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Palynological and Stratigraphic Investigations of Four Deep Wells in the Salisbury Embayment of the Atlantic Coastal Plain.

by
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Contents

Illustrations

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
867-100

Tables

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
867-100

Abstract

Use of palynological zones defined by Brenner and Doyle from the Cretaceous outcrop belt in Maryland, Delaware, and New Jersey permit correlation of the Cretaceous section in four wells drilled to basement in the Salisbury Embayment in the Eastern Shore of Maryland and in Accomack Co., Virginia. These correlations, supplemented by electric log correlations between wells, clarify the Mesozoic depositional history of the outer margin of the Atlantic Coastal Plain. The bulk of the Cretaceous section consists of continental to marginal marine sediments correlative with and probably older than the outcrop Potomac Group (Aptian-lower Cenomanian?). Lower Cretaceous palynological assemblages also occur in at least the top of basal "red beds" considered Triassic or Jurassic by earlier authors. Dinoflagellates and lithological criteria indicate several transgressive-regressive cycles within the generally transgressive Potomac sequence, with maximum marine incursions in the Late Albian and the Early Cenomanian. Equivalents of the lower Raritan Formation of New Jersey (middle-upper Cenomanian?), absent at the Maryland outcrop, are recognized for the first time in the Taylor and Bethards wells. Potomac and lower Raritan equivalents are separated from overlying Magothy equivalents (upper Santonian-lower Campanian) by a major regional unconformity. Well data suggest that further downdip, under the continental shelf, most of the formations should be marine and contain abundant organic matter. Given sufficient heat and trapping structures, oil and gas may have accumulated.

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
867-100

Introduction and purpose of report

In papers by Minard and others (1974), Perry and others (in press), Mattick and others (1974), and Weed and others (1974), the Atlantic Outer Continental Shelf (AOCS) study group of the U. S. Geological Survey have discussed the geologic, stratigraphic and geophysical framework of the emerged and submerged portions of the Atlantic continental margin. One of our objectives has been realistic estimates of the oil and gas resource potential of the study area (fig. 1).

Geologic investigations which discuss the subsurface configuration of Salisbury Embayment are Anderson (1948), Spangler and Peterson (1950), Richards (1967), Maher (1971), Brown and others (1972), and Cushing and others (1973). Glaser (1969) studied the petrology and origin of surficial Potomac and Magothy (Cretaceous) sediments, while Hansen (1969) investigated the depositional environments of the subsurface Potomac Group using electric logs.

Figure 1 near here.

The main thrust of this paper is to report on our detailed studies of palynoflora (spores and pollen), dinoflagellates, and lithostratigraphy from wells in Maryland and Virginia. The wells (fig. 2)

Figure 2 near here.

Figure 1.-- Location of Salisbury Embayment, one of several downwarps along Atlantic continental margin. Metre contours are depth to basement.

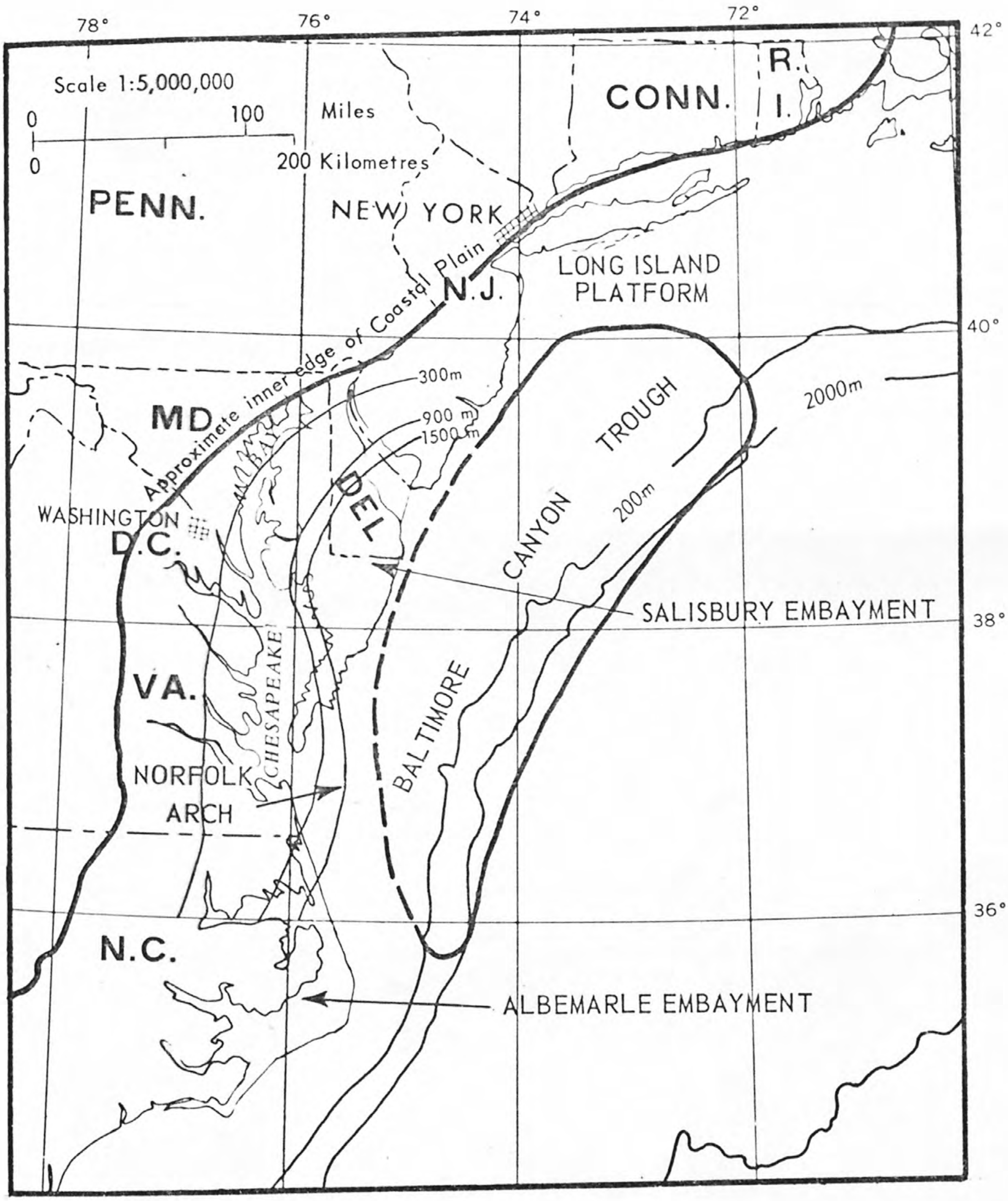
78°
76°
74°
72°
42°
40°
38°
36°
Scale 1:5,000,000
0
100
Miles
0
200 Kilometres
PENN.
NEW YORK
CONN.
R.
I.
LONG ISLAND
PLATFORM
N.J.
Approximate inner edge of Coastal Plain
MD
300m
900 m
1500 m
2000m
BAY
DEL
TROUGH
CANYON
200m
WASHINGTON
D.C.
SALISBURY EMBAYMENT
CHESAPEAKE
VA.
BALTIMORE
NORFOLK
ARCH
N.C.
ALBEMARLE EMBAYMENT

Figure 1

Figure 2.--Location of wells discussed in this report.

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
867-100

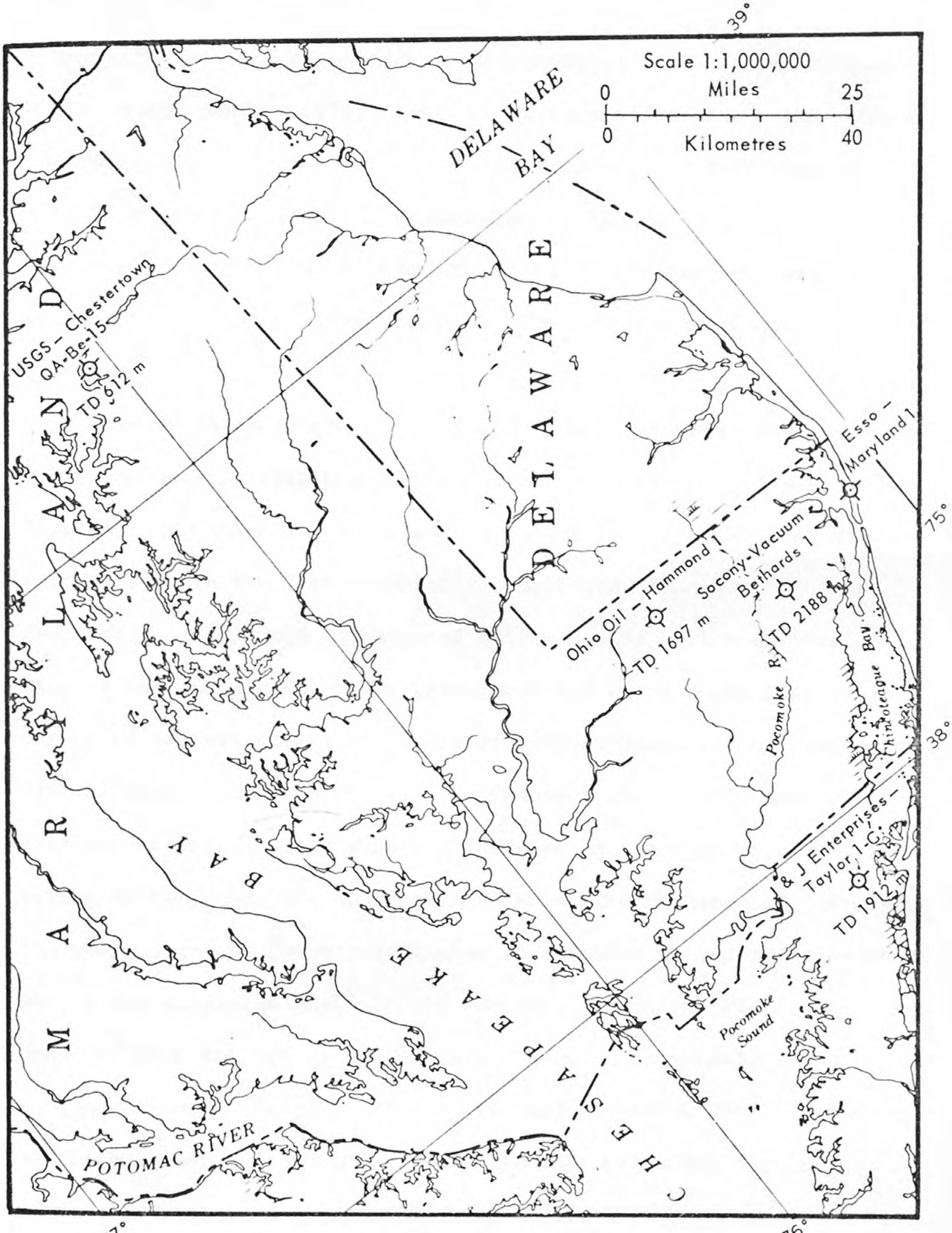
39°
Scale 1:1,000,000
0 Miles 25
0 Kilometres 40
DELAWARE BAY
DELAWARE
MARYLAND
USGS - Chestertown QA-Be-15
TD 612 m
Esso - Maryland 1
Ohio Oil - Hammond 1
TD 1697 m
Socony-Vacuum Bethards 1
TD 2188 m
Pocomoke R.
Chincoteague Bay
& J Enterprises - Taylor 1-C
TD 1912 m
Pocomoke Sound
CHESAPEAKE BAY
POTOMAC RIVER
75°
38°
77°
76°

Figure 2

from which our data has also been incorporated into the other studies, (Mattick and others, 1974; Minard and others, 1974; Perry and others, in press) are: 1) USGS Chestertown QA-Be-15, Queen Anne Co., Maryland; 2) Ohio Oil L. G. Hammond No. 1, Wicomico Co., Maryland; 3) Socony-Vacuum Oil J. D. Bethards No. 1, Worcester Co., Maryland; and 4) J & J Enterprises E. G. Taylor No. 1-G, Accomack Co., Virginia.

Because there is now a substantial amount of detailed literature available dealing with Cretaceous palynofloras of Eastern North America, and because "the thickest wedge of coastal-plain deltaic sediments is in the Cretaceous of the Salisbury Embayment" (Minard and others, 1974), the emphasis of this paper is on the Cretaceous. Many of the beds in the Lower Cretaceous and Lower Upper Cretaceous cannot be differentiated on lithologic ground because they represent similar environments of deposition (Brenner, 1963). A palynological zonation has also become important because of the time transgressive nature of the lower and upper boundaries of the Continental Cretaceous wedge. The recognition of these palynozones furthermore allows correlation between the marine and nonmarine parts of the section. Previous practice has been to consider that the top of the nonmarine section is roughly time-equivalent over a large area (Spangler and Peterson, 1950) or that the Upper/Lower Cretaceous boundary lies far below the top of the nonmarine Cretaceous sequence (Maher, 1971).

Correlating from well to well using the palynologic zonation enables us to recognize relatively close approximations of time lines.

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
867-100

Projecting these lines downdip has enabled us to date unsampled seismic reflecting horizons out under the continental shelf.

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
667-100

Acknowledgements.--Ruth Todd, U. S. Geological Survey, generously furnished unpublished data on foraminiferal identifications. E. M. Cushing and I. H. Kantrowitz, also with the U. S. Geological Survey, provided much of the basic geologic data, including geophysical borehole logs from the Taylor well. Robert R. Jordan, State Geologist of Delaware, James L. Calver, State Geologist of Virginia, and John S. Penny, LaSalle College, furnished valuable pollen slides. Richard Scott and L. Imogene Doher, U. S. Geological Survey, and Leslie A. Sirkin, Adelphi College, and U. S. Geological Survey, did the initial palynological identifications from the Taylor well. Leslie Sirkin prepared the slides for the Chestertown well. Atlantic Richfield Corporation and Exxon Company, U.S.A. prepared the samples from the Taylor well. Exxon lent us preparations from the bottom of the Bethards well, and the Maryland Geological Survey lent one of us (Doyle) samples from the rest of the Bethards well.

