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HYDROGEOLOGIC FRAMEWORK OF THE VIRGINIA COASTAL PLAIN

By ANDREW A. MENG III *and* JOHN F. HARSH

REGIONAL AQUIFER-SYSTEM ANALYSIS

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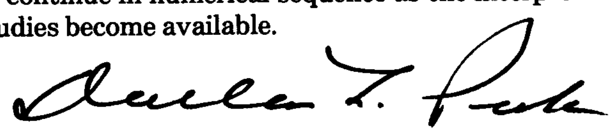
FOREWORD

THE REGIONAL AQUIFER-SYSTEM ANALYSIS PROGRAM

The Regional Aquifer-System Analysis (RASA) Program was started in 1978 following a congressional mandate to develop quantitative appraisals of the major ground-water systems of the United States. The RASA Program represents a systematic effort to study a number of the Nation's most important aquifer systems, which in aggregate underlie much of the country and which represent an important component of the Nation's total water supply. In general, the boundaries of these studies are identified by the hydrologic extent of each system and accordingly transcend the political subdivisions to which investigations have often arbitrarily been limited in the past. The broad objective for each study is to assemble geologic, hydrologic, and geochemical information, to analyze and develop an understanding of the system, and to develop predictive capabilities that will contribute to the effective management of the system. The use of computer simulation is an important element of the RASA studies, both to develop an understanding of the natural, undisturbed hydrologic system and the changes brought about in it by human activities, and to provide a means of predicting the regional effects of future pumping or other stresses.

The final interpretive results of the RASA Program are presented in a series of U.S. Geological Survey Professional Papers that describe the geology, hydrology, and geochemistry of each regional aquifer system. Each study within the RASA Program is assigned a single Professional Paper number, and where the volume of interpretive material warrants, separate topical chapters that consider the principal elements of the investigation may be published. The series of RASA interpretive reports begins with Professional Paper 1400 and thereafter will continue in numerical sequence as the interpretive products of subsequent studies become available.



Dallas L. Peck
Director

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CONVERSION FACTORS

Factors for converting inch-pound units to the International System (SI) of units are given below:

Multiply	By	To obtain
ft (feet)	0.3048	m (meters)
mi (miles)	1.609	km (kilometers)
mi^2 (square miles)	2.590	km^2 (square kilometers)
ft/mi (feet/mile)	0.18943	m/km (meters per kilometers)

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By ANDREW A. MENG III and JOHN F. HARSH

ABSTRACT

This report defines the hydrogeologic framework of the Virginia Coastal Plain and is a product of a comprehensive regional study to define the geology, hydrology, and geochemistry of the northern Atlantic Coastal Plain aquifer system extending from North Carolina to Long Island, New York.

The Virginia Coastal Plain consists of an eastward-thickening wedge of generally unconsolidated, interbedded sands and clays, ranging in age from Early Cretaceous to Holocene. These sediments range in thickness from more than 6,000 feet beneath the northeastern part of the Eastern Shore Peninsula to nearly 0 feet along the Fall Line. Eight confined aquifers, eight confining units, and an uppermost water-table aquifer are delineated as the hydrogeologic framework of the Coastal Plain sediments in Virginia. The nine regional aquifers, from oldest to youngest, are lower, middle, and upper Potomac, Brightseat, Aquia, Chickahominy-Piney Point, St. Marys-Choptank, Yorktown-Eastover, and Columbia. The Brightseat is a newly identified and correlated aquifer of early Paleocene age. This study is one of other, similar studies of the Coastal Plain areas in North Carolina, Maryland-Delaware, New Jersey, and Long Island, New York. These combined studies provide a system of hydrogeologic units that can be identified and correlated throughout the northern Atlantic Coastal Plain.

Data for this study were collected and analyzed from October 1979 to May 1983. The nine aquifers and eight confining units are identified and delineated by use of geophysical logs, drillers' information, and stratigraphic and paleontologic data. By correlating geophysical logs with hydrologic, stratigraphic, and paleontologic data throughout the Coastal Plain, a comprehensive multilayered framework of aquifers and confining units, each with distinct lithologic properties, was developed.

Cross sections show the stratigraphic relationships of aquifers and confining units in the hydrogeologic framework of the Virginia Coastal Plain. Maps show confining-unit thicknesses and altitudes of aquifer tops, provide the basis for assigning aquifers to screened intervals of observation and production wells, and are used for the development of a comprehensive observation-well network in the Virginia Coastal Plain.

INTRODUCTION

In 1977, Congress appropriated funds for a series of ground-water-assessment studies titled the "Regional Aquifer-System Analysis" (RASA) program; this program was designed to identify and evaluate the water resources of major aquifer systems on a regional scale in the United States. In 1979, the U.S. Geological Survey began a comprehensive regional investigation, as part of the RASA program, to define the hydrogeology and geochemistry, and to simulate ground-water flow, in the northern Atlantic Coastal Plain that extends from North Carolina to Long Island, N.Y. (fig. 1). Subsequently, the northern Atlantic Coastal Plain RASA investigation was subdivided into five state-level RASA studies. The Virginia RASA, headquartered in the Virginia Office, Mid-Atlantic District, of the U.S. Geological Survey, was assigned the responsibility of defining a regional hydrogeologic framework and of simulating ground-water flow in the Coastal Plain province of Virginia (fig. 1). This report describes the hydrogeologic framework developed as part of the Virginia RASA study. Companion RASA studies were also conducted for the Coastal Plain areas of North Carolina, Maryland-Delaware, New Jersey, and Long Island, N.Y. (fig. 1). Collectively, these individual studies form a regional system of hydrogeologic units that can be identified and correlated between adjoining States throughout the northern Atlantic Coastal Plain.

PURPOSE AND SCOPE

This report is the result of part of the Virginia RASA study to (1) identify and define the regional hydrogeologic framework of the Coastal Plain sediments of Virginia, and (2) further understand the subsurface Coastal Plain geology and hydrology. The description of the hydrogeologic framework presented herein provides the basis for the RASA modeling study in Virginia.

