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CRETACEOUS AND TERTIARY SECTION, DEEP TEST WELL, GREENWOOD, DELAWARE

BY

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ABSTRACT

Analyses of drillers' and geophysical logs, cuttings, and 29 core samples from well Nc13-3 near Greenwood, Sussex County, Delaware indicate that the 1500-foot section penetrated by the drill can be divided into seven rock-stratigraphic units: Matawan Formation, Monmouth Formation, unit A, Piney Point Formation, Chesapeake Group (undifferentiated), Staytonville unit, and the Columbia Formation. The rock units are identified on the basis of texture, mineralogy, color, and interpretation of electric and gamma-ray logs. The oldest rocks penetrated are Upper Cretaceous; Tertiary and Quaternary rocks were also encountered.

Correlations of the units encountered in the Greenwood test well with subsurface formations in adjacent parts of the Coastal Plain are explored utilizing lithologies, ages, positions in the stratigraphic column, and geophysical characteristics as criteria.

Major time boundaries (Cretaceous-Tertiary; Early-Late Paleocene; Paleocene-Eocene; and Eocene-Miocene) are established by a preliminary study of mainly planktonic Foraminifera. The Miocene-Pleistocene boundary was determined on changes in lithology across the unconformable contact.

INTRODUCTION

Purpose and Scope

In August, 1970, a 1500 foot-deep exploratory water well was drilled near Greenwood, Sussex County, Delaware. The primary purpose of the test well was to obtain additional data for an investigation of the water resources in the Delmarva Peninsula conducted by the United States Geological Survey (USGS) with the cooperation of the Surveys of Delaware, Maryland, and Virginia.

The purpose of this report is to describe the mineralogy, textures, and geophysical characteristics of the sediments in well Nc13-3 and to attempt to correlate the rock-stratigraphic units identified with others in the Coastal Plain. Microfossils present in the sediments were used to recognize the major time-stratigraphic boundaries.

Location and Geologic Setting

Test well Nc13-3 is situated in the Atlantic Coastal Plain. The Coastal Plain consists of a wedge of unconsolidated sedimentary rocks which thicken from a "featheredge" at the Fall Line to approximately 8000 feet in southeastern Delaware. The sands, silts, and clays overlie the crystalline basement complex, which is believed to be a downdip continuation of the Piedmont Province's metamorphic and igneous rocks. The sedimentary rocks dip gently to the southeast and east between 90 feet and 15 feet per mile. Most of the rocks thicken in the downdip direction with successively younger units dipping less steeply (Jordan, 1962b).

The sedimentary rocks are estimated to be approximately 4,500 feet thick in northwestern Sussex County, Delaware (Cushing et al., 1973), the subject area of this report. Well Nc13-3 penetrated 1500 feet of section ranging in age from Upper Cretaceous to Pleistocene.

Previous Investigations

For reviews of regional stratigraphy in the central portion of the Atlantic Coastal Plain, the reader is referred to such references as Richards (1945), Spangler and Peterson (1950), Murray (1961), Maher (1965, 1971), and Brown *et al.*, (1972).

A key study of the subsurface stratigraphy of the central Delmarva Peninsula is that of Anderson (1948) dealing with three deep oil test wells in Maryland. Particularly detailed stratigraphic information was presented for well Wi-Cg 37 near Salisbury.

Rasmussen and Slaughter (1957) describe the subsurface geology of the Maryland Eastern Shore counties of Caroline, Dorchester, and Talbot. Their report includes structure contour and isopach maps of the Cretaceous through Pleistocene time- and rock-stratigraphic units.

A review and discussion of the stratigraphy of the Delaware Coastal Plain has been presented by Jordan (1962b). Jordan (1961a), in a detailed unpublished report, described the textural and mineralogical characteristics of the Tertiary sediments present in central Delaware.

Sundstrom and Pickett (1968, 1969, 1970) in a series of reports on the availability of ground water in Kent and Sussex Counties, Delaware, reviewed the subsurface geology and presented structure contour maps of the aquifers.

Cushing *et al.*, (1973) described the general geology and detailed geohydrology of the Delmarva Peninsula. Geohydrologic maps of the aquifers in the area of study are included in the report.

Well Numbering Systems

The location of test well Nc13-3 and other wells referred to in this report are shown on Figure 1. The wells in Delaware are identified using the Delaware Geological Survey (DGS) statewide well numbering system (Rima *et al.*, 1964). Maryland wells are identified using the well identification system described by Rasmussen and Slaughter (1957).

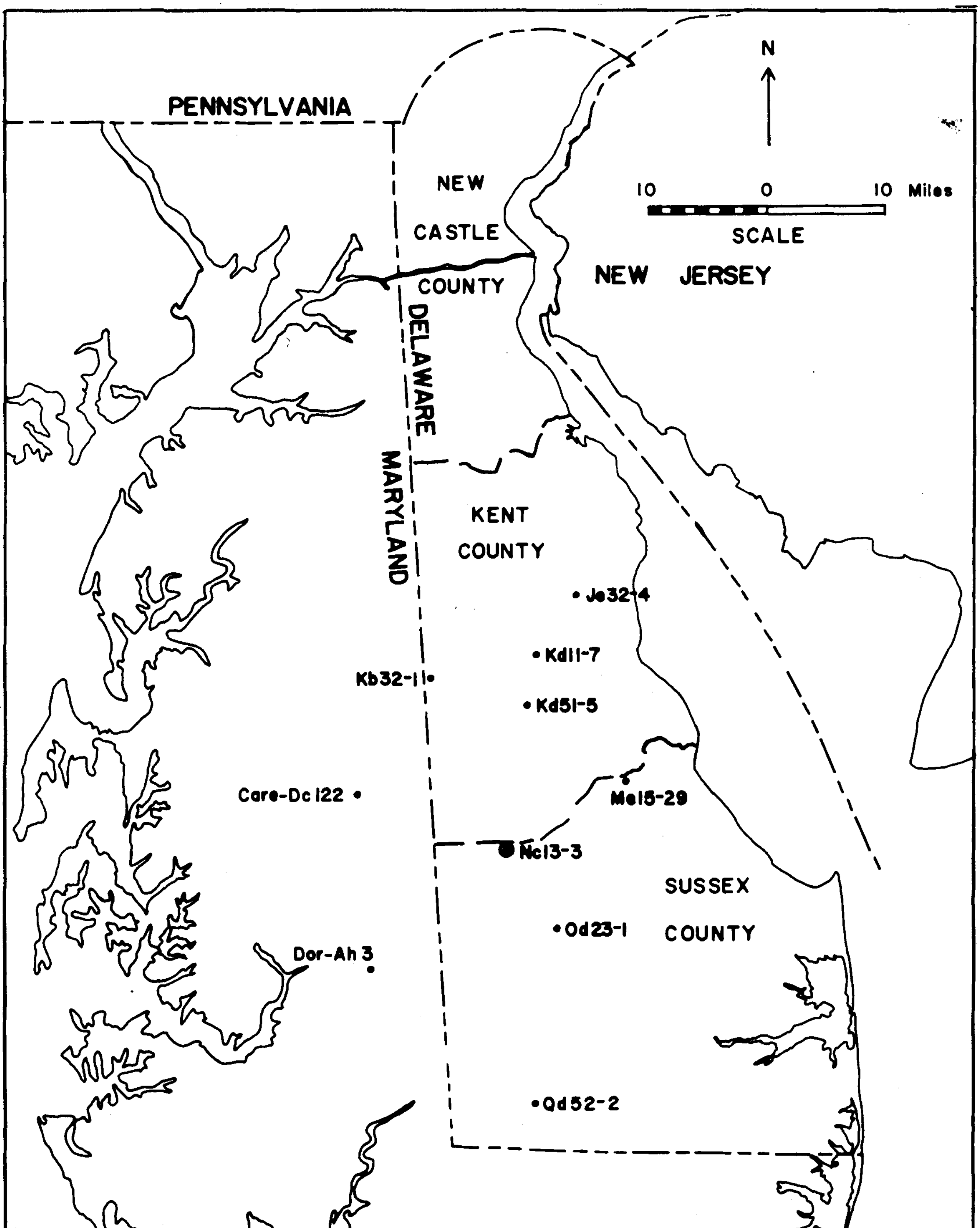

Figure 1. Map showing the location of well Nc13-3 and other wells referred to in this report.

ACKNOWLEDGMENTS

The writer wishes to express gratitude to Robert R. Jordan, Delaware State Geologist, who directed this study in its original form as part of a Master's Thesis. I am also grateful to members of the DGS, especially Nenad Spoljaric, who have been helpful with discussions and constructive criticism. Marvin E. Kauffman and John H. Moss of Franklin and Marshall College provided guidance and support throughout the study. The test well was drilled and cored under the Delmarva Water Resources Project of the USGS. I. H. Kantrowitz and R. H. Johnston of the USGS wrote much of the descriptive log, and along with E. M. Cushing, provided additional pertinent data.

METHODS OF INVESTIGATION

Drilling and Sampling

Test well Nc13-3 was drilled to a depth of 1500 feet from a land surface elevation of 62.7 feet. The hydraulic rotary drilling method used a fresh water-bentonite mud. Thirty-nine cores were taken. Two cores were obtained using a core barrel mounted directly behind the bit and the remainder with a 1.5 foot split spoon sampler lowered through the drill stem on a wire line. Below a depth of 260 feet cores were taken at intervals ranging from 20 feet to 40 feet. In addition, drill cuttings were collected at 10 foot intervals throughout the well. Independent descriptive logs based on ditch and core samples and behavior of the drill were prepared by the drillers and by geologists of the DGS and USGS. Gamma-ray, electrical resistivity, and self-potential logs were made in the open test hole. The hole was later completed as an observation well with a screen set at 620 feet to 630 feet.

Textures

Mechanical analyses of the sediments were done by sieve and centrifugal decantation methods to obtain percentages of sand, silt, and clay. Disaggragation required use of sodium hexametaphosphate and an ultrasonic separator. Percentages of sand, silt, and clay were calculated for each sample and the samples classified according to texture (Shepard, 1954). The classification system used is presented in Figure 2.

The sand fraction was studied under the stereo-binocular microscope to determine the morphology of glauconite (Triplehorn, 1966), the morphology of quartz, and the presence or absence of pyrite, microfossils, shell material, and mica. Glauconite, as referred to in this report, is used "...as a field term for any small (up to a few mm in diameter) greenish clay pellets found in sedimentary rocks," (Triplehorn, 1966, p. 248).