Area of interest.--The Salisbury Embayment is one of a series of downwarps in the crystalline basement of the Atlantic continental margin of North America (fig. 1), filled by clastic deposits of Mesozoic and Cenozoic age. Downwarping slowed substantially during the Tertiary (Anderson, 1948; Maher, 1971). While the fluvial-deltaic deposits of the Potomac Group (chiefly Lower Cretaceous) crop out in Virginia, Maryland, Delaware and southern New Jersey, rocks of the same age are penetrated to depths of 1800 m in the Socony-Vacuum Bethards well (Maryland) of the Salisbury Embayment and 2700 m in the Esso Hatteras Light well (North Carolina) of the Albermarle Embayment (Perry and others, in press). Owens (1970) shows these depths to reflect the magnitude of downwarp.

Previous palynological investigations.-- Although Groot and Penny (1960) and Stover (1964) reported results of palynological reconnaissance studies of samples from the Potomac Group, the first comprehensive attempt at palynological zonation in the Atlantic Coastal Plain continental Cretaceous section was the monographic study of Brenner (1963) of the spores and pollen of the Potomac Group of Maryland. Brenner recognized two broad biostratigraphic assemblage zones in the Potomac section, Zone I and Zone II, the latter subdivided into Subzones IIA and IIB, defined primarily on restricted vertical ranges of various taxa and secondarily on frequency changes in two well sections. At the Maryland outcrop belt, Zone I corresponds to the Patuxent Formation and Arundel Clay, while Zone II corresponds to the Patapsco Formation as customarily defined (e.g., by Glaser, 1969, see fig. 3). Further detailed studies on the angiosperm element (Doyle,

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Figure 3 near here.

1969a, and in press; Doyle and Hickey, in press) have led to minor modifications in the definitions of these zones and recognition of stratigraphically useful changes within them.

Palynological assemblages from the Raritan Formation in its type area around Raritan Bay, New Jersey, particularly from the Woodbridge Clay Member (fig. 3), were first described by Groot, Penny and Groot (1961) and Kimyai (1966). More detailed studies of samples from both

Figure 3.-- Presumed geologic ages, pollen zonation, and stratigraphic relations of outcropping and shallow subsurface geologic units along Atlantic continental margin from Maryland to Long Island. Adapted from (1) Cobban and Reeside (1952), (2) Sohl and Mello (*in* Owens and others, 1970, fig. 24), (3) Brenner (1963), Doyle (1969b, in press), and Sirkin (1974b), (4) Owens and others (1970) and Glaser (1968), (5) Minard and others (1969), and (6) Perlmutter and Todd (1965), and Sirkin (1974b).

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
867-100

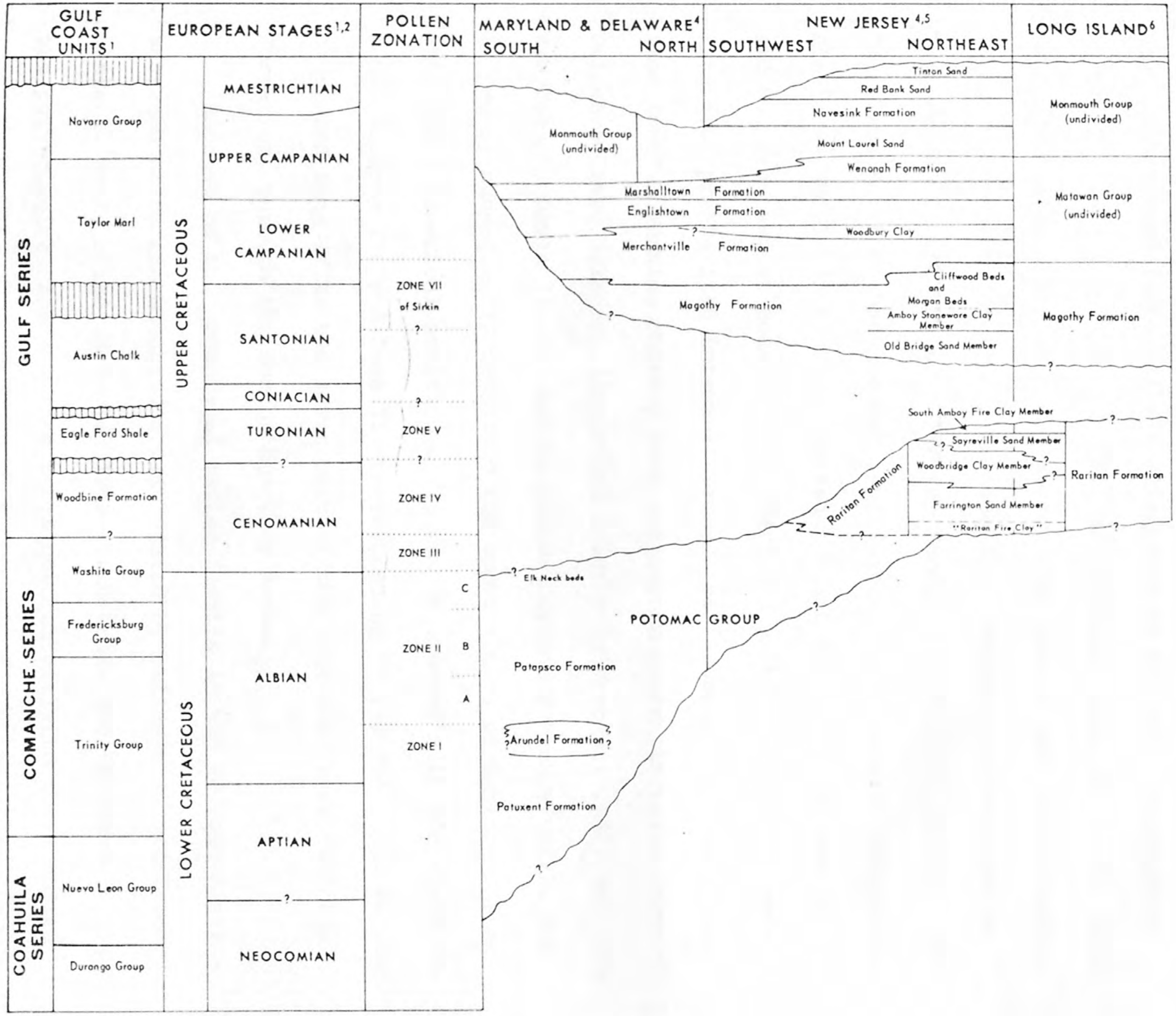
GULF COAST UNITS[1]
EUROPEAN STAGES[1,2]
POLLEN ZONATION
MARYLAND & DELAWARE[4]
SOUTH
NORTH
NEW JERSEY[4,5]
SOUTHWEST
NORTHEAST
LONG ISLAND[6]
GULF SERIES
COMANCHE SERIES
COAHUILA SERIES
Navarro Group
Taylor Marl
Austin Chalk
Eagle Ford Shale
Woodbine Formation
Washita Group
Fredericksburg Group
Trinity Group
Nuevo Leon Group
Durango Group
UPPER CRETACEOUS
LOWER CRETACEOUS
MAESTRICHTIAN
UPPER CAMPANIAN
LOWER CAMPANIAN
SANTONIAN
CONIACIAN
TURONIAN
CENOMANIAN
ALBIAN
APTIAN
NEOCOMIAN
ZONE VII of Sirkin
ZONE V
ZONE IV
ZONE III
ZONE II
C
B
A
ZONE I
Tinton Sand
Red Bank Sand
Navesink Formation
Monmouth Group (undivided)
Mount Laurel Sand
Wenonah Formation
Marshalltown Formation
Englishtown Formation
Woodbury Clay
Merchantville Formation
Matawan Group (undivided)
Cliffwood Beds and Morgan Beds
Amboy Stoneware Clay Member
Old Bridge Sand Member
Magothy Formation
South Amboy Fire Clay Member
Sayreville Sand Member
Woodbridge Clay Member
Farrington Sand Member
"Raritan Fire Clay"
Raritan Formation
Elk Neck beds
POTOMAC GROUP
Patapsco Formation
Arundel Formation
Patuxent Formation

Figure 3

New Jersey and Maryland led Wolfe and Pakiser (1971) to recognize that beds in Maryland (especially well exposed at Elk Neck) which were formerly identified with the Raritan Formation (e.g., by Clark, 1916; Spangler and Peterson, 1950; Glaser, 1969) are in fact intermediate in age between the Patapsco (Subzone IIB) assemblages described by Brenner (1963) and the type Raritan Formation. They reassigned these "Maryland Raritan" beds to the upper part of the Patapsco Formation. Similarly, Doyle (1969a) recognized samples from wells in New Jersey and Maryland and at Bodkin Point, Maryland as belonging to a post-Patapsco, pre-Raritan interval, termed the "Patapsco-Raritan transition zone". Working chiefly with angiosperm pollen in wells from Delaware City, Delaware (described briefly by Brenner, 1967) and from New Jersey, Doyle (1969a, and in press; Doyle and Hickey, 1972, and in press) subsequently redefined the upper limits of Subzone IIB and extended a numerical zonation analogous to Brenner's to post-Patapsco beds, Subzone IIC and Zone III corresponding to the "Maryland Raritan" beds, and Zone IV to the lower part of the type New Jersey Raritan Formation, through the Woodbridge Clay Member.

Because of the absence of marine fossils in the Potomac-Raritan sequence below the Woodbridge Clay (dated by mollusks as mid-Cenomanian: Sohl, cited in Doyle, 1969a, and Wolfe and Pakiser, 1971), the palynological zones cannot be related directly to the standard faunally defined European or Gulf stage sequences. However, palynological correlations with faunally dated floras from Europe (e.g., Kemp, 1970; Pacltová, 1971) and the Gulf Coastal Plain and Western Interior of North America (e.g., Pierce, 1961; Leopold and Pakiser, 1964; Hedlund, 1966; Norris, 1967; Hedlund and Norris, 1968) permit indirect correlations of Zone I with the (Barremian?-) Aptian to lower Albian, of Subzone IIA and IIB with the middle and upper Albian, of Subzone IIC and Zone III with the (latest) upper Albian and lower Cenomanian, and of Zone IV with the middle to upper Cenomanian (-lower Turonian?) (see Brenner, 1963; Doyle, 1969a, and in press; Doyle and Hickey, in press; Kemp, 1970; Wolfe and Pakiser, 1971; Pacltová, 1971; and below for discussion).

Stratigraphic palynological investigations of the post-Woodbridge Cretaceous section are less advanced and their results more controversial. Although Wolfe and Pakiser (1971) considered the Raritan Formation of New Jersey as a single palynological unit, Doyle (1969a) and Sirkin (1974b) recognize a distinctly younger flora, believed by Doyle (1969a) to be of (middle?) Turonian to Coniacian (?) age, in the upper Raritan Formation (South Amboy Fireclay Member), which Sirkin (1974b) designates Zone V. The Magothy Formation, which unconformably overlies the Potomac Group in Maryland and the Raritan Formation in New Jersey, contains a rich flora reported on briefly by Groot, Penny and Groot (1961), Stover (1964), and Doyle (1969a) and in greater detail by Wolfe and Pakiser (1971), who demonstrate its upper Santonian to lower Campanian age on the basis of comparison with European floras (Góczán et al., 1967) and associated mollusks. Sirkin (1974b) terms the Magothy assemblage Zone VII, leaving Zone VI unassigned for post-South Amboy, pre-Magothy floras in the event they are sampled, but until better information is available on the position and extent of the hiatus between the Raritan and Magothy Formations, we prefer not to recognize numbered zones above Zone V.

The first four palynological zones come close to being defined by the appearance and initial proliferation of successive major morphological classes of angiosperm pollen: monosulcate in Zone I, tricolpate and tricolporoidate in Zone II, tricolporate in Zone III, and triporate Normapolles in Zone IV. However it is important to realize that each pollen class continues to diversify above the zone in which it enters. The zones and subzones as we recognize them may be defined more precisely as follows, simplified somewhat from Brenner (1963), Doyle (in press), and Sirkin (1974b); note that not all the features cited are necessarily observed in every sample we have assigned to a particular zone.

<u>Zone I</u>: unfortunately, only a few rather rare species (e.g., <u>Ephedripites virginiaensis</u>, <u>Kuylisporites lunaris</u>) are restricted to Zone I, but it is usually distinguishable on the absence of the Zone II index species of Brenner (1963; see below) and the greater abundance of <u>Cyathidites</u>, striate schizaeaceous spores, and the gymnosperms <u>Exesipollenites</u> and <u>Classopollis</u> (Brenner, 1963). Reticulate monosulcates of the <u>Clavatipollenites</u>, <u>Retimonocolpites</u>, <u>Liliacidites</u>, and "<u>Peromonolites</u>" <u>peroreticulatus</u> complex, all of

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
867-100

which extend into younger beds, are present in minor proportions (Brenner, 1963; Doyle, 1969a, figs. 1c-g, j, k; Doyle, 1973, figs. 2a-f, 1, m). *Retimonocolpites dividuus* Pierce and the first very rare, medium-sized, reticulate tricolpates appear near the top of the zone (Doyle, in press), as at or just below the lower-middle Albian boundary in England (Kemp, 1968, 1970).

Subzone IIA: defined by the appearance of *Apiculatisporis babsae*, *"Monosulcites" chaloneri*, *Perotriletes pannuceus*, and other Zone II index taxa listed by Brenner (1963). *Clavatipollenites tenellis* Paden-Phillips and Felix and tricolpate pollen, including small (10-17 u) reticulate to tectate forms (e.g., *"Tricolpopollenites" micromunus* Groot and Penny and *Tricolpites albiensis* Kemp), though still subordinate, become regularly represented (Brenner, 1963; Doyle, 1969a, and in press). *A. babsae* and similar small tricolpates enter low in the middle Albian in England (Kemp, 1968, 1970).