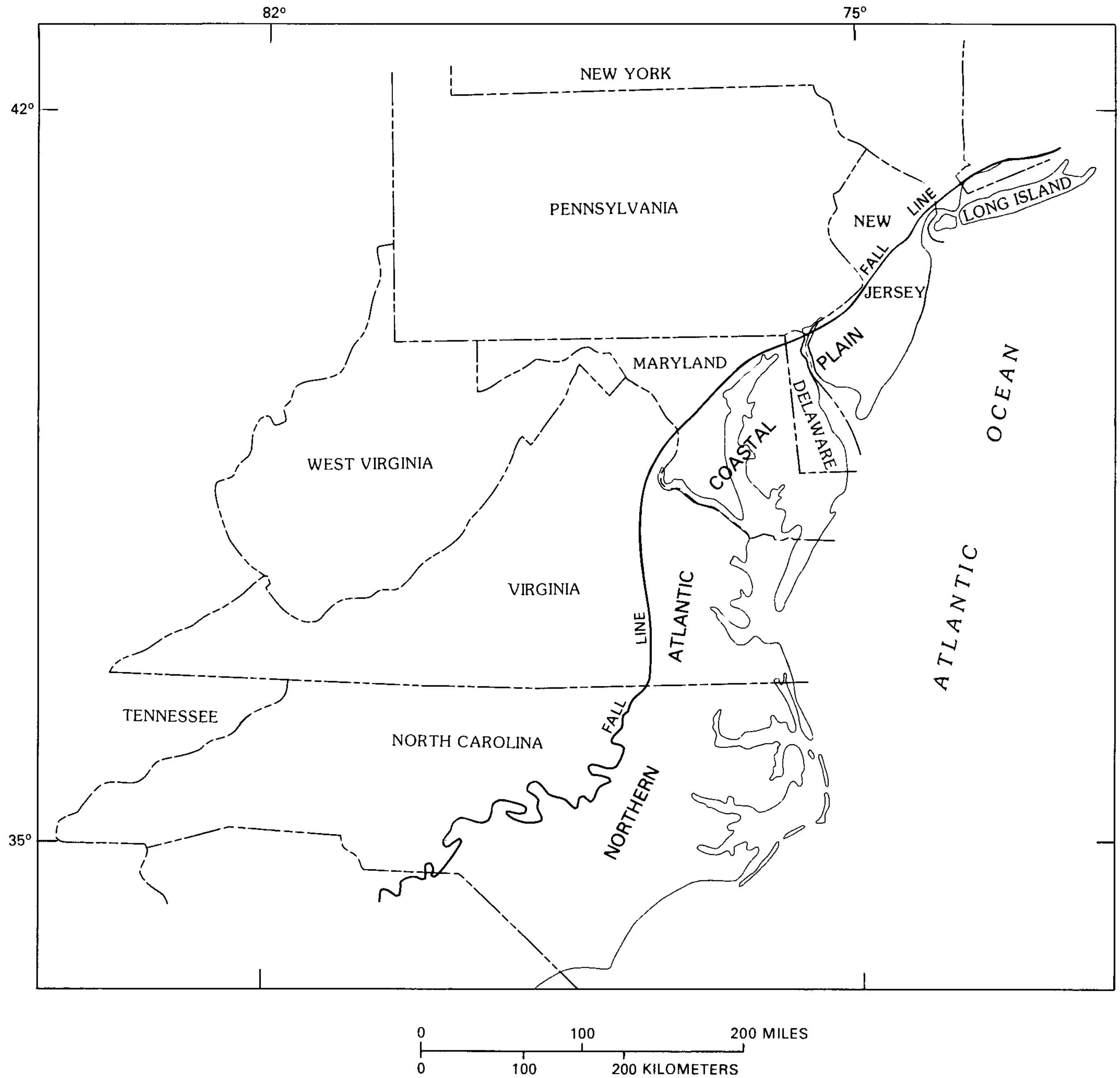

FIGURE 1.—Location of northern Atlantic Coastal Plain.

Specific objectives of this report are to: (1) identify and divide the sediments of the Virginia Coastal Plain into regional hydrogeologic units, (2) delineate and describe the boundaries, stratigraphic relationships, and characteristics of the hydrogeologic units, (3) provide data to construct a digital model to simulate ground-water flow in the Virginia Coastal Plain, and (4) provide data to generate the regional hydrogeologic framework and to construct a regional ground-water flow model of the entire northern Atlantic Coastal Plain from North Carolina to Long Island, N.Y.

The scope of this study is to define a system of hydrogeologic units for the Virginia Coastal Plain that correlates with a regional hydrogeologic framework. The regional hydrogeologic framework is composed of ten aquifers and nine confining units and is based on published literature describing the hydrogeology in the Coastal Plain areas of New Jersey and Maryland. The

Virginia Coastal Plain hydrogeologic units, as presented in this report, have been divided into nine regional aquifers with eight confining units, encompassing nine geochronologic epochs that range in age from Early Cretaceous to Holocene. This hydrogeologic framework correlates areally and hydrologically with units in adjoining States. The hydrogeologic units in the Virginia Coastal Plain are described in terms of age, lithology, stratigraphic position, configuration, areal extent, depositional environment, regional correlations, and their characteristic geophysical log signatures, beginning with the oldest stratigraphic unit and ending with the youngest. Also, the aquifer-unit descriptions briefly refer to the general use and availability of ground water, but a detailed discussion of water supply and water quality is beyond the scope of this report.

LOCATION AND EXTENT

The study area (fig. 2) comprises all of the Coastal Plain physiographic province of Virginia. It encompasses the eastern third of the State and consists of about 13,000 mi^2. The study area is approximately 125 mi wide across the northern section, and 165 mi long along the western section. It is bounded on the west by the Fall Line, a physiographic boundary that separates the Piedmont province from the Coastal Plain province. The Fall Line runs generally north-south near or through the cities of Alexandria, Fredericksburg, Richmond, Petersburg, and Emporia (fig. 2), and closely corresponds to the present route of Interstate 95. The study area is also bounded by Maryland on the north, North Carolina on the south, and by the Atlantic Ocean on the east. For the purpose of this report, the study area is informally divided into five principal geographic regions: the western, central, eastern, northern, and southern. For more precise geographical orientations, the five principal regions are further subdivided into more specific parts, such as the northwestern, north-central, northeastern, west-central, east-central, southwestern, south-central, and southeastern. The above areas and regions are referred to throughout the text so that explanations of the interrelationships and areal extent of the hydrogeologic units can be related to specific parts of the Virginia Coastal Plain.

PREVIOUS INVESTIGATIONS

Many reports describe specific aspects of the geology or ground-water resources in the Coastal Plain of Virginia, but none describe the hydrogeologic framework as a whole. Clark and Miller (1912) provide the first comprehensive view on the geology and physiography of the Coastal Plain in Virginia. Sanford (1913) presents the first integrated view of geology and ground-water resources throughout the Virginia Coastal Plain. Cederstrom (1945a, 1957) describes the hydrogeology of southeastern Virginia and the York-James Peninsula. Sinnott and Tibbitts (1954, 1957, 1968) define the availability of ground water and the uppermost stratigraphy in the Eastern Shore Peninsula of Virginia. The investigation by Brown and others (1972) correlates 17 chronostratigraphic rock units and depicts regional permeability-distribution maps based on the 17 delineated time-rock units for the northern Atlantic Coastal Plain sediments. The Virginia State Water Control Board (1970, 1973, 1974), Siudyla and others (1977, 1981), and Fennema and Newton (1982) present data on ground-water conditions in various county and peninsulawide areas in the Virginia Coastal Plain. A stratigraphic-data report published by the Virginia Division of Mineral Resources (1980) on a U.S. Geological Survey core hole at Oak Grove, Va., supplies invaluable information on subsurface geology in the northwestern part of the Virginia Coastal Plain. Numerous reports prepared by consultants describe the ground-water conditions and potential yields of important aquifers in various parts of the Virginia Coastal Plain, especially the southeastern area. In addition to the information cited above, other important data sources include works by: Cederstrom (1943, 1945b); Richards (1945, 1948, 1967); Spangler and Peterson (1950); Hack (1957); Brenner (1963); Nogan (1964); Drobnyk (1965); Glaser (1969); Hazel (1969); Johnson and Goodwin (1969); Cushing and others (1973); Onuschak (1972); Oaks and Coch (1973); Blackwelder and Ward (1976); Doyle (1977); Doyle and Robbins (1977); Hansen (1978); Blackwelder (1980); Gleason (1980); Ward and Blackwelder (1980); Ward (1980); Meisler (1981); Larson (1981); and Gibson (1982).

METHODS OF STUDY

Data used in this study were collected, analyzed, and interpreted during the period from October 1979 to May 1983. Literature pertinent to the lithology, stratigraphy, and ground-water resources of the study area and the adjoining States was reviewed and synthesized. Water-well and stratigraphic test-hole data consisting of borehole-geophysical logs, drillers' logs, well-completion reports, geologic logs, and paleontologic and core-sample analyses were compiled. This information, together with hydrogeologic interpretations provided by adjoining northern Atlantic Coastal Plain RASA studies, supplies the data used to define the regional hydrogeologic framework of the Virginia Coastal Plain.

Borehole-geophysical logs and drillers' information, supported by pertinent stratigraphic and hydrologic