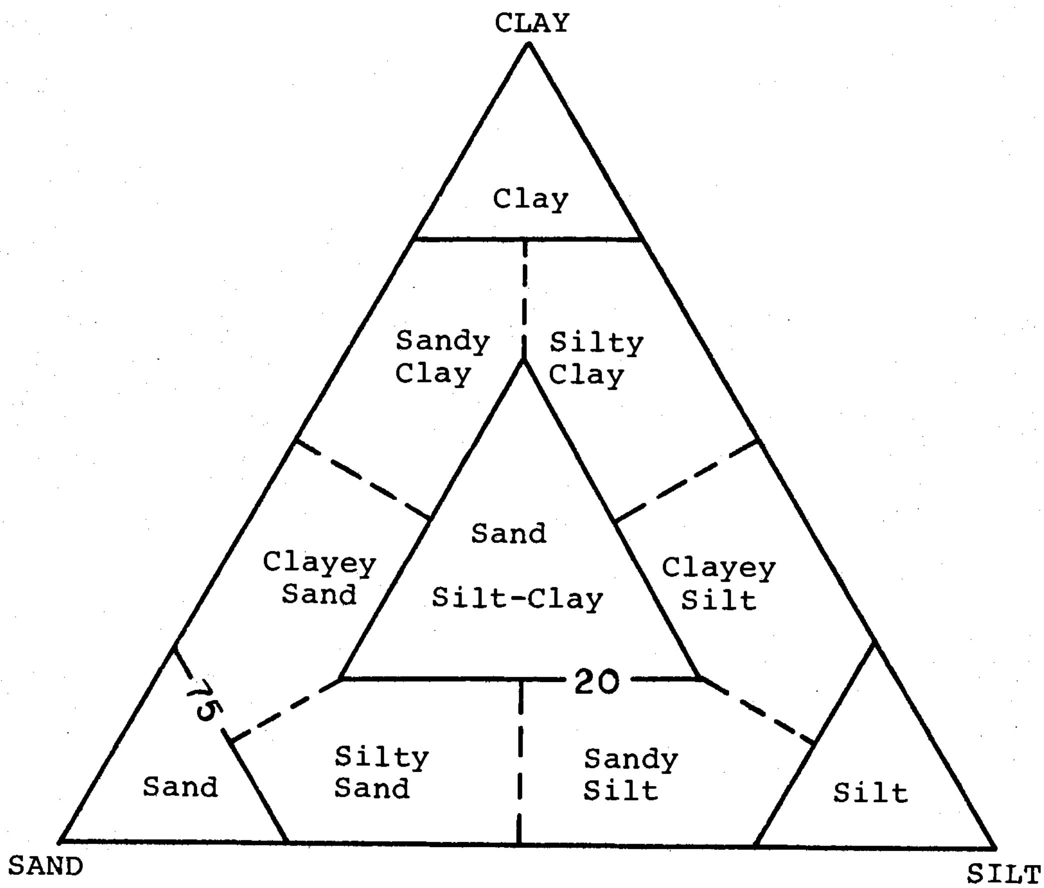

Figure 2. Textural classification of sediments (Shepard, 1954).

Sedimentary Petrography

Thirty-eight thin-sections were prepared by the epoxy impregnation method. Modal analyses of the sections were done using the Glagolev-Chayes point counting method (Glagolev, 1934; Chayes, 1956). Three hundred to 400 points were counted in each slide depending upon the texture of the sediment and the condition of the slide.

The relative percentages of quartz, glauconite, and "others" were determined and are presented for each of the formations or groups except the Columbia (Figure 7). "Others" include unidentifiable matrix, shell debris, foraminifera tests, calcite, mica, feldspar, and opaques. The characteristic morphological and textural features, as well as the color and degree of alteration of glauconite were recorded.

Clay Mineralogy

Sample Preparation

Mounts were prepared by the centrifugal method following the technique described by Spoljaric (1971). The clay slides were run in the following order: (1) dried at room temperature, (2) exposed for one hour at 60°C in an atmosphere saturated with ethylene glycol, (3) heated at 575° for one hour. The diffractograms were made on a General Electric diffractometer using nickel-filtered copper alpha radiation.

Identification of Clay Minerals

The diffractograms indicate that the clay fractions consist predominantly of montmorillonite, illite, and kaolinite (see Figure 3). Illite was identified by the basal 10 Å and 4.99 Å peaks. The montmorillonite group is defined as those clay minerals which expand from a d spacing of about 15 Å to one of about 17-18 Å upon glycolation. Kaolinite and chlorite have very similar basal diffractogram patterns. In order to distinguish between the two minerals, slides were heated at 575° for one hour; peaks in the vicinity of 7 Å and 3.5 Å were

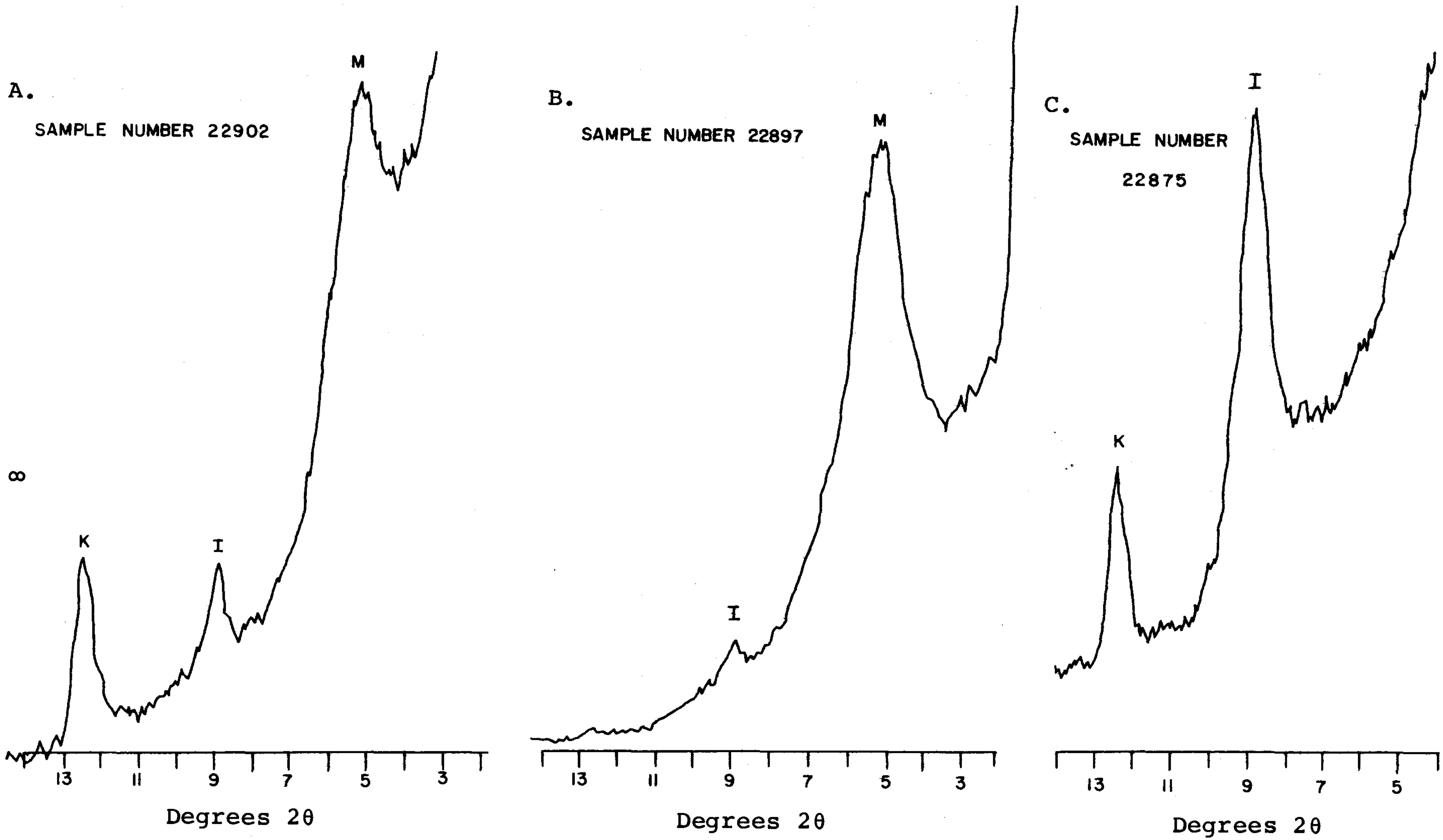

Figure 3. Low-angle diffractograms of typical clay mineral assemblages: (A) Kaolinite-illite-montmorillonite, (B) Montmorillonite-illite, (C) Kaolinite-Illite.

destroyed, indicating that kaolinite, not chlorite, was present.

Semiquantitative Analysis

At present there is no standard method of quantitative analysis of clay minerals from the diffractograms. The method employed in this investigation is that one developed by Biscaye (1965). The peaks and weighing factors used were:

Montmorillonite- the area under the 17 Å glycolated peak;

Illite- four times the area under the 10 Å glycolated peak;

Kaolinite- two times the area under the 7 Å peak.

The results are recorded as parts in ten parts.

Microfossils

Planktonic Foraminifera were picked and identified from each of the cores. Thirty to 100 grams of sample were washed and microfossils were concentrated by flotation. Residues and concentrates were examined and picked for microfossils.

RESULTS

Time-Stratigraphic Boundaries

The stratigraphic framework in well Nc13-3 is based in large part on the positions of the following time-stratigraphic boundaries: Cretaceous-Tertiary; Early-Late Paleocene; Paleocene-Eocene; and Eocene-Miocene. The positions of the boundaries were established through a preliminary study by the author of Foraminifera, especially Tertiary planktonic Foraminifera.

Cretaceous-Tertiary Boundary

The Cretaceous-Tertiary boundary has been placed between 1286 feet and 1265 feet (samples 22897 and 22896, respectively). The boundary is characterized by a faunal break of planktonic Foraminifera in which there is an almost complete change in fauna at the generic level (Loeblich and Tappan, 1957a). Cretaceous genera identified in the youngest Cretaceous sample (22897) include *Globotruncana*, *Heterohelix*, *Guembelitria*, and *Biglobigerinella*. The top of the Cretaceous is identified with the disappearance of the *Heterohelix-Globotruncana* assemblage of Loeblich and Tappan (1957b).