Subzone IIB: defined by the appearance of *Cicatricosisporites patascoensis*, *C. subrotundus*, *"Lycopodiacidites" cerniidites* (=*Camarozonosporites*), *Neoraistrickia robusta*, *Reticulatisporites arcuatus*, and other Subzone IIB index species of Brenner (1963), and the greater abundance of *Araucariacites*, bisaccates, and angiosperm pollen (Brenner, 1963). The great variety of new angiospermous monosulcates and tricolpates include: "crotonoid" monosulcates (new genus A of Doyle, in press), *Ajatipollis* Krutzsch tetrads, and *"Retitricolpites" georgensis*, which enter near the

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
867-100

base of the subzone and extend into higher zones; trichotomosulacte and irregular-aperturate variants of *Clavatipollenites* (*Asteropollis asteroides* and *Stephanocolpites fredericksburgensis* Hedlund and Norris: Doyle, 1969a, fig. 1h, i), restricted to the lower two-thirds; and several large and sometimes trichotomosulacte *Liliacidites* species (Doyle, 1973, figs. 2g-k, n, o), "*Retitricolpites*" *fragosus* Hedlund and Norris (Doyle, 1969a, figs. 2g-i), "*R.*" *prosimilis* Norris, "*R.*" *geranioides* sensu Brenner, "*R.*" *vermimurus* Brenner, "*R.*" *paraneus* Norris, "*Tricolpopollenites*" *minutus* Brenner, and *Penetetrapites mollis* Hedlund and Norris, in the upper two-thirds of the subzone (Doyle, in press). Representatives of tricolpate species (especially "*T.*" *micromunus* and "*T.*" *minutus*) with rudimentary ora (tricolporoidate) become progressively more common higher in the subzone (Doyle, 1969a, fig. 2p-t). Closely comparable floras have been described from dated middle and upper Albian rocks by Norris (1967), Hedlund and Norris (1968), Kemp (1968, 1970), and Paden-Phillips and Felix (1971).

Subzone IIC: defined by the appearance of very small (8-17 u), psilate tricolpates and tricolporoidates ("*Tricolpopollenites*" *parvulus* Groot and Penny, *Tricolporoidites subtilis* Pacltová and "*Tricolporopollenites*" *distinctus* Groot and Penny) and the conifers *Rugubivesiculites reductus* and *R. rugosus* Pierce, the disappearance of "*Retitricolpites*" *vermimurus*, and the relative abundance (as also in lower Zone III) of *Granulatisporites dailyi*, *Lycopodiacidites* *triangularis*, *Taurocusporites reduncus*, and *T. spackmani* (Doyle and Hickey, 1972, and in press; Doyle, in press). Comparable floras occur in the uppermost Albian (-Cenomanian?) of the Western Canada Plains (Norris, 1967).

Zone III: defined by the appearance of additional tricolpates and tricolporoidates, including *Tricolpites vulgaris* (Pierce) Pacltová (Brenner, 1967, Pl. 3, fig. 1), *Tricolporoidites bohemicus* Pacltová, "*Tricolporopollenites*" *triangulus* Groot, Penny and Groot (Brenner, 1967, Pl. 3, figs. 9-11; Wolfe and Pakiser, 1971, figs. 2q, r), and larger (*ca*. 20 u) trianglar tricolporates ("*Tricolporopollenites*" *fortis*). "*Retitricolpites*" *paraneus* occurs near the base of the zone only (Wolfe and Pakiser, 1971, fig. 2s); *Tricolpites nemejci* Pacltová and larger (25-35 u) reticulate and tectate tricolporates (e.g., "*Foveotricolporites*" *rhombohedralis* and "*Tricolporopollenites*" *globularis* of Brenner, 1967, Pl. 3, figs. 2, 5) enter in the upper third of the zone (Doyle, in press). Comparable floras are described from lower Cenomanian rocks elsewhere by Pierce (1961), Hedlund (1966), and Pacltová (1971).

Zone IV: defined by the appearance of still larger (*ca*. 40 u) tricolporates (Kimyai, 1966, Pl. 2, fig. 18; Doyle, 1969a, figs. 3g-i), two new tetrad types (Doyle, 1969a, 3j-m), and the first triporates of the Normapolles group (*Complexiopollis*, *Atlantopollis*: Doyle, 1969a, figs. 3n, o; Wolfe and Pakiser, 1971, figs. 2g, o; Sirkin, 1974b, figs. 4k, l). Similar forms, especially the

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867-100

Normapolles, are reported from middle Cenomanian to lower Turonian rocks by Leopold and Pakiser (1974), Góczán et al. (1967), Pacltová (1971), and Paden-Phillips and Felix (1971).

Zone V: defined by the appearance of additional Normapolles (*Complexiopollis* spp., *Pseudoplicapollis*, aff. *Plicapollis*: Doyle, 1969a, figs. 4a-d; Wolfe and Pakiser, figs. 2c-f), other triporates (aff. *Triatriopollenites*, etc,: Doyle, 1969a, figs. 4e-g), and tricolporates (*Porocolpopollenites* of Doyle, 1969a, fig. 4h; Wolfe and Pakiser, 1971, fig. 2j; Sirkin, 1974b, fig. 5). Somewhat similar assemblages are reported from the McShan and Eutaw Formations of Alabama (Leopold and Pakiser, 1964); the observed association of Normapolles genera does not occur below the middle Turonian in Europe (Góczán et al., 1967).

Magothy equivalents ("Zone VII" of Sirkin, 1974b): recognized by the presence of various advanced Normapolles genera (*Trudopollis*, *Semioculopollis*, *Pecakipollis*, *Vacuopollis*, *Praebasopollis*, and new species of *Plicapollis* and *Pseudoplicapollis* : Wolfe and Pakiser, 1971, fig. 4, 5; Doyle, 1969a, fig. 5; Sirkin, 1974b, fig. 6) and a variety of palmlike monosulcates (e.g., Doyle, 1969a, figs. 51, m).

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
867-100

Results

Appendix 1 gives detailed description and locality data for each well, including the depth and lithology of each sample and the general abundance of microfossils. Figure 4 shows generalized lithology and our interpretations of ages of the beds in all four wells.

Figure 4 near here.

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
867-100

Figure 4.-- Electric log-palynological correlations of wells studied in this report. Chestertown well logged by Birdwell Division of SSC. Other wells logged by Schlumberger WSC. Scale change at 1066.8 m (3500 ft) in Taylor well a result of switch to LL8 resistivity curve. Foraminifera determined by Todd.

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
867-100

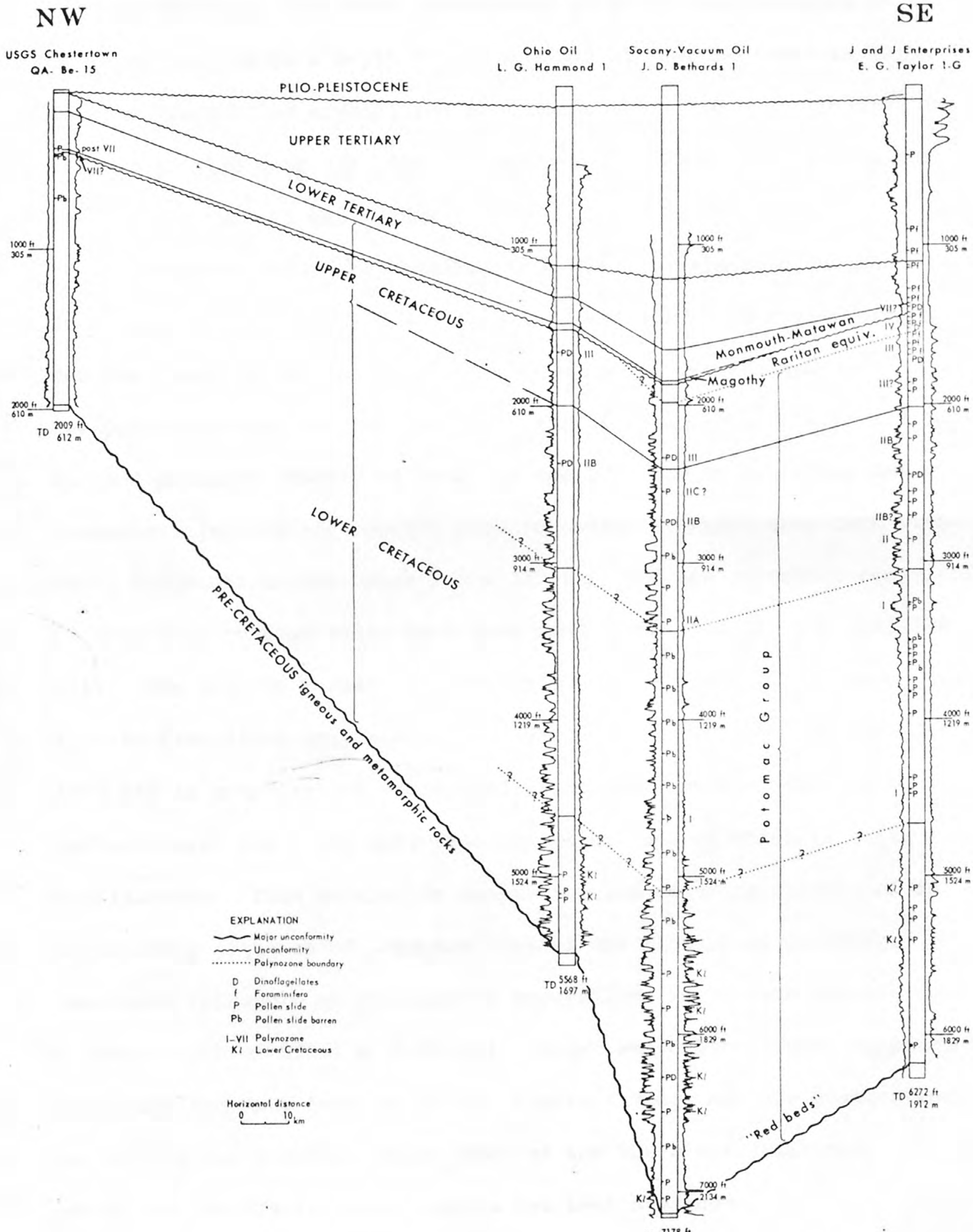
NW
SE
USGS Chestertown
QA- Be- 15
Ohio Oil
L. G. Hammond 1
Socony-Vacuum Oil
J. D. Bethards 1
J and J Enterprises
E. G. Taylor 1-G
PLIO-PLEISTOCENE
UPPER TERTIARY
LOWER TERTIARY
UPPER CRETACEOUS
LOWER CRETACEOUS
PRE-CRETACEOUS igneous and metamorphic rocks
Monmouth-Matawan
Raritan equiv.
Magothy
Potomac Group
"Red beds"
TD 2009 ft 612 m
TD 5568 ft 1697 m
TD 7178 ft 2188 m
TD 6272 ft 1912 m
EXPLANATION
Major unconformity
Unconformity
Polynozone boundary
D Dinoflagellates
f Foraminifera
P Pollen slide
Pb Pollen slide barren
I-VII Polynozone
Kl Lower Cretaceous
Horizontal distance
0 10 km

Figure 4

Chestertown.--The USGS Chestertown QA-Be-15 stratigraphic test well was drilled to a depth of 612 m (2009 ft) and bottomed in Paleozoic or Precambrian crystalline rock (Kantrowitz and Webb, 1971). The well is located near the edge of the Salisbury Embayment, 195 km northwest of the Hammond well (fig. 2).

Geological data were obtained from drill cuttings of 3m (10 ft) intervals in the first 152.4 m (500 ft), and 9.1 m (30 ft) intervals for the remainder of the well. According to Kantrowitz and Webb (1971), the Quaternary and Tertiary section extends to a depth of 42.1 m (138 ft) and consists chiefly of sand and shells. The Monmouth and Matawan Formations (undivided) contain fine to medium greenish gray sand with shell fragments in the upper 7.0 m (23 ft), but are otherwise comprised of very fine to fine silty dark gray sand (from 49.1-115.8 m (161-380 ft)). The Magothy Formation (115.8-120.0 m (380-394 ft)) is a very fine to fine light gray sand. The section from 120.1 to 595.2 m (394 - 1953 ft) is comprised of variegated light-gray, purple, red, brown, and yellow clays, and light gray sand and silt, some of which is quite argillaceous. This section is non-marine and consists chiefly of an alternating sequence of presumed fluvial and floodplain deposits. Weathered Paleozoic or Precambrian crystalline rocks were encountered below a depth of 595.3 m (1953 ft). Brown and others (1972, supplement) also compiled data from the well. Figure 4 shows our age designations as well as the depth of pollen samples and the biostratigraphic zone to which the one fossiliferous sample has been assigned.

Table 1 enumerates a selection of pollen taxa observed in the well. Unfortunately, the deeper samples were oxidized (pink, red and orange),

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Table 1 near here.

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and little pollen was expected or found. A sample from 110.9-111.6 m (364-366 ft) was poor also but contained a flora which included *Pecakipollis*, *Pseudoplicapollis* and two species of *Intratriporopollenites*. These would be consistant with a Magothy or post-Magothy age and in agreement with correlations by both Kantrowitz and Webb (1971) and Brown and others (1972, supplement). No marine microfossils were evident on the slides, and possibly a piece of a megaspore was seen in the sample from 124.4-124.9 m (408-410 ft).

Table 1.--Palynomorphs in USGS Chestertown QA-Be-15 well.

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
867-100

Table 1. Palynomorphs in USGS Chestertown QA-Be-15 well

P-present

SPECIES/SAMPLE DEPTH	m: 110.9-11.6 / ft: 364-66
Spores	
Camarozonosporites sp.	P
Gymnosperms	
Inaperturopollenites sp.	P
Angiosperms	
Complexiopollis sp.	P
Intratriporopollenites sp.	P
Monosulcites sp.	P
Pecakipollis sp.	P
Porocolpopollenites sp.	P
Pseudoplicapollis sp.	P
Tricolporate type 5 (Doyle 1969a)	P
Triporate type 1 (Doyle 1969a)	P

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867-100

Hammond.-- Ohio Oil L. G. Hammond No. 1 was drilled to a depth of 1697.1 m (5568 ft) and bottomed in pre-Mesozoic quartzite or gneiss (Anderson, 1948; Maher, 1971). It is located 100 km southeast of (downdip from) the Chestertown well and 22 km west of the Bethards well (fig. 2). Age assignments, based on foraminifera, ostracods, and mollusks in the upper part of the well (Upper Cretaceous, Tertiary), but largely on lithological correlations in the lower part (Lower Cretaceous), have been published by Anderson (1948), Maher (1971), and Brown and others (1972).