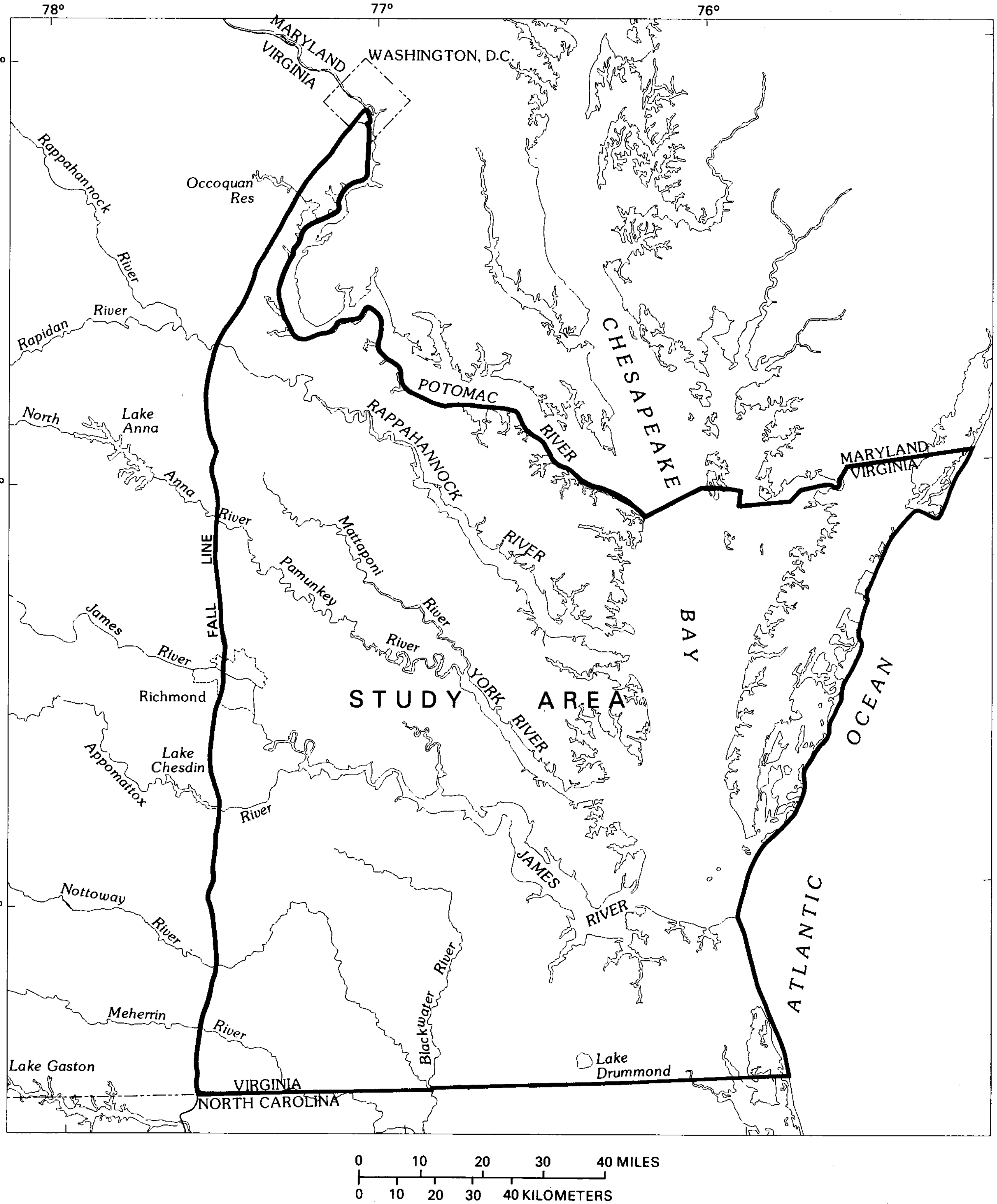

Figure 2.—Location of study area.

data, were used to provide the basis for the identification, correlation, and definition of the areally comprehensive hydrogeologic framework of the Virginia Coastal Plain. Borehole-geophysical logs are a qualitative, graphic representation of the subsurface environment penetrated by drilling. These logs portray a continuous, scaled record of the character of the subsurface sediments, and are used to identify formations and the relative salinity of formation waters. Details on the interpretation, correlation, and application of borehole geophysics to hydrogeologic investigations are given by Keys and MacCary (1971). The types of borehole-geophysical logs most commonly used in this study consist primarily of electric-resistivity and natural-gamma logs. Spontaneous potential (S.P.) and single-point and multipoint electric-resistivity logs identify lithologic contacts, determine gross sand-to-clay ratios in each hydrogeologic unit, and indicate the relative quality of water in the aquifer units. Natural-gamma logs define regional lithologic facies changes in units and dip directions of strata that contain particularly high gamma-emitting lithologies or marker beds. Drillers' information includes sample logs, commonly called drillers' logs or cuttings logs, and well-completion reports. Sample logs describe the physical properties of sediments penetrated during drilling operations. Well-completion reports provide information on depths to screened intervals and water levels in finished wells. Geologic logs provide a detailed, usually microscopic, description and identification of the lithology of cuttings collected from the drilled holes. Paleontologic analyses of cuttings and core samples provide biostratigraphic data on the ages of sediments. Core-sample analyses also provide information on specific lithologic and depositional characteristics of the subsurface sediments not otherwise obtainable from drill cuttings.

Lithologic trends in the type and distribution of sediments are derived by analysis of stratigraphic, borehole, and water-well information. These trends were identified on the basis of stratigraphic and lithologic relationships obtained from different drilled holes over large areas and areally extensive lithologic and geophysical marker units. Log signatures depicting sand lithologies are identified and labeled as aquifers on the geophysical logs; in contrast, log signatures depicting clay lithologies are identified and labeled as confining units (fig. 3). A regional correlation of aquifers and confining units in the Virginia Coastal Plain was developed by comparing geophysical logs and chronostratigraphic and lithostratigraphic units across adjoining State boundaries.

WELL-NUMBERING SYSTEM

The well-numbering system used by the U.S. Geological Survey in Virginia is based on the "Index to Topographic Maps of Virginia" (U.S. Geological Survey, 1978). Topographic map quadrangles covering 7½-min of latitude and longitude, published at a scale of 1:24,000, or 1 in = 2,000 ft, are identified by numbers and letters starting in the southwest corner of the State. The quadrangles are numbered 1 through 69 from west to east beginning at 83°45′ west longitude, and lettered A through Z (omitting letters I and O) from south to north, beginning at 36°30′ north latitude. The area covered by the Coastal Plain includes generally the quadrangles numbered from 50 to 69 containing the letters from A to V. Wells are identified and numbered serially within each 7½-min quadrangle. As an example, figure 4 shows the south-central section of the study area. Well 53A2 is in quadrangle 53A and is the second well in that quadrangle for which the location and other data were recorded by the U.S. Geological Survey. All wells selected as controls for this hydrogeologic framework are listed by increasing well number in the appendix of this report.

ACKNOWLEDGMENTS

Acknowledgment is given to the Bureau of Surveillance and Field Studies and the Tidewater Regional Office of the Virginia State Water Control Board, for furnishing well information, selected stratigraphic cores, and geophysical logs. The authors wish to thank R.L. Magette Co., Gammon Well Co., and Layne-Atlantic Co. for providing single-point electric-resistivity geophysical logs and well data, and to the many drillers in the Virginia Coastal Plain who have supplied valuable information concerning the nature of sediments and their water-bearing properties. Special thanks go to Sydnor Hydrodynamics, Inc. for providing comprehensive well data, multipoint electric-resistivity and natural-gamma geophysical logs, and for their conscientious and continuous efforts in obtaining subsurface hydrogeologic information.

The authors express appreciation to the Virginia Division of Mineral Resources for providing a preliminary revised surficial geologic map of the Virginia Coastal Plain sediments. The authors also wish to convey appreciation to L.W. Ward, L.E. Edwards, R.B. Mixon, J.P. Owens, L. McCarten, and T.G. Gibson, of the U.S. Geological Survey, for providing valuable and timely stratigraphic information and analysis.