Sample 22896 at 1265 feet, the lowermost core of Paleocene age, contains assemblages belonging to the genera *Globigerina*, *Globigerinoides*, *Globorotalia*, and *Chiloguembelina*. These are indicative of the *Globorotalia compressa-Globigerina daubjergensis* zone (Loeblich and Tappan, 1957b), which is Early Paleocene in age. Other Foraminifera identified from this sample include *Globigerina triloculinoides*, *Globorotalia pseudobulloides*, and *Chiloguembelina morsei*.

Early-Late Paleocene Boundary

The Early-Late Paleocene boundary occurs between 1265 feet and 1245 feet (samples 22896 and 22895, respectively). The entry into the Late Paleocene is indicated by the appearance of the *Globigerina-keeled Globorotalia* assemblage of Loeblich and Tappan (1957b). The restricted Danian *Globorotalia compressa-Globigerina daubjergensis* assemblage is not present in sample 22895. The species most typical of the Late Paleocene is *Globorotalia angulata*. Other fairly abundant and persistent Late Paleocene species include *Globorotalia aequa*, *G. elongata*, and *Globigerina triloculinoides*.

Paleocene-Eocene Boundary

A sharp faunal break does not exist at the Paleocene-Eocene boundary. Consequently, this boundary is not as easily defined as the Cretaceous-Tertiary and the Early-Late Paleocene boundaries.

According to Loeblich and Tappan (1957b) the close of the Paleocene is characterized by the disappearance of such species as *Globorotalia acuta*, *G. velascoensis*, *G. occlusa*, *Globigerina mckannai*, *G. spirilis*, and *G. triloculinoides*. Loeblich and Tappan (1957b) believe that the *Globorotalia angulata* zone is restricted to the Paleocene.

The Paleocene-Eocene boundary is believed to occur within a zone bounded by samples 22889 (1075 feet) and 22886 (965 feet). This interval is marked by the disappearance of *Globorotalia angulata*, *G. pseudomenardii*, and *Globigerina mckannai* with the appearance above of several new species characterized by *Globigerina aquiensis*, *G. yeguaensis*, *Hastigerina micrum*, *H. eocenica*, and *Guembelitria columbiana*. *Globorotalia elongata*, *G. perclara*, and *G. aequa* appear to be transitional species that occur in both the Paleocene and Eocene.

The actual boundary has been tentatively and arbitrarily placed between 1035 feet and 995 feet (samples 22888 and 22887, respectively) at the top of the *Globorotalia angulata* zone.

Eocene-Miocene Boundary

The Eocene Piney Point Formation-Chesapeake Group Miocene contact occurs at approximately 582 feet between samples 22872 and 22871. The lowermost core containing Miocene Foraminifera was taken at 525 feet (sample 22871). The microfossils identified include *Bulinina elongata* d'Orbigny, *Nonion pizarrense* Berry, and *Spiroloculina depressa* d'Orbigny. Diatoms are abundant in sample 22871. No fossils were found in sample 22872 (585 feet), a medium- to coarse-grained glauconitic sand. This unconformable contact is evidenced by contrasting lithologies described elsewhere.

Rock-Stratigraphic Units

Matawan Formation

The Matawan Formation extends from 1344 feet to at least 1500 feet, the total depth of Nc13-3. It is a greenish-gray to dark gray, highly to sparingly glauconitic and micaceous, clayey silt and sand-silt-clay, with thin zones of light gray, clayey silt. The top of the formation is marked by a zone of light gray, very fossiliferous, clayey silt (chalk).

The sand fraction consists of variable amounts of glauconite and quartz with small percentages of feldspar, mica, and calcareous fossils. Glauconite is a predominant component of the sand fraction in four samples. Sample 22899 (1366 feet) contains a very small amount of glauconite. Glauconite ranges in size from fine to coarse sand and is medium to light green in color. Rust-brown, highly weathered glauconite occurs in sample 22903 (1500 feet). Several forms of glauconite exist in this formation including vermicular, mammillated, tabular, ovoidal, and capsule-shaped (Triplehorn, 1966). The different forms occur randomingly throughout the formation; no trends in shape or degree of alteration are evident except for the fine-grained glauconite which is consistently ovoidal in shape and light green in color. The larger grains have smooth surfaces regardless of shape and are consistently larger in size than quartz in a particular sample. The pellets occur in various stages of alteration.

Quartz is a subordinate constituent to glauconite in the sand fraction. It occurs in greater amounts than glauconite only in sample 22899 (1366 feet), a very fossiliferous clayey silt. Most of the quartz is very fine to fine sand; however, some coarse silt and medium sand are present throughout the formation. Mica occurs persistently throughout the Matawan Formation in relatively small amounts. An exception is sample 22901 (1436 feet) which contains an abundance of mica. Calcite is present in greater amounts in the upper part of the formation and is represented by calcareous fossils. Shell fragments have been found in samples at 1406 feet and 1366 feet.

The clay mineral assemblage consists essentially of kaolinite-illite-montmorillonite. Kaolinite and illite decrease while montmorillonite increases in abundance up-section. The average clay mineral composition in parts in ten in the Matawan Formation is: montmorillonite, five; kaolinite, three; illite, two.

The boundary between the Matawan and Monmouth Formations is marked by an increase in resistance and gamma radiation and a slight deflection in the negative direction on the self-potential curve.

Monmouth Formation

The interval between 1344 feet and 1300 feet has been identified as the Monmouth Formation. The sediments consist of greenish-gray to tan-gray, fossiliferous and glauconitic, sand-silt-clay. The Monmouth Formation is generally more glauconitic and fossiliferous, and less quartzose and micaceous than the underlying Matawan Formation. The Monmouth Formation appears to overlie the Matawan Formation with a gradational, conformable contact.

Most of the glauconite is larger than the quartz and is dominated by mammillated grains. The quartz is mostly clear and angular to subangular. The clay mineral assemblage is predominantly montmorillonite (seven parts in ten) with lesser amounts of illite and kaolinite (two and one part in ten, respectively).

The lower boundary of the Monmouth Formation is characterized by a relatively sharp increase in resistance and a corresponding decrease in gamma activity. The upper limit of Monmouth sediments is marked by a decrease in resistance and a deflection in the positive direction on the spontaneous potential curve.

Unit A

Unit A consists of greenish-gray to dark gray, sparingly to highly glauconitic, clayey silt and silty clay with some thin beds of white to light gray, silty clay. Clay minerals dominate the clay fraction. Calcite occurs persistently throughout the section as shell fragments and foraminiferal tests. The thickness of unit A is approximately 425 feet (1300 feet to 875 feet).

Unit A has a gradational contact with the underlying Monmouth Formation. Sedimentation appears to have been continuous through this interval. Glauconite morphology in the lowermost 50 feet of unit A is similar to that found in the youngest Monmouth sediments. However, unit A is generally finer grained, less glauconitic, more fossiliferous, and has a different clay mineral assemblage than the underlying Monmouth Formation.

Sediment larger than medium silt is dominated for the most part by coarse silt to very fine quartz sand and calcareous microfossils. Glauconite is a minor constituent in eleven samples of unit A, and in the other four samples occurs in appreciable quantities (Figure 7). Mica is present in trace amounts throughout unit A. Microfossils consisting of planktonic and benthonic Foraminifera are common except in the interval 1184 feet to 1144 feet, where they are very rare or absent. Pyrite occurs in trace amounts in the samples between 1205 feet and 1115 feet.

Glauconite ranges in size from coarse silt to medium sand and is medium to light green in color. The glauconite near the base of unit A is consistently larger than the quartz with which it is associated and is very similar in form and internal structure to the glauconite encountered in the uppermost Monmouth Formation.

In the sediments above about 1265 feet, except in the interval from approximately 1035 feet to 995 feet, glauconite is consistently coarse silt- to very fine sand-size, ovoidal in shape, and light green in color. The pellets contain few cracks. In the interval from approxiamtely 1035 feet to 995 feet, glauconite varies in form and is larger in size than associated quartz grains. Some of the pellets have fibroradiated rims; others are internal molds of Foraminifera.

The clay fraction of unit A consists of a montmorillonite-illite mineral assemblage. Kaolinite is present in trace amounts in the interval 1205 feet to 1185 feet. Montmorillonite dominates the assemblage with a range of five to nine parts in ten. Illite ranges in abundance from one to five parts in ten. The average clay mineral composition of unit A in parts in ten is: montmorillonite, eight; illite, two; kaolinite, trace.

The gamma-ray log is characterized by a relatively large increase in radioactivity near the base of unit A. This zone of increased radiation, which occurs near the Cretaceous-Tertiary boundary, has been documented by such investigators as Woodruff (1975), Cushing et al., (1973), and Minard et al., (1969), in Delaware, Maryland, and New Jersey. The source of the radiation has not been determined at this time. However, it has been suggested that it may be due to a concentration of phosphatic material (Minard et al., 1969) or, perhaps, to a zone of bentonite described by Jordan and Adams (1962).

Piney Point Formation

The Piney Point Formation extends from 875 feet to 582 feet and consists of greenish-gray to bluish-gray, silty, sparingly to moderately glauconitic, very fine to coarse sand. The sediments in the basal part of this formation are somewhat similar to and apparently continuous with unit A sediments. The gradational lithologic contact is marked by a change from greenish-gray silty clay and clayey silt with traces of glauconite and quartz sand in unit A to greenish-gray silty and very glauconitic very fine to medium quartz sand in the Piney Point Formation. Quartz becomes progressively more abundant up-section. The Piney Point Formation is unconformably overlain by the Miocene Chesapeake Group.

The dominant mineral constituents of the coarse silt-sand fraction are quartz and glauconite. Quartz is subangular to subrounded and covers a wide range of grain sizes in any one sample as compared to glauconite. The upper part of the formation consists essentially of medium to coarse sand with shell fragments. The megascopic appearance of the samples suggests that they are green and dominated by glauconite; however, laboratory analysis reveals that glauconite is subordinate to quartz in all but two Piney Point samples. Dolomite rhombs have been identified in sample 22877 (765 feet).

Glauconite ranges in size from very fine to coarse sand with pellets generally increasing in size up-section. It occurs predominantly as very fine to fine sand, dark green, ovoidal or spherical pellets. Glauconite is consistently finer grained than quartz in a particular sample except at the base and the top of the formation. The dominant forms are vermicular, tabular, and mammillated. Most grains have many cracks and consist of composite pellets with many lobes. The uppermost Piney Point sample (22872) contains an appreciable amount of green to rust-brown vermicular and mammillated glauconite in various stages of weathering. Sample 22873 (625 feet) is unique in that the glauconite is uniformly green in color and occurs as well-developed, very slightly altered, ovoidal pellets with oriented microcrystalline internal structure. Sample 22875 (705 feet) is the only Piney Point sample in which glauconite is apparently replacing organic material.