Geological data from the Hammond well are excellent because the well was cored throughout and descriptions of the core samples were published by Anderson (1948, p. 388-413). According to Anderson (1948, p. 98), Quaternary and Tertiary sediments were encountered in this well to a depth of 384.0 m? (1260 ft?). Brown and others (1972) place the Tertiary/Cretaceous boundary somewhat lower, at 411.5 (1350 ft), very close to that of Applin (in Maher, 1971), below highly glauconitic shale assigned to the Paleocene Hornerstown Formation. The upper 13.1 m (43 ft) of Cretaceous strata encountered in this well consist of argillaceous glauconitic sand assigned to the Monmouth Formation (Anderson, 1948), underlain by 9.1 m (30 ft) of white silty chalk of Taylor (Campanian) age. Gray glauconitic clay shale occurs from a depth of 433.7 m to 451.1 m (1423-1480 ft), with 3 m (10 ft) of argillaceous, somewhat glauconitic, conglomeratic sand at the base. From these strata, lithologically similar to the Wood-

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867-100

bury Clay and Merchantville Formation of New Jersey, Ruth Todd (unpublished data, 1973) reports "Lower Taylor" foraminifera, no older than Campanian in age. We place the immediately underlying fine sand and clay beds, which extend to approximately 466.3 m (1530 ft), in the Magothy Formation. Core descriptions of this interval (Anderson, 1948, p. 390-391) suggest that a major break, the pre-Magothy unconformity of Perry and others (in press, and fig. 3), occurs at 466.3 m, immediately above a very hard, indurated, brownish-black shale bed. We place all strata encountered in this well below 466.3 m (1530 ft) in the Potomac Group (cf. Brown and others, 1972, and below), including the basal red beds between 1634.6 m (5363 ft) and 1675.8 m (5498 ft) which Anderson (1948) and Maher (1971) assigned to the Triassic. The distinctive marine unit which has furnished a Zone IV (lower Raritan equivalent) flora in the Taylor well, and is recognized lithologically in the Bethards well, appears to be lacking here, as in the Chestertown well and at the outcrop (cf. also Brown and others, 1972). Stephenson (in Anderson, 1948) assigned molluscan faunas from depths of 484.0-487.1 m (1588-1598 ft), 487.1-488.6 m (1598-1603 ft), and 685.8-687.9 m (2250-2257 ft) to the Raritan, but acknowledged that the resulting excessive thickness of strata placed in the Raritan suggests that at least the lowest of these faunas may represent "a shallow marine or brackish-water facies of one of the formations of the Potomac Group." Core descriptions (Anderson, 1948) indicate that sediments from the interval from 466.3 m (1530 ft) to 725.4 m (2380 ft) are predominantly nonmarine, chiefly coastal swamp, lagoonal, estuarine, or other deposits of the inner delta fringe or lower delta plain, while sediments below 725.4 are entirely nonmarine. The Raritan Formation, as such, is not recognized south of Trenton, New Jersey (Owens, personal communication, 1974).

Five palynological preparations from the Hammond well were originally studied by Groot and Penny (1960). However, in view of the rudimentary state of Lower Cretaceous palynological systematics at that time, we considered it necessary to restudy Groot and Penny's slides, which were kindly loaned to us by J. S. Penny and the Delaware Geological Survey. The depths of the pollen preparations, their zonal assignments, and the lithological sequence in the Hammond well are indicated in fig. 4. Taxa identified are listed in table 2.

Table 2 near here.

The three preparations from near the base of the Hammond section, from 1563.6-1565.2 m (5130-35 ft), 1555.7-1558.1 m (5104-12 ft) and 1517.9-1519.4 m (4980-85 ft) were re-examined only briefly. However, Groot and Penny (1960) indicate that even these samples contain *Cicatricosisporites*, *Trilobosporites apiverrucatus*, *Pilosisporites trichopapillosus*, and *Densoisporites perinatus* together indicating an Early Cretaceous age. Further studies of these samples and of sections covering intervals both correlative with and older than the outcrop Potomac

Table 2.--Palynomorphs in L. G. Hammond No. 1 well.

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
867-100

Table 2. Palynomorphs in L. G. Hammond No. 1 well

A-abundant, P-present, X-contaminant

SPECIES/SAMPLE DEPTH		
m	720.2-23.3	508.4-11.5
ft	2363-73	1668-78
Spores		
Alsophilidites sp.		P
Aratrisporites sp.		P
Camarozonosporites sp.		P
Cicatricosisporites sp.	P	P
C. hallei	P	
C. patapscoensis		P
Cyathidites sp.	P	P
Gleicheniidites sp.	P	
Laevigatosporites sp.	P	
Gymnosperms		
Araucariacites sp.	P	
Classopollis torosus	A	P
Eucommiidites sp.	P	P
Exesipollenites sp.	P	
Inaperturopollenites sp.	P	P
Perinopollenites elatoides	P	
Spheripollenites perinatus	P	
Abietineaepollenites microreticulatus	P	
Podocarpidites sp.	P	
Angiosperms		
Asteropollis sp.		P
Clavatipollenites sp.	P	P
C. minutus	P	P
Juglans sp.	X	
Penetetrapites sp.	P	
"Peromonolites" peroreticulatus	P	
Retimonocolpites (Liliacidites) dividuus	P	P
"Retitricolpites" georgensis	P	P
"R." magnificus		?
"R." vermimurus	P	
"R." virgeus	P	P
Tricolpites-Tricolpopollenites sp.	P	P
Tricolpites sp. 1 (Kemp 1968)		P
T. albiensis		P
T. nemejci		P
T. vulgaris		P
Tricolpopollenites crassimurus	P	P
T. micromunus	P	
T. minutus	P	P
T. parvulus		P
Tricolporoidites bohemicus		P
T. subtilis		P
Tricolporopollenites distinctus		P
T. fortis		P
T. triangulus		P
Trichotomosulcates		P
Other		
Fungi (unicellular)	P	
Microplankton (hystrichospheres and dinoflagellates)	P	P

would be desirable in order to determine whether these samples represent Zone I (Aptian-lower Albian?) or pre-Zone I (Neocomian?) portions of the Lower Cretaceous.

The two slides from intervals 508.4-511.4m(1668-78 ft) and 720.2-723.3 m (2363-73 ft) were studied in greater detail. The lower sample (720.2-723.3 m) can be assigned to the upper half of Subzone IIB (middle-upper Albian?) on the basis of the association of the angiosperms "Retitricolpites" georgensis, "R." vermimurus, "Tricolpopollenites" micromumus, "T." minutus, and Penetetrapites. Our data thus contradict Maher and Applin's (in Maher, 1971) identification of this interval as "rocks of Eagle Ford age" (Turonian?) but are consistent with its assignment to "Unit F" (middle Albian to lower Cenomanian?) by Brown and others (1972).

The uppermost sample, from 508.4-511.4 m (1668-78 ft) can be assigned to the upper third of Zone III (lower Cenomanian?) on the association of Tricolpites nemejci, T. vulgaris, "Tricolpopollenites" parvulus, "Tricolporopollenites" distinctus, "T." triangulus, and larger triangular tricolporates ("T." fortis). These data agree with Brown and others' (1972) assignment of this interval to the upper part of "Unit F", but rule out Maher and Applin's (in Maher, 1971) identification as "rocks of Austin age" (Coniacian to Santonian), and Stephenson's (in Anderson, 1948) correlation of a fauna from 685.8-687.9 m (2250-57 ft) with the Raritan Formation.

Dinoflagellates were observed in both 702.2-723.3 m and 508.4-

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
842-100

511.4 m intervals, consistent with the presumed transitional continental-marine nature of the upper part of the Potomac Group (466.3-725 m) in the Hammond well.

Bethards.-- Socony-Vacuum Oil J. D. Bethards No. 1 was drilled to a depth of 2187.8 m (7178 ft) and bottomed in gabbro (Anderson, 1948) which is considered Triassic (?) by Maher (1971). This well is located 22 km southeast of the Hammond well (fig. 2) and reaches even deeper into the Salisbury Embayment. The lithology and paleontology (foraminifera and mollusks) of the Bethards well are discussed in Anderson (1948). Both Maher and Applin (in Maher, 1971) and Brown and others (1972) have also published age identifications, based largely on lithological correlations in the lower part of the section.

Unlike the Hammond well, the Bethards well was not continuously cored. Cored intervals are described by Anderson (1948, p. 413-416). On the basis of electric log data, we restrict the Magothy Formation to the depth interval 568.4-576.1 m (1865-1890 ft). Geophysical log comparisons of this well with the Taylor well suggest that strata equivalent to the lower Raritan Formation of New Jersey, absent at the outcrop and not recognized in the Hammond and Chestertown wells, are present in the 576.1-606.6 m (1890-1990 ft) interval. According to Anderson (1948, p. 418-419), these beds consist of clay shale, siltstone, and sand with abundant bivalves and gastropods. We assign the entire 1566.7 m (5140 ft) of strata below 606.6 m (1990 ft), including the beds below 1998.0 m (6555 ft) which Anderson (1948) and Brown and others (1972) considered Triassic, to the Potomac Group (see below). Although foraminifera are noted continuously in ditch cuttings from 609.6 m (2000 ft) to 774.2 m (2540 ft), the presence of lignite and oxidized iron (red to red mottled shales) in sample intervals below 624.8 m (2050 ft) suggests that these fossils are contaminants from higher in the section. Descriptions in Anderson (1948, p. 414-416) indicate that the cored intervals at 643.1-647.7m (2110-2125 ft) and below 899.2 m (2950 ft) are composed almost exclusively of presumed nonmarine clastic sediments.

Four palynological preparations from cores between 1976.9 m and 2151.3 m (6486 ft and 7058 ft) were made available to us by Exxon Company, U.S.A. Core samples from 1909.6-1914.4 m (6275-81 ft) through 708.7-713.2 m (2325-40 ft) were provided (to Doyle) by the Maryland Geological Survey. Our palynological zonation and the lithological sequence in the Bethards well are summarized in fig. 4. Taxa identified in all samples are listed in table 3.

Table 3 near here.

Despite contamination by much more recent material, even the lowest sample in the Bethards well, from 2145.8-2151.1 m (7040-58 ft), can be recognized as Lower Cretaceous on the association of *Cicatricosisporites*, *Apiculatisporis asymmetricus*, *Pilosisporites trichopapillosus*, *Concavissimisporites*, *Ephedripites*, etc. (see table 3).

Table 3.--Palynomorphs in J. D. Bethards No. 1 well.

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
867-100

Table 3. Palynomorphs in J. D. Bethards No. 1 well

A-abundant (more than 10%), P-present, X-contaminant

SPECIES/SAMPLE DEPTH	2145.8-51.3	2112.3-17.4	1976.9-81.5	1909.6-14.4	1777.6-82.5	1710.5-15.4	1542.9-49.0	1411.8-16.7	1028.7-33.6	961.6-66.5	833.6-38.5	774.2-80.3	708.7-13.2
m													
ft	7040-58	6930-47	6486-501	6265-81	5832-48	5612-28	5062-82	4632-48	3375-91	3155-71	2735-51	2540-60	2325-40
Spores													
Alsophilidites pannuceus	P												
Apiculatisporis asymmetricus	P					P							
A. babsae											P		
Appendicisporites sp.					P			P	P		P	P	P
Camarozonosporites sp.											P	P	P
Ceratosporites parvus	P											P	
Cicatricosisporites sp.	P	P		P	P	P	P	P	A	P	P	P	P
C. patapscoensis											P		
Cingulatisporites sp.					P	P					P		
Cirratriradites spinulosus								P					
Concavissimisporites sp. (psilate)	P	P				P		P	P		P	P	P
C. punctatus				P	P	P		P	P			P	
Cyathidites sp.			P		P	P		P	A		P	P	P
C. minor	P			P	P	P	P	P	A	P	A	P	A
Densoisporites microrugulatus						P							
D. perinatus						P							
Gleicheniidites sp.	P					P	P		P	P	P	P	P
Granulatisporites dailyi										P	P	P	
Ischyosporites crateris			?										
Klukisporites sp.					P	P		?			P		
Laevigatosporites sp.					P				P		P	P	P
"Monosulcites" chaloneri									P				
Peromonolites/Aratrisporites sp.									P		P		A
Perotriletes pannuceus									?				P
Pilosisporites trichopapillosus	P		P	P	P	P		P	P				
Reticulatisporites sp.						P			P	P		P	
Sphagnumsporites sp.						P					P		
Taurocusporites reduncus				?	P	R				P		P	
T. segmentatus					P							P	
T. spackmani												P	
Todisporites minor	P												
Trilites verrucatus	P												
Trilobosporites sp.						P		P			P		
Gymnosperms													
Araucariacites australis	P				P	P		P	P		P	P	P
Classopollis torosus	A	A	A	P	A	A	A	A	P		P	P	P
Decussosporites microreticulatus											P		
Ephedripites sp.	P			P	P	P			P		P	P	
Eucommiidites troedssonii					P	P	P	P			P		
Exesipollenites tumulus	P			P	A		P		P	P	P	P	P
Inaperturopollenites sp.	P	P	P	P	P	P	P	P	P	P	A	P	A
Laricoidites sp.					P	P		P	P		P	P	P
Monosulcites sp.	P			P	P	P		P	P		P	P	P
Perinopollenites elatoides							P	P					
Tsugaepollenites mesozoicus					P	P		P					P
Zonalapollenites sp.						P					P		
Alisporites bilateralis	P												
Parvisaccites/Phyllocladidites sp.					P	P		P	P		P	P	P
Pinuspollenites spherisaccus		P											
Podocarpidites radiatus		P						P			P		
Rugubivesiculites reductus											P		P
R. rugosus												P	
Vitreisporites pallidus	P				P	P		P	P		P		
Bisaccates undifferentiated					P	A	P	P	P		P	P	P

