed under the Calvert formation. It is unlikely that the presence or absence of these formations will be decided from surface exposures; further study of well samples and their micro-faunas may solve the problem.

SUBSURFACE GEOLOGY

Calvert Formation, Fairhaven Diatomaceous Earth Member

General statement: The recognition and delimitation of the Fairhaven member was discussed in detail in the section on Surface Geology. The description of the Fairhaven diatomaceous earth member at its type locality indicates that there the term was applied to those beds which are characterized by diatoms. Since nearly all the well samples show, lying above the Aquia formation, a rock unit characterized by the presence of diatoms, this unit is here called the Fairhaven member of the Calvert formation. The relatively large numbers of diatoms in this part of the geologic section and their widespread distribution point to an environmental difference in the deposition of the beds from those preceding or following them.

The bottom of the Fairhaven member is rather definitely fixed in well cuttings by four features—disappearance of diatoms, appearance of glauconite, appearance of coarse muscovite, change in types of foraminifera. In one or two wells diatoms carry over past the first appearance of glauconite, but this is to be expected since the diatom frustules are very light and remain in the drilling water.

The top of the Fairhaven member in the well cuttings is placed at the top of the sample interval marked by the first appearance of noticeable numbers of diatoms or of diatom fragments. This point is very easily picked, and in the absence of fauna was the one used where no other changes in lithology were noted. The fact that the thickness of the formation is rather uniform in nearly all the wells shows that this criterion has practical value. The presence of diatoms does not necessarily mean that they are so abundant as to constitute a diatomite bed.

Distribution: The Fairhaven is recognized in all wells in the northeastern section of the county and in nearly all wells in the southeastern section from which samples have been obtained.

Lithology: Since the lithology of the Fairhaven member is the same for most of the wells, it need not be described for each well separately.

The samples vary slightly in color from pale olive to pale brown to grayish-yellow. The grayish-yellow is characteristic of those samples that are especially high in diatoms. The rock is almost entirely clay or clay and diatoms, so that on washing nearly all the material passes through a 230-mesh screen. Some of the samples indicate a slightly more sandy phase at the top.

Toward the southeast corner of the county, the lithology of the samples changes. In the Orth well at Mt. Victoria, sand predominates in the samples, and about one-half show gravel. No diatoms were found. In the Pace well at Wayside, about 3½ miles west of Mt. Victoria, diatoms are abundant, and the rock is clay except at the very top where it is sand. The Menders well at Woodlawn Point near Cobb Island shows the interval where the Fairhaven member should occur made up chiefly of sand, some clay, shell fragments, but carrying no diatoms. A short distance southeast of the Menders well on Cobb Island the Norris No. 2 well shows pale brown sandy clay carrying rather abundant diatoms. The Williams well at Tompkinsville shows very little diatomaceous material. Practically all wells drilled in this section of the county are jetted wells, and as shown above samples from jetted wells are likely to be contaminated. For this reason one cannot be too sure that the diatom beds are really absent in the wells in which they do not show up in the well samples, but it does appear that diatoms may be somewhat less abundant in the Fairhaven member of this southeastern part of the county.

As explained above the top of the diatomaceous beds was selected as the top of the Fairhaven member. There appears to be no other definite lithologic break between the diatom beds and the overlying Plum Point marls.

In the Maryland State Police well sand and gravel are found to within 5 feet of the top of the first diatom bearing bed. This material is classified as Pleistocene series.

In the Parlett well the upper part of the Fairhaven member for about 15 feet is somewhat more sandy than the overlying unit, but the color is the same—pale brown—both in the Fairhaven and in the overlying beds. About the only difference is the appearance of abundant diatoms in the lower unit.

In the Southern Maryland Electric Cooperative well a heavy sea-shell bed (probably zone 10 of the Plum Point marls) occurs about 30 feet above the top of the Fairhaven member. Unfortunately no samples cover this interval in any of the other wells. The beds immediately above the top of the Fairhaven member are pale olive sandy clay. The Fairhaven member follows with grayish-yellow diatomaceous clay.

In the La Plata Town well, Southern Maryland Cleaners well, the Hayden well near Popes Creek, and in the Pace well at Wayside the diatomaceous clay lies directly under the Pleistocene gravel.

Thus there is no definite and distinct lithologic change in the well samples that might be of value in distinguishing the top of the Fairhaven if it should be proved that the diatomaceous beds are not always and necessarily the top bed of the Fairhaven member.

The basal portion of the Fairhaven is of interest lithologically. As noted above (p. 54) pebbles are found at some of the outcrops which expose the basal portion of the Fairhaven member. Pebbles were found also in well cuttings from the base of the Fairhaven member from the following wells: Parlett, Menders, Norris No. 1, Norris No. 2. In the Southern Maryland Electric Cooperative well at Hughesville, black calcareous pebbles and hard black calcareous internal casts of gastropods were found. In the Southern Maryland Cleaners well at Spring Hill hard black gastropod casts were likewise found, but no pebbles.

Except for the occurrence of the pebbles there is little difference in lithology in the well samples between this basal bed and the beds above it.

Organisms: Diatoms are by far the most abundant and distinctive organic remains in the Fairhaven member.

Radiolaria are also very abundant in some of the wells.

Foraminifera were found rather sparingly in the Southern Maryland Electric Cooperative well, the Parlett well, the Norris No. 1 well, and the Williams well. These all occurred in the basal Fairhaven bed. The foraminifera are definitely Miocene forms and are sharply differentiated from the underlying Eocene assemblage.

Zonal distribution of the middle Miocene foraminifera has been studied by Ann Dorsey.[13] Correlation of these zones with possibly similar faunal zones in the well samples from Charles County is not yet possible because of paucity of material. The most abundant types of Miocene foraminifera found in outcrop by Miss Dorsey are the following:

[13] Anderson, Judson L., op. cit.

Nonion grateloupi
Nonion advenum
Spiroplectammina mississippiensis
Valvulineria floridens
Virgulinella miocenica
Lagena clavata
Nonionella auris
Bulimina elongata
Nonion pizarrense
Lagena tenuis
Cibicides lobatulus
Textularia gramen
Cibicides concentrica
Pseudopolymorphina rutile

Bone fragments are very generally found in the cuttings.

Thickness: The thickness (see Table XII) of the Fairhaven member as indicated by the well cuttings averages about 60 feet. The thickness in the Maryland Police well is out of line with that in the nearby Parlett well where sampling was carefully supervised. It is to be noted that the thickness of the Fairhaven member is about the same in the north part of the county at Waldorf as in the southeastern part of the county at Wayside.

TABLE XII
Thickness of Miocene Fairhaven Member

1		2	3	4	5	6
Well		El. base, Pleistocene Ser. (feet)	El. top, Fairhaven Member (feet)	El. bottom, Fairhaven Member (feet)	Thickness, Fairhaven Member (feet)	Tota Thickness, Miocene Ser. (feet)
	NE quadrant					
P. 1770	Md. State Police	+175 (1)	+170	+95	75	80
P. 741	Parlett	+173	+150	+90	60	83
P. 850	So. Md. Elec. Coop.	+139	+28	−32	60	171
P. 1398	La Plata Town	+141	+141 (2)	+85	56	56
	SE quadrant					
P. 1122	So. Md. Cleaners	+135	+130	+65	65	70
P. 1445	Hayden	+40	+40 (2)	+6	34	34
P. 1797	Clemens	+107	−3	−43	40	150
P. 1540	Bowling	+115	+20	−40	60	155
P. 1462	Pace	+40	+40	−20	60	60
P. 1050	Orth	+18	? (3)	−52	—	—
P. 572	Menders	−9	? (3)	−66	—	—
P. 477	Norris No. 2	−9	−9	−62	53	—

(1) Base of Pleistocene series indefinite from well samples and figures given above are approximate—±10 feet.
(2) Diatoms directly under Pleistocene rocks; part of Fairhaven member may have been eroded.
(3) Top of Fairhaven member could not be recognized.

Structure: No intraformational strikes and dips of the Fairhaven member were obtained.

Calverl Formalion, Plum Poinl Marls Member

General stalement: The Plum Point marls member of the Calvert formation lies above the Fairhaven member in the typical Maryland section of the Miocene rocks.

In most of the wells in which the marls are believed to occur their upper contact is an erosional one with the overlying Pleistocene deposits; and as a consequence the full thickness of the member is exposed in possibly only three wells.

In the type section the differentiation between the Choptank and the Calvert is based on a megafauna, and not on any marked lithologic change. The microfauna is not yet well enough known to permit a distinction to be made. The top of the Plum Point marls member, therefore, cannot be determined definitely now from well cuttings.

In the type section of the Calvert formation the Fairhaven member is characterized by the presence of varying, but significant amounts of diatoms. The bottom of the Plum Point marls has, therefore, been placed at the top of the well cutting sample interval that shows appreciable numbers of diatoms.

Distribution: The wells in which the Plum Point marls are believed to occur are: the Parlett at Waldorf, Maryland State Police well at Mattawoman, the Southern Maryland Electric Cooperative well at Hughesville, the Clemens and the Bowling wells at Wicomico.

Lithology: The Southern Maryland Electric Cooperative well supplies the most complete suite of samples from the Plum Point marls member. As will be shown (p. 66) the upper part of this well may be in the Choptank formation. The top of the Plum Point marls member is placed provisionally at elevation +89 feet and the bottom at elevation +28 feet. The rocks in this interval are a light olive-gray, light brownish-gray, and pale olive sandy clay. The grade of the sand is fine to very fine.

In the Parlett well the rock is pale brown clay and a little very fine sand.

In the Bowling and Clemens wells the rock is a light olive-brown to moderate olive-brown slightly sandy clay. The sand is fine to very fine.

Organisms: In the Hughesville well organisms are rather abundant. They consist of shell fragments of megafossils, rather abundant foraminifera, and a very few diatoms.

Megafossil shell fragments are particularly abundant starting about 30 feet above the bottom of the member. It is probable that this is zone 10 of the Plum Point marls member. Zone 10 outcrops about 3½ miles east of Hughesville and is there very fossiliferous.

The foraminifera are common and are Miocene types. The dominant forms are large *Nonions* but not enough data are available to permit a zonal breakdown.

As in all Miocene samples, bone fragments are common.

In the Parlett well samples, no diatoms, shell fragments, nor foraminifera were found. Radiolaria are common to abundant.

No organisms were found in the Clemens or Bowling wells.

Thickness: Since the top of the Plum Point marls member is not recognizable from the well cuttings, a definite thickness for the member cannot be given. In the Hughesville well a possible thickness of 61 feet is suggested. In the Parlett well about 23 feet of the member is exposed, but the upper contact is an erosional one. No thickness can even be estimated for the Clemens and Bowling wells.

Resumé: The study of the well cuttings adds little to our knowledge of the distribution of the Plum Point marls member in Charles County. It is certainly present in the Hughesville well, and probably present in the Parlett, Clemens and Bowling wells.

Presumedly the Plum Point marls member is present in several of the other wells, such as Southern Maryland Cleaners, I. and P. Co., and Hayden well. Samples from these wells, however, were lacking or were extremely contaminated.

Choptank Formation

General statement: In the discussion of the surface geology of the Miocene series it was shown that the Calvert formation has been found at a number of places in the county in exposure, but that the Choptank formation had been nowhere definitely recognized. Studies of the well samples, however, furnish presumptive evidence that the Choptank formation is probably present in the eastern and southeastern parts of the county. Conclusive evidence will have to come later when more is known about the zonal distribution of the foraminifera.

The evidence for the presence of the Choptank formation is based chiefly on a comparison of thicknesses of the Miocene rocks in the wells with those in the type section in the Calvert Cliffs. It is probable that the formations in wells in Charles County will be thinner than where measured in the type section of Calvert County. Table XII, which gives the thickness of the Miocene rocks shows 171 feet in the Hughesville well, and 150 and 155 feet in the Bowling and Clemens wells. If now the average thickness of the Fairhaven member is taken as 60 feet and the maximum thickness of the Plum Point marls member as 75 feet (see p. 65) the total thickness of the Calvert formation would be only 135 feet in the Charles County area. The excess footage is then probably Choptank and Pleistocene rocks.

It was pointed out above that the study of heavy minerals from samples from the Hughesville well suggested correlation with the Choptank formation because of the presence of rather abundant hornblende.

Distribution: The Choptank is possibly present in the Southern Maryland Electric Cooperative well at Hughesville in the northeast section of the county, and in the Bowling and Clemens wells near Wicomico in the southeast section of the county.

Lithology: In the Southern Maryland Electric Cooperative well the rocks that are probably Choptank are a light olive-gray clay, carrying a fair amount of fine or very fine sand, and characterized particularly by an abundance of large diatoms and diatom fragments. Above the diatom-bearing bed is a pale olive-gray sandy clay.

In the Bowling and Clemens wells, the samples that may be Choptank rocks are a light yellowish-brown, somewhat sandy clay. The diatom bed of the Southern Maryland Electric Cooperative well is not found in samples from these wells.

Organisms: In the Hughesville well a few diatoms are found at the top of the unit, but are very much more abundant nearer the bottom. Radiolaria are fairly common in samples from near the bottom of the probable Choptank rocks. Foraminifera are fairly common also toward the bottom. Shell fragments are common and among them a piece of *Melina* was recognized. *M. maxillata* is particularly abundant in the Choptank formation along the cliffs in Calvert County, but it also occurs in the Calvert formation.

In the Wicomico wells, no organisms were found.

Thickness: In the Hughesville well possibly 50 feet of the Choptank have been penetrated. No estimate can be given for the Bowling or Clemens wells.

QUATERNARY SYSTEM

PLEISTOCENE SERIES—SURFACE GEOLOGY

Physiography: Gravels, sands, and clays of Pleistocene age cover perhaps 90 per cent of the area of the county. This cover is almost unbroken in some areas of considerable size, notably the high, undrained flat north and northeast of La Plata, and the low, equally undissected "necks" and peninsulas bordering the Potomac. Older rocks are exposed chiefly in bluffs along the river, in the walls of many of the stream valleys, and in road-cuts and artificial excavations. In only one section are these older rocks responsible for the topography, and in this area, between Hughesville and Benedict, Miocene sands make a small-scale, rolling topography found nowhere else in the county. Alluvium, derived from Pleistocene and older rocks, floors many of the larger valleys and mantles the gentler slopes.

The Pleistocene gravels form extensive flat areas or "terraces." The highest part of the county—at about 200 feet and above—is particularly noteworthy. The surface is almost undissected, and swampy areas emphasize the complete lack of surface drainage. The lowest parts of the county, bordering the Potomac, are similar. Flat, undissected areas several square miles in extent are common; because of their low altitude, erosion of these surfaces is proceeding principally along wave-cut cliffs bordering the Potomac.

At intermediate levels, preservation of such flat surfaces is much less perfect. For example, in the western half of the county, at elevations of a hundred to almost two hundred feet, there are no large undissected areas. It must be admitted that much of this country is wooded; seldom is it possible to get unobstructed views. But in traveling over these areas one gets the impression of a very gently rolling terrain. Dissection has reached almost every part of these areas; although in most cases stream valleys are broad and open. Undoubtedly, there were more extensive flat, gravel-capped areas at these intermediate elevations before dissection by streams.

Preservation of large, undissected areas at these two elevations—lowest and highest—offers no particular problem. The lowest surfaces give every indication of being extremely recent, so that erosion has not had long to act. In addition, they lie at such slight elevations that streams crossing them have low gradients and correspondingly low erosive power; the absence of streams and swamps in much of their area points to good subsurface drainage—a further factor in their preservation. The high-level surfaces are preserved because dissection has not as yet reached them. They lie inland, away from the main stream valleys; where they are being dissected—as, for example, along Zekiah Swamp and its tributaries—there is every indication that they are being rapidly destroyed.

General statement: Flint has recently discussed the special conditions attending the investigation of glacial deposits (Flint, 1947, pp. 188–190). Though the Pleistocene deposits of Charles County cannot be called "glacial" in the sense used by Flint, almost all of the restrictions noted by him apply to the terrace deposits of this area. In no case can the ordinary rule of superposition be applied, since younger deposits lie not on older ones, but beyond and topographically below them. Fossils are either completely lacking or so scarce as to be of no value for local correlation, and lithologic character varies so greatly both horizontally and vertically that it is of little value in tracing formations or beds. The chief recourse has been to classify these deposits on their topographic position and expression.

Wentworth has made the only detailed study of Pleistocene lithology that applies to the Charles County area (Wentworth, 1930). He carried out a large number of mechanical analyses and other sedimentary studies, and has considered the bearing of this work on the origin of the Pleistocene sediments. The reader is referred to this publication for a fundamental discussion of most of the problems involved in the Charles County Pleistocene.

A much briefer consideration of the heavy minerals of the terraces of Virginia is also applicable to Charles County (reference and discussion in Dryden, 1932).

The Terraces—Their Physiography and Origin: The flat, or more or less flat surfaces of the Pleistocene deposits are considered to be essentially the original surfaces of deposition. Proof of this assumption is strongly suggested by the following. The highest Pleistocene rocks—at about 200 feet—have a thickness which averages no more than about 10 to 20 feet. Yet this thin cover remains unbroken except where comparatively recent stream erosion has destroyed it. It is considered very unlikely then, that these sediments were ever significantly thicker; if they had been, reduction of their thickness to the present figure would have undoubtedly meant their complete destruction at many places. This same point can be made for gravels at lower elevations. In general, flat surfaces on the Pleistocene deposits have been essentially unmodified (again excepting stream valleys cut through these deposits); the nature and origin of these surfaces—the "terraces" of various authors—is the outstanding problem of the late geologic history of the county.

Cooke's views on the origin of the terraces have been outlined above (Cooke, 1931). He believes them to be marine features, or at least to have been controlled by the height of sea level at the time of their formation. Sea level, according to Cooke, stood during the formation of these terraces at 270, 215, 170, 100, 70, 42, and 25 feet above present sea level. Consequently one should find sea-cut cliffs, or scarps, at about these elevations; in the case of estuaries, or behind off-lying islands or bars, these scarps might have been poorly developed or lacking.

Flint and Wentworth agree that terraces below about 90 feet are largely marine in origin (Flint, 1940; Wentworth, 1930). The highest scarp recognized by these authors has its toe at 90 feet. Flint has followed this scarp from South Carolina to near the James River in Virginia, but he believes that it does not continue farther north, nor does a lower scarp, at about 25 feet seem to continue to the north. If Flint is correct, wave-cut scarps at these two elevations probably are lacking in Charles County, some hundred miles beyond their northern limit.

Much of Wentworth's work on the Pleistocene deposits of Virginia has direct application to the terrace problem of Charles County. One significant contribution is that many of the terraces bordering or adjacent to the Potomac River have had a fluvial origin, as shown by "islands" of higher land now enclosed or isolated by old meander cut-offs (Wentworth, 1930, pp. 77, 103). Also, he has presented evidence that the terraces above about 100 feet in elevation were formed from coalescing alluvial fans, and were hence independent of the height of sea level at that time.

Campbell is in essential agreement with the conclusions of Wentworth (Campbell, 1931). He considers that all Pleistocene material in Charles County above about 100 feet was deposited by the Potomac River, chiefly in the form of a large alluvial fan. Higher wave-cut scarps as postulated by Cooke should therefore be lacking.

Dryden has proposed an explanation for the occurrence of Pleistocene gravels at very different elevations (Dryden, 1935A). Noting a warping of the underlying rocks, he considered the possibility that the terraces, too, had been warped from their original almost-horizontal positions. This warping of an essentially continuous sheet of gravel would explain the elevation of the "high gravels" as being due to the position on the axis of up-warping.

These conflicting views on the origin of the terraces, or even as to their existence, have not been reconciled by geologic work in Charles County. Certain observations made by the writer, however, contribute to this end.

The highest erosional feature which is known to the writer, and which he would call a scarp, is at an elevation of 60 feet. This scarp (fig. 2) has a height of about 15 feet, from the toe at 60 feet to a flat surface at 75 feet. From this locality, about midway between Riverside and Trappe Bridge (southwestern part of the county), the same scarp seems to continue around to the east and southeast, conforming roughly to the course of the present Potomac. The other points along what is believed to be the same scarp are near Brentland (Cedar Point Neck), at Chapel Point (across Port Tobacco River from Brentland), and near Wayside (about 12 miles slightly east of south of La Plata). The elevations of the toe at the four localities, in order, are 60, 55, 55, and 43 feet, as determined by Paulin altimeter tie-ins to bench marks. In order to check the consistency and accuracy of elevation readings, three independent measurements were made along the Brentland scarp; the toe readings were 56, 54, and 55 feet. It is believed, then, that the previous readings—60, 55, 55, and 43 feet—are significantly different and are not the result of faulty location of toe of the scarp.

It has not been proved that this is the same scarp at the four localities. At Brentland and Chapel Point, the points of observation are only a mile apart, but the other localities are some eight to ten miles away, and between Wayside and Chapel Point the scarp is clearly missing for a distance of some five miles, presumably as a result of later erosion by the Potomac. The writer believes that this is the same scarp at the four localities, that the scarp was cut by the Potomac River when flowing at a higher elevation, and that there are at least two reasonable explanations why the toe elevation should differ.

First, the scarp faces the Potomac and conforms to its course. It could in all four cases be regarded as the cut-back on the convex side of old meanders. Differences in elevation of the toe are a result of the gradient of the river itself, its surface sloping at that time about one foot per mile. A meandering river with gentle gradient would not be expected to transport coarse material; this is in agreement with the one-half inch or finer material found at and near the base of the scarp.

Second, although the above explanation is thought to be sufficient, and probably the correct one, it is possible that warping has affected this scarp. The highest elevation lies near the axis of up-warping, the lowest at about the proper distance to the east of the axis. Whatever the true explanation, there seems no necessity to appeal to a marine, wave-cut origin, or to control of elevation by sea level.

The only other well-defined scarp (other than those of the present erosion cycle) known to the writer seems to be a very local feature. The only place it was seen is some three miles north of Riverside, quite near the elevation figure "55" of the county map. At this place the scarp is about six feet high and is faced with cobbles averaging three to six inches in size. It is approximately parallel to the higher scarp described above, and it has probably had a similar origin. At this one locality, its toe is at an elevation of 30 feet; other localities could probably be found, although the country hereabouts is not favorable.

A search for scarps at other elevations—particularly those given by Cooke—has resulted in failure. Of especial interest is the apparent lack of scarps which are clearly older than the Potomac River. However, the existence of additional scarps cannot be definitely denied. For reasons given above, such minor features are difficult to find in wooded, dissected country. Contour maps of small interval or aerial photographs of suitable scale are necessary for a final decision on the presence or absence of such scarps.

The lower terraces, below the 60-foot scarp described above, seem to be clearly related to the Potomac River, and to have been formed at an earlier stage in the river's history. For example, the "island" at Indian Head (Indian Head Quadrangle, Md.-Va.; 1925 ed.) is cut off from the adjoining high country by a channel-like depression about 40 feet above the present Potomac. This depression probably was the main, or a subsidiary channel of the river, and was abandoned by meander cut-off, as described by Wentworth for adjacent areas in Virginia (Wentworth, 1930, pp. 77, 103).

The present elevation of the abandoned meander may represent the height of the river bed at the time of formation of the 60-foot scarp—that is, the depth of water through the meander was about 20 feet. At the same time, it is possible that terraces like Tayloe Neck and Cedar Point Neck were being formed. Present elevation of these terraces ranges from a few feet to 30 feet or more. Flat areas at these different elevations could have been formed at successively lower levels during the down-cutting of the Potomac; the presence of a scarp at about 30 feet agrees with this interpretation. It should be noted, however, that terraces of different elevation could be formed at the same stage of river-cutting. At present, there is an extensive shoal (a "future terrace") at about −5 feet, to the west of Indian Head (Indian Head Quadrangle), extending into Occoquan Bay, Virginia. Some five miles and more downstream, shoals of the same character have an elevation of about −20 feet. If exposed, these shoals would presumably form terraces similar to those bordering the Potomac, but their elevations could not be used to correlate them. In similar fashion, elevations of the river bed in meander cut-offs cannot be used as proof of exact equivalence or difference in age.

So far it has been seen that: (a) The Pleistocene deposits of the county cannot be differentiated on lithologic grounds; (b) therefore, physiographic criteria must be employed; and, (c) physiographic studies based on elevations alone, without well-defined scarps, are of doubtful value for correlation of the Potomac terraces. In view of the unsatisfactory results attained by the methods outlined above, a new line of attack on the problem is needed. A possible line of attack, as yet largely untried, is given below.

The traditional method of study of the Pleistocene "terraces" has been correlation by elevations of their upper surfaces. Equally valuable data might be derived from a similar study of their lower surfaces, from the nature and elevation of the surface of unconformity between the Pleistocene and older rocks.

The writer has paid particular attention to the unconformity between the Miocene and Pleistocene. In a number of cases, such as localities (27), (30), (42), (43), and (45), the contact is clean, sharp, and almost mathematically straight for distances up to 50 feet; no signs of channeling have been seen. Such contacts have been found at elevations of 104, 110, 113, 115, 116, 120, 120, 120, 125, 134, 135, 142, 145, 152, and 154 feet.

The sharp and straight-line nature of the contact might be interpreted as the result of either marine or fluviatile erosion. At first thought, a marine origin might seem the more likely. However, an almost plane surface below or between rocks formed in flood-plains or in other environments is commonplace. Detailed work on the physical features of the contact may reveal significant data not observed by the writer.

The elevation readings given above were made in connection with other work, and were not chosen to test any theory of formation of the terraces. The higher elevations were found to lie toward the center of the county, corresponding to higher present elevations of the land surface; lower elevations of the contact are found in the topographically lower portions. This fact has no particular significance in itself, since lower terraces would ordinarily have lower surfaces of unconformity as their bases. On the theory of marine erosion, however, it might be expected that there would be a higher frequency of readings at certain levels, corresponding to sea levels at the time of formation of the several terraces postulated. The lack of any apparent "elevation-tendency" in the readings may be taken as very tentative evidence against the theory of marine erosion. Additional data may serve to test the utility of this method of study.

Conclusions: The Pleistocene deposits of Charles County still present a number of baffling problems. These problems are perhaps not insoluble, but their solution awaits sufficiently detailed field and laboratory work. The conclusions presented at this time are tentative.

(1) So far, it has not been possible to work out their nature and origin by ordinary geologic methods. Poor exposures, great variation in lithology, and lack of fossils make it difficult to unravel their origin or to correlate them from place to place.

Physiographic expression has been used in the past as the chief criterion for distinguishing different units; the great lack of unanimity among workers using this method is a measure of the difficulties encountered in its use.

(2) The writer's views are largely in accord with those of Wentworth and Campbell. The lower terraces—up to an elevation of about 60 feet—are believed to be clearly the work of the Potomac River. Higher gravels are thought to have been formed in flood-plains or alluvial fans, probably of an ancient Potomac. There is no evidence for scarps higher than 60 feet, and there is no known method for separating gravels higher than that figure.

(3) Since the writer has been unable to separate definite units within the Pleistocene, he has used the old, and probably artificial classification in the geologic map of the county. With no new classification to propose, the choice was between mapping all gravels (and associated sands and clays) as one unit, or to employ the criteria used in previous Coastal Plain reports.

There are valid reasons for not treating all the gravels as a unit. For one thing, some are obviously younger than others, as, for example, the low terraces bordering the present Potomac. And though lithologic criteria are seldom applicable for any specific case of differentiation, there are some over-all differences. The highest materials, mapped as Brandywine, are usually made up in considerable part of clay and silt; coarse sand is fairly common, but pebbles larger than one-half inch or an inch are unusual. At intermediate elevations, coarse sand and gravel predominate; pebbles and cobbles up to six inches in size make beds several feet thick. Clay and silt, though admixed with coarser materials, seldom form thick beds. In the lowest terraces there is a similar variety, but horizons of more cleanly "washed" sand and gravel occur. In addition, large blocks a foot or several feet across may represent ice-rafted materials; blocks of this size have not been seen in the higher terraces.

The geologic map, therefore, gives some recognition to these lithologic differences associated with differences in elevation. The contact between the "Talbot" and "Wicomico" terraces has been drawn at the 60-foot scarp described above. Contacts at higher elevations have been drawn in at elevations established in earlier reports. There are no data, other than a broad lithologic difference, to support the present mapping of higher terraces.

SUBSURFACE GEOLOGY

General statement: The separation, by means of well samples, of the Pleistocene deposits from the underlying Miocene formations is difficult. In the first place the rocks are generally very similar both in constituents and in color. In the second place samples taken from the upper few feet of a well are more likely to be contaminated than those from lower down, because the hole is larger near the surface and the material is more unconsolidated and hence caves easily. The criterion for separation in surface exposures, the presence or absence of gravel, cannot very well be applied to well samples, since gravel is likely to contaminate well samples in the upper part of the hole. On the lowest marine terrace the presence or absence of marine fossils cannot be used as a criterion.

Distribution: All the wells studied start in Pleistocene or Recent deposits, but satisfactory samples from the top of the hole are usually lacking.

Lithology: The Pleistocene material is sand, clay, and gravel, and its color is generally moderate yellow, and dark grayish and grayish-yellow orange. The color is due chiefly to oxidation.

Thickness: No definite thickness of the Pleistocene can be obtained from the well samples.

In the Kierstead well the thickness appears to be about 13 feet; in the Maryland State Police well, a change in lithology of the samples from sand and gravel to clay occurs at 35 feet below the surface; in the Southern Maryland Cleaners well a change is found at 30 feet and in the La Plata Town well, at 20 feet. In the Clemens and Bowling wells the change is at 35 feet; in the Pace well, at 20 feet, and in the Sullivan well, at 10 feet.

From the above figures the maximum is indicated to be about 35 feet, but the actual thickness may be somewhat less than this.

Strike and Dip: The well samples give no data that would permit the determination of the strike or dip of the deposits.

Age: Neither the age of the deposits nor their relative age can be determined from the well cuttings.

STRUCTURE

General Statement: In the section on "Popular Geology," it was shown that the portion of the earth that is now Charles County has undergone considerable movement during its geologic history. It has been lifted above sealevel, depressed below sealevel, and has been tilted. During these movements, the rock probably broke at some places, giving rise to faults. It is also probable that some lateral compressive forces acted on the rocks.

The method of determining the structure of an area is to get the strikes and dips of beds, of contacts between formations, and of faults, or other features that might have a bearing on the study. Surface observations of many kinds can be made on hard rocks, but on soft rocks such as those of Charles County these are greatly limited. The difficulty is immeasureably increased when the beds have a very low dip as they do in Charles County. Almost nothing could be learned there of the details of the structure until samples of well cuttings became available. Even now the well cuttings can give but a generalized picture of the subsurface because of the small number of wells from which cuttings have been obtained.

Charles County is only a very small part of the Coastal Plain province of Maryland; its contribution to the knowledge of the structure of the Coastal Plain as a whole can be only a small one. This contribution does, however, point the way for future work.

Structure Contour Maps. Plates I, III, V (in pocket) are maps which show subsurface contours on certain geologic features. To those who are not familiar with contour maps and their use, a word of explanation may be necessary. A topographic map, such as the county maps issued by the Department of Geology, Mines and

Water Resources, is one which in addition to culture—houses, roads, towns, and other man-made features—and drainage—streams, swamps, rivers—shows surface relief—hills, valleys, plains. This relief is indicated by brown lines known as contour lines. A contour line is a line drawn through points of equal elevation—the elevation being measured from sea level. A contour line marked 100 on the county maps would mean that all points on that line are 100 feet above sea level. If the water in the ocean should rise 100 feet it would come up to the 100-foot contour which would then be sea level and the shore line. On the county maps the intervals between the adjacent brown lines represent 20 feet difference in elevation. If the lines are close together in an area, it means that the slopes or hillsides in the area represented by the map are steep.

A subsurface contour map is based on the same principle as the surface topographic map. The difference is that the picture presented by the contour lines has nothing to do with present day topography. It may however tell something about ancient topography, or may show the folding, tilting, or fracture of the beds beneath the surface.

To make such a map we find out where certain recognizable beds or geologic features are located underground and in outcrops on the surface. To locate them on a map we must know their geographic location and their elevation above or below sea level. When as many as possible of these points have been determined lines are drawn through similar points of equal elevation, and a contour map such as Plate I is the result; such a map shows us where the geologic feature depicted lies underground, and how deeply it is buried.

A homely illustration will show the method used in making is these maps. Suppose you were in Baltimore and didn't know where the No. 10 bus ran. Suppose also you had a map of Baltimore, and while wandering around the streets you noted just where you saw a No. 10 bus every time you saw one. As your points accumulated you got a better and better idea of just where the bus went, and soon you would be able to make a map of its route. In a similar way we look for say a No. 10 fossil bed underground as shown by our well samples. As we find this bed in more and more wells, we are able finally to make a map which shows the depth at which it lies anywhere in the county.

As a result of this type of work it is possible now to make maps of the position underground of three very well marked geologic features. These features, described in detail in another part of the report, are the bottom of a diatomaceous earth bed, the bottom of a "pink" clay bed, and the bottom of a series of greensand beds. If you should be interested in diatomaceous earth the maps will show you where to look for it and at what depth you will find it; if you are interested in clay you can find out just where and how deep to look for the "pink" clay bed; if you are looking for water the maps will give the approximate depth it will be necessary to drill below sea level to reach the water-bearing sands.

Contact Surface—Cretaceous-Aquia Rocks: The contour map (Plate I) showing the contact surface between the Aquia formation and the Cretaceous system is based on only 8 points. The contour lines are, therefore, generalized and only bring out the more prominent features of the surface. These features are the dip of the surface toward the southeast at about 20 feet to the mile; the flattening of this dip in the vicinity of Zekiah Swamp to about 6 feet to the mile; the overall strike of N 35°E; and the valley-like bend in the contour lines in the vicinity of Spring Hill and Port Tobacco.

Figure 7 shows that the Basement complex at the base of the Cretaceous system had an average dip toward the southeast of about 43 feet to the mile. This wedge-like relationship between the Cretaceous-Aquia surface and the Basement surface necessitates the thickening to the southeast of the Tertiary-Cretaceous geologic section as a whole. Individual formations, however, such as the Aquia and Nanjemoy, seem to thin out to the east and disappear altogether.

A long time interval of which we have no record of deposition exists between the Cretaceous system of Charles County and the Eocene series. Erosion of the Cretaceous surface undoubtedly took place in that interval, but the effects of it are not known. There is no evidence to show whether or not the surface represented by the map is due to erosion alone or to a combination of erosion and earth movements.

Contact Surface—Aquia-Nanjemoy Formations: The contour map Plate III (in pocket) showing the contact surface between the Aquia and the Nanjemoy formations is based on a fairly large number of well observations. More detail is shown here than on the map of the surface at the base of the Aquia formation.

The principal feature brought out here and one that may have considerable geologic significance is the marked flattening of the dip east of the St. Marys County line. The dip in the central part of Charles County is about 19 feet to the mile and in St. Marys County only about 5 feet to the mile. A similar flattening, although not so marked was noted in the basal Aquia formation surface (Plate I). The greater detail of this map shows three valley-like depressions, and several very marked swings of the contour lines. An overall strike is approximately N 42°E—one not greatly different from that of the Miocene—Eocene contact surface, or of the Eocene—Cretaceous contact surface.

Whether the surface is an erosional one, which it looks like, or a combination of erosion and movement cannot yet be determined. These interpretations will have to await study over a larger area.

An isopach map (Plate II) indicates a troughlike area of maximum deposition trending about N 32°E from the central part of the county. This possible depression extends at least as far as Upper Marlboro in Prince Georges County.

Contact Surface—Calvert-Nanjemoy Formations: The contour map (Plate V (in Pocket)) is based on a large number of observations. The map indicates a uniformly southeastward dipping plane, which shows very little change in dip and only two rather minor changes in strike.

As in the Nanjemoy-Aquia contact surface, flattening of the dip occurs east of the Charles County boundary in St. Marys County, but this is not so abrupt as on the older surfaces. The change, however, seems to be of considerable significance. In southern Calvert County, well samples contain foraminifera that are probably of Upper Eocene (Jackson) age. In St. Marys County in the area of flattened dip, well samples so far examined show rocks lithologically similar to the Jackson rocks of Calvert County. These facts suggest that the line along which the change of dip occurs corresponds rather closely to the westward extent of the Jackson rocks, and consequently may indicate the approximate location of the shores of the Jackson sea.

TABLE XIII

Comparison of Average Dips on Contact Surfaces in Charles and St. Marys Counties

(Feet to the Mile)

Contact Surfaces	Charles County	St. Marys County
Basement—Cretaceous	43	43
Cretaceous—Aquia	20	6
Aquia—Nanjemoy	19	5
Nanjemoy—Miocene	12	7

The general strike of the Calvert-Nanjemoy contact surface is N. 38° E. This strike has been rather constant for all three surfaces.

The flattening of the dip of the contact planes toward the southeast is brought out in table XIII.

DETAILED DESCRIPTION OF SURFACE ROCK EXPOSURES IN CHARLES COUNTY

Explanatory Statement

The following sections, at numbered localities, have been measured at the more important exposures within the county; a few sections just outside the county have been added for completeness. All thicknesses are in feet.

In a number of cases, the elevation of some part of the section is given. These elevations are corrected Paulin altimeter readings, and are probably no more than a few feet in error. In a few cases, elevations have been estimated; these may be in error by 20 feet or more. Locations along the Potomac River are given in feet from some named map locality; these measurements, made by pacing along the shore, may be considerably in error.

Insofar as possible, localities have been numbered in accordance with the age of the rocks exposed, the lowest numbers corresponding to oldest beds. Because of the simple structure, this arrangement is approximately geographic; most of the localities with low numbers are in the western half of the county. But since the correspondence is by no means invariable, the list below should be consulted.

Pleistocene beds will be found under the following: (1), (2), (4), (8), (12), (19), (25), (26), (27), (30), (31), (32), (34), (39), (42), (43), and (44).

Miocene beds will be found under the following: (7), (8), (11), (12), (13), (14), (17), (19), (21), (24), (25), (26), (27), (28), (29), (30), (31), (34), (36), (38), (39), (40), (41), (42), (43), (44), (45), (46), and (47).

Eocene beds will be found under the following: (2), (3), (4), (5), (6), (7), (8), (9), (10), (11), (12), (13), (15), (16), (17), (18), (19), (20), (21), (22), (23), (28), (29), (30), (31), (33), (35), (36), and (37).

Cretaceous beds will be found under the following: (1), (2), and (4).

It should be understood that exposures in the unconsolidated rocks of Charles County are likely to change appearance radically within a few years. Some of the sections described below were visited as far back as 1927, others in the 1930's. Several of these, when revisited in 1947, were so overgrown as to be unrecognizable. Even the exposures along the Potomac River may be well-exposed one year, almost hidden by vegetation a few years later. Recognition of these possible changes may explain failure to find exposures as described.

Description of Sections

Locality (1)

This is not one specific locality, but the shore of the Potomac River from the northwest boundary of Charles County to about 3 miles below Indian Head; about 10 to 12 miles N.W. of La Plata.

The greater part of this shore, with the exception of localities (2) and (3), is formed by Cretaceous or Pleistocene deposits. Above Glymont, the shore is mostly overgrown; exposures are poor. Below Glymont, exposures are much better, but are in highly variable Cretaceous clays and sands. No persistent beds or horizons were seen.

Locality (2)

Bluff about 1500 feet above (northeast of) Glymont wharf, Potomac River. Locality about 10½ miles N.W. of La Plata. This important exposure has not been adequately described below. It is the finest and most complete section of the Eocene rocks in Charles County, and should serve as the starting point for more detailed work on these beds.

Age		*Thickness feet*
Pleistocene	Reddish material with pebbles and boulders	20
Eocene	Light yellowish and greenish sands	3
	Very much weathered greensand without fossils	5
	Greensand with fossils, becoming much weathered toward top, where fossils stop	6
	Indurated zone, impressions and shells	1
	Fossiliferous greensand; quite green but not dark. *Ostrea* and *Turritella* common	22
	Greensand without fossils; quite dark near base and becomes lighter (more weathered ?) upward	8
	Sharp contact, with few small pebbles lying just above. Minor erosional irregularities.	
Cretaceous	Light blue or olive yellowish or brownish clays, weathering light gray to whitish	6
	Firmly indurated zone ½ inch thick	
	Yellow sands and sandy clays	15

Locality (3)

Bluff on shore of Potomac River, about ½ mile above wharf at Glymont, about 10 miles N.W. of La Plata.

It is believed that this is the approximate location of the section given in the Eocene volume, p. 68. It is very similar to the section at locality (2).

Locality (4)

Shore of Potomac River, about 1000 to 2000 feet below Sandy Point, at beginning of Mallow Bay, about 16 miles W. of La Plata.

Low bluffs of Eocene greensand; few molds and impressions of pelecypods; greensand weathered and yellow.

(North of this locality, from Stump Neck to Mallow Bay there are small exposures, some Pleistocene rocks, others probably in Cretaceous beds. Fossil wood seen about 1500 feet below Budds Ferry.)

Locality (5)

Shore of Potomac River, 2150 feet south of wharf at Liverpool Point, about 17 miles W.S.W. of La Plata.

(In this stretch Eocene greensand is visible more or less continuously from 1730 feet to 4840 feet below the wharf).

Age		*Thickness feet*
Eocene	Apparently much weathered greensand	5
	More weathered greensand, not so many fossils, including *Meretrix* and *Ostrea*. Sharp contact at bottom.	5
	Greensand with many fossils, especially in two bands of about two feet at bottom and two feet at top.	10½
	Dark greensand with some impressions and shells	4½
	(In this vicinity there is an indurated zone with *Ostrea* at elevation of 18½ feet. At 4300 feet there is indurated zone at 22–23 feet.)	

Locality (6)

Shore of Potomac River, from 12000 to 17700 feet below Liverpool wharf (or 6880 to 1180 feet above Clifton Beach wharf). Outcrops of Eocene greensand occur intermittently along this stretch of shore. For a great part of the distance there is an indurated zone at elevation of about 4½ to 5½ feet. In the more southerly exposures there is an indurated zone at about 11–12 feet, with large *Turritella mortoni*, resembling the indurated zone described from Aquia Creek in Virginia. The section is 12080 feet below Liverpool wharf:

Age		*Thickness feet*
Eocene	Firmly indurated zone with casts of *Turritella* and *Crassatellites*	1
	Greensand packed with fossils—*Ostrea*, *Isocardia* (?), *Dosiniopsis*, *Crassatellites alaeformis*, *Turritella mortoni*, *Venericardia*	5½
	Indurated zone, very firm	1
	Greensand, few fossils	4½

The section 15320 feet below Liverpool wharf (or 3560 feet above Clifton Beach):

Age		*Thickness feet*
	(at about 15000 feet large fallen slabs of indurated zone full of *Turritella mortoni* along the shore)	
Eocene	Zone full of *Turritella mortoni*	3½
	Firmly indurated zone	1
	Greensand packed with fossils	5½
	Zone of discontinuous indurations	1
	Very dark greensand with *Meretrix*	3½

Locality (7)

Eocene-Miocene formations contact near Pomonkey. To reach: Property of J. Warren (in 1927) is on road going off to south from elevation "175" about ½ mile S.W. of name "Pomonkey" on map. Across road is house not marked on map. Keep to right of house, past pump house, and into head of little stream which starts nearby; about 100 yards down stream is waterfall 3 to 4 feet high, which is part of exposure. Locality about 8 miles N.W. of La Plata.

Age		Thickness feet
Miocene	Greenish-blue clay, lying on irregular surface of sandstone where latter is present	4
	Light gray to yellowish-gray firm sandstone, containing about 5% greensand. Lies on erosion surface of greensand below and is discontinuous	½
Eocene	Dark greensand with many molds and impressions of fossils, especially *Venericardia*	8

Locality (8)

Road-cut on hill, Pomfret-Pomonkey road, west side of Mattawoman Swamp about 1½ miles S.E. of "B.M.168" at Pomonkey; about 7 miles N.W. of La Plata.

Age		Thickness feet
Pleistocene	Coarse sand and pebbles to 1 inch in diameter	5
Miocene	Brown sand and sandy clay, grading into Pleistocene above	3
	Indurated zone about ½ inch thick. Whitish or light gray sandy clay. Near Eocene contact this clay is dove-colored, pure and fine-grained. About 1 foot above contact, bedding surface shows iron-stained vertical "joints," producing polygonal pattern; material filling "joints" is in places indurated	6
Eocene	Greensand with *Venericardia* and other pelecypod impressions. Contact with Miocene shows small waves few inches across and irregular larger penetrations of Miocene lithology into Eocene; suggest burrowing animals. Eocene just below contact is dull, light-greenish-gray, peppery greensand, overlain sharply by Miocene clay. About 11 feet below contact, indurated zone with many impressions	28
	Elevation of Eocene-Miocene contact, 119 feet.	

Locality (9)

About 1 mile north of Mason Springs (9 miles W.N.W. of La Plata), road crosses railroad tracks. Walk down track to the west (toward Indian Head) about 3500 feet, where outcrops begin. Railroad cuts on north side of track extend for about 750 feet. The section 3540 feet from road:

Age		Thickness feet
Eocene	Greensand, many fossils, especially *Turritella mortoni, C. alaeformis*	5
	Firmly indurated zone, many casts of *Turritella, Ostrea,* and *Crassatellites*	1
	Greensand, weathered, many shells, especially *Ostrea* and *Crassatellites.*	3

The section 3930 feet from road:

Eocene	Steel-gray fine sand covered at surface with reddish-yellow crust	12
	Weathered greensand, fine-grained, few fossils, yellow stain;	8
	Indurated zone	½
	Same as lowest at 3540 feet	3

Locality (10)

Up stream (which flows to north) crossing state road about 1½ miles southeast of Millards Mill (near Mason Springs). Take second branch of this stream to the right, heading off to the southwest (branch heads up toward Redhill). Locality about 7½ miles W.N.W. of La Plata.

A few hundred yards up this stream, low banks of Eocene greensand, with few impressions of pelecypods, probably *Meretrix*.

Locality (11)

Exposure in stream bed about 1¼ miles S.W. of Durham Church, about 12 miles S.W. of La Plata. About 1¾ miles S.W. of Durham Church there is a triangular road intersection; approximately ½ mile northeast of this intersection, a small south-east-flowing stream heads up just to east of intersection. Locality is a few hundred yards down stream valley.

Age		*Thickness feet*
Eocene	Approximately 50 feet below the level of the road is greensand containing *Meretrix*. Above, there is a more or less continuous exposure of light olive-green to greenish clay and sandy clay. Some of this material may be of Miocene age. This locality was visited only once; it was wet and dark, and lithologies could not be readily differentiated.	

Locality (12)

Eocene-Miocene contact, and associated beds; road-cut on main road, Hilltop Hill, east side of Wards Run about 8 miles W.S.W. of La Plata.

Age		*Thickness feet*
Pleistocene	Pebble and cobble bed, exposed about at top of this hill; on north side of road there is isolated exposure of Pleistocene in pit. Material is very coarse, size up to 4–5 inches; typical of highest coarse beds in this part of county	5
Miocene	Generally brown, iron-stained, rather coarse sand, changing to fine-grained buff clayey sand above, with thin bed of "jointed" clay exposed at top	6
Eocene	Greensand, partly weathered with numerous lighter clay pieces included. At top is sharp, wavy contact, with Eocene beds often indurated somewhat for about 2–3 inches below	10
	Elevation of Eocene-Miocene contact, 105 feet	

Locality (13)

Eocene-Miocene contact on main road, road-cut on hill, curve on west side of Mill Run (Mill Swamp), about 6 miles W.S.W. of La Plata.

Age		*Thickness feet*
Miocene	Fine-grained, white sand, slightly clayey, more so above	11
	Gray, clayey sand, with more clay toward top. At base there is thin layer of fine-grained light yellow sand which is partly indurated. At contact are few quartz pebbles to ¼ inch in size.	5
Eocene	Somewhat weathered greensand; within few feet of top is irregular, and stained pinkish. Concretions about three feet below contact, which is sharp and wavy.	20
	Elevation of Eocene-Miocene contact, 97 feet	

Locality (14)

Down stream bed to west from La Plata-Rock Point road; stream crosses road about 1 mile south of town limits of La Plata.

Age		*Thickness feet*
Miocene	A few hundred yards down this stream, at an estimated elevation some 30 feet below the level of the road is exposed about 20 feet of clay, mostly greenish and bluish, containing casts of fossils. No other information can be given; the material in all probability is Miocene in age, and the scarcity of fossils in the Miocene rocks of the county makes this mention worthwhile.	

Locality (15)

In the bed of Hoghole Run, at a location estimated by stream intersections and contours to be about the 35 foot contour. Locality is about 3½ miles W.S.W. of La Plata.

Age	
Eocene	Exposed about 5 feet only of greensand with casts of *Venericardia*, *Corbula*, and *Fusus* (?). The first is rather scarce, but the other two are very numerous.

Locality (16)

In bed of second stream coming from west, north of Port Tobacco bridge on old La Plata-Indian Head road. Locality about 3 miles W.N.W. of La Plata.

Age	
Eocene	At an estimated elevation of from 60 to 70 feet: About 10 feet of greensand full of casts of small pelecypods and few gastropods. Recognized are *Lucina*, *Meretrix*, *Corbula*, and *Venericardia*.

Locality (17)

This locality includes two road-cuts which are $\frac{4}{10}$ mile apart, along the road to Brentland and Blossom Point. This road starts from the main La Plata-Riverside road 1 mile west of McConchie. The road-cut lower stratigraphically is $1\frac{3}{10}$ miles south along the Brentland road, just at escarpment, east side of road; the other road-cut is $\frac{9}{10}$ mile from the main road ($\frac{4}{10}$ mile north of other exposure), both sides of road. About 7 miles S.W. of La Plata.

Age		*Thickness feet*
Pleistocene	Pebble and cobble bed and clay above, sharp contact	—
Miocene	Clay, pure at base, becoming less distinct above; makes prominent band on surface	3
	Greenish-gray clayey sand, somewhat mottled; darker at base from moisture	7
	Pure, white, fine-grained sand, diatomaceous (?)	2
	Slightly clayey mottled sand, changing gradually to layer above	5

(The beds above are found at the exposure $\frac{9}{10}$ mile from main road; elevation of base, 105 feet; beds below found at other road-cut.)

	At base clayey whitish sand making lighter band on exposure; above whitish to brown sands. Just above Eocene contact are irregular, very firm indurated masses about 3 inches thick. Few quartz pebbles to $\frac{1}{2}$ inch just above contact	10
	Eocene-Miocene contact (elevation, 95 feet)	
Eocene	Greensand, darker, "salt and pepper" toward base, weathering brown; lighter, and weathering light greenish toward top	20

The elevations show that the two exposures exactly join, and are stratigraphically continuous from one to the other

Locality (18)

Shore of Potomac River, 5820 feet above (north) Popes Creek, which is 9 miles almost south of La Plata.

Age		*Thickness feet*
Eocene	Greensand	—
	Zone of concretions	1
	Dark greensand, with numerous fossils. One foot above base is 2-inch band packed with *Venericardia*	$9\frac{1}{2}$
	Hidden	$2\frac{1}{2}$

Locality (19)

Shore of Potomac River, 6070 feet above Popes Creek. (Measurements from about 35 feet upward were estimated.)

Age		*Thickness feet*
Pleistocene	Reddish pebble-bearing material	15
Miocene	Diatomaceous earth	16
	Light-colored sandy material	8
	Light, whitish-gray clay	9
	Dark clay (wet?)	3
	Sharp contact	
Eocene	Greensand, largely without fossils. Bottom 22 feet much darker; zone of concretions 29 feet from the base.	35½

Locality (20)

Shore of Potomac River, from about 7000 feet to 10000 feet above Popes Creek.

Age		*Thickness feet*
Eocene	Along this section of the river there is but little opportunity to study the higher beds, but bluffs showing some 10 to 20 feet of greensand are almost continuous. Fossils are to be found in almost every exposure, those at 8400 and 8800 feet containing the best preserved fossils found in the Eocene of Charles County.	

Locality (21)

Shore of Potomac River, 10970 feet above Popes Creek. (Elevations above about 25 feet were not reached for examination or measurement.)

Age		*Thickness feet*
Miocene	Diatomaceous earth and associated beds	—
	Sharp contact	
Eocene	Weathered greensand with some traces of fossils. Much yellow and brown coloring	23
	Weathered greensand with large, prominent rosettes of selenite crystals. Fossil impressions and sharks' teeth not rare	9
	Variegated greensand with some fossils	13

Locality (22)

Shore of Potomac between 11000 feet and 27000 feet north of Popes Creek, 27000 feet being the beginning of bath-house at Chapel Point. Chapel Point is about 5½ miles S.S.W. of La Plata.

Age		*Thickness feet*
Eocene	The shore for this considerable distance has rather consistently low bluffs, which seldom rise over 15 to 20 feet. Greensand with or without fossils is exposed throughout the whole length except where valleys break the continuity. The localities at the following number of feet above Popes Creek have well preserved or numerous	

		Thickness feet
	fossils: 14220, not many *Venericardia*, more *Corbula* and *Crassatellites*; 14650, many *Ostrea compressirostra*; 19080, many fossils; 20860, many fossils; 23200, many fossils in band just above water level; 23620, *Ostrea* near water level, other fossils above; 26780 shows the following section:	
	Lighter greensand above weathered greensand, few impressions	11
	Weathered greensand, many fossils	7
	Yellow and brownish greensand	2
	Fossiliferous greensand	1

Locality (23)

Up stream from intersection of road and stream; stream comes from a little N. of E. and crosses road just south of Warehouse Landing (about 3 miles S.W. of La Plata).

Age	
Eocene	Along this stream there are very low banks of Eocene greensand. At elevations estimated to be about 20 feet and 40 feet above the intersection with the road, impressions of shells are to be seen. These are poorly preserved, but resemble *Venericardia*.

Locality (24)

Ravine about 200 yards southeast of St. Thomas Church (overlooking Chapel Point, about 5 miles S.S.W. of La Plata).

Age		Thickness feet
Miocene	Sand, from nearly pure white to yellowish. Very fine	23
	Green, firm clay; breaks with "crackle"—exposed	1
	(The elevation of the base of this exposure was estimated from map to be about 90 feet.)	

Locality (25)

Road-cuts on main road leading east from La Plata, east and west sides of Clark Run, about ½ mile east of La Plata.

On both these hills: Miocene sandy clay or clayey sand overlain by Pleistocene deposits. The latter is usually coarse, some cobbles to 6 inches near the contact. Elevation of contact, east side of Clark Run, 178 feet.

Locality (26)

Road-cut on hill and exposure in gulley south of road; road leaves Allens Fresh-Newport road on east side of Zekiah Swamp and runs to Dentsville; about 1¼ miles along this road, just after making right turn (going north); about 7 miles S.S.E. of La Plata.

At this locality there are two sections, one exposed in the road-cuts and the other in a gulley at the south side of the road. The two sections were not correlated. One is apparently the weathered equivalent of the other, illustrating the difficulty of distinguishing the same stratum of the lower Calvert formation in its two conditions, weathered and unweathered. These sections deserve more study.

Age	*Section in road*	*Thickness feet*
Pleistocene	The Pleistocene deposits noted at this point are not the highest in the immediate vicinity; it follows the slope of the hill topographically and is found down to this level.	—
Miocene	At base light gray, slightly clayey sand, changing into light gray and light tan fine-grained pure sands (this is not the highest Miocene bed exposed in the hill, but the relations above are not clear).	24
	Earthy buff sandy clay with slight purplish tone; contains more than 50% diatoms and may be diatomite bed. Toward top contains rather pure clay layers alternating with iron-stained sandy layers ½ to 1 inch thick.	5
	Elevation base, 56 feet.	

Age	*Section in gulley*	*Thickness feet*
Miocene	Top exposed at 122 feet. From top to bottom is fine-grained light brown to light yellow sand, becoming more clayey toward the base	13
	Very sandy clay, with iron stains arranged in laminae or irregularly—grades into overlying and underlying	11
	Greenish, dark gray, very slightly sandy, firm, plastic clay. At first glance this clay looks glauconitic, but no grains of that mineral can be found.	2
	Dirty dark-buff clayey sand with slightly purplish (?) tone, grades into overlying	21
	Greenish very sandy clay which looks almost like greensand. At top is sharp and clean but irregular contact	12
	Elevation of base, 63 feet.	

Locality (27)

Road-cut on La Plata-Indian Head road; steep hill on east side of Port Tobacco Creek valley. About 2 miles N.W. of La Plata.

Age		*Thickness feet*
Pleistocene	Very coarse material, most over 1–2 inches in size and much 4–6 inches—exposed about	10
Miocene	Brown sand and sandy clay merging into overlying	11
	Fine-grained white sand; middle 10 feet look diatomaceous in type of weathering; top few feet more clay and iron staining; indefinite contact with overlying	32
	Elevation base Pleistocene series, 154 feet.	

Locality (28)

Road-cut on hill, west side of Clark Run, on road running east from Bel Alton, about 2 miles E.N.E. of Bel Alton, which is itself about 5 miles south of La Plata.

Age		Thickness feet
Miocene	Whitish, apparently diatomaceous material, but which seems heavier than diatomite at Popes Creek	10
	Yellow sand, fine-grained, indefinite upper contact	20
	White, fine-grained sand, rather sharp upper contact, exposed about	5
Eocene (?)	(About 50 to 100 yards east of this exposure, at beginning of valley flat, at north side of road is small tenant house with dug well. Owner stated that at depth of about 15 feet encountered dark green "earth" in which found vertebra and sharks' teeth. There is little doubt that this is the Eocene series. At depth reported this would be 45 feet below the top of the 5-foot bed of white sand (Miocene). However, there is no reason why this should be the highest Eocene bed in the immediate neighborhood. Eocene rocks may extend up into the hill to just below the white sand of the Miocene series, but its exact limits are not known.)	
	Elevation of top of 5-foot bed of white sand, about 105 feet.	

Locality (29)

Eocene-Miocene contact, small road-cut on hill, La Plata-Indian Head road, west side of Port Tobacco Creek valley, about 3½ miles N.W. of La Plata.

The location of this exposure cannot be given very closely. This stretch of road is later than the topographic map, and the new part is not put on accurately. However, after one crosses the valley on the main road, there is a fairly sharp right turn, and about two or three hundred yards along the road, in the very low and obscure exposures on the left side is the Eocene-Miocene contact.

Age		Thickness feet
Miocene	Fine-grained light-brown sand. Some slight reworking of greensand into base of Miocene deposits for few inches, and occasional pebbles to ¼ inch along contact.	3
Eocene	Somewhat weathered greensand. For about 2 feet below contact is indurated, locally firmly. Poor impressions of *Venericardia* and *Turritella*.	3
	Elevation of contact, 92 feet.	

Locality (30)

Popes Creek, section combined from bluff just downstream from mouth of Creek, and from road-cut along the north road entering Popes Creek. Popes Creek is 9 miles almost south of La Plata.

Age		Thickness feet
Pleistocene	Overlies Miocene rocks with sharp contact. At base is 6-inch gravel bed with material to 4 inches in size; then 3 feet of smaller material, 2 feet to 1–2 inches in size, then 3–4 feet of coarse sand at top of exposure. The Pleistocene bed at base is indurated for about 2 inches, this zone containing bituminous-looking black sand.	9½
Miocene	Fine-grained brown sand, lying with wavy contact on underlying	1
	Fine-grained white sand, changing downward to light brown sand with small content of clay	18
	Fine-grained whitish sand, slightly clayey, brownish below	19
	Dirty white sand, apparently overlying the diatomaceous earth which is not exposed on the road itself, but which can be seen in the gulley to the east of road	5½
	(Strata above exposed on road; strata below exposed in bluff on river).	
	Brownish fine-grained sand (probably bottom part of 19 ft. bed on road) with Pleistocene pebbles worked into the upper part.	5
	White, fine-grained sand, somewhat clayey at bottom, transitional from diatomaceous earth (probably same as 5½ ft. bed on road)	5
	Diatomaceous earth (diatomite) proper. Very light in weight; weathers dirty white with jointed, vertical faces. Few pebbles to ½ inch near base, no other signs of break.	17
	Sand, with little clay. Slightly indurated in places. Weathers spotted dirty gray and is not very different from underlying except possibly from greater content of water, which makes it darker	2
	Clayey sand. Earthy light brown with gray or purplish tone, fine, firm. The middle 2–3 feet are much purer sand; firmer toward top, passing without break into overlying. Slightly indurated at base, causing overhang of cliff just above the Eocene-Miocene contact.	15½
Eocene	Eocene greensand, fossils not rare. In the lower part of the section are fossil nuts (*Carpolithus*). The upper contact is sharp and unconformable, as is shown from the details of its configuration. Borings down into the greensand, filled with the overlying material, are found a foot or more below the contact.	22½
	Base of section at sea-level.	