The Piney Point Formation is characterized by two clay mineral assemblages: kaolinite-illite and kaolinite-illite-montmorillonite. The kaolinite-illite-montmorillonite assemblage dominates the middle portion. Kaolinite is present throughout the section and ranges in abundance from one to ten parts in ten. Illite and montmorillonite average four and two parts in ten, respectively. The transition zone between unit A and the Piney Point Formation is marked by the appearance of kaolinite and a decrease in the proportion of montmorillonite. Montmorillonite was identified in six of the eleven samples. Sample 22875 (705 feet) consists almost entirely of illite.

The electric log can be used to distinguish between the Piney Point Formation and the overlying and underlying units. The top of the Piney Point shows a characteristic increase in resistance and a negative deflection on the spontaneous potential curve. Resistance decreases and spontaneous potential exhibits a shift in the positive direction towards the bottom of the formation.

Chesapeake Group

The Chesapeake Group occupies the interval 582 feet to 69 feet in well Nc13-3. The section, of variable composition, consists of five units of silt separated by four sand bodies. The Chesapeake Group has been informally divided into hydrologic units such as the Cheswold, Federalsburg, Frederica, Pocomoke, Manokin, and minor Miocene aquifers (Rasmussen et al., 1960; Sundstrom and Pickett, 1969, 1970; Cushing et al., 1973). Cushing et al., (1973) have presented descriptions and maps of the Miocene hydrologic units in the Delmarva Peninsula.

The samples analyzed fall into five textural groups: sand, silty sand, sandy silt, clayey silt, and silt. The sands are quartzose and subangular to subrounded. Quartz ranges in size from very fine to coarse sand but is predominately very fine to fine sand. Shell fragments occur in most of the samples. Dolomite rhombs were identified in samples 22869 (405 feet) and 22866 (166 feet). Glauconite is present in trace to small amounts in the lower part of the group (samples 22870 and 22868) and is represented by dark green to brown, very fine-grained, ovoidal pellets. Many of the grains appear to have been weathered as evidenced by their brown color.

The Chesapeake Group rests unconformably on the eroded surface of the Eocene Piney Point Formation. The location of the contact with the underlying Piney Point Formation was determined on the basis of lithology and geophysics. The base of the Chesapeake contains essentially no glauconite, is very silty, brown to gray in color, and slightly diatomaceous, whereas the Piney Point Formation is sandier and much more glauconitic than the Chesapeake and is green to grayish-green in color. The Pleistocene Columbia Formation unconformably overlies the Chesapeake Group. This contact was picked on changes in lithology and interpretation of geophysical logs.

The Chesapeake Group contains two clay mineral assemblages: montmorillonite-illite and kaolinite-illite-montmorillonite. The former assemblage dominates the clay mineralogy. Montmorillonite occurs throughout the section ranging in abundance from three to eight parts in ten. Illite is also present in all samples and averages four parts in ten. Kaolinite has been identified in trace amounts in samples 22869 (405 feet) and 22867 (265 feet) and in small quantities in samples 22871 (525 feet) and 22868 (365 feet).

The electric log in the Chesapeake Group is variable indicating sandy zones separated by silt and clay. This trend contrasts with that observed in the underlying Piney Point Formation. A sharp increase in gamma radiation occurs at the Piney Point-Chesapeake boundary.

Staytonville unit and Columbia Formation

The thickness of the deposits of Pleistocene age in well Nc13-3 is 69 feet. The uppermost 12 to 18 feet consist of fine to very fine, clayey and silty, tan to gray, sand. This material is assigned to the Staytonville unit, a unit of probably estuarine origin that occupies a relatively small area in southwestern Kent and northwestern Sussex Counties (Jordan, 1964, 1967).

Underlying the Staytonville unit to a depth of 69 feet and unconformably overlying the gray sandy silts and clays of the Chesapeake Group are very fine sands and gravels of the Pleistocene age Columbia Formation. A major unconformity exists at this boundary as evidenced by the absence of Pliocene materials.

Correlation

General Statement

The information gained from well Ncl3-3 permits the comparison and establishment of correlations of the rock-stratigraphic units in the central Delmarva Peninsula. Most of the descriptions of the units penetrated fit well with those of existing established subsurface formations. However, the relationship of unit A with associated units in Maryland is not completely understood at this time. In the following paragraphs the similarity of rocks from well Ncl3-3 to rocks from other wells and sources of information are described.

Matawan Formation

The Matawan Formation identified in well Ncl3-3 is similar to that described by Rasmussen *et al.*, (1960), and Jordan (1962b), and also to the Matawan sediments described by Jordan (1961b) in well Je32-4 at Dover, Delaware. However, the Matawan in Ncl3-3 is somewhat finer grained, less quartzose, and more glauconitic than the Matawan at Dover. Rasmussen and Slaughter (1957) described the same formation in nearby Maryland as a dark green, glauconitic, and silty clay, sand, and clayey sand containing shell and Forminifera.

Sediments described by Anderson (1948) from well Wi-Cg 37 near Salisbury, Maryland as belonging to the Matawan Formation are very similar in lithology to those in Ncl3-3.

The thickness, boundary elevations, and lithology of the Matawan Formation in Ncl3-3 correspond well with those determined by Brown *et al.*, (1972) as belonging to a unit identified as Cretaceous Unit B.

Monmouth Formation

Because of the similarity of lithology with overlying and underlying formations and units, a lack of adequate well control throughout the region, and the inadequate sampling in well Nc13-3, identification and correlation of the Monmouth Formation is difficult. Nonetheless, an attempt was made to correlate the formation with lithology, position in the stratigraphic column, paleontology, and geophysical characteristics as criteria.

The Monmouth Formation in Nc13-3 is similar to a section described in well Wi-Cg 37 near Salisbury, Maryland by Anderson (1948). Brown et al., (1972) have identified a chronostratigraphic unit in the Atlantic Coastal Plain referred to as Cretaceous Unit A that compares favorably with the 44-foot thick section in Nc13-3 assigned to the Monmouth Formation.

The Monmouth Formation has been identified in many of the Maryland Eastern Shore counties adjacent to Delaware and is described as a "...dark gray glauconitic sand and lead-gray clay containing shells and Foraminifera...." (Rasmussen and Slaughter, 1955, p. 45).

Unit A

The informal name unit A was applied to sediments described in well Je32-4 at Dover Air Force Base by Jordan (1962b). The presence of unit A has been confirmed in wells at Dover (Je32-4, Id53-4), Woodside (Kd11-7), Felton (Kd51-5), and Milford (Me15-29), (Jordan, 1962b). In addition, a unit with similar lithologic and geophysical features has been recognized in a well at Sandtown, Delaware (Kb32-1). Rasmussen and Slaughter (1957) report a similar unit in well Care-Dc 122 near Denton, Maryland. They divided the unit into formal names such as the Brightseat, Aquia, and Nanjemoy Formations; the latter two comprising the Pamunkey Group. In 1960, Rasmussen et al., indicated that sediments of Paleocene age in well Od23-1 near Bridgeville, Delaware, were possibly equivalent to the Brightseat Formation of Maryland. In addition, Sundstrom and Pickett (1970, p. 14) suggested that unit A "...is probably equivalent to the Pamunkey Group of Maryland and Virginia...." Their hypothesis was based on projections into Delaware from Maryland and Virginia, stratigraphic position, and ages. The writer supports the position that unit A may be equivalent in age to the Pamunkey Group of Maryland. However, the lithology of unit A in well Nc13-3 is quite unlike that of the type localities of the Aquia and Nanjemoy Formations (Clark, 1896; Clark and Martin, 1901). It has been reported by Glaser (1968, p. 16) that in Southern Maryland "...the Aquia Formation is typically a dark greenish-gray, variably glauconitic, well-sorted, fine to medium silty sand." The Aquia Formation is reported to occupy a northeast-southwest trending basin that wedges or thins out to the northwest and southeast (Glaser, 1968). The differences in lithologies of the Pamunkey Group of Maryland and unit A in Delaware probably result from changes in facies across the depositional area. At this time the relationship of unit A with the Pamunkey Group (Aquia and Nanjemoy Formations) is not completely understood because of a lack of adequate well control.

Anderson (1948) described sediments from well Wi-Cg 37, Salisbury, Maryland, of similar lithology and occupying similar stratigraphic position to the materials belonging to unit A in well Nc13-3. A 30-foot thick section of highly glauconitic material occurs at the base of the Paleocene directly above the Cretaceous Monmouth Formation in Wi-Cg 37. A similar glauconite-rich zone has been identified at the base of unit A in well Nc13-3. The Cretaceous-Tertiary boundary lies within this glauconite zone. The Globorotalia compressa-Globigerina daubjergensis assemblage of lowermost Paleocene age was identified in the subsurface by Jordan (1962a) at Dover, Delaware, in unit A. This faunal assemblage has also been confirmed as occurring in the lower part of the Hornerstown Formation in New Jersey (Olsson, 1963) and in the Brightseat Formation of Maryland (Bennett and Collins, 1952). The strike and dip of the Cretaceous-Tertiary boundary was determined using control points from wells Je32-4, Nc13-3, Od23-1, Wi-Cg 37, and Care-Dc 122. The strike and dip along the Kent-Sussex County line are approximately N62^{o}E and 16 feet per mile to the southeast, respectively. The strike changes rather abruptly in central and southwestern Sussex County to a north-northwesterly direction with a corresponding increase in dip (29-48 feet per mile), Figure 4. These data support Jordan's (1963) interpretation of the configuration of the Cretaceous-Tertiary boundary in the Delmarva Peninsula.