Table 3. cont'd. Palynomorphs in J. D. Bethards No. 1 well

SPECIES/SAMPLE DEPTH m	2145.8-51.3	2112.3-17.4	1976.9-81.5	1909.6-14.4	1777.6-82.5	1710.5-15.4	1542.9-49.0	1411.8-16.7	1028.7-33.6	961.6-66.5	833.6-38.5	774.2-80.3	708.7-13.2
ft	7040-58	6930-47	6486-501	6265-81	5832-48	5612-28	5062-82	4632-48	3375-91	3155-71	2735-51	2540-60	2325-40
Angiosperms													
Ajatipollis sp.													P
Asteropollis asteroides											P		?
Clavatipollenites hughesii					?			P					
C. minutus								?	P		P	P	P
C. tenellis									P		P		P
Liliacidites sp.											P		P
L. sp. (trichotomosulcate)											P		
New genus A (crotonoid monosulcate)													P
Penetetrapites mollis											P	P	
"Peromonolites" peroreticulatus								P			P	P	P
Retimonocolpites dividuus								P			P	P	
"Retitricolpites" fragosus											P	P	
"R." georgensis											P	P	P
"R." magnificus											P	P	P
"R." paraneus											?		?
"R." prosimilis											P		
"R." vermimurus											P	P	
Tricolpites sp.									P	?	P	P	P
T. albiensis											P	P	
T. vulgaris													P
Tricolpopollenites crassimurus											P	P	P
T. micromunus											A	A	P
T. minutus											P		
Tricolporoidites subtilis												P	P
Tricolporopollenites distinctus												P	P
T. fortis												P	
T. triangulus												P	P
Incertae sedis													
Schizosporis reticulatus											P	P	
Contaminants													
Compositae	X		X	X				X	X				
Tricolporates/triporates	X	X	X		X		X						X
Other													
Microplankton (hystrichospheres and dinoflagellates)				P							P		P

Similar floras occur in the poorer and also contaminated samples from intervals 2112.3-2117.4 m (6930-47 ft), 2043.7-2046.1 m (6705-13 ft), 1976.9-1981.5 m (6486-6501 ft), 1909.6-1914.4 m (6265-81 ft), 1777.5-1782.5 m (5832-48 ft), and in the richer, uncontaminated sample from 1710.5-1715.4 m (5612-28 ft). One species of Classopollis dominates the flora throughout this interval. Our data thus contradict the suggestions of Anderson (1948), Maher (1971), and Brown and others (1972) that the sediments below 2013.2 m (6566 ft) are Triassic (see below). Further study of uncontaminated material and correlative sections is required to determine how much further down in the Lower Cretaceous these basal samples extend than the outcrop Potomac Group. The first sample which we assign confidently to Zone I (Aptian-lower Albian?) is from 1411.8-1416.7 m (4632-48 ft); it contains both the Barremian and younger species Clavatipollenites hughesii and other typical outcrop lower Potomac Group angiospermous monosulcates including "Peromonolites" peroreticulatus.

The next sample with a datable flora, from 1027.5-1033.6 m (3375-91 ft), can be correlated with Subzone IIA on the presence of "Monosulcites" chaloneri and small reticulate tricolpates and the absence of Subzone IIB index forms. Since the base of Zone II is believed to lie near the lower-middle Albian boundary (cf. Kemp, 1970), these data are consistent with Brown and others' (1972) placement of the boundary between "Unit G" (Aptian-

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
867-100

lower Albian?) and "Unit F" (middle Albian lower Cenomanian?) at 1043.6 m (3424 ft).

The sample from 833.6-838.5 m (2735-51 ft) yields a rich flora assignable to the upper half of Subzone IIB on the association of the IIB index species *Cicatricosisporites patapscoensis* and *Rugubivesiculites reductus* and the angiosperms *Liliacidites* (including a trichotomosulcate species), "*Retitricolpites*" *vermimurus*, "*R.*" *georgensis*, "*R.*" *fragosus*, "*R.*" *prosimilis*, *Penetetrapites*, tricolporoidate "*Tricolpopollenites*" *micromunus* and "*T.*" *minutus*, and rare *Asteropollis asteroides*.

The next sample, from 774.2-780.3 m (2540-60 ft), yields several forms found only above Subzone IIB, e.g., *Rugubivesiculites rugosus*, *Tricolporoidites subtilis*, and "*Tricolporopollenites*" *distinctus*. The presence also of medium-sized triangular tricolporates ("*Tricolporopollenites*" *fortis*) suggests an age near the Subzone IIC-Zone III boundary, but since they are still somewhat smaller than typical basal Zone III triangular tricolporates, and other Zone III forms are lacking, the sample is tentatively referred to upper Subzone IIC rather than Zone III. The highest pollen sample, from 708.6-713.2 m (2325-40 ft), contains the typically Zone III tricolpate *Tricolpites vulgaris*. However, it lacks *Tricolpites nemejci* and the larger tricolporates characteristic of latest Zone III, and it could hence be at least slightly older than the 508.4-511.4 m (1668-78 ft) interval in the Hammond well. The implied latest Albian-basal Cenomanian age of these two samples is consistent with their assignment by Brown

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
867-100

and others (1972) to the upper part of "Unit F" (middle Albian-lower Cenomanian?).

Dinoflagellates suggest marine or near-marine conditions at the well locality at depths of 708.6-713.2 m (2325-40 ft) and 833.6-838.5 m (2735-51 ft), in the upper part of the Potomac Group. A lower occurrence, at 1909.6-1014.4 m (6265-6281 ft) is uncertain because of the presence of obvious contaminants in the same sample.

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
867-100

Taylor.-- J & J Enterprises E. G. Taylor No. 1-G was drilled to a depth of 1911.7 m (6272 ft) and bottomed in metamorphic rocks of undetermined age (Onuschak, 1972). This well is located 49 km south of the Hammond well (fig. 2), and hence south of the main axis of the Salisbury Embayment. Data from below 914.4 m (3000 ft) in the Taylor well were released in 1973. Age designations based largely on lithological correlations have been published by Onuschak (1972) and are available from Brown and others (1972, supplement). Results of studies of foraminiferal preparations by Ruth Todd (unpublished data, 1973) are incorporated in this report.

Following Onuschak (1972) and Brown and others (1972, supplement), we place the Tertiary/Cretaceous boundary in the Taylor well at about 420.6 m (1380 ft). Lithological, foraminiferal, and palynological evidence (see below) indicates that a major break, the pre-Magothy intra-Cretaceous unconformity mentioned in discussions of previous wells, occurs at about 438.9 m (1440 ft). The entire 18.3 m (60 ft) of Cretaceous section above this unconformity consists of calcareous clay and chalk. Foraminifera from near the base of this interval, at 435.9 m (1430 ft), indicate a Campanian age (Todd, unpublished data, 1973). Presumed marine clays and silts correlated palynologically with the lower Raritan Formation of New Jersey occur directly below the unconformity, in the depth interval 438.9-463.3 m (1440-1520 ft). According to Todd (unpublished data, 1973), foraminifera from near the top of this unit, at 442.0 m (1450 ft), are pre-Santonian. A recognizable

Magothy sand is absent from this well; a sandy sequence encountered between depths of 463.3-475.5 m (1520-1560 ft) is presumably equivalent to a lower part of the Raritan Formation of New Jersey. Strata from a depth of 475.5 m (1560 ft) to 1855.0 m (6086 ft), near the top of the contact metamorphosed Triassic (?) redbeds of Onuschak (1972), are assigned to the Potomac Group; this includes beds from 1563.1-1855.0 m (5128-6086 ft) considered Triassic by Brown and others (1972, supplement). Marginal-marine and coastal-margin sands, silts, and clays occupy the top of this interval, but below a depth of 701.0 m (2300 ft) the strata appear to be chiefly nonmarine.

Three sets of palynological slides of cores and sidewall cores from the Taylor well were made available by Exxon Company, U.S.A., and Atlantic Richfield Corporation. These are: 1) H465 series, green labels, 40 slides, 628.5-1870.0 m (2062-6135 ft), deposited with the Virginia Geological Survey; 2) SMC series, white labels, 43 slides, 990.9-1851.4 m (3251-6074 ft), deposited with the Virginia Geological Survey; and 3) H465 series, yellow labels, 34 slides, 132.5-1207.9 m (435-3963 ft), which were regretably lost in the course of a move. If found, they will be deposited with the Virginia Geological Survey. Duplicates of all slides were kept by Exxon and Atlantic Richfield. Sets 1 and 2 were also studied by Scott and Doher, and Sirkin, whose results have been included. Our palynological zonation and the lithological sequence in the Taylor well are shown in fig. 4. Table 4 lists all species of pollen, spores, and foraminifera identified in the well.

Table 4 near here.

Table 4.--Palynomorphs and microfauna in E. G. Taylor No. 1-G well.

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
867-100

Table 4. Palynomorphs and microfauna in E.G. Taylor No. 1-G well
A. Palynomorphs of Zone I. (Also studied by *1 Doher and Scott, *2 Sirkin)

A-abundant, C-common, P-present, R-one grain, X-contaminant

SPECIES/SAMPLE DEPTH	m: 1850.7-51.4 ft: 6072-74 *1*2	m: 1850.1-50.7 ft: 6070-72 *1	m: 1849.5-50.1 ft: 6068-70 *1	m: 1848.9-49.5 ft: 6066-68 *1	m: 1848.3-48.9 ft: 6064-66 *1	m: 1847.7-48.3 ft: 6062-64 *1	m: 1646.2 ft: 5401 *1*2	m: 1606.3 ft: 5270 *1*2	m: 1583.4 ft: 5195 *1	m: 1544.1 ft: 5066 *1*2	m: 1362.4 ft: 4470 *1*2	m: 1353.3 ft: 4440 *1	m: 1331.9 ft: 4370 *1	m: 1207.9 ft: 3963	m: 1166.5 ft: 3827	m: 1164.3 ft: 3820 *1	m: 1140.9 ft: 3743	m: 1107.3 ft: 3633	m: 1090.6 ft: 3578	m: 1064.7 ft: 3493 *1	m: 996.7 ft: 3270
Spores																					
Acanthotriletes sp.										P			P								
Apiculatisporis sp.							P								P						P
Appendicisporites sp.							P				P		P		P	P					P
Calamaspora sp.		P																			
Chomotriletes sp.									P				P								
Cicatricosisporites sp.	P	P	P	P	P	P	P		P	P	P	P	P	P	P						P
Concavissimisporites sp.										P	P			P	P			P			
Cyathidites sp.							P							P	P						
C. minor																					P
Decussosporites sp.																P					
Deltoidospora sp.							A	P													
D. hallii														P							
Densoisporites sp.							P														
Gleicheniidites sp.		P					P	A													
Klukisporites sp.							P							P							
K. pseudoreticulatus														P							
Lycopodiacidites sp.							P														
Lycopodiumsporites sp.									P	P	P		P								
Lygodiosporites sp.							P						P								
Matonisporites sp.														P	P						
Pilosisporites sp.							P								P			P			
Reticulatisporites sp.													P								
Sphagnumsporites							P										P				
Taurocusporites sp.							P							P							
Triletes sp.							P														
Trilobosporites sp.							P			P			P	P		P					
T. marylandensis														P							
Verrucosisporites sp.							P					P									
Gymnosperms																					
Classopollis sp.										P	P		P	A	A						P
Cycadopites sp.							P		P	P	P										
Eucommiidites sp.							P														
Inaperturopollenites sp.							P			A								P			P
Monosulcites sp.							P														
M. epakros							P														
Spheripollenites perinatus																					P
Taxodiaceaepollenites sp.							P														P
Tsugaepollenites sp.							P														
Abietineaepollenites sp.							P								P						
Alisporites sp.																					P
Pinuspollenites sp.							P														
Vitreisporites sp.	P						P	P	P												
Angiosperms																					
Clavatipollenites sp.							?				P										
Incertae sedis																					
Schizosporis reticulatus															P						
Other																					
Fungi (unicellular)																			P		P
Contaminants																					
Chenopodiaceae			X	X																	
Compositae														X							
Tricolpites-Tricolpopollenites sp.				X	X	X		X		X	X										

Table 4. Palynomorphs and microfauna in E. G. Taylor No. 1-G well
B. Palynomorphs of Zone II-Eocene.