Locality (31)

Road-cut on curve $\frac{4}{10}$ mile east of Mill Creek, La Plata-Riverside road, 6½ miles S.W. of La Plata.

Age		*Thickness feet*
Pleistocene	Pebble bed containing white clay pellets resembling bone	5
Miocene (?)	Light-colored sand or clay possibly to be included with underlying Eocene. Impressions of *Venericardia, Turritella*	10
Eocene	Greensand—generally darker at bottom and mostly much weathered. Lighter toward top	26
	Elevation base of Pleistocene, 104 feet.	

Locality (32)

Road running northwest from bridge on state road at Port Tobacco, about 3 miles W.S.W. of La Plata.

Age		*Thickness feet*
Pleistocene	At elevation of 153 feet have 12 feet of Pleistocene rocks, mostly composed of pebbles from 1–2 inches in size and rather evenly assorted. Slightly indurated with coarse sand matrix.	

Locality (33)

On road from Port Tobacco to Chapel Point, about 4 miles S.W. of La Plata.

Age	
Eocene	Near stream just south of Warehouse Landing road is little exposure of Eocene greensand at side of road, overlain by Pleistocene material much of which is 6 inches in diameter, some to 12 inches, average more than 3 inches.
	$\frac{3}{4}$ mile from Chapel Point main road is small exposure of Eocene greensand at side of road.

Locality (34)

Hill on Pomfret-Pomonkey road, about 1 mile northwest of Pomfret, east side of Mattawoman Swamp, about 7 miles northwest of La Plata.

Age		*Thickness feet*
Pleistocene	Pebble bed, with cobble bed at base, elevation of base 140 feet	5
Miocene	Brown clayey sand turning into sandy clay above	8
	Whitish fine-grained sand, slightly clayey; resembles that overlying diatomaceous earth at Popes Creek	3

Locality (35)

Small road-cut $\frac{2}{10}$ mile east of Mill Creek, La Plata-Riverside road, $6\frac{1}{2}$ miles S.W. of La Plata.

Age	
Eocene	Exposed about 5 feet of weathered greensand with minor contact of purplish clay (elev. 43 ft.) one inch thick at top; above, few feet of more weathered greensand.

Locality (36)

Small exposure on old road from near Newburg to Laidlows Ferry; approximately 1 mile from main road, at side road to right, where road crosses small stream on plank bridge; exposure to left (south), about 15 feet from road. Locality about 11 miles S. of La Plata.

Age		*Thickness feet*
Miocene (?)	Firmly indurated clayey material	½
	Clayey sand, greenish color	2
	Elevation of contact, 62 feet.	

Locality (37)

Port Tobacco Hill, 2½ miles S.W. of La Plata. Just south of rightangle turn in state road at Port Tobacco, an old abandoned road goes up over Port Tobacco Hill to the east. About 300 yards up this road and in small stream valley and dump to the left are small exposures of Eocene greensand with *Venericardia* shells and impressions.

Locality (38)

Ravine about 2½ miles east of Hughesville, about 13 miles E. of La Plata. On property occupied by Elmer Stonestreet (1947). Turn north on side road 0.9 mile east of intersection of Aquasco road and main Hughesville-Benedict road; follow side road for 0.5 mile, turn left into Stonestreet farm road; go to right of house. Just before reaching old barn, go through gate to right into field; continue along farm road through field for about 300 yards (about 50 yards beyond first tobacco barn). Exposure is in small stream valley which heads up to right near road; section described is near head of stream.

Age		*Thickness feet*
Miocene	Olive-green somewhat clayey, rather coarse sand. Resembles greensand in color and texture, but contains no glauconite. Generally without fossils	15
	Bed of shells; 4 inches at bottom full of shells, 5 inches bare, top 3 inches full. Contains the following forms:	1
	Venus	
	Turritella variabilis	
	Astarte thomasii	
	Cytherea staminea	
	Ecphora fragments	
	Astarte cuneiformis	
	Crassatellites melinus	
	Chione	
	Pecten madisonius	
	Greenish sand with thin bed of fossils (2–3 inches) about same as above; near base have two part-	

	Thickness feet
ings of pure sand, and possibly unconformable contact on underlying. On both sides of contact have discontinuous, firm indurations	$2\frac{1}{2}$
Bed almost solidly packed with well-preserved fossils. Fossils begin just under indurations described above. The fossils and their distribution are as follows:	10
Astarte cuneiformis	
Cytherea staminea	
Turritella variabilis	
Turritella plebeia	
Phacoides foremani	
Crassatellites melinus	
Pecten madisonius	
Macrocallista marylandica	
Corbula inaequalis	
Siphonalia devexa	
Cardium	
Arca subrostrata	
Polynices heros	
Ecphora fragments	
Venericardia granulata	
Venus	
Corbula elevata	
Glycymeris parilis	
The above forms are most numerous in the top 7 feet of the bed. *Glycymeris* is most numerous in a band about 4 feet from the top. At 7 feet from the top there is a band of indurations full of shells as follows:	
Pecten madisonius	
Melina maxillata	
Paramya	
Clementia inoceriformis	
Ostrea percrassa	
Astrhelia palmata	
The bottom 2–3 feet are formed of almost nothing but *Pecten madisonius* with practically no matrix. The very base is generally firmly indurated for a few inches.	
Greenish clayey sand; has olive-green color at top and becomes lighter downward. The top of this bed is extensively bored and irregular just beneath the indurations of the overlying, indicating unconformable relation. Generally not fossiliferous	8
Elevation of top (1 ft.) fossil band, 65 feet.	

Locality (39)

Road-cut near top of hill $1\frac{7}{10}$ miles west of Benedict, main road from Hughesville to Benedict. Locality about 14 miles east of La Plata.

Age		*Thickness feet*
Pleistocene	Reddish material with 1 foot band of pebbles to 1–2 inches in size	10
	Sharp contact showing signs of erosion	
Miocene	Mostly yellow fine-grained sand; clayey and partly indurated near top and having few "joints." About 8 feet above base are 2–3 feet of light-dove clay which breaks into small angular fragments	25
	Zone of iron-indurated bands each about ½ inch thick	. 1
	Whitish or light gray sand, slightly clayey	10
	Elevation of Miocene-Pleistocene contact, 120 feet.	

Locality (40)

Road-cut on hill on east side of stream about 500–600 yards east of Beantown, about 8 miles N.E. of La Plata.

Age	
Miocene	About 15 or 20 feet of very fine sand, which belongs doubtfully to the lower part of the Calvert formation, but which may be the Choptank formation. Impressions of fossils found in about the middle part of the exposure.

Locality (41)

In stream bed ("swamp") about 1½ miles east of Gallant Green, about 12 miles E.N.E. of La Plata.

Age	
Miocene	A more accurate location of this section cannot be given. The guide was a local resident, who said the "whole swamp" was underlain by blue clay containing shells. The shells are impressions of *Pecten*, about 5 inches high. According to Schoonover, pectens this large probably come from the Choptank formation. About 5 feet of section were seen.

Locality (42)

Road-cut on main road, Newton-Dentsville, east side of Zekiah Swamp valley; near top of hill. About 4½ miles S.E. of La Plata.

(This section is not described completely because it is so like (43), about 1 mile to the west. No mention is made of Pleistocene beds though they are at the top of the section, and attention is paid mostly to the iron-indurated, wavy contact of (43).)

Age	
Miocene	Brown clayey sand and clay, with vertical joints— The contact is an irregular, wavy iron-indurated zone from ½–1 inch thick, which may be single,

or may split into two parts as much as 2–2½ feet apart. Contains impressions of shells as follows:

Phacoides contractus
Turritella variabilis
Cardium (?)
Clementia (?)
Pecten madisonius
Venus (?) (large)
Solarium (?)
Astarte cuneiformis
Crassatellites (?)

Below, (3–4 feet) is white sand which is partly indurated or has indurations 1–2 feet below contact. White sand continues downward.

Elevations:

Pleistocene contact, 142 feet; indurated contact, 112 feet.

Locality (43)

Road-cut on main road, Newtown-Dentsville, west side of Zekiah Swamp valley. Hill is sharp break from flat on which Newtown lies. About 3½ miles S.E. of La Plata.

Age		*Thickness feet*
Pleistocene	Pebble bed, about 1–2 inch size	5
	Coarse sand and pebbles, generally less than 1 inch in size	3
	Pebble and cobble bed, most to 3–4 inches, and many to 6 inches in size; sharp, wavy contact below	1
Miocene	Fine-grained, tan-colored sand, with irregular but not sharp lower contact	2½
	Brown to tan sandy clay and clayey sand. Iron-stained vertical "joints" are numerous. About 3 feet below upper contact is ½ inch layer of light gray clay, in and near which there is bituminous-looking black material similar to that at Popes Creek	35
	The contact between the overlying and underlying may itself be from ½ inch to some 6 inches thick. It is a zone of iron indurations and iron laminae between which there is sand or clay. On the upper surface of the zone an impression of *Pecten madisonius* was seen. The contact is wavy and irregular and apparently represents an erosion surface.	
	White, somewhat clayey sand, at top, just under contact may have red, clayey, irregular patches. About 1–2 feet below contact have more or less ellipsoidal concretions or indurations, with long axes horizontal; firm, gray sandstone. Irregularly arranged in bed. In these concretions found:	20

Astarte cuneiformis
Turritella variabilis
Turritella plebeia
Calyptraea (?)
Nucula
Pecten madisonius
Pecten sp.
Asaphis or *Psammobia*
Polynices heros
Cadulus (?)

The proportions are roughly:
Turritella, 75%
Pectens, 20%
Others, 5%

Elevations: Top hill, 160 feet; base Pleistocene rocks, 145 feet; zone of concretions, 110 feet; lowest Miocene bed, 89 feet.

Locality (44)

Large road-cut at intersection of Waldorf-Bryantown road and road to Brice. About 1 mile northwest of Bryantown, and 7 miles E.N.E. of La Plata.

Age		*Thickness feet*
Pleistocene	Brown clay, weathers gray, without pebbles	10
	Clayey sand, mottled red, pebbles near top	4
	Sand at bottom changing to pebbly material and to pebble bed 2 feet thick at top. Iron-indurated layers from 5 to 8 feet above base	10
	Coarse pebble and cobble bed	2
	(In the Pleistocene deposits of this locality is a considerable percentage of light-colored chert pebbles, some of which contain Paleozoic fossils. *Spirifer*, *Stropheodonta*, and bryozoa were seen.)	
Miocene	Fine-grained brown sand	8
	Elevation of Miocene-Pleistocene contact, 160 feet.	

Locality (45)

Road-cut, south side of Swanson Creek, on Patuxent-Aquasco road, 1.1 miles north of Patuxent, 2.4 miles south of Aquasco; about 12½ miles E.N.E. of La Plata.

Age		*Thickness feet*
Miocene	At base 3 ft. layer of whitish fine-grained sand, diatomaceous (?), changing upward to brownish sand with some clay.	8
	Mostly gray clayey sand; enough clay to be coherent. Number of molds and casts of *Astarte*. Toward top is more sandy and brown	19
	At base gray sandy clay, changing near top to greenish dark clay containing fish scales and some impressions of pelecypods. Possibly the more sandy part is clay which has dried out	11
	Elevation of base of section, 50 feet.	

Locality (46)

Hollin Cliff, Calvert County (about 16 miles E.N.E. of La Plata). To reach, turn west off main road at Huntingtown. About a mile out of town keep left and continue to place where road has been blocked off, near entrance to house. Come back about ¼ mile to cattle bars leading into field to left. Continue at right angles to road across field toward river, which will be seen when top of bluffs is reached To the right (upstream) there is a good exposure of about the lowest 30 feet of the section, and some hundred yards downstream, in rather unpromising brush, is a continuation to about 70 feet above the river. The section is a composite of the two exposures.

Age		*Thickness feet*
Miocene	Clay, top fine-grained, weathered buff with yellow stains. More sandy toward bottom and apparently conformable on underlying	10
	Mostly light brown, pure sand with the following subdivisions:	18
	5 feet pure brown sand	
	½ foot iron-stained and indurated; some black (carbonaceous ?) material in and just below.	
	3 feet brown sand	
	7 feet very fossiliferous sand, with 2½ foot bed of *Ostrea percrassa* at base	
	2½ feet sand, lying on bored surface of underlying	
	Mostly greenish or bluish clay as exposed in lower (southern) part of bluff. However, at northern part looks sandy; offers another example of difference in appearance between weathered and unweathered material of the lower Calvert formation. At the top is an indurated zone about 1 foot thick, very firm and resistant (found as blocks on the shore)	21
	Diatomaceous earth (diatomite). This material grades imperceptibly into material above and below, so that the pure material is about 4 feet thinner than the thickness recorded	18
	Buff clay, rather sandy	5
	Blue, "brittle" clay, in places blue-green; firm, and chips under shale hammer	2
	Hidden to water level	6

Locality (47)

Road-cut on main Washington-La Plata road, south side of Piscataway Creek, turn on steep hill. Locality about 14 miles E.N.E. of La Plata or 2 miles N.W. of T.B. (Prince Georges County).

Age		*Thickness feet*
Pleistocene	Reddish material with pebbles	—
Miocene	Light brown, fine-grained somewhat clayey sand; contains more clay near upper contact and more near base. Changes gradually into underlying	10

	Thickeess feet
Light-gray pure clay (exposed)	2
(The above beds are exposed on the south side of road, and between them and the following beds on north side of road is a hidden vertical interval of some 30 feet.)	
Whitish sandy diatomite; the middle 15 feet seem to be more pure	35
Elevation of base of diatomite, 160 feet.	

DETAILED DESCRIPTION OF WELL CUTTINGS

Explanatory Statement

The following pages, Well Logs, give a detailed description of the well samples. Explanations of the terms used are needed.

Loc. No. is the location number of the well. The basis of the system is the U. S. Geological Survey Topographic sheet. The names of the sheets used are abbreviated as follows: Br.—Brandywine, Nj.—Nanjemoy, Wic.—Wicomico, I. H.—Indian Head, St.—Stafford. The sheet is divided into 9 equal rectangles. The northwest rectangle is numbered 1; the northeast, 3; the southeast rectangle is numbered 9. These rectangles are further subdivided into 9 smaller ones, and the secondary rectangles are still further subdivided if a precise location is needed.

The P. number is the well number.

Maryland State Coordinates are preceded by MSC.

El. (elevation) is the general elevation of ground level at the well.

The numbered intervals, such as 20–30, are the depths of the top and bottom of the sampled interval below ground level at the well. The elevation above or below sea level of any of these points can be obtained by subtracting the elevation of ground level from the depth given.

The color terms used are based on a standard color nomenclature.[14]

The lithologic terms are self-evident, but from the well samples it is not possible to say much about the structure of the materials; for example, one cannot tell definitely from a sample whether it represents a sandy clay or streaks of sand and clay.

The term "residue" is the name given to the material that remains after the sample has been washed over a 200-mesh screen; that is, after all the silt and clay have been washed away.

The size or grade terms used are based on the Wentworth System, and are determined by sieving.

WELL LOGS

Bowling Well

Loc. No.—Wic. 5-281; P. 1546; MSC 835-207
Loc.—Wicomico
El.—147 feet

Pleistocene series	
0–20	Dark-orange sandy clay; little sand.
20–30	Dark-orange sandy clay; a little gravel.
	Sand residue, fair, chiefly medium and coarse, a little fine and very fine; much oxidation.
Pleistocene-Miocene series	
30–40	Mixed moderate yellowish-orange and light yellowish-brown sandy clay.

[14] Judd, Deane B., and Kelly, Kenneth L. Method of Designation of Colors. Research Paper RP-1239, National Bureau of Standards, 1939.

	Sand residue, fair, chiefly fine and very fine, some medium and coarse; iron staining.
Miocene series	
40–50	Light yellowish-brown clay.
	Sand residue, small; sand, chiefly fine and very fine.
50–70	Weak brown sandy clay.
	Sand, little; fine and very fine.
70–80	Light olive-brown sandy clay.
	Sand residue, fair; sand, chiefly fine, some very fine and medium; medium sand, chiefly clear quartz, angular to subangular.
80–100	Light olive-brown, somewhat sandy clay.
	Sand residue, fair; fine and very fine.
100–120	Moderate olive-brown clay.
	Sand residue, fairly small; chiefly fine grain.
120–130	Weak-brown clay.
	Sand residue, very small; grade fine.
Miocene series	
Calvert formation	
Fairhaven member	
130–150	Weak-brown clay, little sand.
	Sand, chiefly fine and very fine; a little bone; diatoms, scarce.
150–160	Weak-yellow diatomaceous earth.
	Sand residue, very small; diatoms, common.
160–170	Weak-yellow diatomaceous earth.
	Residue, very small; quartz, fine, angular; diatoms, common; large forms, common.
Miocene (?) series	
170–180	Pale-olive sand.
	Sand residue, large; size, about equal parts fine to coarse; uncommon number of dark minerals in the very fine portion; coarse quartz, generally subangular with rounded edges; quartz, clear to partly cloudy.
	Shell fragments, fair; bone, fair; no diatoms noted.
Eocene (?) series	
180–190	Pale-olive sand; some clay.
	Sand residue, fair; size as in 170–180; no glauconite.
	Some shell fragments, considerable bone, a few teeth.
Eocene series	
Nanjemoy formation	
190–200	Olive-gray glauconitic sand; some clay.
	Sand residue, large; size, about equal parts coarse to very fine. Coarse material: shells, bone, quartz, and glauconite; quartz, subangular to subrounded, rounded edges, generally somewhat cloudy, but much clear quartz; glauconite, dull, rounded and irregular, black to light green; a little fine pyrite. Medium fraction: glauconite, much, chiefly irregular, dull, light green, some dark rounded grains; rare pieces of "book" type. Fine-grain portion: much glauconite, fair mica.
	Some shell fragments.
200–210	Weak-olive galuconitic sand; some clay.
	Sand residue, fair; size, about equal coarse to very fine. Coarse fraction: quartz, subrounded to rounded, partly cloudy, some pale milky quartz, shell and bone fragments; some pyrite,

pyrite generally associated with dusky-green glauconite; glauconite, irregular, dull, much dusky to weak green. Medium size: abundant glauconite, dark green and green-black, dull. Fine size: glauconite very abundant, some mica; some shell fragments.

210–220 Weak-olive glauconitic sand; some clay.

Sand residue, fair; about equal coarse to fine. Coarse glauconite, chiefly light olive-brown; much smooth and partly shiny glauconite, some dull botryoidal. Medium fraction: much glauconite, light olive-brown and green-black, generally irregular, dull, rare "book" types; quartz, angular to subangular, somewhat rounded on the edges. Fine fraction, abundant glauconite, chiefly dark green, dull, very little brown.

220–230 Weak-brown glaucomitic sand; some clay.

Sand residue, fair; size, coarse, a little medium to very fine. Coarse fraction, quartz, smooth, subrounded to rounded, shiny, partly cloudy, very little glauconite. Medium portion, much glauconite, irregular, dull, green-black, a little light olive-brown, a little pyrite. Fine fraction, much glauconite, fair mica, considerable green-stained quartz.

230–240 Weak-olive glauconitic sand; some clay.

Sand residue, fair; about equal parts coarse to fine. Coarse fraction, quartz as in 220–230, little glauconite. Medium fraction, much glauconite, rather dull, somewhat botryoidal, mostly green-black, but considerable weak dusky-green. Fine fraction, much glauconite, fair mica.

240–250 Weak-olive glauconitic sand.

Sand residue, large; sizes, about equal very coarse to fine; glauconite, chiefly in medium and fine sizes; mica, common in very fine. Medium portion: glauconite, somewhat botryoidal, shiny in part, green-black, a little dusky green; quartz, subrounded to rounded, partly cloudy, dull, and some clear shiny angular pieces.

250–260 Weak-olive sand; some clay.

Sand residue, fair; size, about equal amounts very coarse to medium; little fine and very fine. Coarse portion: glauconite, fair, botryoidal, shiny; quartz, subrounded, smooth, clear and partly cloudy. Medium size, glauconite, somewhat botryoidal, green-black, dull.

260–270 Weak-olive sandy clay.

Sand residue, small to fair.

270–280 Weak-olive sandy clay.

Sand residue, small to fair; size, chiefly medium, but fair amount of coarse, fine, and very fine; glauconite, chiefly in medium and fine. Coarse fraction: quartz, smooth, subangular to rounded, much subrounded, edges rounded, clear and partly cloudy, some green-stained; glauconite, fair, green-black, smooth, somewhat shiny, a little pyrite. Medium size: quartz, angular to subrounded, some sharp edged; glauconite, very abundant, somewhat rounded to somewhat botryoidal, generally dull, but a few shiny ends, green-black predominantly, a little dusky green, very rare light olive-brown pieces. Fine grade: very abundant glauconite, somewhat shot-like; fair mica.

280–290	Olive-gray glauconitic sand; some clay. Sand residue, fair; size, chiefly medium, fair, coarse, little fine or very fine; glauconite, chiefly fine, but much medium; cf. 270–280 for description of the glauconite.
290–300	Olive-gray glauconitic sand; some clay. Sand residue, fair; size, chiefly medium, but much coarse, little fine; glauconite, chiefly in fine, much in medium; cf. 270–280 for description.
300–310	Olive-gray glauconitic sand; some clay. Sand residue, fair; size, coarse and medium about equal; glauconite, chiefly in fine, fair in coarse, a little less in medium. Cf. 270–280.
310–320	Olive-gray glauconitic sand, some clay. Sand residue, fair; size, most medium, much coarse, little fine and very fine. Coarse portion: quartz, subangular to rounded, rounded edges, smooth, partly cloudy and clear, a little rose quartz, a little pyrite, some green-stained quartz, cinnamon-colored grains; glauconite, in part botryoidal, somewhat rounded. Medium fraction: quartz, subangular to angular, some rounded edges, some sharp edges; glauconite, abundant, black-green, botryoidal chiefly, some shiny pieces. Glauconite is about evenly distributed in the various size grains.
320–330	Olive-gray glauconitic sand; some clay. Sand residue, fair; sizes, about equal amounts coarse to fine; glauconite, evenly distributed. Coarse fraction: quartz, subrounded to rounded (cf. 270–280); glauconite, green-black botryoidal, rather dull, fair pyrite, crystallized. Medium size (cf. 270–280).
330–340	Weak brown clay; some sand. Sand residue, small; size, medium and fine; coarse fraction, quartz (cf. 270–280). Medium fraction: quartz, subangular to subrounded, much of it clear, etched; glauconite, fair, dull green-black, irregular and rounded; pieces of bone; glauconite much less than in previous specimens, and most of it in the fine size.
340–350	Weak brown clay; some sand. Sand residue, small; size, chiefly medium but nearly equal amounts of coarse and fine. Very coarse: shows bone and a piece of gastropod internal cast (hard, black). Coarse size: quartz, as in previous specimens; glauconite, rather dull, irregular to botryoidal. Medium size: quartz subangular, glauconite, generally dull and irregular; glauconite only fair in whole sample.
350–360	Pale olive clay; some sand. Sand residue, small; sizes, chiefly fine and medium; glauconite, scarce; bone fragments, common.
Eocene series	
Aquia formation	
360–370	Weak olive-gray sand. Sand residue, large; size, chiefly medium, much fine, no coarse or very fine; glauconite, fairly abundant in both sizes. Medium fraction: glauconite, dull, green-black chiefly, somewhat rounded; quartz, angular to subangular.
370–380	Weak olive-gray sand and clay. Sand residue, fairly large; sizes, medium, fair fine (cf. 360–370).
380–390	Weak olive-gray clay and sand.

Sand residue, fair; size, chiefly medium, much fine; glauconite, rather abundant (cf. 360–370).

I. & P. Company Well

Loc. No.—Wic. 1-847; P. 1231; MSC 808-217
Loc.—Spring Hill. Eight miles south of La Plata.
El.—140 feet

Pleistocene-Eocene series	
0–220	No samples taken.
Eocene series	
Nanjemoy formation	
Top (?)	
220–235	Weak-olive argillaceous greensand. Sand residue, fair; grade, chiefly medium, but much fine, fair coarse, some very fine; quartz, subrounded, etched, clear to partly cloudy; glauconite, abundant, black-green.
Nanjemoy formation	
Marlboro Clay member	
235–260	Light-brown (pink) clay.
Eocene series	
Aquia formation	
260–265	Olive-gray argillaceous greensand. Sand residue, small; sand, chiefly medium, much fine; quartz, subangular to ovoid, clear chiefly; glauconite, abundant in residue, botryoidal, mostly shiny, green-black.
265–279	Sandy marl. Residue, large, chiefly shell fragments; some lime-cemented hardshell.
279–285	Pepper and salt marly greensand.
285–295	Light olive-gray argillaceous greensand; grade, chiefly medium, fair fine; quartz, angular to ovoid, clear; glauconite, abundant, mixed light-green, some green-black, a little light-olive, smooth rather than botryoidal; many lime-cemented pieces. Foraminifera, abundant.
295–310	Moderate olive argillaceous greensand. Sand residue, fair; grade, medium, much fine quartz, as above; glauconite, abundant, much very fine, chiefly green-black, dull, but some light-green and a little dark-brown; yellow grains and yellow-stained quartz, common. Foraminifera, common.
310–320	Light olive-gray argillaceous greensand. Sand residue, little; grade, medium to fine; quartz, as above, mostly fine; glauconite, very abundant, particularly medium green-black, somewhat botryoidal, rather dull; some light-green; yellow grains, fair. Foraminifera, fair.
320–350	Mixed moderate yellow and green-black greensand. Sand residue, rather large; grade, medium, much fine, some coarse; quartz, as above; glauconite, very abundant, chiefly medium, mixed light-green and green-black, some light-olive; yellow grains, common.
350–380	Mixed moderate-yellow and green-black greensand.

	Sand residue, large; grade, chiefly medium, some fine and some coarse.
380–390	Argillaceous greensand.
	Sand residue, very small.
390–393	Pale-olive greensand.
	Grains chiefly fine, but considerable medium; glauconite abundant, chiefly black-green, but a little light-green and pale-olive, generally smooth and shiny, somewhat botryoidal, a few "book" forms; quartz, angular, etched, generally clear; a few yellow grains; mica, noticeable but not abundant.
	Foraminifera, scarce.
Cretaceous system	
393–408	Clay, mixed colors, chiefly moderate yellowish-brown.
	Very little sand; a few hard black shiny cherty pebbles, maximum diameter 8 mm.
408–415	Pale-brown arkosic sand.
	Sand, chiefly coarse and medium, little of the other grades; much quartz with grayish tinge ("blue quartz"), some pinkish quartz grains subangular, many etched; some pale milky.

Kierstead Well

Loc. No.—Br. 1-567; P. 930; MSC 813-316
Loc.—Piscataway, Prince Georges County
El.—50 feet
Pleistocene—Recent

0–13	Grayish yellowish-orange, slightly sandy clay.
	Sand residue, very small; sand, chiefly very fine, some fine.
13–20	Light-olive sticky clay.
	Sand residue, small; sand, chiefly very fine, some fine and medium; a little glauconite; considerable cloudy quartz. Organisms, very rare and very small.
	Foraminifera, fair.
Eocene (?) series	
Nanjemoy formation (?)	
20–32	Grayish-orange, pale-brown clay.
	Sand residue, very small, chiefly glauconite and quartz; probably the "pink" clay at the base of the Nanjemoy; forams, very rare; radiolaria, very rare.
Eocene series	
Aquia formation	
32–37	Grayish-olive clay.
	Sand residue, small; grade of sand chiefly very fine, much fine; quartz, generally clear, subrounded to ovoid; glauconite, not abundant, chiefly fine; fine mica, fairly common; a few shell fragments, ostracods, pieces of bone, a few radiolaria.
	Foraminifera, rare.
37–45	Brownish-gray clay.
	Sand residue, little to fair; grade, chiefly fine, but much very fine; quartz, as above; glauconite, fairly abundant, green-black, dull, somewhat botryoidal.
	Shell fragments, abundant; foraminifera, scarce.
45–55	Brownish-gray somewhat sandy clay.
	Cf. preceding interval.

55–62	Light olive-gray, slightly sandy clay. Sand residue, small; grade of sand, chiefly fine, much very fine, some medium; quartz, as above, but shows some etching; glauconite, abundant in residue, green-black, dull, irregular, a little light-green. Ostracods, few. Foraminifera, abundant.
62–70	Light olive-gray sandy clay. Sand residue, fair; sand grade, chiefly fine, but considerable medium and very fine; quartz, clear, subangular to subrounded, rounded edges; glauconite, abundant in the residue, green-black, dull, irregular; pieces of lime-cemented hard-shell; shell fragments, common. Foraminifera, abundant.
70–75	Light olive-gray sandy clay. Sand residue, fair; grade, chiefly fine, some very fine, little medium; glauconite, most abundant in very fine grade; some shell fragments. Foraminifera, common.
75–80	Olive-gray sandy clay. Sand residue, fair; grade, fine, but much medium and very fine; glauconite, very abundant, green-black, dull, somewhat botryoidal; little quartz. Foraminifera, rather scarce.
80–86	Grayish-olive sandy clay. Sand residue, fair; grade, fine to medium; glauconite, very abundant, green-black, dull, somewhat botryoidal; quartz, chiefly fine-grained. Foraminifera, scarce.
86–94	Light olive-gray clay. Sand residue, small; grade, fine, much very fine, some medium; much hard-shell (lime-cemented glauconite and quartz); glauconite, common, but much less than in previous intervals, green, black, dull, irregular. Foraminifera, scarce.
94–100	Cf. preceding interval; foraminifera, none.
100–104	Light olive-gray clay. Sand residue, small; grade, fine; some large gray shell fragments; quartz, subrounded, some of it etched, chiefly clear; glauconite, dull, green-black. Foraminifera, scarce.
104–109	Light brownish-gray sandy clay. Sand residue, fair; muscovite, fair; some hard-shell; some sea shell fragments.
109–113	Light brownish-gray sandy clay. Sand residue, fair; grade, fine; glauconite in residue, abundant; a little fine muscovite; much hard-shell. Foraminifera, scarce; shell fragments, abundant. *Turritella mortoni* fragments.
113–120	Brownish-gray slightly sandy clay. Sand residue, small to fair; grade, fine; glauconite, abundant in residue; few shell fragments. Foraminifera, very scarce, Eocene types.

Eocene (?) series	
120–128	Brownish-gray somewhat sandy clay. Sand residue, small to fair; grade, fine; glauconite, common, chiefly medium grade; muscovite, little. No foraminifera found.
Upper Cretaceous system	
Monmouth (?) formation	
128–137	Brownish-gray clay. Sand residue, small; grade, chiefly fine, but much very fine and some medium; glauconite, common; muscovite, fine, fair; a few shell fragments. Foraminifera, scarce; Upper Cretaceous types.
137–151	Brownish-gray, somewhat sandy clay. Sand residue, small; glauconite, much less than in preceding samples; a few shell fragments, mica common.
151–158	Brownish-gray, somewhat sandy clay. Sand residue, small; grade, very fine, some fine and medium; glauconite and quartz, as previously described; glauconite and quartz, cf. preceding sample; muscovite, common; a few shell fragments. No foraminifera.
158–166	Cf. preceding sample. Foraminifera, scarce, Upper Cretaceous forms.
Upper Cretaceous system	
Magothy (?) formation	
166–171	Brownish-gray sandy clay; pink clay at 169 feet; gravel at 170 feet. Residue, fair; chiefly very coarse sand and gravel, also some fine, very fine, and medium sand. Gravel maximum 18 mm, chiefly quartz, clear, gray and cloudy; some vein quartz, generally rounded; large (32 mm) pieces of wood abundant.
171–175	Gray gravel; maximum 14 mm, much 4 to 5 mm; most of it gray quartz, a little pinkish, some glassy, some greenish; much of the gray quartz in the 1 to 2 mm size; almost nothing below coarse grade.

La Plata Town Well

Loe: No.—Br. 7-574; P. 1398; MSC 809-254
Loc.—La Plata
El.—160 feet

Pleistocene series	
0–19	Weak yellowish-orange sand, clay and gravel. Gravel (max. 20 mm), subangular; chiefly white quartz, a little chert; some iron-stained quartz.
Miocene series	
Calvert formation	
Fairhaven member	
19–22	Weak-brown argillaceous sand. Sand residue, large. Sand, chiefly fine, much very fine, little medium; quartz, subangular to subrounded, clear.
22–30	Weak-brown argillaceous sand.

	Cf. preceding interval.
	Diatoms, fairly common.
30–40	Weak-brown sandy clay.
	Sand residue, fair; sand, nearly all very fine; mica, fair, fine.
	No diatoms noted.
40–75	Pale-olive clay, very little sand.
	Considerable bone; diatoms, abundant.
Eocene series	
Nanjemoy formation	
75–80	Light olive-gray sandy clay.
	Sand, considerable, chiefly very fine, much fine, little medium; quartz, subangular, clear, smoothly rounded; glauconite, common, green-black; mica, considerable, fine and very fine.
80–90	Weak-brown sandy clay.
	Sand, medium, fine, very fine; quartz, rounded on edges; glauconite, very abundant, green-black, somewhat botryoidal, shiny on edges; mica, common, fine; bone, scarce.
90–100	Olive-gray sandy clay; much sand.
	Sand, medium; quartz, generally clear, subangular, rounded edges, some of it green stained; glauconite, very abundant, green-black, somewhat botryoidal, shiny; mica, much, fine; shell fragments, rare.
100–110	Weak-brown sandy clay; sand, fair.
	Cf. previous interval; but shell fragments fairly common.
110–120	Pale-olive sandy clay; sand, fair.
	Sand, medium, fine, very fine, about equal.
120–160	Weak-olive sandy clay; sand, fair.
	Cf. 90–100 foot interval for description of constituents.
160–170	Pale-olive sandy and clayey marl.
	Sand, chiefly fine and very fine; quartz, angular, fine, clear, some green staining; glauconite, common, green-black, dull, somewhat angular; mica, common, fine and very fine; shell fragments, abundant.
	Foraminifera, scarce.
170–180	Brownish-gray sandy clay; fair sand.
	Sand, chiefly fine, fair medium; quartz, subangular, generally clear; glauconite, scarce; mica, fair to scarce; bone, common; pieces of lime-cemented glauconite grains.
180–190	Light brownish-gray clay.
	Sand, very little; mica, fine, considerable; some large shell fragments.
Nanjemoy formation	
Marlboro Clay member	
190–200	Light-brown (pink) clay.
	Much fine mica.
	Foraminifera, scarce.
200–210	Mixed light-brown and yellowish-gray clay.
Eocene series	
Aquia formation	
210–220	Olive-gray sandy clay.
	Sand, fair; grade, fine and very fine; glauconite, fairly common in fine grades; mica, common; some shell fragments.
220–230	Olive-gray sandy clay (marl).

	Residue, large; shell fragments; considerable sand, grade, fine; glauconite, abundant, green-black, a few pieces of light-green.
230–240	Olive-gray and light-brown argillaceous sand.
	Residue, as in previous interval.
	Hard-shell, 236–238 feet.
240–250	Weak yellow-green sandy clay.
	Sand residue, large; sand, chiefly fine, some medium; glauconite, abundant, green-black, not shiny, a few pieces of light-green; some lime-cemented glauconite grains; shell fragments, fairly abundant.
250–260	Weak yellow-green clay; little sand.
260–270	Weak yellow-green sandy clay.
	Sand residue, fair; sand, chiefly medium, but much fine; glauconite, abundant, dark-green, dull, irregular, a little light-green and olive.
270–290	Olive-gray argillaceous sand.
	Sand residue, large; grade, chiefly medium, much fine; quartz, clear, subangular, fine; glauconite, very abundant, green-black, irregular, dull, coarse-medium.
290–306	Light olive-gray argillaceous sand.
	Sand residue, fair; grade, chiefly fine, but fair medium and very fine; glauconite, abundant dark-green, dull; shell fragments, few.
306–313	Dusky yellow-green sandy clay.
	Sand residue, fair; grade, chiefly medium; quartz, subrounded to rounded; a little milky quartz; glauconite, common, dark-green; yellow and yellow stained quartz grains, common; shell fragments, fairly common.
	Foraminifera, scarce.
313–340	Dusky yellow-green argillaceous sand.
	Sand residue, large; grade, fine; glauconite, common, green-black, dull, a little olive; yellow grains, fair.
340–350	Brownish-gray sandy clay.
	Sand residue, fair; chiefly fine and very fine; glauconite, common, green-black, a little light-green, a few pieces of olive; mica, very common; sharks' teeth, a few shells, a few black pebbles. (Cf. 341—Parlett well for first appearance of mica.)
350–370	Light brownish-gray rather sandy clay; sand, chiefly fine and very fine, but up to gravel in size; much glauconite, medium and coarse, very little fine; glauconite, much green-black, but considerable light-green in finer sizes; mica, much in fine and very fine sizes; quartz, some ovoid, some milky, rounded edges.
	Foraminifera, scarce.
370–380	Light brownish-gray clay, very little sand; a little gravel; pyrite, common in coarser material, coarse, well-crystallized; quartz, angular to round, clear and partly clear; glauconite, common in medium and coarse grades, generally green-black, but some light-green.
Cretaceous system	
380–390	Weak to moderate-orange clay.
390–400	Weak-red clay; glauconite fairly abundant in residual material; some undetermined nodules.
400–420	Moderate yellowish-brown clay, little sand; nodules, common; glauconite, abundant in the washed residue, but very little in

	the whole sample; glauconite, light- and dark-green mixed; quartz, little, angular, much iron staining.
420–430	Moderate yellowish-brown clay. Little residue; a little gravel, glauconite, pellets (siderite (?)) scarce; quartz, angular, much iron staining.
	Foraminifera, none.
430–440	Moderate yellowish-brown clay.
	Little residue; sand, medium to very fine, chiefly fine—very fine; glauconite, scarce.
440–460	Pale-brown clay; some sand.
	Residue, rather large; sand, chiefly fine and very fine; much agglutinated material; quartz, angular, etched; lignite, scarce; no glauconite.
460–463	Weak-yellow arkosic sand.
	Sand residue, large; chiefly fine, but also much medium; quartz, angular, partly cloudy, a fair amount has a faint pink tinge; feldspar, scarce; much of the quartz etched.
463–470	Light olive-brown sand.
	Cf. previous interval for constituents.
470–480	Moderate yellowish-brown and moderate olive-brown sand.
	Cf. previous interval for constituents.
480–490	Dusky yellowish-orange clay; some sand.
	Sand residue, rather small; sand, medium to very fine; quartz, angular; muscovite, scarce; glauconite, rare.
490–510	Moderate yellowish-brown clay.
	Sand residue, very small.
510–520	Moderate-brown clay.
	Residue, very small, chiefly clay pellets.
520–545	Moderate yellowish-brown clay.
	(Similar to previous interval.)
545–546	Light yellowish-brown sand.
	Sand residue, large; sand, chiefly medium, but much coarse and fair fine; quartz, angular, etched; noticeable smoky-gray quartz, some carrying many inclusions ("blue quartz"—first appearance in this well); considerable medium-gray milky quartz.
546–550	Pale-brown clay.
	Sand residue, very small; lignite, common.
550–560	Light olive-brown clay; some sand.
	Sand residue, fair; sand, chiefly fine—very fine, some medium and coarse; considerable gray quartz in larger sizes.
560–570	Moderate yellowish-brown clay; some sand.
	Cf. previous interval.
570–580	Light brownish-gray clay.
	Sand residue, very small; yellow and iron-stained quartz; fair pyrite; well-crystallized quartz, etched.
580–590	Light brownish-gray clay.
	Sand residue, fair; much yellow-stained quartz; some pyrite.
590–600	Pale-brown slightly sandy clay.
600–620	Pale-brown sandy clay. A mechanical analysis of the sand shows the following: very coarse sand—12%; coarse sand—24%; medium sand—36%; fine sand—20%; very fine sand—8%.
620–630	Coarse sand and gravel.
630–640	Very pale-brown sandy clay.
640–734	Sample missing.

at 735	Reddish-brown argillaceous sand.
735–816	Sample missing.
at 816	Gray clay; very little sand.
at 835	Brown clay; little sand.
at 865	Red clay.
at 875	Yellowish sand; little clay.
at 880	Yellowish sand; red clay.
at 945	Red clay; a little gray clay.
1050–1072	Weak-brown sand; quartz, angular to subrounded; cloudy and partly cloudy; grade, chiefly medium.
1072–1076	Pale-brown medium sand; quartz, angular to subrounded, some cloudy, some faintly tinged hyacinth; fair pyrite or marcasite; fair opalescent quartz; "blue quartz" not seen.
1076–1094	No samples.

Maryland State Police Well

Loc. No.—Bra. 5-257; P. 1770; MSC 834-298
Loc.—Mattawoman, Charles County
El.—215 feet

Recent—Pleistocene series	
0–10	Moderate-yellow clay; little sand.
Pleistocene series	
10–20	Dusky yellowish-orange sand, clay, and gravel. Residue, chiefly gravel, very coarse, max. 10 mm, average 4–5 mm. Also about equal amounts coarse, medium, fine sand some very fine.
20–30	Weak yellowish-orange gravel, sand, and clay; gravel, much very coarse, max. 23 mm; sand about equal amounts very coarse to very fine.
Pleistocene-Miocene series	
30–40	Weak-yellow clay; little sand.
Miocene series	
Calvert formation	
Fairhaven member	
40–100	Weak-yellow clay, very little sand. Foraminifera scarce; diatoms abundant; some radiolaria.
100–110	Pale-olive sandy clay; sand residue, fair, grade chiefly very fine; some medium and fine. Coarse: chiefly bone fragments. No foraminifera found; a few radiolaria; fair diatoms.
110–120	Weak-brown sandy clay. Sand residue fair; size, chiefly very fine, some fine, no glauconite. Bone fragments, common. Diatoms, fair.
Eocene series	
Nanjemoy formation	
120–130	Pale-brown sand; some clay. Sand residue, large; size, about equal medium to very fine; some small pebbles (a thin pebble bed at the base of the Miocene series has been noted at a number of places); glauconite abundant in medium and fine sizes, a little coarse glauconite, somewhat shiny, botryoidal, green-black, sutures weak-green; quartz subrounded, smooth, clear and partly cloudy; medium glauconite rounded, chiefly dark-green, dull; a little rose quartz.

130–140	Pale-brown sand, some clay. Sand residue, large; size, medium—fine—very fine; glauconite abundant in medium and fine, little in very fine; coarse glauconite, mixed light-green and green-black, botryoidal, somewhat shiny; quartz, subangular, etched.
140–150	Light olive-gray sand; some clay. Sand residue, much; sizes, fine most, medium much, very fine some; glauconite abundant, coarse size, botryoidal, shiny; glauconite, much medium; quartz, angular to subangular, much clear; mica, some. Foraminifera—*Eponides lotus, Cibicides neelyi.*
150–160	Olive-gray sand and clay. Sand residue, fairly large; size, medium—fine; glauconite abundant, particularly in fine and very fine; medium glauconite, rounded to slightly botryoidal, green-black, a few weak-green pieces; quartz, etched; mica, some.
160–170	Light olive-gray sand and clay. Sand residue, fairly large; glauconite, cf. 150–160; more mica in this sample.
170–180	Light olive-gray sand and clay. Sand residue, fair; size, about equal medium to very fine; glauconite, abundant; coarse glauconite, irregular to somewhat rounded, generally green-black, but some grains a lighter green; quartz, angular to somewhat rounded, clear and cloudy; mica.
180–190	Light olive-gray clay. Sand residue, small, about equal amounts medium to very fine; glauconite abundant (cf. 170–180). Foraminifera—*Eponides lotus.*
190–200	Light olive-gray micaceous clay. Sand residue, very small; some pyrite. Foraminifera, fair.
200–210	Light olive-gray clay. Sand residue, little; size, fine, some medium; glauconite, fair, very dark, irregular and botryoidal; quartz, subangular to subrounded, mostly clear; glauconite, abundant in very fine fraction; some shell fragments and bone, dental pavements. Foraminifera, fairly common.
210–220	Light olive-gray clay and sand. Sand residue, fair; size, about equal medium to very fine; glauconite, rather abundant, black, dull, irregular to slightly rounded; medium quartz, subangular to subrounded. Shell fragments, fairly common. Foraminifera, fairly common.
Nanjemoy formation Marlboro Clay member	
220–230	Light-brown (pink) clay. Sand residue, very little. Foraminifera, scarce.
230–240	Pale-brown (pink) clay. Sand residue, none. Foraminifera, rather scarce.
Eocene series Aquia formation	
240–250	Light olive-gray sand; some clay.

	Sand residue, large; size, chiefly medium, much fine; quartz, angular to subrounded, mostly clear, some cloudy; glauconite, rather abundant in all fractions, dull, green-black, rounded to irregular.
	Foraminifera, scarce.
250–260	Light olive-gray clay.
	Sand residue, very small; coarse to very fine; coarse quartz, angular to smooth rounded; glauconite, very little, medium; mica, some. A little bone.
	Foraminifera, scarce.
260–270	Light olive-gray sandy marl.
	Residue, large, chiefly shell fragments.
	Sand size, medium to fine; glauconite, rather abundant in all sizes; medium glauconite somewhat darker than in following samples, chiefly dull, irregular and smooth.
270–280	Light olive-gray sandy marl.
	Residue, large, chiefly shell fragments.
	Grade of sand fraction, medium to fine.
	Bits of hard limestone (cf. Zone 9 of Standard Maryland section); glauconite, rather abundant as in 260–270.
	Foraminifera, abundant.
280–290	Light olive-gray sand, marl; a little fine pyrite (cf. 270–280).
	Foraminifera, fairly common.
290–300	Dusky yellowish-green sand; some clay.
	Sand residue, large; size, medium—fine; glauconite abundant in all fractions; dull, smooth, and slightly botryoidal, green-black to somewhat lighter green, a few pieces of olive-brown; a few yellow grains.
	Foraminifera, not abundant.
300–310	Dusky greenish-yellow sand; some clay.
	Sand residue, large; size, fine—medium; glauconite, rather abundant, about equal in all grades; glauconite, green-black, dull, somewhat botryoidal and rounded, a few olive-brown pieces; medium quartz, angular to subrounded, mostly clear.
	Foraminifera, rather abundant.
310–320	Dusky greenish-yellow sand; some clay.
	Sand residue, large; size, medium—fine; glauconite, abundant from coarse to very fine, generally botryoidal and smooth, green-black, partly shiny and some rounded olive-brown in the coarse size; in the medium size, glauconite green-black, irregular, dull, a few olive-brown pieces; quartz in medium size, subangular and angular with rounded edges; yellow grains common in coarse size.
	Foraminifera, fairly abundant.
320–330	Greenish-yellow sand; some clay.
	Sand residue, much; size, fine—medium; glauconite, common, irregular, green-black, some smooth, a little olive-brown and light-green; quartz, chiefly fine.
	Foraminifera, fairly common.
330–340	Dusky greenish-yellow sand; a little clay.
	Sand residue, large; chiefly fine grain, but fair medium grain; quartz, subangular to rounded and ovoid, clear to cloudy, yellow grains very noticeable; glauconite, rather abundant, dull, rounded to irregular, a little botryoidal, a few pieces of "book"

form, green-black chiefly, a few pieces of olive-brown, very little weak-green; glauconite, about equal percentages in all size grades; mica, fair in medium size.
Foraminifera, few; rare shell fragments.

340–350 Dusky greenish-yellow sand; a little clay.
Sand residue, large; glauconite, abundant, all size fractions.
Lithologic description as in previous sample.
Foraminifera, few.

350–360 Sample missing.

360–370 Light olive-gray sand; some clay.
Foraminifera, few.

370–380 Light olive-gray sand; some clay.
Sand residue, large; size, medium and fine; quartz subrounded to ovoid, some deep-red grains, a few yellow grains. Glauconite, fairly abundant in above sizes; rounded to irregular, fairly dull, most of it green-black, but a few olive-brown and weak-green pieces. Mica, fair, particularly in medium size.
Some large shell fragments.
Foraminifera, common.

380–390 Light brownish-gray clay.
Sand residue, small, about equal parts coarse to very fine; medium quartz, subangular to subrounded, rounded edges; glauconite, fair, dull, generally irregular; mica, fair.
Some bone and bone pebbles.

390–400 Light-gray clay.
Sand residue, very small; glauconite, very little; grade, fine to very fine; fair coarse and medium; medium quartz, angular to subrounded, clear and cloudy.
Fine pyrite, common; mica, fairly common.

400–410 Light olive-gray sand; some clay.
Sand residue, large; size, medium—fine; glauconite, rather abundant, somewhat rounded, some grains shiny.
Shell fragments, abundant.
Foraminifera, abundant.

Upper Cretaceous (?) system

410–420 Brownish-gray micaceous clay; some sand.
Sand residue, rather small; grade, medium to very fine; glauconite, rare. Some very coarse vein quartz; hard, cemented black rock; shell fragments, few; medium quartz, subrounded to rounded, mostly clear, fine and very fine; mica, fair.
Bone fragments.

420–430 Brownish-gray micaceous sandy clay.
Sand residue, fair; size, chiefly very fine, but some fine and medium. Quartz, subangular to rounded, clear to cloudy; glauconite, very little; a little bone and a few shell fragments; no feldspar or blue quartz seen.

430–448 Light brownish-gray sand.
Sand residue, very large; grade, coarse to very coarse, fair medium, very little fine and very fine. Very coarse: quartz, angular, rounded edges generally, dull, most of it smoky-gray translucent, also fair opaque, light gray. Coarse: similar to very coarse; a few grains of quartz show faint pinkish tinge, rare pyrite, and glauconite. Medium fraction: Cf. coarse; feldspar not seen.
Foraminifera, absent.

Menders Well

Loc. No.—Wic. 8-812; P. 572; MSC 832-163
Loc.—Woodlawn Point
El.—12 feet

Recent and Pleistocene series	
0–21	Dark and weak yellowish-orange sand. Sand grade, fine to very fine; mica, fine, scarce; quartz, angular, much clear, fair amount stained.
Miocene series	
Calvert formation	
21–32	Light olive-gray sand and clay. Washed sand, pale-brown; grade, medium, much coarse; quartz, smooth, subrounded, a little pink quartz.
32–42	Pale-brown sand and clay. Sand poorly sorted from very coarse to very fine; quartz grains, angular to subrounded, smoothed mostly, partly cloudy; shell fragments, abundant.
42–53	Weak-yellow clay and sand. Sand, medium to fine to very fine; sand is very pale brown; quartz, chiefly angular, some clear, most partly cloudy; shell fragments, rare.
53–76	Weak-olive sand and clay. Sand, medium to fine; a little coarse and very coarse; sand, pale-olive; mostly clear, sparkling, subangular to subrounded and rounded edges and corners; bone, fairly common; pebbles in lower portion.
Eocene series	
Nanjemoy formation	
76–93	Weak-olive sand and clay. Sand, chiefly coarse and medium; some gravel and fair shell fragments; glauconite, common, much of it light-green; some pyrite crystals on the glauconite. (Cf. 226–231, Southern Maryland Electric well.)
93–97	Weak-olive sandy clay. Sand, chiefly coarse and medium, some gravel, fair fine and very fine; glauconite, mixed light- and dark-green, rather dull, irregularly botryoidal, some in "book" form; some brown pieces; much mica; some yellow-stained quartz.
97–134	Weak-olive sandy clay. Sand, about equal amounts coarse to very fine; glauconite, very abundant, various shapes and colors; mica, some; some yellow-stained quartz; shell fragments, common; some red glauconite.
134–210	Weak olive-green sandy clay. Sand, chiefly medium; quartz, smooth, subangular to subrounded to rounded, some green-stained; glauconite, fine to medium, green-black, shiny; (Note change in character of the glauconite); mica, common; shells, rare.
210–230	Olive-gray clayey sand. Sand, chiefly medium grain; quartz, shiny, rounded, clear; glauconite, common, green-black, botryoidal.
Nanjemoy formation	
Marlboro Clay member	
230–240	Pale-brown clay.

Eocene series
Aquia formation

240–254	Brownish-gray sand; a little clay. Sand, chiefly medium; glauconite, very abundant, reddish-brown and some with green grains, irregular; hard shell at 253 feet.
254–268	Light brownish-gray greensand; grade, chiefly medium; quartz, rounded and subrounded, much iron-stained; glauconite, common, chiefly green-black in coarser grain, also reddish-brown; a few shell fragments, particularly at 262–268 feet.
268–273	Olive-gray greensand; grade, chiefly medium, some fine; glauconite, abundant, green-black, botryoidal; a few shell fragments; hard-shell.

Norris No. 2 Well

Loc. No.—Wic. 8-863; P. 477; MSC 840-159
Loc.—Cobb Island
El.—12 feet

Recent and Pleistocene series

0–21	Weak yellowish-orange sand; a little clay.

Miocene series

21–32	Pale-brown sandy clay. Sand residue, fair; grade, fine.

Miocene series
Calvert formation
Fairhaven member

32–42	Pale-brown sandy clay. Diatoms, fairly abundant.
42–53	Pale-brown sandy clay. Sand residue, small. Diatoms, very abundant.
53–63	Pale-brown sandy clay. Sand residue, fair; quartz, generally angular, edges smooth and rounded; bone, rare; barnacle fragments, few.
63–74	Pale-brown argillaceous sand. Sand, grade, fine generally; a few rounded pebbles; quartz, angular having edges rounded; larger quartz grains smooth and polished. Shell fragments, few. Cf. pebbles with thin pebble bed at base of Miocene series, Popes Creek outcrop. Diatoms, few.

Eocene series
Nanjemoy formation

74–84	Light olive-gray sand and clay. Sand, fine to coarse; glauconite, fairly abundant, dark-green and very light-green, no brown; muscovite, fairly common; some bone. Foraminifera, very rare, small.
84–95	Weak-brown sandy clay. Sand, fine to coarse; coarse grains rounded, smoothly polished, some grains slightly yellow stained; glauconite, abundant, fine to coarse, chiefly green, a few brown and red pieces; mica, common; shell fragments, present. Foraminifera, very rare.

95–105	Brownish-gray sandy clay. Cf. previous sample. Foraminifera, rare.
105–116	Olive-gray clayey sand. Glauconite, very abundant, some dark-green, but chiefly brownish to yellowish-green, some bright red pieces; mica, common. Shell fragments, common.
116–126	Olive-gray greensand, small amount of clay; glauconite abundant, chiefly dark-green, somewhat coarser than in previous sample; mica, common; shell fragments less than in preceding interval. Foraminifera, scarce.
126–137	Olive-gray greensand; glauconite, dark-green and generally coarse; quartz, rounded and subangular; corners of quartz grains rounded, smooth, polished. Foraminifera, very rare.
137–147	Olive-gray greensand; glauconite, dark-green, medium; quartz generally coarser than the glauconite; quartz, subangular to rounded, smooth, a fair amount has greenish tinge. Foraminifera, rare.
147–179	Olive-gray greensand, little clay; glauconite, dark-green, very abundant; little quartz, subangular to rounded, smooth. Foraminifera, very rare, small forms.
179–200	Olive-gray greensand; glauconite, abundant, dark-green; quartz, fair and fairly coarse, rounded and angular, smoothed edges; shell fragments, few. Foraminifera, very rare.
200–210	Olive-gray greensand; both quartz and glauconite abundant; glauconite, dark-green; no shell fragments. Foraminifera, very rare.
210–221	Pale-brown sand; quartz, abundant, subangular to rounded; glauconite, very common, green-black; bone; a little pyrite. Foraminifera, scarce.
221–231	Light olive-gray greensand; quartz, abundant, subangular, rounded edges; glauconite, very common, dark to light-green; some bone; a very little pyrite. Foraminifera, rare.
Nanjemoy formation Marlboro Clay member 231–241	Pale-brown clay; some sand. The "pink" clay (Marlboro Clay member) is not very well defined in samples from this well, but it shows up well in Miles Norris No. 1 well at 230–241 feet, about a mile away.
Eocene series Aquia formation 241–262	Mixed pale-brown and light olive-gray sand and clay; glauconite, green-black chiefly but much of it red; quartz, grains stained red. Foraminifera, very rare, poorly preserved.

Orth Well

Loc. No.—Wic. 5-587; P. 1050; MSC 837-194
Loc.—Mt. Victoria
El.—38 feet

Pleistocene series	
0–20	Weak yellowish-orange clayey sand and fine gravel.
Pleistocene (?) and Miocene (?) series	
20–50	Pale-brown mixed clay, sand, gravel.
Miocene series	
50–60	Pale-brown clay, sand, gravel. No diatoms found.
60–70	Light brownish-gray sand, clay, and gravel. No diatoms found.
70–80	Pale-brown clay, sand, and gravel. No diatoms found.
80–90	Light olive-gray clay. Quartz residue, fine. Foraminifera, rare.
Eocene series	
Nanjemoy formation	
90–110	Light olive-gray clay. Sand, fine; glauconite, abundant, light and dark-green; mica, much.
110–140	Brownish-gray clay; glauconite, abundant; mica, much.
140–170	Light olive-gray clay. Glauconite, light and dark-green; shell fragments, abundant; spicules and spines; mica, much.
170–230	Light olive-gray clayey sand. Green-black glauconite, abundant.
230–240	Olive-gray clayey sand. Quartz, subangular to angular; glauconite, very common, green-black; some bone; shell fragments.
240–250	Light olive-gray clayey sand. Quartz, fine; glauconite, common, fine. Foraminifera, rare.
250–270	Very pale-brown clay.
Eocene series	
Aquia formation	
270–280	Weak-olive sand and clay. Glauconite, abundant, considerable olive, much yellow-stained quartz; yellow grains present.
280–290	Weak-olive sand and clay. Cf. preceding interval. Foraminifera, very rare.
290–295	Sandy marl. No foraminifera.
295–300	Sample missing.
300–310	Light olive-gray sandy clay. Glauconite, abundant, chiefly green-black. Foraminifera, abundant.
310–320	Argillaceous greensand. Sand, fine; glauconite, mixed, green-black, light-green, olive. Foraminifera, scarce.
320–325	Dusky yellow-green argillaceous sand. Glauconite, green and olive; yellow grains, fair. Foraminifera, common.

325–330 Dusky yellow-green greensand.
Glauconite, mixed colors; yellow grains and stained quartz.
Foraminifera, scarce.

Pace Well

Loc. No.—Wic. 4-953; P. 1462; MSC 819-189
Loc.—Wayside
El.—60 feet

Recent and Pleistocene series

0–20 Weak yellowish-orange sand and gravel.
Residue, from gravel (max. 13 mm) to very fine sand, chiefly fine sand; quartz, angular to subangular, about half of it clear, much faintly iron-stained.

Miocene series
Calvert formation
Fairhaven member

20–30 Pale-olive sandy clay.
Grade, chiefly fine sand, much very fine; quartz, angular to subangular, much of it clear; bone fragments, scarce; diatoms, fairly common.

30–60 Dusky-yellow clay.
Sand residue, very small; grade, fine and very fine; bone, fairly common; diatoms, large, abundant.

60–80 Pale-olive clay.
Sand residue, very small; quartz, angular, somewhat black stained, much of it clear; bone, fair; diatoms, large, rare.

Eocene series
Nanjemoy formation

80–100 Light olive-gray clayey sand.
Some gravel and pieces of hardshell.
Sand, very fine to fine; quartz, generally clear, angular; glauconite, common, fine grain; mica, common.
No foraminifera.