Graphic solutions utilizing various combinations of well defined control points from eight wells in Kent and Sussex Counties, Delaware, and Caroline and

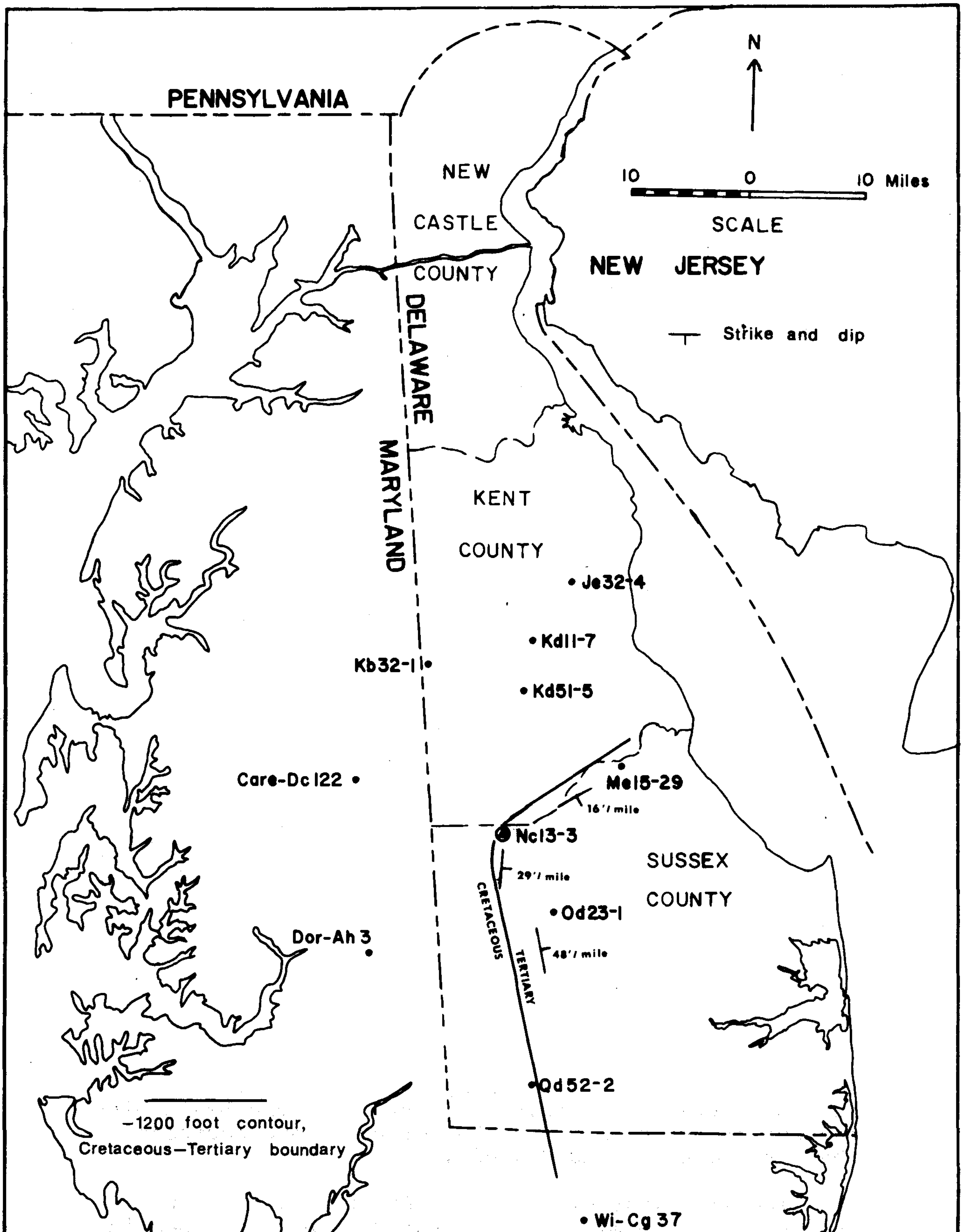

Figure 4. Configuration of the Cretaceous–Tertiary boundary.

Dorchester Counties, Maryland yield variable strikes and dips for the top of unit A. The structural elements are presented in Figure 5. Near the Kent-Sussex County line, the strikes range from N62°E to N66°E with dips about 11 feet per mile to the southeast. Updip to the north and west the strikes changes progressively to a more northerly direction (N51°E to N26°E) with increasing dips (25 to 37 feet per mile). South of Greenwood the strike becomes north to northwest with dips to the east and northeast of 11 to 30 feet per mile. The changes in strike in the area for the top of unit A are similar to those determined for the Cretaceous-Tertiary boundary. The dips, however, are different in that the Cretaceous-Tertiary boundary dips more steeply in the southern part of Sussex County than in Kent County while the top of unit A dips more gently in Sussex than in Kent County.

The change in strike in the vicinity of Greenwood, Delaware from an east-northeast to a north-northwest direction may be part of the reflection of the Salisbury Embayment, the name proposed by Richards (1948) for a structural low (basement depression) in this portion of the Coastal Plain. This feature has also been spoken of by such investigators as Spangler and Peterson (1950); Rasmussen and Slaughter (1957); Jordan (1962b, 1963); Sundstrom and Pickett (1970); and Cushing <u>et al</u>. (1973).

Piney Point Formation

The Piney Point Formation is one of the most readily identifiable rock-stratigraphic units in central and southern Delaware and adjacent Maryland. The Piney Point is a major aquifer in this portion of the Coastal Plain and there are many wells to provide good vertical and horizontal control.

It lies in a northeast trending basin with the thickest section occurring along a line from Greenwood to Magnolia, Delaware (Cushing <u>et al</u>., 1973). Well Ncl3-3 occurs in the thickest portion of the basin with the formation thinning to the northwest and southeast, that is, both up- and downdip.

The lithology of the Piney Point Formation in well Ncl3-3 is similar to the Piney Point described in central and southern Kent County, Delaware, and the

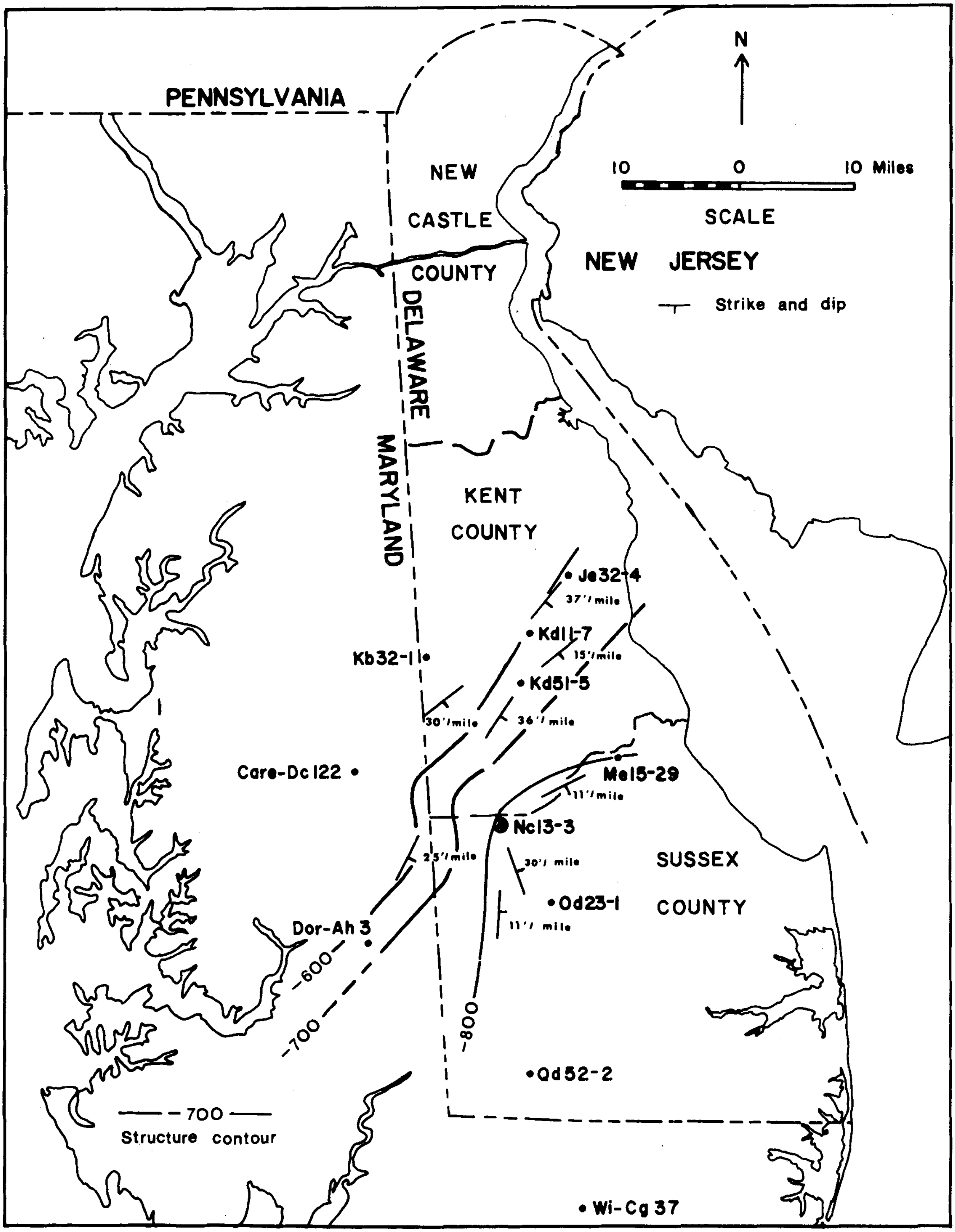

Figure 5. Configuration of the top of Unit A.

Maryland Eastern Shore (Rasmussen et al., 1957; Rasmussen et al., 1958; Rasmussen et al., 1960; Jordan, 1962b; Sundstrom and Pickett, 1970). The strike of the formation as determined from graphic solutions using control points from nine wells ranges from N10°E to N49°E with dips between 15 and 33 feet per mile to the east and southeast. The structural elements are presented in Figure 6. In central and southern Kent County the strike is between N30°E and N47°E with dips of 15 to 31 feet per mile to the southeast. The strike becomes more northerly (N36°E to N30°E) in the northwestern part of Sussex County. The strike in southwestern Sussex County ranges between N10°E and N16°E. The change in strike of the top of the Piney Point Formation is similar to the trends noted at the top of unit A and the Cretaceous-Tertiary boundary. However, the changes in strike across the area are more subtle on top of the Piney Point Formation than on top of the older units. The top of the Piney Point Formation is marked by a major unconformity.

Chesapeake Group

The Chesapeake Group has been differentiated into the Calvert, Choptank, and St. Mary's Formations in the outcrops of the western shore of the Chesapeake Bay and in the subsurface on the Eastern Shore where well control is good. The term Chesapeake was extended to Delaware by Dall and Harris (1892) to include beds containing similar fauna and having the same general horizons on the Gulf and Atlantic Coasts. The name Chesapeake Group has been used in Delaware over the years by various investigators (Richards, 1945; Jordan, 1962b; Sundstrom and Pickett, 1968, 1969, 1970) and therefore, is well established. However, differentiation into formal units in Delaware has been impeded by the lack of outcrops and paucity of well control.