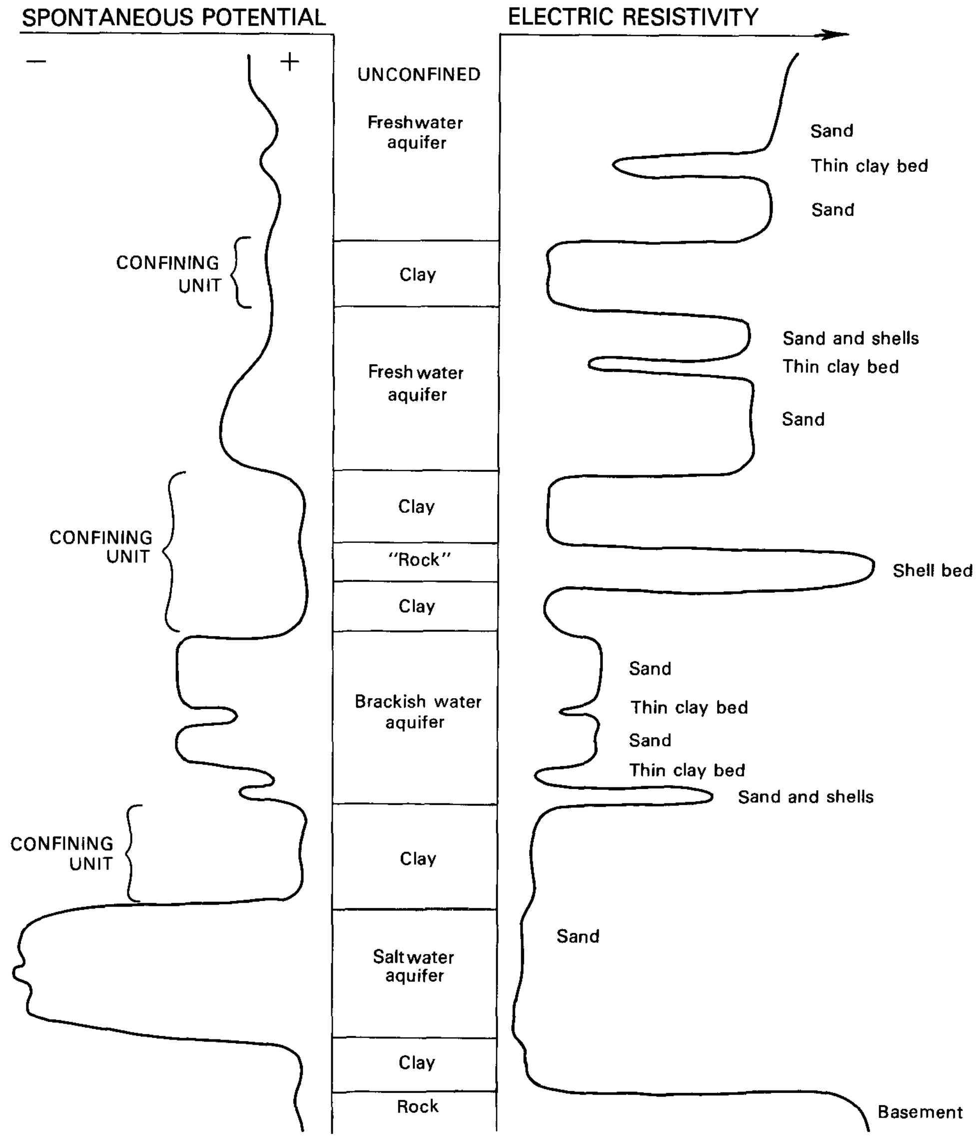

FIGURE 3.—Idealized geophysical log showing aquifers and confining units and characteristic electric and spontaneous potential traces.

GENERAL GEOLOGY

The study area is part of the Atlantic Coastal Plain province that extends from Cape Cod, Mass., southward to the Gulf of Mexico. The Coastal Plain province of Virginia consists of an eastward-thickening sedimentary wedge (fig. 5) composed principally of unconsolidated gravels, sands, silts, and clays, with variable amounts of shells. This sedimentary wedge generally is devoid of hard rocks, although calcareous cementations are present locally, forming thin lithified strata. The unconsolidated deposits rest on a rock surface, referred to as the "basement," that slopes gently eastward. The sediments attain a maximum thickness of over 6,000 ft in the northeastern part of the study area. Onuschak (1972) reports that the sediments are 6,186 ft thick beneath the Eastern Shore Peninsula at Temperanceville, Va. (fig. 5). Coastal Plain sediments thin westward to nearly zero thickness at the Fall Line and are highly dissected by streams throughout the western region. Small, isolated erosional remnants of Coastal Plain deposits are common, just west of the main sedimentary wedge, in the Fall Line area. The surface of the Virginia Coastal Plain consists of a series of broad gently sloping, highly dissected terraces bounded by seaward-facing, ocean-cut escarpments extending generally north-south across the province. Most of the study area is less than 100 ft in altitude and one-fifth is covered by water, principally the Chesapeake Bay. The land surface is highest along the

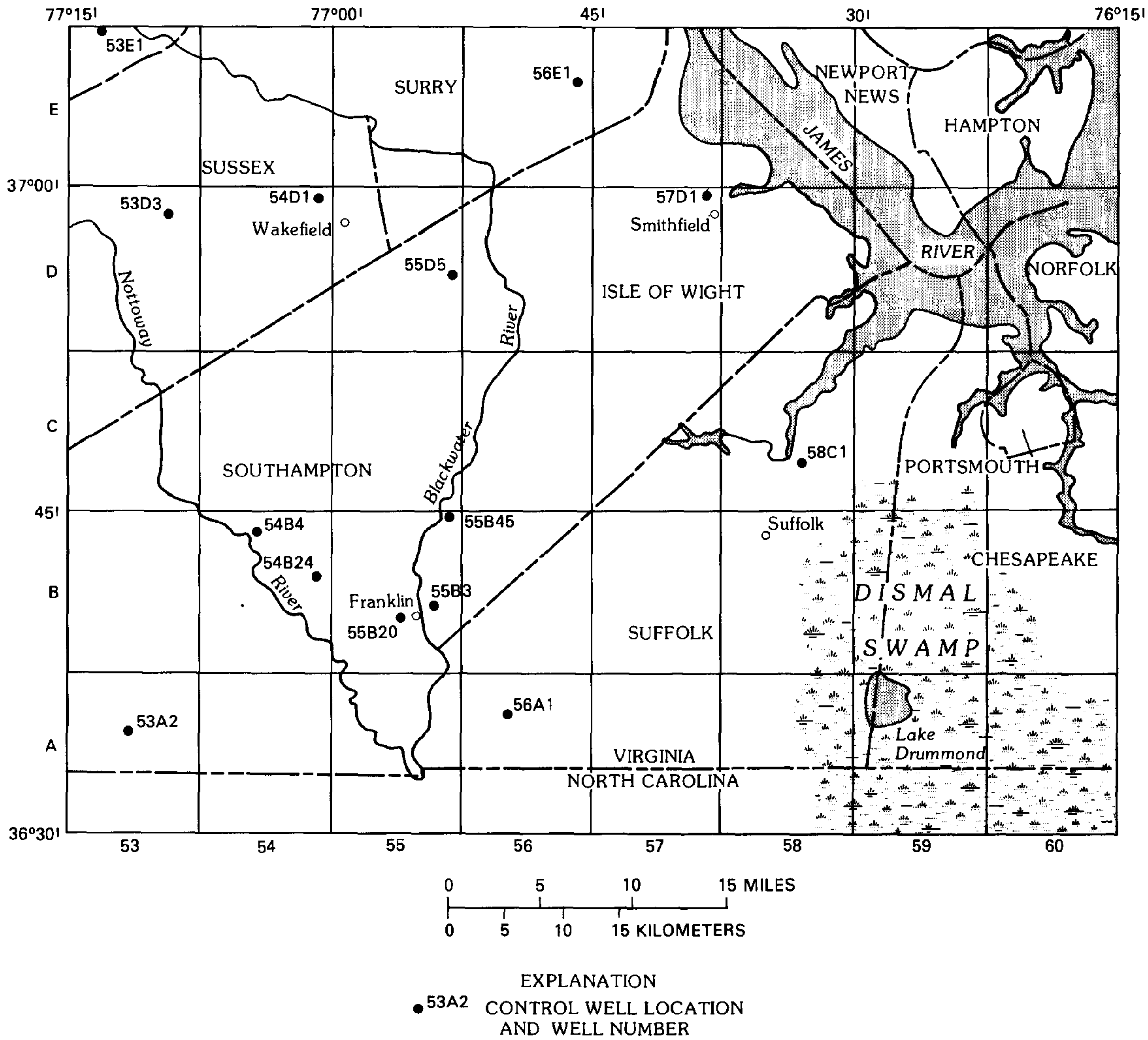

FIGURE 4.–Example of well-numbering system.

Fall Line, especially in the northwestern part of the study area. The sedimentary section, in general, consists of a thick sequence of nonmarine deposits overlain by a much thinner sequence of marine deposits. These deposits are, for the most part, undeformed throughout, except for slight warping and tilting, with associated local faulting. All depositional units strike approximately parallel, or subparallel, to the Fall Line. The average dip of each successively younger depositional unit decreases upward, with the oldest deposits dipping nearly the same as the basement-rock surface (about 40 ft/mi) and the youngest deposits dipping less than 3 ft/mi. Sediments range in age from Early Cretaceous to Holocene, and have a complex history of deposition and erosion.

DEPOSITIONAL HISTORY

Many different depositional environments existed during the formation of the Virginia Coastal Plain. Numerous marine transgressions and regressions, punctuated by varying periods of erosion, produced an assorted, but ordered, array of sediments in the study area. The shoreline has occupied positions far to the east of the present shoreline, as evidenced by offshore submerged Pleistocene barrier beach deposits, and positions at least as far west as the Fall Line, as shown by marine deposits at the Fall Line.