SPECIES/SAMPLE DEPTH m	880.3	823.6	797.1	776.6	743.7	674.8	648.0	585.2	566.9	514.5	504.4	492.6	475.5	463.3	455.7	451.1	442.0	435.9	423.1	417.6	403.9
ft	2888	2702	2615	2548	2440	2214	2126	1920	1860	1688	1655	1616	1560	1520	1495	1480	1450	1430	1388	1370	1325
Spores																					
Alsophilidites pannuceus	?								P			P									
Apiculatisporis sp.						P					P										
Appendicisporites sp.									P	P	P	C	P	P	P		P	P			
A. potomacensis					P							P	P								
A. tricornitatus													P	P	P						
A. tricuspidatus													P				P				
Aratrisporites sp.									P	P	P	P	P								
Camarozonosporites sp.													P	P	P	P	P	P	P	P	
Ceratosporites parvus										?		?	P								
Cicatricosisporites sp.	P	P				P			P	P	C	C	P	P	P	P	P	P	P	P	P
C. hallei		P																			
C. patapscoensis									P			P		P							
C. subrotundus		P				P					P	P	P			P					
Cingulatisporites sp.											P							P			
C. distaverrucosus									P		P	P	P					P			
C. reticingulus													P	P							
Cirratriradites spinulosus											P										
Concavissimisporites sp.			P		P	P			P				P	P	P	P		P	P	P	
Cyathidites sp.	P	P	P		P	P		P	P	P	P	P	P	P	P	P	P		P		
C. minor	P	P				P			P	P	P		P	P	P	P	P	P			
Deltoidospora hallii						P				P											
Dictyophyllidites sp.										P	P		P	P							
Foveotriletes subtriangularis						P					P	P	P	P							
Gleicheniidites sp.			P			P			P		P		P	A	P	P	P	P	P	P	
G. apilobatus										P			P								
G. senonicus						P															
Granulatisporites dailyi			P						P		P										
aff. Hemitelia																		P	P		
Hymenozonotriletes sp.													P								
Klukisporites sp.			P									?		P	P						
K. pseudoreticulatus			P									P									
Laevigatosporites sp.				P							P	P	P	P	P	P		P	P	P	
L. gracilis													P	P							
Lycopodiacidites triangularis			P						P	P	P		P								
Lycopodiumsporites austroclavatidites													P								
Matonisporites sp.											P			P							
Microreticulatisporites crassiexinous															P						
Neoraistrickia robusta				R																	
Peromonolites sp.	P					P			P	P		P									
P. allenensis	P					P			P	P		P			P						
Perotriletes sp.																		P			
P. pannuceus	R																				
Pilosisporites trichopapillosus						P				P											
Psilatriletes circumundulatus										P	P										
P. radiatus						P								P			P				
Reticulatisporites arcuatus				P									P								
Rotaspora sp.																		P	P	P	
Sphagnumsporites sp.													P	P	P	P	P	P	P	P	
Sporites arcifer													P								
Taurocusporites sp.											P		P								
T. reduncus									P		P		P								
T. segmentatus											P										
Todisporites minor					P																
Trilobosporites sp.													?	P		P		P			
Undulatisporites undulapolus										P			P								
Gymnosperms																					
Araucariacites australis	P					P					P	P	P	P	P	P	P	P	P		
Circulina parva	P				P								P								
Classopollis sp.	P	P	P		P	P		P		P	P	C	A	A	P	P	P	P	P		

Table 4. Palynomorphs and microfauna in E. G. Taylor No. 1-G well
B. cont'd. Palynomorphs of Zone II-Eocene

SPECIES/SAMPLE DEPTH m	880.3	823.6	797.1	776.6	743.7	674.8	648.0	585.2	566.9	514.5	504.4	492.6	475.5	463.3	455.7	451.1	442.0	435.9	423.1	417.6	403.9
ft	2888	2702	2615	2548	2440	2214	2126	1920	1860	1688	1655	1616	1560	1520	1495	1480	1450	1430	1388	1370	1325
Ephedripites sp.			P			P			P		P	P	P			P					
Eucommiidites sp.	P	P				P			P	P	P	P	P	P		P					
Exesipollenites sp.		P				P			P		P	P	P	P	P	P	P	?	P		
Inaperturopollenites sp.	P	P	P		P	P		P	P	P	A	A	P	P	P	P	P			P	P
Laricoidites sp.											P							P			
Monosulcites sp.	P					P			P	P	A		P	P	P						
Perinopollenites sp.						P		P				P					P			A	
P. elatoides									P			P	P	P	P		P				
Pistillipollenites sp.																		?	?		
Sequoiapollenites sp.						P			P	P			P			P					
Spheripollenites perinatus										P											
Taxodiaceaepollenites sp.														P			P				
Tsugaepollenites sp.	?														P		P	P		P	
Zonalapollenites dampieri																P					
Abietineaepollenites sp.	P					P							P	P	P		P	P	P		
Alisporites sp.																			P		
Dacrydiumpollenites sp.															P	P		P			
Parvisaccites sp.						P							P	P	P		P	P	P		
Phyllocladidites sp.						P			P		P		P	P	P	P	P	P	P		
Pinuspollenites sp.													P		P			P		P	
Podocarpidites sp.													P		P	P		P	P		
Punctabivesiculites sp.														P							
Rugubivesiculites sp.						P				P	P		P	P	P		P	P	P		
R. reductus						P					P		P		P	P	P	P			
R. rugosus										P			P	P	P	P	P	P	P		
Vitreisporites sp.																		P			
Angiosperms																					
Ajatipollis-Dicotetradites sp.													P	P	P	P					
Atlantopollis sp.																A	P			?	
cf. Betulaceae																				P	
cf. Celastraceae																		P			
Clavatipollenites sp.						P			P	P	P	P	P	P	P						
Complexiopollis sp.								X					A	P		A		P			
cf. Ericaceae																				P	
Extratriporopollenites sp.																				P	
Faramea sp.																				P	
Foveotricolporoites rhombohedralis												P	P		P	P	P				
cf. Juglandaceae															R					P	
Minorpollis sp.															?			P	P		
Monocolpopollenites sp.																			P		
cf. Myricaceae																X				P	
Normapolles unidentified											P	P	C	P	P	P	P	P	P	P	
Nudopollis sp.																				P	
Pecakipollis sp.																		P			
Penetetrapites sp.						P															
"Peromonolites" peroreticulatus						P															
Plicapollis sp.																			P		
Porocolpopollenites sp.																	P				
Pseudoplicapollis sp.																			P	P	
Pterocarya sp.																				P	
Retimonocolpites (Liliacidites) sp.							P			P	P	P	P	P					P	P	
R. dividuus									P		P	P	P	P							
"Retitricolpites" georgensis						P			P		P		P			P					
"R." geraniodes		X									P				P						
"R." paraneus									P			?							?		
"R." prosimilis						P					?		P								
"R." vermimurus						A															
"R." virgeus													P		P						
Rhoipites sp.													P		P	P					

Table 4. Palynomorphs and microfauna in E. G. Taylor No. 1-G well
B. cont'd. Palynomorphs of Zone II-Eocene

SPECIES/SAMPLE DEPTH	880.3	823.6	797.1	776.6	743.7	674.8	648.0	585.2	566.9	514.5	504.4	492.6	475.5	463.3	455.7	451.1	442.0	435.9	423.1	417.6	403.9
m																					
ft	2888	2702	2615	2548	2440	2214	2126	1920	1860	1688	1655	1616	1560	1520	1495	1480	1450	1430	1388	1370	1325
cf. Sapotaceae																				P	
aff. Triatriopollenites sp.																		P			
Tricolpites-Tricolpopollenites sp.	?		P		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	
Tricolpites sp. 2 (Kemp 1968)									P				P								
T. albiensis									P			P				P		P			
T. barrandei													P								
T. constrictus													P			?	?				
T. nemejci		X									P	P	P	P		?					
T. vulgaris									?				P				P				
Tricolpopollenites crassimurus	P				P	P			P	P	P	P	P		P						
T. debilis									P												
T. extraneus																		P			
T. micromunus	?		?			?					P	P	P		P	P	P		?		
T. minutus						P			P	P	P				P	P			?		
T. parvulus									P		P		P	P							
T. retiformis													P	P				P	P		
T. simplicissimus									P		P		P								
Tricolporate type 2 (Doyle 1969a)													A	P		P					
Tricolporate type 5 (Doyle 1969a)									X									P	P		
Tricolporites-Tricolporopollenites sp.									P	P	P	P	C	P	P	P	P	P	P	P	
Tricolporites sp. Fig. 5u (Wolfe and Pakiser 1971)													P								
Tricolporoidites bohemicus											?										
Tricolporopollenites distinctus											?	P	P	P		P					
T. fortis												P	P	P							
T. globularis											P										
T. megaexactus													P					P	P		
T. orbiculatus													P	P							
T. subtilis									P	P	P	P	P	P	P	P					
T. triangulus									P				P		P	P		C			
Trudopollis sp.													X					P	P		
Group 13 (Krutzsch 1957)																			P		
Group 72 (Krutzsch 1957)																			P		
Monosulcates -reticulate unidentified						P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	
Triporates (non-Normapolles) unidentified														P	P	P	P	P	P	P	
Monoporates unidentified																				P	
Trichotomosulcates									P		P		P		P					P	
Incertae sedis																					
Schizosporis reticulatus						P				P					P						
Other																					
Fungi (unicellular)		P				P				P	P	P	P	P	P	P	P	P	P	P	
Microplankton (hystrichospheres and dinoflagellates)					P					P		P	P		P	P	P	P	P	P	
Contaminants																					
Alnus sp.									X						X	X				X	
Betula sp.					X										?	?			X	X	
Carya sp.															X	X				X	
Compositae		X	X	X	X	X									X				X	X	
Gramineae			X																	X	
Juglans sp.																X					
Pinus sp.		X	X	X											X						
Quercus sp.	X				X				X						X	X		?	X	X	
Tilia sp.																?				X	
Ulmus sp.																?					

Table 4. Palynomorphs and microfauna in E.G. Taylor No. 1-G well
C. Foraminifera. (Work done by M. Ruth Todd)

SPECIES/SAMPLE DEPTH						
m	463.3	455.7	451.1	442.0	423.1	403.9
ft	1520	1495	1480	1450	1388	1325
Archaeoglobigerina blowi					P	
A. bosquensis					P	
Bolivina incrassata					P	
Buliminella carseyae plana		P				
Cibicides spp.		P				
Globigerina biforaminata					P	
G. gautierensis	P	P	P	P		
Globigerinelloides aff. caseyi			P			
Globorotalites micheliana					P	
Globotruncana fornicata					P	
G. linneiana					P	
G. ventricosa					P	
Guembelitria sp.	P			P		
Hedbergella delrioensis				P		
H. planispira	P	P	P			
Heterohelix spp.				P		
H. sp. (smooth form)			P			
H. moremani	P					
Hoeglundina sp.			P			
Nodosaria affinis		P				
Palmula rugosa					P	
Praeglobotruncana aff. delrioensis				P		
Pseudotextularia elegans					P	
Pseudouvigerina cristata					P	
Quinqueloculina moremani	P					
Rotalipora greenhornensis	P					
Stensioiana americana					P	
Eocene globigerinids						P

Although Brown and others (1972, supplement) consider sediments between 1560.0 m and 1852.0 m (5128-6086 ft) in the Taylor well to be Triassic, the sample from 1646.2 m (5401 ft) in the upper part of the same interval contains a rich, typically Lower Cretaceous flora, with *Cicatricosiporites*, *Appendicisporites*, *Pilosisporites*, *Trilobosporites*, *Concavissimisporites*, *Taurocusporites*, etc. (table 4). Even the sparsely fossiliferous and partially contaminated composited samples from near the base of this interval, from 1847.7-1851.4 m (6062-6074 ft), contain *Cicatricosisporites*, which if not a contaminant indicates an Early Cretaceous or latest Jurassic age. The first identification of the Barremian and younger angiosperm *Clavatipollenites* which we have verified is from 1362.4 m (4470 ft); samples below this could be significantly older than the exposed Potomac Group.

Samples from depths of 880.3-743.7 m (2888-2440 ft) and higher contain Zone II index forms such as *Perotriletes pannuceus* and small to medium-sized tricolpates, and from 823.6 m (2702 ft) Subzone IIB spores such as *Cicatricosisporites subrotundus*, and from 776.6 m (2548 ft) *Reticulatisporites arcuatus*, *Neoraistrickia robusta*, etc., but because of the scarcity of palynomorphs and the presence of obvious contaminants, we have not attempted to define subzonal boundaries in the 880.3-675 m interval. However, the sample from 674.8 m (2214 ft) contains a good upper Subzone IIB flora, with "*Retitricolpites*" *georgensis*, "*R.*" *vermimurus*, "*R.*" *prosimilis*, "*Tricolpopollenites*" *minutus*, *Penetetrapites*, and *Rugubivesiculites* *reductus*.

Although most forms in the sample from 566.9 m (1860 ft) would be consistent with a Subzone IIC age (e.g., *Tricolporoidites subtilis* and relatively abundant *Taurocusporites reduncus*, *Lycopodiacidites triangularis*, and *Granulatisporites dailyi*), it is tentatively referred to lower Zone III on the presence of "*Tricolporopollenites*" *triangulus* and possibly *Tricolpites vulgaris*. The next sample, 514.5 m (1688 ft), also contains *T. subtilis*, but there is insufficient other pollen to determine where it falls within the Subzone IIC-Zone III interval.

Samples from 475.5 m (1560 ft) through 442.0 m (1450 ft), in a predominantly clayey interval with foraminifera can be assigned to Zone IV on the presence of the Normapolles genera *Complexiopollis* and *Atlantopollis* and characteristic Raritan tricolporates. This is the first palynological evidence of equivalents of the lower Raritan Formation of New Jersey in the Salisbury Embayment (although Brown and others, 1972, assign the lithostratigraphically correlative interval in the Bethards well to "Unit E" and "Unit D", together middle Cenomanian-Turonian?).

The immediately overlying sample, from 435.9 m (1430 ft) contains a much younger, Magothy equivalent or younger flora (Santonian-Campanian?), with more advanced Normapolles genera such as *Plicapollis*, *Pseudoplicapollis*, *Praebasopollis*, *Trudopollis*, *Minorpollis*, etc. Zone V (later Turonian-Coniacian?) age rocks are thus lacking; if ever deposited in the Salisbury Embayment, they were removed in the

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pre-Magothy erosional interval.

A more modernized flora, including tilioid, juglandaceous (caryoid), and monoporate types and the Maestrichtian-Eocene Normapolles genus Nudopollis is present in the sample from 417.6 m (1370 ft) which Brown and others (1972, supplement) date as Paleocene, and Onuschak (1972) as Eocene. According to Todd (unpublished data, 1973), foraminifera from 403.9 m (1325 ft) are Eocene, probably middle or lower; Onuschak (1972) suggests Eocene, Brown and others (1972, supplement) Paleocene. Pollen from this latter interval is highly oxidized and cannot be determined to genus.

The sample from 353.6 m (1160 ft) contains pine (Pinus), from 341.4 m (1120 ft) spruce (Picea) and periporate pollen, from 313.9 m (1030 ft) fir, and from 274.3 m (900 ft) high and low spine composites. These forms indicate a Late Tertiary age, consistent with the assignment of the 34.1-384.7 m (112-1262 ft) interval to the Miocene by Onuschak (1972) and Brown and others (1972, supplement).

Occurrences of dinoflagellates and other marine plankton indicate several marine incursions (cf. fig. 4) during deposition of the Potomac Group. Dinoflagellates and foraminifera occur continuously in the section we have identified as mid-Cenomanian (lower Upper Cretaceous) to Miocene.

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Age of the basal red beds and arkosic sands

Near the base of the Hammond, Bethards and Taylor wells are unfossiliferous conglomeratic and arkosic sands, mottled red, brown and yellow clays, and compact gray red, gray brown, and mottled red micaceous shales of controversial age. Log correlations indicate that these red beds and arkosic sands represent a seaward-thickening blanket deposit immediately overlying the basement under the outer Salisbury Embayment as shown by Spangler and Peterson (1950). Projected seaward, using dip rates established from wells, this deposit can be tied to seismic reflection events midway to the basement in deeper parts of the Baltimore Canyon trough under the outer continental shelf. The age of this stratigraphic interval is thus critical in determining the age and depositional history of the lower half of the sedimentary rocks in Baltimore Canyon trough.