The silt-sand sequences encountered in well Nc13-3 have been observed in several other wells in Delaware and nearby Maryland. Geophysical logs (electric and gamma-ray) have been used extensively to identify and correlate the beds of sand and silt (Cushing et al., 1973). Regional correlation is difficult because of the changes in facies both vertically and laterally over short distances.

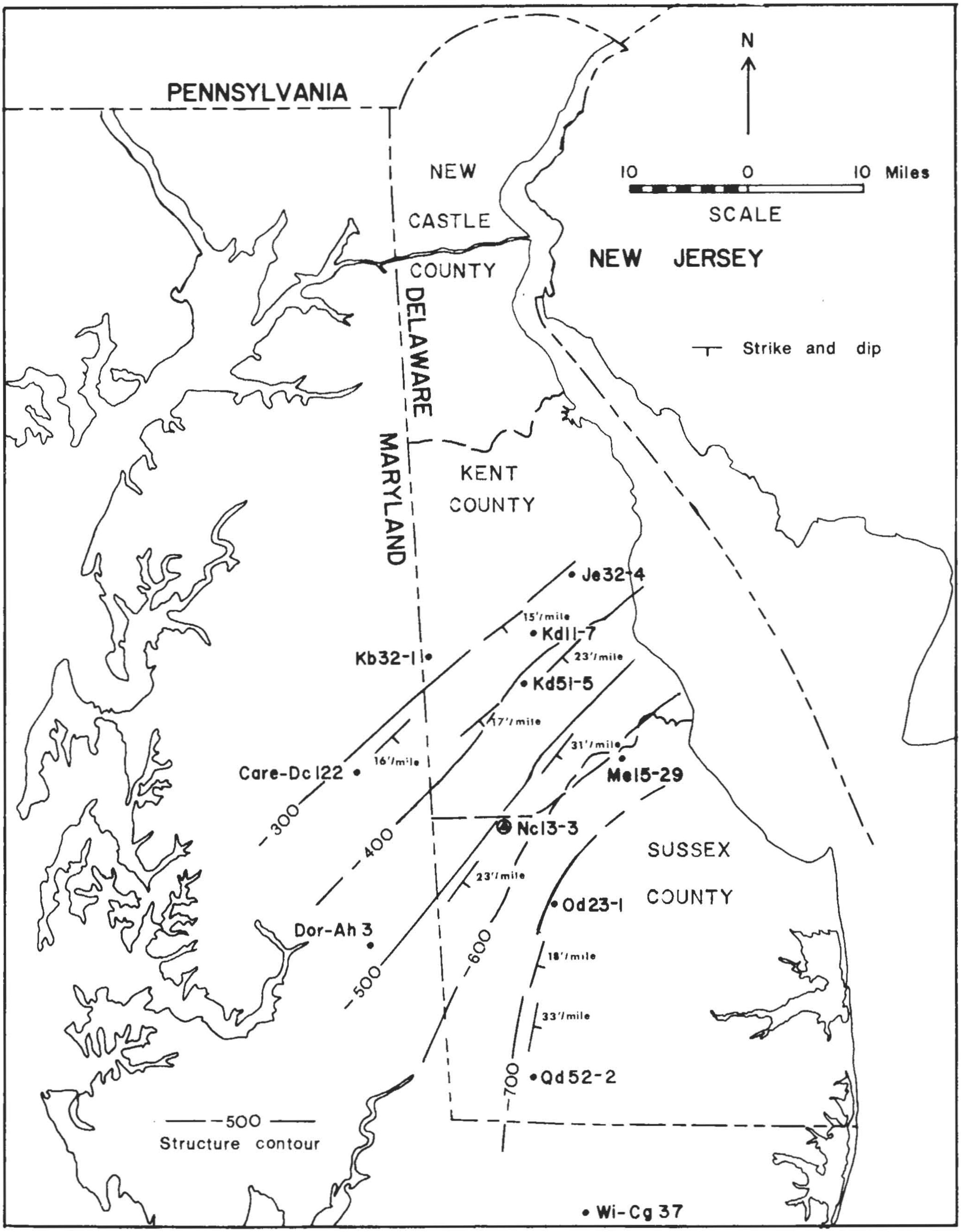

Figure 6. Configuration of the top of the Piney Point Formation.

The Miocene section in Nc13-3 consists of four sand bodies separated by five silty zones. The lowermost sand (465 feet to 380 feet) is the Cheswold aquifer. It is similar in lithology, stratigraphic position, and geophysical characteristics to the Cheswold in southern Delaware and Maryland Eastern Shore. Rasmussen et al., (1958, p. 29) referred to a sandy zone of Calvert age that occurs in well Od23-1 near Bridgeville, Delaware at a depth of 500 to 600 feet as possibly being part of the Cheswold recognized in the Dover area. However, due to inadequate well control, they were unable to determine if it was continuous with the Cheswold at Dover. With the additional control point provided by Nc13-3 it appears that the sand zone recognized by Rasmussen et al., (1958) in well Od23-1 is part of the Cheswold aquifer.

Overlying the Cheswold and separated from it by approximately 20 feet of clayey silt is a thin sandy zone referred to in this report as a "Miocene sand unit." The stratigraphic position of this zone, deciphered from geophysical logs, is similar to that occupied by the Federalsburg aquifer, a thin water-bearing unit mapped in adjacent Maryland. The type section of the Federalsburg aquifer is situated approximately 15 miles to the southeast of Nc13-3 and is based on a single point electric log of test well Dor-Ah 3 (Cushing et al., 1973).

A fairly thick sandy zone identified as the Frederica aquifer occurs above the "Miocene sand unit" described above and is separated from it by 20 feet of clayey silt. The central part of the Frederica consists of sandy silt and clayey silt with shell beds while the upper and lower portions are comprised of silty sands. The Frederica in Nc13-3 is correlative with the Frederica mapped by Sundstrom and Pickett (1970) and Cushing et al., (1973).

The Frederica aquifer is overlain by a thick silty and clayey section containing a thin sandy zone which appears to be the same "Miocene sand unit" mapped by Sundstrom and Pickett (1970) in western Sussex County. The stratigraphic position of this zone is also correlative with the Manokin aquifer mapped by Cushing et al., (1973). The discrepancy in interpretation in the two states undoubtedly results from a lack of adequate well control.

CONCLUSIONS

The mineralogical and textural characteristics of the Upper Cretaceous and Tertiary sediments of well Ncl3-3 have been presented. The major time-stratigraphic boundaries were determined through a preliminary study of planktonic Foraminifera, especially Tertiary planktonic Foraminifera. Benthonic Foraminifera were also identified near the Eocene-Miocene boundary.

Relatively distinct trends in texture, clay mineralogy, glauconite occurrence and morphology, quartz-glauconite percentages, and geophysical characteristics were used to subdivide the section into rock-stratigraphic units. The relationships of the Upper Cretaceous and Tertiary rock- and time-stratigraphic units are presented in Figure 7. A geologic cross section of central and southwestern Delaware incorporating the rock-stratigraphic units identified in well Ncl3-3 is presented in Figure 8.

The Matawan through Miocene sediments were deposited in a marine environment. The Pleistocene materials are of fluvial origin with possibly some "estaurine (?) facies" sediments (Jordan, 1964, 1967). Gradational lithologic contacts which delimit the three oldest rock-stratigraphic units suggest that sedimentation was continuous from Upper Cretaceous to at least Middle Eocene time. The Cretaceous-Tertiary boundary occurs within unit A. The sediments on either side of this time boundary are similar, indicating that an unconformity probably does not exist. This conclusion is in agreement with that arrived at by such investigators as Spangler and Peterson (1950), and Olsson (1960). Jordan (1962b, p. 17) has stated that in well Je32-4 at Dover Air Force Base "...the presence of any break in sedimentation associated with the boundary is not demonstratable in this well."

The unit A-Piney Point Formation boundary occurs in Eocene time. Textural and mineralogical differences above and below 875 feet suggest a change in the environment of deposition. Sediments become much coarser, and more quartzose and glauconitic as one passes from unit A into the Piney Point Formation. This gradational lithologic contact is also accompanied by a distinct change in the clay mineral assemblages from montmorillonite-illite to illite-kaolinite-mortmorillonite.

The Eocene-Miocene contact (Piney Point Formation-Chesapeake Group)is unconformable as indicated by changes in texture, mineralogy, fossil content, and a lack of Oligocene materials.

The top of the Miocene section is also marked by an unconformity. Pleistocene sands and gravels directly overlie fine sands, silts, and clays of the Chesapeake Group. Pliocene sediments are not present.

Attempts were made to correlate the rock-stratigraphic units identified in Nc13-3 with those units in central and southern Delaware and adjacent Maryland. Because of a lack of wells which have penetrated the Matawan and Monmouth Formations in this portion of the Coastal Plain, only general comparisons could be made. Nevertheless, the lithologic and geophysical characteristics compare favorably with the same formations as described in Delaware by Rasmussen et al., (1960) and Jordan (1961b), and in Maryland by Anderson (1948) and Rasmussen and Slaughter (1957). The elevations of the tops of the two formations are in agreement with the structure contour lines presented on structure maps by Spangler and Peterson (1950).

The lithologic composition of unit A in well Nc13-3 is similar to that of the unit A type section in well Je32-4 at Dover (Jordan, 1962b) and to other sediments assigned to unit A in central and southern Delaware. The stratigraphic position of the Pamunkey Group (Aquia and Nanjemoy Formations) of several Maryland Eastern Shore counties is similar to that of unit A in Delaware, although they differ somewhat in their lithologic characteristics. Additional well control will be required to determine if these differences in lithologies are significant enough to assign different formational (group) names for those sediments in Maryland and Delaware.

The Piney Point Formation was readily identified in Nc13-3 on the basis of lithology and geophysical logs. This formation compares favorably with the Piney Point Formation in adjacent parts of the Delmarva Peninsula.