100–110 Light olive-gray, somewhat sandy clay.
Sand residue, fairly small; sand, chiefly fine, a little very fine and medium; glauconite, abundant, rather fine; shell fragments, few.
Foraminifera, few.

110–140 Light olive-gray, somewhat sandy clay.
Residue, small, chiefly glauconite; glauconite, rather fine, botryoidal, dark-green chiefly, a little light-green.

140–160 Olive-gray sandy and glauconitic clay; some hardshell.
Residue, fair, much glauconite; sand, chiefly medium, fair fine; glauconite, very dark, somewhat coarse, distinctly botryoidal, shiny, very little light-green.

160–190 Olive-gray sandy and glauconitic clay; similar to preceding interval except more coarse quartz, clear, subangular to subrounded, rounded edges; some quartz grains show faint green stain, some slightly green internally.

190–200 Pale-olive sandy and glauconitic clay.
Residue, fair; chiefly glauconite, grade, chiefly fine and very fine, but some medium.

200–210	Pale-olive clay.
	Very small sand and glauconite residue; glauconite generally dark, somewhat dull.
210–230	Olive-gray sandy and glauconitic clay.
	Residue, fair, somewhat more quartz than glauconite; quartz, clear, some pink and some greenish; glauconite, rather fine, dull.
230–240	Pale-brown clay; some greensand.
	Residue, fair, chiefly quartz; quartz, angular, clear, medium and fine grain; considerable bone; glauconite, little and fine.
Nanjemoy formation	
Marlboro Clay member	
240–250	Light-brown ("pink") clay; no residue.
Eocene series	
Aquia formation	
250–260	Olive-gray, fairly sandy and glauconitic clay.
	Residue, fair, chiefly glauconite; grade, medium to fine, botryoidal, both dark and light-green, a few shiny pieces.
260–270	Dark yellow-green, somewhat sandy clay.
	Residue, fair, glauconite and quartz, chiefly medium grained; glauconite, both very dark and light-green, rather more light-green than in preceding samples, botryoidal.
	Foraminifera, scarce.
270–280	Dusky yellow-green greensand, chiefly medium grain.
	Foraminifera, abundant.
280–290	Pale-olive greensand; chiefly medium grade, fair fine grade; most of the glauconite is light-green; some hardshell; sea shell fragments.
	Foraminifera, abundant.
290–300	Light olive-gray greensand and clay.
	Residue, fair; many yellow grains; considerable limonite-stained quartz; some brown glauconite (first place noted in this well); chiefly mixed light and dark-green glauconite.
	Foraminifera, scarce.
300–310	Light-olive greensand and clay.
	Residue, rather large, chiefly medium, little limonite-stained quartz, a few large shiny glauconite grains, considerable light-green glauconite, botryoidal.
	Foraminifera, scarce.

Parlett Well

Loc. No.—Br. 5-449; P. 791; MSC 826-287
Loc.—Waldorf
El.—215 feet

Pleistocene and Miocene series	
0–42	Sample missing.
Miocene series	
Calvert formation	
Plum Point marls member	
42–65	Pale-brown sandy clay.
	Sand residue, rather small; sand, very fine; some bone.
	Radiolaria, abundant.

Miocene series	
Calvert formation	
Fairhaven member	
65–78	Pale-brown sandy clay. Sand residue, moderate; chiefly very fine; sand, quartz, angular; some bone fragments. Diatoms, scarce to common.
78–111	Pale-brown sandy clay. Sand residue, moderate to small, chiefly very fine; bone fragments. Diatoms, very abundant.
111–123	Pale-brown diatomaceous earth.
123–125	Pale-brown sandy clay. Sand residue, small; some smooth pebbles (max. 7 mm). Sand chiefly very fine; quartz, clear, angular, etched; considerable bone. Diatoms, scarce.
Eocene series	
Nanjemoy formation	
125–135	Pale-olive clay; fair sand. Sand, medium to very fine; quartz, generally clear, subangular to subrounded, edges rounded, some green-stained; glauconite abundant, chiefly in medium and fine grades, dark-green chiefly, dull, some light-green; mica, considerable in fine and very fine fractions.
135–162	Weak-olive sandy clay. Sand, chiefly medium, but fair fine and very fine; quartz, clear subangular to subrounded, edges rounded; glauconite, abundant, green-black, smooth, botryoidal; mica, considerable in fine fraction.
162–174	Weak-olive sandy clay. Much more sand than in previous sections; sand, very fine and fine, chiefly, fair medium; quartz, clear; glauconite, abundant green-black.
174–180	Weak-olive sandy clay; sand, fair. Sand, chiefly very fine and fine; some medium; glauconite, black-green, rather dull, much of it medium grain; quartz, as in previous samples, a little of it green-stained; mica, much.
180–212	Weak-olive sandy clay; sand, fair to little. Sand, fine—very fine, some medium; quartz, as above; glauconite common, chiefly very fine, green-black, dull; shell fragments and bone at 180 feet and 200 feet.
212–215	Moderate yellowish-brown clay; tough, very little sand; glauconite, very little, very fine. Foraminifera, scarce.
Nanjemoy formation	
Marlboro Clay member	
215–220	Light-brown (pink) clay; tough.
220–240	Light-brown (pink) clay, moderately hard. Very little sand; mica, noticeable; shell fragments.
Eocene series	
Aquia formation	
240–245	Weak-brown clay; fair sand. Sand, chiefly fine—very fine; glauconite, abundant, green-black, dull; mica, common; shell fragments, common.

245–253	Weak-brown clay, moderately hard; sand, fair. Sand, chiefly fine; much very fine; glauconite, abundant, green-black, dull; mica, common; shell fragments, common.
253–260	Marl
260–268	Light olive-gray argillaceous sand. Sand, residue large; grade, chiefly fine and very fine; glauconite, abundant, green-black, dull; shell fragments and hardshell, common. Foraminifera, abundant.
268–275	Light olive-gray argillaceous sand. Sand residue, large; grade, fine to very fine, some medium; glauconite, green-black; shell fragments, common, chiefly *Turritella*. Foraminifera, very abundant.
275–300	Weak olive-green argillaceous sand. Sand residue, large; grade, medium to very fine; glauconite, very abundant, much light-green, some black-green, little olive; a few yellow grains; shell fragments, fair. Foraminifera, abundant.
300–312	Weak olive-green argillaceous sand. Sand residue, large; grade, medium to fine; glauconite, abundant chiefly green-black, some light-green and olive-green; very few yellow grains. Foraminifera, scarce.
312–315	Light olive-gray argillaceous sand. Residue, large; grade, chiefly fine, but considerable medium; glauconite, mostly dark, but a little light-green and olive; a few yellow grains. Foraminifera, common.
315–319	Light olive-gray argillaceous sand. Sand residue, large; grade, medium to fine; glauconite, mostly green-black; yellow grains, common; shell fragments, abundant. Foraminifera, present.
319–341	Weak-olive argillaceous sand. Sand residue, large; grade, medium to fine; some quartz grains of large size, smoothly ovoid; glauconite, mixed green-black, light-green, olive; yellow grains, common; hardshell at 325 feet.
341–365	Weak-olive sand. Sand residue, large; grade, chiefly fine; glauconite, mixed, but chiefly green-black; yellow grains, scarce; mica, fair.
365–374	Weak-brown sandy clay. Sand residue, moderate; grade, fine; glauconite, abundant, green-black; mica, very common.
374–379	Weak-brown argillaceous sand. Sand residue, large; grade, fine and much medium; glauconite abundant, green-black; mica, very common; a few yellow grains.
379–393	Medium-gray arkosic sand. Sand residue, large; grade, coarse to medium; glauconite, very rare; quartz, subrounded to ovoid, partly cloudy, some pale milky quartz, some with inclusions (blue quartz). Lithologically this sand has the characteristics of Cretaceous: water analysis and position in well suggest Eocene-Aquia formation.

Southern Maryland Cleaners

Loc. No.—Wic. 1-152; P. 1122; MSC 804-240
Loc.—3 mi. S. of La Plata
El.—165 feet

Pleistocene series	
10–35	Dark yellow-orange argillaceous sand and gravel. Sand residue, large; grade, gravel (max. 12 mm) to very fine; gravel, abundant.
Miocene series	
Calvert formation	
Fairhaven member	
35–40	Light olive-brown clay. Sand residue, small; grade, very fine; mica, scarce. Diatoms, scarce.
40–50	Cf. preceding interval. Diatoms, common.
50–60	Pale-olive sandy clay. Sand residue, fair; grade, very fine, a little fine; mica, scarce. No diatoms seen.
60–70	Cf. preceding interval. Diatoms, scarce.
70–80	Cf. preceding interval. Diatoms, abundant.
80–100	Pale-olive clay. Sand residue, small; grade, chiefly very fine, some fine; pieces black internal casts of gastropods; bone, much; quartz, angular to subangular, mostly clear; diatoms, abundant.
Eocene series	
Nanjemoy formation	
100–140	Brownish-gray clay; sand, little. Sand is fine to very fine, some medium quartz, subrounded to ovoid, clear, rounded edges and corners; glauconite, abundant, green-black, dull; mica, fair; bone, fair; a few shell fragments at 110 feet.
140–166	Weak-olive sandy clay. Sand, moderate, medium to very fine; quartz, clear, subangular; glauconite, very abundant, particularly medium to fine, green-black, shiny, a few light-green pieces; mica, much, chiefly fine; shell fragments, abundant 140–150 feet.
166–210	Brownish-gray sandy clay. Cf. previous interval.
210–244	Olive-gray sandy clay. Sand, moderate, medium to very fine; quartz, subangular, rounded edges; glauconite, abundant, green-black, somewhat shiny; mica, common; shell fragments, common.
244–255	Pale-brown clay; very little sand; mica, fair, fine.
255–260	Mixed weak-orange, weak yellowish-orange, and light-brown clay.
Nanjemoy formation	
Marlboro Clay member	
260–269	Very pale-brown and weak-orange clay.
269–275	Light brownish-gray clay.

Eocene series	
Aquia formation	
275–282	Pale-olive sandy clay. Sand residue, moderate; grade, chiefly fine, fair medium and very fine; some iron-stained quartz grains; glauconite, abundant, mixed green-black and light-green; shell fragments, common.
282–290	Pale-olive sandy clay. Sand residue, small; grade, fine to very fine; glauconite, green-black and light-green, dull, some hard-shell; yellow grains, some; shell fragments, fair.
290–302	Sample missing (driller's log, hard green rock, shell).
302–314	Weak-olive argillaceous sand. Sand residue, large; grade, medium, some fine; glauconite, very abundant, green-black, some olive grains (first appearance), shiny.
314–323	Weak-olive argillaceous sand. Sand residue, large (cf. previous interval). Piece of *Ostrea compressirostra;* fair shell fragments.
323–328	Dusky olive-gray argillaceous sand. Sand residue, moderate. Cf. previous interval.
328–331	Dusky olive-gray argillaceous sand. Sand residue, large. Cf. previous interval.
331–350	Weak-olive argillaceous sand. Sand residue, fairly large; grade, chiefly fine, some medium; glauconite, abundant, green-black, dull; quartz, cf. previous samples. Shell fragments, few. Foraminifera, scarce.
350–390	Weak olive-green argillaceous sand. Cf. previous interval.
390–410	Weak-olive clay. Sand residue, little; sand, chiefly fine, a little medium and very fine; mica, fair; pieces of bone, rounded and polished; a few pebbles (max. 5 mm) of milky quartz; glauconite, abundant in the residue, green, black, shiny, a few olive-green pieces; some pieces of a large *Nodosaria.*
Cretaceous system	
410–420	Light-brown clay. Sand residue, very small; much iron staining; a little pyrite; glauconite, little in the residue.
420–430	Moderate yellowish-brown clay. Cf. previous interval.
430–440	Weak yellowish-orange clay. Cf. previous interval.
440–448	Light brownish-gray clay. Cf. previous interval.
448–462	Pale-brown arkosic sand (at 459 feet). Sand residue, large; grade, coarse to medium, very little fine; quartz, chiefly angular, etched; a little pink-tinged quartz; fair pale milky quartz, fair gray quartz having inclusions ("blue quartz"); considerable white feldspar; no glauconite; pieces of lignite; a little crystallized pyrite.

462–465	Light yellowish-brown sandy clay.
	Sand residue, moderate.
	Cf. previous interval for constituents.
465–508	Dusky yellowish-orange clay.
	Sand residue, little; cf. previous interval for constituents; much iron-stained, yellow-orange quartz; no gray quartz noted; feldspar, common.
508–512	Weak-yellow clayey sand.
	Residue, moderate; grade, chiefly fine to very fine; arkosic; mica, very common; much agglutinated material.
512–519	Weak-yellow arkosic sand.
	Residue, large; sand, chiefly medium, a little fine and a little coarse; considerable pale milky quartz; a little pinkish quartz; quartz, angular.
519–521	Light yellowish-brown clay.
521–632	No samples.

Southern Maryland Electric Cooperative Well

Loc.. No.—Br. 9-594; P. 850; MSC 862-255
Loc—Hughesville
El.—179 feet

Pleistocene series	
0–23	Moderate yellowish-orange sand and gravel; gravel (max. 12 mm).
Pleistocene-Miocene (?) series	
23–40	Sample missing.
Miocene series	
Choptank (?) formation	
40	Pale-olive sand; grade, medium to fine.
40–57	Pale to light olive-brown sandy clay.
	Sand residue, fair; grade, chiefly fine, considerable very fine.
57–65	Pale-olive sandy clay.
	Sand residue, fair; grade, fine.
	Diatoms, few.
65–80	Light olive-gray sandy clay.
	Sand residue, small; grade, fine; shell fragments; piece of *Melina* hinge.
	Diatoms, many.
Miocene series	
Calvert (?) formation	
Plum Point (?) marls member	
80–83	Cf. preceding interval.
	Diatoms, scarce.
83–106	Cf. preceding interval.
	Shell fragments; pectens.
	No diatoms.
106–110	Pale-olive clay.
	Sand residue, very small.
	Diatoms, few, unlike Fairhaven forms.
110–116	No samples.
116–121	Light brownish-gray sandy clay.
	Sand residue, small; grade, fine to very fine; some medium; barnacle fragments.

121–128	Light brownish-gray sandy clay. Sand residue, fair; grade, chiefly fine to very fine; abundant shell fragments.
128–131	No data.
131–139	Light brownish-gray sandy clay. Grade, sand, very fine to fine.
139–143	Light brownish-gray sandy clay. Sand residue, small. Foraminifera, common.
143–145	Pale-olive sandy clay. Sand residue, small; sponge spicules. Foraminifera, fairly common.
145–151	Pale-olive clay. Very little sand.
Miocene series	
Calvert formation	
Fairhaven member	
151–189	Weak-yellow clay; little sand. Diatoms, many.
189–193	Pale-olive clay. Sand residue, very small; gastropod, internal casts. (Cf. Southern Maryland Cleaners well.) Foraminifera, scarce.
193–201	Pale-olive clay. Sand residue, small; grade, chiefly very fine; a little fine. Foraminifera, rare and small.
201–206	Pale-olive clay. Sand residue, small; much sparkling quartz; shell fragments. Foraminifera, scarce.
Miocene-Eocene (?) series	
206–212	Pale-olive clay. Foraminifera, fairly common.
Eocene series	
Nanjemoy formation	
212–220	Pale-olive clay. Glauconite and mica.
220–226	Light brownish-gray clay; little sand; quartz, fine; glauconite, scarce; bone, fair; sharks' teeth; a little lignite. Foraminifera, small.
226–260	Light brownish-gray sandy clay. Sand residue, fair; grade, chiefly fine, but considerable very fine; quartz, clear, subangular; glauconite, scarce, about 50 per cent of it light-green; mica, common; scarce shell fragments.
260–271	Light brownish-gray clay; little sand. Sand, very fine and fine; glauconite, abundant, irregular, green-black, some "book" form, a little brown; mica, much.
271–277	Brownish-gray clay, little sand. Sand, chiefly fine, fair medium grain; glauconite, medium, over 50 per cent brown; fine glauconite, chiefly green-black.
277–290	Weak-brown sandy clay. Sand, chiefly fine—very fine, considerable medium; glauconite, abundant, coarser grades, pale-olive to dusky yellow-green, finer grades, green-black.

290–299	Weak-brown clay, little sand.
	Much mica; glauconite, abundant in residue.
299–397	Weak-olive sandy clay.
	Sand residue, fair; chiefly medium, but considerable fine to very fine; quartz, subangular to subrounded, rounded edges; glauconite, very abundant, most in fine fraction, green-black, botryoidal, shiny; mica, much, fine.
397–413	Weak-olive clayey sand.
	Sand, chiefly medium, some fine; quartz, clear, subangular, rounded edges; glauconite, common, green-black, botryoidal.
413–420	Olive-gray clay; little sand; glauconite, fine and very fine, dark-green.
420–428	Pale-brown clay; very little sand.
Eocene series	
Nanjemoy-Aquia formations	
428–444	Light-brown clay; very little sand.
Eocene series	
Aquia formation	
444–454	Weak-brown sandy clay.
	Sand, fair, chiefly medium, considerable fine. Some yellow-stained quartz and yellow grains; glauconite, green-black, not very shiny, irregular.
	Heavy shell bed.
454–455	Weak-brown argillaceous sand.
455–456	Pale-brown clay.
456–461	Moderate olive-brown argillaceous sand.
461–492	Moderate olive-brown argillaceous sand.
	Sand residue, large; grade, chiefly medium, considerable fine; some yellow grains, glauconite.
492–500	Pale-olive argillaceous sand; a little more quartz and a little less glauconite than in previous specimens.
500–501	Pale-olive argillaceous sand.
	Sand residue, large; grade, chiefly medium, but considerable fine; glauconite, abundant, green-black, shiny; some yellow grains; some calcite cement.
	Foraminifera, abundant.
501–527	Light olive-brown argillaceous sand.
	Sand residue, much; grade, chiefly medium, much fine; glauconite, abundant, chiefly green-black, a little olive-green and red; much calcite-cemented glauconite.
	Foraminifera, abundant.
Paleocene (?) series[15]	
527–534	Light olive-brown argillaceous sand.
	Sand residue, large; quartz, smooth, subrounded to ovoid, some yellow-stained; glauconite, abundant, chiefly reddish-brown, fair green-black; much of the green-black glauconite is fine; many shell fragments.
534–540	Moderate yellowish-brown argillaceous sand.
	Cf. previous interval; few shells.

[15] Shifflett, Elaine: Eocene Stratigraphy and Foraminifera of the Aquia Formation, Maryland, Department of Geology, Mines and Water Resources, Bulletin 3, 1948.

Sullivan Well

Loc. No.—St. 3-658; P. 1548; MSC 726-218
Loc.—Near Nanjemoy
El.—28 feet

Pleistocene series	
0–10	Weak yellowish-orange sand; small amount of clay; sand residue, large; chiefly medium grade, but considerable fine and very fine; mica, noticeable, fine to very fine; quartz, variable, chiefly angular but some rounded, particularly rounded on edges; most quartz partly cloudy, much of it iron-stained, some pale milky; considerable dark opaque material.
Pleistocene-Eocene series	
10–15	Mixed yellowish-orange and dark constituents; sand residue large; chiefly fine, but much medium and very fine. Quartz, variable; mica, little; many dark constituents, in part at least altered glauconite.
Eocene series	
Aquia formation	
15–20	Pale-olive sandy marl; sand residue, large; sand, chiefly fine, but fair medium and very fine; much glauconite, dull dark-green and brown; quartz, generally subangular to subrounded, a fair number of ovoid grains; most grains show rounded edges; some etching; quartz, milky, partly cloudy, and clear; shell fragments, abundant.
	No foraminifera found.
20–35	Dusky yellow-green greensand; grade, chiefly fine, some very fine; quartz, angular, rounded edges, much of it clear; glauconite, rather abundant, green-black, somewhat shiny; mica, little.
	No foraminifera.
35–41	Gravel and shell fragments; grade, from very coarse to very fine sand; quartz, sharply angular; glauconite, fair.
Upper Cretaceous system	
41–45	Moderate yellowish-brown clay.
	Very little quartz, fine and very fine.
45–55	Weak-yellow clayey arkosic sand.
	Sand, coarse to very fine, portions about equal. Quartz, angular; some gray quartz carrying many inclusions ("blue quartz"); considerable white feldspar; some quartz, clear, some pinkish; opaque minerals rather common, a few grains pale milky; a little pyrite.
55–70	Light-brown clay. Very little sand.
70–83	Light yellowish-brown sandy clay.
	Sand, chiefly fine to very fine; arkosic; quartz, angular, clear and partly cloudy; a little gray quartz; feldspar, opaque, white.
83–105	Light yellowish-brown sand; some clay.
	Sand, chiefly coarse to medium, small amounts of fine and very fine and very coarse. Considerable coarse gray quartz grains with inclusions ("blue quartz"); a little pinkish and pale milky quartz, some clear quartz but most partly cloudy, some quartz etched; grains angular to subrounded; opaque minerals and feldspar, mostly in fine grade. (This sand was tested, but was not water-bearing.)

105–126	Weak yellowish-orange arkosic sand. Grade, medium to coarse, a little fine and very fine; quartz, generally sharply angular, but some of it subrounded; pale milky quartz particularly noticeable. Considerable quartz with slight pinkish tinge, some gray quartz ("blue quartz").
126–147	Cf. previous specimen; somewhat less sand.
147–168	Light yellowish-brown arkosic sand; a little clay. Sand not well sorted, chiefly medium but fair amounts of all other grades; quartz, sharply angular; fair gray quartz ("blue quartz"); some pinkish and pale milky quartz; some iron staining; feldspar generally white, opaque; fair black opaque material in fine grade.
168–189	Light yellowish-brown sand; a little clay. Grade, chiefly medium to coarse, some fine to very fine; considerable quartz, angular; chiefly partly cloudy; some gray ("blue quartz"), considerable quartz with pinkish tinge; feldspar, generally opaque white and in medium and fine grades.
189–210	Yellowish-gray arkosic sand. Grade, chiefly medium, fair, fine; quartz subangular, shows more round grains than in previous Cretaceous specimens, gray ("blue quartz") etched; some quartz has a pinkish tinge; feldspar mostly in medium and fine grades.

Williams Well

Loc. No.—Wic. 8-228; P. 1449; MSC 838-181
Loc.—Tompkinsville
El.—15 feet

Recent and Pleistocene series	
0–20	Weak yellowish-orange argillaceous sand; grade, medium and fine grains about equal, very fine, fair; quartz, angular to subrounded, chiefly cloudy.
Pleistocene (?)-Miocene (?) series	
20–40	Shell fragments
Miocene series	
Calvert formation	
Fairhaven member	
40–50	Weak-olive argillaceous sand; sand chiefly medium, some fine and very fine; quartz, clear, sparkling, subangular to subrounded, rounded edges; bones, fish dental pavements. No foraminifera; diatoms present but rare.
50–60	Weak-olive sand, little clay; sand, chiefly medium grade; no foraminifera; no diatoms; some bone.
Miocene-Eocene series	
60–70	Pale-olive micaceous sand and gravel. Gravel, smooth, rounded (max. 7 mm, very little); quartz, clear and somewhat smoky, very highly polished, rounded and ovoid; sand, all grades, angular, rounded edges; muscovite, common; some bone. Foraminifera, scarce.
Eocene series	
Nanjemoy formation	
70–80	Pale-olive micaceous sand; sand, chiefly fine and very fine, some

	medium; muscovite, common; glauconite, fairly common; quartz, clear to partly cloudy, larger grains distinctly etched. No foraminifera.
80–90	Olive-gray micaceous argillaceous sand; sand chiefly fine and very fine, some medium; glauconite, very dark-green, very abundant; muscovite, fairly common; quartz, angular, clear. Foraminifera, rare.
90–100	Olive-gray micaceous argillaceous sand; sand, medium to very coarse; mica, common; glauconite, very abundant below coarse size. Foraminifera, very rare.
100–110	Olive-gray greensand. Sand, chiefly medium to coarse; coarse quartz, angular to very smoothly rounded, some yellow-stained grains; glauconite, abundant, generally very dark-green but some pale-olive; generally botryoidal, but a considerable number of "book" forms; shell fragments, fairly common. Foraminifera, very rare.
110–120	Olive-gray micaceous greensand; grade, medium to fine; glauconite, abundant; shell fragments, fairly common.
120–200	Olive-gray micaceous sand; grade, chiefly medium, some fine and very fine, a little coarse; glauconite, fairly coarse, very dark, shiny, generally rounded, botryoidal; quartz, rather scarce, angular.
200–220	Pale-olive glauconitic sand; sand, chiefly medium to fine; glauconite, fairly common, but very fine; quartz, clear, angular to rounded; bone, common.
Nanjemoy formation	
Marlboro Clay member	
220–232	Mixed pale-brown and gray clay; a little sand residue, chiefly greensand; glauconite, dark, angular, not so smooth and shiny as in preceding samples. Foraminifera, scarce, small.
Eocene series	
Aquia formation	
232–273	Pale-olive greensand; grade, chiefly med um to fine; glauconite, abundant; generally dark, some light-green and smooth; some stained yellowish and greenish quartz.

MINERAL RESOURCES OF CHARLES COUNTY

BY

LINCOLN DRYDEN

For a variety of reasons, the mineral resources of Charles County have been and probably will continue to be of comparatively little value. First, there is no indication of the presence of resources of high or even moderately high unit value. There are no ores of precious or base metals, no coal, petroleum, or building stone. There is little likelihood of petroleum being discovered in the future. Second, the county is at a disadvantage in supplying low-cost materials like sand and gravel to the main centers of consumption. It is close to Washington, but Prince Georges County, nearer to the city, has a more varied and valuable supply of the same materials, and counties adjacent to Baltimore supply that city. Third, the county, up to the present, has not been the site of large-scale construction or other activities which would demand the equally large-scale development of local resources such as clay, sand, and gravel.

The two most valuable mineral resources of the county—though seldom thought of in this way—are the soils and the water supply; these resources are treated elsewhere in this report. Apart from these two, the resources of greatest actual or potential value are the sands, clays, gravels, marls, and diatomaceous earth.

The Sands

Sands of various types are present in all parts of the county but in almost all cases they are mixed with both finer and coarser grain sizes.

Sands for concrete and other construction purposes are not known to be present in thick or extensive beds. The Eocene sands are mixed with a considerable amount of clay, and the Miocene sands in addition are too fine-grained; in both cases the larger sizes are probably too well-rounded to serve the purpose. Pleistocene sands, widely distributed over the county, are in places both large and angular, but they are seldom found pure enough to be used without washing or screening.

Sands suitable for glass making have not been reported from the county. Their iron content and other impurities will probably prevent their use.

Molding sands have been described in another publication (Maryland Geological Survey, vol. 12, 1928, pp. 64–67). At a few places within the county there are deposits of fair to good grade, but distance from markets and high costs of transportation make the use of these sands unlikely.

Clays

The occurrence and property of Maryland clays are described in Volume 4 of the Maryland Geological Survey, 1902. The clays of Charles County are treated briefly (pp. 391–395), and are considered to be of minor importance compared with the clays of other counties. Perhaps the most important potential source is the "pink clay" at the base of the Nanjemoy formation. This clay has not been reported from surface exposures, but it is known to underlie most of the county. It could probably be located by test holes and worked by stripping if the occasion ever demands.

GRAVELS

Almost the entire surface of the county is veneered with a fairly thin deposit of Pleistocene gravels, mixed with varying proportions of finer material. Clean gravel is exceptional, occurring only in thin and discontinuous layers within the Pleistocene, so that in general washing or screening is necessary for removal of finer grades.

By far the greatest use of the gravels has been in road construction. The material is worked locally, insofar as possible, and is spread on the road surface without treatment. Most desirable is a mixture of gravel with enough fines to act as a binder to prevent rapid removal of the gravel under traffic. With the increasing number of hard-surface roads in the county, the once great importance of gravel as a surfacing material has been decreasing in recent years.

MARLS

The marls of southern Maryland received a large share of attention in the early works on the geology and agriculture of the State, since they were one of the few sources of fertilizer. Especially noteworthy in this respect were the Eocene greensands and shell marls, and the shell marls of the Miocene. These marls are still a potential source of fertilizer, but with the advent of stronger and more rapid artificial fertilizers their use has been almost completely given up.

DIATOMACEOUS EARTH

Diatomaceous earth deposits have been worked intermittently for a number of years along the Patuxent River in Calvert County. The same deposits extend under most of Charles County, and appear at the surface in the vicinity of Popes Creek. If the demand ever warrants, they can probably be worked by stripping in the western part of the county.

WATER RESOURCES OF CHARLES COUNTY
SURFACE WATER RESOURCES

BY

V. R. BENNION

General

Water is the natural resource most vital to man's existence. It determines those places on the face of the earth where he can live. If there is insufficient water, as in the desert, he cannot live, or if there is too much water or a continual threat of it, as in the flood plains of the streams, he cannot live except in fear of his life. Without water the average man would live but a few days, and most of the modern industrial processes would cease operation immediately.

Many of the people of this country, and especially those in the eastern section, seem to assume that the water supply is inexhaustible. As a matter of fact, the water supply is definitely limited and already in many places its scarcity has become an acute problem and it has been necessary to establish laws governing the use and conservation of this valuable resource. The quantity of available water in any region varies from year to year, month to month, and day to day, and it cannot be adequately determined by measurements covering a period of only a few months or even of a few years. The immediate source of nearly all water is precipitation from the clouds, and the wide variations in this factor are known to all. The relation between rainfall and the resulting surface water and ground water supplies is also variable and complex; therefore, the records of rainfall alone do not serve as a measure of the water supply available for use.

The earth has a fixed amount of water which circulates in an endless cycle maintained in approximate balance by processes, the principal of which are precipitation, evaporation, transpiration from vegetation, and runoff in streams. This vast movement of water from the atmosphere to the land, from the land to the ocean, and from land and ocean back to the atmosphere is known as the hydrologic cycle. Figure 8 illustrates the operation of the hydrologic cycle and the methods used in measuring some of its factors.

The water resources of principal concern to man as sources of supply may be classified as surface water and ground water. Surface water is the water resting on the earth's solid surface, such as streams, lakes and ponds. Ground water is the water that accumulates in the ground below the water table. Although both surface water and ground water originate from precipitation, there is a distinct difference in their occurrence and behavior, and the methods and science involved in their investigation and utilization are also distinct. Ground water investigation and utilization are discussed in another and separate section of this report.

Surface water is easily accessible and has a wide variety of uses including potentialities for producing power. The force of gravity causes surface water to flow along the path of least resistance, as long as the ground surface is sloping or until it is halted by some barrier to form a lake or pond. Essential to considering the utilization of surface water is a knowledge of the quantity and quality of the water, the topography of drainage basin, the type of soil, and the land use practices.

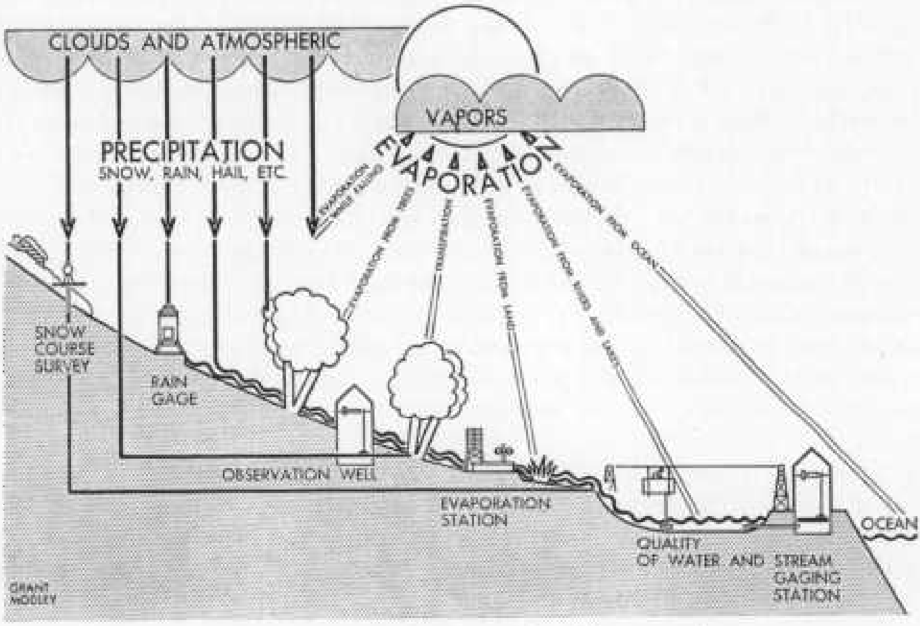


FIG. 8. The hydrologic cycle and how it is measured

The development of any region is directly dependent upon the availability of an adequate water supply. The history of any country or community has shown the importance of water resources, and the future development and expansion will depend to a great extent on the wise use of these resources. Generally, as a community develops in density of population and scope of industry, little thought is given to the prospect that there may not be sufficient water in nearby stream sources to satisfy the demands. It has then been necessary to extend the water supply system to more distant streams. Many of the larger cities of the country are faced with an acute water problem today that threatens to stall any future developments.

Streams may serve a community in several ways. Many streams are used as a municipal water supply, as a source of water for industrial uses, and for sewage disposal. Streams have an important role in the conservation of fish and wildlife. A recreational area would not be complete unless there was a good lake, pond, or stream for boating, fishing and swimming. Improvement of streams and adjacent areas and the construction of artificial ponds and pools contribute importantly to the program of recreation and to the conservation of fish and wildlife. In recent years greater attention has been directed to this improvement, and the efforts of conservationists have produced good results. However, many of our scenic streams are laden with waste and pollution which have resulted in the killing of vegetable and fish life. Under favorable conditions streams purify themselves in a relatively short distance, but when they become overloaded with pollution, the bacteria supplied by nature for purification are killed, the natural oxygen content of the water is depleted, and a so-called dead river results.

Streams are subject to great fluctuation of flow, depending upon the amount and intensity of the precipitation, and during floods a large portion of the water runs off without serving any useful purpose. In addition, the periodic flood damage to cities, highways and other developments is tremendous. Much of this damage can be averted if there is proper planning and adequate knowledge of stream flow at the time the developments are made. In the early days, cities and municipalities were nearly all located along a stream so as to have a readily accessible water supply or means of transportation. As the towns grew into cities, the flood plains of the stream were encroached upon by structures of all kinds. The stream was crowded into a narrow channel of insufficient size to carry the flood flows, with resulting large flood damages in each major flood. In order to reduce or eliminate these damages, it is necessary to build flood control works, and these cannot be properly designed unless a record of the stream flow is available for a sufficient number of years to determine the flood flow characteristics of the stream.

Stream Flow Measurement Stations

The collection of systematic records of stream flow may be classified or divided into three major units: (1) establishment and construction of stream flow measurement stations; (2) operating and maintaining those stations; and (3) computing, compiling and preparing stream-flow data for publication.

ESTABLISHMENT AND CONSTRUCTION

Before a stream flow measurement station is established or constructed, a general reconnaissance is made of the stream, in the reach where such records are needed, to determine the most suitable site. This survey is facilitated by an examination of topographic maps and all other maps of the area to determine the accessibility of the stream in all kinds of weather and for all stages of the stream. Tentative sites are generally indicated on the maps prior to an actual field survey. When the field reconnaissance is made the various sites indicated on the maps are examined in detail to determine the best one. Consideration should be given to the channel characteristics in the vicinity of each proposed site with particular reference to the hydraulic conditions necessary for maintaining a fixed relation between stage and discharge at the gage. The selection of a suitable cross section of the stream for making discharge measurements at various elevations of the stream and the proper placing of gages with respect to the measuring section and to that part of the channel which controls the stage-discharge relation are some of the factors to be considered in selecting the best site for a stream measurement station.

The construction of a stream measurement station includes all the work pertaining to the installation of some type of gage to determine the fluctuations of the stream. If the gage is to be read by a local resident once or twice daily, and more often during periods of rapidly changing stage, generally a staff gage or wire-weight gage is installed so that it will register the height of the water at all stages and be readily accessible to the observer. If the record of the stage is to be obtained automatically by a recording instrument, it is necessary to construct a gage well and shelter. The structure is either located on the bank or attached to a bridge pier. It must be deep enough in the ground to be below the lowest possible stage and high enough to be above the highest expected stage and must be accessible for all stages of the stream. The gage well is connected to the stream by one or more pipes and the water in the well fluctuates the same as the stream. The type of instrument generally used to record the stage is designed to produce a graphic record of the rise and fall of the stream with respect to time and is called a water-stage recorder. In order to check elevation of gages and to be able to reset them to the correct datum in case they are disturbed by floods, ice, or vandals, reference marks are established on some permanent object, such as rock outcrops, bridge abutments, or a specially constructed concrete monument.

In addition to installing a device to obtain a record of stage, it is necessary to have suitable facilities from which to make measurements of the amount of water in the stream for all stages. If there is a suitable bridge available near the gage, it may often be utilized. In the event such a structure is not available it is the usual practice to construct a cableway across the stream sufficiently high so that all the flood flow will pass under the cable. On this cable is installed a small car to carry the engineer and the necessary measuring equipment. For low stages, stream-flow measurements are often made by wading at a favorable section of the stream near the gage.

For smaller streams it is often desirable to improve the channel condition in the vicinity of the gage by removing logs or other debris. Quite often a weir or dam is built just below the gage to stabilize the stage discharge so that it remains constant or nearly so. A concrete shelter for a water-stage recorder over a 5-foot square well, a cableway, and a concrete control at the gaging station on the Antietam Creek near Sharpsburg, Md. are shown in Pl. VI, fig. 1.

OPERATION AND MAINTENANCE

If the stream flow measurement station is not equipped with an automatic water-stage recorder, the elevation of the water on the gage is generally read twice a day by a person living near the station. His readings are recorded in a special notebook. He not only records the stage reading, but also the time the reading was made and any unusual conditions. These books hold readings for a three-month period and are transmitted to the central office after they have been filled. This constitutes the stage record, one of the basic components of stream flow records. At times a reliable gage reader cannot be located or the stream may fluctuate, as by regulation by a mill, so that two readings a day are not sufficient to define the stage. The factor of personal or human errors is one of the large problems that is encountered in obtaining a reliable record by this type of installation. Automatic recording instruments have the advantage that they record an accurate and continuous record of the stage and result in a higher degree of accuracy. The recorder graphs are removed from the machine at regular intervals, usually about once a month. Pl. VI, fig. 2 shows an automatic recorder in operation. The instrument is periodically checked by an engineer to see that everything is in good condition.

An engineer makes an actual determination of the amount of water flowing in the stream at each periodic visit. The measurement is made by the area-velocity method by means of an instrument called a current meter which is used to obtain the velocity of the stream at numerous selected points in the cross section. At each point he observes the velocity, obtains the depth, and records the distance each point is taken from some fixed point or edge of the stream. These flow measurements are made by wading if the stage is low or from bridge, cableway, boat, or ice. Plate VII, figures 1 and 2, shows the type of current meters commonly used and equipment used to make a discharge measurement from a bridge. The purpose of making flow measurements is to define the stage-discharge relation. These measurements are distributed from the lowest to the highest stages of the stream. During periods of critical stream flow, either flood or drought, the gaging stations are visited to assure a satisfactory record.

COMPUTATION AND PREPARATION OF RECORDS FOR PUBLICATION

A few technical terms are commonly used in the presentation of stream-flow records. As some of these terms may be unfamiliar, brief explanations follow.

Second-foot.—A measure of rate of flow of water—20 second-feet is 20 cubic feet of water flowing past a given point in every second.

Acre-foot.—A measure of volume—the quantity of water necessary to cover an acre to a depth of one foot.

Discharge.—Rate of flow of water, usually expressed in second-feet, gallons per minute, or gallons per day. One second-foot flowing for one day equals 86,400 cubic feet, equals 646,317 gallons, equals about 2.0 acre-feet.

Runoff.—The portion of precipitation that appears as flow in the stream, usually expressed in inches of water depth. For example, one inch of runoff means that if all the water draining from an area were uniformly distributed over the area, the layer of water would be one inch deep.

Second-foot-day.—One second-foot flowing continuously for one day.

Water year.—A special annual period selected to facilitate water studies, usually October 1 to September 30.

Watershed or Drainage Basin.—The area drained by a stream or stream system, usually expressed in square miles.

At periodic intervals, generally at the end of each water year, the field data collected during that year are analyzed and prepared for publication. The daily gage heights are computed by averaging the gage heights for each day. For a stream-flow station not equipped with automatic recorder, this is generally done by computing the arithmetical average of daily readings for days when stage of the stream did not fluctuate too widely. For days of rapidly changing stage a graph is drawn through the readings to approximate the shape of the hydrograph and the mean stage is obtained from the graph. For stations equipped with an automatic recorder, the mean daily gage heights are computed direct from the recorder graph. Figure 9 shows a typical graph made by a water-stage recorder.

The data of the discharge measurements are tabulated on suitable cross-section paper. The gage heights or stages of the measurement are plotted against the respective discharges, and a smooth curve averaging all the points is drawn. This is known as the rating curve and defines the stage-discharge relation (see Figure 10). A table of stage and corresponding discharge is prepared from the curve. This table is called the rating table. If the stage-discharge relation changes it is necessary to develop additional rating curves and rating tables for each change. These new curves are based on additional groups of discharge measurements.

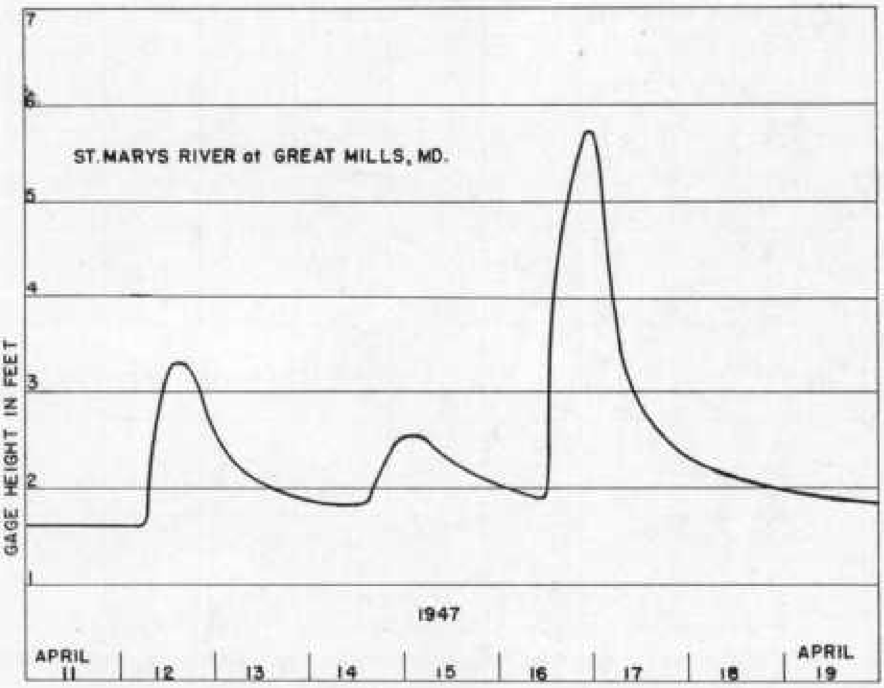


FIG. 9. Graph of river stage produced by a water-stage recorder

The daily gage heights are listed on a form and the daily discharge is computed for each day by entering the gage height in the rating table. The daily discharge is computed in second-feet or occasionally in gallons per day.

Stream-flow records are published annually in the series of Water Supply Papers of the U. S. Geological Survey. These data consist of a short description (giving location of gaging station, drainage area, records available, extremes of discharge during water year and period of record, remarks giving the accuracy of the records and explaining any unusual conditions), table of daily discharge, and table of monthly discharge. The table of monthly discharge includes second-foot days, maximum and minimum daily discharge, average discharge, discharge per square mile, and runoff in inches or acre-feet. These publications make available, in statistical form, a permanent record of the stream flow for a given year. Many states issue bulletins containing compilation of records; for example, a bulletin may be published every ten years containing a concise summary of stream-flow records and related data during that period. Maryland has two such compilation reports; "Flow data and draft storage curves for major streams in Maryland, 1927–39," published by the State Planning Commission and the Water Resources Commission, and "Bulletin 1, Summary of Records of Surface Waters of Maryland and Potomac River Basin, 1892–1943," published by the Department of Geology, Mines and Water Resources.

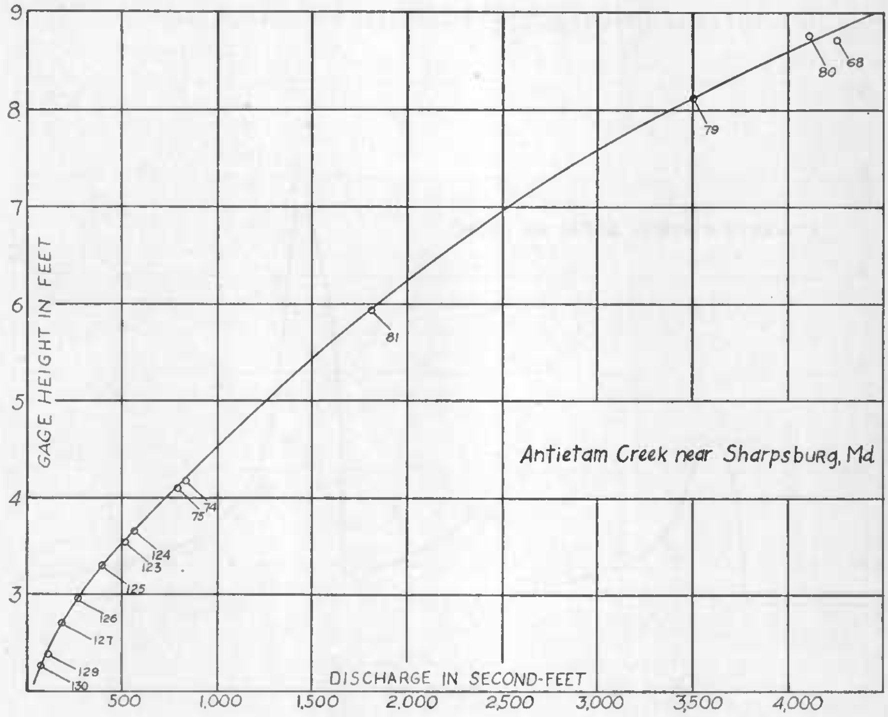


FIG. 10. Typical rating curve showing relation between stage and discharge at a stream-gaging station.

SURFACE WATER RESOURCES OF CHARLES COUNTY

The principal streams of this area are the Potomac River along the western and southern boundary; Mattawoman Creek along part of the northern boundary; Nanjemoy Creek, which drains the southwest section, and Wicomico River which drains the eastern half of the county. The more important streams and their drainage areas are:

STREAMS IN CHARLES COUNTY

Potomac River Basin

Stream	*Drainage area, square miles*
Mattawoman Creek	98.1
Nanjemoy Creek	78.0
Port Tobacco River	47.4
Port Tobacco Creek	24.2
Wicomico River	247
Zekiah Swamp	105
Gilbert Swamp	45.0

Patuxent River Basin

Swanson Creek	27.4

Nearly all of the streams are in tide water for several miles above their mouths. The county is almost entirely in the basin of the Potomac River, which forms the western and southern boundaries. A small area in the northeastern part of the county drains into the Patuxent River. The entire area is part of the Chesapeake Bay drainage. Practically all the streams flow through swamps. The topography, geology, soil and soil cover, and climatic conditions of this county are fully described elsewhere in this report.

GAGING STATIONS

There are no stream-flow records available for streams in Charles County. However, there are records on a few streams in nearby areas, with similar drainage areas and topography, that can be used to obtain a rough estimate of the surface water resources of Charles County. The following is a list of these gaging stations operated by U. S. Geological Survey in cooperation with the State of Maryland and Maryland municipalities.

Station	*Drainage Area*	*Records*
South River Basin		
North River near Annapolis	8.5	1931–
Bacon Ridge Branch at Chesterfield	6.9	1942–
Potomac River Basin		
Chaptico Creek at Chaptico	10.7	1947–
St. Marys River at Great Mills	24.0	1946–

A gaging station has recently been established on Mattawoman Creek in the vicinity of Pomonkey.

The record for the station on North River near Annapolis is continuous since 1931 and using it as an index, the mean annual runoff for streams in Charles County would be about 1.4 second-feet per square mile or about 900,000 gallons per day per square mile. The minimum annual runoff is about 0.9 and the maximum about 1.9 second-feet per square mile or 580,000 and 1,200,000 gallons per square mile, respectively. The records for North River do not include the great drought of 1930 and, therefore, the minimum annual discharge would be lower had that period been included. The data given are annual averages, and the minimum and maximum daily, weekly, or monthly will vary much more widely. This rough comparison indicates that if sufficient reservoir capacity be provided for storage over extended periods, there is ample supply of surface water for domestic and industrial uses in Charles County. Swamps act as a natural reservoir. There are no factual data on the chemical quality of these waters such as are desirable prior to any domestic or industrial development.

GROUND-WATER RESOURCES

BY

ROBERT M. OVERBECK

Introduction

Water is the chief mineral resource of Maryland. It is so intimately associated with us in our daily life that, like the air we breathe, it is rarely given a second thought. With the great increase in population and with increase in industrial uses of water, more and more water is being consumed every year. The consumption of ground water in the State has increased greatly in recent years; in 1943, the consumption of ground water in the Baltimore area alone was 50,000,000 gallons daily. This, then, brings up the very serious question, "Are we depleting our supply of ground water?" Declining water levels in wells in some places suggests that depletion may be occurring. The next step naturally is to make an inventory of our ground-water supply, and knowing the amount of water being withdrawn and the effects of the withdrawal on the water levels, we can tell over a period of years whether more water is being withdrawn from the underground reservoir than is being added to it, and from this can determine the safe yield of the underground reservoir.

Before we can hope to know anything about the occurrence of underground water we have to accumulate a large number of data. The State made a big step toward solving the problems by passing the Well Drillers Law of 1945. As a result of this law, which requires a permit for each well drilled over 50 feet, pertinent information will be obtained for each well as it is drilled. Samples of the formation through which the well is drilled are sent to the Department when requested. With such a body of data, a very comprehensive and detailed study will be possible of the occurrence and amount of ground water in the various parts of the State. The work is being concentrated at present on the Coastal Plain of the Western Shore of Maryland, and an over-all report covering this area as a unit will be made. The following account presents the available data pertinent to the ground water resources of Charles County.

General Principles of Occurrence of Ground Water

"I wonder where the water comes from!" is a statement almost always made by a bystander who is watching the drilling or digging of a well. The purpose of this section is to tell briefly and simply where the water comes from, how it moves underground, and how it gets to the surface.

The first question is answered in a general way by saying that the chief source of the water is precipitation. Not all the water that falls on the surface on the ground enters the ground. In fact, only a relatively small part eventually gets into the underground system or reservoir, for a part runs off in streams and the rest evaporates or is used by plants. Inasmuch as water does enter the ground, there must be openings or voids in the rocks that permit the passage of the water. Many types of openings occur in rocks and the type of opening depends on the kind of rock. In Charles County we need be concerned with only one type. The rocks of Charles County are unconsolidated sand, clay, and gravel. The openings therefore are the spaces or interstices between the particles of sand, clay, or gravel. It must be evident that the water will sink into and move more readily through the clean sand and gravel than it will through the clay. In fact, it moves so very slowly through the clay that for practical purposes it does not move at all. Clay is, therefore, said to be impermeable. Sand and gravel, on the other hand are permeable. Sand mixed with clay may also be relatively impermeable, and for that reason large thicknesses of sandy clay rocks in Charles County do not transmit water readily enough to supply wells.

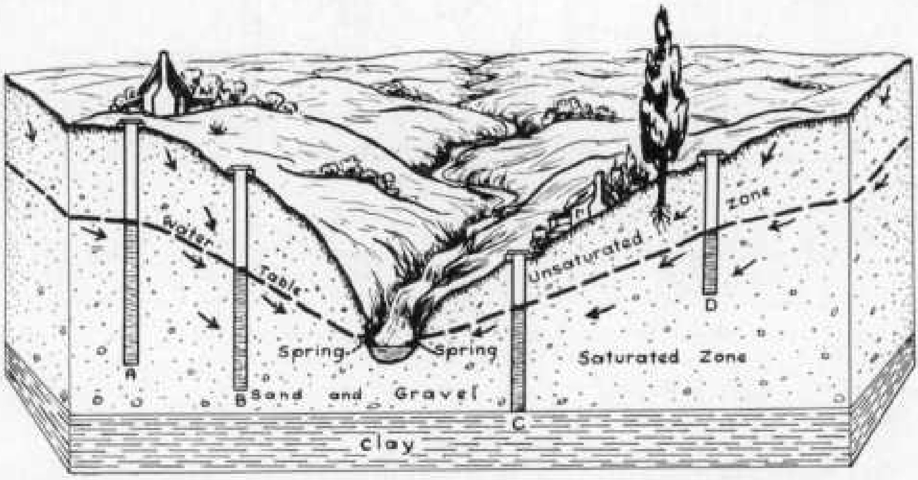


FIG. 11. Sketch Showing Relation Between the Water Table and Surface Topography. Springs form where the land surface intersects the water table. The arrows indicate the direction of movement of the water.

When water falls on the surface of the earth as rain or snow, a part of it sinks into the ground under the influence of gravity. It does not sink indefinitely however but soon reaches a surface below which the pores are already filled with water and can take no more. This portion of the earth's crust where openings and pores are filled or saturated with water is called the *zone of saturation*. Above the zone of saturation lies the *unsaturated zone*. The dividing line between the two zones is called the *water table*.

Most of Charles County is covered with a relatively thin veneer (10–30 feet thick) of sand, gravel, and clay. These have been described in the section on Geology as Recent and Pleistocene deposits. Into these rocks the rain water readily sinks and at different depths in different localities encounters the saturated zone. If, now, a hole is dug from the surface down into the saturated zone, this hole will fill with water and a well is made. The water in such a well will have an upper surface that corresponds with the water table. (See Plate VIII (in Pocket).) The water table can, therefore, be mapped by measuring the elevation of the water level in a large number of wells. A map of the water table will show that it corresponds roughly to the surface topography; that is, the water table will be high on the hill tops and low in the valleys. At places the change in slope of the surface topography will be more abrupt than will that of the water table so that the two surfaces will intersect. Where this takes place, water must move out from the saturated zone to the surface, and at such places seeps or springs are formed.

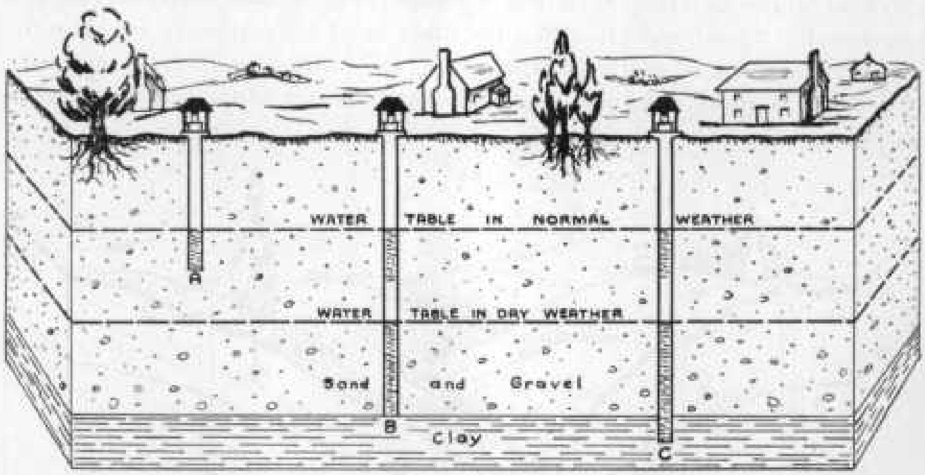


FIG. 12. Sketch Showing Effect of Decline in Water Table at Wells A, B, and C. Well A would go dry in time of drought; wells B and C would have a decline in water level, but would not go dry. Well C, because of the additional storage space in the underlying clay, would be the most reliable in extreme droughts.

Observations on the water table show that it is not a fixed surface, but that it fluctuates. These fluctuations are caused by the quantity of water that goes into the saturated zone, and also by the water that goes out. Since the source of the ground water is rainfall, the amount of water in the saturated zone will vary with the rainfall. The effect of heavy rains or of a drought may not be noticed in a well for a long time owing to the fact, as pointed out above, that the water moves so slowly underground. In some places certain dug wells never go dry, whereas others nearby may frequently go dry. This situation may arise from several causes. First, the well that goes dry might not be deep enough; that is, it may not have been sunk far enough into the saturated zone to take care of the lowering of the water table in times of drought; second, the sands and gravel beds may be thin and have little storage capacity; third, the well may penetrate a water-bearing stratum of very low permeability. Deepening the well may or may not help, depending on whether the saturated zone had been completely penetrated.

Dug or water table wells are the chief source of domestic and farm water supply of Charles County.

Depending on whether or not an impermeable confining bed is present at the top of the zone of saturation, water may be classified as free water and confined water. Where no confining bed is present the zone of saturation has a water table that is free to rise or fall as water enters and leaves the saturated zone. The water is called free water, unconfined water, or water table water. It does not, of course, flow as freely as water in streams, because it generally is moving through many very small openings. Where a confining bed is present at the top of the saturated zone, the water is confined under pressure and is called confined or artesian water. The water enters the saturated zone where the permeable rock comes out from beneath the confined bed, passes

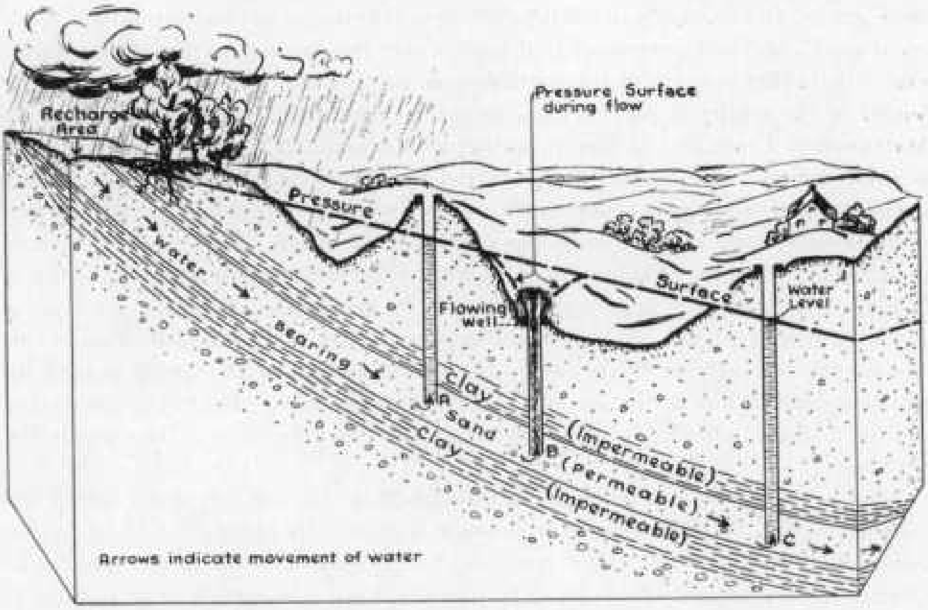


FIG. 13. Sketch Showing Principle of Artesian Flow. Water moves down from the surface (recharge area) along a permeable sand bed which is sealed above and below by impermeable clay beds. When wells A and C, which are on hills, were drilled, water rose into them to the pressure surface, but the wells did not flow. Well B was drilled in a valley at an elevation below the pressure surface and it became, therefore, a flowing well.

beneath the confining bed under the influence of gravity and exerts an upward pressure on the bottom of the confining bed. Typically the water is not able to move through the permeable bed to distant areas of ground-water discharge as rapidly as it is able to enter so that the permeable bed fills up to the level of the edge of the confining bed, and the water spills over, forming springs. The situation is analogous to that in which water is poured into the top of an inclined pipe that has only a very small outlet at the lower end. At any point along the pipe the water is confined under pressure and will spurt out if the pipe is pierced. The farther down the pipe from the upper end, the greater the pressure and the higher the water will rise above the pipe. It will not, of course, rise above the level of the upper end of the pipe; in fact, due to the loss in head owing to the escape of water at the lower end of the pipe, the pressure head of the water as measured from a horizontal line becomes lower from the upper toward the lower end of the pipe. The confining water-bearing beds of

Charles County are analogous to the pipe if we imagine it being buried in the ground, with the upper end exposed and the lower end provided with a means by which water can escape at an elevation lower than that of the upper end of the pipe.