In the absence of fossils, correlations of these red beds and arkosic sands have been based on lithological comparisons with neighboring sequences, but these are unfortunately highly equivocal. For example, similar lithologies occur not only in the "Newark" basins of the Piedmont province and the Connecticut Valley, which are dated paleontologically as Late Triassic and (in the Connecticut basin) Early Jurassic in age (Cornet and others, 1973), but also at the base of the Esso Hatteras Light No. 1 well drilled in the thickest part of the Albemarle Embayment of North Carolina, the next basement warp to the south, where they contain ostracods of Late Jurassic age and pass conformably upward into the Cretaceous (Swain and Brown, 1972). Accordingly, estimates on the age of the basal red beds and arkosic sands in the Salisbury Embayment have ranged from Triassic (cf. Spangler and Peterson, 1950) to basal Cretaceous, possibly Neocomian (cf. Maher, 1971). Anderson (1948) identified Triassic between 1634.6 m (5363 ft) and 1675.8 m (5498 ft) in the Hammond well and between 2001.3 m (6566 ft) and 2173.2 m (7130 ft) in the Bethards well. Maher (1971, p. 36) questioned Anderson's (1948) identification of Triassic in both the Hammond and Bethards wells. He termed the red beds sequence "Mesozoic rocks of uncertain age, possibly Neocomian" (Maher, 1971, plates 11 and 12). Brown and others (1972), on the other hand, reject Anderson's (1948) identification of Triassic in Hammond, but accept it in the Bethards well. Furthermore, whereas Onuschak (1972) assigned only the 35.4 m (116 ft) of indurated "red beds" below 1850.1 m (6070 ft) in the Taylor well to the Triassic, Brown and others (1972, supplement) identify the entire 1563.0 m (5128 ft) to 1855.0 m (6086 ft) interval as Triassic. Brown and others (1972) admit the possibility of at least uppermost Jurassic rocks in all three wells, plus the Chestertown well, by assigning the overlying (unquestioned Potomac) beds to "Unit H", which is bracketed as Late Jurassic (?) to Aptian on the presence of Jurassic ostracods near its base in the Esso Hatteras well.

Our palynological data, though not entirely conclusive because of the small number of productive samples and the presence of obvious contaminants, indicate that most if not all of the red bed sequence in the Bethards well and at least its upper portion in the Taylor well are of Early Cretaceous rather than either Triassic or Jurassic age (*cf*. above). The geophysical log data are consistent with this conclusion, since they indicate that the red beds and arkosic sands form a conformable sequence with the Potomac Group, and are hence Neocomian to possible Late Jurassic in age, rather than being separated from the Potomac Group by an unconformity of the magnitude that would be required if they were Triassic.

A Triassic-Cretaceous unconformity, representing a gap in the sedimentary record of some 50 m.y., should be revealed by the relative consolidation of the sediments above and below it. This is evident at the outcrop, where Triassic mudstones and arkose are moderately consolidated (dewatered), whereas the Cretaceous sediments are not (Weed and others, 1974). No abrupt increase in consolidation is revealed in the Maryland and Virginia coastal wells, either within the definite Lower Cretaceous sequence or at the top of, or within, the underlying red bed sequence. The effect of consolidation (de-watering) appears to be pronounced in gamma ray-neutron logs, where the neutron curve measures hydrogen concentration such that significant decrease in porosity (or a gas-filled porous zone) causes displacement of the neutron curve to the right. Density and sonic logs also show the effect of loss of porosity due to compaction. The expected abrupt displacement of the neutron curve occurs at the

Cretaceous/Triassic unconformity at a depth of 674 m (2211 ft) in the J.S.C. Drilling Company E. T. and Shirley Thompson No. 1 well, King George Co., Virginia, but not in the 1372 to 1855 m (4501 to 6086 ft) depth interval in the Taylor well.

Though more problematical, the geophysical log data do not support Onuschak's (1972) identification of Triassic red beds still lower in the Taylor well, between 1850.1 m (6070 ft) and 1885.5 m (6186 ft). Passing downward from ca. 1850 m, the rocks gradually increase in density, resistivity, consolidation (as inferred from the neutron curve) and velocity. However, the electric logs suggest that the dewatering and compaction had a strong downward component, as would result if water had been drawn downward into the basement rocks, a two mica (biotite and muscovite) calcareous metasiltstone of low water content. In view of this possibility and the gradual rather than abrupt increase in consolidation indicated by the logs, the over-consolidation of the red bed and arkosic sand sequence below 1850 m may have no age significance.

Although red bed lithologies are best developed in the lower part of the Salisbury Embayment wells, they are by no means unknown in the Potomac Group of the outcrop area and in wells drilled on both sides of Chesapeake Bay. Red mudstone and clay occur in the Taylor well as high as 1524 m; arkosic sand is present above 1851 m and is a dominant lithology in the outcropping lower Potomac Group of Virginia (Glaser, 1969). As is mentioned above, red (and green) shales and mudstones and arkose also occur in the paleontologically dated upper

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867-100

Jurassic to Neocomian of the Hatteras Light well of North Carolina and the Dickinson well of southeastern New Jersey (Brown and others, 1972), the Jurassic Mohawk Formation of the Scotian Shelf (McIver, 1972, p. 59), and subsurface Jurassic beds of Florida (Applin, 1951; Applin and Applin, 1965). Across the ocean from the Hatteras well, the Al Kinz well in Mauritania penetrated similar Upper Jurassic rocks, plus rock salt (Rona, 1973). However, before making direct correlations with these Jurassic beds, it should be noted that the basement is shallower in the Salisbury Embayment wells than in the Hatteras well, which penetrated over 3000 m of sedimentary section and was much closer to the outer edge of the continental shelf.

In summary, we cannot accept the concept of a seaward-thickening wedge of Triassic sediments in the exposed portion of the Salisbury Embayment, and by extension the Baltimore Canyon trough, separated from the Potomac Group by a major unconformity. On the other hand, analysis of geophysical logs, the limited palynological evidence, and comparisons with neighboring sections are all consistent with a model in which the red beds in question represent the earlier phases of a conformable, generally transgressive sequence, of which the later phases are represented in the outcrop Potomac Group. This sequence may include a significant thickness of (Late?) Jurassic under the outer shelf (cf. Minard and others, 1974), but little if any in the onshore well area. Sedimentation did not reach the present outcrop area until the latter

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867-100

half of the Early Cretaceous (Aptian?). The analogies between this model and the Gulf Coast Jurassic-Lower Cretaceous sequence (cf. Murray, 1961) are evident. We suggest that future palynological studies of carefully collected and prepared core samples have great potential in elucidating the timing of the early stages of this transgression.

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867-100

Mesozoic depositional environments and resource potential

Within the generally transgressive (Late Jurassic?-) Early Cretaceous through Cenomanian sequence seen in deep wells in the Salisbury Embayment, smaller-scale environmental fluctutions are indicated by both paleontology and geophysical and other borehole log data. A depositional-environment model of the Cretaceous of the Salisbury Embayment, based on our interpretation of all available data from the Hammond and Bethards wells and a third well, the Esso-Maryland well, is presented in fig. 5.

Figure 5 near here.

As is discussed above, data from the Hammond well are best, because the well was cored continuously, and detailed descriptions of the cores, as well as electric logs and core descriptions were published by Anderson (1948). Data from the Bethards well also include a large number of detailed core descriptions (Anderson, 1948), but continuous coring was not undertaken. The Esso-Maryland No. 1 well, shown in figs. 2 and 5, was drilled to 2350 m (7710 ft) in Ocean City, Maryland; only one core was taken, from 1485.9-1488.9 m (4875-85 ft), which yielded a molluscan fauna described by Vokes (in Anderson, 1948). Descriptions of ditch samples from this well are excellent (Overbeck, in Anderson, 1948, p. 428-440), but Tertiary and Upper Cretaceous foraminifera are found throughout much of the

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867-100

Figure 5.-- Inferred depositional environments of Mesozoic sediments. Environmental interpretations after LeBlanc, 1972.

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867-100

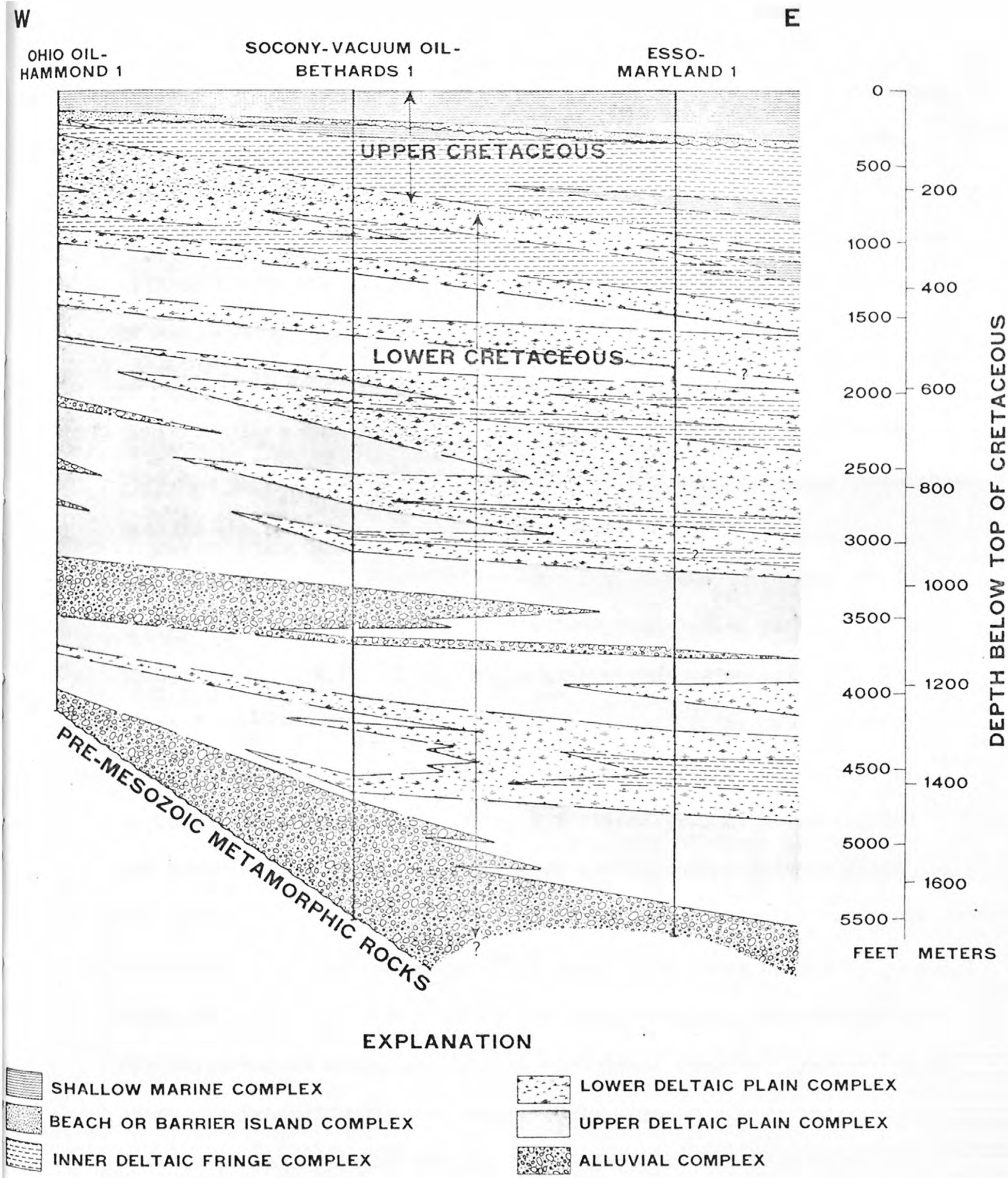
W
E
OHIO OIL-
HAMMOND 1
SOCONY-VACUUM OIL-
BETHARDS 1
ESSO-
MARYLAND 1
UPPER CRETACEOUS
LOWER CRETACEOUS
PRE-MESOZOIC METAMORPHIC ROCKS
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
200
400
600
800
1000
1200
1400
1600
FEET
METERS
DEPTH BELOW TOP OF CRETACEOUS
EXPLANATION
SHALLOW MARINE COMPLEX
BEACH OR BARRIER ISLAND COMPLEX
INNER DELTAIC FRINGE COMPLEX
LOWER DELTAIC PLAIN COMPLEX
UPPER DELTAIC PLAIN COMPLEX
ALLUVIAL COMPLEX

Figure 5

lower portion of the well, apparently as a result of severe contamination by sloughing or "caving" of sediments from the walls of the drill hole from shallower depths during drilling and sample recovery. This caving problem had to be taken into account in dealing with published lithic descriptions of the well.

We refer the beds below 2191.8 m (7191 ft) in the Esso-Maryland well to the same stratigraphic sequence seen at the base of the Bethards well. These beds were not recognized as distinct from the Potomac Group by Anderson (1948), but they were referred to the older "Unit I" (Late Jurassic?) by Brown and others (1972). We suggest they are at least in part of Early Cretaceous age, like the comparable beds in the Bethards and Taylor wells.

Although the interpretation in fig. 5 is speculative, it is internally consistent, and the admittedly incomplete data are firm enough to support the major transgressive-regressive pulses shown. As is discussed above, no major hiatus appears to be present within the (Late Jurassic?-) Cretaceous sequence until the pre-Magothy unconformity (Turonian-Santonian). The change from alluvial red bed and arkosic sand deposits to the more typical upper deltaic plain deposits of the Potomac Group is considered gradational, and alluvial sediments (although with less red coloring) reappear at several horizons in the Potomac Group of the Bethards and especially Hammond wells. The entire pre-Magothy sequence represents a fluvial-deltaic complex within which at least six transgressive-regressive cycles can be recognized. Lower deltaic plain and inner deltaic fringe deposits are best developed

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867-100

in the Esso-Maryland well; the environment inferred from the geophysical logs and ditch sample descriptions is validated by the brackish water-estuarine character of the mollusk fauna and the absence of foraminifera in the core from 1485.9-1488.9 m (4875-85 ft) (Vokes, *in* Anderson, 1948).[1] Lower deltaic plain deposits are less

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1/ Footnote near here.