The Chesapeake Group of Miocene age in Nc13-3 has similar gross lithologies and stratigraphic sequences to Miocene sediments encountered in adjacent portions of Kent and Sussex Counties, Delaware, and Maryland Eastern Shore counties. Although the Miocene sediments in their entirity are similar, detailed regional correlation

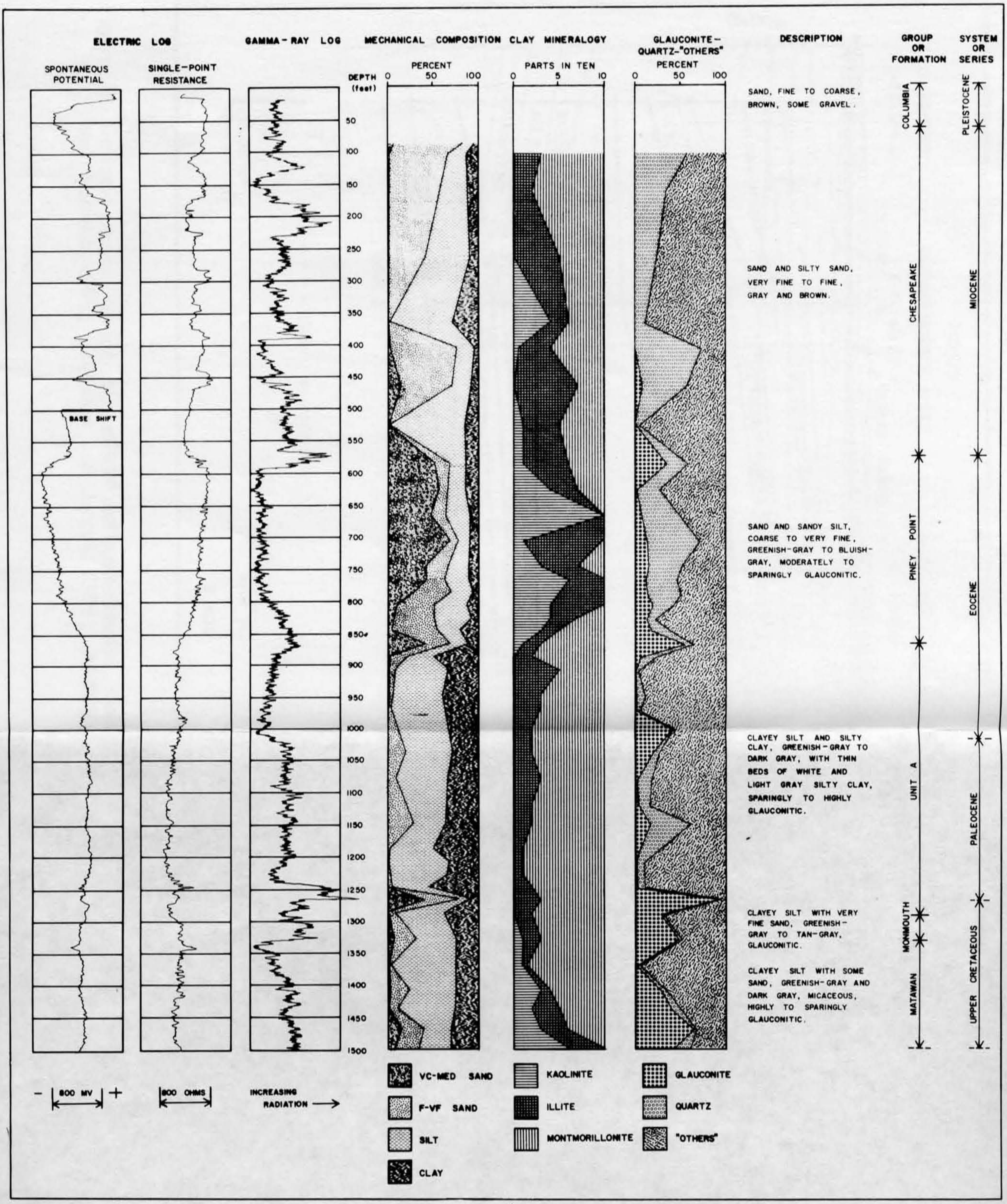

FIGURE 7. COMPOSITE LOG OF TEST WELL Nc13-3.

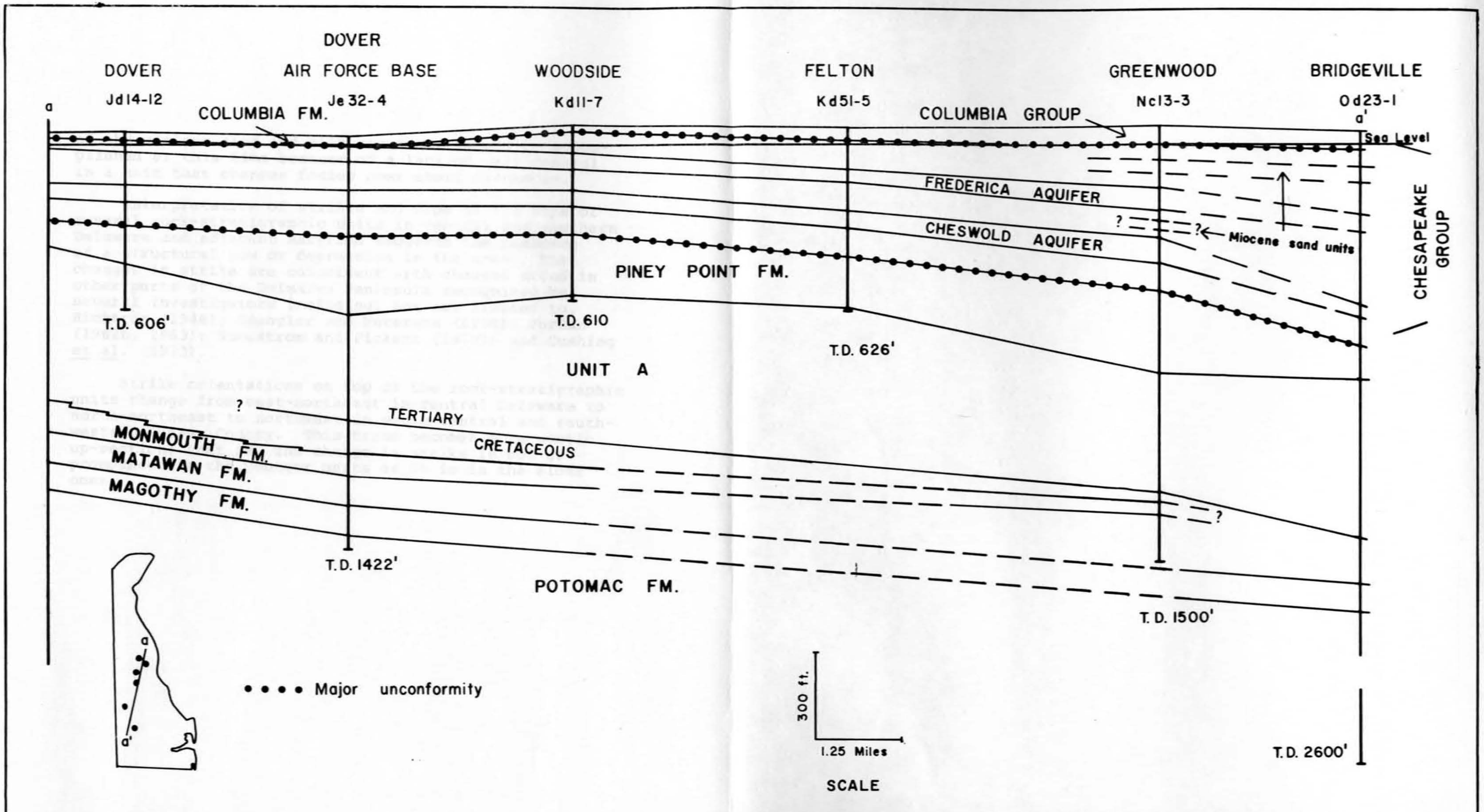

Figure 8. Geologic cross section of central and southwestern Delaware (Modified after Kraft and Maisano, 1968; Spoljaric and Jordan, 1966; Jordan, 1963).

of the various sand and silt sequences cannot be accomplished at this time because of a lack of well control in a unit that changes facies over short distances.

Interpretation of strikes and dips of the tops of several rock-stratigraphic units in central and southern Delaware and adjacent Maryland suggests the presence of a structural low or depression in the area. The changes in strike are coincident with changes noted in other parts of the Delmarva Peninsula recognized by several investigators including, but not limited to, Richards (1948); Spangler and Peterson (1950); Jordan (1962b, 1963); Sundstrom and Pickett (1970); and Cushing et al. (1973).

Strike orientations on top of the rock-stratigraphic units change from east-northeast in central Delaware to north-northeast to northwest in south-central and southwestern Sussex County. This trend becomes more subtle up-section; that is, the change in strike is not as pronounced in the younger units as it is in the older ones.

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APPENDIX A

Table for the conversion of English Units to the International System of Units (SI)

APPENDIX A

The following factors may be used to convert data from the English Units published herein to the International System of Units (SI).

Multiply English units	By	To obtain SI units
inches (in)	25.4	millimeters (mm)
inches (in)	.0254	meters (m)
feet (ft)	.3048	meters (m)
miles (mi)	1.609	kilometers (km)

APPENDIX B

Geologists' descriptive log of well Ncl3-3

APPENDIX B

This log was compiled from descriptions of the ditch and core samples by I. H. Kantrowitz and R. H. Johnston of the USGS and J. H. Talley of the DGS while drilling was in progress.