Ages of sediments exposed at the surface within the study area consist of Early Cretaceous, Paleocene, Eocene, Oligocene, Miocene, Pliocene, Pleistocene, and

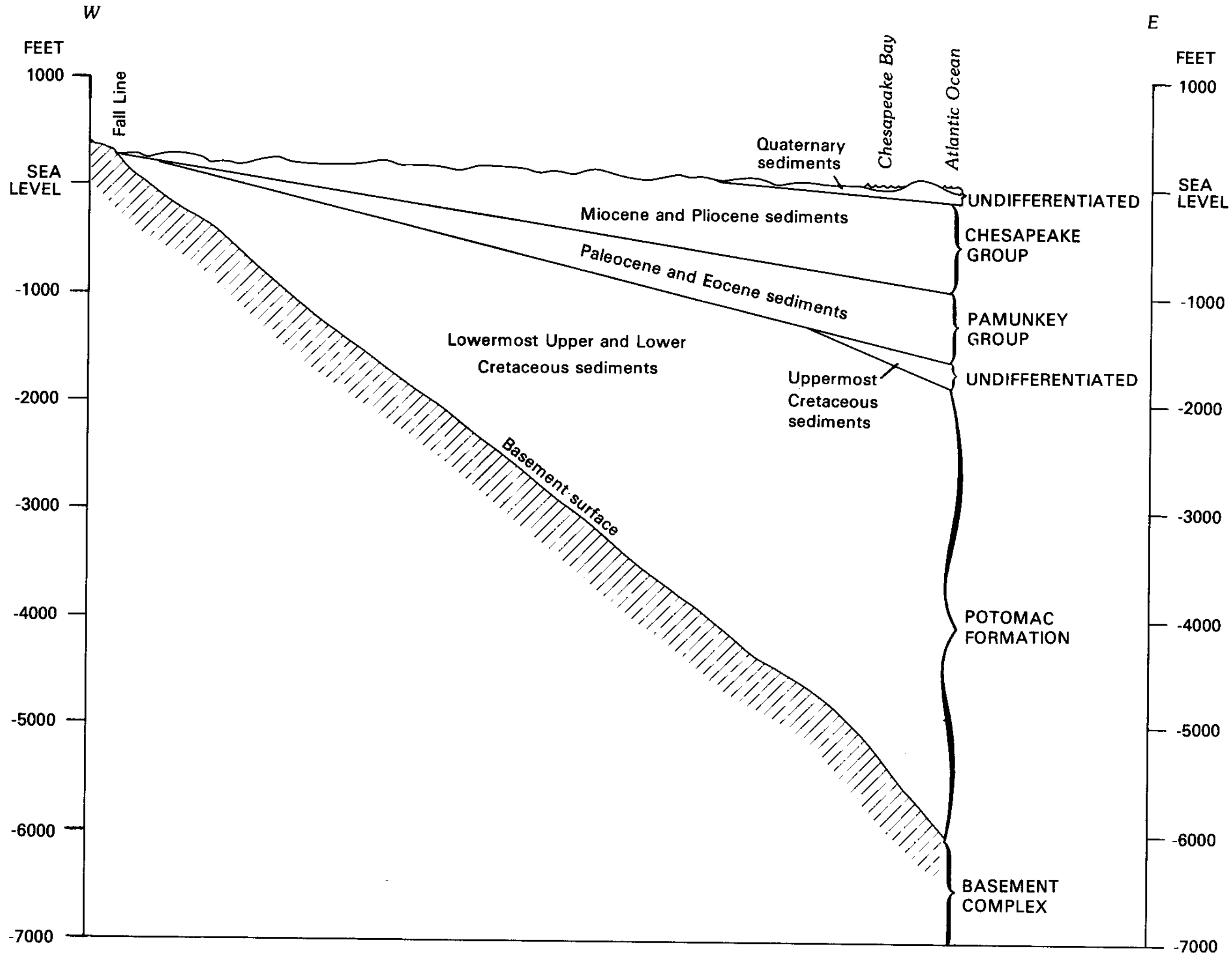

FIGURE 5.–Generalized geologic section showing eastward-thickening sedimentary wedge of Virginia Coastal Plain.

Holocene. Sediments of Late Cretaceous age are overlain by younger sediments and are not exposed at the surface in the study area. Sediments of Early Cretaceous and Paleocene age crop out extensively between the Fall Line and the Potomac River in the northwestern part of the study area. Sediments of Eocene, Oligocene, and Miocene age are exposed principally along the major stream valleys throughout the western and central regions of the study area. The uppermost sediments of Pliocene, Pleistocene, and Holocene age crop out extensively in broad areas throughout the eastern and southern regions, and, to a lesser extent, in the central and north-central parts of the study area. The Coastal Plain deposits of Virginia can be divided into five principal lithostratigraphic groups based primarily on their mode of deposition. These five groups, from oldest to youngest, are (1) Lower Cretaceous and lowermost part of the Upper Cretaceous Potomac Formation, (2) uppermost Cretaceous deposits, (3) lower Tertiary Pamunkey Group, (4) upper Tertiary Chesapeake Group, and (5) Quaternary sediments, undifferentiated.

Throughout the Early Cretaceous, the land area now comprising the study area was elevated in relation to sea level, and thick sequences of fluvial-deltaic continental and marginal marine sediments were deposited on a broad rock surface. These sediments, at first, were deposited by high-gradient streams, which formed large subaerial deltas that prograded into the Cretaceous seas. As the deltas developed, the depositional pattern gradually changed to a lower-gradient, subaqueous environment throughout the latter half of the Early Cretaceous. Early in the Late Cretaceous, the first major marine transgression occurred, which inundated the eastern half of the study area with shallow seas and broad estuaries. A marine regression soon followed that resulted in a long period of nondeposition which lasted throughout most of the remaining Late Cretaceous. Toward the end of the Late Cretaceous, marine seas once again transgressed into the study area, but only marginally along the northeastern and southeastern sections, where a very thin veneer of clays, sandy clays, and marls was deposited. Throughout the following Tertiary period, interbasinal marine seas covered the study area to varying degrees and deposited relatively thin, but areally extensive, sediments that consisted primarily of glauconite, diatoms, sands, silts, clays, and shells. These Tertiary marine deposits represent two major lithologically distinct groups: the glauconitic sands, silts, and clays of the Pamunkey Group; and the shelly clays, silts, and sandy clays of the Chesapeake Group. Sediments of Quaternary age overlie much of the Tertiary deposits. These sediments include fluvial and marine deposits that reflect Pleistocene sea-level fluctuations.

STRUCTURAL SETTING

Crustal deformation along the Atlantic continental margin has produced the regionally downwarped Atlantic Coastal Plain province and the adjoining regionally uplifted Piedmont province. Weathered rock debris eroded from the uplifted areas was transported and deposited into the downwarped areas as Coastal Plain sediments. The Coastal Plain's thin western edge, defined by the Fall Line, marks the limit of the unconsolidated sediments overlapping onto the crystalline rocks of the Piedmont highlands. The Coastal Plain sediments thicken and extend eastward to the submerged margin of the Continental Shelf approximately 65 mi offshore of Virginia. Within the regionally downwarped area, local differential subsidence produced a series of structural highs and lows, commonly referred to as arches and embayments (basins). Thick accumulations of sediments were deposited within the embayments, with thinner accumulations over the arches. The arches, in effect, separated each of the basins, and together with other environmental factors, produced basins with characteristic depositional sequences. Deposition in the Virginia Coastal Plain was affected by three major structural deformation features. These structural features are, from north to south, the Salisbury embayment, the Norfolk arch, and the Albemarle embayment (fig. 6).

The Coastal Plain of northern and central Virginia forms the southern flank of the Salisbury embayment (Richards, 1948)—an eastward-plunging, open-ended sedimentary basin with an axis that trends across southern Maryland. Structure contours of the top of the basement rocks (fig. 6) bend noticeably toward the northwest as they approach the axis of the Salisbury embayment.

This structural low has had a pronounced influence on the deposition of sediments throughout the northern and central sections of the study area. Lower Cretaceous fluvial-deltaic deposits thicken considerably toward the axis of the embayment; Glaser (1968) reports that more than 70 percent of the sedimentary section in southern Maryland and northern Virginia is composed of Lower Cretaceous sediments. Lower to middle Tertiary marine deposits also thicken toward the axis of the embayment in this area, but the uppermost Tertiary marine and overlying Quaternary fluvial and marine deposits seem not to be affected by the embayment structure.