Throughout the Coastal Plain region of Maryland, including Charles County, the main supply of ground water for industrial purposes comes from confined or artesian water, and the wells supplying such water are generally called artesian wells.

In the section on Geology it was shown that the relatively thin veneer of Pleistocene sand, gravel, and clay rests on the beveled edges of geologically older formations made up of sand, clay, and greensands that have a very low inclination toward the southeast. Beds that outcrop in the northwestern part of the county are found deeply buried in the southeast part of the county. For example, beds which outcrop on Mattawoman Creek east of Mason Springs will be found at a depth of over 200 feet at Cobb Island. The inclined beds covered by the veneer of Pleistocene materials are made up of sand which is permeable and clay which is impermeable. Water from the free-water zone in the Pleistocene sediments percolates down into the inclined sand beds or other permeable beds in the underlying strata along which it continues to move as long as there is no real obstruction. Obstructions, however, are eventually encountered in some form of change in permeability of the bed. Because of this and the friction involved in movement the water in the sand beds tends to back up just as water would in the inclined pipe described previously. The impermeable clay beds correspond to the walls of the pipe and confine the movement of the water to the sand bed.

What happens now if a well is drilled to puncture the sand bed which carries the confined water? Where the artesian pressure is sufficiently high and the land surface sufficiently low, the water might spurt out of the well, but this rarely happens in Charles County because the hydrostatic pressure is not now great enough to carry it more than two or three feet above sea level. Only a few years back, however, water did flow from some of the low lying wells in the eastern part of Charles County.

The position of the water surface in an artesian well is not that of the water table. The position of the water table depends on the relative elevation and distance of recharge and discharge areas, permeability of the water-bearing materials and amount of replenishment and discharge, and the water table is free to fluctuate with variations in the rates of replenishment and discharge. The elevation of the water level in an artesian well depends on the elevation of the intake or recharge area of the particular bed from which the water comes, the elevation of the discharge area and the loss in head caused by friction. The frictional losses vary with the permeability of the beds. The surface represented then by measurements of water levels in artesian wells is a pressure surface. Changes in pressure will cause changes in the water levels in the wells. The pressure is reduced if water is used extensively from the water-bearing bed by heavy pumping from a single well or from a group of wells. In the Baltimore industrial area the water level has been lowered as much as 160 feet since the first records of water levels were kept. Except near the recharge area variations in rate of recharge do not cause large fluctuations of the pressure surface.

To summarize, then, we see that the primary source of underground water is precipitation; that the water moves underground through the pores of the rocks or spaces between the sand grains and gravel; and that it reaches the surface again through water-table wells and springs, and through artesian wells and springs; and also by upward leakage through the confining beds where the water is under hydrostatic pressure.

RELATIONSHIP OF GROUND WATER OCCURRENCE AND GEOLOGY

A knowledge of the geology of an area is essential for the knowledge of the occurrence of ground water. Rocks are the natural conduits in which the water runs and are also the reservoirs that store the water. The stratification and inclination of the sedimentary rocks, such as those in Charles County, and their changes in texture from place to place are important controls that govern the movement of ground water. The composition of the rocks largely determines the quality of the water, that is, whether the water will be hard or soft, palatable or not palatable. Geology, then is the framework into which the study of ground water must be fitted.

GROUND WATER IN CHARLES COUNTY

INTRODUCTORY STATEMENT

The close relation between the occurrence of ground water and the geology of a region was pointed out. In the early part of this report the geology of Charles County is described. The purpose of this section is to show specifically how the geology and the occurrence of ground water are related in Charles County.

In Charles County the rocks are unconsolidated sand, clay, gravel, and greensand. The openings in which ground water occurs are the pore spaces between the particles of clay, sand and gravel, which make up the beds. Since clays generally are of low permeability, they do not serve as aquifers or water supplying beds; thus the principal aquifers are the sand and gravel beds. Since, too, the rocks are unconsolidated, rain or snow water, which are the chief sources of ground water, will sink rapidly into them. It was shown that the older formations have a low dip or inclination toward the southeast. This together with the alternation of sand and clay beds affords the necessary condition for the occurrence of water under pressure or artesian water. In Charles County the principal water-bearing rocks are of Pleistocene, Eocene and Cretaceous age.

UTILIZATION OF GROUND WATER IN CHARLES COUNTY

Ground water in Charles County is obtained from springs, dug wells, drive point wells, and drilled wells. Surface water is obtained also from the Potomac River and from some of the other streams, but water from these sources will not be discussed here.

Springs: Springs are widespread in Charles County, and are relied on for water when shallow dug wells go dry. Springs are likely to occur where there are abrupt changes of slope in surface topography, hence they are found in stream valleys eroded into the flat lying upland parts of the county. After a dry spell during which the water table is lowered many of the springs go dry.

Most of the springs of the county are found along the outcrops of the contact be-

TABLE XIV

Selected List of Dug Wells

Explanation

Table XIV is a list of dug wells located in various parts of the county. Since practically all wells in towns are sealed against surface contamination, few can be measured for the depth of the well or the depth to water. The list of wells will give anyone who is contemplating digging a well in any particular section of the county an idea as to the depth to water he may have to dig. The data given in the columns are as follows:

Col. 1—Identifying number.

Col. 2—Town nearest the well.

Col. 3—Elevation in feet. This is the average elevation above sea level, of the land surface at the well. It is determined either from topographic maps or altimeter checks on nearby bench marks.

Col. 4—Depth of well in feet. This depth is measured from ground level to the bottom of the well.

Col. 5—Depth to static water level in feet (SWL). This is the distance from the ground to the surface of the water in the well.

Col. 6—Depth of water in feet—the distance between the static water level and the bottom of the well. Most people are interested in the depth of the water in their well, hence this column is added.

Col. 7—El. SWL in feet. This is the elevation above sea level of the static water level in the well, and shows the position of the water table at that place.

Col. 8—Date. This is the date on which the water level in the well was measured. This date is important, since the water table fluctuates with the seasons, the local weather, and the quantity of water used. Observation wells in the county are measured from time to time, to obtain data on these fluctuations.

1	2	3	4	5	6	7	8
No.	Location	El.	Depth Well	Depth SWL	Depth Water	El. SWL	Measured Date
	Northeast Section						
Be 1	Berry	200	25	12	13	188	11/14/46
Be 14	Middletown	200	17	13	4	187	5/26/47
Be 15	White Plains	180	26	25	1	155	5/26/47
Bf 4	Mattawoman	215	18	16	2	199	5/17/46
Bf 16	Waldorf	215	22	10	12	205	9/ 4/46
Bf 19	Piney Church	215	20	19	1	196	9/ 5/46
Bf 21	Beantown	184	18	16	2	168	9/24/46
Bf 22	Radio Station, U. S.	203	24	22	2	181	11/ 6/47
Bf 23	St. Peters Church	184	13	11	2	173	9/24/46
Bf 25	Waldorf	186	42	31	11	155	9/25/46
Bf 40	Mattawoman	220	21	12	9	208	3/31/47
Bf 41	Mattawoman	220	19	13	6	207	3/31/47
Bf 44	Waldorf	215	19	16	3	199	3/31/47
Bf 46	Waldorf	215	18	11	7	204	4/ 3/47
Bf 48	Mattawoman	215	20	16	4	199	4/ 3/47
Bf 50	Mattawoman	225	17	7	10	218	4/ 3/47
Bf 52	Mattawoman	225	20	11	9	214	4/ 3/47
Bf 55	Mattawoman	220	20	12	8	208	4/ 3/47
Bf 72	St. Peters Church	193	28	24	4	169	4/ 9/47
Bf 73	Waldorf	215	14	8	6	207	4/ 9/47
Bf 74	Waldorf	215	18	6	12	209	4/ 9/47

TABLE XIV—*Continued*

1	2	3	4	5	6	7	8
No.	Location	El.	Depth Well	Depth SWL	Depth Water	El. SWL	Measured Date
	Northeast Section—*Continued*						
Bf 75	Waldorf	225	18	7	11	218	4/ 9/47
Bf 78	Waldorf-Mattawoman	190	17	14	3	176	4/10/47
Bf 81	Waldorf-Mattawoman	210	14	5	9	205	4/10/47
Bf 91	Waldorf	215	18	5	13	210	4/10/47
Bg 2	Gallant Green	186	18	16	2	170	9/ 5/46
Bg 3	Malcolm	170	33	29	4	141	9/ 5/46
Bg 4	Malcolm	192	19	15	4	177	9/25/46
Bg 6	Gallant Green	191	14	12	2	179	10/ 7/47
Bg 7	Swanson Creek	183	34	33	1	150	10/ 7/47
Bg 8	Malcolm Sta.	194	8	5	3	189	10/ 7/47
Ce 5	La Plata	190	17	9	8	181	5/23/46
Ce 11	Nr. La Plata	167	24	20	4	147	10/14/47
Cf 7	Burnt Store	189	18	17	1	172	7/14/47
Cg 2	Hughesville	175	12	5	7	170	11/13/46
Cg 3	Old Field Church	189	29	23	6	166	10/ 7/47
Cg 4	Gallant Green	181	15	12	3	169	10/ 7/47
Cg 5	Bryantown	166	10	8	2	158	10/ 7/47
Cg 8	Gilbert Run Road	162	10	9	1	153	10/10/47
Ch 2	Patuxent	143	5	5	0	138	9/ 1/47
Ch 3	Patuxent	183	36	29	7	154	10/ 7/47
	Southeast Section						
De 2	Nr. Fair Grounds	180	19	17	2	163	3/10/47
De 7	Newtown	172	28	26	2	146	10/14/47
De 8	Clark Run Bridge	60	12	9	3	51	10/ 4/47
De 12	Faulkner Jct.	152	28	25	3	127	10/14/47
De 13	Faulkner Jct.	145	24	24	0	121	10/14/47
De 14	Faulkner	137	31	29	2	108	10/14/47
Df 1	Olivers Shop	187	21	21	0	166	11/13/46
Df 2	Dubois	180	29	27	2	153	10/10/47
Df 3	Dubois	178	38	35	3	143	10/10/47
Df 5	Newport	75	14	4	10	71	10/10/47
Df 6	Bowlings Alley	165	28	27	1	138	10/10/47
Df 8	Dentsville	184	28	23	5	161	10/14/47
Dg 1	Charlotte Hall	180	38	35	3	145	5/ 5/47
Ee 15	Wayside	103	64	48	16	55	5/10/46
Ee 16	Wayside	44	23	16	7	28	11/ 6/47
Ee 22	Popes Creek-Newburg	110	25	19	6	91	9/26/46
Ee 32	Faulkner	151	34	29	5	122	11/13/46
Ee 33	Morgantown	5	69	4	65	1	1/22/47
Ee 34	Wayside	129	42	39	3	90	5/27/47
Ef 6	Air Beacon 11	140	20	19	1	121	10/10/47
Ef 7	Wicomico	151	20	19	1	132	10/10/47
Ff 24	Issue	14	15	7	8	7	11/13/46

TABLE XIV—*Concluded*

1	2	3	4	5	6	7	8
No.	Location	El.	Depth Well	Depth SWL	Depth Water	El. SWL	Measured Date
	Northwest Section—*Continued*						
Bc 10	Potomac Heights	125	39	28	11	97	11/46
Bc 11	Mason Springs	18	13	11	2	7	12/46
Bd 6	Old Benville School	192	9	3	6	189	6/47
Bd 10	Pomfret	200	19	14	5	186	6/47
Cb 1	Rison	100	41	39	2	61	12/47
Cb 2	Rison	143	40	38	2	105	12/47
Cb 3	Chicamuxen	140	46	44	2	96	12/47
Cb 4	Doncaster	107	38	37	1	70	12/47
Cb 5	Doncaster	140	34	32	2	108	12/47
Cc 1	Ripley	174	19	9	10	165	12/47
Cc 2	Ripley	120	18	15	3	105	12/47
Cc 3	Marbury	60	22	17	5	43	12/47
Cd 2	Ripley	193	21	17	4	176	5/47
Cd 3	Pomfret	180	8	6	2	174	5/47
Cd 6	McConchie	172	29	28	1	144	12/47
	Southwest Section						
Da 2	Blue Bay	20	29	27	2	7	12/47
Db 1	Nanjemoy	82	59	27	32	55	7/47
Db 2	Grayton	114	13	10	3	104	10/47
Db 3	Grayton	113	35	22	13	100	10/47
Db 5	Nanjemoy	65	20	17	3	48	12/47
Db 6	Nanjemoy	130	36	35	1	95	12/47
Dc 2	Grayton	120	39	21	18	99	10/47
Dc 3	Grayton	118	20	15	5	103	10/47
Dc 4	Tayloe Neck	20	14	10	4	10	12/47
Dc 6	Welcome	140	29	28	1	112	12/47
Dc 7	Ironsides	127	31	30	1	97	
Dc 8	Ironsides	127	14	13	1	114	12/47
Dc 9	Durham Church	120	34	31	3	89	12/47
Dc 10	Tayloe Neck	15	22	8	14	7	12/47
Dc 12	Hilltop	136	24	22	2	112	12/47
Dd 6	Welcome	151	25	23	2	128	12/47
Eb 4	Maryland Point	28	10	5	5	23	12/47
Eb 5	Maryland Point P. O.	76	19	14	5	62	12/47
Eb 6	Maryland Point P. O.	84	45	41	4	43	12/47
Ec 1	Riverside	20	28	0	28	20	12/47
Ec 2	Riverside	20	12	5	7	15	12/47
Ec 3	Riverside	20	20	19	1	1	12/47
Ec 4	Tayloe Neck	20	6	2	4	14	12/47

tween the Pleistocene sand and gravel and the underlying formations where they consist of clay. These outcrops occur on valley slopes or along streams. One large spring on the highway west of Beantown is coming from a fissure in rocks older than Pleistocene. This water may, therefore, have its origin in the older rocks.

Springs are of importance in the economy of the county in that they feed the streams which water the county, particularly in times of drought. They are, therefore, a source of supply for livestock and for the wild life of the county. As a direct supply of drinking water for many people, however, they are of no great importance.

Drive point wells: Drive point wells are used in some places in Charles County, but not so extensively as in some other Coastal Plain counties of the State. A driven well is simply a small diameter pipe driven into the ground into the saturated zone below the water table. If the ground is easy to penetrate, a drive point well may be completed and brought in production within a few hours. Since the diameter of the pipe is necessarily small and the pump cylinder is attached directly to the pipe, the water table must lie less than 22 feet below the pump cylinder, the practical lift for ordinary suction pumps. In many parts of Charles County the water table lies at a greater distance than 20 feet below the land surface; so drive point wells would be of no use there.

Dug wells: Dug wells are very generally used in Charles County to obtain water for domestic use. Most of these wells are 3 feet in diameter and have concrete rings to hold up the side walls. Generally the wells are shut in to prevent surface contamination—a fact that makes if difficult to get many measurements on the water table.

Table XIV shows a number of dug wells throughout the county from which measurements were obtained of the elevation of the water table. This list is not a complete inventory of the wells in the county. In closely settled communities where wells are most crowded, they are nearly all closed in so that observations cannot be made.

Drilled wells: Drilled wells are necessary where an abundant and assured supply of water is wanted. Since Charles County is largely agricultural and has abundant rainfall, the number of drilled wells is comparatively small; although in places such as Indian Head, Waldorf, Cobb Island, and Benedict, drilled wells are common. Cobb Island alone has about 200 drilled wells.

Drilled wells are less likely to be contaminated than dug wells, and the supply of water is more abundant.

Table XV is a list of wells drilled in Charles County since July 1, 1945.

WELLS IN PLEISTOCENE SEDIMENTS

In the section of this report on Geology it was shown that much of the surface of Charles County is underlain down to depths at places of 30 to 40 feet by Pleistocene sand, gravel, and some clay. Rain water sinks into this material quickly, and at depths that vary from place to place encounters the saturated zone, the top of which is called the water table. Below the water table all openings are filled with water. If, now, a well is sunk into the saturated zone, it will fill with water. The top of the water surface in the well, therefore, represents the water table. The elevation of this surface is determined simply by measuring its distance below the land surface, and substracting this distance from the ground elevation. Plate VIII shows the elevation of the water table at a number of places in the county at the time the measurements were made. The list of wells in Table XIV (p. 144) gives the elevation of the water table at the time specified. The surface of the water in the well is also known as the

TABLE XV

Wells Drilled Since July 1, 1945

From July 1, 1945, well drillers have been required by law to send to the Department of Geology, Mines and Water Resources, on completion of a well, data requested about the drilling of the well and the results of the drilling. The table herewith gives some of the data supplied by the driller and additional data supplied by the Department. An explanation of each of the columns is given here.

Column 1—The number of the well is the number of the permit issued for the drilling of the well. Here it is simply an identifying number.

Column 2—Location is given here in a general way only. The location is pin-pointed in the last column of the table.

Column 3—Owner or tenant. This is the name that appears on the driller's application for a permit.

Column 4—Elevation, feet. The elevation or altitude is taken either from the topographic maps or from altimeter observations. The altitude is the average altitude of the land surface at the well. Altitudes should be correct within 3 feet. The altitude determinations are made by the Department.

Column 5—Depth. This is obtained from the driller's report.

Column 6—Elevation, bottom, feet. This indicates the distance of the bottom of the well above or below sea level. (−) before the number means below sea level; (+) means above sea level.

Column 7—Geologic unit. This is the geologic age of the rocks that are the source of the water in the well.

Column 8—S. L. El. Ft. This is the elevation above or below sea level at which the water stood in the well when the wall was not being pumped and when the well was first drilled. F indicates flowing well.

Column 9—Meth. drill. J. means the well was drilled by the jetting method; C., drilled with cable or percussion tools.

Column 10—Diameter casing. This is the diameter of the casing left in the lower part of the well.

Column 11—Screen, feet. Number of feet of screen in the well at the water sand.

Column 12—Pump test, rate. Upon completion of the drilling of a well, the driller runs a test from which he gets an approximate idea of the least amount of water that can be expected over a long period, in gallons per minute (g.p.m.). Since very little water is used from domestic wells, the maximum yield of the well is rarely determined by the driller.

Column 13—Use. D., domestic and farm; I., industrial; PS—public service.

Column 14—Date of completion of the well; also date of pumping test.

Column 15—Loc. number. This gives the approximate location of the well. (for explanation see p. 97) The letters are abbreviations of the U. S. Geological Survey topographic sheets covering the area. Br.—Brandywine quadrangle; Nj.—Nanjemoy quadrangle; Wic.—Wicomico quadrangle; I. H.—Indian Head quadrangle; St.—Stafford quadrangle.

Wells drilled prior to July 1, 1945, are not included here because of the uncertainty of the data. These wells were drilled prior to the time when reports on wells were required by the Department.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Office P. No.	Location	Owner or Tenant	Elev., Ft.	Depth, Ft.	El. Bot., Ft.	Water-bearing beds Geologic unit	S.L. El., Ft.	Meth. Drill.	Diam. Casing, In.	Screen, Ft.	Pump Test Rate, g.p.m.	Use	Date Drilled	Loc. No.
P-240	Waldorf—½ mi. N.	Md. Tobacco Growers Assn.	215	345±	−130	Aquia	+65	J	2	45	4	D	1946	Br. 5-452
P-396	Maryland Point	Merrick Boys Camp	20	97	−77	?	0	C	6	7	25	Camp	1946	Nj. 4-821
P-476	Cobb Island	Miles Norris #1	14	277	−263	Aquia	+6	J	1½	20	8	D	1946	Wic. 8-964
P-477	Cobb Island	Miles Norris #2	12	262	−250	Aquia	+4	J	1½	20	14	D	1946	Wic. 8-863
P-478	Cobb Island	Harry Panzer	10	272	−262	Aquia	+8	J	1½	20	8	D	1946	Wic. 8-967
P-479	Cobb Island	Mrs. A. D. Hough	10	267	−257	Aquia	+8	J	1½	20	18	D	1946	Wic. 8-957
P-546	Cobb Island	W. F. Smith	3	260	−257	Aquia	F	J	1½	20	15	D	1946	Wic. 8-918

P-547	Cobb Island	F. M. Posey	12	275	−263	Aquia	+5	J	1½	20	10	D	1946	Wic. 8-946
P-548	Cobb Island	G. W. Ackerman	8	265	−257	Aquia	+3	J	1½	20	10	D	1946	Wic. 8-946
P-549	Cobb Island	R. H. Robinson	10	275	−265	Aquia	−1	J	1½	20	10	D	1946	Wic. 8-954
P-572	Woodlawn Point	L. J. Menders	12	273	−261	Aquia	+9	J	1½	20	9	D	1946	Wic. 8-812
P-620	Rock Point	Major Grimes	14	273	−259	Aquia	+6	J	1½	20	12	D	1946	Wic. 8-932
P-621	Rock Point	Henry Stein	14	269	−255	Aquia	+6	J	1½	20	10	D	1946	Wic. 8-962
P-622	Rock Point	Potomac Fish & Oyster Co.	5	283	−278	Aquia	F	J	1½	40	15	D	1946	Wic. 8-961
P-651	Issue	J. T. Simpson	14	274	−260	Aquia	+9	J	1½	20	8	D	1946	Wic. 8-546
P-652	Tompkinsville	W. L. Simms	17	273	−256	Aquia	+12	J	1½	20	8	D	1946	Wic. 8-162
P-653	Tompkinsville	E. A. Bauman	12	308	−296	Aquia	+7	J	1½	20	15	D	1946	Wic. 8-259
P-654	Tompkinsville	W. S. Stein	2	274	−272	Aquia	F	J	1½	20	20	D	1946	Wic. 8-378
P-702	Cobb Island	Carroll Hill	12	272	−260	Aquia	+5	J	1½	20	10	D	1946	Wic. 8-9?
P-703	Cobb Island	K. C. White	12	264	−252	Aquia	+7	J	1½	20	12	D	1946	Wic. 8-9?
P-704	Cobb Island	P. F. Richards	12	271	−259	Aquia	+6	J	1½	20	10	D	1946	Wic. 8-9?
P-705	Cobb Island	G. W. Hogge, Jr.	12	268	−256	Aquia	+6	J	1½	20	10	D	1946	Wic. 8-9-
P-756	Cobb Island	J. Doyle, Jr.	12	278	−266	Aquia	+5	J	1½	24	12	D	1946	Wic. 8-9-
P-791	Waldorf	L. L. Parlett	215	392	−177	Aquia	+55	J	6	11	50	D	1946	Br. 5-449
P-810	Cobb Island	John Simms	12	273	−261	Aquia	+3	J	1½	20	10	D	1946	Wic. 8-95-
P-850	Hughesville	Southern Md. Elec. Coop.	179	548	−369	Aquia	+29	C	6	10	50	D	1946	Br. 9-594
P-1045	Rock Point	H. J. & A. M. Stein	17	280	−263	Aquia	+9	J	1½	20	15	I	1946	Wic. 8-678
P-1050	Mt. Victoria	H. J. Orth	38	324	−286	Aquia	+21	C	6	9	25	D	1946	Wic. 5-587
P-1076	Mt. Victoria	F. M. Reeder	5	347	−342	Aquia	+3	C	6	10	24	D	1947	Wic. 5-912
P-1122	La Plata—3 mi. S.	Southern Md. Cleaners	165	632	−467	Cret.	+15	C	6	12	24	I	1947	Wic. 1-152
P-1231	La Plata—8 mi. S.	I. P. Co.	140	420	−280	Cret.	+40	C	4½	12	20	I	1947	Wic. 1-847
P-1335	Cobb Island	Mrs. Lillian Baker	12	270	−258	Aquia	+4	J	1½	20	15	D	1947	Wic. 8-9-
P-1336	Rock Point—1 mi. W.	J. M. Hill	14	260	−246	Aquia	+7	J	1½	20	15	D	1947	Wic. 8-923
P-1398	La Plata	Town	160	1094	−934	Cret.	+25	C	8	24	100	Pub. Ser.	1947	Br. 7-574
P-1444	Rock Point	John Bauman	12	273	−261	Aquia	+2	J	1½	20	9	D	1947	Wic. 8-938
P-1445	Popes Creek	Mrs. Mary Hayden	100	346	−246	Aquia	+10	J	1½	25	4	D	1947	Wic. 4-428
P-1446	Tompkinsville	P. J. Martin	10	277	−267	Aquia	+5	J	1½	20	9	D	1947	Wic. 8-812
P-1447	Cobb Island	H. Hickson, Jr.	12	280	−268	Aquia	+3	J	1½	20	7	D	1947	Wic. 8-96-
P-1448	Rock Point	John Thomas	10	290	−280	Aquia	−5	J	1½	20	8	D	1947	Wic. 8-938
P-1449	Tompkinsville	M. Williams	15	273	−258	Aquia	+13	J	1½	20	10	D	1947	Wic. 8-228
P-1462	Wayside	F. C. Pace	60	314	−254	Aquia	+30	J	1½	10	—	D	1947	Wic. 4-953
P-1502	Cobb Island	B. Crane	12	273	−261	Aquia	+6	J	1½	20	12	D	1947	Wic. 8-95-
P-1503	Tompkinsville	Wm. Simms	15	267	−252	Aquia	+6	J	1½	20	9	D	1947	Wic. 8-127
P-1546	Newport	W. Bowling	147	400	−253	Aquia	+67	J	2½	20	10	D	1947	Wic. 5-281

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Office P. No.	Location	Owner or Tenant	Elev., Ft.	Depth, Ft.	El. Bot., Ft.	Water-bearing beds Geologic unit	S.L. El., Ft.	Meth. Drill.	Diam. Casing, In.	Screen, Ft.	Pump Test Rate, g.p.m.	Use	Date Drilled	Loc. No.
P-1547	Port Tobacco	F. L. Peckham	35	200	−165	Aquia	+15	J	2½	—	10	D	1947	Nj. 3-371
P-1548	Nanjemoy	E. Sullivan	28	210	−182	Cret.	+7	J	1½	—	18	D	1947	St. 3-658
P-1549	Cobb Island	Grady Bell	12	283	−271	Aquia	+4	J	1½	20	6	D	1947	Wic. 8-95-
P-1551	Tompkinsville	S. Robey	5	272	−267	Aquia	+2	J	1½	20	12	D	1947	Wic. 8-173
P-1552	Woodland Point	Rynearson	10	271	−261	Aquia	+8	J	1½	20	12	D	1947	Wic. 8-812
P-1553	Tompkinsville	C. Dent	14	276	−262	Aquia	+4	J	1½	20	9	D	1947	Wic. 8-234
P-1596	Newburg	Weisbrod	22	249	−227	Aquia	+9	J	1½	20	10	D	1947	Wic. 4-575
P-1702	Wayside	P. Bowling	105	349	−244	Aquia	+25	J	2½	20	4	D	1947	Wic. 4-952
P-1705	Cobb Island	C. Daley	12	269	−257	Aquia	+6	J	1½	20	12	D	1947	Wic. 8-9-
P-1706	Woodland Point	Rossiter	12	270	−258	Aquia	+7	J	1½	20	8	D	1947	Wic. 8-499
P-1715	Wayside	Wedding	5	281	−276	Aquia	F	J	1½	—	60	D	1947	Wic. 4-884
P-1734	Woodland Point	Shelton	14	273	−259	Aquia	+9	J	1½	20	12	D	1947	Wic. 8-495
P-1770	Waldorf	Md. State Police	215	440	−233	Cret.	+40	C	6	12	40	D	1947	Br. 5-257
P-1797	Wicomico	Clemens	147	398	−251	Aquia	+47	J	2½	20	6	D	1947	Wic. 5-222

"static water level"; that is, the level at which the water is standing at the time of measurement. It is not truly static as it fluctuates with the water table as described previously.

Many people find it difficult to understand what bearing the water level in a well has on the general problem of water conservation. These same people would have no difficulty in understanding that the water level behind a dam indicates how much water there is in the reservoir, nor that when more water is being used from a reservoir than is going into it the water level in the reservoir falls. The reason for this difficulty is, of course, that the ground water cannot be seen as forming a reservoir as can the water behind a dam.

In simple terms, then, the observations that are made from time to time on the water table tell us how the water is behaving in the underground reservoir and they warn of danger if the fall of the water table is continuous over a long period of time.

In the discussion of general principles it was pointed out that water levels in wells represent two types of ground water. One is unconfined or water-table water; the other is confined or artesian water. The water level in a water-table well shows the balance between the force of gravity which causes the rain water to descend to the water-table and the ground water to move slowly toward surface outlets, and the counteracting, replenishing effect of recharge. The water level in an artesian well represents the hydrostatic pressure of water in the confined aquifer penetrated by the well. The Pleistocene sediments in Charles County contain largely unconfined water, and wells penetrating the zone of saturation in them are called water-table wells.

The list of dug wells in Table XIV on which water table measurements were made shows the direct relationship between elevation of the surface and elevation of the water table. For example, well Bf 16 at Waldorf has an elevation of 215 feet and the water table has an elevation of 205 feet; that is, the water table is only 10 feet below the surface. Well Cg 8 at Gilbert Run Road has an elevation of 162 feet and the elevation of the water table is 153 feet. Well Df 5 at Newport has an elevation of 75 feet and the elevation of the water table is 71 feet; well Ee 33 at Morgantown has an elevation of 5 feet and the water table an elevation of 1 foot.

The cause of the fluctuations of the water table in wells has been discussed. The survey of the dug wells in Charles County shows that only a few of them go dry in the average year.

The depth of the well may or may not be significant in regard to its yield of water. The thickness of the saturated zone and its permeability are the factors which control the supply of the water to the well; and the daily amount of water used determines whether this supply will be overreached. Most of the dug wells in Charles County appear to be able to take care of the ordinary domestic use of the water. For this reason there are comparatively few drilled wells in the county as a whole. The drilled wells are generally for industrial use, or for domestic use in certain places such as Benedict, Cobb Island, and other low lying settlements near tide water.

Certain wells in Charles County are now being used as observation wells. Measurements in these wells are made from time to time to get a long range picture of the movement of the water table; but data will have to be accumulated over a number of years before significant trends can be determined.

WELLS IN EOCENE ROCKS—AQUIA FORMATION

In order to get water from below the Pleistocene beds, one must drill to the Eocene Aquia formation. This means that no suitable water-producing beds, or aquifers, occur in either the Miocene series in Charles County nor in the Eocene Nanjemoy

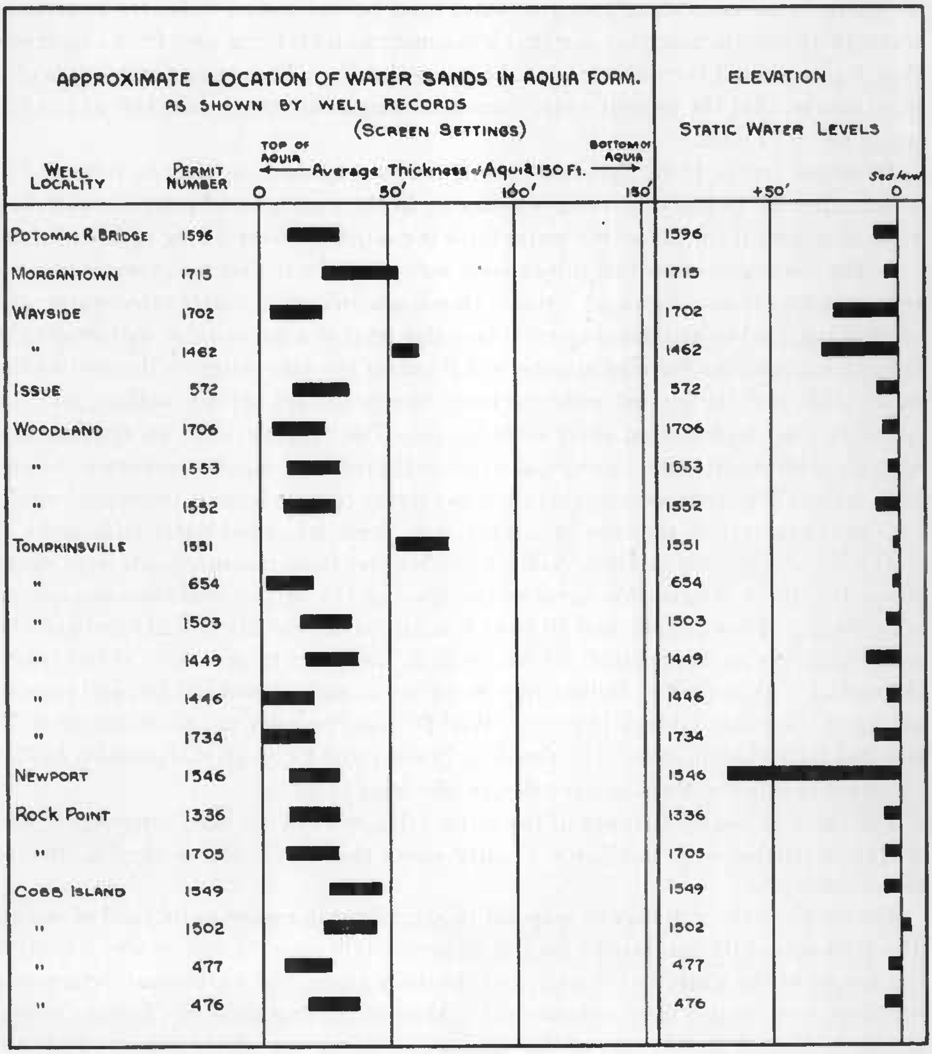


FIG. 14. Location of Water-bearing Sands and Static Water Levels in the Aquia Formation, as shown by well records.

formation. Water in the wells that pierce the Aquia formation are under pressure, and hence are classed as artesian wells.

A brief summary of most of the wells drilled, since July 1, 1945, into the Aquia formation is given here. Attention is called to the term "light brown" or "pink" clay. This clay is that described in the section on Geology as lying at the base of the Eocene

Nanjemoy formation and is the Marlboro clay member of the Nanjemoy formation. Under this clay lies the Eocene Aquia formation. Since its color is distinctive, this clay is easily recognized by the well driller and hence is designated as a "marker" bed. In many of the drillers' logs (records of the rocks penetrated by the drill) the "pink" clay bed is noted but the depths at which it was cut are not given.

The water-bearing bed is indicated by the location of the well screen. This interval may or may not represent the entire thickness of the bed.

Under "Remarks" is given the distance in the Aquia formation, that is, the distance below the base of the Marlboro clay, at which the top of the water-bearing bed was encountered.

Figure 14 (P. 152) shows graphically the location of producing water-bearing sands in the Aquia formation as well as the static water levels in some of the wells. It brings out the fact that in nearly all the wells, the top of the water-bearing beds lies less that 25 feet under the base of the "pink" clay.

Plate III (contours on the base of the Nanjemoy formation) serves a practical purpose. From it we can determine the depth needed to drill in order to reach water-bearing bed or beds of the Aquia formation. The contour lines give the depth below sea level of the bottom of the "pink" clay marker bed (Marlboro clay member of the Nanjemoy formation) where it is present in the county. To find the depth of the well, add to the contour line elevation the elevation of the land surface at the point where the well is to be drilled and another 35 feet to allow for sufficient penetration of water sand. For illustration, in the vicinity of Cobb Island the top of the Aquia is at elevation −230 feet, the surface elevation is 12 feet, and add 35 feet to penetrate the water sand. This gives a total of 280 feet for the approximate depth of a well on Cobb Island.

NOTES ON WATER-BEARING BEDS—DEEP WELLS, AQUIA FORMATION

NORTHEAST SECTION

Waldorf-La Plata-Hughesville Area

P-791 Br. 5-449; El. 215; L. L. Parlett; Waldorf
Sampled—See description, p. 117; light brown (pink) clay, elevation +8 to −25 feet
Driller's log—Pink clay, elevation +5 to −23 feet
Static water level—+55 feet
Depth of well—392 feet; bottom elevation −177 feet
Water-bearing bed—Elevation −165 to −177 feet
Remarks—Aquia formation (?);142 feet below Marlboro clay member of Nanjemoy formation
Pumping test (reported)—Water level lowered 27 feet after 12 hours of pumping at rate of 50 g.p.m.

P-240 Br. 5-452; El. 215; Maryland Tobacco Growers Association; Waldorf
Driller's log—Nothing significant
Static water level—Elevation +65 feet
Depth of well—345 feet (?)
Water-bearing bed—Record incomplete
Remarks—In Aquia formation
Pumping test (reported)—Water level lowered 30 feet after 12 hours of pumping at rate of 4 g.p.m.

SOUTHEAST SECTION

Cobb Island Area

P-1335 Wic. 8-9; El. 12; L. Baker; Cobb Island
Driller's log—Pink clay bed reported; no depth given
Static water level—Elevation +4 feet
Depth—270 feet; bottom elevation −258 feet
Water-bearing bed—Elevation −238 to −258 feet
Remarks—In Aquia formation not far below pink clay (Marlboro Clay Member) of Nanjemoy
Pumping test (reported)—Water level lowered 22 feet in 4 hours at rate of 15 g.p.m.

P-476 Wic. 8-964; El. 14; Miles Norris No. 1; Cobb Island
Sampled
Driller's log—Shows pink clay; depth not given
Static water level—Elevation +6 feet
Depth—277 feet; bottom elevation −263 feet
Water-bearing bed—Elevation −243 to −263 feet
Remarks—In Aquia formation, 17 to 37 feet below pink clay (Marlboro clay member) of Nanjemoy formation.

P-477 Wic. 8-863; El. 12; Miles Norris No. 2; Cobb Island
Sampled—See description, p. 113
Driller's log—Shows pink clay marker; depth not given
Static water level—Elevation +4 feet
Depth of well—262 feet; bottom elevation −250 feet
Water-bearing bed—Elevation −230 to −250 feet
Remarks—In Aquia formation, 7 to 27 feet below the base of pink clay (Marlboro clay member) of Nanjemoy formation.

P-478 Wic. 8-967; El. 10; Harry Panzer; Cobb Island
Driller's log—Shows pink clay marker; depth not given
Static water level—+8 feet.
Depth of well—272 feet; bottom elevation −262 feet
Water-bearing bed—Elevation at −242 to −262 feet.
Remarks—In Aquia formation

P-479 Wic. 8-957; El. 10; A. D. Hough; Cobb Island
Driller's log—Shows pink clay marker, depth not given
Static water level—+8 feet
Depth of well—267 feet; elevation of bottom −257 feet
Water-bearing bed—Elevation −237 to −257 feet
Remarks—In Aquia formation, not far below pink clay (Marlboro clay member) of Nanjemoy formation

P-546 Wic. 8-918; El. 3; W. F. Smith; opposite Cobb Island
Driller's log—Shows pink clay marker bed; depth not given
Static water level—Not measured; well flows
Depth of well—260 feet; elevation of bottom −257 feet
Water-bearing bed—Elevation −237 to −257
Remarks—In Aquia formation close under the pink clay (Marlboro clay member) of Nanjemoy formation. Well flows about 1 g.p.m.

P-548 Wic. 8-946; El. 8; G. W. Ackerman; Cobb Island
Driller's log—Shows pink clay marker bed, depth not given
Static water level—Elevation +3 feet
Depth of well—265 feet; bottom elevation −257 feet
Water-bearing bed—Elevation −235 feet to −257 feet
Remarks—In Aquia formation, close under pink clay (Marlboro clay member) of Nanjemoy formation
Pumping test (reported)—Water level lowered 17 feet in 8 hours at rate of 10 g.p.m.

P-547 Wic. 8-946; El. 12; F. M. Posey; Cobb Island
Driller's log—Shows pink clay marker; depth not given
Static water level—+5 feet
Depth of well—275 feet; bottom elevation −263 feet
Water-bearing bed—Elevation −243 to −263 feet
Remarks—In Aquia formation, close under base of pink clay marker bed (Marlboro clay member) of Nanjemoy formation
Pumping test (reported)—Water level lowered 15 feet in 7 hours at rate of 10 g.p.m.

P-549 Wic. 8-954; El. 10; R. H. Robinson; Cobb Island
Driller's log—Shows pink clay marker bed, depth not given
Static water level—Elevation −1
Depth of well—275 feet; bottom elevation −265 feet
Water-bearing bed—Elevation −245 to −265 feet
Remarks—In Aquia formation close under base of pink clay marker bed (Marlboro clay member) of Nanjemoy formation
Pumping test (reported)—Water level lowered 11 feet in 8 hours at rate of 10 g.p.m.

P-702 Wic. 8-9; El. 12; C. Hill; Cobb Island
Driller's log—Shows pink clay marker bed, depth not given
Static water level—Elevation +5 feet
Depth—272 feet; bottom elevation −260 feet
Water-bearing bed—Elevation −240 feet to −260 feet
Remarks—In Aquia formation close under pink clay (Marlboro clay member) of Nanjemoy formation
Pumping test (reported)—Water level lowered 15 feet in 5 hours at rate of 10 g.p.m.

P-703 Wic. 8-9; El. 12; K. C. White; Cobb Island
Driller's log—Shows pink clay marker, depth not given
Static water level—Elevation +7 feet
Depth—264 feet; elevation −252 feet
Water-bearing bed—Elevation −232 to −252 feet
Remarks—In Aquia formation, close under pink clay (Marlboro clay member) of Nanjemoy formation
Pumping test (reported)—Water level lowered 17 feet in 5 hours pumping at rate of 12 g.p.m.

P-1502 Wic. 8-95; El. 12; B. Crane; Cobb Island
Driller's log—Pink clay marker bed, elevation −213 to −219 feet
Static water level—Elevation +6 feet
Depth—273 feet; bottom elevation −261 feet
Water-bearing bed—Elevation −243 to −261 feet
Remarks—In Aquia formation, 24 to 44 feet below base of pink clay (Marlboro clay member) of Nanjemoy formation
Pumping test (reported)—Water level lowered 19 feet in 4 hours at rate of 12 g.p.m.

P-1549

Wic. 8-95; El. 12; J. Bell; Cobb Island
Driller's log—Shows pink clay marker bed at elevation −219 to −224
Static water level—Elevation +4 feet
Depth—283 feet; bottom elevation −271 feet
Water-bearing bed—Elevation −251 to −271 feet
Remarks—In Aquia formation, 26 to 46 feet below pink clay (Marlboro clay member) of Nanjemoy formation
Pumping test (reported)—Water level lowered 22 feet in 4 hours at rate of 6 g.p.m.

P-1705

Wic. 8-9; El. 12; C. Daley; Cobb Island
Driller's log—Pink clay marker bed, elevation −218 to −228 feet
Static water level—Elevation +6 feet
Depth—269 feet; bottom elevation −257 feet
Water-bearing bed—Elevation −237 to −257 feet
Remarks—In Aquia formation, 9 to 29 feet below pink clay (Marlboro clay member) of Nanjemoy formation
Pumping test (reported)—Water level lowered 14 feet in 4 hours at rate of 12 g.p.m.

P-756

Wic. 8-9; El. 12; J. Doyle, Jr.; Cobb Island
Driller's log—Pink clay marker bed reported, depth not given
Static water level—Elevation +5 feet
Depth—278 feet; bottom elevation −266 feet
Water-bearing bed—Elevation −242 to −266 feet
Remarks—In Aquia formation not far below pink clay (Marlboro clay member) of Nanjemoy formation
Pumping test (reported)—Water level lowered 15 feet after 7 hours at rate of 12 g.p.m.

P-810

Wic. 8-95; El. 12; John Simms, Cobb Island
Driller's log—Pink clay marker bed reported, depth not given
Static water level—Elevation +3 feet
Depth—273 feet; bottom elevation −261 feet
Water-bearing bed—Elevation −241 to −261 feet
Remarks—In Aquia formation close under pink clay (Marlboro clay member) of Nanjemoy formation
Pumping test (reported)—Water level lowered 13 feet in 5 hours at rate of 10 g.p.m.

P-1447

Wic. 8-96; El. 12; H. H. Hickson, Jr.; Cobb Island
Driller's log—Shows pink clay marker bed, depth not given
Static water level—Elevation +3 feet
Depth—280 feet; bottom elevation −268 feet
Water-bearing bed—Elevation —248 feet to −268 feet
Remarks—In Aquia formation, close under pink clay (Marlboro clay member) of Nanjemoy formation
Pumping test (reported)—Water level lowered 26 feet after pumping 4 hours at rate of 7 g.p.m.

P-704

Wic. 8— ; El. 12; P. F. Richards; Cobb Island
Driller's log—Shows pink clay marker bed, depth not given
Static water level—Elevation +6 feet
Depth—271 feet; bottom elevation −259
Water-bearing bed—Elevation −239 to −259 feet
Remarks—In Aquia formation, close under pink clay (Marlboro clay member) of Nanjemoy formation
Pumping test (reported)—Water level lowered 16 feet in 5 hours at rate of 10 g.p.m.

P-705 Wic. 8-9; El. 12; G. W. Hogge, Jr.; Cobb Island
Driller's log—Shows pink clay marker bed, no depth given
Static water level—Elevation +6 feet
Depth—268 feet; bottom elevation −256 feet
Water-bearing bed—Elevation −236 to −256 feet
Remarks—In Aquia formation, close under pink clay (Marlboro clay member) of Nanjemoy formation
Pumping test (reported)—Water level lowered 16 feet after 5 hours of pumping at rate of 10 g.p.m.

Rock Point Area

P-621 Wic. 8-962; El. 14; H. Stein; Rock Point
Driller's log—Shows pink clay marker, depth not given
Static water level—+6 feet
Depth—269 feet; bottom elevation −255 feet
Water-bearing bed—Elevation −235 to −255 feet
Remarks—In Aquia formation close under base of pink clay (Marlboro clay member) of Nanjemoy formation
Pumping test (reported)—Water level lowered 14 feet in 8 hours at rate of 10 g.p.m.

P-622 Wic. 8-961; El. 5; P. Fish & Oyster Co.; Rock Point
Driller's log—Shows pink clay marker bed, depth not given
Static water level—Well flows
Depth—283 feet; bottom elevation −278 feet
Water-bearing bed—Elevation −238 to −278 feet
Remarks—In Aquia formation, close under base of pink clay (Marlboro clay member) of Nanjemoy formation
Pumping test—Water lowered to 10 feet below sea level in 3 hours at rate of 15 g.p.m.

P-620 Wic. 8-932; El. 14; Major Grimes; Rock Point
Driller's log—Shows pink clay marker bed, depth not given
Static water level—Elevation +6 feet
Depth—273 feet; bottom elevation −259
Water-bearing bed—Elevation −239 to −259
Remarks—In Aquia formation close under base of the pink clay (Marlboro clay member) of Nanjemoy formation
Pumping test (reported)—Water lowered 14 feet in 8 hours at rate of 12 g.p.m.

P-1336 Wic. 8-923; El. 14; J. M. Hill; Rock Point
Samples—Yes; show pink clay marker bed, elevation −206 to −216
Driller's log—Shows red clay marker bed; depth not given
Static water level—Elevation +7 feet
Depth—260 feet; bottom elevation −246 feet
Water-bearing bed—Elevation −226 to −246 feet
Remarks—In Aquia formation, 10 to 30 feet below the pink clay (Marlboro clay member) of Nanjemoy formation
Pumping test (reported)—Water level lowered 23 feet in 3 hours pumping at rate of 15 g.p.m.

P-1444 Wic. 8-938; El. 12; J. Bauman; Rock Point
Driller's log—Shows pink clay marker bed, depth not given
Static water level—+2 feet
Depth—273 feet; bottom elevation −261 feet
Water-bearing bed—Elevation −241 to −261 feet

Remarks—In Aquia formation, close under pink clay marker bed (Marlboro clay member) of Nanjemoy formation
Pumping test (reported)—Water level lowered 20 feet in 3 hours at rate of 9 g.p.m.

P-1448 Wic. 8-938; El. 10; J. Thomas; Rock Point
Driller's log—Shows pink clay marker bed, depth not given
Static water level—Elevation −5 feet
Depth—290 feet; bottom elevation −280 feet
Water-bearing bed—Elevation −260 to −280 feet
Remarks—In Aquia formation, close under pink clay (Marlboro clay member) of Nanjemoy formation
Pumping test (reported)—Water level lowered 25 feet in 4 hours at rate of 8 g.p.m.

Newport Area

P-1546 Wic. 5-281; El. 147; W. Bowling; Wicomico
Sampled—Yes, see description, p. 97
Driller's log—Shows pink clay marker bed, elevation −213 to −223 feet
Static water level—Elevation +67 feet
Depth—400 feet; bottom elevation −253 feet
Water-bearing bed—Elevation −233 to −253 feet
Remarks—In Aquia formation; from 10 to 30 feet below pink clay marker bed (Marlboro clay member) of Nanjemoy formation
Pumping test (reported)—Water level lowered 20 feet after 8 hours at rate of 10 g.p.m.

P-1797 Wic. 5-222; El. 147; Clemens; Wicomico
Sampled—Yes
Driller's log—No pink clay reported
Static water level—Elevation +47 feet
Depth—398 feet; bottom elevation −251 feet
Water-bearing bed—Elevation −231 to −251 feet
Remarks—In Aquia formation
Pumping test (reported)—Water level lowered 10 feet in 6 hours at rate of 6 g.p.m.

Tompkinsville-Issue Area

P-1734 Wic. 8-495; El. 14; Shelton; Woodland Point
Driller's log—Shows pink clay marker bed, bottom elevation −238 feet
Static water level—Elevation +9 feet
Depth—273 feet; bottom elevation −259 feet
Water-bearing bed—Elevation −238 to −259 feet
Remarks—In Aquia formation; water sand directly under pink clay (Marlboro clay member) of Nanjemoy formation
Pumping test (reported)—Water level lowered 15 feet in 4 hours at rate of 12 g.p.m.

P-1446 Wic. 8-812; El. 10; P. J. Martin; Woodland Point
Driller's log—Shows pink clay marker, bottom elevation −247 feet
Static water level—Elevation +5 feet
Depth—277 feet; bottom elevation −267 feet
Water-bearing bed—Elevation −247 to −267 feet
Remarks—In Aquia formation; water sand directly under pink clay (Marlboro clay member) of Nanjemoy formation

P-1449 Wic. 8-228; El. 15; M. Williams; Tompkinsville
Sampled—See description, p. 126
Driller's log—Shows pink clay marker, depth not given
Static water level—Elevation +13 feet
Depth—273 feet; bottom elevation −258 feet
Water-bearing bed—Elevation −238 to −258 feet
Remarks—In Aquia formation; sample log ahows bottom of pink clay at elevation −227 feet. Water horizon is 18 to 38 feet below base of Nanjemoy pink clay (Marlboro clay member) of Nanjemoy formation

P-1503 Wic. 8-127; El. 15; Wm. Simms; Tompkinsville
Sampled
Driller's log—Shows pink clay marker bed at elevation −205 to −211 feet
Static water level—Elevation +6 feet
Depth—267 feet; bottom elevation −252 feet
Water-bearing bed—Elevation −232 to −252 feet
Remarks—In Aquia formation; water horizon 21 to 41 feet below base of pink clay (Marlboro clay member) of Nanjemoy formation
Pumping test (reported)—Water level lowered 21 feet in 4 hours at rate of 9 g.p.m.

P-654 Wic. 8-378; El. 2; W. S. Stein; Hatton Creek, Tompkinsville
Driller's log—Shows pink clay marker bed, depth not given
Static water level—Flowing
Depth—274 feet; bottom elevation −272 feet
Water-bearing bed—Elevation −252 feet to −272 feet
Remarks—In Aquia formation; water sand lies close under pink clay (Marlboro clay member) of Nanjemoy formation
Pumping test (reported)—Water lowered to −10 feet below sea level at rate of 20 g.p.m.

P-1551 Wic. 8-173; El. 5: S. Robey; Perry Branch, Tompkinsville
Driller's log—Shows pink clay at elevation −184 to −194 feet
Static water level—+2 feet
Depth—272 feet; bottom elevation −267 feet
Water-bearing bed—Elevation −247 to −267 feet
Remarks—In Aquia formation; 53 to 73 feet below base of pink clay (Marlboro clay member) of Nanjemoy formation
Pumping test (reported)—Water level lowered 12 feet in 3 hours at rate of 12 g.p.m.

P-1552 Wic. 8-812; El. 10; Rynearson; Woodland Point
Driller's log—Shows pink clay marker bed at elevation −221 to −232
Static water level—Elevation +8 feet
Depth—271 feet; bottom elevation −261 feet
Water-bearing bed—Elevation −241 to −261 feet
Remarks—In Aquia formation; water-bearing bed 9 to 29 feet below pink clay (Marlboro clay member) of Nanjemoy formation
Pumping test (reported)—Water level lowered 8 feet in 4 hours at rate of 12 g.p.m.

P-1553 Wic. 8-234; El. 14; C. Dent; Wicomico Beach, Tompkinsville
Driller's log—Shows pink clay marker bed at elevation −231 to −236
Static water level—Elevation +4 feet
Depth—276 feet; bottom elevation −262 feet
Water-bearing bed—Elevation −242 to −262 feet

Remarks—In Aquia formation; 6 to 26 feet below pink clay marker bed (Marlboro clay member) of Nanjemoy formation
Pumping test (reported)—Water level lowered 20 feet in 4 hours at rate of 9 g.p.m.

P-1050 Wic. 5-587; El. 38; H. J. Orth; Mt. Victoria
Driller's log—Shows pink clay marker bed at elevation −217 to −237
Static water level—Elevation +21 feet
Depth—324 feet; bottom elevation −286 feet
Water-bearing bed—Elevation −277 to −286
Remarks—In Aquia formation, 45 to 54 feet below base of pink clay (Marlboro clay member) of Nanjemoy formation
Pumping test (reported)—Water level lowered 33 feet in 8 hours at rate of 25 g.p.m.

P-653 Wic. 8-259; El. 12; E. A. Bowman; Tompkinsville
Driller's log—Shows pink clay marker bed, depth not given, but above −235 feet
Static water level—Elevation +7 feet
Depth—308 feet; bottom elevation −296 feet
Water-bearing bed—Elevation −276 to −296 feet
Remarks—In Aquia formation; unknown distance below pink clay marker bed (Marlboro clay member) of Nanjemoy formation
Pumping test (reported)—Water level lowered 11 feet in 5 hours at rate of 15 g.p.m.

P-1706 Wic. 8-499; El. 12; Rossiter; Woodland Point
Driller's log—Shows pink clay marker bed at elevation −222 to −233 feet
Static water level—Elevation +7 feet
Depth—270 feet; bottom elevation −258 feet
Water-bearing bed—Elevation −238 to −258 feet
Remarks—In Aquia formation; 5 to 25 feet below pink clay (Marlboro clay member) of Nanjemoy formation
Pumping test (reported)—Water level lowered 15 feet in 4 hours at rate of 8 g.p.m.

P-651 Wic. 8-546; El. 14; J. T. Simpson; Issue
Driller's log—Shows pink clay marker bed, depth not given
Static water level—Elevation +9 feet
Depth—274 feet; bottom elevation −260 feet
Water-bearing bed—Elevation −240 to −260 feet
Remarks—In Aquia formation, close under pink clay (Marlboro clay member) of Nanjemoy formation

P-572 Wic. 8-812; El. 12; L. J. Menders; mainland, about 1.3 miles northwest of Cobb Island bridge
Sampled—See descriptions, p. 112
Driller's log—Shows pink clay marker bed, depth not given
Static water level—+9 feet
Depth of well—273 feet; bottom elevation −261 feet
Water-bearing bed—Elevation −241 to −261 feet
Remarks—In Aquia formation, 13 to 33 feet below the base of the pink clay (Marlboro clay member) of Nanjemoy formation
Pumping test (reported)—Water lowered 16 feet in 8 hours at rate of 9 g.p.m.

P-652 Wic. 8-162; El. 17; Wm. L. Simms; Tompkinsville
Driller's log—Shows pink clay marker bed, no depth given

Static water level—Elevation +12 feet
Depth—273 feet; bottom elevation −256 feet
Water-bearing bed—Elevation −236 to −256 feet
Remarks—In Aquia formation; close under bottom of pink clay (Marlboro clay. member) of Nanjemoy formation
Pumping test (reported)—Water level lowered 17 feet in 7 hours at rate of 8 g.p.m.

Wayside-Newburg Area

P-1462 Wic. 4-953; El. 60; F. C. Pace; Wayside
Sampled—Yes, pink clay marker bed, elevation −170 to −190 feet; see p. 116
Static water level—Elevation +30 feet
Depth—314 feet; elevation, bottom −254 feet
Water-bearing bed— −243 to −253
Remarks—In Aquia formation; 53 to 63 feet below base of pink clay (Marlboro clay member) of Nanjemoy formation
Pumping test—Water level lowered 50 feet after pumping 8 hours at 40 g.p.m.

P-1702 Wic. 4-952; El. 105; P. Bowling; Wayside
Driller's log—Shows pink clay marker bed, elevation −189 to −220 feet
Static water level—Elevation +25 feet
Depth—349 feet; elevation −244 feet
Water-bearing bed—Elevation −224 to −244
Remarks—In Aquia formation; 4 to 24 feet below pink clay (Marlboro clay member) of Nanjemoy formation
Pumping test (reported)—Water level lowered 10 feet in 5 hours at rate of 4 g.p.m.

P-1715 Wic. 4-884; El. 5; Wedding; Wayside
Driller's log—Shows pink clay marker bed at elevation −185 to −197 feet
Static water level—Flowing at 5 feet above sea level
Depth—281 feet; bottom elevation −276 feet
Water-bearing bed—Between elevation −226 and −276 feet
Remarks—Aquia; from 29 feet below pink clay to 79 feet
Pumping test (reported)—Water level lowered 20 feet below top of casing in 5 hours at rate of 60 g.p.m.

P-1596 Wic. 4-575; El. 22; Weisbrod; near Potomac River Bridge
Driller's log—Shows pink clay marker bed at elevation −162 to −196 feet
Static water level—Elevation +9 feet
Depth—249 feet; bottom elevation −227 feet
Water-bearing bed—Elevation −207 to −227 feet
Remarks—In Aquia formation; 11 to 31 feet below pink clay marker bed (Marlboro clay member) of Nanjemoy formation
Pumping test (reported)—Water lowered 17 feet in 4 hours at a rate of 10 g.p.m.

P-1445 Wic. 4-428; M. Hayden; near Popes Creek
Driller's log—Red clay, elevation −149 to −180
Static water level—Elevation +10 feet
Depth −346 feet; bottom elevation −246 feet
Water bearing bed—Elevation −221 to −246 feet
Remarks—In Aquia formation; about 40 to 65 feet below Marlboro clay marker bed
Pumping test (reported)—Water lowered 10 feet in 6 hours at rate of 4 g.p.m.

SOUTHWEST SECTION

Chapel Point Area

P-1547 Nj. 3-371; El. 35; F. L. Peckham; Chapel Point
Driller's log—Pink clay, elevation −51 to −54 feet
Static water level—Elevation +15 feet
Depth—200 feet; bottom elevation −165 feet
Water horizon—Elevation from −91 to −165 feet; open hole
Remarks—In Aquia formation from 37 to 111 feet below pink clay bed (Marlboro clay member) of Nanjemoy formation
Pumping test (reported)—Water level lowered 50 feet in 4 hours at rate of 10 g.p.m.

P-396 Nj. 4-821; El. 20; Merrick Boys Camp; Maryland Point
Static water level—Sea level
Depth—97 feet; bottom elevation −77 feet
Water-bearing bed—Elevation −70 to −77 feet
Remarks—In Aquia formation, 55 to 62 feet below top.
Pumping test (reported)—Water level lowered 15 feet in 8 hours at rate of 25 g.p.m.