Depth Interval (feet)	Sample Number (core)	Description
0-10		Sand, fine, clayey, silty, tan to tannish-gray
10-20		Sand, fine to very fine, silty, clayey, gray; some gravel, coarse sand
20-30		Sand, very fine to coarse, gravel; some silt and clay
30-69		Sand, fine to very coarse, with gravel. Generally smaller than above
69-71		Silt, clay, dark gray, with sand, very fine
71-76		Sand, fine to very fine, silty, dary gray
76-86		No recovery
86-91	22864	Sand, very fine, silty, gray
91-101		No recovery
101-106	22865	Silt, dark gray, with clay and sand, very fine to fine
106-111		Silt, dark gray, with clay and sand, very fine to fine
111-121		Silt, dark gray, with sand, very fine to fine

(continued)

Depth Interval (feet)	Sample Number (core)	Description
121-131		Silt, dark gray, sand, very fine to fine, with shell fragments
131-141		Silt, dark gray, with shell fragments, white
141-151		Silt, dark gray, with sand, fine to medium, shell fragments (gastropods and pelecypods)
151-161		Silt, dark gray, with abundant shell fragments
161-166	22866	Silt, dark gray, with shell fragments
166-171		Sand, fine to coarse, silty, gray, with many shell fragments
171-184		Clay, dark gray, with streaks of silt; some shell fragments
184-194		Clay, silty, sand, fine, gray, with shell fragments
194-204		Clay, silty, gray, little or no sand; some shell fragments
204-224		Clay, gray, very little silt and sand; some shell fragments
224-264		Clay, silt, gray, shell fragments, with some sand, very fine to fine
264-266	22867	Silt, gray
266-274		Silt, clay, gray
274-284		Clay, shells, some silt, sand, very fine. Shells at 281.5'

(continued)

Depth Interval (feet)	Sample Number (core)	Description
284-304		Clay, silt, shells, with some sand, very fine. Several zones of hard drilling
304-314		Clay, shell fragments, with some sand, very fine
314-324		Clay, some silt and shell fragments
324-364		Clay, silty, dark gray, with shell fragments
364-366	22868	Silt, slightly micaceous, gray to dark brownish-gray
366-374		Silt, dark brownish-gray, with sand, very fine, clay
374-384		Silt, dark brown, with sand, very fine, shell fragments, clay binder
384-394		Silt, dark brown. Cemented shell beds 386-389'
394-404		Silt, sand, fine, dark brown, with shell beds
404-406	22869	Sand, very fine, silty, light gray, with shell fragments
406-424		Sand, very fine, silt, grayish-brown, with shell fragments
424-434		Sand, very fine, silt, brownish-gray
434-444		Silt, sand, very fine, grayish-brown, with many shell fragments. Drilling indicates many hard thin shell beds

(continued)

Depth Interval (feet)	Sample Number (core)	Description
444-454		Sand, very fine, silt, grayish-brown, with shell fragments
454-464		Sand, very fine, silt, brownish-gray, with abundant shell fragments. Drills like there are many hard shell beds
464-466	22870	Sand, very fine, silt, brownish-gray, shell fragments
466-474		Sand, very fine, silt, brownish-gray, shell fragments
474-484		Sand, very fine, silty, grayish-brown, shell fragments
484-504		Sand, very fine, silt, grayish-brown, few shell fragments. Easy drilling
504-524		Silt, slightly clayey, brownish-gray, with sand, very fine, shells
524-526	22871	Silt, grayish-brown, with sand, very fine
526-544		Clay, silty, dark gray, with some sand, very fine
544-554		Clay, dark gray, with some sand, very fine
554-574		Clay, dark gray, with some silt, sand, very fine
574-584		Clay, silt, sand, very fine; some cemented layers. Hard drilling 578'
584-586	22872	Sand, very fine, silt, gray; some cemented zones

(continued)

Depth Interval (feet)	Sample Number (core)	Description
586-594		Clay, silt, sand, very fine; some cemented zones
594-614		Sand, fine, shell fragments; almost all cemented. Formation probably sand, very fine to fine, and/or silt, with some layers of sand, fine, cemented
614-624		Sand, fine, shell fragments, cemented. Probably sand, very fine, and/or silt, with some layers of sand, fine
624-626	22873	Sand, very fine to fine, silty, clayey, olive; some cemented sand, shell fragments. May contain some glauconite
626-644		Sand, very fine to fine, with shell fragments
644-654		Sand, very fine to fine, with shell fragments and layers of clay, dark gray. Contains some quartz grains, subrounded; black grains (glauconite?)
654-656		Sand, fine to medium, partially cemented, greenish-gray, some glauconite
656-664		Sand, fine to medium, silty
664-666	22874	Sand, fine to medium, silty, glauconitic, greenish-gray
666-674		Sand, fine to medium, silty, glauconitic, greenish-gray

(continued)

Depth Interval (feet)	Sample Number (core)	Description
674-694		Silt, sand, fine to medium, glauconitic, greenish-gray, with some sand, very coarse, and many shell fragments
694-704		Silt, sand, fine to medium, glauconitic, greenish-gray, with some black grains, very fine to fine
704-706	22875	Sand, fine to medium, silty, glauconitic, greenish-gray
706-714		Sand, fine to medium, silty, glauconitic, greenish-gray
714-724		Sand, fine to coarse, silty, glauconitic, greenish-gray; some shells
724-734		Sand, fine to coarse, silty, clayey, glauconitic, greenish-gray
734-744		Sand, very fine to medium, silty, clayey, glauconitic, greenish-gray
744-746	22876	Sand, very fine to medium, silty, glauconitic, greenish-gray
746-764		Sand, very fine to medium, silty, greenish-gray
764-766	22877	Sand, very fine to fine, silty, glauconitic, greenish-gray
766-784		Sand, very fine to fine, silty, clayey, greenish-gray
784-786	22878	Silt, clay, sand, very fine to fine, greenish-gray; somewhat glauconitic

(continued)

Depth Interval (feet)	Sample Number (core)	Description
786-794		Sand, very fine to medium, silty, clayey
794-804		Sand, very fine to medium; less silt and clay than above
804-806	22879	Silt, sandy, clay, bluish-gray; moderately glauconitic
806-824		Clay, sand, very fine, silt
824-826	22880	Clay, silty, very slightly glauconitic, gray
826-834		Clay, very silty, gray
834-844		Clay, silty, gray, with sand, very fine to medium
844-846	22881	Sand, very fine, silty, clayey, greenish-gray; some glauconite
846-854		Sand, very fine, silt, clayey, greenish-gray
854-864		Sand, very fine, silt, greenish-gray
864-866	22882	Silt, sandy, very fine, greenish-gray, with glauconite
866-874		Sand, very fine, silt, firm, greenish-gray
874-884		Silt, glauconitic, with sand, very fine and clay, greenish-gray
884-886	22883	Silt, with sand, very fine and clay, somewhat glauconitic

(continued)

Depth Interval (feet)	Sample Number (core)	Description
886-904		Silt, glauconitic, firm, with sand, very fine and clay, greenish-gray
904-906	22884	Silt, clayey, firm, with sand, very fine, grayish-green; microfossils
906-914		Silt, clayey, firm, with sand, very fine, grayish-green
914-924		Silt, clayey, with traces of sand, very fine, grayish green
924-944		Silt, clayey, greenish-gray, with small amount of sand, very fine, black
944-946	22885	Silt, clayey, firm, grayish-green, with traces of glauconite; many microfossils
946-964		Silt, clay, firm, grayish-green, some sand, very fine, black
964-966	22886	Clay, silty, grayish-green, with traces of glauconite; very fossiliferous
966-994		Clay, silty, grayish-green, with sand, very fine, black
994-996	22887	Silt, very clayey, grayish-green, with layers of sand, very fine, black; very fossiliferous
996-1004		Clay, silty, grayish-green, with sand, very fine, black
1004-1014		Clay, silty, grayish-green, with layers of sand, very fine, black, cemented

(continued)

Depth Interval (feet)	Sample Number (core)	Description
1014-1034		Silt, clayey, with sand, very fine, black
1034-1036	22888	Clay, silty, olive green, with sand, very fine, cemented, and traces of glauconite
1036-1044		Clay, silty, grayish-green. No cemented layers for last 15' (1029-1044), but sand, very fine, black still present; possible as contamination from drilling mud
1044-1064		Clay, silty, greenish-gray, with traces of sand, very fine, black. Drills like clay
1064-1074		Clay, silty, grayish-green, with a trace of sand, very fine, black
1074-1076	22889	Clay, silty, grayish-green, with traces of glauconite; fossiliferous
1076-1114		Clay, silty, grayish-green, with snad, very fine
1114-1116	22890	Clay, silty, firm, greenish-gray, with sand, very fine, black; fossiliferous
1116-1124		Clay, silty, firm, grayish-green, with sand, very fine, black
1124-1144		Clay, silty, grayish-green, with sand, very fine, black. Recovery is poor due to slow drilling
1144-1146	22891	Clay, with traces of silt, quartz sand, glauconite, dark gray
1146-1164		Clay, gray

(continued)

Depth Interval (feet)	Sample Number (core)	Description
1164-1184		Clay, gray, some silt
1184-1186	22892	Silt, clayey, greenish-gray, grading to clay, dark gray, waxy, with very little silt
1186-1204		Clay, dark gray, very little silt
1204-1206	22893	Clay, slightly silty, waxy, dark gray, with traces of glauconite, mica, quartz, pyrite
1206-1214		Clay, slightly silty, dark gray
1214-1224		Clay, dark gray to greenish-gray, with silt, traces of sand, very fine
1224-1226	22894	Clay, silty, greenish-gray, traces of glauconite, sand, very fine; fossiliferous
1226-1244		Clay, silty, greenish-gray, traces of sand, very fine
1244-1246	22895	Silt, clayey, white to light gray; clay, gray, waxy; very fossiliferous
1246-1254		Sand, very fine, silty, greenish-gray
1254-1264		Clay, sand, very fine, black
1264-1266	22896	Clay, glauconitic, dark gray, with sand, very fine to fine
1266-1285		Clay, dark gray, sand, very fine to fine, black. Sand content decreases with depth
1285-1287	22897	Clay, silty, glauconitic, dark gray

(continued)

Depth Interval (feet)	Sample Number (core)	Description
1287-1325		Clay, silty, greenish-gray, with sand, very fine, black
1325-1327	22898	Clay, silty, greenish-gray to tan-gray, with sand, very fine, black, glauconitic; fossiliferous
1327-1355		Clay, silty, greenish-gray, with sand, very fine, black
1355-1365		Clay, silty, with traces of sand, very fine
1365-1367	22899	Clay, slightly silty, gray, with traces of glauconite; very fossiliferous
1367-1395		Clay, light gray, some wilt and sand, very fine to fine, black
1395-1405		Clay, silt, with sand, very fine to fine
1405-1407	22900	Clay, silty, glauconitic, dark gray, with some shell fragments
1407-1415		Clay, silty, glauconitic, dark gray. Drills streaky
1415-1425		Clay, silt, dark gray, with sand very fine to fine, black
1425-1435		Silt, light gray; clay, silty, dark gray, with some sand, very fine to fine, black
1435-1437	22901	Clay, glauconitic, dark gray, with silt and mica; greasy
1437-1445		Clay, dark gray, with silt and mica; somewhat glauconitic

(continued)

Depth Interval (feet)	Sample Number (core)	Description
1445-1466		Clay, silty, gray, with silt, greenish-gray and sand, very fine, black
1466-1468	22902	Silt, clayey, glauconitic, grayish-green, with traces of sand, very fine, black
1468-1476		Silt, clay, grayish-green, with glauconite and sand, very fine, black
1476-1486		Silt, clayey, greenish-gray, with sand, very fine, black
1486-1498		Silt, clayey, greenish-gray, with sand, very fine, black, brown
1498-1500 T.D.	22903	Silt, clayey, greenish-gray, with glauconite and sand, very fine