In contrast to the structural low that flanks the northern and central sections, a structural high is located midway in the southern section of the study area. This structural high was originally termed the "Fort Monroe High," by Richards and Straley (1953), and now is more commonly referred to as the "Norfolk arch" (Gibson, 1967). The axis of this structural high dips gently eastward beneath the Coastal Plain sediments (fig. 6). This arch has had a strong control on the deposition of some sediments in the southern part of the study area. Stratigraphic evidence indicates that the Norfolk arch was most active throughout Late Cretaceous and Paleogene time (J.P. Owens, U.S. Geological Survey, oral commun., 1983). Generally, the sediments thin drastically as they approach the arch from both the north and south, and some sediments are missing from the area because of nondeposition or erosion. Like the Salisbury embayment, this arch has not noticeably affected the deposition of upper Tertiary marine and Quaternary fluvial and marine deposits.

The Norfolk arch separates two distinct sedimentary basins that are characterized by their Paleogene deposits—the glauconite-rich Salisbury embayment to the north from the limestone-rich Albemarle embayment to the south. The arch is probably the controlling structural feature responsible for the general lack of limestone-type deposits in the Coastal Plain areas to the north. Being relatively higher than the surrounding basinal areas, this arch modified the depositional environment to the south and restricted the northward migration of southern limestone-depositing seas across the arch. Generally, the sediments north of the arch dip to the northeast and sediments south of the arch dip to the southeast into basinal lows.

South of the Norfolk arch, deposition in the Virginia Coastal Plain was influenced by yet another basement low in central North Carolina, named the "Albemarle Embayment" by Straley and Richards (1950). This embayment, also referred to as the "Hatteras Low" by Johnson and Straley (1953), is a broad, open-ended sedimentary basin that dips gently eastward. The south flank of the Norfolk arch is the northern limit of the limestone-rich Albemarle embayment. Sediments in the

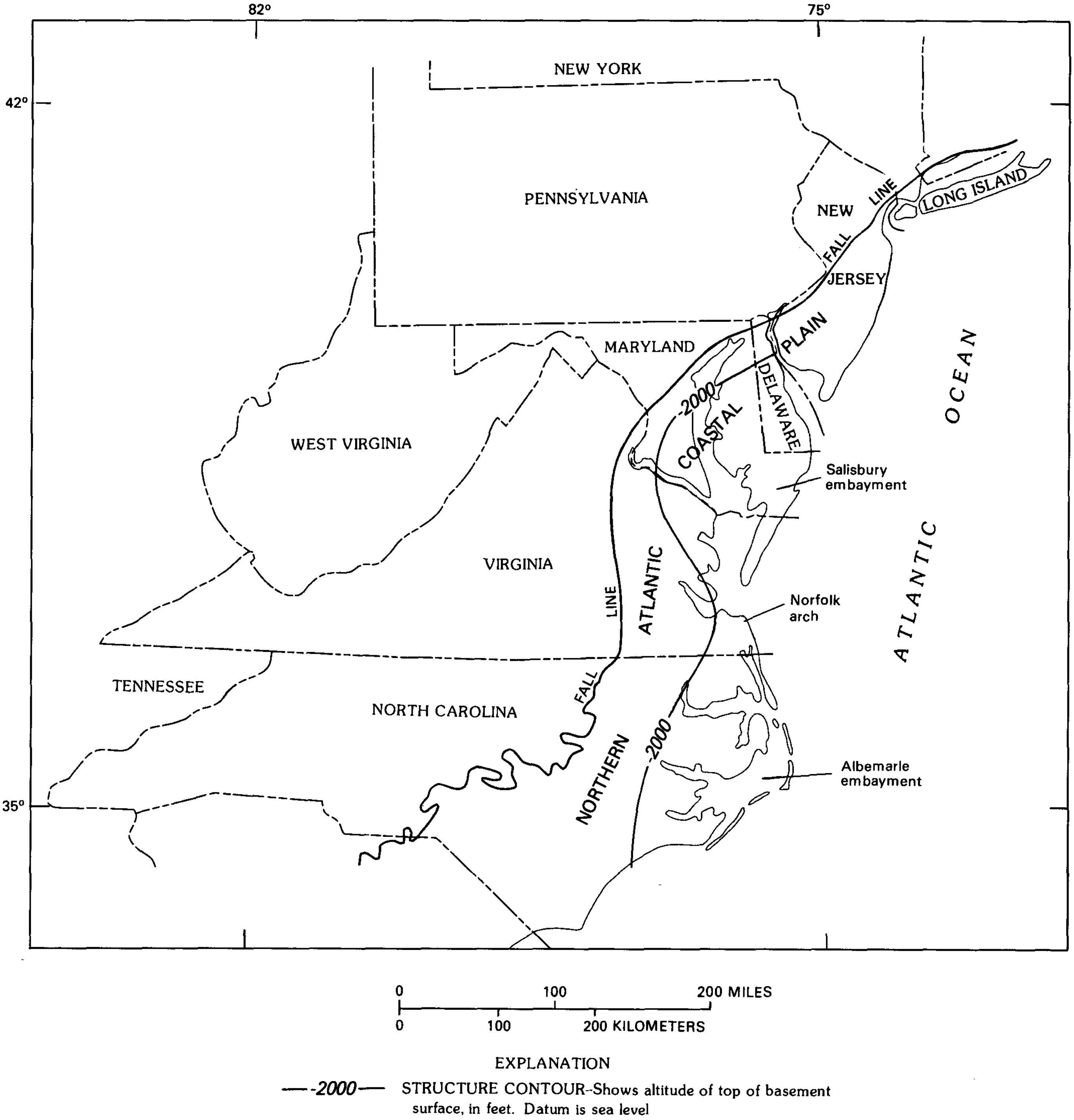

FIGURE 6.—Major structural basement-deformation features of the Virginia Coastal Plain and adjoining areas.

lowermost part of the study area (south of the structural basement high) are generally much finer grained than sediments to the north. In this area, limestone stringers and limy-matrix deposits of Paleogene age are common. These limy deposits become more numerous and thicker in the northern North Carolina Coastal Plain (M.D. Winner, Jr., U.S. Geological Survey, oral commun., 1982), and eventually thicken into the extensive limestone beds of Eocene, Oligocene, and Miocene age in the central North Carolina Coastal Plain.

HYDROGEOLOGIC FRAMEWORK

The regional hydrogeologic framework described in this report identifies and delineates eight major confined aquifers, eight major confining units, and an uppermost water-table aquifer. Recognition of the nine aquifers and eight confining units is based on lithologic and hydrologic characteristics of geologic formations, and is supported by analysis of water-level data. Hydrogeologic units are defined on the basis of their water-bearing properties and not necessarily on stratigraphic boundaries. A formation may contain more than one hydrogeologic unit, or may be an aquifer in one area and a confining unit in another. Therefore, the hydrogeologic units commonly consist of combinations or divisions of geologic formations.

The hydrogeologic names of aquifers and confining units used in this report are based on the name of the predominant geologic formation, or formations, that comprise each unit. Geologic names are used so that a clear and concise relationship is developed between stratigraphic formations and their hydrologic properties. With this geologically orientated nomenclature, the hydrogeologic unit name will immediately indicate a qualitative description and relative position to those familiar with Virginia Coastal Plain stratigraphy. For those not familiar with the Virginia Coastal Plain, each hydrogeologic unit is described in the following sections of this report and delineated on maps and hydrogeologic sections following the text of this report. Regional correlations of hydrogeologic units in the Virginia Coastal Plain with those in adjoining States are included in the description of each aquifer and confining unit based on written and oral communications with D.A. Vroblesky (U.S. Geological Survey, 1984) in Maryland and M.E. Winner (U.S. Geological Survey, 1984) in North Carolina. The correlative aquifer- and confining-unit names in adjoining States are terms applied by the RASA studies in the respective States and usually reflect the name of the predominant geologic formation, or formations, that compose each aquifer unit. However, the correlative confining-unit names in North Carolina were not given hydrogeologic names, as was done for the Virginia Coastal Plain. Rather, these correlative confining units in North Carolina are simply denoted as "the confining unit overlying . . ." a particular aquifer.