WELL IN PALEOCENE (?) ROCKS

Very recent work on foraminifera indicate the possibility that the Southern Maryland Electric Cooperative well at Hughesville is producing from the Paleocene rocks.[16] Paleocene rocks have been recognized in several wells at Upper Marlboro in Prince Georges County.

P-850 Br. 9-594; El. 179; Southern Maryland Electric Cooperative; Hughesville
Samples—See p. 122. Base of pink clay elevation −262 feet
Driller's log—Pink clay elevation −246 to −271 feet
Static water level—Elevation +29 feet
Depth of well—548 feet; bottom elevation −369 feet
Water-bearing bed—Elevation −355 to −369
Remarks—Paleocene (?) about 84 feet below pink clay (Marlboro clay member) of Nanjemoy formation
Pumping test (reported)—Water level lowered 150 feet in 8 hours at rate of 50 g.p.m.

WELLS IN CRETACEOUS ROCKS

In the western and northwestern parts of the county drilled wells get their water from Cretaceous rocks. At the Indian Head Naval Powder Plant, large amounts of water are used daily from Cretaceous aquifers. The hydrologic properties of the sands at Indian Head and elsewhere in the western and northwestern parts of the county will not be included in this report but will be taken up in a future general report on the hydrology of the western Coastal Plain region.

In the eastern and southern parts of the county only four drilled wells are known to be producing from the Cretaceous. Two other wells get their water so close to the Tertiary-Cretaceous contact that it cannot be decided definitely from which system the water is coming.

In the section on Geology it was stated that the sands in the Cretaceous of Charles County are scarce and probably lenticular. For this reason it is impossible to know

[16] Shifflett, Elaine, Op. cit., p. 19.

just where in the great thickness of Cretaceous rocks a water sand will be found. At La Plata, for example, it was necessary to drill to 934 feet below sea level before a water sand was found, whereas wells only about a half mile to the west are producing from a much lesser depth in the Cretaceous.

NORTHEAST SECTION

Waldorf-La Plata-Hughesville Area

P-1770 Br. 5-257; El. 215; Maryland State Police; Mattawoman
Sampled—See p. 108
Driller's log—Pink clay at elevation +15 to −30 feet
Static water level—Elevation +40 feet
Depth of well—448 feet; bottom elevation −233 feet
Water-bearing bed—Elevation −225 to −233 feet
Remarks—Cretaceous (?); 170 feet below pink clay (Marlboro clay member) of Nanjemoy formation
Pumping test (reported)—Water level lowered approximately 40 feet in 12 hours at rate of 40 g.p.m.

P-1398 Br. 7-574; El. 160; La Plata Town; La Plata
Sampled—Not continuously; pink clay at elevation −30 to −50 feet. See log p. 104
Static water level—Elevation +25 feet
Depth of well—1094 feet; bottom elevation −934 feet
Water-bearing bed—Approximately −880 to −904 feet
Remarks—In Cretaceous rocks; top about −220 feet; water-bearing bed, approximately 700 feet below top of Cretaceous
Pumping test (reported)—Water level lowered 285 feet in 24 hours at rate of 100 g.p.m.

SOUTHEAST SECTION

Bel Alton Area

P-1122 Wic. 1-152; El. 165; Southern Maryland Cleaners; La Plata-Bel Alton
Samples—Yes, to elevation −356, see description, p. 120 shows pink clay, elevation −79 to −110 feet; top of Cretaceous rocks at elevation −247 feet
Driller's log—Shows pink clay, elevation −79 to −133 feet
Static water level—Elevation +15 feet
Depth—632 feet; elevation, bottom −467 feet
Water-bearing bed—Elevation −457 to −467 feet
Remarks—In Cretaceous rocks; top of Cretaceous −247 feet; water-bearing bed 210 feet below top of Cretaceous
Pumping test (reported)—Water level lowered 30 feet in 6 hours at rate of 24 g.p.m

Popes Creek Area

P-1231 Wic. 1-847; El. 140; I. and P. Co.; Popes Creek
Sampled—For lower part of hole; pink clay, elevation −95 to −120 feet; see p. 101
Driller's log—Shows pink clay at elevation −95 to −118 feet
Static water level—Elevation +40 feet
Depth of well—420 feet; bottom elevation −280 feet
Water-bearing bed—Elevation −268 to −280 feet
Remarks—In Cretaceous rocks; top 133 feet below base of pink clay (Marlboro clay member) of Nanjemoy formation
Pumping test (reported)—Water level lowered 80 feet in 8 hours at rate of 20 g.p.m.

SOUTHWEST SECTION

Nanjemoy Area

P-1548 St. 3-658; El. 28; E. Sullivan; Nanjemoy
Sampled—See description, p. 125
Driller's log—Indicates top of Cretaceous at elevation −17 feet
Static water level—Elevation +7 feet
Depth—210 feet; bottom elevation −182 feet
Water-bearing bed—Hole open from −119 feet to bottom; water sand reported at −182 feet
Remarks—In Cretaceous rocks; water sand about 160 feet below top of Cretaceous
Pumping test (reported)—Water level lowered 8 feet in 5 hours at rate of 18 g.p.m.

NORTHWEST SECTION

Indian Head

Well No. 15; I.H. 4-98 El. 32; U. S. Government; Indian Head
Driller's log—See p. 171
Depth of well—1200 feet; approximate elevation of bottom −1168 feet
Water-bearing beds—Reported at elevations −180, −286, −340, −470 feet
Remarks—This well struck the hard basement rock at about elevation −709 feet. This is an old well and is included to show the character of water occurrence in the Cretaceous rocks. All the wells at Indian Head are producing from Cretaceous horizons. Their distribution shows them to be lenticular sands rather than continuous horizons.

DRILLERS' LOGS

Drillers' logs for some of the drilled wells are given here, since they illustrate the drillers' terms for the types of rocks or formations which are passed through by the drill. The driller can detect differences in the character of the material while drilling by the feel of the drill and rate of drilling, as well as by the well cuttings. Colors of the drilling mud are more vivid than those of the dry samples, so changes in color are generally logged. Hard beds reduce the speed of drilling, and likewise are noted on many of the logs. The driller, however, is not particularly interested in the rocks a long way above the expected position of the water sand, hence only a generalized logging is usually given for the upper part of the hole. The value of these logs for correlation is shown by the fact that a "pink" or "red" clay bed about 20 feet thick (Marlboro clay member of the Nanjemoy formation, a very distinctive marker bed) is recorded in many of the logs. The drillers' logs are very useful in filling in gaps between wells that have been sampled.

Several of the wells—P. 1050, P. 1122, P. 1231, P. 1445, P. 1770—for which drillers' logs are given were also sampled.

The term "marl" generally indicates the presence of some shell fragments; "black sand" refers to glauconite sand (greensand); "rock" is hard material, generally lime-cemented in Charles County. The green color of greensand is due to the presence of glauconite, a mineral showing variations in color from light to very dark green, and also from red to moderate yellow brown.

Well: P. 240; Maryland Tobacco Growers Association
Loc. No.: Br. 5-452; elevation 215 feet
Driller: Taylor Leatherbury
Location: 0.5 mi. N. of Waldorf; Route 301

Formation	Thickness (feet)	Depth (feet)
Sand	25	25
Gravel	15	40
Clay marl	10	50
Sandy marl	150	200
Water bearing	145±	345±

Well: P. 396; Merrick Boys Camp, Inc.
Loc. No.: Nanj. 4-821; elevation 20 feet
Driller: Columbia Pump and Well Co.
Location: Maryland Point

Formation	Thickness (feet)	Depth (feet)
Yellow clay	30	30
Brown clay	10	40
Light clay	10	50
Sand and clay	20	70
Brown clay	10	80
Brown clay, sand	10	90
Sand and gravel	7	97

Well: P. 652; William L. Simms
Loc. No.: Wic. 8-162; elevation 17 feet
Driller: J. W. Wilson
Location: Tompkinsville; Route 3

Formation	Thickness (feet)	Depth (feet)
Gray clay	10	10
Yellow sand	10	20
Gray sand and clay	20	40
Soft gray clay	60	100
Gravel	15	115
Blue clay	20	135
Black sand and clay, mixed	90	225
Red clay	28	253
Water sand	20	273

Well: P. 850; Southern Maryland Electric Cooperative
Loc. No.: Bra. 9-594; elevation 179 feet
Driller: Columbia Pump and Well Co.
Location: Hughesville

Formation	Thickness (feet)	Depth (feet)
Dry sand	10	10
Gravel	8	18
Sand	22	40
Brown clay	10	50
Marl	89	139
Shells	11	150
Marl	260	410
Gray clay	25	435
Red clay	25	460
Green marl	84	544
Water sand	14	558

Well: P. 1050; H. J. Orth
Loc. No.: Wic. 5-587; elevation 38 feet
Driller: Columbia Pump and Well Co.
Location: Mt. Victoria

Formation	Thickness (feet)	Depth (feet)
Sand, gravel	30	30
Marl	225	255
Pink clay	20	275
Black sand	20	295
Green marl	20	315
Water-bearing sand	9	324

Well: P. 1076; F. M. Reeder
Loc. No.: Wic. 5-912; elevation 5 feet
Driller: Columbia Pump and Well Co.
Location: Mt. Victoria

Formation	Thickness (feet)	Depth (feet)
Sandy marl	20	20
Sand, gravel	10	30
Green marl	30	60
Blue marl	80	140
Green marl	120	260
Marl, shell	60	320
Blue marl	17	337
Water-bearing sand	10	347

Well: P. 1122; Southern Maryland Cleaners
Loc. No.: Wic. 1-152; elevation 165 feet
Driller: Columbia Pump and Well Co.
Location: Route 301, 3 mi. S. of La Plata

Formation	Thickness (feet)	Depth (feet)
Sand, gravel	30	30
Marl	214	244
Brown clay	54	298
Rock	4	302
Black sand	20	322
Rock	2	324
Marl	36	360
Black sand	10	370
Black clay	42	412
Brown clay	38	450
Blue clay	10	460
Sand	2	462
Brown clay	43	505
Blue clay	7	512
Sand	4	516
Brown clay	106	622
Water-bearing sand	10	632

Well: P. 1231; I. & P. Paint Co.
Loc. No.: Wic. 1-847; elevation 140 feet
Driller: F. N. Hagmann, Jr.
Location: Route 301, 8 mi. S. of La Plata

Formation	Thickness (feet)	Depth (feet)
Clay and gravel	5	5
Blue clay	215	220
Blue sandy clay	15	235
Red clay	23	258
Gray clay	7	265
Oyster shell and black marl	14	279
Black sandy clay, little water	16	295
Green clay	15	310
Gray sand, clay	0	320
Green sand, clay	30	350
Black sand, clay	40	390
Black and white sand	2	392
Hard brown clay	16	408
Water-bearing sand	12	420

Well: P. 1445; Mary Hayden
Loc. No.: Wic. 4-428; elevation 100 feet
Driller: John W. Wilson & Sons
Location: 2 mi. E. of Popes Creek

Formation	Thickness (feet)	Depth (feet)
Red clay	22	22
Brown sand	8	30
Sand and gravel	30	60
Blue and white clay	3	63
Blue clay	17	80
Greenish clay sand	14	94
Black sand, clay, shells	29	123
Black sand, clay	126	249
Red clay	31	280
Clay and shells	41	321
Water-bearing sand, rock	25	346

Well: P. 1503; William Simms
Loc. No.: Wic. 8-127; elevation 15 feet
Driller: John W. Wilson & Sons
Location: 1½ mi. W. of Tompkinsville

Formation	Thickness (feet)	Depth (feet)
Yellow clay	5	5
Yellow sand	10	15
Gravel and sand	5	20
Blue clay	60	80
Black sand and clay	145	225
Red clay	6	231
Water-bearing sand	36	267

Well: P. 1547; F. L. Peckham
Loc. No.: Nanj. 3-371; elevation 35 feet
Driller: John W. Wilson & Sons
Location: 1.1 mi. N. of Chapel Point, East side of Port Tobacco River

Formation	*Thickness (feet)*	*Depth (feet)*
Sand	10	10
Gray mud, sand	10	20
Sand, mud	10	30
Gravel, fine, mud	56	86
Red clay	3	89
White clay	6	95
Black sand, clay, shells	15	110
Water-bearing sand, coarse	75	185
Greenish water-bearing sand	7	192
?	8	200

Well: P. 1548; E. Sullivan
Loc. No.: St. 3-658; elevation 28 feet
Driller: John W. Wilson & Sons
Location: 1.5 mi. W. of Nanjemoy

Formation	*Thickness (feet)*	*Depth (feet)*
Yellow sand	10	10
Black sand	5	15
Sand, shells	5	20
Black Sand	15	35
Gravel, shells	5	40
Gray clay	5	45
Gray sandy clay	10	55
Red clay	5	60
Red and gray clay	5	65
Gray clay	15	80
Gray sand	15	95
Gray sand, clay, a little gravel	10	105
Red clay, sand	20	125
Gray clay, red clay	40	165
Gray white sand, clay	20	185
Water-bearing sand, white, gray	25	210

Well: P. 1551; S. Robery
Loc. No.: Wic. 8-173; elevation 5 feet
Driller: John W. Wilson & Sons
Location: 1 mi. S. W. of Tompkinsville

Formation	*Thickness (feet)*	*Depth (feet)*
Yellow sand	25	25
Gray sand, shells, mud, gravel	93	118
Black sand	71	189
Red clay	10	199
Water-bearing sand and rock	73	272

Well: P. 1552; Rynearson
Loc. No.: Wic. 8-812; elevation 10 feet
Driller: John W. Wilson & Sons
Location: 1.2 mi. S. of Issue P. O.—Woodland Point

Formation	Thickness (feet)	Depth (feet)
Yellow clay	10	10
Yellow sand	7	17
Soft mud	10	27
Gravel	3	30
Blue clay	60	90
Black and gray mud and shells	23	113
Black sand and clay	107	220
Gray clay	11	231
Red clay	11	242
Water-bearing sand	29	271

Well: P. 1553; C. Dent
Loc. No.: Wic. 8-234; elevation 14 feet
Driller: John W. Wilson & Sons
Location: Wicomico Beach

Formation	Thickness (feet)	Depth (feet)
Yellow clay	11	11
Yellow sand	9	20
Sand, gravel, clay	20	40
Gray sand, clay	20	60
Gray sand, clay	40	100
Black sand, clay	141	241
Red clay	5	246
Water-bearing sand	30	276

Well: P. 1596; Weisbrod
Loc. No.: Wic. 4-575; elevation 22 feet
Driller: John W. Wilson & Sons
Location: 0.65 mi. E. of Potomac Bridge toll house

Formation	Thickness (feet)	Depth (feet)
Soil	5	5
Yellow sand	8	13
Blue clay	7	20
Black sand, clay, shells	30	50
Black sand, clay	134	184
Red clay	34	218
Black sand, clay, shells	11	229
Water-bearing sand, rock	20	249

Well: P. 1706; Rossiter
Loc. No.: Wic. 8-499; elevation 12 feet
Driller: John W. Wilson & Sons
Location: 1 mi. S.S.W. of Issue P. O.—Woodland Point

Formation	Thickness (feet)	Depth (feet)
Yellow clay	12	12
Sand, gravel	25	37
Blue clay	50	87
Rock, sand	30	117
Black sand, clay	113	230
Gray clay	4	234
Red clay	11	245
Water-bearing sand	25	270

Well: P. 1715; Wedding
Loc. No.: Wic. 4-884; elevation 5 feet
Driller: John W. Wilson & Sons
Location: 0.6 mi. S.E. of Morgantown

Formation	Thickness (feet)	Depth (feet)
Sand, yellow	15	15
Sand, gravel	5	20
Sand, gravel	15	35
Gravel	15	50
Sand, gravel	40	90
White sand, gravel	15	105
Sand, gray, mud	23	128
Black sand, clay	52	180
Gray clay	10	190
Red clay	12	202
Water-bearing sand, rock	79	281

Well: P. 1770; Maryland State Police
Loc. No.: Bra. 5-257; elevation 215 feet
Driller: Columbia Pump and Well Co.
Location: Mattawoman; Route 301

Formation	Thickness (feet)	Depth (feet)
Brown clay	10	10
Gravel and sand	25	35
Blue marl	85	120
Green marl	60	180
Gray clay	40	220
Pink clay	25	245
Green marl	30	275
Rock	5	280
Marl, shells	15	295
Green marl	5	300
Black sand	5	305
Green marl	10	315
Marl, shell	15	330
Sandy marl	60	390
Gray clay	38	428
Blue clay	12	440
Water-bearing sand	?	

Well: No. 15; U. S. Navy
Loc. No.: I. H. 4-98 elevation 32 feet
Driller: —
Location: Indian Head

One well in Charles County was drilled through the rocks of Cretaceous age into the basement complex. The driller's log is given here, since it gives a good picture of the general lithologic character of the Cretacous rocks. The well was drilled to a depth of 1200 feet and bedrock was encountered at 740 feet. The elevation of the well collar is 32 feet above sea level.

Formation		Thickness (feet)	Depth (feet)
Clay, sand, and gravel		14	14
Gray clay		36	50
Blue clay		30	80
Gray clay		20	100
Gray sandy clay		11	111
Brown sandy clay		38	149
Light sandy clay		16	165
Dark-red sandy clay		29	194
Sand, water-bearing		24	218
Dark-brown clay		86	304
Light sand		23	327
Gray clay		39	366
Sand, water-bearing		10	376
Sandy clay		22	398
Green clay		14	412
Brown clay		7	419
Brown sandy clay		8	427
Gray clay		55	482
Fine sand		51	533
Mixed clays		47	580
Brown sandy clays		20	600
Mixed clays		54	654
Sand and loam mixed		36	690
Hard white clay		13	703
Brown clay		5	708
?		33	741
Basement complex	Hard, green rock	182	923
	Hard, red and gray rock	277	1200

WELL SAMPLE CORRELATION

The purpose of geologic correlation has been explained (see p. 15) and the methods used in making such correlations by means of well samples have been discussed (see p. 15). Figures 15–18 (pp. 172–175) show by means of vertical sections some of the results of the correlations and the practical use to which the correlations can be put.

On the figures the approximate position of ground level is shown by a heavy broken line. The wells are indicated by their name and elevation. The wells are shown spaced at equal distances apart so that they may be observed together; but the true distance apart of neighboring wells and their direction from one another are indicated at the top of the sheet. For example, (fig. 17), the Pace well is shown to be 10 miles

S 16° E of the Southern Maryland Cleaners well. The surface locations of these key wells are indicated on Plate III.

The correlation sections show the position underground of the geologic formations that were passed through or encountered in the drilling of the wells. On the sections

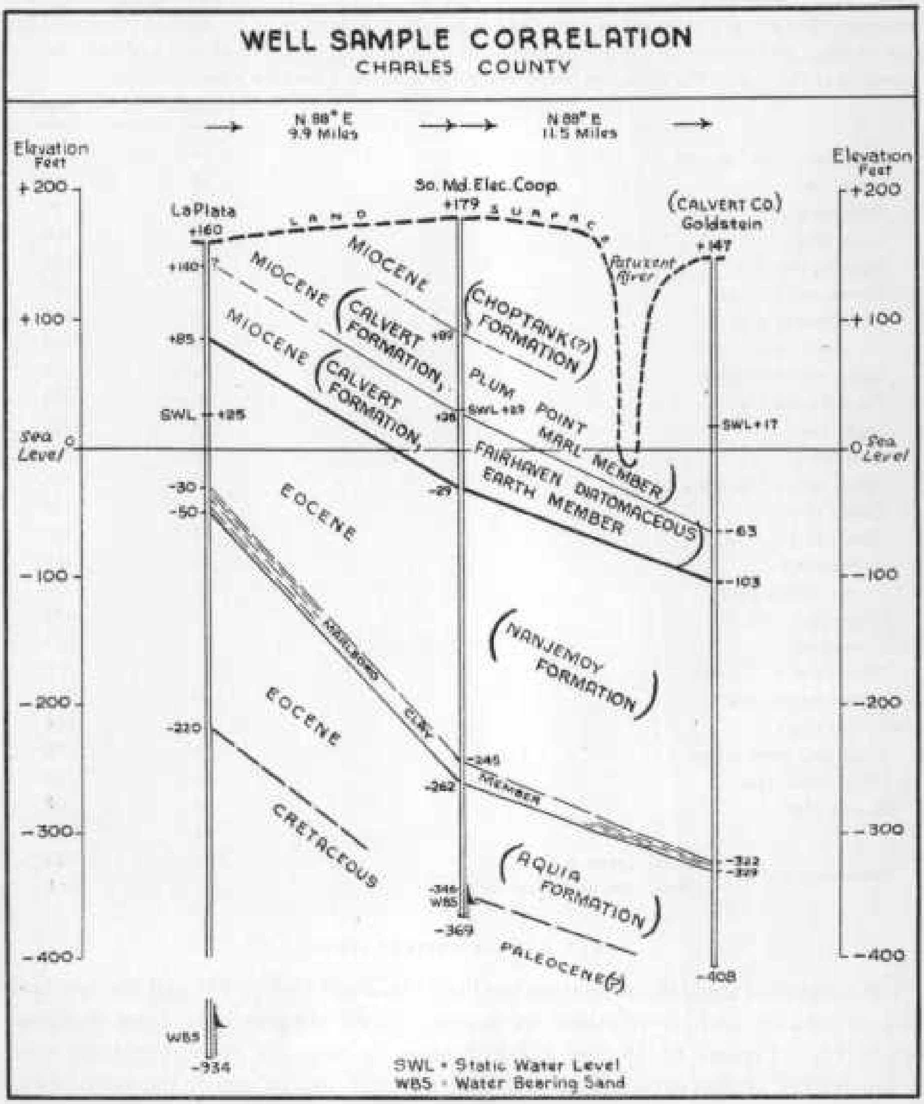


FIG. 15. Geologic Profile—La Plata to Goldstein Wells

the elevations above or below sea level of the tops and bottoms of the formations are indicated. A distinctive and easily recognized geologic bed or member such as the pink clay (Marlboro clay member) of Nanjemoy formation is very useful as a marker bed or underground sign post.

The positions of the water-bearing sands also are indicated on the sections. The sections show that the known producing water bearing sands lie in the Aquia formation, in Cretaceous rocks, and possibly in Paleocene rocks, (see p. 162).

These sections should be of interest to the well driller, and to the man who wishes to have a well drilled; for the sections, together with Plate III, will give a close ap-

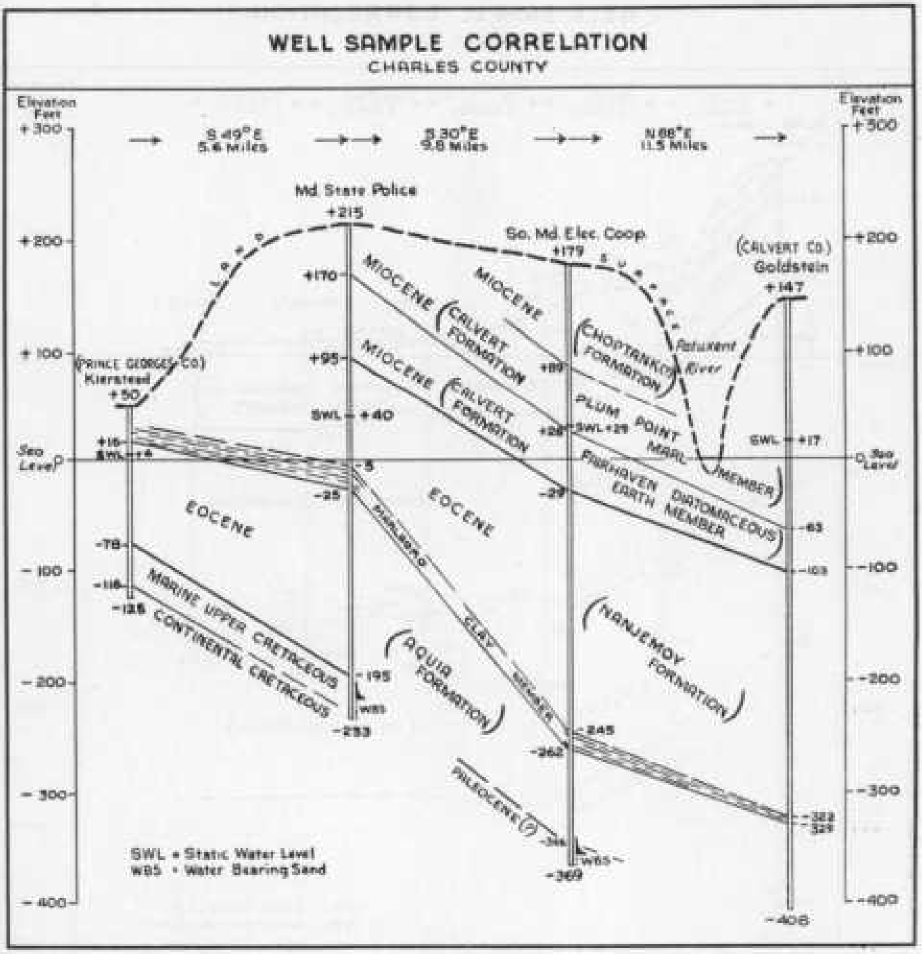


FIG. 16. Geologic Profile—Kierstead to Goldstein Wells

proximation of the depth to be drilled to get water in those areas where water is obtained from the Aquia formation, marine Cretaceous or Paleocene; that is, in the northern, eastern, and southeastern parts of the county. Water bearing sands in the non-marine Cretaceous appear to be lenticular and non-continuous, hence no close approximation can be made as to the minimum depth to be drilled to obtain water in the central and western part of the county.

As an illustration of the way in which the sections may be used to get an approximation of the depth of the well, let us assume you want to drill a well about half way between the Maryland State Police well and the Hughesville Southern Maryland Electric Cooperative well, and that the elevation of the ground level at the point where the well is to be drilled is 200 feet above sea level. An examination of fig. 16

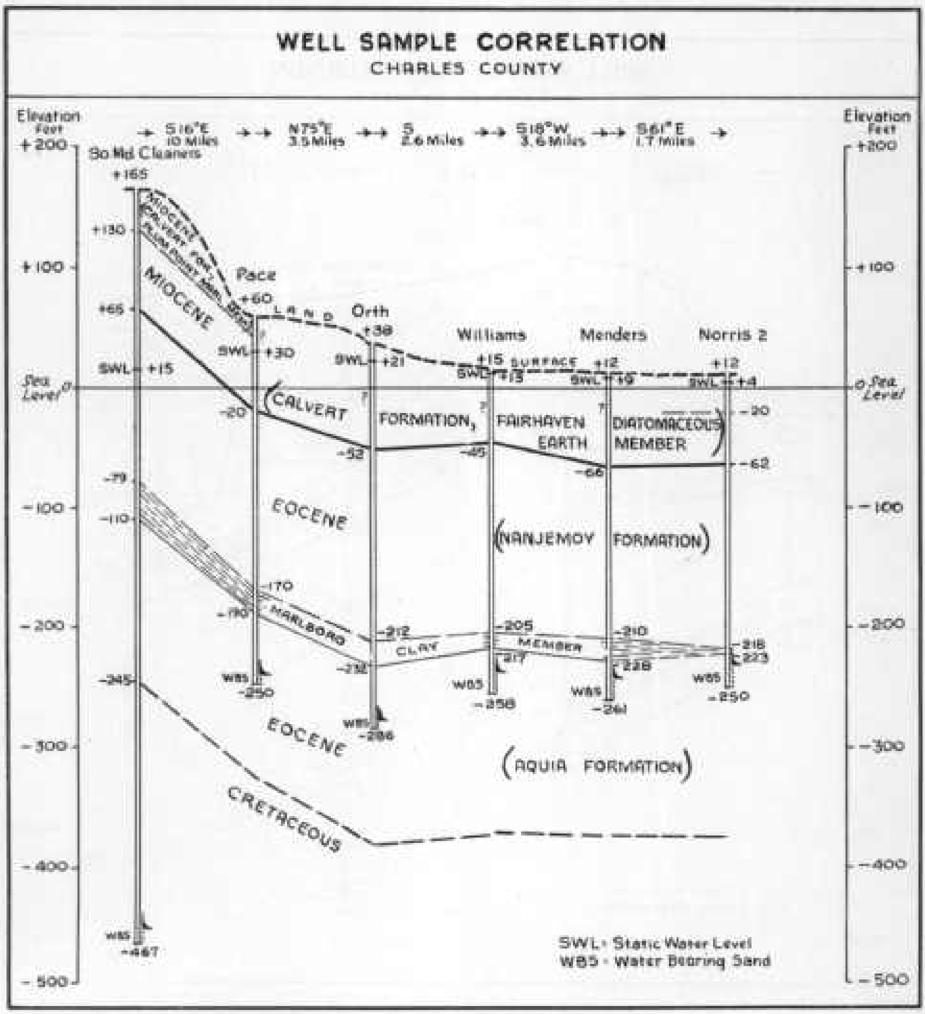


FIG. 17. Geologic Profile—Southern Maryland Cleaners to Norris No. 2 Wells

shows that a water bearing sand lies about 300 feet below sea level at that point. Your well, then, would have to be drilled about 500 feet below the surface in order to reach the productive water bed.

Fig. 17 indicates that in the Cobb Island area the top of water-bearing sands lie about 235 feet below sea level.

Fig. 18 indicates the lack of a persistent water bearing bed in the Cretaceous rocks. Predictions as to the depth to which a well must be drilled to get water from the non-

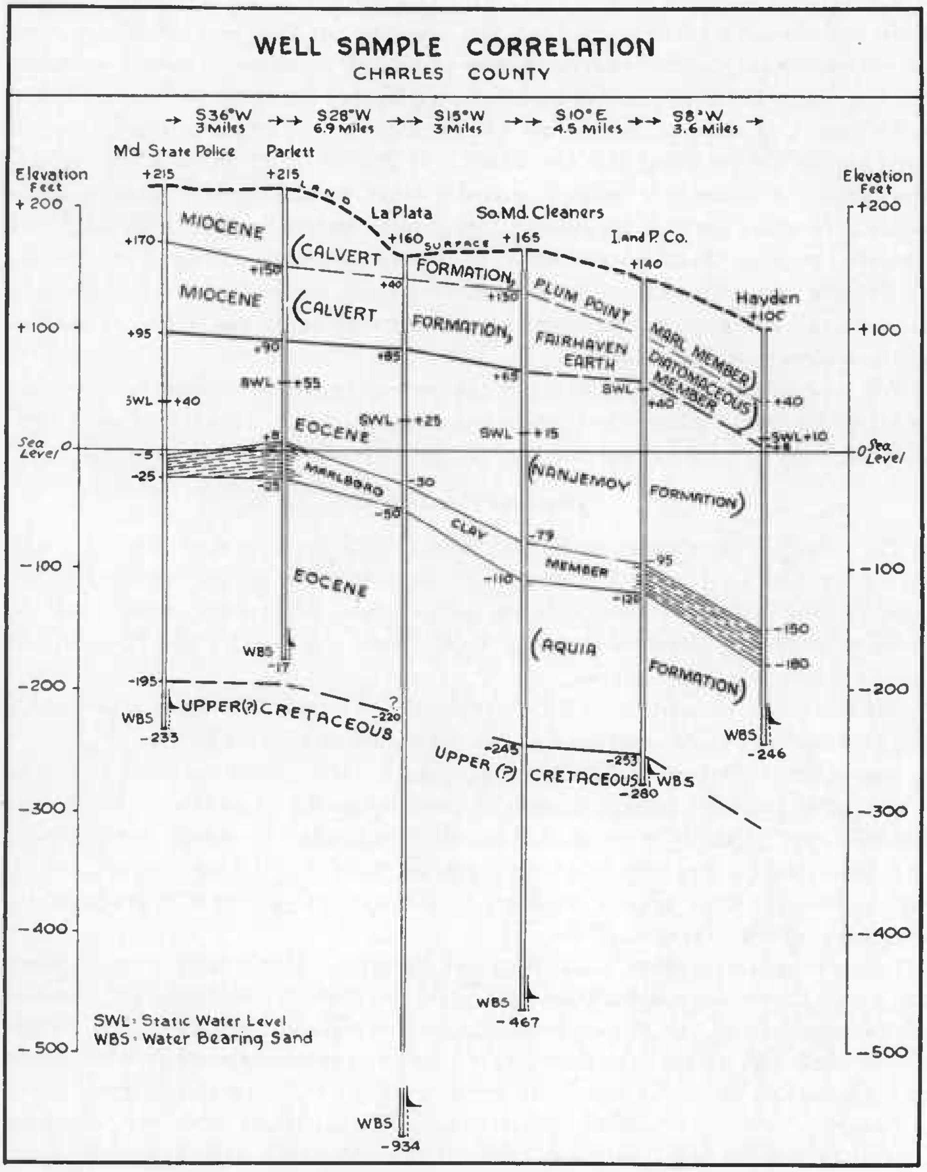


FIG. 18. Geologic Profile—Maryland State Police to Hayden Wells

marine Cretaceous rocks are, therefore, not possible. The figures do show, however, the approximate depth to the top of the Cretaceous rocks.

QUALITY OF WATER

Introductory Statement

The original source of all ground water, as the term is used here, is precipitation. Pure water is clear, odorless, colorless, and tasteless; but pure water is seldom found in nature. Rain water dissolves various gases and particles of soluble materials floating about in the air, and when rain water reaches the surface of the earth and flows over it, or sinks below it, other soluble materials are encountered and are dissolved in or carried along with the water. As ground water moves along beneath the surface, it comes into contact with still other materials which dissolve in the water. In many parts of the country, the ground waters become so charged with dissolved material that the water has to be treated before it can be used for drinking or for industrial purposes. Charles County waters, fortunately, do not generally fall into this category, although some treatment may be necessary for certain uses of the waters from Eocene rocks.

When people speak of the quality of the water, they usually mean its suitability or safety for drinking from the bacteriological stand point. This side of the subject properly belongs to the Department of Health and will not be discussed here.

Chemical Composition

The principal chemical constituents found in solution in ground water are relatively few and are present in very small amounts in the waters described in this report. The principal constituents are iron, calcium, magnesium, sodium, and potassium which are called cations; and bicarbonate, sulfate, chloride, fluoride, and nitrate which are called anions.

Silica in small amounts is of little significance in water. However, moderate to large amounts of silica contribute to the formation of boiler scale.

Iron is one of the most bothersome constituents. Iron causes red stains on clothes and fixtures and when present in sufficient amount causes a bad taste. Iron causes hardness, but generally is not present in sufficient amount to cause much hardness. It is objectionable if present in amounts greater than 0.3 or 0.4 part per million. It can be eliminated by aeration or other treatment, but treatment is generally too expensive for the average well owner.

Calcium and magnesium cause hardness in water. Hard water requires much more soap to produce a lather than soft water; also calcium and magnesium combine with carbonate and sulfate to form scale, which is a hard deposit of mineral matter on the inside of a tea kettle or the tubes of a boiler or automobile radiator. Calcium and magnesium in combination with chloride causes the corrosion of metal parts.

Moderate amounts of sodium have no effect on the suitability of water for domestic and practically all industrial uses. Sodium chloride gives a salty taste to water if present in an amount greater than about 800 parts per million. Sodium in combination with carbonate gives water a greasy feel and the water may be corrosive if sufficient sodium carbonate is present.

Nitrate in large amount may indicate organic pollution, as may an unusually large amount of chloride. An example of this is shown by the analysis (not given in this report) of the water of a shallow well near Chapel Point, Charles County. Nitrate is present in the amount of 26 parts per million. A neighboring unpolluted well shows 0.3 part per million of nitrate and 2.5 parts per million of chloride.

Fluoride in water has received much attention in recent years because of its effect on the teeth when used by young children. Permanent mottling of teeth is likely to occur among young children brought up in regions where the water contains more than 1 part per million of fluoride, though the mottling generally is very mild at 1.5 parts per million, and this figure has been recommended by the Public Health Service as the maximum for water used on interstate carriers. Small amounts of fluoride up to 1 part per million tend to inhibit tooth decay.

Analytic Expression

After a chemical analysis has been made of a water to determine the constituents in solution this analysis must be given expression in the form of an analytic statement. Some years ago the statement was given in the form of hypothetical combinations which took various forms particularly adaptable to engineering problems. For geochemical work, and now generally for problems connected with the treatment of water, the analysis is given in the weights of ions present, usually in parts per million, and not in their hypothetical combinations.

From the weights of the constituents, their chemical values as dissolved salts in a very dilute solution are determined as reacting values expressed in equivalents per million, by dividing the amount of each constituent, in parts per million, by its chemical combining weight. These classifications of the waters are useful in comparing the waters.[17]

Water from Cretaceous Rocks and Probable Cretaceous Rocks

Analyses of waters from the following wells known to tap sands of Cretaceous age were obtained:

Indian Head, No. 1.
Indian Head, No. 8.
La Plata Town.

Waters from the following wells indicate by their analyses that they are from Cretaceous aquifers, but more definite information as to age is lacking:

Chapel Point well—212 feet deep, no samples or log.
Popes Creek well—reported 300 ± feet deep, no log.
Smith well, Cobb Island—no information as to depth; no log.

Character of the Water

In the section on subsurface geology, a discussion is given of the distribution of sand beds in the Cretaceous. Mention was made that data are lacking for correlation of the different sands, or even for a determination of the geologic structure of the Cretaceous. The water-bearing sands, then, are merely known to be of Cretaceous

[17] For details of the method consult U. S. Geol. Survey Water-Supply Paper 596-H, Notes on Practical Water Analysis, by W. O. Collins.

TABLE XVI

Analyses of Waters from Wells in Charles County

(Parts per million, except pH)

Loc. No. Name Water-bearing unit	I.H. 4-9 Indian Head No. 1 Cretaceous	I.H 4-9 Indian Head No. 8 Cretaceous	Br. 7-577 La Plata Town Cretaceous	Nj. 3-611 Chapel Point Cretaceous	Wic. 4-146 So. Md. Elec. Popes Creek Cretaceous	Wic. 9-787 Smith Cobb Island Cretaceous	Bra. 5-449 Parlett Eocene (?)	Bra. 9-594 So. Md. Elec. Hughesville Paleocene ?
Silica (SiO_2)	42	36	34	16	13	10	16	10
Iron (Fe)	0.06	0.05	0.21	0.04	0.82	0.04	0.05	0.01
Calcium (Ca)	1	1.1	1.1	2.9	3.4	3.4	44	29
Magnesium (Mg)	.6	0.6	0.8	1.7	1.6	1.6	15	13
Sodium (Na)	65	60	121	69	68	69	6.3	5.3
Potassium (K)	2.1	2.0	4.7	4.8	5.7	6.0	9.9	14
Bicarbonate (HCO_3)	155	144	321	184	188	176	222	174
Sulphate (SO_4)	12	13	11	11	8.5	8.6	7.3	12
Chloride (Cl)	7.6	4.3	3.8	2.5	2.2	2.5	1.2	1.4
Fluoride (F)	1.0	1.0	1.2	0.4	0.3	0.4	0.1	0.1
Nitrate (NO_3)	0.5	0.6	0.2	0.3	0.3	0.0	0.5	1.4
Dissolved solids	210	192	338	206	204	201	196	162
Total Hardness as $CaCO_3$	6.5	5.2	6.0	14	15	15	172	126
pH	—	—	8.0	8.5	8.6	8.8	8.0	7.7
Analyst	M. D. Foster	M. D. Foster	N. K. McShane	N. K. McShane	N. K. McShane	N. K. McShane	N. K. McShane	A. Theriault
Date of Collection	7/19/38	7/19/38	1/22/47	1/22/47	1/27/47	1/8/47	1/9/47	10/28/46
Temp., °F				57° (?)		60.5°		

age and cannot be correlated with any particular formation of the Cretaceous. The very marked resemblance of these waters, however, indicates that they had a similar source and occur in very similar lithologic associations in the Cretaceous.

A study of the chemical analyses given in the Table XVI shows that all the waters belong to the sodium bicarbonate type. The water is of generally good quality, soft and low in iron. Only one of the six samples contained a significant amount of iron, that from Popes Creek with 0.82 part per million. Two of the waters, those from Indian Head, occur in the area in which the Cretaceous rocks are covered only by a thin coating of Pleistocene sand and gravel. The Chapel Point well and Popes Creek well started in Eocene rocks and the Smith well in Miocene rocks.

TABLE XVII

Analyses of Waters from Wells in Charles County

(Equivalents per Million)

Field No. / Name	Indian Head No. 1	Indian Head No. 8	Ce 3 La Plata Town	Dd 5 Chapel Point	Ee 18 So. Md. Elec. Popes Cr.	Ff 18 Smith Cobb Island	Parlett	So. Md. Elec. Hughesville
Iron	0.00	0.00	0.01	0.00	0.03	0.00	0.00	0.00
Calcium	0.05	0.05	0.05	0.14	0.17	0.17	2.20	1.45
Magnesium	0.05	0.05	0.07	0.14	0.13	0.13	1.23	1.07
Sodium	2.83	2.61	5.26	3.00	2.96	3.00	0.27	0.23
Potassium	0.05	0.05	0.12	0.12	0.15	0.15	0.25	0.36
	2.98	2.76	5.51	3.40	3.44	3.45	3.95	3.11
Bicarbonate	2.54	2.36	5.26	3.02	3.08	2.88	3.63	2.85
Sulphate	0.25	0.27	0.23	0.23	0.18	0.18	0.15	0.25
Chloride	0.21	0.12	0.11	0.07	0.06	0.07	0.03	0.04
Fluoride	0.05	0.05	0.06	0.02	0.02	0.02	0.01	0.01
Nitrate	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.02
	3.06	2.81	5.66	3.34	3.34	3.15	3.83	3.17

Indian Head Wells. The waters produced by these wells are similar in chemical character; they are soft, and low in dissolved solids.

La Plata Town Well. The La Plata well lies about 12 miles east southeast of the Indian Head wells. The well is reported to be about 580 feet deep. The water-bearing sand is about 180 feet below the top of the Cretaceous.

The water is very similar to the Indian Head water, except that it is higher in dissolved solids as would be expected inasmuch as the well is farther down the dip of of the Cretaceous rocks. The increase is mainly in sodium and bicarbonate. The iron content is slightly higher.

Chapel Point Well. The well is a flowing well and has a measured depth of 211.8 feet. Since this depth seems hardly enough to carry the well to Cretaceous rocks, it is possibly not the true depth.

The well is about 13 miles south southeast down dip from the Indian Head wells, and about 6 miles southwest of La Plata Town well.

The water is quite similar in composition to that at Indian Head, but with about one-half the silica content.

Popes Creek Well. This well is reported to be about 300 feet deep. This depth is sufficient for the well to reach Cretaceous rocks but not enough for deep penetration into them. The well is about 5 miles south-southeast of Chapel Point well and about 10 miles down dip from the Cretaceous-Eocene contact.

The only significant difference between this water and that at Chapel Point is its relatively high iron content, 0.82 part per million.

Smith Well, Cobb Island. This well is on the mainland half a mile northwest of Cobb Island. It is a flowing well and is reported to be cased almost to the bottom. The depth is unknown. The well is about 26 miles down dip from the Cretaceous-Eocene contact at sea level.

The water is practically identical with that at Chapel Point, and, except for iron content, with that at Popes Creek. This is unusual in view of the distance between the wells.

Water from Eocene (?) Rocks

Parlett Well. The Parlett well is located at Waldorf. It has a depth of 392 feet and the water-bearing sand lies 152 feet below the base of the pink clay (Marlboro clay member) of the Nanjemoy formation. The water bearing sand is judged to belong to the Aquia formation because of its position in the well. Lithologically, however, the sand resembles Cretaceous water bearing sand. The base of the Aquia formation outcrops at sealevel about 9 miles to the northwest.

The chemical character of the Eocene (?) water is very different from the Cretaceous water described in the preceding section. The differences are in the relative amounts of calcium and magnesium and in sodium. The quantities of acid radicals are about the same in the waters from the two sands. It is a moderately hard calcium bicarbonate water.

The Aquia formation is of marine origin and contains several shell beds. Glauconite also is present in large amounts. The shell beds may be the source of the calcium in solution in the water. As indicated by the analysis (Table XVII), potassium also shows a notable increase. For example, the ratio Na/K in the Indian Head wells is 51, and in the La Plata well 51; whereas in the Parlett well the ratio is 1, that is the potassium and sodium are about equal. Although the calcium and magnesium are much higher in waters from this well the ratio is about the same as that for the Cretaceous waters.

Water from Paleocene (?) Rocks

Southern Maryland Electric Well. The Southern Maryland Electric well lies about 9 miles down dip from the Parlett well. The top of the aquifer is about 84 feet below the base of the Nanjemoy formation. The possibility that the water bearing sand may be Paleocene in age has been discussed (p. 162).

The water is similar to that from the Parlett well, except that it is softer and lower in dissolved solids. The calcium is lower, the magnesium and sodium about the same, and the potassium higher. The water contains the least iron and the most nitrate of all eight waters listed but the difference is not significant.

COMPARATIVE TABLES

Table XVIII shows the dissolved solids content of the waters described above and the relative location of the wells. The table shows little variation in dissolved solids in the waters throughout the area and from the two formations. It also indicates no increase in concentration with distance down dip from the outcrop.

TABLE XVIII

Dissolved Solids

Parts Per Million

Water from Cretaceous Rocks	Dissolved Solids	Relative Location
	p.p.m.	
Indian Head #1	210	
Indian Head #8	192	
La Plata	338	About 12 miles down dip from I.H. wells.
Water from Probable Cretaceous Rocks		
Chapel Point	206	About 13 miles down dip from I.H. wells.
Popes Creek	204	About 10 miles down dip from outcrop.
Smith	201	About 26 miles down dip from outcrop.
Water from Eocene (?) Rocks		
Parlett	196	
Water from Paleocene (?) Rocks		
So. Md. Electric	162	About 9 miles down dip from Parlett well.

Table XIX compares location with total hardness. The table shows a very marked difference in hardness of the waters from the Cretaceous and Eocene (?) and Paleocene (?) rocks. If this difference in hardness is proved to hold through the county a very simple rule of thumb is afforded to determine the source of water from a deep well in Charles County; namely, water from Cretaceous rocks is very soft; from Eocene and Paleocene (?) is hard.

Table XX compares location with iron and fluoride content. The table shows only one well excessively high in iron. Iron is objectionable if more than 0.3 part per million is present. The presence of iron has no correlative value here.

The waters from the Cretaceous carry more fluoride than the waters from the Eocene (?) and Paleocene (?), but there appears to be no correlation with location.

TABLE XIX

Total Hardness (calculated)

Parts Per Million

Water from Cretaceous Rocks	Hardness as $CaCO_3$	Relative Location
Indian Head #1	6.5	
Indian Head #8	5.2	(As in Table XVIII)
La Plata	6	
Water from Probable Cretaceous Rocks		
Chapel Point	14	
Popes Creek	15	(As in Table XVIII)
Smith	15	
Water from Eocene (?) Rocks		
Parlett	172	(As in Table XVIII)
Water from Paleocene (?) Rocks		
So. Md. Electric	126	(As in Table XVIII)

TABLE XX

Iron and Fluoride

Parts Per Million

Water from Cretaceous Rocks	Iron	Fluoride	Relative Location
Indian Head #1	0.06	1.0	
Indian Head #8	.05	1.0	Locations as in Table XVIII
La Plata	.21	1.2	
Water from Probable Cretaceous Rocks			
Chapel Point	.04	.4	
Popes Creek	.82	.3	
Smith	.04	.4	
Water from Eocene (?) Rocks			
Parlett	.05	.1	
Water from Paleocene (?) Rocks			
So. Md. Electric	.01	.1	

PUMPING TESTS

In 1937 the United States Geological Survey made an intensive investigation of the hydrologic properties of the water sands at the Naval Powder Factory at Indian Head. A supplementary study was made in 1944. A discussion of this work will be

TABLE XXI

Driller's Pumping Tests

Well	Sec.	Area	Geologic Age	Feet Draw-down	Rate	Spec. cap. gal. ft. drawdown	Time
					gpm		*hours*
P-850	NE	Hughesville	Eocene (?)	150	50	.33	8
P-1398	NE	La Plata	Cretaceous	285	100	.35	24
P-1770	NE	Mattawoman	Cretaceous (?)	40	40	1.00	12
P-791	NE	Waldorf	Eocene	27	50	1.86	12
P-1122	SE	La Plata-Bel Alton	Cretaceous	30	24	.80	6
P-1231	SE	Popes Creek	Cretaceous	80	20	.25	8
P-1462	SE	Wayside	Eocene	50	40	.80	8
P-1702	SE	Wayside	Eocene	10	4	.40	5
P-1596	SE	Potomac River Bridge	Eocene	17	10	.59	4
P-621	SE	Rock Point	Eocene	14	10	.71	8
P-620	SE	Rock Point	Eocene	14	12	.86	8
P-1336	SE	Rock Point	Eocene	23	15	.65	3
P-1440	SE	Rock Point	Eocene	20	9	.45	3
P-1448	SE	Rock Point	Eocene	25	8	.32	4
P-1335	SE	Cobb Island	Eocene	22	15	.68	4
P-548	SE	Cobb Island	Eocene	17	10	.59	8
P-547	SE	Cobb Island	Eocene	15	10	.67	7
P-549	SE	Cobb Island	Eocene	11	10	1.00	8
P-702	SE	Cobb Island	Eocene	15	10	.67	5
P-703	SE	Cobb Island	Eocene	17	12	.71	5
P-1502	SE	Cobb Island	Eocene	19	12	.63	4
P-1549	SE	Cobb Island	Eocene	22	6	.27	4
P-1705	SE	Cobb Island	Eocene	14	12	.86	4
P-756	SE	Cobb Island	Eocene	15	12	.80	7
P-810	SE	Cobb Island	Eocene	13	10	.77	5
P-704	SE	Cobb Island	Eocene	16	10	.62	5
P-705	SE	Cobb Island	Eocene	16	10	.62	5
P-1734	SE	Tompkinsville	Eocene	15	12	.80	4
P-1503	SE	Tompkinsville	Eocene	21	9	.43	4
P-1551	SE	Tompkinsville	Eocene	12	12	1.00	3
P-1552	SE	Tompkinsville	Eocene	8	12	1.50	4
P-1553	SE	Tompkinsville	Eocene	20	9	.45	4
P-653	SE	Tompkinsville	Eocene	11	15	1.36	5
P-1706	SE	Tompkinsville	Eocene	15	8	.53	4
P-572	SE	Tompkinsville	Eocene	16	9	.56	8
P-652	SE	Tompkinsville	Eocene	17	8	.48	7
P-1546	SE	Wicomico	Eocene	20	10	.50	8
P-1797	SE	Wicomico	Eocene	10	6	.60	6
P-1548	SW	Nanjemoy	Cretaceous	8	18	2.25	5
P-396	SW	Nanjemoy	Eocene	15	25	1.67	8
P-1547	SW	Chapel Point	Eocene	50	10	.20	4

reserved for a later report which will cover the water resources of the western shore Coastal Plain as a whole.

No detailed investigations have been made of the hydrologic properties of the sands in the other parts of the county, since generally the drilled wells have yielded sufficient water to fulfil the purpose for which they were drilled.

When the drilling of a well is completed, a pumping test is run by the driller to determine in a rough way whether sufficient water is present for the required purpose. Generally a domestic user is satisfied if he has enough water, and does not care how much more he may be able to get. The industrialist, on the other hand, wants to know the maximum amount his well will produce. In Charles County at the present time there are no large industrial users of water except for the Government establishments along the Potomac.

The method used by the driller to test the well is to pump or bail the well for a fixed time at a set rate. The water level is measured at the start of pumping and again at the end of the period. The decline in water level gives a rough idea of the capacity of the well. If the decline of water level is great and the pumping rate is low, the capacity of the well is low, although it might be sufficient for most domestic needs. The longer the period of pumping, the more satisfactory the test.

As a means of comparison among the wells, a figure called the specific capacity is used. It is obtained by dividing the rate of pumping in gallons per minute by the number of feet the water level declines in the time of the test. The figures given for specific capacity in Table XXI are not much better than qualitative figures since the maximum capacity is rarely determined and the period of pumping is too short. Also a bailer test does not determine the true draw down of the water level as the rate of withdrawal is uneven and the water level recovers somewhat by the time the measurement is made after the bailer is withdrawn the last time.

A summary of capacities of the wells shows little difference between those tapping the Cretaceous water sands and those from the Eocene and Paleocene sands. The well showing the largest specific capacity is the Sullivan well (P-1548), producing from Cretaceous rocks. However, all the specific capacities are rather low, which may indicate that the sands are not highly permeable but may also be due in part to the small diameter of most of the wells and to the fact that most of them are equipped with short screens.

THE SOILS OF CHARLES COUNTY

BY

MERL F. HERSHBERGER AND E. Z. W. COMPY[18]

Soil may be defined as the relatively thin layer of disintegrated mineral and organic material at the earth's surface, the character of which has been more or less changed by weathering process. It is of primary importance because it is the ordinary medium for the growth of plants to which it supplies nutrients, moisture and anchorage.

The soil characteristics which influence its usefulness and which serve as a means of identification come from two sources. Some of them are inherited from the parent rock material. Others are acquired as the parent material is changed by weathering processes. The effect of the weathering is influenced by the length of time it has been operating and by the kind of plants that were present during this time. From this it is evident that within an area such as Charles County, with relatively uniform climatic conditions, many of the soil characteristics are closely related to the geology of the area. This relation applies not only to the mineralogical and structural character of the parent material but also to the surface topography, the height of water table and the time when the parent material was laid down or exposed to the action of the weather.

One of the principal effects of weathering is the formation of a "soil profile," consisting of two or more horizontal layers or "horizons" which vary in texture, structure, color, thickness and chemical composition. These horizons are the result of two phases of weathering:

1. Maximum physical disintegration and chemical alteration in the upper few inches of soil material.
2. Transportation of salts in solution and fine particles in suspension. Percolating water carries these downward from the weathered surface and deposits them in the subsoil. The degree of difference between the surface soil and subsoil can be taken as a measure of the progress of soil development or of "maturity" of the soil.

Soil Surveys of Charles County

An early soil survey of Charles County was made during the field season of 1918. This work was done by the United States Department of Agriculture, Bureau of Soils, in cooperation with the Maryland Geological Survey and the Maryland Agricultural Experiment Station. A map and report prepared by Howard C. Smith of the U. S. Department of Agriculture, in charge, and R. C. Rose of the Maryland Geological Survey, was published in 1922. The county soil map based on this survey is available from the Maryland Department of Geology, Mines and Water Resources.

[18] Merl F. Hershberger, State Soil Scientist; E. Z. W. Compy, Soil Scientist, Survey Party Chief in Charge, Charles County.

TABLE XXII

Acreage and Percent of Land Capability Classes by Soil Groups in Charles County[1]

Soil Group No.	Acres	%	Land Suited for Cultivation: Class I Acres	Class I %	Class IIa Acres	Class IIa %	Class IIb Acres	Class IIb %	Class IIc Acres	Class IIc %	Class IIIa Acres	Class IIIa %	Class IIIb Acres	Class IIIb %	Class IIIc Acres	Class IIIc %	Land Suited for Limited Cultivation: Class IV Acres	Class IV %	Land Not Suited for Cultivation: Class VI Acres	Class VI %	Class VII Acres	Class VII %	Class VIII Acres	Class VIII %
1	55,234	18.6	4,131	7.5	14,178	25.7					21,452	38.8					24		15,399	27.9	50	0.1		
2	24,053	8.1	1,070	4.5	2,956	12.3					12,560	52.2							7,415	30.8	50	0.2		
3	5,939	2.0			947	15.9					4,039	68.0					72	1.2	687	11.6	194	3.3		
4	9,799	3.3			1,584	16.2					1,205	12.3					5,887	60.0	292	3.0	831	8.5		
5	6,533	2.2			788	12.1					4,224	64.6					1,325	20.3	28	0.4	168	2.6		
6	1,484	.5					979	66.0					504	34.0										
7	14,254	4.8					13,604	95.5					615	4.3			31	0.2			3			
8	1,781	.6					1,745	98.0					35	2.0										
9	1,187	.4					1,172	98.8					14	1.2										
10	3,860	1.3					3,750	97.2					109	2.8										
11	16,629	5.6					12,810	77.0					3,618	21.8			133	0.8	28	0.2	40	0.2		
12	53,463	18.0					42,096	78.7					11,103	20.6			117	0.2	144	0.3	90	0.2		
13	3,860	1.3							3,060	79.3					678	17.6	105	2.7			14	0.4		
14	8,908	3.0											8,830	99.1					7	0.1	70	0.8		
15	15,738	5.3											15,706	99.8							32	0.2		
16	10,393	3.5											10,172	98.0					210	2.0				
17	5,345	1.8											5,231	97.9					99	1.8	14	0.3		
18	32,071	10.8													30,893	96.3					1,177	3.7		
19	11,878	4.0																	11,878	100.0				
20	7,424	2.5																			7,424	100.0		
21	7,127	2.4																					7,127	100.00
Total...	296,960	100.0	5,201	1.7	20,453	6.9	76,156	25.7	3,060	1.0	43,480	14.6	55,847	18.8	31,571	10.6	7,684	2.7	36,187	12.2	10,157	3.4	7,127	2.4

[1] The survey information supplied in this table is based on actual survey data compiled from recent soil conservation survey maps covering about 42% of Charles County (4th, 5th, 8th and 9th election districts). In addition, these data were projected to the remaining part of the County by interpretation of this information together with soil survey data reported in the earlier 1922 soil survey report for Charles County.

The county soil report may be obtained from the Maryland Agricultural Experiment Station.

In the development of a soil conservation program, additional information is needed to show the distribution of soils, present use of the land, the slope, and the kind and degree of erosion. This information is being recorded on aerial photographs at a scale of 4 inches to the mile. At the end of 1947 field season about two-thirds of the county had been covered by this survey. The soil conservation work is done in cooperation with a soil conservation district organized by the farmers of the county in 1941.

Plates IX and X and Plates XI and XII are land use capability maps and detailed farm planning conservation survey maps of two representative areas to illustrate the soil conservation work being done in Charles County.

LAND-CAPABILITY CLASSES

There are in the county 75 different soil types; most of them occur on a considerable range of slope and have been affected over part of their area by soil erosion. Thus a very large number of land conditions have been distinguished in terms of soil, slope, and erosion. Each of these many types of land has its own management needs. That is one reason why farm conservation planning must be done individually for each farm, preferably with the help of a professional soil conservationist. To see the possibilities of land use and the land-management needs of a farm, however, we need a broader grouping of land facts. For this purpose we use the land-capability classification.

The land-capability classification is an arrangement of land units according to those natural characteristics that determine how the land can be used safely on a long-time basis. Natural characteristics such as the hardpan or tight subsoil found in some of the soils make it somewhat difficult to use the land. The farmer on such a soil has to know how to get along with this natural limitation. Slope of the land also limits safe land use and management methods. Slopes steeper than 15 percent in Charles County, for example, are too steep for a regular cropping system even if the soils are some of the best. Any natural land factor that affects the permanence of the soil or the difficulty of using the land is considered in the land-capability classification.

Eight land-capability classes have been defined. In Charles County, 2 of the classes are subdivided to give convenient expression to different kinds of limitations and resulting needs for management practices.

The land-capability classes, including the major subdivisions, defined for Charles County, are:

LAND SUITED FOR CULTIVATION

Class I. Very good land that can be cultivated safely with ordinary good farming methods. It is nearly level and easily worked. In Charles County the soils in Class I are naturally well-drained.

Class II. Good land that can be cultivated safely with easily applied practices.

IIa. Productive, well-drained soils that are gently sloping and subject to erosion.

IIb. Fairly productive, level or slightly sloping land that has imperfect natural drainage. It needs artificial drainage and may also need erosion-control practices.

IIc. Level or gently sloping sandy land on which crops are affected somewhat by drought. It needs moisture conservation and practices to maintain or improve soil fertility. Some areas need erosion-control practices.

Class III. Moderately good land that can be cultivated safely with intensive treatments. Natural limitations are greater than on Class II land.