For the purposes of continuity and clarity, only one set of geologic names is used throughout the study area, even though the study area includes parts of two distinct sedimentary-basin systems—the Salisbury and Albemarle embayments. The geologic formations that developed within the Salisbury basin are the predominant depositional units throughout most of the study area; therefore, these formation names are used. The much smaller, lowermost part of the study area, in which sediment depositional history was controlled primarily by the Albemarle basin system, is similar in deposition and stratigraphy to the study area to the north, and, therefore, these units are denoted accordingly.

The regional hydrogeologic units identified in this study and the corresponding hydrogeologic units of adjoining RASA studies are illustrated on plate 1. Also illustrated are diagnostic and correlative ages, stages, pollen zones, corresponding group names and formation names, lithologies, origins, and areal distribution of each framework unit, together with a combined, idealized, single-point electric-resistivity and lithologic log representative of the total hydrogeologic section. This plate provides a quick reference for the characteristics and correlations associated with the regional hydrogeologic units identified throughout the Virginia Coastal Plain. Table 1 provides an overview of significant Virginia Coastal Plain stratigraphic nomenclature, from a review of present and past literature, relative to the hydrogeologic units identified in this study and the corresponding modeling units used in the ground-water flow model developed under the Virginia RASA study (Harsh and Laczniak, 1983, p. 592).

Stratigraphic test-well and water-well data from more than 600 sites throughout the study area were compiled, analyzed, and interpreted. Of these, 185 control wells were selected as being representative of the hydrogeologic framework of the Virginia Coastal Plain. Control-well identifiers and their locations are shown in figure 7 together with the lines of hydrogeologic sections (pls. 2–4) that were developed to illustrate the stratigraphic relationships of the hydrogeologic units. These control wells were selected on the basis of location and quality of the geophysical, hydrologic, and stratigraphic data.

Stratigraphic- and geophysical-log data necessary for the identification and correlation of each hydrogeologic unit are not available for some parts of the study area. Generally, the areas from the western shore of the Chesapeake Bay to the Fall Line, and south of the James River, contain the most complete data required for hydrogeologic correlations. In areas where data are not available, or where borehole information does not extend deeply enough, hydrogeologic units are correlated by projecting dips of the units from known data points, commonly from the updip sections, into those areas that lack sufficient data (Hansen, 1969b). Two major areas that commonly lack data are the Chesapeake Bay and the Eastern Shore Peninsula.

Hydrogeologic correlations of the lower hydrogeologic units beneath the Chesapeake Bay are, for the most part, approximate due to the general lack of borehole

TABLE 1.—*Significant stratigraphic nomenclature in relation to hydrogeologic framework*

PERIOD	EPOCH	AGE	Group	STRATIGRAPHIC FORMATION	VIRGINIA RASA HYDROGEOLOGIC UNIT
QUATERNARY	HOLOCENE	POST-GLACIAL		Holocene deposits	Columbia aquifer
	PLEISTOCENE	WISCONSIN TO NEBRASKAN		Pleistocene undifferentiated deposits	
TERTIARY	PLIOCENE	PIACENZIAN		Bacons Castle Formation (Oaks and Coch, 1973)	Yorktown confining unit
		ZANCLEAN	Chesapeake Group	Yorktown Formation	Yorktown-Eastover aquifer
	MIOCENE	MESSINIAN		Eastover Formation	
		TORTONIAN			
		SERRAVALLIAN		St. Marys Formation	St. Marys confining unit
				Choptank Formation	St. Marys-Choptank aquifer
		LANGHIAN		Calvert Formation	Calvert confining unit
		BURDIGALIAN			
		AQUITANIAN		Old Church Formation	Chickahominy-Piney Point aquifer
	OLIGOCENE	CHICKASAWHAYAN[1]		Not present in study area	
		VICKSBURGIAN[1]			
	EOCENE	JACKSONIAN[1]	Pamunkey Group	Chickahominy Formation	Chickahominy-Piney Point aquifer
		CLAIBORNIAN[1]		Piney Point Formation	
		SABINIAN[1]		Nanjemoy Formation	Nanjemoy-Marlboro clay confining unit
	PALEOCENE			Marlboro clay	
		MIDWAYAN[1]		Aquia Formation	Aquia aquifer
				Brightseat Formation	Brightseat confining unit
					Brightseat aquifer
CRETACEOUS	LATE CRETACEOUS	MAASTRICHTIAN		Undifferentiated sediments	Upper Potomac confining unit
		CAMPANIAN			
		SANTONIAN			
		CONIACIAN			
		TURONIAN			
		CENOMANIAN		Potomac Formation	Upper Potomac aquifer
	EARLY CRETACEOUS	ALBIAN			Middle Potomac confining unit
					Middle Potomac aquifer
		APTIAN			Lower Potomac confining unit
		BARREMIAN			
		HAUTERIVIAN			Lower Potomac aquifer
		VALANGINIAN			
		BERRIASIAN			

[1]Commonly used ages in Atlantic Coastal Plain province

units and modeling units of the Virginia Coastal Plain RASA study

VIRGINIA RASA MODEL UNIT	RADER 1983	TEIFKE 1973	CEDERSTROM 1957	CLARK AND MILLER 1912	BROWN, MILLER, AND SWAIN 1972
AQ10	Alluvial deposits Tabb Formation Norfolk Formation Windsor Formation	Columbia Group	Columbia Group	Columbia Group: Talbot Formation —?———?— Wicomico Formation —?———?— Sunderland Formation	Rocks of post Miocene age
CU9	Chesapeake Group: Bacons Castle Formation	Columbia Group		Lafayette Formation	Rocks of post Miocene age
AQ9	Chesapeake Group: Yorktown Formation and Eastover Formation (undifferentiated)	Columbia Group		Lafayette Formation	Rocks of post Miocene age
CU8	Chesapeake Group: Yorktown Formation and Eastover Formation (undifferentiated)	Yorktown Formation	Chesapeake Group: Yorktown Formation —?———?—	Chesapeake Group: Yorktown Formation —?———?—	Rocks of late Miocene age
AQ8	Chesapeake Group: St. Marys Formation, Choptank Formation, and Calvert Formation (undifferentiated)	Yorktown Formation	Chesapeake Group: St. Marys Formation —?———?—	Chesapeake Group: St. Marys Formation —?———?—	Rocks of middle Miocene age
CU7	Chesapeake Group: St. Marys Formation, Choptank Formation, and Calvert Formation (undifferentiated)	Calvert Formation	Chesapeake Group: Calvert Formation	Chesapeake Group: Calvert Formation	Rocks of middle Miocene age
AQ7					
AQ7	Pamunkey Group: Nanjemoy Formation	Calvert Formation (continued)	Chickahominy Formation Nanjemoy Formation	Pamunkey Group: Nanjemoy Formation	Rocks of Jackson age Rocks of Claiborne age
CU6	Pamunkey Group: Nanjemoy Formation Marlboro clay	Nanjemoy Formation	—?———?— Aquia Formation	Pamunkey Group: —?———?— Aquia aquifer	Rocks of Sabine age
AQ6	Pamunkey Group: Aquia Formation	Mattaponi Formation	Mattaponi Formation		Rocks of Sabine age Rocks of Midway age
CU3	Brightseat Formation	Mattaponi Formation	Mattaponi Formation		Rocks of Midway age
AQ3		Mattaponi Formation	Mattaponi Formation		Rocks of Midway age
CU3	Unit A Unit B Unit C Unit D	Mattaponi Formation	Mattaponi Formation		Rocks of unit A Rocks of unit B Rocks of unit C Rocks of unit D
AQ3	Unit E	"Transitional beds"	—?———?— Potomac Group		Rocks of unit E
CU2	Unit F	Patuxent Formation	Potomac Group	Potomac Group: Patapsco Formation	Rocks of unit F
AQ2	Unit F Unit G	Patuxent Formation	Potomac Group	Potomac Group: Patapsco Formation —?———?—	Rocks of unit F Rocks of unit G
CU1	Unit H	Patuxent Formation	Potomac Group	Potomac Group: Patuxent Formation	Rocks of unit H
AQ1	Unit H	Patuxent Formation	Potomac Group	Potomac Group: Patuxent Formation	Rocks of unit H

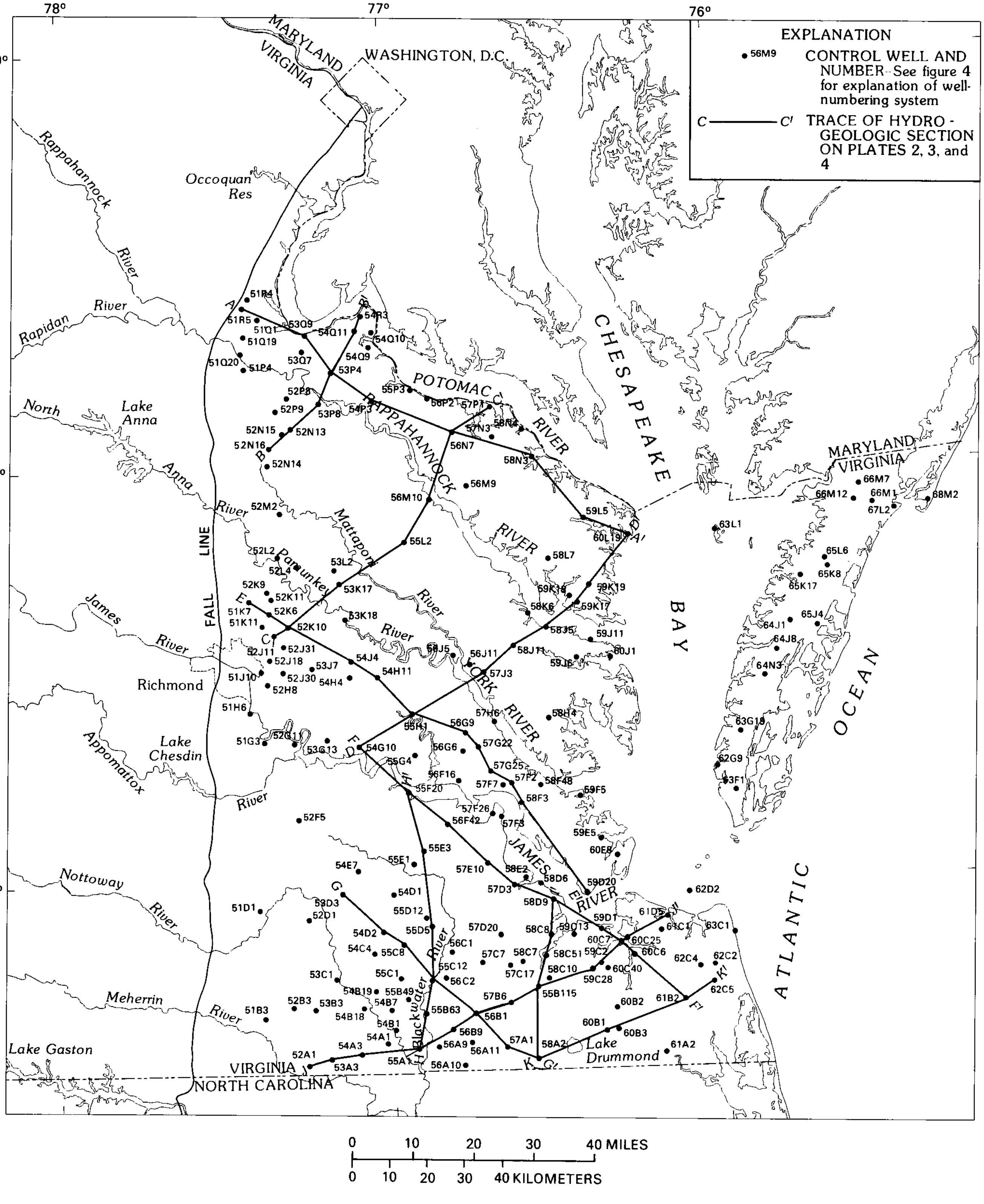

FIGURE 7.—Location of control wells, well numbers, and lines of hydrogeologic sections.

information. There are no wells that extend to the basement in this area. Water wells located on Tangier Island (63L1, fig. 7) and the water-test well (62D2, fig. 7) located at milemarker 3.7 on the Chesapeake Bay Bridge-Tunnel provide only partial borehole information to depths of 1,000 ft and 1,500 ft, respectively. The uppermost hydrogeologic units beneath the Chesapeake Bay and its tributaries were studied in detail because of interest in the erosional effects induced by sea-level lowering during Pleistocene glaciations. This erosion created deeply incised stream channels in the Coastal Plain sediments (Hack, 1957; Harrison and others, 1965), which caused a disruption in aquifer and confining-unit continuity and a change in the distribution of hydraulic heads within the affected aquifers.

The hydrogeology of the sediments beneath the Eastern Shore Peninsula has been previously investigated to a depth of approximately 450 ft (Sinnott and Tibbitts, 1954, 1957, 1968; Fennema and Newton, 1982). This area has only three wells—the J&J Taylor oil-test well, the Coast Guard Cobb Island well, and the New York, Philadelphia, and Norfolk Railroad Co. well—which were drilled to 1,000 ft or greater. Only the J&J Taylor well (66M1, fig. 7) has either geophysical and geologic information available for analysis. The general lack of deeper hydrogeologic data throughout the Eastern Shore Peninsula area makes correlations of most hydrogeologic units only tentative south of well 66M1.

The information obtained from the interpretation and correlation of geophysical logs, as illustrated in the hydrogeologic sections, was then used to construct sets of hydrogeologic unit maps (figs. 8–24) delineating thicknesses of confining units and altitudes of aquifer tops. For the most part, the hydrogeologic sections and maps can be used to determine the relative positions of, and depths to, the major aquifers and confining units. However, these hydrogeologic sections and maps are to be used only as a guide, and, because of the variable nature of subsurface sediments, should not be a substitute for test-hole drilling, especially in areas where data are sparse. Outcrop areas of the geologic formation, or formations, that form hydrogeologic units are illustrated on the Geologic Map of Virginia (Milici and others, 1963). It is important to note that, in many cases, the hydrogeologic units constitute only the sandy or clayey facies of specific geologic formations and, therefore, represent an undefined part of the geologic outcrop areas.

Identification of each hydrogeologic unit is based on biostratigraphic and lithostratigraphic analysis obtained from literature describing outcrops, core samples, and (or) cuttings. A test hole (well 58H4, fig. 7) was drilled, in cooperation with the Virginia State Water Control Board's Bureau of Surveillance and Field Studies, to obtain stratigraphic and hydrologic data by analyses of core samples, cuttings, water-level measurements, water samples, and geophysical logs. Correlation and delineation of the identified hydrogeologic units are based on compiled data in combination with the interpretation of geophysical logs, drillers' logs, and water-level data.

BASEMENT COMPLEX

The basement, which is overlain unconformably by the unconsolidated deposits of the Virginia Coastal Plain, generally consists of a gently eastward-dipping erosional surface of warped, crystalline rocks (fig. 8). This basement rock emerges along the Fall Line and extends westward forming the Piedmont province. The exposed Piedmont complex consists mainly of massive igneous and highly deformed metamorphic rocks that range in age from Precambrian to Lower Paleozoic (Milici and others, 1963), but also includes unmetamorphosed, consolidated sediments and igneous intrusives of probable Triassic age within isolated grabens and half grabens (fig. 8). It seems reasonable to assume that basement rocks underlying the Coastal Plain in Virginia are similar to the adjacent exposed rocks of the Piedmont terrain. It should be noted that evidence is conflicting (Brown and others, 1972; Doyle and Robbins, 1977) concerning the presence of consolidated Jurassic sediments within the study area. If, in fact, these consolidated sediments are present, they would be considered as part of the basement complex.

The slope of the basement-rock surface ranges from 50 to 100 ft/mi near the Fall Line; the slope then decreases to about 40 ft/mi to the Atlantic Coast (fig. 8). Data from wells that penetrate basement rock in the Coastal Plain (fig. 8) indicate an irregular, undulating surface composed of the aforementioned variable lithologies. Many authors document these irregularities in the basement surface beneath the Coastal Plain and suggest various origins. Cederstrom (1945b) interprets many of the local steep-sided basement features common throughout the Coastal Plain to be stream-cut channels and erosional scarps. Other studies, however, (Minard and others, 1974; Mixon and Newell, 1977) suggest that major breaks in slope of the basement surface can be attributed more to faulting and warping than to erosion. In wells that penetrate the basement, drillers' logs indicate that a saprolitic mantle overlies the basement surface in many places, which suggests that not all of the underlying basement surface was eroded. The basement surface forms the basal limit of the study area and is overlain principally by sediments of the lower Potomac aquifer. The basement surface is overlain by younger-age deposits only near the Fall Line.