IIIa. Productive, well-drained land sufficiently sloping or eroded to require intensive erosion-control practices such as extra years of hay in the crop rotation, terracing, or careful strip cropping.

IIIb. Nearly level land difficult to drain, or fairly productive sloping land that needs some drainage and also erosion control.

IIIc. Very sandy level or gently sloping land or somewhat sandy land that is sloping and subject to erosion. Needs moisture conservation, intensive fertility practices, and may need erosion-control practices.

LAND SUITED FOR LIMITED CULTIVATION

Class IV. Fairly good land that is best suited to pasture or hay but can be cultivated occasionally. Land a little too steep or too severely eroded for regular cultivation.

LAND NOT SUITED FOR CULTIVATION

Class V. Land suited for grazing or forestry with slight or no limitations. Does not occur in Charles County.

Class VI. Land suited for grazing or forestry with minor limitations. Includes steep or severely eroded areas of the good soils, land subject to overflows that prevent cropping, and wet land not suited for drainage.

Class VII. Land suited for forestry with major limitations. Not ordinarily recommended for pasture. Consists of land that is very steep, very severely eroded, or very wet.

Class VIII. Land suited only for wildlife or recreation. Tidal marsh, quarries, beaches, and graded or disturbed rights of way.

Within each of the land-capability classes or subdivisions it is necessary to recognize those groups of soils or other land characteristics that make up significant land-management units. These groupings are discussed further under Soil Groups.

GENERAL OCCURRENCE OF DOMINANT SOILS

As previously stated, the soils of Charles County have developed upon unconsolidated beds of sand, gravel, silts, and clays that range from recent alluvial deposits and recent marine terrace deposits to old marine terraces of the Coastal Plain. This series of geologic formations from which the various soils have originated includes in order of age from the youngest to the oldest the Recent, Talbot, Wicomico, Sunderland, Brandywine, Calvert, Nanjemoy and Aquia formations. The comparatively recent deposits have given origin to the young or immature soils which are imperfectly developed; the older geologic formations have given origin to the more mature soils which have well-developed characteristics produced by the natural processes of soil formation. The most recent soil materials have been deposited by alluvial or colluvial action as flood plains, colluvium, or terraces.

The flood plains occupy the nearly flat areas along stream courses which are generally subject to overflow. The soil series identified in these locations are the well-drained Ochlockonee, the moderately well-drained Iuka and the poorly-drained Bibb soils. The Bibb soils constitute by far the greatest acreage. Most of them are subject to damaging stream overflow and as a result of these conditions they are Class VI land. However, there are small acreages of the Ochlockonee, Iuka and Bibb soils which are not subject to serious stream overflow and these are in land-capability Classes I, IIb and IIIb, respectively. They can be used for cultivated crops with suitable practices. These soils occur predominantly throughout the areas known as Zekiah, Mattawoman, Gilbert, Kerrick, Port Tobacco and Wards Run swamps; and along the streams feeding into these areas.

Swamp, Tidal Marsh, and other undifferentiated soil materials are the designations given to some of the recent alluvial deposits. The swamp consists of a complex of poorly drained immature soils, mainly inorganic and usually forested and wet throughout the the year. They occur mainly throughout the swamp areas and are classified as land-capability Class VII. The tidal marsh includes wet land bordering salty or brackish water periodically covered by tide. It is most common bordering the heads of bays formed by Nanjemoy Creek, Wicomico River, Port Tobacco River and Mattawoman Creek. This land is in capability Class VIII.

The recent colluvial materials consist for the most part of heterogeneous deposits accumulated at the base of steeper slopes. The Hyattsville soils are mapped in these locations. These soils most frequently occur on the Talbot, Wicomico and Sunderland geological formations on deposits which originated from older soil material. They are usually in land-capability Class I or II, depending on the slope.

Soils developed on comparatively recent terraces are almost wholly on the Talbot terrace formation which runs to an elevation of approximately 40 feet. Small areas of soils from more recent stream terraces have been included with the various soil series mapped on the Talbot marine terrace. This terrace occurs as a flat rather narrow plain, and usually with a steep front, bordering the streams or flood plains and rivers. The Talbot terrace has its maximum width of about four miles on Cobb Neck. It is less than this on Cedar Point and Tayloe Neck and narrows to a fringe bordering the Potomac River at Marshall Hall. Soils on this terrace formation include the Galestown, Choptank, Klej and Plummer series which are the sandy soils having varying degrees of natural drainage; and the Greenwich, Matapeake, Showell, Mattapex, Keyport, Fallsington, Othello and Elkton series which differ among each other in texture and drainage. Most of these soils are in land-capability Classes IIb and IIIb because they have restricted natural drainage. However, the much smaller acreage of the well-drained members constitutes some of the best and most valuable land of the County. The Greenwich and Matapeake soils are well drained.

Some of the soil series on the Wicomico formation are also mapped on the next higher and older terrace formation, the Sunderland. They may overlap slightly into the terrace formations above or below them. The soils include the Sassafras, Woodstown, Keyport, Fallsington and Elkton series. The very sandy soils such as the Evesboro, Doncaster, Wayside and Marbury series with more developed or compact subsoils are generally confined to the Wicomico and Sunderland terrace formations. The Doncaster and Marbury soils are largely in the western part of the County. The Sassafras, Wayside and Doncaster soils are some of the best and most extensive agricultural soils. Because of slope and erosion these soils are primarily in land-capability Classes IIa and IIIa. A smaller acreage is nearly level and in Class I. A relatively large area is in Class VI because of steep slopes and erosion. A relatively small acreage of the Sassafras and Hyattsville loamy sand is classed in IIc and IIIc. The Matawan soils which occur on the Sunderland and also on the younger Wicomico and the older Brandywine terrace formations are primarily in Classes IIc and IIIc. The much more extensive Evesboro soils are for the most part in land-capability Classes IIIc and VII. These soils commonly occur on the steep, eroded, gravelly and sandy slopes.

The La Plata, Beltsville, and Leonardtown soil series occur on the older Brandywine as well as the Sunderland formations. They are some of the most extensive soils of the County. The best drained member, the La Plata, which is underlain by a compact subsoil is generally in land-capability Class IIa or IIIa. The Beltsville and Leonardtown soils are the corresponding imperfectly and poorly drained series. The Beltsville soils are generally in land-capability Class IIb or IIIb, the classification depending upon the steepness of slope and degree of erosion. The Leonardtown soil is generally in land-capability Class IIIb.

These soils are extensive and are all underlain by a compact subsoil or hardpan layer. They present one of the most important agricultural problems of the County.

It has generally been assumed that hardpans in the Beltsville and Leonardtown soils have been cemented by some binding material such as free silica. However, the findings of Nikiforoff, Humbert and Cady[19] tend to rule out any cementation of hardpans in these soils, especially by silica. The authors of this paper conclude that the lower part of the profile of the Leonardtown and Beltsville soils consist of uncemented "physical" hardpan. They suggest that this hardpan is not a true soil horizon. Instead it was formed by the weathering of an exposed gravelly stratum which was later covered by the loess-like sediments from which the A and B horizons of these soils were developed. The hardness of the pan is largely due to the dense packing of its primary particles.

Underlying the previously described terrace formations are the much older marine deposits, the Calvert, the Nanjemoy and the Aquia formations. The relatively small exposed areas of these deposits bordering the steep bluffs or slopes, particularly adjacent to the swamp and deeply cut stream areas, give origin to the Westphalia and Marr soil series. The land-capability classification for these soils ranges from Class IIa on the gentle slopes to Class VII on the steepest and most eroded slopes.

In general the occurrence of soils in the deeply dissected areas of the County is well illustrated by the sample map area on page 253. The Leonardtown soils are

[19] C. C. Nikiforoff, R. P. Humbert and J. G. Cady. The Hardpan in Certain Coastal Plain Soils. Soil Science, Vol. 65, No. 2, pp. 135–153, February, 1948.

generally back on the nearly level topography in the Brandywine and Sunderland formations.

Beltsville soils occur on the slightly sloping land. On the abrupt breaks will be found the Wayside and sometimes the Sassafras and Evesboro soils. Near lower parts of the steep slopes can be found exposed parts of the Calvert and Nanjemoy formations which give origin to the Westphalia soils. The colluvial materials which give rise to the Hyattsville soils are commonly found at the base of the steeper slopes. The more nearly flat or less dissected younger soils on the Talbot formation appear bordering the recent flood plain soils in some places.

SOILS GROUPS

It is apparent that the same capability class may occur on a number of soils. These soils may vary in the type of conservation problem which they present, in the adaption of different kinds of plants and in other respects. The application of a soil and moisture conservation program depends on these factors as well as on the general land use capability classification. To aid in using the soil conservation survey maps in planning for conservation farming, the 75 soil separations shown on the map may be considered in 21 groups. The soils in any group have limited differences in depth of weathering, character of parent material, natural drainage, texture and permeability. They are near enough alike, however, that fairly detailed recommendations on type of farming, type of crop and type of treatment may be made for the entire group. Such recommendations for one soil group may be quite different from those for another. By considering the land use capability class and the soil group, proper recommendations may be made for good agricultural use and treatment of any tract of land in the county.

DESCRIPTIONS OF SOILS

Soils that have similar physical characteristics are grouped together. Designations of the groups indicate effective soil depth, texture, natural drainage, permeability and available moisture capacity.

SOIL GROUP 1

The soils in group 1 are deep, light-textured and well-drained; they have moderate permeability and moderate available moisture capacity. These soils are:

Sassafras fine sandy loam
Sassafras sandy loam
Sassafras gravelly sandy loam
Wayside gravelly sandy loam
Doncaster fine sandy loam
Westphalia fine sandy loam
Evesboro-Sassafras-Westphalia complex
Marr fine sandy loam
Hyattsville fine sandy loam
Hyattsville sandy loam
Hyattsville gravelly sandy loam
Greenwich fine sandy loam

Greenwich sandy loam
Greenwich gravelly sandy loam
Matapeake fine sandy loam
Matawan fine sandy loam
Ochlockonee fine sandy loam

This group constitutes the major tobacco producing soils of the County. The Sassafras soils are developed from silts and sands of the Sunderland formation. The medium-textured subsoil is underlain by sand and gravel. The Wayside soils were formerly mapped as Sassafras but are much deeper and redder in color with a slightly compacted gravelly layer in the subsoil. They are characterized as the broken gravelly edge of the Coastal plain and occur on the Wicomico formation. The gravelly textures occur on the steeper slopes and are not as productive, due to erosion and steepness. The Sassafras and Wayside are well adapted to tobacco, Irish and sweet potatoes, tomatoes, peppers, cucumbers, cabbage, sweet corn, peas, beans and squash. The Doncaster fine sandy loam is confined to the western portion of the County and occupies the more level and gently undulating to gently rolling portions of the Wicomico formation. It is a deep, fairly heavy, reddish soil, much deeper and heavier than either the Sassafras or Wayside. Tobacco is raised on it, but fertility practices must be adjusted so that a good quality of tobacco can be maintained. It is well adapted to deep-rooted crops and small grains.

The Westphalia soil occurs in small areas in the southern portion but mainly in the eastern neck of the County. It is developed from slightly glauconitic fine sands of the Nanjemoy and Calvert formations. Most of the glauconitic material has been leached out where the soil is mapped. It has a characteristic fine sandy texture throughout the profile with a shallow subsoil sometimes present. The Marr series is closely associated with the Westphalia and has a deeper subsoil. It occupies the more level areas, whereas the Westphalia is confined to the steeper slopes. These soils are particularly well adapted to tobacco and truck, but because the topography is rough and steep they are subject to much erosion and loss of nutrients. Where erosion control practices are followed excellent yields are obtained.

The Evesboro-Sassafras-Westphalia complex is made up of a mixture of very small areas of these three soils. The areas of each soil are so small and so close together that they cannot be separated on the map, so in the survey this condition is indicated as a complex. The complex is confined largely to steeper slopes and knolls. In descending a slope, first is found a narrow band of Evesboro, then a narrow band of Sassafras, and last a narrow band of Westphalia. The crop adaptation is similar to the Westphalia, but erosion and steepness limit its use to a large extent.

The Hyattsville soils are developed upon old colluvial fans of Coastal Plain material such as Sassafras. They also occur as colluvial material at the base of slopes and in depressions. All crops do well on these soils which because of their location have a good plant-moisture relationship.

The Greenwich soils are developed on the Talbot formation and are similar to the Sassafras in profile development. The subsoil is not as thick as that in the Sassafras. Associated with the Greenwich on the same Talbot formation is the Matapeake whose profile is deeper than that of the Sassafras. The Greenwich and Matapeake that have developed upon younger formations are not as thoroughly leached as the soils on the older formations and have a better plant-moisture relationship. These soils are particularly well adapted to tobacco and truck.

The Matawan series occurs on sands over clays on the Sunderland formation and is found in the vicinity of Waldorf. The fine sandy loam surface grades into a sandy loam subsoil and then into a sandy clay which overlays a slightly mottled clay. This soil is adapted to general farm crops and some truck.

All the soils in this group respond readily to treatment and allow the planting of an early crop which on other soils might be delayed by wet soil conditions. After rains, they can be cultivated sooner than the heavier soils.

The Ochlockonee fine sandy loam is the only well-drained flood plain soil in the County. The areas are small and are not subject to damaging overflow. Good yields of all cultivated crops are obtained.

SOIL GROUP 2

The soils of group 2 are deep, medium-textured, well-drained and moderately permeable, with a moderate available moisture capacity. They are:

Sassafras loam
Wayside loam
Wayside gravelly loam
Doncaster silt loam
Hyattsville silt loam
Matapeake silt loam
Ochlockonee silt loam

The Sassafras loam is formed on the Sunderland formation and is similar in profile to the lighter textured Sassafras with the exception that it has a heavier textured surface soil. It is particularly well adapted to deep-rooted crops, especially corn and grain. The Wayside series was formerly mapped Sassafras, but the Wayside is deeper and much redder with a slightly compacted gravelly layer in the subsoil. The areas mapped are not extensive, and the soil is confined largely to the rougher, steeper land of the Wicomico formation. Steepness and erosion limit its use for cropping, but where cropping is permissible all general farm crops do well on it. On the more level areas of the Wicomico formation is the Doncaster silt loam. This is heavier and redder and deeper than either the Sassafras or Wayside. It is well adapted to general farm crops.

The Hyattsville silt loam occurs on colluvial material derived mainly from Sassafras and related soils. It is adapted to general farm crops and deep-rooted long growing crops.

The Matapeake silt loam is formed on a deposition of fairly deep silt over sand, occurring on the Talbot formation. It is well adapted to the growing of deep-rooted crops and small grains. The Ochlockonee silt loam is the soil developed from silt depositions on the flood plains and is well adapted to cultivated crops. Areas are small and are generally not subject to damaging overflow.

The soils in this group are not too well adapted to tobacco, but are the most productive in the County for other crops. The factors which make these soils best adapted to deep-rooted crops and small grains tend to produce a heavier tobacco of poorer quality.

SOIL GROUP 3

The soils of group 3 are moderately deep, light-textured, well-drained. They have moderately permeable surface soils with slowly permeable subsoils and a moderate to high available moisture capacity, and are moderate in productivity. They are:

La Plata fine sandy loam
Cliffwood fine sandy loam

The La Plata fine sandy loam occupies rolling to strong breaks on the Brandywine and Sunderland formations. It is well scattered throughout the County. It has a reddish-yellow, fairly heavy, very compact subsoil, passing below into a mottled or marble splotched or streaked red, yellow and gray light sandy clay texture. Much of the La Plata has been severely eroded. This limits its agricultural use. Where uneroded it is adapted to general farm crops, and sometimes tobacco where good surface drainage is obtained. The Cliffwood fine sandy loam grades rapidly into a silty clay or clay which has some mottling in the lower depths. It is adapted to general farm crops and some truck crops.

SOIL GROUP 4

The soils of group 4 are moderately deep, medium-textured and well-drained with slow permeability and a high available moisture capacity. They are moderate to low in productivity. They are:

La Plata silt loam
Tuxedo silt loam
Marbury silt loam

The La Plata silt loam has a heavier surface texture than the fine sandy loam but otherwise is similar in profile development and location. It is adapted to general farm crops. The Tuxedo silt loam is formed from a complexity of materials and has no well-developed profile. The subsoil may contain undeveloped sands but is predominantly clays and silts of variegated colors. Its area is very small in this County. The Marbury silt loam is closely associated with the Doncaster series and is formed in the same areas. The profile difference consists of a hardpan in the lower part of the subsoil. The fertility level is not as high as the Doncaster, but is adapted to small grains and hay.

SOIL GROUP 5

The soils of group 5 are moderately deep, well-drained, gravelly, light-textured, with a rapidly permeable surface over a moderately permeable sand and gravel semi-hardpan which interferes with root development but does not impede drainage. They are:

Croom gravelly sandy loam
Croom gravelly loam

The Croom soils are only moderately productive and their occurrence on the steep gravelly breaks of the Brandywine formation is such that erosion is usually severe. Careful management is needed for crop production.

SOIL GROUP 6

The soils in group 6 are deep, very light-textured, moderately to poorly drained, with a low available moisture capacity and very rapid permeability. They are:

Klej loamy sand
Plummer loamy sand

The Klej loamy sand is imperfectly drained and sandy throughout the profile with mottling at about 24 inches. It is formed from a sand deposit of the Talbot formation having a seasonal moderately high water table. It is not too well adapted to deep-rooted crops. The Plummer is the poorly drained associate of the Klej. Because of their small acreage, they are included in the same group, but the Klej is better adapted for crop production than the Plummer. When drained, care should be taken to avoid over-drainage which, because of their sandy nature, may cause these soils to become droughty.

SOIL GROUP 7

The soils of group 7 are deep, light-textured, moderately well-drained and moderately permeable with a moderate available moisture capacity. They are moderately productive. They include:

Woodstown fine sandy loam
Woodstown sandy loam
Showell fine sandy loam
Showell gravelly sandy loam
Mattapex fine sandy loam
Iuka fine sandy loam

The Woodstown fine sandy and sandy loam soils are closely associated with the Sassafras and occur as moderately well-drained soils in the same areas occupying the basins and stream banks as well as the bases of slopes. The grayish-brown sandy surface is underlain by a friable sandy loam or sandy clay loam subsoil with gray and yellowish-brown mottling beginning at about 24 inches and getting stronger with depth. Sand and gravel occur at about 32 inches. The imperfect drainage may be caused by either a moderately high water table or seepage from above. Where seepage occurs, the water should be intercepted on the upper slope bordering the area receiving the seepage. Where the imperfect drainage condition is caused by a high water table, the nature of the soil and its underlying material are strong factors in the determination of its suitability for drainage. In the case of Woodstown, the sand and gravel which underlie it would make for easy lowering of the water table by open ditches or tile. It is adapted to cultivated crops, but is improved by drainage.

The Showell is similar to the Woodstown except that its subsoil is shallower and it is not as deep to the underlying sand and gravel. It is associated with the Greenwich and occurs on the Talbot formation. A high water table makes it slightly wet but better adapted to cultivated crops than the Woodstown. It is improved by drainage. The Mattapex occurs as the moderately well-drained counterpart of the well-drained Matapeake soil. It has a deeper and sometimes heavier subsoil than either Showell or Woodstown. It is adapted to cultivated crops but is improved with drainage.

On the stream flood plains is the Iuka fine sandy loam which has a moderately high water table, as indicated by mottling at depths from 18 to 24 inches below the surface. The land is occasionally overflowed with some resultant damage to crops. Siltation of the stream channel, particularly along Gilbert Swamp, is causing many fields to be damaged by overflow. Areas which once grew good corn and hay can no longer be cultivated.

SOIL GROUP 8

The soils of group 8 are moderately deep, medium-textured and moderately well-drained with moderate permeability and moderately high available moisture capacity. They are:

Woodstown loam
Mattapex silt loam
Iuka silt loam

The Woodstown loam is the medium-textured moderately wet soil associated with the Sassafras. It is similar in profile development to the Woodstown fine sandy loam. It is restricted in crop adaptation, not being suited to alfalfa or other deep-rooted crops, but lends itself readily to drainage by tile or open ditches. It is improved by drainage. The Mattapex silt loam is the medium-textured moderately wet soil found on the Talbot formation. The depth of the subsoil and its heavy nature do not make it as good for crops as the Woodstown but good soil management can build it up to produce good crops. The Iuka silt loam is the medium-textured moderately wet soil on the flood plains and is adapted to shallow-rooted crops. Areas are small and generally not subject to damaging overflow.

SOIL GROUP 9

The soils of group 9 are moderately deep, light-textured, moderately well-drained with a moderately permeable surface over a slowly permeable substratum and a moderately high moisture capacity. They are:

Keyport fine sandy loam
Keyport sandy loam
Berwyn sandy loam

The Keyport fine sandy loam and sandy loam are underlain by a heavy silty clay or clay subsoil and substratum which is moderately wet, with mottling at about 18 inches. The heavy nature of the subsoil and substratum limits the type of drainage which will improve it. Tiling will not work well, but open ditches are effective. It is adapted to shallow-rooted crops such as some hays and grasses, but with drainage, other crops including truck do well.

The Berwyn sandy loam is a soil on colluvial deposits which is moderately wet and heavy in the subsoil and sometimes compacted in the subsoil. It occupies small depressions, areas at the base of slopes and drainage heads. Since the areas mapped are usually small it is generally utilized for the same crops as the surrounding area. Some very poorly drained areas are included in it, as small wet spots, because they are too small to delineate. Cultivated crops do not do too well on it, but small grains and hay are better adapted.

SOIL GROUP 10

The soils of group 10 are moderately deep, medium-textured and moderately well-drained with a moderately permeable surface over a slowly permeable substratum and a high available moisture capacity. They include:

Keyport silt loam
Berwyn silt loam

The Keyport silt loam is the moderately wet heavy soil usually found on Talbot formation. The heavier textured surface does not make it as good as the sandy or fine sandy loam for crops. The fertility level is usually rather low. When treated it responds readily and good yields are obtained, especially where surface water is removed. It is adapted to cultivated crops and grasses when adequately drained.

The Berwyn silt loam is similar to the lighter textured type in occurrence and profile. Because of its location, it is best adapted to small grains and hay but is usually cropped like the surrounding area but does not do as well. Its high moisture-holding capacity even in dry periods limits its effective use for cultivated crops.

SOIL GROUP 11

The soils of group 11 are moderately deep, medium-textured, moderately well-drained with a moderately permeable surface soil over a slowly permeable hardpan subsoil and a moderate available moisture capacity. They are:

Beltsville fine sandy loam
Beltsville sandy loam

The Beltsville fine sandy and sandy loams occur on the Brandywine and Sunderland formations. The Beltsville was formerly mapped as Leonardtown, but the range in drainage condition covered by Leonardtown in older surveys was too great; therefore, the better drained Beltsville soils were delineated in later surveys. The hardpan occurs at about 20 inches or below. They are adapted to the growing of shallow-rooted crops. Some tobacco is grown where good surface drainage occurs, but in wet years a good quality is not produced.

SOIL GROUP 12

The soil in group 12 is medium-textured, moderately well-drained with a moderately permeable surface over a slowly permeable hardpan subsoil and a moderate available moisture capacity. It is:

Beltsville silt loam

The soil is similar to the fine sandy and sandy loam in profile development except that its surface is heavier. Where the lighter textured Beltsville occupies small rises and gently rolling ridges, the silt loam occurs on the flatter areas. It is usually low in fertility, and where the hardpan is not exposed by erosion, shallow-rooted crops respond readily to good fertility practices.

SOIL GROUP 13

The soils of group 13 are deep, very light-textured and well-drained with rapid permeability and a moderately low available moisture capacity. They are:

Sassafras loamy sand
Hyattsville loamy sand
Matawan loamy sand
Muirkirk loamy sand

The Sassafras loamy sand is developed from sands on the Sunderland formation. Although of the same series as the other Sassafras soils, it differs in that the loamy sand extends to a depth of 18 to 30 inches and the subsoil can be as little as six inches thick. The subsoil is underlain by sand. The Sassafras loamy sand is moderately low in productivity except for specialized crops such as asparagus, sweet potatoes and tobacco. Special fertility practices are needed for these crops since the soil is sandy and inclined to be droughty. The addition of organic matter is of prime importance in building up fertility.

The Hyattsville loamy sand is derived from colluvial material from the Sassafras and Evesboro soils, and although very light in the texture of the profile, plant moisture conditions are better than in the Sassafras. By reason of its location as colluvial fans, in depressions and at the base of slopes, water from surrounding or higher areas is generally present. It is particularly well adapted to truck and other deep-rooted crops. Areas are not very extensive.

The Matawan loamy sand has a loamy sand surface which grades into a sandy loam and then a sandy clay underlain by faintly mottled grayish-yellow to grayish-brown clay. It is usually found on the Sunderland formation. It is moderately low in productivity and is adapted to the growing of most vegetables, melons and sweet potatoes. The Muirkirk loamy sand differs from the Matawan in that the subsoil grades into a reddish-brown clay at 30 to 36 inches. Its plant moisture relationship is not as good as that of the Matawan but is adapted to growing of most vegetables. The addition of organic matter materially helps these soils.

SOIL GROUP 14

The soils of group 14 are deep, light-textured and poorly-drained, with moderate permeability and a moderate available moisture capacity. They are:

Fallsington fine sandy loam
Fallsington sandy loam
Othello fine sandy loam
Bibb fine sandy loam

The Fallsington series is the poorly drained counterpart of the Sassafras soils and is closely associated with them. It occurs in depressions and drainage heads, also at the base of slopes. It has a gray surface and mottled gray and yellow sandy loam subsoil underlain by sand or sand and gravel. When drained it is adapted to cultivated crops. It lends itself readily to both tile and open ditch drainage. Undrained, it is suited to hay and pasture. Small grains are grown when not too wet. The Othello fine sandy loam is found on the Talbot formation and is the poorly drained soil associated with the Matapeake and Mattapex. It has a gray surface and mottled silt loam or silty clay subsoil underlain by sand. It differs from the Fallsington in that its subsoil is deeper. It is readily drained by open ditches. Tiling is effective but requires proper maintenance and a good initial layout. It is adapted to cultivated crops when drained, and undrained it is best suited to small grains, hay and pasture.

The Bibb fine sandy loam is the poorly drained soil on flood plains and when not subject to damaging overflow can be cultivated or drained.

SOIL GROUP 15

The soils of group 15 are moderately deep, medium-textured, poorly-drained and moderately to slowly permeable with a high available moisture capacity. They are:

Othello silt loam
Bibb silt loam

The Othello silt loam is the heavy-textured, poorly-drained soil associated with the Matapeake and Mattapex on the Talbot formation. It is best adapted to grasses and is moderately productive when drained.

The Bibb silt loam is the poorly-drained, heavier textured soil found on flood plains. It comprises the major type of soil found along streams. Most of it is subject to damaging overflow. When adequately drained and not subject to overflow, it is well adapted to all crops, particularly truck.

SOIL GROUP 16

The soils of group 16 are shallow to moderately deep, medium-textured, and poorly to very poorly drained, with a slowly permeable surface over a very slowly permeable substratum and a high available moisture capacity. They are:

Elkton silt loam
Alloway silt loam
Elkton silty clay loam

The Elkton is the poorly drained soil associated with the Keyport, and the Alloway is the very poorly drained. Because of poor drainage and heavy clay subsoil, they are restricted in use for cultivation and are best adapted to grasses when adequately drained.

SOIL GROUP 17

The soil in group 17 is shallow to moderately deep, medium-textured, and poorly drained. It has a slowly permeable surface soil over very slowly permeable hardpan subsoil, with a moderately low available moisture capacity. It is:

Leonardtown silt loam

The Leonardtown silt loam is the poorly drained soil associated with the Beltsville on the Sunderland and Brandywine formations. Due to its poor drainage and the presence of a hardpan, it is not too well adapted to cultivated crops. When drained, it is best adapted to grasses and pasture.

SOIL GROUP 18

The soils of group 18 are deep, very light-textured, and very rapidly drained, with rapid permeability and a low available moisture capacity. They are:

- Evesboro gravelly loamy sand
- Evesboro loamy sand
- Galestown gravelly sandy loam
- Galestown loamy sand
- Choptank loamy sand
- Beach sand

The Evesboro gravelly loamy sand and the loamy sand are strongly leached deposits of sand and sand and gravel on the Sunderland formation. Due to their droughty nature, they are adapted to growing of specialized crops such as melons and sweet potatoes with proper fertility practices. Tobacco is raised successfully by some farmers who have learned how to manage the soil in relation to its nutrient requirements.

The Galestown loamy sand is a deposition of pale yellow sand on the Talbot formation, and although similar to the Evesboro in profile, it is not as leached because it is a younger geologic formation. Its crop adaptions are similar to those of Evesboro, but it is slightly better in productivity of the same crops. The Galestown gravelly sandy loam occurs mainly as gravelly breaks on the Talbot formation. Although similarly adapted as the loamy sand, the steepness of the slopes, erosion and small narrow areas restrict its use for cropping.

The Choptank loamy sand is formed from the brown to yellowish-brown sandy deposits of the Talbot formation. It is not as leached as either the Galestown or Evesboro but is adapted to the same crops. Its productivity and response to special fertility practices are greater than that of the Galestown or Evesboro.

A few small areas of Beach sand were mapped. It is best suited to trees where not subject to tidal action.

SOIL GROUP 19

The soils in group 19 are derived from stream alluvium and are subject to damaging overflow. They are:

- Bibb silt loam
- Alluvial soils well-drained, undifferentiated

These soils occur along streams all over the County and, owing to their subjection to damaging overflow, are limited in use. The Bibb is usually used with other areas as pasture land or woodland. The undifferentiated soils have varied soil materials which could not be mapped separately. They are best suited for pasture land or woodland.

SOIL GROUP 20

Very poorly-drained, undifferentiated soil materials, usually covered with standing water or subject to damaging overflow, make up group 20. They are:

Alluvial soils, poorly drained, undifferentiated
Swamp

These soils, because of very poor drainage and frequent flooding, are best suited to certain species of trees and wildlife plantings.

SOIL GROUP 21

Very poorly drained undifferentiated soil materials, usually covered with tidal water make up group 21. Such areas are designated as tidal marsh. They are not considered suitable for the economical production of cultivated crops, grains, pasture or forest.

LAND USE AS RELATED TO GEOLOGY AND EROSION OF SOILS

The chief factors which control the use that might be made of land are climate, geology, soil, slope, erodibility, and drainage. The climate is rather uniform in this area and produces no significant variations of land in Charles County.

The geology contributes the source materials from which the soils are formed and, therefore, the natural nutrient elements in the soil. The geology vitally influences the drainage of the area. Loose open sand or gravel strata underlying the soil, for example, promote free drainage through the ground and often make for droughtiness. On the other hand, heavy clay formations beneath the soil make for retarded internal drainage, generally producing unfavorable conditions within the soil or even at the surface. The water table of the area is a product of geologic conditions whether low, high or at the surface.

Erosion depends largely upon the character of the soil, slope, erodibility, and the treatment the soil receives by man. When the protective cover of trees and grasses is stripped from the land through lumbering, farming and other operations, the soil is laid bare to the action of erosion. Unless farming is practiced with care, large amounts of soil are washed or blown away.

In Charles County, with its highly specialized agriculture, on the soils where air-cured tobacco is grown, and even where general farming and dairying are practiced, erosion has become a swift, destructive force on steep cultivated land. It continues to carry the soil away and deposit it in streams and reservoirs and on valuable land. It seriously affects the welfare of all citizens of Charles County, and it is important that they become more conscious of their problem.

Although few have realized what a harmful part erosion has played in the history of the county, its disastrous effects could scarcely be more strikingly demonstrated than in the rapid decline of a once prosperous trading port—Port Tobacco. Here, where the revenue from shipping maintained a prosperous town of 80 houses within the memory of living men, there are today less than ten occupied dwellings.

The silt from the eroding farm lands of the Port Tobacco watershed has filled this once active harbor and has deprived Charles County of its principal port within the short space of man's memory. Port Tobacco River from more than a mile above the town to more than a mile below the town has now been silted by erosion.

Less noteworthy, but just as significant, is the silting of the other tidal creeks and rivers of the County. Here, too, sailing vessels once plied their trade with the plantations. Now they, too, are silted so full that a rowboat has difficulty in obtaining passage.

The progression of erosion can readily be seen in driving over the county and noting the areas now in pine. Practically all of the pine stands were once cleared and under cultivation. Bare spots in fields as well as abandoned fields indicate readily apparent erosion.

Any aerial photograph showing a portion of the County depicts narrow strips of trees which run up the sloping land. These were once active gullies which after being abandoned, finally obtained a growth of trees and honeysuckle. Many present active gullies can be noted as long irregular scars.

THE FORESTS OF CHARLES COUNTY

BY

KARL E. PFEIFFER

Among Maryland counties, Charles, next to Garrett and Allegany in the west, is the most extensively forested. Of its 293,120 acres, 179,000 acres or 61% are in woodland. Unlike the forests of the two western counties, those of Charles County occupy, in the main, land once cleared for crops, but since abandoned for that purpose, and on which natural reforestation has taken place.

Charles County is in the Coastal Plain Division and is distinctively "Southern Maryland." On the south and west, it is bounded by the Potomac River and on the east in part by the Wicomico and Patuxent Rivers and in part by St. Marys County, and on the north and northeast by Prince Georges County.

Three fairly large sluggish streams cut through the County for varying distances. These are the Zekiah Swamp, Port Tobacco Creek and Mattawoman Creek. It is along these streams and the smaller tributaries to the Potomac and Patuxent Rivers and the slopes above them that a good part of the timber is found. Also on some of the flatter land above the slopes the once cultivated land has reverted to forests. Light soils—from pure sand to sandy loam—predominate, with a large amount of clay along the swampy sections.

The forests consist of hardwoods 40%, pine 10% and mixed pine and hardwood 50%. Great differences in elevation, with corresponding change of timber types, do not exist in Charles County. The pine stands are found mostly on the abandoned farm lands on the higher slopes and flats. These are both young and mature stands, in accordance with when the land was abandoned, and consist mostly of Virginia pine with some shortleaf and pitch pine mixed in. To the east and south, loblolly pine comes in also. There is a distinct type of swamp hardwood forest consisting of pin, willow and swamp oak, red gum, black gum, red maple, river birch, yellow poplar, sycamore, and beech, with some walnut. In other sections are the upland and lowland type of hardwood forest. The upland type consists of black, scarlet and red oaks, hickory and mixed pines mostly Virginia pine. This is the type in which most of the chestnut was found in former years. In the lowland type are found the white and red oaks together with black gum, red gum, and yellow poplar. Some of these stands are ready for cutting, but most are either not yet mature or have been culled over.

A number of forest trees are indigenous to the county, and some have escaped cultivation and are growing wild. The accompaning list contains most species found growing wild that normally reach a height of 15 feet or more.

LIST OF TREES IN CHARLES COUNTY

CONIFERS

Common Name	*Botanical Name*
1. White Pine	Pinus strobus (Linneaus)
2. Virginia Pine	Pinus Virginiana (Miller)
3. Pitch Pine	Pinus rigida (Miller)
4. Shortleaf Pine	Pinus echinata (Miller)
5. Loblolly Pine	Pinus taeda (Linneaus)
6. Red Cedar	Juniperus virginiana (Linnaeus)
7. White Cedar	Chamaecyparis thyoides (Linnaeus) Britton, Sterns & Poggenberg
8. Cypress	Taxodium distichum (Linnaeus) Richard
9. Black Walnut	Juglans nigra (Linnaeus)

HARDWOODS

10. Butternut	Juglans cinerea (Linnaeus)
11. Bitternut Hickory	Hicoria cordiformis (Wangenheim) Britton
12. Mockernut Hickory	Hicoria alba (Linnaeus) Britton
13. Pignut Hickory	Hicoria glabra (Miller) Sweet
14. Largetooth Aspen	Populus grandidentata (Michaux)
15. Black Willow	Salix nigra (Marshall)
16. Brittle Willow	Salix fragilis (Linnaeus)
17. Blue Beech	Carpinus caroliniana (Walter)
18. Hop-Hornbeam	Ostrya virginiana (Miller) Koch
19. River Birch	Betula nigra (Linnaeus)
20. Beech	Fagus grandifolia (Ehrhart)
21. Chinquapin	Castanea pumila (Linneaus) Miller
22. Chestnut	Castanea dentata (Marshall) Borkhausen
23. White Oak	Quercus alba (Linnaeus)
24. Post Oak	Quercus stellata (Wangenheim)
25. Overcup Oak	Quercus lyrata (Walter)
26. Bur Oak	Quercus macrocarpa (Michaux)
27. Chinquapin Oak	Quercus muehlenbergii (Engelmann)
28. Chestnut Oak	Quercus montana (Willdenow)
29. Swamp Chestnut Oak	Quercus prinus (Linnaeus)
30. Cow Oak	Quercus prinus (Linnaeus)
31. Northern Red Oak	Quercus borealis maxima (Marshall) Ashe
32. Southern Red Oak	Quercus rubra (Linnaeus)
33. Scarlet Oak	Quercus coccinea (Muenchhausen)
34. Black Oak	Quercus velutina (Lamarck)
35. Pin Oak	Quercus palustris (Muenchhausen)
36. Blackjack Oak	Quercus marilandica (Muenchhausen)
37. Water Oak	Quercus nigra (Linnaeus)
38. Willow Oak	Quercus phellos (Linnaeus)
39. Shingle Oak	Quercus imbricaria (Michaux)
40. American Elm	Ulmus americana (Linnaeus)
41. Slippery Elm	Ulmus fulva (Michaux)
42. Hackberry	Celtis occidentalis (Linnaeus)
43. Red Mulberry	Morus rubra (Linnaeus)
44. Sweet Bay	Magnolia virginiana (Linnaeus)
45. Yellow Poplar	Liriodendron tulipifera (Linnaeus)

46. Papaw	Asimina triloba (Linnaeus) Dunal
47. Sassafras	Sassafras variifolium (Salisbury) Kuntze
48. Witch Hazel	Hamamelis virginiana (Linnaeus)
49. Red Gum	Liquidambar styraciflua (Linnaeus)
50. Sycamore	Platanus occidentalis (Linnaeus)
51. Serviceberry	Amelanchier canadensis (Linnaeus) Medicus
52. Thorn	Crataegus species
53. Wild Plum	Prunus americana (Marshall)
54. Hercules Club	Aralia spinosa (Linnaeus)
55. Wild Black Cherry	Prunus serotina (Ehrhart)
56. Sweet Cherry	Prunus avium (Linnaeus)
57. Ailanthus	Ailanthus glandulosa (Desfontaines)
58. Red bud	Cercis canadensis (Linnaeus)
59. Black Locust	Robinia pseudoacacia (Linnaeus)
60. Staghorn Sumach	Rhus hirta (Linnaeus) Sudworth
61. Holly	Ilex opaca (Aiton)
62. Silver Maple	Acer saccharinum (Linnaeus)
63. Red Maple	Acer rubrum (Linnaeus)
64. Box Elder	Acer negundo (Linnaeus)
65. Black Gum	Nyssa sylvatica (Marshall)
66. Dogwood	Cornus florida (Linnaeus)
67. Persimmon	Diospyros virginiana (Linnaeus)
68. Black Ash	Fraxinus nigra (Marshall)
69. White Ash	Fraxinus americana (Linnaeus)
70. Red Ash	Fraxinus pennsylvanica (Marshall)

Included in the foregoing list are the principal commercial species as well as other trees of lesser importance. It indicates the diversity of species found in the county. The list may be reduced to a comparatively few species by considering only those which by reason of their abundance and good qualities have a wide use.

THE OAKS

White Oaks—The different species in this group are usually cut and sold as white oak without distinction. The woods are scarcely distinguishable except by an expert, and are usually used indiscriminately. Probably 90 percent of what is cut and sold for white oak is the true white oak—Quercus alba. The other common trees constituting this group are post oak, chestnut oak, swamp white oak, and cow oak. The wood of the white oak is heavy, strong, hard, tough, close-grained, and durable, and since it is found in all sections of the county is the most important of all tree species. Its uses are many, including construction, ship building, tight cooperage, furniture, wagon and car stack, piling, railroad ties, logs for export, veneer, and a variety of other uses which call for a high-grade wood.

Red Oaks—Sold as red oak are a number of different species of oak. These include black oak, northern and southern red oak, scarlet oak, pin oak, and willow oak. Sometimes the last two are not included, and are sold at a somewhat lower price. The wood is hard, strong, coarse-grained, and used for construction, furniture, boat building, interior finish, and railroad crossties.

OTHER HARDWOODS

Yellow Poplar—This species, also called tulip tree, is often separated into two classes by mill men—one in which the trees contain a very large percentage of yellowish heartwood, called "yellow poplar", and the other containing considerable sapwood, principally white, and called "white poplar". Botanically it is the same tree, the difference in the color of the wood being principally due to the rate of growth and to some extent to soil conditions. The wood is light, soft, easily worked, but not durable in the ground. The better grades of "yellow poplar" are used in construction, interior finish, furniture, veneer, and wooden ware. The "white poplar" or poorer grades are used mostly for pulpwood.

Red Gum—This tree is also known as sweet gum and is mostly confined to moist and wet places. The wood is heavy, moderately hard, close-grained, and not durable on exposure. The wood is used for lumber, interior finish, barrel staves, veneers for baskets of all kinds, and the heartwood for furniture veneer as imitation mahogany. The smaller trees and tops are used for pulpwood.

PINE

Virginia Pine—The most important of the pines in the county, because it is the most abundant, is the Virginia Pine. It is widely distributed and is found particularly on land that was once cultivated. It is quick to seed in old fields, and often represents a transition from unproductive land to valuable forests, since it is generally succeeded by better hardwoods. The wood is usually knotty except on large sized trees, because of the persistence of the side branches, and is light and soft, but fairly durable in contact with the soil. It is used for rough construction, piling and pulpwood.

During the last World War a considerable amount of wood was cut in Charles County.

PRODUCTION

The lumber production for 1942 amounted to about 4,545,000 board feet, of which 85% was hardwood and 15% pine or soft wood. A goodly portion of this was used locally.

Pulpwood accounted for a quantity of the pine cut, although some of the hardwoods, such as red gum and tulip poplar, find their way into the pulpwood market. Pulpwood production is one of the largest industries in the county. This product is valued at nearly twice as much as the other wood and timber, including lumber, taken out of Charles County woodlands.

Nearly all of the original stands have been lumbered, and some have been cut a second time. There are some 20 mills cutting lumber in the county, mostly on a small scale.

Only about 21 miles of public railroad traverse the county, and about 24 more miles of Government owned railroads running to the Naval Powder Factory at Indian Head and the air base at Cedar Point in St. Marys County.

During World War II, there was more activity in the timber market, and, as in other sections of the State, the forest products taken out far exceeded annual growth. Since the war the cutting has fallen off, and now is back slightly under the 1942 mark.

DESTRUCTIVE INFLUENCES

Constant changes are being brought about in the forest, due to a combination of agencies. The forest with a vast number of trees of different species and varying requirements struggling for existence and supremacy may be regarded as an organism. By proper management regulations of the cut, the maximum yield can be obtained. On the other hand, rapid deterioration follows where the forest is regarded as a more or less inexhaustible resource from which all material of value can be taken without thought of the future. In order to maintain the forest in its highest state of efficiency and productivity, various destructive agencies must be constantly combated. The most important is that of forest fires, which every year do many thousands of dollars worth of damage. This loss is inexcusable, as practically all fires are the result of carelessness. The responsibility for much of the waste land and low production of the forest can be laid to destructive and wasteful methods of cutting. Always present and only awaiting a favorable opportunity for serious outbreaks are the insects and fungous diseases.

FOREST FIRES

Forest fires continue to be the chief source of damage to the forests. The effects of fire are (a) the burning of the leaves and litter on the ground which are needed to conserve the moisture, protect the seed, and to fertilize the soil; (b) the destruction of the seed and the young seedlings that have already started, which are so essential for the renewal of the forests; (c) the burning of the cambium, or living wood, of young trees, on the side most exposed to fire, causing the bark to peel off, thus exposing the wood to decay (the tree becomes stunted, decay enters the wood and gradually works its way up into the trunk, rendering the tree practically worthless); (d) a severe fire in the spring often kills all the trees, entailing a total loss of growing stock; (e) the protective cover of food for game is consumed and frequently much wild life is destroyed. A single fire may destroy the growth of twenty or thirty years and in addition may bring about such conditions as will make a satisfactory renewal of the forest impossible for many years to come.

Brush burning, smoking, and railroads are the chief causes of fires. In 1947 Charles County had 21 fires which burned over about 125 acres, slightly under an average year. With "Regulation 4" which limits brush burning during March, April, May, and September 15 to December 15 to between the hours of 4:00 P. M. and midnight EST, it is hoped to cut down the number of fires. During the evening and after dark there is likely to be less wind and more humidity, which together mean less danger that fire will get away.

Wagon or hauling roads and wide paths through the woods often serve as effective barriers to the spread of fire, and therefore should be kept clear of leaves and dry brush.

INSECTS AND DISEASES

The forest insects are normally held in check by their natural enemies, but occasionally there is a serious outbreak which causes considerable damage. Forest tree insects cannot be controlled like those that attack fruit trees, on account of the high cost of treatment. The main reliance must be placed upon preventive measures, clean management, and the prompt removal of the dead trees and wood which harbor the insects. Dying and defective trees should also be cut and utilized, as insects often attack trees of low vitality and power of resistance, rapidly multiplying, and then successfully attack the vigorous ones.

The sycamore leaf and twig blight, commonly known as anthrocnose, caused by the fungus "gnomonia veneta" is one of the commonest, though not too serious, of the fungi diseases. This attacks the young leaves and twigs of the sycamores in the early summer, causing a great portion of the leaves to dry up and fall off. A second set of leaves then grows out. While this does not kill the tree it weakens it.

MANAGEMENT

The misuse of the forests for the last hundred years has brought about a steady decrease in their productive capacity. In the past when timber had little value, only the best trees of the best species were cut. The forests have deteriorated under cutting of this character, the best being taken and the poorer materials left to occupy the ground. As timber increased in value and became harder to get, more of the lower grade material was used, but no thought was given to maintenance of a proper proportion of the best species by selective cuttings or of protecting the young growth. Nor was thought given to timber production; cut and get out was the idea. This practice has been carried to such an extent and the abuse of the forests has been so great that it will take many years of careful management to bring them back to their full productive capacity. Forest management is "the practical application of the principles of forestry to a forest area." In short, it is the science of making woodlands pay—making them pay in wood, timber, or other forest products, and so in money. This will result in producing the heaviest crop of the best quality in the shortest time.

It was with the above in mind that the Conservancy Districts Act was passed in 1943. Local Boards were set up in each county by this act to help formulate the best management plans for that area. The Charles County Board has seen fit to recommend that no hardwoods of the approved species of oak, tulip poplar, red gum, ash and walnut shall be cut if less than 16" in diameter, stump height, unless recommended by an agent of the Department. Loblolly pine can be clear cut, leaving six seed trees to the acre, and Virginia pine can be cut clear, letting it seed from the surrounding stands. Loblolly shall be given preference over the Virginia pine.

The Department is still carrying on its program of cooperation with the woodland owners, and will examine wooded areas and give reports on the best handling of the areas. When desired by the owner and the tract report warrants a cutting, the Department's representative will mark the trees that should come out, and give the owner a detailed estimate and valuation of his timber that is ready to harvest. He will also be furnished with a list of sawmill operators who may be interested in buying the trees.

FOREST PLANTING

There are small waste areas on nearly every farm which should be planted in timber. They produce nothing now for the owner, and he must pay taxes on them. Lands along ravines, steep slopes, or overflow lands that are not suited for field crops are capable of producing good timber. Nature will take care of reseeding the area, but the process will be very slow and drawn out; forest planting is much faster and not very expensive. No matter what may be the condition of the land, unless it is a salt marsh, suitable tree species are available, and generally the only productive use of such land is in timber growing. Small trees, suitable for forest planting, are not expensive and the work can be done at a reasonable cost, with assurance that waste land may be reclaimed and made productive.

STATE FORESTS

There are two areas in Charles County acquired and set aside as State Forests' namely, Cedarville State Forest and Doncaster State Forest. The former is in the North Central section with 2,909 acres of its 3,509 acres in Charles County and the remaining in Prince Georges County. The topography here is rather rolling with several "swamps" draining into Zekiah Swamp traversing the area. The timber is mostly Virginia pine, but some good hardwoods are also found. While the primary object of the State Forest is timber growing, there are several picnic areas available which have been increasingly used in the past several years.

Doncaster is in the west-central part of the county and contains 1,464 acres, composed mostly of Virginia pine with some hardwood areas, as in the Cedarville State Forest. This area is used very little for recreation on account of its remoteness.

Both areas are used for demonstrations of the proper use and handling of woodlands, and act as forest laboratories for the Southern Maryland area.

WILDLIFE RESOURCES OF CHARLES COUNTY

BY

EDWIN M. BARRY

Introduction

Early reports of the abundance of wildlife resources in Charles County, by Captain John Smith and others are recorded fact. When settlers first came to Maryland, landing in St. Marys County in 1637, deer, bear, wild turkey, grouse, elk, fox, squirrel, and the more common upland game birds and animals now known to us, were abundant. As settlement from the St. Marys Colony expanded northward, Charles County became the fourth established Maryland political sub-division in 1658. The plantation economy became well established in the eighteenth and nineteenth centuries. This economy was characterized by the clearing of much of the land for tobacco crops. Fishery resources along the Potomac River were abundant, and large catches of herring and shad during the migration period were used to feed the slaves of this region. Fur resources became a medium of exchange between the Colony and England. The first exports to the Mother Country were beaver otter, and muskrat hides secured from the Indians of this region.

One hundred years after the first colony was established in St. Marys County, 1737, most of the arable land was producing crops. The transition from a near-total wilderness area, which included ninety percent forest cover and approximately ten percent marsh and waterways, gave rise to increases in white-tail deer herd, bobwhite quail, and gray squirrel. The loss of the wilderness, which meant decrease in forest cover, draining of marshes, increase in human populations, brought about an equally definite decline in wilderness game, such as the wild turkey, elk, bear, wolf, fox, squirrel, otter, and beaver.

Two hundred years after the colonization and development of agricultural enterprise within Charles County most of the wilderness game was depleted, marshes and swamps were drained, forest land cut over and burned, and populations increased many fold. The deer herd was decimated about 1870, and the last native ruffed grouse were noted at the turn of the twentieth century. The fisheries in the tidewaters of the Potomac River were rapidly depleted by continued operations of haul seines, gill nets, and pound nets in the eighteen-nineties. The once large runs of anadromous fishes had been severely depleted by 1920. The oyster beds, so abundantly distributed in Charles County, along the Potomac River, were well on their way to near exhaustion through exploitation by both Maryland and Virginia by 1930.

Physiographic and Topographic Relationships to Wildlife

LAND PATTERNS

Charles County takes the form of a great fist, with the thumb touching the productive waters of the Patuxent River, bordering on the southern fringe of the great Patuxent marshes, famous for waterfowl and railbird hunting. The fingers of this great fist, the Wicomico River, the Port Tobacco River, the Nanjemoy Creek, and the Mattawoman Creek, form one of the most effective topographical land patterns for wildlife in the State of Maryland. Bordered on the east and south by the Potomac River, a picturesque and famous waterway for waterfowl using the Atlantic flyway in migration, and divided by these aforementioned water courses with their accompanying marshes and swamps, Charles County has a very important part in the production of wildlife resources in the State.

REGIONAL FAUNA

Charles County, situated in the Carolinian Life Zone of the western division of the Coastal Plain province, is known to natives as Southern Maryland. The rolling terrain, ranging in elevation from 100 to 200 feet, which borders many swamps and marshes, provides sub-marginal land areas which, although in former years intensively tilled, have now grown up to trees and declined in usefulness as a result of erosion through continual cropping. The river bottoms are on the average much broader and flatter than in most regions of the State, particularly in the headwaters of Mattawoman Creek, Port Tobacco River, and Wicomico River. These broad, flat, productive river bottoms have potential value to the now nearly depleted woodcock, snipe, waterfowl, and fur bearers. Zekiah and Gilbert Swamps and the Mattawoman Plains have provided abundant supplies of raccoon, otter, black duck, and wood duck. The fur resources of Charles County included in the eighteenth and nineteenth centuries otter, beaver, mink, and muskrat. The present century includes only the muskrat, which depends largely on terrain within the region of Pomonkey Creek, Mattawoman Creek, Reeder Run, Nanjemoy Creek and tributaries, Port Tobacco River, Wicomico River, Patuxent River, and the Zekiah and Gilbert Swamps, and the many inland tributaries. The uninventoried tidal and fresh water streams of this county play an important part in the production of all wildlife species and, with the exception of the northwestern region of the county, have been unaffected by present increases in human population and their attendant decimating factors on wildlife crops.

The agricultural survey[20] of Charles County, according to the 1945 census, showed 1,346 farms, with a gain of 70 farms in 5 years. This trend indicates the dividing of larger farms into smaller ones with the average reduction, per farm, of 12.7 acres, or an average per farm of 130.1 acres, which gives Charles County fourth place in the acreage per farm in Maryland. These farms produced products totalling

[20] Hamilton, A. B. "Comparative Census of Maryland by County." Miscellaneous Publication No. 52. University of Maryland Agricultural Experiment Station, College Park, Maryland, 1946.

$3,651,659., or an average of $2,779. per farm. Tobacco led all farm crops, being the third ranking County in the State of Maryland, and other agricultural products were relatively insignificant, showing sweet potatoes, rye, and cabbage, 10th, 11th, and 12th in the production of the State, respectively. From this land pattern is seen that with 65 percent of the land in forest, and 5 to 10 percent in marsh land, together with land in farms of 59.5 percent, that much of the surface area of Charles County is highly suitable for wildlife crop production. A decrease of 3.8 percent of the land in farms from the period 1940 to 1945 has taken place, and agricultural authorities believe this trend will be even greater. It is estimated by the Department of Forests and Parks that 193,000 acres of land is in forest, which gives Charles County a rank of third place in the State for forest cover. There is a definite trend in tobacco production of intensifying land-use through the addition of fertilizers, which tends to increase the amount of sub-marginal agricultural land for wildlife by using the better soil types with improved agricultural methods.

CLIMATIC PATTERNS

Accurate weather records for Charles County show important implications on wildlife. Charles County, with a relatively long growing season, is affected by the water courses of the Potomac River and other tidal and non-tidal waters. These water courses provide habitat, nesting conditions, and environment conducive to the native fauna of the area. The county is located within the average annual snowfall zone of between 15 and 20 inches. To the wildlife technician, this has at least two major management implications: (1) that the bobwhite quail range is well-suited to this environment; and (2), on the other hand, despite a high trapping of muskrat, the short winter season does not bring the high fur prices which colder regions secure. Lack of severe and prolonged ice conditions on the marshes and uplands has an effect which is more favorable to wildlife than in some of the colder climates of our State. The average annual temperature for Charles County is 54°F, which is favorable to the majority of wildlife species native to this region. However, it is believed that the high temperatures have pathological effects, which set up barriers to the wild turkey, ruffed grouse, and a number of species of waterfowl. This average annual temperature is conducive to tidal and non-tidal fisheries, and excluding the decimating factors of human society, both fresh and salt water forms do exceedingly well within this county. The average annual precipitation of 40 inches in the western part of the county and increasing to 46 inches on the eastern side, provides sufficient rainfall, not only for good land crops, but fish, bird, and mammal life also are benefited. The abundant rainfall is fairly well distributed over the entire county, and only in unusual years does it take an excess toll of ground nesting birds and aquatic mammals. The average annual number of days of rainfall with 0.01 inches ranges from 100 days in southern Charles County to 110 days on the eastern and nothern borders.

FOREST WILDLIFE RELATIONSHIPS

The change in forest cover type in Charles County over the past three centuries has had important effects on the wildlife of this region. All of the virgin stands have been cut, and present forests are the result of many logging operations, which have changed ecological relationships of the animals that inhabited this region. Charles County is unique in that the tobacco crop has required virgin forest soil for seed beds, which has necessitated frequent cutting of forests to provide these small plots scattered over the County. The preparation of these forest plots has been of great assistance to species such as bobwhite quail, woodcock, mourning dove, cottontail rabbits, and other upland game species. The continual harvest of forest lands has, however, had disastrous effects on wilderness game, such as the wild turkey, ruffed grouse, otter, beaver, and the like. There were more deer in Charles County in the nineteenth than in the eighteen century due primarily to the fact that clearings were made in the forest as a result of agricultural practices, which encouraged sprout growth and other preferred shrubs and grasses. The present practices in forest management of selective cutting and development of multiple-use programs for recreation, timber production, and wildlife have been effected through a demand from the general public and cooperative agreements with the State Forester and Game Director.

MARSH WILDLIFE RELATIONSHIPS

The uninventoried salt and fresh water marshes of Charles County have, and will continue to have, a high potential breeding capacity for fur bearers and waterfowl. With the cutting of the wilderness and the development of intensive farming practices, erosion has filled many of the marshes and streams, not only reducing the habitat for aquatic animal and plant life, but reducing water transportation as well. The beaver and otter, dependent on extensive marsh and swamp lands, are practically extinct in this region. The muskrat, with a high breeding potential, has been faithful to human society despite the heavy inroads, heavy trapping pressures, misuse of the land, and ignoring the importance of this crop as a definite part of the farm economy.

SWAMP WILDLIFE RELATIONSHIPS

The extensive swamps, with their flat, broad river bottoms, are an important factor in the preservation of wildlife within Charles County. Fluctuations in raccoon populations brought about through biological or economic conditions have been at a minimum in Charles County even when other areas of the State have been depleted of raccoon populations, due to Zekiah Swamp, and the White Plains region of the Mattawoman Creek. These extensive swamps of southern river bottom trees, shrubs, and vines have provided an almost impenetrable wilderness for the protection of the otter, woodcock, wood duck, raccoon, and other animal life that depends on this type of habitat. Wildlife biologists may well review the ecological conditions of this type of land pattern for application to other regions since it plays, and has played, so important a part in maintaining annual wildlife crops.

PRESENT WILDLIFE POPULATIONS

Heretofore, wildlife as an agricultural crop has never been considered important to the farmer or land manager, other than incidental to recreation. Even the important fisheries, such as the oyster, crab, and fin fish, have been exploited as a wild crop available to the individual who chose to take it. The State has been charged with the ownership of wildlife and its protection within the jurisdiction of the Commonwealth. Land ownership in Charles County, and in Maryland, is vested in the individual, with the State's power lying only within the province of protective ownership of the game. The property owner upon whose land the wildlife resides, subject only to the State regulations, can harvest this game on his own land, making it difficult to control wildlife which by its nature is volatile. Not until recent years, with the rapid decline in wildlife populations, has any effort been made to inventory, manage, and restore our wildlife crop. With the stepping up of intensive land-use, wildlife management has come into its own. We have passed the period, with the exception of fur and fishery resources, where wildlife is considered an industry, and have entered into the new era of recreational development.

WATERFOWL

With the rapid and steady decline in waterfowl populations throughout the United States, regulation of this interstate resource has gradually been turned over to the Federal Government. Charles County, situated on the Atlantic flyway, receives large flights of waterfowl from the feeding grounds on the famous Susquehanna flats. Present surveys indicate that, despite the rapid decline in surface and diving ducks of the Atlantic flyway, Maryland, and Charles County in particular, have had above average flights. An unestimated large brood of local black ducks and summer ducks nest within the County, providing good hunting to this and adjoining areas. The major species found within this County flyway are the pintail, baldpate, black duck, and blue winged-teal, which are early arrivals in this section, followed by the ruddy duck, scaup, canvasback, redhead, and the mergansers. Freezes in the middle and late winter months send the majority of waterfowl farther south, but leading the return flight to the breeding grounds in the early spring is the pintail, followed by the mallard, geese, and diving ducks.

SHORE BIRDS

The shore birds, so intensively hunted in the past, have been for the most part on the protected list, and most species are now not legal game. Rapid recovery of the terns, plovers, and other species has been noted in recent years.

MARSH BIRDS

Nationally famous has been the railbird shooting on the Patuxent River marshes, only a small part of which border on Charles County. The decline of the sora, Virginia, and king rails, and to a lesser degree the clapper rail of the salt marshes, required severe restriction by Federal and State laws. Conditions which have brought about these regulations are outside the province of Charles County and will not be discussed.

PREDACIOUS BIRDS

The hawks, owls, buzzards, and eagles for the most part have been unwantonly hunted by man because of their destructive nature as it bears on the competitive interests of man. Considerable research in stomach analysis of these birds has revealed beneficial habits of many hawks and owls heretofore believed very destructive to economic forms. Only recently has the national bird, the bald eagle been placed on the protected list, and its increase in numbers, particularly in the tidal waters, has been noted. A general demand for protection of beneficial species within this group of birds is being made by sportsmen and conservationists.

SONG BIRDS

This is the largest of the bird groups, and many species are found in Charles County, nearly all of which are protected by State laws. Charles County, within the transition zone, between northern and southern avifauna, provides an excellent "birding county" for those with camera and binoculars. A twenty-year survey of bird populations during the Christmas season of each year has been made of the Port Tobacco region by Federal and State employees, and is expected to be published in the near future. Other county-wide studies of bird life are now being carried out, the results of which are not yet available.

Population estimates made for Southern Maryland, during the month of December, 1947, including Charles, St. Marys, Calvert, and Prince Georges Counties, indicate there are approximately 30 deer; 62,000 rabbits; 30,000 gray squirrels; no grouse; no pheasants; no wild turkeys; 5,600 quails; 2,500 mourning doves; 500 woodcocks; 12,000 red and gray foxes; 6,000 skunks; 12,000 weasels; 2,000 hawks; 15,000 raccoons; 10,000 opossums. A breeding bird census of this region during the period June, 1947, has been estimated by wildlife technicians and authorities from the Patuxent Wildlife Research Center and indicates approximately 2,500 quails; 31,000 doves; 2,000 woodcocks; and 3.040 hawks.

Charles County estimates have been made by the Regional State Game Warden, with assistance of local wildlife interests, and show the following populations for the period December, 1947: 8 deer; 13,000 rabbits; 10,000 gray squirrels; 15,000 bobwhite quails; 1,500 mourning doves; 500 woodcocks; 1,200 red and gray foxes; 200 skunks; 300 weasels; 1,000 hawks; and 2,000 raccoons.

DECIMATING FACTORS

Reviewing the development and trends of Charles County, we find that several major factors play an important part in the variation in wildlife crops. The following are factors of importance: (1) competition for living space by man and wildlife; (2) changing agricultural land patterns; (3) development of highways since 1920; (4) improvement in ammunition and fire arms; (5) continual forest and marsh fire destruction; (6) drainage of swamps and marshes; (7) pollution, both chemical, physical, and biological, which includes the important factor of siltation through land erosion; (8) urban development; and (9) acquisition and development of lands by the Federal Government.

THE CLIMATE OF CHARLES COUNTY

PREPARED UNDER THE DIRECTION OF

G. N. BRANCATO

The state of the atmosphere at a particular time and place is expressed in terms of temperature, precipitation, state of the sky, wind direction and velocity, humidity, fog, frost, etc. These elements go to make up what is called 'weather'. Weather varies from day to day and throughout the various hours of the day because of the changes in one or more of the values used to express weather. When we obtain a generalization of the day to day weather conditions, we have values which make up 'climate'. A sharp line of distinction cannot be drawn between climate and weather. It is difficult to say where one leaves off and the other begins. A satisfactory and adequate description of both is difficult.

Charles County, as does all of Maryland and practically all of the United States, lies in what is known as the "belt of the prevailing westerlies." That is, the prevailing direction of the wind is from some westerly direction. Therefore, most of the weather experienced in this area would come from some westerly direction, borne along by the prevailing direction of the wind.

Cold air masses reach Charles County from two primary directions. Those moving directly southward from eastern Canada produce the lowest temperatures because they have had a more direct journey from the Arctic source region. Those moving from central Canada into the Midwest and then eastward moderate considerably before reaching the Maryland area. During the summertime, these cold air masses bring practically all the cool periods which provide relief from the hot, sultry conditions which frequently prevail in this section. Another type of cool air mass reaches Maryland after a long journey over the Pacific Ocean, the high western mountains of the United States, and the central and eastern portions of the country. This type generally brings cool and dry weather to Charles County.

Warm masses of air have their origin over the Gulf of Mexico, off the south Atlantic Coast, and over the desert and plateau sections of northern Mexico and southwestern United States. The over-water warm air masses are moist and are good producers of precipitation, whereas those originating in the desert and plateau regions are dry and produce very little, if any, precipitation. The occurrence of this latter type is rather infrequent in Charles County. The action between cold and warm air masses, and within the air masses themselves, produces the weather of a locality.

The large scale air masses are subject to modifications imposed by the geographical features of the area. The character of the soil, the configuration of the land, elevation, soil covering, presence of large bodies of water, presence of mountain barriers, latitude, and prevailing direction of the wind all exert influences which enter into the composite picture of weather and climate.

Soil is an aggregation of small particles of matter, separated from each other by particles of air or water. The heat capacity and the ability of air to conduct heat are much smaller than in the case of the particles which make up the soil. If the air is replaced by water, the heat capacity and conductivity of the soil are increased. Therefore, during the daylight hours, coarse soils, such as a sandy one with a high percentage of air, do not conduct the heat received into the ground to a high degree. Instead, the surface layers become very warm which heats the air layers in contact. At night there is little heat stored in the ground and temperatures quickly drop to low levels. Fine soils, such as clay and loam, have a higher heat capacity, are able to store heat better when the sun is shining, and thus have a supply of heat to help offset the heat losses by radiation at night. Other conditions being equal, this type of soil will be less likely to have frost. Air over fine soils has a lower daily range in temperature than air over a coarse soil. Charles County soil is a sandy loam, with an increased loam content in the southern and western portions. Northward and eastward from the Potomac River, the increasing sandiness of the soil produces a tendency toward warmer daytime temperatures and lower nighttime temperatures.

The configuration of the land affects the formation of fog and frost. During a clear night, the ground loses heat by radiation at varying rates, cooling the air in contact with it. If the wind is so light that the air near the ground is not mixed with air a hundred or more feet above the ground, the air near the ground becomes heavier and begins to flow to lower levels, in much the same manner that a stream of water would. The colder air tends to pool in lower levels. The greater the slope and depth of the depression, the greater will be the lowering of nighttime temperatures. The countryside of Charles County is slightly rolling. The southern and western portions are indented by many small estuaries of the Potomac River. But there are no deep valleys or steep slopes. Therefore, the pooling of cold air on clear, calm nights would not be too pronounced.

Temperatures, on an average, decrease about 3°F. for each 1000 feet of increase of elevation. With the elevation of Charles County varying from a little above sea-level near the Potomac River to about 245 feet in the northeastern and eastern portions of the County, this effect is negligible.

More intense radiation from a snow cover at night and absorption of the heat of the sun by day in melting snow tends to lower the temperature of the air near the snow layer. However, a snow cover prevents radiation of heat from the earth and the penetration of frost into the ground, thereby protecting winter grains and other vegetation.

Other conditions being equal, temperatures decrease slowly with change of latitude from south to north. Charles County is a relatively small area and this effect is negligible.

When the land is warmed by sunshine and cooled by radiation at night, the changes in the temperature of the land are limited to a relatively shallow layer of ground. When the surface of the water area is heated by solar radiation, the additional heat is distributed by the agitation of the water through a much thicker layer than when the ground is heated. Thus, the temperature of the surface of the water will remain cool during the day and the air in contact with the water surface will be cooler than air in contact with nearby land areas. During the night, the temperature of the air above the land cools faster than the air above the water and eventually becomes colder than the latter which has a more constant source of heat. Thus, the air over water becomes a little warmer than air over land by night, while the opposite usually occurs during the day. As air moves from water surfaces to land surfaces, it tends to decrease the daily, or diurnal, variation in temperature. The Potomac River in the vicinity of Charles County is not sufficiently large to produce this effect to a marked degree except over a narrow strip near the river. An illustration of this can be noted in that the average diurnal variation of temperature in July at La Plata is 21.6°F. and at Dahlgren, 17.5°F.

Proximity to large water surfaces, such as the Atlantic Ocean, tends to increase the humidity of the atmosphere, provides a greater tendency toward rainfall, and does its share toward giving humid summertime conditions.

Air which is forced to rise over mountain barriers as it flows with the general circulation of the atmosphere is cooled by expansion as the air pressure decreases. The amount of cooling is dependent upon the change of elevation of the air. Frequently, this cooling is such that the supply of moisture cannot be contained and some is dropped out as rain or snow. When the direction of the winds is predominantly west or northwest, air reaching Charles County has crossed the relatively low Appalachian Mountains. However, the mountains are sufficiently high to take some moisture from the air and the heat of condensation is added to the air. After crossing the mountains, the air sinks slowly to lower levels. The compression provides a warming effect. The removal of moisture and the added heat of compression reduce the amount of cloudiness on the leeward side of the mountains. Since clouds reflect back to space varying amounts of the sun's heat received on the top of the clouds, a decrease in cloudiness will allow more heat to reach the ground layers. The net effect of the Appalachian Mountains in the colder months is more sunshine, slightly higher temerpatures, and a little less precipitation. During the warmer months, much of the moisture comes from the Atlantic Ocean as the result of a higher percentage of southerly winds, and the effect of the Appalachian Mountains is proportionately decreased.

The climate and weather depend, to a large extent, on characteristics assumed by air before it reaches Charles County. Thus, air from surrounding sections flows over Charles County in proportion to the prevailing direction of the wind.

While the general trends of climate and weather are set up by the extensive masses of cold and warm air which flow over the country, the small variations which can be observed over a relatively limited area, such as Charles County, are due to local conditions.

WEATHER OBSERVATIONS

Sporadic and unorganized weather observations have been entered in the journals of many of the early settlers of Charles County. Near the end of the 19th Century, the United States Weather Bureau began the establishment of cooperative weather stations in Charles County for the purpose of collecting systematic reports which would serve in a comparison with reports from other localities. Only the LaPlata station has been in operation in this southern Maryland county for a sufficient period of time to give a reasonably reliable picture of climatic conditions. Several other stations have been established but have been abandoned after very short periods of time, and the records have not been included in this summarization. Data from Charlotte Hall, in the western portion of St. Marys County, have been included as representative of the eastern portion of Charles County; from Cheltenham, in southern Prince Georges County, as representative of northern Charles County;

TABLE XXIII

List of Weather Reporting Stations

1. LaPlata, Maryland	
July 1894–December 1895	J. Samuel Turner
March 1910–May 1911	R. H. Lee Reich
January 1920–March 1926	John P. Burdette
April 1926–May 1926	J. J. Jones
December 1930–May 1940	Walter M. Page
September 1941–	Wallace S. Barnes
2. Charlotte Hall, Maryland	
January–April, 1892	R. W. Sylvester
June–August 1893	George M. Thomas
October 1893–May 1904	Prof. J. Francis Coad
September 1905–February 1906	J. Neilson Barry
August 1936–February 1938	Prof. B. F. Crowson
June 1938–March 1944	A. D. V. Burr
April 1944–	J. Burch Tennyson
3. Cheltenham, Maryland	
May 1901–	U. S. Coast and Geodetic Survey
4. Quantico, Virginia*	
1896–	U. S. Marine Corps
5. Dahlgren, Virginia*	
1920–1923	Naval Proving Grounds
1923–	Edward B. Scott

* Some short breaks in record.

from Quantico and Dahlgren, Virginia, as representative of the western and southern portions, respectively, of the County. In addition, certain information on temperature, humidity and winds from the records at Washington, D. C., but not available from any closer point, has been included.

The periods of observation by the various stations and observers have been listed in Table XXIII. The climatological records of the U. S. Weather Bureau, to a large extent, have resulted from the interest and civic pride of these volunteer observers.

Temperatures are recorded on instruments enclosed in a louvered housing. However, the readings thus obtained are in the shade and are not in themselves indicative of the effect of temperatures on human behavior and activities. Whether or not the sun is shining, the degree of saturation of the air, and the velocity of the wind,

TABLE XXIV
Temperatures

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
La Plata, Maryland													
Mean Maximum	45.8	47.7	58.0	66.5	76.0	83.8	87.2	85.6	80.7	69.8	58.4	47.6	67.3
Mean Minimum	26.5	27.1	34.6	42.0	51.8	61.6	65.6	63.9	59.1	45.6	36.4	28.3	45.2
Mean	36.2	37.4	46.3	54.2	63.9	72.7	76.4	74.8	69.9	57.7	47.4	38.0	56.2
Highest of Record	79	85	89	94	98	100	108	104	100	97	85	74	108
Date of Highest	17, '43	25, '30	30, '10	6, '42	23, '25	5, '25	20, '30	9, '30	1, '30	5, '41	2, '29	18, '37	7/20/30
Lowest of Record	−12	−8	2	15	28	38	48	42	35	23	6	−4	−12
Date of Lowest	14, '12	9, '34	1, '34	1, '23	2, '43	1, '38	2,'43	31, '34	30, '42	28, '36	29, '30	21, '42	1/14/12
Avg. No. Days 90° or higher				*	1	7	12	9	4	*			33
Avg. No. Days 32° or lower	24	21	18	4	*	—	—	—	—	3	11	22	103
Charlotte Hall, Maryland													
Mean Maximum	43.6	45.2	56.4	65.9	76.9	84.1	86.9	85.7	81.0	69.0	57.9	50.1	66.9
Mean Minimum	25.4	25.4	34.5	42.4	53.7	62.1	66.0	64.3	58.1	46.6	36.2	27.8	45.2
Mean	34.5	35.3	45.4	54.2	65.3	73.1	76.4	75.0	69.6	57.8	47.0	39.0	56.0
Highest of Record	76	75	88	97	96	100	102	102	100	95	79	72	102
Date of Highest	17, '43	22, '99	17, '45	19, '96	2, '45	20, '93	3, '98	11, '00	7, '00	5, '41	18, '38	28, '46	7/3/98
Lowest of Record	−1	−19	11	23	34	41	42	47	34	23	13	−4	−19
Date of Lowest	22, '99	11, '99	18, '00	13, '40	2, '45	1, '94	17, '03	26, '42	30, '42	29, '95	15, '05	21, '42	2/11/99
Avg. No. Days 90° or higher				1	3	7	10	8	5	1			35
Avg. No. Days 32° or lower	24	22	14	4	*	—	—	—	—	2	12	21	99
Cheltenham, Maryland													
Mean Maximum	43.8	45.1	56.2	65.5	75.5	82.4	86.4	84.3	79.3	68.6	56.5	45.1	65.7
Mean Minimum	25.3	25.3	33.7	41.8	51.9	60.6	65.2	63.5	57.6	45.4	35.6	27.0	44.4
Mean	34.6	35.2	45.0	53.6	63.7	71.5	75.8	73.9	68.4	57.0	46.0	36.0	55.0
Highest of Record	79	78	91	95	97	101	106	105	100	96	83	76	106
Date of Highest	14, '32	11, '32	23, '07	26, '15	28, '41	29, '34	20, '30	7, '18	1, '30	5, '41	2, '29	19, '24	7/20/30
Lowest of Record	−16	−8	4	12	29	36	47	43	34	20	5	−7	−16
Date of Lowest	14, '12	9, '34	1, '34	1, '23	11, '13	1, '30	4, '33	31, '34	26, '40	28, '36	29, '30	30, '17	1/14/12
Avg. No. Days 90° or higher				*	*	6	10	6	3	*			26
Avg. No. Days 32° or lower	24	22	16	5	—	—	—	—	—	3	13	23	106

Quantico, Virginia													
Mean Maximum	44.3	45.4	56.3	66.2	76.3	83.2	87.3	84.6	79.2	68.6	56.3	45.7	66.1
Mean Minimum	25.4	25.6	34.3	42.2	52.5	62.0	66.7	64.5	58.4	46.4	35.7	27.2	45.1
Mean	34.8	35.5	45.3	54.2	64.4	72.6	77.0	74.6	68.8	57.5	46.0	36.4	55.6
Highest of Record	78	85	92	96	98	104	107	102	101	97	82+	76	107
Date of Highest	15, '32	25, '30	21, '21	7, '29	28, '41	19, '44	1, '17	5, '44	8, '39	5–7, '41	18, '21	19, '24	7/1/17
Lowest of Record	−16	−20	8	16	28	37	40	38	35	24	7	−2	−20
Date of Lowest	14, '12	11, '99	4, '43	1, '23	11, '06	1, '30	29, '00	4, '00	23, '13	22, '13	27, '30	27, '14	2/11/99
Avg. No. Days 90° or higher													
Avg. No. Days 32° or lower													
Dahlgren, Virginia													
Mean Maximum	44.2	46.1	55.5	64.3	73.9	82.0	85.7	83.8	78.8	68.0	56.8	46.6	65.5
Mean Minimum	28.6	29.2	36.6	44.9	54.7	64.3	68.2	66.8	61.5	48.8	39.4	31.2	47.8
Mean	36.4	37.6	46.0	54.6	64.3	73.2	77.0	75.3	70.2	58.4	48.1	38.9	56.6
Highest of Record	79	86	89	94	97	100	106	102	99	97	84	76	106
Date of Highest	17, '43	25, '30	21, '21	11, '30	23, '25	21, '34	20–1, '30	4, '30	9, '39	6, '41	2, '29	19, '24	7/20–1/30
Lowest of Record	3	−3	13	21	34	42	50	49	39	26	6	5	−3
Date of Lowest	28, '35	9, '34	3, '25	1, '23	2, '45	1, '30	5, '27	30, '27	24, '28	28, '26	29, '30	26, '35	2/9/34
Avg. No. Days 90° or higher													
Avg. No. Days 32° or lower													

* Less than 0.5 day.

are factors which have effects to be considered. A heavy layer of clouds overhead during the day has the capacity to reflect back to space well over half the solar heat which would otherwise be received. During the night, the cloud layer serves as a blanket to prevent the escape of heat from the air near the ground, in many cases eliminating the formation of frost. The rate of evaporation of perspiration from the body is inversely proportional to the degree of saturation of the air, and is directly proportional to the velocity of the wind. These are prime factors in the comfort of the human body.

Based on detailed data for Washington, D. C., in January the lowest temperature occurs about 6:30 a.m. and the highest about 3:00 p.m. daily. In July, the lowest

TABLE XXV

Growing Season

	LaPlata, Md.	Charlotte Hall	Cheltenham	Quantico, Va.	Dahlgren, Va.
Killing Frosts					
Average dates of:					
Latest date of last in Spring..	May 6	May 2	May 12	May 17	April 20
Average date of last in Spring.	April 16	April 14	April 18	April 12	April 1
Earliest date of last in Spring.	March 18	March 30	March 22	March 11	March 12
Earliest date of first in Autumn..................	October 7	October 1	October 7	October 2	October 14
Average date of first in Autumn..................	October 22	October 23	October 20	October 31	November 8
Latest date of first in Autumn	November 10	November 13	November 13	November 23	November 30
Growing Season					
Longest.......................	237	213	221	241	266
Shortest.......................	165	173	163	153	190
Average.......................	189	192	185	201	221

reading occurs about 5:30 a.m. and the highest again about 3:00 p.m. Cloudiness tends to decrease the daily variation in temperature by reflecting back to space some of the daytime heat and by preventing the escape of heat by nighttime radiation. This factor diminishes the change in temperature from night to day in direct proportion to the thickness of the clouds.

Generally, relative humidity varies inversely with temperature; that is, on an average, when temperatures are high, relative humidity is low, and vice versa. Thus, high values of humidity normally occur during the early morning hours when temperatures are low, and low values of humidity normally occur when temperatures are high in mid-afternoon. In January, the highest average relative humidity, 74%, occurs at 8:00 a.m., and the lowest, 54%, at 3:30 p.m. In July, relative humidity reaches its highest value, 86%, at 5:30 a.m., and its lowest, 52%, at 3:00 p.m.

To be entirely comparable, data from two or more stations should cover the same period of time. Some of the differences in average temperatures of Table XXIV can be ascribed to a lack of conformity in this regard. In the case of extreme temperatures, the value of a long, continuous record can be readily noted. One of the coldest January periods of the last fifty years was the morning of the 14th in 1912. The Charlotte Hall and Dahlgren stations were not functioning at that time. Thus, the January lowest for those stations are not comparable with those of the other stations. The coldest period in the memory of the oldest citizen of Charles County was February 10 and 11, 1899, when the mercury dipped to 19 and 20 degrees below zero at Charlotte Hall and Quantico, respectively. But the LaPlata, Cheltenham and Dahlgren stations, with shorter records, do not show this extremely cold period. Table XXIV gives the averages of highest, lowest, and mean temperatures, the highest and lowest temperatures of record with dates, and the average number of days when temperatures climbed to 90 degrees or higher, or fell to 32 degrees F. or lower.

GROWING SEASON

The interval between the last killing frost of Spring and the first killing frost of Fall is called the "growing season." It is generally considered to be a safe period for growing vegetation. However, the length of this period in Charles County has been rather variable. Table XXV gives a summary of the record which is of great importance to the horticulturist. The effect of the proximity of Quantico and Dahlgren to the moderating influence of the Potomac River is indicated in a longer growing season. The average period at Dahlgren is 32 days longer than at LaPlata.

PRECIPITATION

During the warmer months of the year, generally from April through September, most rainfall results from showery and thunderstorm conditions. During the sunny daylight hours, the ground becomes heated. The air near the ground becomes warmed to the extent that it becomes relatively lighter than the air above it. In such a state, the lighter air begins to rise, forming convective currents of air. As these currents rise, they cool about 5.5 degrees F. for each 1000 feet, if unsaturated. Soon the temperature has lowered to the extent that the air has become saturated and condensation in the form of clouds begins. The general circulation of the air near the earth's surface is frequently such as to produce converging streams of air over relatively large areas. This convergence, together with the process described above, forces the vertical currents of air to higher and higher, and, consequently colder and colder levels, thus forming the typical thunderstorm clouds. The action within the thunderstorm cloud causes different charges of electricity to build up in different parts of the cloud. The difference in potential between two portions of a cloud, between one cloud and another, or between a cloud and the ground becomes so great that a discharge of electricity takes place. The visible portion of this discharge is the lightning flash and, whether forked or sheet lightning, it is basically the same. The explosive violence of the air, produced by the intense heat of the discharge, generates sound waves which travel out in all directions and which are heard as thunder.

The undercutting of warm, humid air by an advancing cold air mass forces the warm air to rise, producing lines of thunderstorms or "squalls" as they are frequently called. Cold front thunderstorms are more likely to produce general showers in Charles County than those which are heat produced.

TABLE XXVI
Precipitation

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
La Plata, Maryland													
Greatest Precipitation	10.48	6.73	7.24	8.67	8.39	7.95	14.05	13.60	14.41	9.34	5.81	6.30	61.73
Average Precipitation	3.75	2.97	3.39	4.01	3.62	4.36	4.74	4.63	3.71	3.12	2.76	2.83	43.89
Least Precipitation	0.84	0.66	0.89	0.65	0.50	1.20	0.85	0.27	0.52	0.58	0.52	0.35	22.41
Greatest 24-hr. Precipitation	2.66	2.20	2.03	3.12	2.14	3.50	3.34	5.48	5.92	3.70	3.40	2.11	5.92
Avg. No. Days 0.01 or more	9	9	10	11	11	10	10	10	8	7	8	9	112
Avg. Snowfall	5.7	5.1	2.4	0.2	—	—	—	—	—	0.1	0.6	3.2	17.3
Greatest 24-hr. snowfall	20.0	16.3	7.0	2.5	—	—	—	—	—	2.0	6.5	10.0	20.0
Avg. No. Days 0.1 or more snowfall	2	3	1	*	—	—	—	—	—	*	*	2	9
Avg. No. Days Thunderstorms	*	1	2	2	5	7	8	5	3	1	*	*	34
Charlotte Hall, Maryland													
Greatest Precipitation	10.15	5.75	6.30	7.08	7.98	6.20	15.72	6.69	6.73	7.43	5.05	5.78	56.68
Average Precipitation	3.24	3.21	3.31	3.68	3.36	3.60	5.36	3.45	2.92	3.31	2.31	2.88	40.63
Least Precipitation	1.75	1.10	0.91	0.72	0.60	0.51	2.59	0.58	0.21	0.50	0.44	0.34	26.28
Greatest 24-hr. Precipitation	2.12	3.00	2.04	3.67	1.93	2.70	3.36	4.55	2.40	3.95	4.28	2.60	4.55
Avg. No. Days 0.01 or more	9	8	10	9	10	9	11	8	6	7	6	7	
Avg. Snowfall	5.2	5.5	2.0	0.1	0	0	0	0	0	0.1	0.6	2.5	16.0
Greatest 24-hr. snowfall	19.0	30.0	7.0	2.0	—	—	—	—	—	1.0	4.2	6.0	30.0
Avg. No. Days 0.1 or more snowfall	2	2	1	*	—	—	—	—	*	*	*	1	7
Avg. No. Days Thunderstorms	*	1	1	1	4	5	5	3	1	1	*	*	22
Cheltenham, Maryland													
Greatest Precipitation	9.52	4.95	8.43	10.10	7.64	8.81	11.57	18.68	13.16	8.68	5.91	6.38	58.50
Average Precipitation	3.69	2.81	3.72	3.99	3.60	4.05	4.57	4.84	3.56	3.04	2.66	3.20	43.73
Least Precipitation	1.08	0.63	1.14	0.56	0.36	0.52	0.78	0.68	0.55	0.35	0.61	0.92	22.58
Greatest 24-hr. Precipitation	2.57	2.00	2.30	3.85	2.91	4.10	4.02	11.66	5.85	3.70	3.17	2.29	11.66
Avg. No. Days 0.01 or more	10	10	11	11	11	11	11	11	8	8	8	10	120
Avg. Snowfall	6.2	4.9	3.6	0.6	—	—	—	—	—	0.1	0.4	3.5	19.3
Greatest 24-hr. snowfall	24.0	14.0	14.0	6.0	—	—	—	—	—	3.0	6.0	9.5	24.0
Avg. No. Days 0.1 or more snowfall	3	3	2	*	—	—	—	—	—	*	*	2	11
Avg. No. Days Thunderstorms	*	*	1	2	3	4	5	3	2	1	*	*	22

Quantico, Virginia													
Greatest Precipitation	7.89	5.76	6.81	7.41	8.45	6.55	10.88	15.27	10.45	8.73	5.73	6.35	49.52
Average Precipitation	3.13	2.46	3.05	3.17	3.20	3.62	4.29	4.58	3.15	2.84	2.23	2.67	38.39
Least Precipitation	0.65	0.38	0.41	0.40	0.47	0.70	0.73	0.19	0.21	0.23	T	0.79	18.86
Greatest 24-hr. Precipitation	2.78	3.00	4.20	3.50	4.97	3.60	3.90	7.70	4.66	3.42	1.88	2.49	7.70
Avg. No. Days 0.01 or more	9	8	9	8	10	10	9	9	7	6	7	8	100
Avg. Snowfall	4.9	4.1	1.7	0.2	0.0	0.0	0.0	0.0	0.0	T	0.4	3.0	14.3
Greatest 24-hr. Snowfall													
Avg. No. Days 0.1 or more Snowfall													
Avg. No. Days Thunderstorms													
Dahlgren, Virginia													
Greatest Precipitation	8.78	6.34	6.70	6.11	6.80	6.04	15.51	14.97	13.22	7.90	5.89	5.18	48.93
Average Precipitation	3.13	2.61	3.06	3.35	3.06	3.41	4.80	4.45	3.36	2.53	2.25	2.53	38.54
Least Precipitation	0.79	0.59	0.79	0.67	0.59	1.91	0.89	0.18	0.04	0.55	0.43	0.69	20.47
Greatest 24-hr. Precipitation	2.13	1.73	2.12	2.23	1.95	2.70	5.22	5.47	6.47	2.74	2.93	2.33	6.47
Avg. No. Days 0.01 or more	10	10	10	10	11	10	11	10	8	8	8	10	116
Avg. Snowfall	4.3	3.7	0.9	0.2	0.0	0.0	0.0	0.0	0.0	T	0.4	2.0	11.5
Avg. No. Days 0.1 or more Snowfall													
Avg. No. Days Thunderstorms													

* Less than 0.5 day.

As temperatures and moisture are usually highest in July and August, the highest average and greatest extremes of monthly precipitation occur in those months.

Most of the precipitation of the colder months of the year, whether rain or snow, results from atmospheric lifting of a different nature. From October through March, most precipitation falls more gently and more continuously. Usually, relatively cold air overlays the area. Warm moist streams of air, having their origin over the Gulf of Mexico or the south Atlantic Ocean, encounter these colder

TABLE XXVII

State of the Sky

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
LaPlata, Maryland													
Average No. Days													
Clear	12	11	13	13	14	14	16	15	15	17	13	11	164
Partly Cloudy	7	7	8	8	10	10	9	9	8	7	7	8	98
Cloudy	12	10	10	9	7	6	6	7	7	7	10	12	103
Charlotte Hall, Md.													
Average No. Days													
Clear	12	13	14	14	14	14	15	17	17	17	15	14	176
Partly Cloudy	8	7	9	9	11	11	12	10	8	7	6	7	105
Cloudy	11	8	8	7	6	5	4	4	5	7	9	10	84
Cheltenham, Md.													
Average No. Days													
Clear	11	12	13	13	14	13	14	14	15	16	13	11	159
Partly Cloudy	7	6	8	8	9	10	11	10	8	7	8	8	100
Cloudy	13	10	10	9	8	7	6	7	7	8	9	12	106

and heavier masses of air to the north and are forced, by their relative lightness, to flow over the colder air. The lifting action ordinarily is gentle but over a large area, producing an extensive area of precipitation. This type of rain or snow is usually associated with an area of low barometric pressure as it moves over or near the region.

From September through November, the lower layers of atmosphere are heated less and less as the days become shorter and the total amount of sunshine decreases. The movement of areas of low barometer over or near Charles County during this season are relatively infrequent. With the decreased activity of the two main rain producing methods, amounts of precipitation gradually fall and November becomes the month of lowest average precipitation.

A hurricane, or what remains of a once vicious tropical storm, very infrequently brings a torrential rain to Charles County during the August to October period.

After November, areas of low barometer become more active over the eastern portion of the country and there is a corresponding increase in the average amounts of precipitation. Statistical information on the rain and snow in and around Charles County is contained in Table XXVI. The statistics show little variation in the various phases tabulated.

Probably the heaviest snowfall to reach Charles County in the last fifty years followed the most intense cold period of February 10–11, 1899. The Charlotte Hall station reported a fall of 30 inches on the 12–13th. Reports from nearby points indicate the generalness of the snow. On January 8, 1940, a snowstorm produced from 20 to 24 inches, while 15 to 18-inch snowfalls occurred on January 27–29, 1922, and on February 7, 1936.

FOGS

In a broad sense, a fog is a cloud at ground-level. Fogs are formed usually by the temperature of the air lowering to the condensation point, or, less frequently, by the addition of water vapor to the air. Most often, it is a combination of the two, with the addition of the water vapor being the minor factor.

Radiation, or ground, fogs form on clear nights when the winds are light or calm. As discussed under the effect of the configuration of the land above, the cold air pools in low places and tends to become colder by continued radiation. If the condensation point of the air is reasonably close to the temperature of the air during the evening, the temperature will lower quickly to the condensation point, forming shallow fog layers, which slowly build up from the ground as the night progresses.

When warm, moist air flows over cold or snow covered ground, the temperature of the air is quickly reduced to the dew point and condensation occurs. Fog produced in this manner is frequently referred to as advection fog. In both types of fog, the air near the ground is relatively heavier than the air above and there is no upward dispersion of the fog particles. Fogs in Charles County are infrequent. Detailed data for Washington, D. C., indicate that heavy fog occurs on about 10 days of each year. The greatest frequency is during the colder months when nighttime cooling is longest and the ground is more likely to be cold.

SUNSHINE AND CLOUDINESS

Sunshine data are based on Washington, D. C., records. These records indicate about 58% of the possible amount for the year. Ordinarily, the sun shines on Charles County over 60% of the possible time from May through October, with 63% in June and July being the highest. December and January are very low, comparatively, having only 46% of the possible amount. Table XXVII gives the average number of clear, partly cloudy, and cloudy days, monthly and annually, for LaPlata, Charlotte Hall, and Cheltenham. The variation between stations is very little. The largest number of clear days occurs during the summer months and the largest number of cloudy days occurs during the winter months.

WINDS

Washington, D. C., data indicate that the prevailing direction of the wind for Charles County is from the northwest and the velocity averages 7 miles per hour. From June through September, however, the prevailing direction is southerly at 6 miles per hour. The highest velocities occur for very short intervals during the gusts associated with thunderstorms.

MAGNETIC DECLINATION IN CHARLES COUNTY

BY

H. HERBERT HOWE

U. S. Coast and Geodetic Survey

WHY WE MUST STUDY THE EARTH'S MAGNETISM[21]

We seldom stop to think about the great changes which the compass wrought in the progress of civilization. There have been seafaring nations since the dawn of history, but in olden times a ship was always in peril when out of sight of land. In fair weather, there was no problem, for the captain could find his way by the sun and stars; but in foul weather, he had no way of telling one direction from another, unless he could guess from the wind and the waves.

The invention of the compass, not long before the time of Columbus,[22] changed all this. Now, a ship's captain could find his bearings in any weather. General use of the compass was delayed for a time by the superstititious dread that always haunts anything new and strange. But the compass was finally accepted, and in the next era daring navigators conquered the seven seas.

Even to-day, the compass is important in navigation. Small vessels still depend on it. Large ships now use the gyrocompass, which orients itself by the rotation of the earth—but they have magnetic compasses to use in case the gyrocompass gets out of order. Air navigation still relies on the earth's magnetism for finding direction, since the gyrocompass has not yet been adapted to airplanes. (A directional gyro is reset at short intervals, by reference to the magnetic compass.)

For many years, the compass was an important surveying instrument. It is not very accurate, and its use should be avoided where possible. It is, however, still useful for certain classes of surveying.

Geologists and geophysicists use magnetic instruments to find magnetic iron ore, and to trace rock formations that may contain oil and other minerals. Changes in the ionosphere are related to radio reception and also to changes in the earth's magnetic field. Natural electric currents in the ground are related to magnetic changes, and also interfere with telegraph and power lines. Cosmic rays are affected by the earth's magnetic field.

With so many matters of everyday interest affected directly or indirectly by the earth's magnetism, it is important to find out all we can about it: its cause; how it is distributed over the earth; how and why it changes from hour to hour, and from year to year; and how it is related to earth currents, atmospheric electricity, and solar activity.

[21] This subject is covered more fully in "The Physical Features of Carroll and Frederick Counties," and in the Coast and Geodetic Survey's Serials 618 and 663. See bibliography at the end of this chapter.

[22] A brief history of the compass is given in Serial 663.

GENERAL INFORMATION ABOUT THE EARTH'S MAGNETISM

THE MAGNETIC ELEMENTS

The earth is a great magnet, surrounded by a magnetic field. To measure the earth's magnetism at any place, we must measure the direction and intensity of this field.

A magnet perfectly free to turn in any direction, and balanced at its center of gravity, would show the direction of the earth's magnetic field. It is almost impossible to suspend a magnet in that way, but we can get the same result by using two different magnets. One of them, a compass needle, is constrained to turn about a vertical axis, and shows the direction of the horizontal components of the field. The other, a dip needle, is constrained to turn about a horizontal axis, and shows how much the field dips below the horizontal.

The angle between magnetic north and true north is the *magnetic declination.* It is sometimes called the variation of the compass. "East declination" means that the north end of the needle is east of true north.

The *dip* or *inclination* is the angle that a dip needle makes with the horizontal—i.e., the angle between the plane of the horizon and the lines of force. In Charles County, the dip is about 71°. That is, the position assumed by a dip needle is more nearly vertical than horizontal.

We can measure the *total intensity* of the earth's magnetic field, but it is usually better to measure its horizontal component. The declination, dip, and horizontal intensity are called the *magnetic elements.* From them, we can compute the total intensity, and its component in any specified direction. Most of this chapter deals with the declination only.

DISTRIBUTION OF THE EARTH'S MAGNETIC FIELD

The earth's magnetic field is different in different places. It is so irregular that it must be measured in many places to get a satisfactory picture of its distribution. There are, however, certain regular features.

At the *magnetic poles,* a dip needle stands vertical, the horizontal intensity is zero, and a compass does not show direction. At the north magnetic pole, the "north" end of the dip needle is down; at the south magnetic pole, the "north" end is up.

The north magnetic polar region is probably centered at about latitude 74° N., longitude 100° W. Within this region, there are no doubt many magnetic poles, none of them stationary; and throughout the region, the compass is useless for practical purposes. The position of the south magnetic polar region is even more uncertain; it is perhaps near latitude 73° S., longitude 156° E.

As one goes away from the magnetic polar regions, the dip decreases and the horizontal intensity increases. At the so-called *magnetic equator,* dip is zero. The magnetic equator is south of the Equator in South America, and north of it in Africa and the orient.

Some Fallacies About the Magnetic Poles

Many people believe that the compass points true north. If it did, there would be no need to measure the magnetic declination. The compass does, in fact, point in a general northerly direction in most places—but not usually exactly north. For example, in northeastern Maine, it points 22° west of true north; in northwestern Washington, 24° east of true north.

Many other people believe that the compass points toward the magnetic pole. If it did, we would only have to measure the declination at two places to locate the magnetic pole, and then could compute the declination for other places. The compass does, in fact, point in the general direction of the magnetic pole over nearly all of the earth—but not usually exactly toward it. For example, along the 100th meridian in the United States, the north magnetic pole bears due north—but the compass points 10° or more to the east of true north.

The compass is not drawn toward the magnetic pole, nor in any other direction. The effect of the earth's magnetism is to turn a compass, not to pull it. Nor does it turn it toward any particular point in the earth or in the heavens. It merely turns it into a direction called the magnetic meridian, which is peculiar to the point of observation.

The action of the compass is in no way controlled by the magnetic poles. The earth's magnetic field results from some magnetic cause distributed throughout much of the interior of the earth; the magnetic pole is one of its manifestations, and the magnetic declination in Charles County is another.

Now, it is true that an airplane which traveled always in the direction shown by the "north" end of its compass would finally reach the vicinity of the north magnetic pole, in northern Canada. This does not conflict with the preceding paragraphs, but shows merely that the earth's magnetism has a measure of world-wide coordination. If the airplane flew in the direction shown by the "south" end of the compass, it would reach the south magnetic pole, in Antarctica.

The magnetic poles of the earth are quite different from the "poles" of a bar magnet or a horseshoe magnet. The poles of a bar magnet are imaginary points near the ends, at which the magnetism may be considered to be concentrated; the magnetic poles of the earth are imaginary points at which a dip needle stands vertical. If we imagine a bar magnet that has the same magnetic field as the earth (as nearly as possible), we get the best fit with observed facts if we make the bar magnet very short and put it near the center of the earth. The "poles" of this fictitious magnet are thus far removed from the "magnetic poles" of the earth. The intensity of the earth's magnetic field is only about twice as great at the magnetic poles as it is at the equator.

The magnetic poles are thus not centers of attraction—they are merely regions in which the magnetic field happens to be vertical. Very likely there would be much less popular interest in magnetic poles if it were thoroughly understood that their positions do not determine the direction taken by a compass needle. The principal real concern about magnetic poles is that a compass is useless near them.

It is also widely supposed that secular change results from motion of the magnetic poles. Secular change is too complex to explain in this way, and it is too great to reconcile with known facts about motion of the magnetic poles. Secular change is primarily a regional phenomenon, rather than a world-wide one. The secular change in Charles County shows no relation to the secular change in China or Madagascar.

If secular change resulted from motion of the magnetic poles, there would have to be such a relation.

CHANGES OF THE EARTH'S MAGNETISM

The earth's magnetic field is always changing. The changes discussed here are the daily variation, irregular disturbance, magnetic storms, secular change, annual change, and annual variation.

TABLE XXVIII

Average Daily Variation of Magnetic Declination in Charles County

A plus sign means that west declination is greater than the mean for the day. For individual quiet days, the range may be more or less, and the extremes may come at different times.

75th Meridian Time	Jan., Feb., Nov., Dec.	Mar., Apr., Sept., Oct.	May, June, July, Aug.	75th Meridian Time	Jan., Feb., Nov., Dec.	Mar., Apr., Sept., Oct.	May, June, July, Aug.
	′	′	′		′	′	′
1 a.m.	+0.1	−0.4	−0.2	1 p.m.	+3.0	+4.6	+5.5
2 a.m.	+0.2	−0.5	−0.3	2 p.m.	+3.2	+4.8	+5.5
3 a.m.	+0.2	−0.6	−0.4	3 p.m.	+2.7	+4.0	+4.4
4 a.m.	−0.1	−0.9	−0.9	4 p.m.	+1.6	+2.4	+2.7
5 a.m.	−0.4	−1.3	−1.9	5 p.m.	+0.8	+1.2	+1.2
6 a.m.	−0.8	−2.2	−3.9	6 p.m.	+0.2	+0.7	+0.3
7 a.m.	−1.1	−3.4	−5.5	7 p.m.	−0.2	+0.4	+0.1
8 a.m.	−2.3	−4.7	−6.0	8 p.m.	−0.4	0.0	+0.4
9 a.m.	−3.1	−4.1	−4.9	9 p.m.	−0.6	−0.2	+0.2
10 a.m.	−2.7	−2.6	−1.8	10 p.m.	−0.6	−0.4	0.0
11 a.m.	−0.7	+0.6	+1.8	11 p.m.	−0.4	−0.2	−0.2
Noon	+1.6	+3.3	+4.5	Midnight	−0.2	−0.4	−0.2

This table shows the average variation for 10 quiet days of each month for 1918–28, at the Cheltenham Magnetic Observatory. 75th Meridian Time is the time that has usually been Eastern Standard Time. "Daylight-saving time" is one hour later, e.g., 10:00 daylight-saving time is 9:00 by 75th meridian time.

Daily Variation

There is usually a fairly systematic departure of the magnetic field from its daily mean value. This repeats itself with fair regularity day after day. The amount of departure depends upon the time of day, the season, the magnetic latitude, and other factors. This systematic change is called *daily variation.*

The amplitude of the daily variation is not predictable for any one day. Table XXVIII shows the average daily variation of the magnetic declination in Charles County. For individual undisturbed days, departures from the mean may be more or less than shown, and the extremes may come earlier or later. On disturbed days, the changes are quite different.

In northern latitudes, the north end of the needle moves eastward in the morning with an easterly extreme about 8 or 9 a.m., local time. The westerly extreme comes about 1 or 2 p.m., followed by easterly motion. From dusk to the early morning, there is little change. The daily range is greater in summer than in winter, and greater toward the magnetic pole than toward the equator.

In the Southern Hemisphere, the westerly extreme is in the morning and the easterly one is in the afternoon; the greatest amplitude is in December. Part of the Tropics lies in a transition belt, in which the northern type of variation predominates in June and the southern type in December.

In the United States in summer, the north end of the compass needle points on the average about 12′ more to the west at 1 p.m. than at 8 a.m. A line run 1,000 feet by compass at 8 a.m. would end 3 feet to the right of where it would end if run at 1 p.m. Thus, daily variation is one factor limiting the accuracy of compass surveys.

Irregular Disturbance and Magnetic Storms

Superposed on the regular daily variation, there are usually irregular changes. When they become very large, we say there is a *magnetic storm.* These "storms" are quite different from ordinary storms. They are associated, however, with the Northern Lights and with radio anomalies. A magnetic storm may last many hours or even several days, and the more severe ones occur all over the earth at the same time.

Secular and Annual Changes

The average value of a magnetic element for one year differs from the average for the next year. The change usually continues in one direction for many years. This is called the *secular change.* The amount in one year is called the *annual change.*

Table XXXI illustrates the fact that the change from year to year is not uniform. It also shows that the change does not go on indefinitely in one direction. At some stations, two turning points have been recorded. Thus, at London the declination reached an extreme of 11° East in 1580; and another extreme of 24° West in 1810.

Tables showing secular change in the United States are given in Serial 602 and 664. Table XXX shows secular change of declination in Charles County.

It now appears that there is no tangible basis for predicting secular change. It can be determined *only* by actual observation. When one must forecast declination for a future date, he can only assume that the rate of change in the future will be the same as in the recent past. Actually, every now and then the rate undergoes a large change. This can be seen in Table XXXI: the rate before 1933 was about 4 minutes per year; since then, it has been practically zero.

Annual Variation

When the average monthly values are corrected for secular change, there remains a small systematic seasonal effect. This is called *annual variation.* In Maryland, west declination is about a minute larger in winter than in summer.

LOCAL MAGNETIC DISTURBANCE

The declination changes from place to place. In most regions, the change is gradual enough so that a surveyor can use the same declination throughout a small area. In some regions, however, there are large changes within a small area—sometimes several degrees within a hundred feet or less. Sometimes, it makes considerable difference how high the compass is above the ground.

In such a region, *local disturbance* or *local anomaly* is said to exist. If it is caused by the works of man, it is called *artificial disturbance*. Otherwise, it is *natural disturbance*.

Local disturbance is often called "local attraction," but this is rather misleading. The needle is not attracted toward any particular point. Nor is it even necessarily deflected toward the disturbing mass—it may be deflected away from it. The term "local irregularity" would perhaps be better than "local disturbance."

Local disturbance can usually be detected by observing the compass bearing of a line at two or more points on the line.

Natural Disturbance

Natural anomalies of several degrees are usually caused by a mineral called magnetite (one of the iron ores). Other ores and geological formations cause smaller anomalies.

Even in "undisturbed" regions, minor irregularities are the rule. Almost anywhere, the declination at two points 100 feet apart differs by a few minutes. Natural anomaly is probably the most significant cause of the relatively low accuracy of the compass as a surveying instrument.

The effect of magnetic material diminishes rapidly with increasing distance. Large natural disturbances are uncommon at sea, since the nearest disturbing matter is at or below the bottom of the sea. Likewise, an airplane in flight is far removed from any source of natural disturbance. (For both sea and air navigation, the principal uncertainties of the compass arise from the effect of iron in the craft itself, and the dynamical effects of the craft's motion.)

Local disturbance is not merely an inconvenient obstacle. Oil and valuable ores are often associated with geological formations that can be traced by their magnetic effects.

Artificial Disturbance

Whenever magnetic observations are being made for any purpose, the possibility of artificial magnetic disturbance should be kept in mind. Iron, steel, or direct electric currents near the instrument will have an effect. The magnitude of the effect diminishes rapidly with increasing distance.

Unless precautions are taken, the clothes of the observer are likely to contain iron in hat brim, spectacles, belt buckles, zippers, etc. Pure brass is non-magnetic; but much commercial "brass" contains iron as an impurity, and is quite magnetic.

On land, there may be iron in buildings, fences, or buried pipes. An alternating electric current has no effect on a compass, because the magnetic field of the current reverses direction so fast that the compass cannot respond to it. However, power lines are often supported by steel towers large enough to have considerable magnetic effect.

The most far-reaching artificial disturbance is that due to a direct-current electric railway with grounded rails for the return current. The leakage from the rails may affect sensitive magnetic instruments 10 miles away. For ordinary compass surveys, a quarter mile from such a railway is enough to avoid the effect.

At sea, the iron of the ship causes magnetic disturbance. Most of this can be "compensated" for, by placing permanent magnets, soft iron spheres, and soft iron bars in the proper places.

MAGNETIC SURVEYS

Since the earth's magnetic field cannot be computed from knowledge about magnetic poles, it must be observed. The methods used by the United States Coast and Geodetic Survey are described in detail in Serial 166, and briefly in Serials 618 and 663.

To get information about daily variation and irregular changes, and to get the best information about secular change, magnetic observatories are built. At an observatory, continuous photographic records are made of the changes in direction and intensity of the magnetic field. The buildings are well insulated, to free the instruments from the effects of rapid temperature changes. The Coast and Geodetic Survey has operated magnetic observatories at intervals since 1860, and continuously since 1900. At present, it has 6 of them: one in Puerto Rico, one in the Hawaiian Islands, two in Alaska, one in Arizona, and one in Maryland. The one in Maryland is near Cheltenham, in Prince Georges County.

For less expensive information about declination only, the Coast and Geodetic Survey has recently devised the "declination recording station." This produces a photographic record of changes of declination only, and requires attention only at intervals of several months. (A standard observatory requires daily attention.) Two declination recording stations have been established, one in Tennessee and one in Utah. Others are contemplated.

In addition, magnetic observations have been made at about 7,000 other places in the United States. Each of these is called a "magnetic station." At about 200 of these, called "repeat stations," observations are repeated at intervals of about 5 years, to measure changes in the earth's magnetism.

A magnetic station is often marked by a stone or concrete post. Many stations were established near county seats, so that they could be used by local surveyors for testing compasses. The observers tried to choose sites free from artificial or natural disturbance—but nevertheless many stations have been made useless by later industrial developments.

In a magnetic survey, declination and horizontal intensity are usually measured with a magnetometer, and dip with an earth inductor or a dip circle. The magnet of a magnetometer is suspended by a fine gold ribbon, to eliminate the friction of a pivot. Since declination is the angle between the true and magnetic meridians, both of these must be found. The magnetic meridian is found with the magnetometer, and the true meridian is usually found by observing the sun with a theodolite.

MAGNETIC SURVEY OF MARYLAND

The original magnetic survey of Maryland was made between 1896 and 1900. In 1896, the Maryland Geological Survey employed the late Dr. L. A. Bauer. He borrowed a magnetometer and a dip circle from the United States Coast and Geodetic Survey, and by prodigious effort made a fairly complete survey of the State in three months. The Geological Survey found it possible to continue to employ him, and he occupied many additional stations in 1897 and 1898. In May 1899, Bauer entered

TABLE XXIX

Values of Magnetic Declination

Station	Date of Observation	Declination, Reduced to Jan. 1, 1945	Latitude	Longitude
		° ′	° ′	° ′
Benedict	9/10/08	7 19W	38 31	76 40
La Plata (1896)	9/10/96	6 51	38 32	76 59
La Plata	6/3–5/97	6 50	38 32	76 59
La Plata (1905)	6/26–27/05	6 46	38 32	76 59

NOTE.—This table is of historical interest only. It is not to be used by surveyors.

the Coast and Geodetic Survey, becoming chief of its new division of Terrestrial Magnetism (now known as the Division of Geomagnetism and Seismology). The survey of Maryland was continued by the Coast and Geodetic Survey in 1899 and 1900. The results of this survey were published in two reports, described in the bibliography at the end of this chapter.

Most of the magnetic observations made in Maryland by the Coast and Geodetic Survey between 1901 and 1938 were at "repeat stations." In 1939, a number of stations were occupied by an observer attached to a triangulation party.

Magnetic Observations in Charles County

Brief descriptions of the stations occupied in Charles County follow. Table XXIX shows the declination at these stations:

La Plata.—A station was established in 1896 by the Maryland Geological Survey. It was 49 paces NW of the NW corner of the courthouse. In 1897, this station was covered by a wooden fence.

In 1897, a meridian line was established by the MGS, in the west grounds of the courthouse yard. Magnetic observations were made at various points, and no appreciable local disturbance was found. The value given in Table XXIX is for the south monument.

In 1905, the Coast and Geodetic Survey occupied an unmarked point in an open field, due south of the south meridian stone. In 1934, it was reported that buildings had been built in this field.

Benedict.—The magnetic station was at an unmarked point near triangulation station CITY, about $\frac{1}{4}$ mile NNE of the ferry wharf. The triangulation station is about 4 feet above high-water mark, 20 yards NW of the shore, 100 yards WSW of the extreme end of the point, 8 yards SE of a slough, and 36.6 feet ENE of power pole number 124. It is marked by a monument of the Maryland Shell Fish Survey, lettered MSFS and USCS; the marker projects 8 inches above ground.

The magnetic station is 32.8 feet from the triangulation station in a direction S. 0° 45.0′ W. It is in prolongation of the line to triangulation station TEAGUE, which is about a mile away. The magnetic observations were made in 1908; the triangulation station was last recovered in 1943.

MAGNETIC CHARTS

Results of magnetic surveys are often shown by magnetic charts. The most common magnetic chart is the *isogonic chart*, which has a number of curved lines called *isogonic lines*; each isogonic line is drawn through places having a specified value of the declination. An *isoclinic chart* shows dip or inclination; an *isodynamic chart* shows some component of intensity.

Since the earth's magnetic field changes from year to year, a chart must be made for some specified year or *epoch*.

ISOGONIC CHART OF CHARLES COUNTY

Figure 19 shows an isogonic chart of Charles County. Its nominal epoch is 1945. However, in this region the secular change has been so small during the last few years that the chart is equally valid for any year from 1934 to 1950. It was made by a method similar to that described in Serial 664, using observations in Charles County (see Table XXIX) and neighboring counties.

INTERPRETING A MAGNETIC CHART

Making magnetic charts is a special art. One might suppose that we should draw an isogonic line so that all greater values of declination fell on one side, and all smaller values on the other. This is always possible, but is not usually desirable. If we did this, the chart would not fulfill its main purpose, which is to show the most likely value of declination at a point at which observations have not been made.

This may be made clear by an analogy. Consider the elevation of the earth's surface above sea level. There are general trends in elevation across Maryland, and there are also many local irregularities where the elevation changes 50 feet or more within a quarter mile. Since we can see the changes, it is feasible to make maps of equal elevation (topographic maps) with a reasonable amount of work, and this has been done for all of Maryland.

There are similar variations in the earth's magnetic field. The real lines of equal declination (at a given moment) are a very complex system of bends, loops, and closed curves. But the irregularities cannot be seen; an observation at a point tells only the value at that point. Hence, the real lines cannot be drawn without many more observations than we have.

Suppose it were impossible to tell anything about elevation except by setting up an instrument and making observations; and suppose only a few hundred such observations had been made in Maryland. No one could draw a good topographic map from such data. An observation would tell little about the elevation a quarter mile away, since the point of observation might be on a mountain or in a valley. The best one could do would be to draw lines showing the general trends of altitude across the State. If all observations in a region agreed well, we would guess that it was a region of gentle slopes and that we could interpolate fairly accurately for other points; if they disagreed, we would know that it was a region of rugged topography, and that any estimate for another point was a guess.

Similarly, we have observed the declination at only a few hundred points in Maryland. We cannot use these observations to give accurate values for other points. The best we can do is to draw lines indicating general trends, and that is what we do when we make an isogonic chart.

We now see that if we scale a value of declination from a chart, it is usually not the real declination for that point. It is, however, the best value for a surveyor to

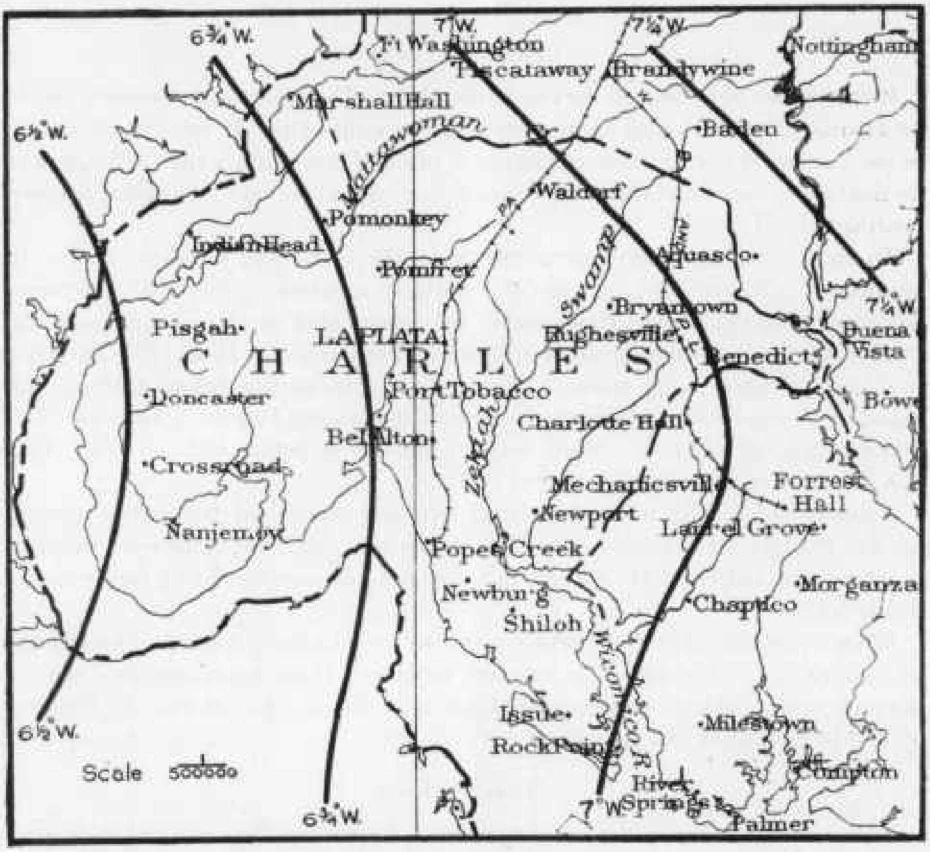


FIG. 19. Isogonic chart, Charles County, for 1945

use unless he has other information. It may be called the "normal value" for the point, and is roughly equal to the average declination over a circle of 10-mile radius. There is perhaps an even chance that a chart value will agree with the real value within one-half degree; occasionally, they differ by many degrees.

There is not yet general agreement as to the best method of drawing isogonic lines from given data. This is most readily seen by comparing charts drawn in different countries. Some of them have lines much smoother than others. It is the general feeling in the U. S. Coast and Geodetic Survey that much of the "detail" shown on many foreign charts is illusory. Within the Coast and Geodetic Survey, also, the principles used in drawing charts change from time to time. For example, the iosgonic chart for Carroll and Frederick Counties has straighter lines than does figure 19, because different methods were used in drawing them.

A value scaled from figure 19 is to be considered as the mean value for the period 1934–1950, eliminating daily variation and irregular variation. To get the declination before 1934, a correction for secular change must be applied as shown in example (g) below.

RETRACING OLD COMPASS SURVEYS

GENERAL PRINCIPLES

Retracing an old compass survey is not easy. The Coast and Geodetic Survey gets many letters each year from surveyors who want help. In most cases, the surveyor has found one or more corners of a piece of land, and wants to know what declination to use to find the lines. Sometimes, instead, he asks the present magnetic bearings of old lines.

To help surveyors answer these questions, the Coast and Geodetic Survey has studied all available old data, some of it not very accurate. Since 1855, the Survey has made magnetic observations useful for determining secular change, and since 1900 it has made systematic observations for that purpose. From these have been prepared "secular-change tables." The tables of declination before 1750 are published in "United States Magnetic Declination Tables and Isogonic Charts for 1902," which is now out of print. More recent tables are in Serials 602 and 664. Table XXX is derived from these published tables.

Annual-change rates or mathematical formulas should not be used to compute secular changes for extended periods. At one time, such formulas were published by the Coast and Geodetic Survey, but they are now superseded by tables such as Table XXX.

When a surveyor asks us for help in retracing an old survey, we answer his question as best we can. The answer is not very reliable. There is no assurance that the surveyor will be able to retrace the old line if he uses it. Let us see why this is so, and what a surveyor can do about it.

Some Problems

First, secular-change tables are not perfect. In making them, we had to reconcile all sorts of inadequate data. The difference between two observed declinations is not all secular change: Part is daily variation, part is error in the two instruments, often part is local disturbance.

Second, every compass has an *index error;* that is, its readings will be consistently wrong, to a greater or lesser extent. For modern compasses, the error is usually small; for old ones, it may have been a quarter or half degree.

Third, the surveyor may not know when the original survey was made. He has a deed giving compass courses. The deed is dated, but the courses may not have been run at that time. Compass bearings in one deed are sometimes copied into another deed 50 years later, when the bearings are really a degree or more different. Worse, when land is subdivided, sometimes old bearings are copied for the old lines, while the bearings of new lines are observed at the time of subdivision.

Fourth, accurate surveys cannot be made with a compass. There is uncertainty in reading the needle, and the needle is affected by local disturbance, daily variation, and irregular disturbance. Local disturbance causes errors in resurveys unless the surveyor sets up at the exact points used in the old survey, and these are usually not known.

Fifth, secular change is affected somewhat by local disturbance. For example, the change of declination over 50 years is not exactly the same at two nearby points if they have different values of horizontal intensity. In most regions, this discrepancy is small compared with other uncertainties, and we use a table giving the change for average conditions.

How to Meet These Problems

First, the surveyor may know of a well-defined line that was run about the same time as the lost line. He can measure the change in compass bearing of this line, and use this to get the compass bearing of the line he is trying to find. This eliminates the uncertainty in the secular change, and he does not use the table at all.

Second, if this well-defined line was run with the same compass as the line the surveyor is seeking, this process also eliminates the errors of the two compasses.

Third, a careful study of all of the deeds will often tell when the survey was really made. If the same compass course is given in two deeds, it was probably copied into the second without resurvey.

If it is known (or assumed) that all lines of the tract were surveyed at the same time, the uncertainty of the date can be eliminated by the method described under "First" above, provided the "well-defined line" is a line of the tract itself.

Fourth, the compass is normally used for surveying only when the accuracy required is such that the daily variation and the uncertainty of reading the compass are negligible. If a magnetic storm is in progress, the needle may be noticeably unsteady; in that case, the surveyor should wait until another day.

SECULAR-CHANGE TABLE (TABLE XXX)

Table XXX was prepared from the tables given in Serial 664 and in "United States Magnetic Declination Tables and Isogonic Charts for 1902." It gives the approximate mean magnetic declination at two magnetic stations in Charles County, at intervals of 5 or 10 years. Values for other years may be found by interpolation. The change is not really uniform from year to year (see, for example, Table XXXI), but the error resulting from using a uniform change is not significant for surveying. Futhermore, for most of the period covered by Table XXX, we have no information about more detailed changes.

Since secular change follows no known law, we cannot predict it for more than a few years. Table XXX gives estimated declinations for 1950. However, a sudden change in rate, such as Table XXXI shows for 1933, might affect the 1950 value appreciably. Extrapolation beyond 1950 should be avoided.

Examples of Use of Table XXX

Before a surveyor tries to use this table, he should read the section on "General Principles," which tells some of the difficulties he will have and some ways to meet them. He should not be surprized if the change of declination since 1800, as given by Table XXX, differs as much as 30′ from the value indicated by his own retracing of old lines.

Entries in Table XXX from 1650 to 1740 are rounded off to the nearest 5′. Those since 1740 are stated to minutes. The examples are carried out to minutes. This precision is used only to avoid accumulating rounding-off errors; in no case are secular changes known within 1′.

The secular changes shown for La Plata and Benedict may, with adequate accuracy, be used for other points in their respective parts of Charles County, even when the declination itself is different. This is illustrated in some of the examples.

TABLE XXX

Secular Change of the Magnetic Declination

This table shows the approximate magnetic declination at the sites of the specified magnetic stations, for the beginnings of the specified years. The middle part is uncertain by 15′ or perhaps 30′, and the older part by 1° or more.

Year	Benedict	La Plata (1905)	Year	Benedict	La Plata (1905)	Year	Benedict	La Plata (1905)
	° ′	° ′		° ′	° ′		° ′	° ′
1650	5 00W	4 35W	1770	1 24W	0 58W	1890	4 37W	4 07W
1660	5 35	5 10	1780	0 57	0 31	1900	5 14	4 44
1670	5 35	5 10	1790	0 40	0 13	1905	5 33	5 03
1680	5 45	5 20	1800	0 31	0 04	1910	5 54	5 24
1690	5 35	5 10	1810	0 33	0 04	1915	6 15	5 44
1700	5 15	4 50	1820	0 43	0 14	1920	6 31	5 59
1710	5 00	4 35	1830	1 03	0 34	1925	6 50	6 18
1720	4 25	4 00	1840	1 32	1 02	1930	7 05	6 33
1730	3 55	3 30	1850	2 07	1 37	1935	7 19	6 47
1740	3 15	2 50	1860	2 44	2 13	1940	7 18	6 45
1750	2 36	2 11	1870	3 24	2 53	1945	7 19	6 46
1760	1 58W	1 32W	1880	4 03W	3 33W	1950	7 19W	6 45W

(*a*) *What was the magnetic declination in September 1843 at the point later occupied by magnetic station Benedict?* Table XXX gives 1° 32′ West for January 1840, and 2° 07′ West for January 1850. Interpolating, we get 1° 45′ West for September 1843.

(*b*) *How much did the declination in eastern Charles County change between September 1843 and January 1945?* For Benedict, Table XXX gives 7° 19′ West for 1945, and example (a) gave 1° 45′ West for September 1843. The change was 5° 34′. This same change may be used with adequate accuracy for other points in that area.

(*c*) *In September 1843, the following magnetic bearings were observed near Hughesville: N. 45° W.; N. 30° E.; S. 60° E.; S. 27° W.; S. 2° E. What are the magnetic bearings of these lines in January 1945?* (This is one of the most common problems involving secular change.) In example (*b*), we found a secular change of 5° 34′ during this interval. West declination increased, and magnetic north moved westward (see Fig. 20). Bearings in the northeast and southwest quadrants increased, while those in the northwest and southeast quadrants decreased. The bearings desired for January 1945 are: N. 39° 26′ W.; N. 35° 34′ E.; S. 54° 26′ E.; S. 32° 34′ W.; S. 3° 34′ W. (The original bearings are stated only to degrees; these bearings are thus not known to minutes. In practice, they would be rounded off to quarter-degrees.)

(*d*) *What was the declination at Pisgah in January 1945?* The chart shows 6° 38′ West. This is the best value to use in any compass survey near Pisgah, unless the declination has been observed in the near vicinity of the survey. The declination at any one point may be considerably different from this value; but, in the absence of other information, this average is the best value to use.

(*e*) *What will be the declination at Pisgah in 1950?* As far as we now know, the isogonic chart will be as good in 1950 as in 1945; therefore, we may use the same value, 6° 38′ West.

(*f*) *What will be the declination at Pisgah in 1955?* We do not know. The rate of change is variable, and follows no known law. No attempt should be made to predict changes for more than about 5 years. It is, however, very unlikely that the rate of change will exceed 4′ per year during the next few years; hence, if a result within half a degree will suffice, we may guess that the declination will be the same in 1955 as in 1945.

(*g*) *What was the declination at Hughesville in September 1843?* By example (*b*), it was 5° 34′ less than in 1945. By the chart, it was 6° 59′ West in 1945; hence, in September 1843 it was 1° 25′ West. This value is subject to the uncertainties of both an isogonic chart and a secular-change table.

TABLE XXXI

Annual Means of Magnetic Declination at Cheltenham Magnetic Observatory

(Cheltenham is in Prince Georges County, Maryland. Latitude, 38° 44′; Longitude, 76° 51′)

Year	Declination	Year	Declination	Year	Declination	Year	Declination
	° ′		° ′		° ′		° ′
1902	5 06.8W	1914	5 59.8W	1926	6 42.8W	1938	7 05.1W
1903	10.0	1915	6 04.0	1927	45.7	1939	05.0
1904	13.3	1916	07.7	1928	49.0	1940	04.8
1905	17.8	1917	10.4	1929	52.0	1941	05.4
1906	21.5	1918	12.4	1930	6 55.9	1942	05.9
1907	26.0	1919	15.0	1931	7 00.0	1943	06.3
1908	31.1	1920	18.5	1932	03.7	1944	06.0
1909	36.4	1921	22.4	1933	06.2	1945	05.8
1910	41.4	1922	27.7	1934	06.8	1946	04.8
1911	45.6	1923	32.0	1935	06.5	1947	7 04.3W
1912	50.0	1924	35.8	1936	06.2		
1913	5 54.6W	1925	6 39.4W	1937	7 05.4W		

1902–37: Based on 10 least disturbed days of each month.
1938–45: Provisional, and based on all days.
1946–47: Provisional, and based on 24th hour of each day.

NEW COMPASS SURVEYS

Nowadays, the compass is not widely used in new surveys. A land survey is of little value unless it can be retraced later, and we have seen some of the troubles which arise in retracing compass surveys. Nevertheless, there are circumstances which make it desirable to use a compass. In such cases, all reasonable care should be taken to eliminate errors. We now discuss a few of these errors.

Daily variation may be partly eliminated by applying the corrections given in Table XXVIII. The actual daily variation, however, is different on different days. Daily variation, and irregular changes as well, can be eliminated by writing to the Coast and Geodetic Survey, Washington 25, D. C., to obtain a correction applicable to the particular date and time. In practice, however, it hardly pays to use the compass unless the required accuracy is such that daily variation and ordinary irregular changes can be neglected. If the change is very irregular, the needle may be visibly disturbed, and observations should be deferred until another day.

Local magnetic disturbance is an ever-present cause of uncertainty. In general, its effect cannot be avoided. Note, however, that if the man who makes the original survey records the actual points at which he sets up the compass, another surveyor should be able to set over the same points and reproduce the survey without trouble from local disturbance. It is likely that Charles County has less magnetic disturbance than some parts of Maryland.

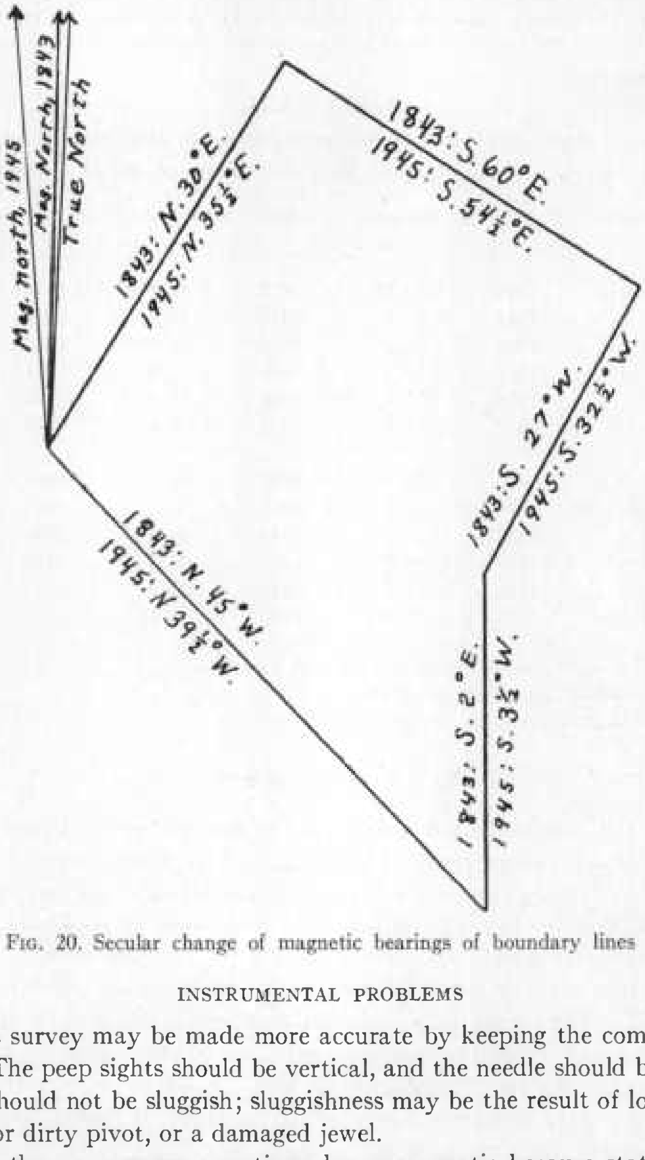


FIG. 20. Secular change of magnetic bearings of boundary lines

INSTRUMENTAL PROBLEMS

A compass survey may be made more accurate by keeping the compass in good condition. The peep sights should be vertical, and the needle should be horizontal. The needle should not be sluggish; sluggishness may be the result of loss of magnetism, a dull or dirty pivot, or a damaged jewel.

In dry weather, a compass sometimes becomes erratic because static electricity accumulates on the glass cover. This may be removed by moistening a finger and rubbing it over the glass.

Even though it is in good operating condition, a compass may have an appreciable index correction. At any rate, it is desirable to check the index correction at regular intervals, as discussed below, *Determining the Compass Correction*

The *compass correction* or *index correction* is the angle between the real magnetic north and the direction shown by a given compass. It is measured by observing the declination with the compass at a point at which the actual declination is known.

There is no magnetic station in Charles County suitable for testing magnetic compasses. Surveyors from that county may test their compasses at the Cheltenham Magnetic Observatory, in Prince Georges County. The observatory is on the grounds of the Maryland Reform School, about a mile west of the Cheltenham post office. A surveyor may write to the Observer in Charge, Cheltenham Magnetic Observatory, for an appointment; or he may come without an appointment, with good chance of finding someone there. He will observe declination with his compass, and the next day the observatory can tell him what the declination was at the time he observed. The difference is the correction to the surveyor's compass.

REFERRING COMPASS SURVEYS TO THE TRUE MERIDIAN

Instead of measuring the compass correction, as described above, a surveyor may determine the combined effect of the compass correction and the magnetic declination. He may, for example, have a meridian line, consisting of two stones, one due north of the other. (True north will be found by observations on the sun or on Polaris, or by transferring azimuth from a triangulation station.) To test his compass, he sets up at the south stone, and reads the magnetic bearing of the north stone; this figure combines the declination and compass correction. This value is to be recorded with the survey.

Then, in later years, if another surveyor wants to retrace the survey, he can measure the "magnetic declination" at the same station with his compass. The difference between the old and new values is the secular change, combined with the difference of the compass corrections. This difference is to be applied to the old compass bearings. This method, however, will be vitiated if any artificial magnetic disturbance has been introduced, either at the meridian line or at the site of the survey.

The importance of this method of testing compasses is recognized in Maryland by the following sections of article 25 of the 1939 Code:

137. It shall be lawful for the county commissioners of each county in the State, if they shall deem it expedient, to cause to be erected at some public spot adjacent to the courthouse of each county, two good and substantial stone pillars, one hundred feet distant apart . . . upon the same true meridian line, . . . the said pillars . . . to be free to the access of any surveyor of lands or civil engineer residing in said county, or engaged in surveying therein, for the purpose of testing the variation of the compass for the time being, and to cause the said meridian line to be verified at any time when required so to do by order of the circuit court for the said county . . .

139. It shall be the duty of each and every surveyor surveying land in any county of this State that shall adopt the provisions of the two preceding sections to test and note the actual variation of his compass from the aforesaid true meridian line at least once in every year, and to deposit a copy of the same, with the date and time of such test, accompanying the same with affidavit verifying its correctness, with the clerk of the county in which he may reside, to be by him recorded in a book kept for that purpose, and every surveyor neglecting or refusing to comply with the provisions of this section, shall be liable to a penalty of fifty dollars, to be recovered before any justice of the peace in the county . . .

141. Any person or persons who shall wilfully erase, deface, displace, or otherwise injure said pillars . . . shall, upon conviction therefore, be punished by a fine of not less than fifty nor more than five hundred dollars.

Instead of setting two stones as a meridian line, it is sometimes better to set just one stone. One must then determine the true bearings of various "marks," such as tanks, steeples, buildings, etc. Whenever a surveyor tests a compass at such a station, he finds the true meridian by turning off the true bearing of a "mark," on the horizontal circle. Just as with a meridian line, the station should be in a place free from natural or artificial magnetic disturbance.

A magnetic station can be used either in this way or in the manner described in the previous section. At present, there are no magnetic stations in Charles County suitable for such a test. However, the Cheltenham Magnetic Observatory is near enough to Charles County to be used for this purpose.

A triangulation station may also be used, if it is free from local disturbance. The Coast and Geodetic Survey has a number of triangulation stations in Charles County. A surveyor wishing to use one, for this or any other purpose, can get the necessary data by writing to the Director, U. S. Coast and Geodetic Survey, Washington 25, D. C. It should be noted, however, that sites for triangulation stations are selected without reference to magnetic disturbance, and sometimes the markers are magnetic.

Bibliography

Maryland Geological Survey

The original magnetic survey of the State was described in two reports:

First Report upon magnetic work in Maryland, including the history and objects of magnetic surveys, by L. A. Bauer, Maryland Geological Survey, volume I, part V, 1897, pp. 405–529. This report gave data on declination only. Much of the history and description of objects and methods of magnetic surveys is still of interest, although parts of it are obsolete.

Second Report on magnetic work in Maryland by L. A. Bauer, Maryland Geological Survey, volume V, part I, 1905, pp. 23–98. This gives data for declination, dip, and horizontal intensity. It is more nearly an actual report on the survey than was the First Report.

The following has been largely if not entirely superseded by the Coast and Geodetic Survey's Serials 457 and 602:

Report on the lines of equal magnetic declination in Maryland for 1910, by L. A. Bauer, Maryland Geological Survey, volume IX, part IV, pp. 331–338.

The Maryland Geological Survey has issued several publications similar to the present one. Each of these contained a chapter dealing with the magnetic declination. The latest one of the series, issued by the Department of Geology, Mines, and Water Resources is

The Physical Features of Carroll County and Frederick County. Published at Baltimore, 1946. The chapter, Magnetic declination in Carroll and Frederick Counties, covers pages 247–272.

United States Coast and Geodetic Survey

A leaflet describing the current publications of the Survey on the earth's magnetism can be obtained from the Director, U. S. Coast and Geodetic Survey, Washington 25, D. C. Serial 618, described below, can be obtained in the same way.

The following publications concern Maryland. *Any of them except Serial 618 must be ordered from the Superintendent of Documents, Washington 25, D. C.*

Name	Serial No.	Price
Directions for Magnetic Measurements	166	$1.00
Magnetic Declination in Delaware, Maryland, Virginia, West Virginia, Kentucky, and Tennessee, 1925	457	0.20
United States Magnetic Tables and Magnetic Charts for 1935	602	0.60
Practical Uses of the Earth's Magnetism	618	Free
Magnetism of the Earth	663	0.35
Magnetic Declination in the United States in 1945	664	0.50

Serial 166 is intended mainly for observers of the Coast and Geodetic Survey.

Serial 457 includes secular-change tables, two isogonic charts, and descriptions of magnetic stations. The charts show all magnetic stations in these States, and the observed value of declination at each, reduced to 1925. Although the charts are 23 years old, the reduced values are still useful for showing whether the observations reveal any local disturbance. The stations of the Maryland Geological Survey are included.

Serial 602 is one of a series issued every 10 years. It gives observed values of declination, dip, and horizontal intensity, together with values reduced to 1935. It also contains charts of declination, dip, horizontal intensity, and vertical intensity. The volume for 1945 will probably be issued in 1948 or 1949, and will be known as Serial 667.

Serial 618 and 663 tell about the earth's magnetism, as non-technically as possible. They do not contain secular-change tables or charts, except as examples. Serial 663 goes into more detail than 618.

Serial 664 is the standard publication for surveyors who use the compass. It contains secular-change tables for the entire country, an isogonic chart of the United States, and directions for finding the true meridian.

PLATE VI, *Fig. 1.* Stream Flow Measurement Station on Antietam Creek near Sharpsburg, Md.

PLATE VI, *Fig. 2.* Automatic Water-Stage Recorder and Engineer making inspection.

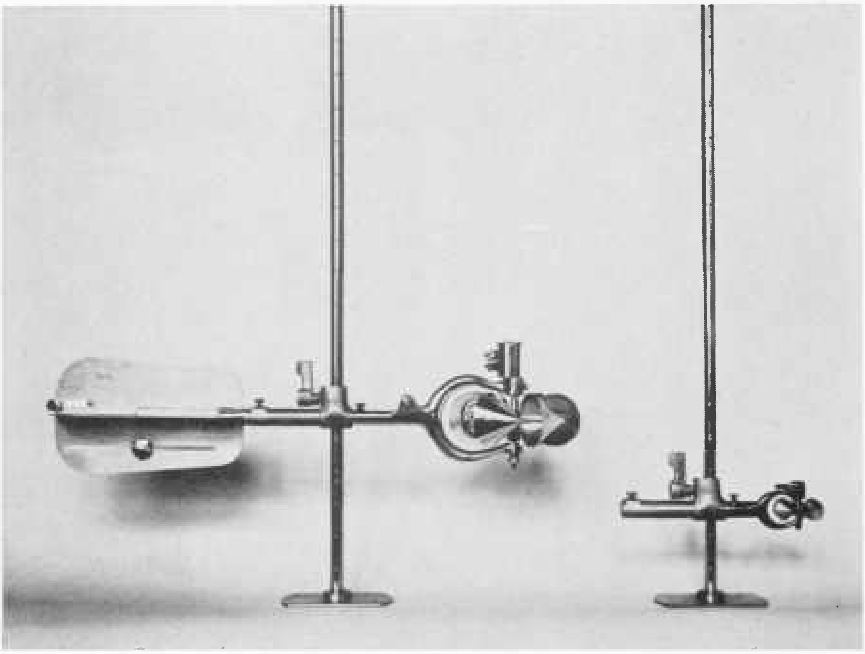


PLATE VII, *Fig. 1.* Standard Price current meter and pygmy meter, suspended on wading rods, used to measure discharge.

PLATE VII, *Fig. 2.* Equipment used in making discharge measurements from bridge.

PLATE IX. Land use capability map for the same area as shown in plate X

Land suited for cultivation:

Class I Very good land that can be cultivated safely with ordinary good farming methods. It is nearly level and easily worked. The soils in this class are naturally well-drained.

Class II Good land that can be cultivated safely with easily applied practices.

IIa Productive well-drained soils that are gently sloping and subject to erosion.

IIb Fairly productive, level or slightly sloping land that has imperfect natural drainage. It needs artificial drainage and may also need erosion-control practices.

IIc Level or gently sloping sandy land on which crops are affected somewhat by drought. It needs moisture conservation and practices to maintain or improve soil fertility. Some areas need erosion-control practices.

Class III Moderately good land that can be cultivated safely with intensive treatments. Natural limitations are greater than on Class II land.

IIIa Productive, well-drained land sufficiently sloping or eroded to require intensive erosion-control practices such as extra years of hay in the crop rotation, terracing, or careful stripcropping.

IIIb Nearly level land, difficult to drain, or fairly productive sloping land that needs some drainage and also erosion-control.

IIIc Very sandy, level or gently sloping land or somewhat sandy land that is sloping and subject to erosion. Needs moisture conservation, intensive fertility practices and may need erosion-control practices.

Land suited for limited cultivation:

Class IV Fairly good land that is best suited to pasture or hay, but can be cultivated occasionally. Land a little too steep or too eroded for regular cultivation.

Land not suited for cultivation:

Class VI Land suited for grazing or forestry with minor limitations. Includes steep or severely eroded areas of the good soils, land subject to overflows that prevent cropping and wet land not suited for drainage.

Class VII Land suited for forestry with major limitations. Not ordinarily recommended for pasture. Consists of land that is very steep, very severely eroded, or very wet.

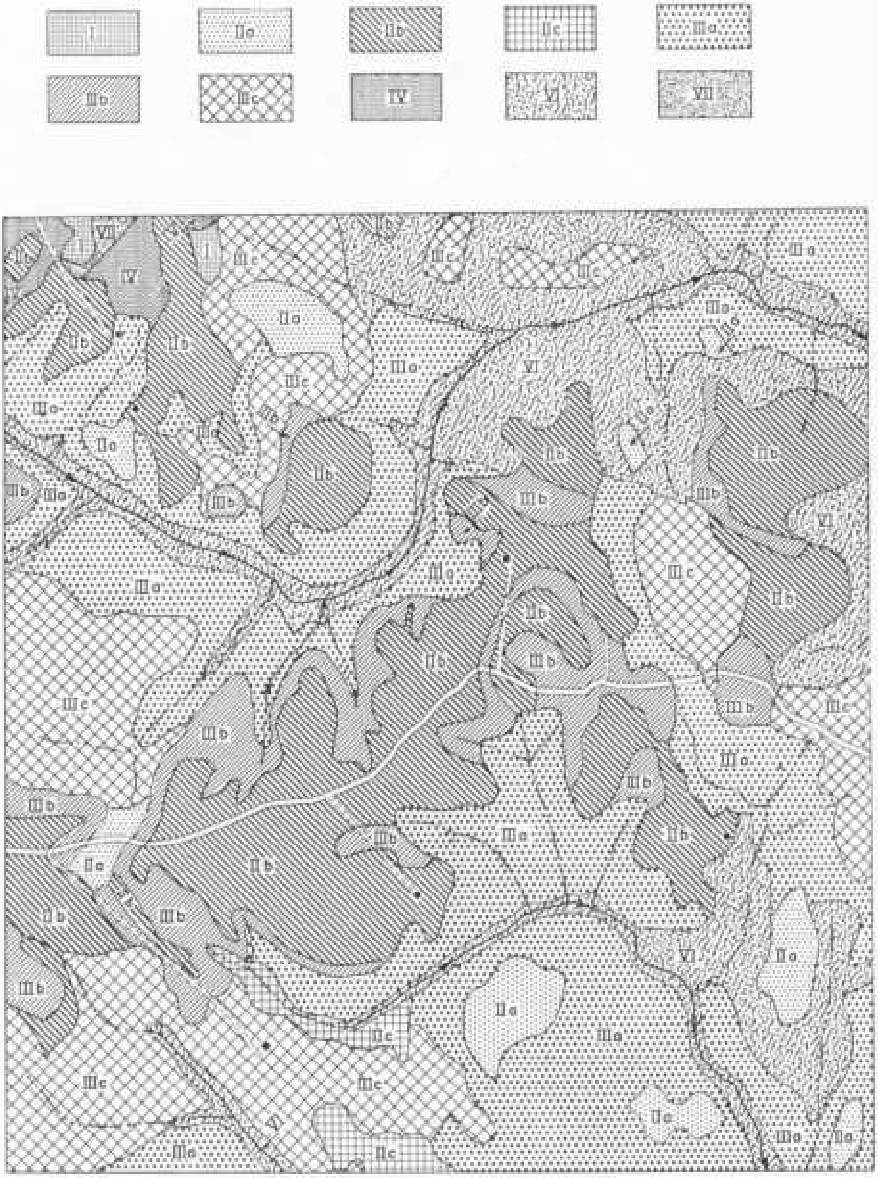


PLATE IX

PLATE X. Sample of detailed farm planning conservation survey map from a representative area, illustrating drainage, erosion, land use, slope, and soil pattern on the Sunderland, Brandywine and Calvert geologic formations. Soil, slope and erosion boundaries are shown by solid lines and areas are identified by symbols. First number in compound symbol is soil type.

Deep, well drained soils:
- 103 Sassafras fine sandy loam
- 104 Sassafras sandy loam
- 105 Sassafras gravelly sandy loam
- 107 Sassafras loamy sand
- 145 Evesboro gravelly loamy sand
- 147 Evesboro loamy sand
- 303 Westphalia fine sandy loam
- 309 Sassafras-Evesboro-Westphalia complex
- 703 Hyattsville fine sandy loam
- 704 Hyattsville sandy loam

Moderately deep, well-drained soil:
- 201 La Plata silt loam.

Moderately deep, moderately well-drained soils:
- 161 Beltsville silt loam
- 163 Beltsville fine sandy loam
- 711 Berwyn silt loam

Deep, poorly drained bottom land:
- 581 Bibb silt loam.

Slope is shown by letter A; B; C; D; E. Following classification applies to these soils:
- Evesboro: A, 0–3%; B, 3–8%; C, 8–15%; D, 15–25%; E, 25–35%.
- Westphalia and complex: A, 0–2%; B, 2–6%; C, 6–12%; D, 12–20%; E, 20–35%.
- All other soils: A, 0–2%; B, 2–5%; C 5–10%; D 10–15%; E 15–30%.

Erosion is shown by the final number of symbol: 0, no apparent erosion; +, recent deposition; 1, 0–25% of top soil lost; 2, 25–75% of top soil lost; 3, 75% of top soil to 25% of subsoil lost; 37, 75% of top soil to 25% of subsoil lost and occasional gullies.

Land use areas are bounded by dashed lines and land use is shown by letters standing alone, as follows: L, cropland; x, idle land; P, pasture; F, woodland; H, residential areas.

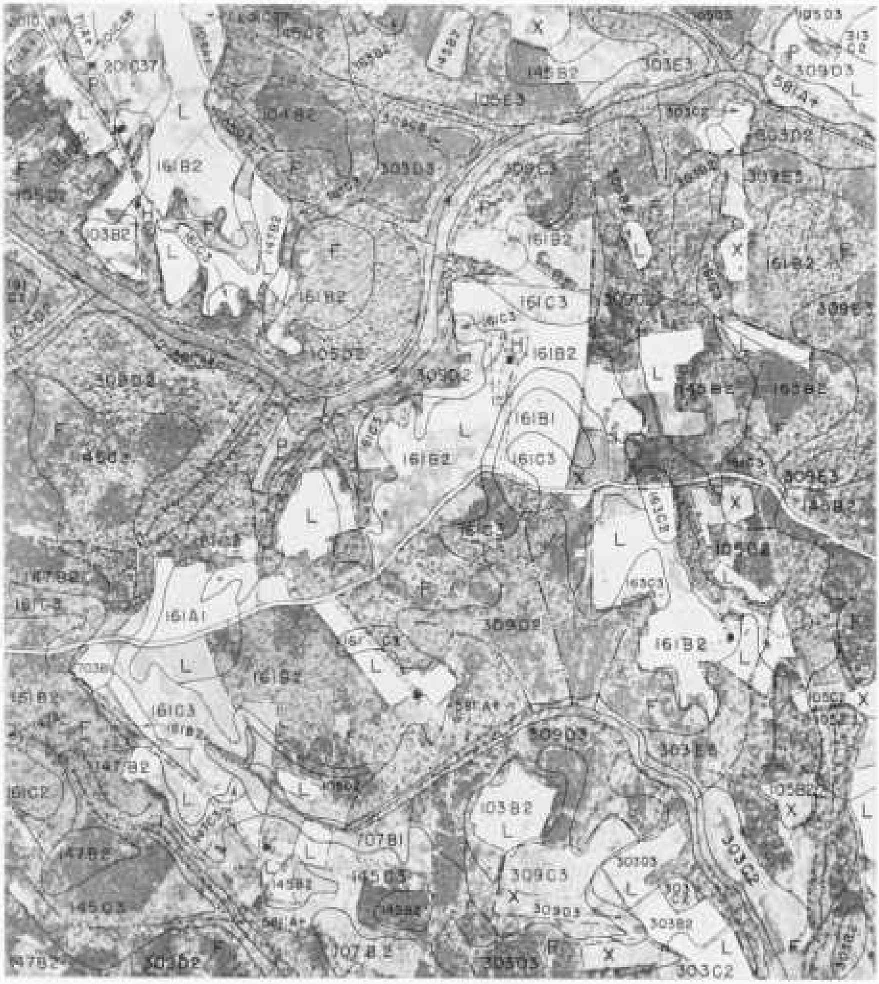

201037
104B2
161B2
103B2
303D3
145B2
105E3
303E3
309D3
303D2
309E3
161C3
105D2
303D2
161B1
161B2
161C3
145D2
161A1
309D2
163B2
309D3
303E3
103B2
707B1
145D3
309C3
303C2
145C3
707B2
303D3
303C2
L
F
X
P
H

PLATE X

PLATE XI. Land use capability map for the same area as shown in plate XII

Land suited for cultivation:

IIa Productive, well-drained soils that are gently sloping and subject to erosion.

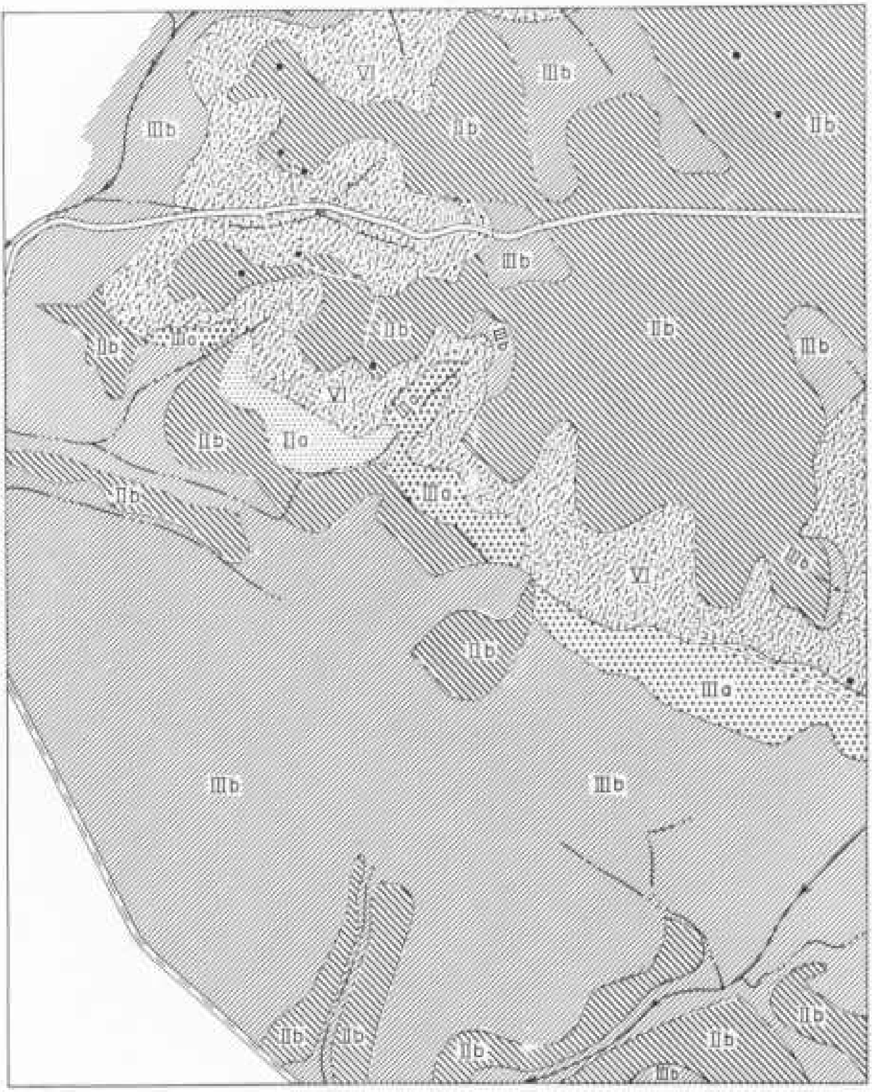
IIb Fairly productive, level or slightly sloping land that has imperfect natural drainage. It needs artificial drainage and may also need erosion-control practices.

IIIa Productive, well-drained land sufficiently sloping or eroded to require intensive erosion-control practices such as extra years of hay in crop rotation, terracing or careful strip cropping.

IIIb Nearly level land difficult to drain, or fairly productive sloping land that needs some drainage and also erosion-control.

Land suited for limited cultivation:

IV Fairly good land that is best suited to pasture or hay but can be cultivated occasionally. Land a little too steep or too severely eroded for regular cultivation.


VI
IIIb
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IIIb
IIb
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IIIa
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VI
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IIIa
VI
IIIb
IIb
IIIa
IIIb
IIIb
IIb
IIb
IIb
IIb
IIb
IIIb

PLATE XI

PLATE XII. Sample of detailed farm planning conservation survey map illustrating drainage, slope, erosion and soil pattern on the Talbot, Wicomico, Sunderland and remnants of the Calvert geologic formations. Soil, slope and erosion boundaries are shown by solid lines and areas are identified by symbols. First number in compound symbol is soil type.

Well drained soils:
- 215 Wayside gravelly sandy loam
- 303 Westphalia fine sandy loam
- 703 Hyattsville fine sandy loam
- 705 Hyattsville gravelly sandy loam

Moderately well-drained soils:
- 161 Beltsville silt loam
- 401 Keyport silt loam
- 511 Mattapex silt loam
- 513 Mattapex fine sandy loam

Poorly drained soils:
- 123 Fallsington fine sandy loam
- 411 Elkton silt loam
- 521 Othello silt loam
- 523 Othello fine sandy loam
- 581 Bibb silt loam

Slope is shown by letters A; B; C; D; E. Following classification applies to these soils:
- Wayside and Westphalia: A, 0–2%; B, 2–6%; C, 6–12%; D, 12–20%; E, 20–35%
- All other soils: A, 0–2%; B, 2–5%; C, 5–10%; D, 10–15%; E, 15–30%

Erosion is shown by the final number of symbol: 1, 0–25% of top soil removed; 2, 25–75% of top soil removed; 3, 75% of top soil to 25% of subsoil lost; +, recent deposition.

Land use areas are bounded by dashed lines and land use is shown by letters standing alone, as follows: L, cropland; x, idle land; P, pasture; F, woodland; H, residential areas.


215E2
161B2
161C2
561A+
215E3
161D2
513B2
521A1
705B2
703B2
303C2
511A1
523A1
513A1
703C2
411A1
161C3
401A1
123A1

PLATE XII

INDEX

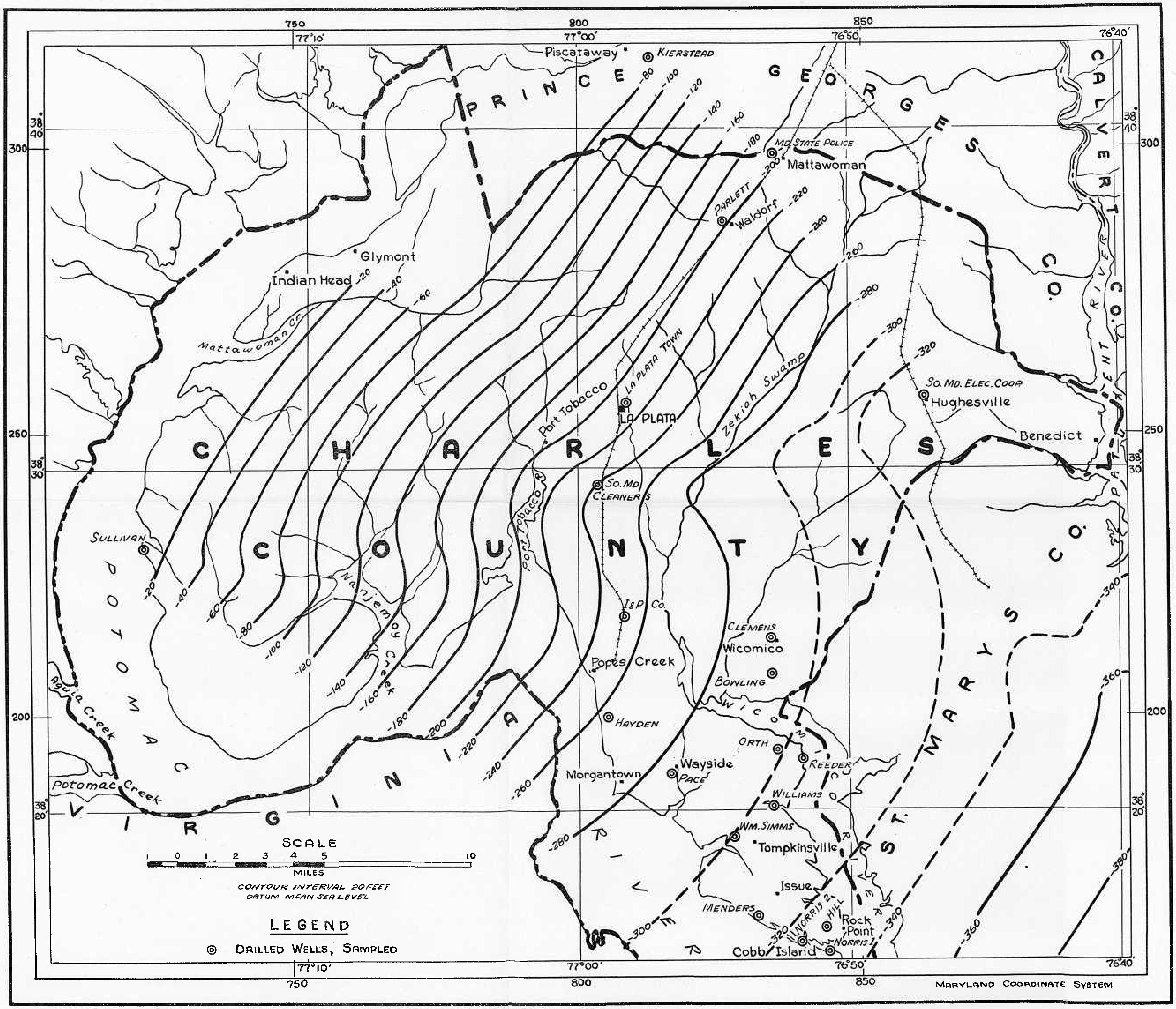

Plate I. Map of Charles County Showing Contours Drawn at Base of the Aquia Formation

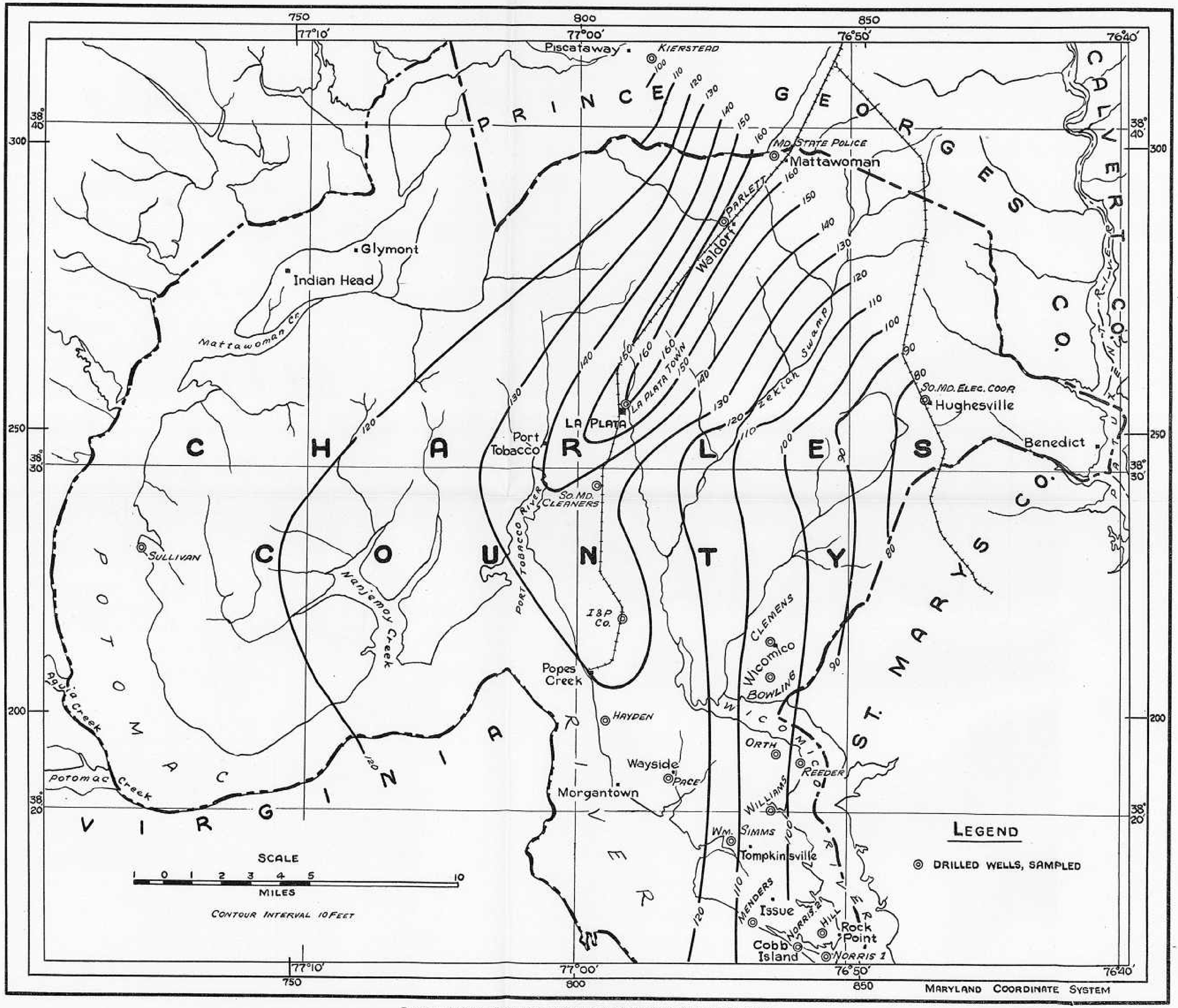

Plate II. Isopach Contour Map Showing the Thickness of the Aquia Formation

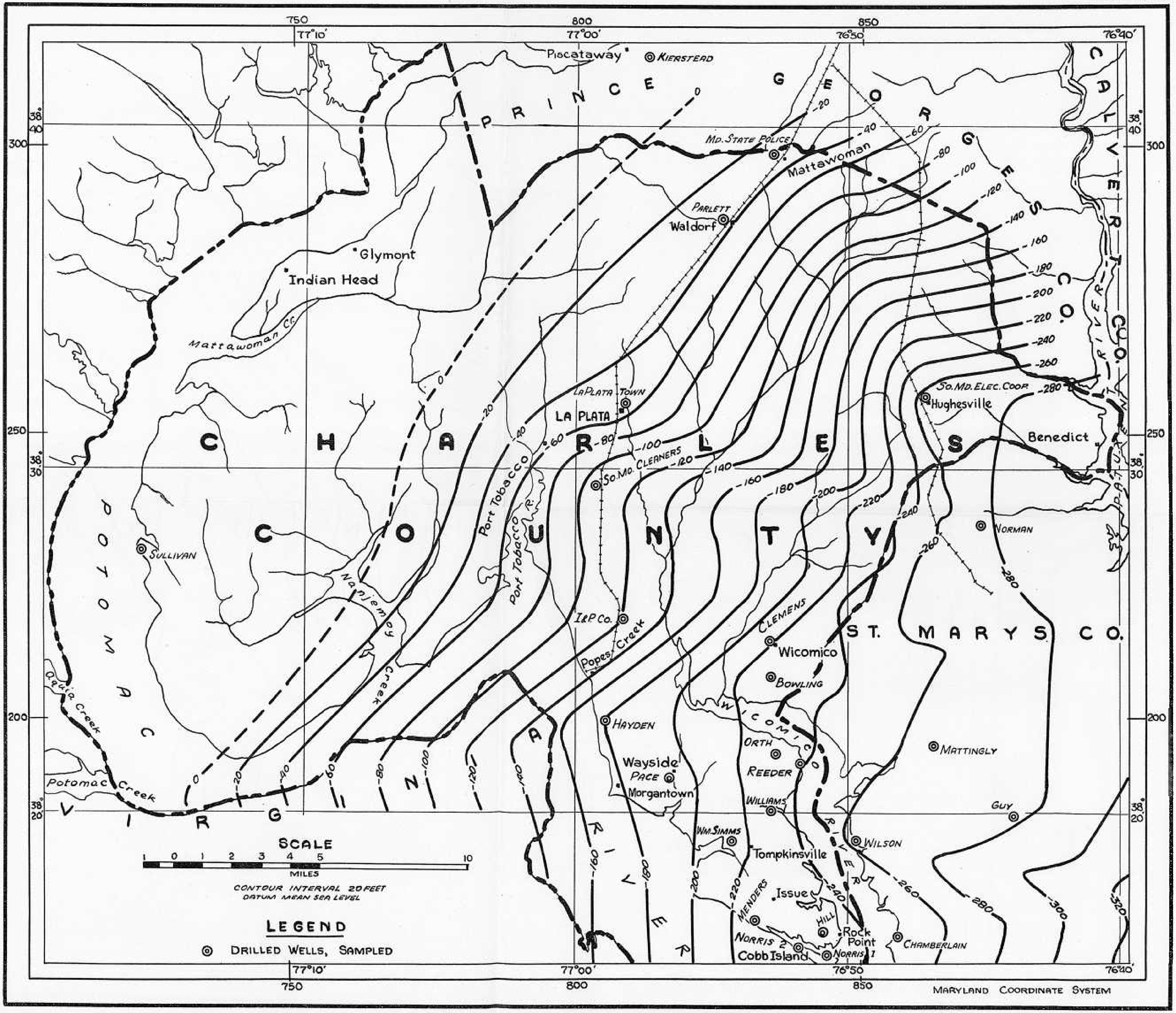

PLATE III. Map of Charles County Showing Contours Drawn at Base of the Nanjemoy Formation

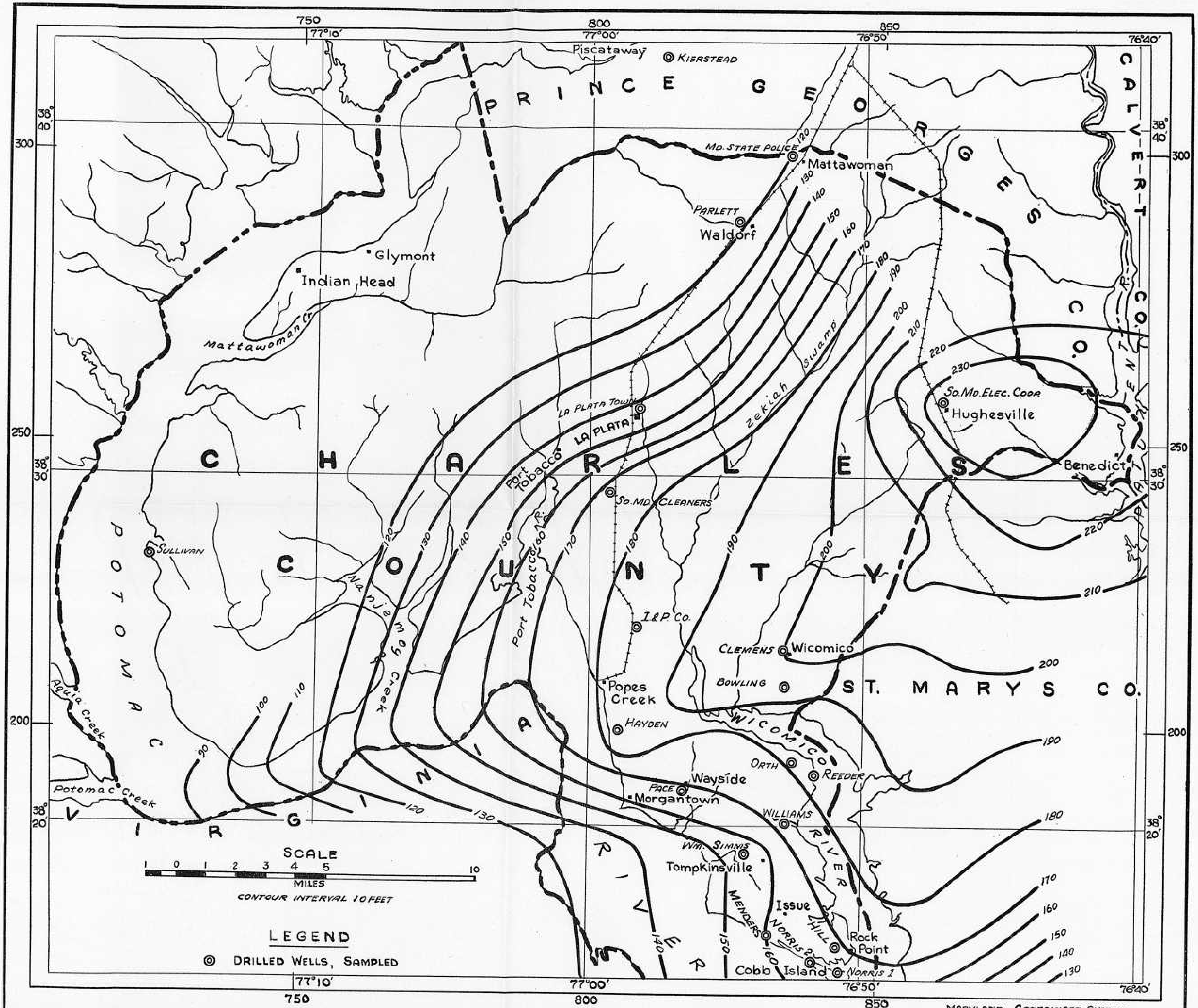

PLATE IV. Isopach Contour Map Showing Thickness of the Nanjemoy Formation

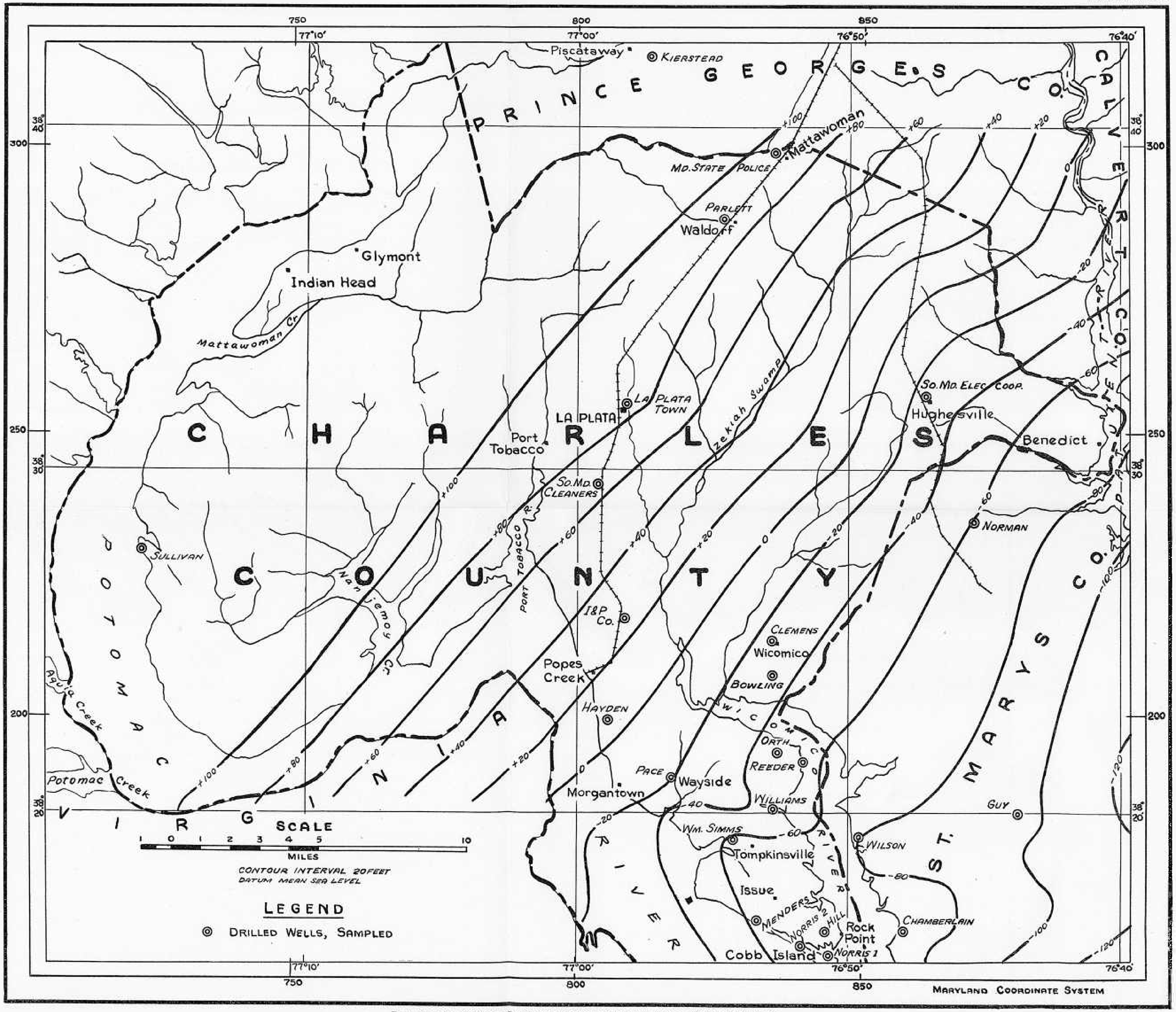

PLATE V. Map of Charles County Showing Contours Drawn at Base of Calvert Formation

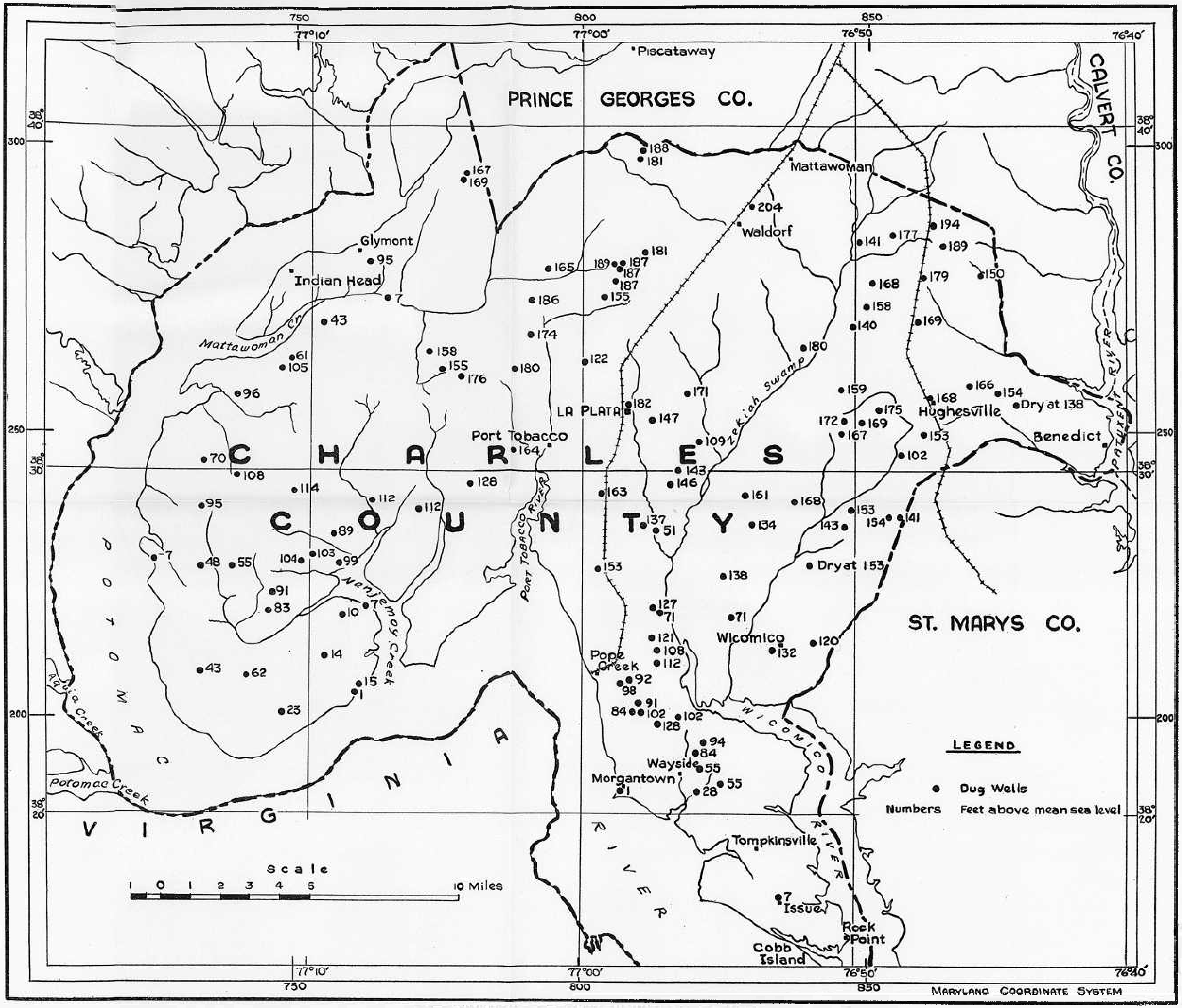

Plate VIII. Map Showing Elevation of Water Table in Selected Dug Wells

CHARLES COUNTY

1948