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frequent in the Bethards well, and almost absent in the Hammond well below the uppermost part of the Potomac Group, which yielded the brackish water faunas described by Stephenson (*in* Anderson, 1948). Below the pre-Magothy unconformity, sediments deposited under true shallow marine conditions appear to occur only near the top of the Potomac Group in the Esso-Maryland well, and in beds correlative with the lower Raritan Formation of New Jersey which conformably overlie the Potomac Group in the Bethards (and Taylor) wells (note however the evidence from dinoflagellates in the Taylor well, cited below). Organic matter, derived from plants, is most abundant in the inferred lower deltaic plain and inner deltaic fringe environmental complexes in these wells.

The presence and relative abundance of dinoflagellates provide independent evidence on the existence and extent of the marine incursions indicated in fig. 5, and hence they have special significance in evaluating the resource potential of the Salisbury Embayment.

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867-100

1/ Vokes correlated this fauna with the Woodbine Formation of Texas and extended the resulting Cenomanian age determination to the outcrop Arundel Clay on the basis of Anderson's (1948) lithological correlations of the Esso-Maryland well. This precipitated a controversy on the age of the Potomac Group (cf. Spangler and Peterson, 1950; Dorf, 1952) which indirect palynological evidence may now help to resolve. Since electric log correlations between the Bethards and Esso-Maryland wells are unusally good, the sample from 1485.9-1488.9 m can be securely correlated with the interval between Bethards samples from 1411.8-1416.7 m (4632-48 ft) and 1027.5-1033.6 m (3375-91 ft), which yield good Zone I and Subzone IIA palynofloras, respectively. This strongly indicates a late Aptian or early Albian age for Vokes' fauna. In view of the peculiar, dwarfed nature of the fauna, we would suggest that the similarities seen between it and the Woodbine fauna are more the result of similar facies than similar age.

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867-100

Hydrocarbon accumulation and preservation are favored by rapid nearshore marine deposition (McCulloch, 1973). In general, nearshore marine environments are characterized by abundant organic matter of both terrestial and marine sources and can be recognized by the abundant occurrence of both land plant spores and pollen and dinoflagellates. Dinoflagellates can be carried inland only to the limit of tidal flow (Hughes and Pacltová, 1972), and when they are abundant in pre-Tertiary sediments they are almost certain indicators of marine or brackish conditions (Evitt, 1964). Further offshore, spores and pollen are less common, and marine organisms such as dinoflagellates, silicoflagellates, foraminifera and radiolarians predominate (Tschudy and Scott, 1969).

The latter sort of deeper water marine conditions is exemplified by the relatively thin latest Cretaceous section (Campanian-Maestrichtian) of the Salisbury Embayment; samples from this interval in the Taylor well contain an abundance of both dinoflagellates and foraminifera (cf. above). Rapid sedimentation under nearshore marine conditions of the sort favorable for hydrocarbons is represented by the sediments deposited during Early Cretaceous-Cenomanian transgressive phases, which are most extensive in the upper and more eastern portions of the Potomac Group of the Salisbury Embayment. Floras from such intervals showing the abundance of both dinoflagellates and spores and pollen typical of nearshore marine conditions are seen in the samples from 720.2-723.3 m (2363-73 ft) and 508.4-511.4 m (1668-78 ft) in the Hammond well, 833.6-838.5 m (2735-51 ft) and 708.6-713.2 m (2325-40 ft)

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867-100

in the Bethards well, and at several horizons in the Taylor well, such as 514.5 m (1688 ft), 475.5 m (1560 ft), 463.3 m (1520 ft), 451.1 m (1480 ft), 435.9 m (1430 ft), 423.1 m (1388 ft), and 417.6 m (1370 ft). Some samples contain abundant dinoflagellates but few or no spores pollen grains, suggesting outer shelf conditions and hence more extensive marine incursions in the Taylor well at 743.7 m (2440 ft) and 442.0 m (1450 ft) and in the Bethards well at 1909.6-14.4m (6265-81 ft). The most promising area for hydrocarbons is presumably to the east of the onshore wells, under the continental shelf, where the Potomac section continues to thicken and marine conditions should become increasingly predominant, providing there are suitable traps for hydrocarbon concentration.

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867-100

Vegetational history and paleoecology

Pre-Cretaceous floras are not known as such from the Salisbury Embayment. However, Late Triassic and Early Jurassic floras of the Hartford Basin to the north were dominated by members of the extinct conifer family Cheirolepidiaceae, represented in the pollen record by *Circulina* and *Classopollis* (Cornet and others, 1973). Such forms are extremely abundant in the Jurassic of most areas of the world except (colder?) eastern Siberia and the Arctic (Vakhrameev and others, 1970). In the Early Cretaceous, when *Classopollis* was already in decline, its greater abundance in nearshore marine facies has led to suggestions that the parent plants formed a sea margin association (Pocock, 1962; Hughes and Moody-Stuart, 1967), but in the Jurassic they must have occupied a far wider range of habitats.

While Early Cretaceous seas with dinoflagellates and invertebrate faunas were encroaching on the Salisbury Embayment, the adjacent deltas and flood plains were covered by a rich and varied forest dominated by gymonsperms and ferns. The gymnosperms included not only extinct groups such as *Classopollis*-producing conifers (never as abundant as in the Hartford basin), the cycad-like Bennettitales, and the last of the seed ferns (*Caytonia*/*Vitreisporites*), but also early members of such modern conifer families as Pinaceae, Taxodiaceae, Cupressaceae, Podocarpaceae (?), and Araucariaceae, the last two now largely restricted to the Southern Hemisphere. Ferns were highly diverse, especially tree ferns (Cyatheaceae) and the now largely tropical families Schizaeaceae and Gleicheniaceae. Very similar floras are reported from western

North America (Pocock, 1962; Norris, 1967), the Wealden and Lower Greensand of England (Couper, 1958; Kemp, 1970), Portugal (Groot and Groot, 1962), Central Asia (Bolchovitina, 1953) and other parts of southern Laurasia (cf. Couper, 1964; Brenner, in press). In general aspect and climatic requirements, this vegetation may have been analogous to the subtropical and warm temperature rain forests of New Zealand (Brenner, 1963). To the north, in the Canadian Arctic and Siberia, floras were poorer in ferns and Classopollis, presumably because of colder climates (Brenner, in press).

By the time Potomac deposition had reached the outcrop area, primitive flowering plants represented by Clavatipollenites and related monosulcate pollen types had become a subordinate element in this "Wealden" flora, as in the Barremian of England (Couper, 1958; Kemp, 1968). Throughout Potomac and Raritan deposition, angiosperms gradually increased in abundance and diversity, represented by progressively more specialized pollen types (Doyle, 1969a, 1973; Wolfe and Pakiser, 1971; and above). In Europe and presumably in the Salisbury Embayment, clearly dicotyledonous tricolpates joined the monosulcates in the early or middle Albian (Kemp, 1968), although tricolpates already existed in the Aptian in South America, Africa and Isreal (Müller, 1966; Brenner, in press), where floras were dominated by Classopollis and Ephedraceae, suggesting hot, dry climates. More advanced dicotyledonous groups are represented by the tricolporates which appear later in the Albian, and by the first triporates of the

Normapolles complex which appear in the middle Cenomanian, at the height of the Raritan transgression. In exceptional cases, angiosperm pollen already consititutes a majority of the pollen and spore flora in late Albian samples. However, conifer pollen continues to predominate in most samples, especially those from nearshore marine facies, which represent the sum of wind and water borne pollen from all sources (Chaloner and Muir, 1968). This suggests that conifers still dominated inland (Piedmont) forests until well into the Late Cretaceous, while angiosperms were most abundant in less stable fluvial-deltaic environments (Pierce, 1961; Doyle, in press).

When seas re-entered the Salisbury Embayment in the late Santonian-Campanian after the long post-Cenomanian erosional interval, the forests growing in the coastal habitats represented by the Magothy Formation were dominated by a mixture of conifers and angiosperms, many of the latter being members of the Normapolles group, dominant at the same time in Europe (Góczán and others, 1971). The Salisbury Embayment and other parts of eastern North America were hence clearly part of the Normapolles floristic province, spearated from the contemporaneous Aquilapollenites province of western North America and Siberia by the Western Interior epicontinental sea (Góczán and others, 1967; Doyle, 1969a; Muller, 1970), although Wolfe and Pakiser (1971) have pointed out that the species similarities between Europe and North America were not as strong in the Santonian-Campanian as they had been in the Cenomanian. As with other extinct Cretaceous groups, the paleoecological significance of the Normapolles is problematical. Góczán and others (1967) have argued that the abundance of Normapolles in marine sediments indicates that they were wind-pollinated, like their possible distant descendants among modern temperate amentiferous (catkin-bearing) groups (Betulaceae, such as birches; Juglandaceae, such as walnuts and hickories), but the presence of palm leaves (*cf.* Read and Hickey, 1972) and palm-like pollen in the Magothy suggests that the late Santonian climate of the Salisbury Embayment was at least subtropical.

Paleocene-Eocene forests fringing the Salisbury Embayment still contained relict Normapolles-producing plants, but were much more modernized otherwise, with grasses, Juglandaceae (including hickory- or *Carya*-like forms) and early representatives of other families characteristic of North America temperate floras. By the Miocene, pollen can be ascribed with confidence to modern genera. The modern vegetation of the Salisbury Embayment is dominated by oak, hickory and pine (Braun, 1950). The pollen rain as described by Sirkin (1974a) is dominated by wind-pollinated plants such as oak (*Quercus*), pine (*Pinus*) and birch (*Betula*). Other important arboreal elements are black gum (*Nyssa*), sweet gum (*Liquidambar*), hickory (*Carya*) and walnut (*Juglans*). The principal non-arboreal pollen producers are grasses, sedges, *Typha*, Ericaceae, Compositae, Polygonaceae, Plantaginaceae, Chenopodiaceae-Amaranthaceae, and ferns.

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867-100

Summary and conclusions

By use of palynology, we have refined the dating of principally nonmarine Cretaceous deposits in three wells drilled to basement on the Delmarva Peninsula in Maryland (Chestertown, Hammond, Bethards) and one in Virginia (Taylor). Our palynologic studies were supported by analysis of electrical, gamma-ray, neutron, and lithologic well-logs, as well as well cuttings from the Taylor well. The wells were chosen because we felt they could shed light on the geological history of the Salisbury Embayment, and, through it, the Baltimore Canyon trough.

Our studies have shed additional light on interpretations of the basal stratigraphic units of the emergent Atlantic Coastal Plain north of Cape Hatteras. The data suggest that these beds, predominantly red in color, are at least in part of Early Cretaceous age, and probably no older than latest Jurassic. No major hiatus appears until the pre-Magothy unconformity (Turonian-Santonian).

A depositional-environment model elucidates shoreward movements of Mesozoic seas into the Salisbury Embayment. Broad, shallow marine, beach or barrier island, inner deltaic fringe, lower and upper deltaic plain, and alluvial depositional complexes can be delineated from the lithological sequences which make up the Mesozoic section of the Coastal Plain. The Cretaceous Potomac Group represents a generally transgressive fluvial-deltaic complex within which at least six lesser transgressive-regressive cycles can be recognized. Beds correlative with the lower Raritan Formation of New Jersey conformably overlie the Potomac Group in the Bethards and Taylor wells. Above the pre-Magothy unconformity, marine rocks dominate the Upper Cretaceous section.

The abundance of dinoflagellates intermingled with pollen, spores, and other land-derived organic matter, pinpoints areas of nearshore marine deposition, areas favorable for the accumulation and preservation of hydrocarbons. The most promising area for hydrocarbons is presumably to the east of the onshore wells, under the continental shelf, where the section equivalent to the Potomac Group continues to thicken and marine conditions become increasingly predominant.

While Early Cretaceous seas were encroaching on the Salisbury Embayment, the adjacent deltas and flood plains were covered by a rich and varied forest dominated by gymnosperms and ferns, vegetation possibly analogous to the subtropical and warm temperate rain forests of New Zealand. By Aptian time, when deposition of Coastal Plain sediments had reached the outcrop area, primitive flowering plants had become a subordinant element of the flora. Throughout Albian and Cenomanian time, angiosperms gradually increased in abundance and diversity. Conifers probably dominated inland (Piedmont) forests until well into the Late Cretaceous, while angiosperms were most abundant in less stable fluvial-deltaic environments.

When seas re-entered the Salisbury Embayment in the late Santonian or Campanian after the long post-Cenomanian erosional interval, the forests growing in the coastal habitats represented by the Magothy Formation consisted of a mixture of conifers and angiosperms. Many

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867-100

of the angiosperms were members of the extinct Normapolles group. Paleocene-Eocene forests fringing the Salisbury Embayment still contained relict Normapolles-producing plants, but were dominated by representatives of families characteristic of Recent North American temperate floras.

Projecting offshore from the wells we studied in the Salisbury Embayment, we have been able to tentatively date seismic reflecting horizons in terms of the palynological zonation. These interpretations are being used by the U.S. Geological Survey in the study of offshore Atlantic oil and gas resource potential.

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Appendix 1

Well summary descriptions

USGS-Chestertown QA-Be-15

Drilling contractor: Delmarva Drilling Co.
Completion date: September, 1970
Location: Near Chestertown, Md., Queen Anne Co., 39° 12' 03" N, 76° 02' 43" W
Elevation: 22 ft GL (depths measured from GL)
Depth: 2009 ft
References: Kantrowitz and Webb, 1971; descriptions of samples by Robbins

Depth (ft)	Lithologic summary	Spores, pollen, and marine organisms
364-366	Sandy clay, mottled orange and black, very fine, compact	Productive
398-400	Clay, light gray	Barren
408-410	Silt, white and dark red to yellow, compact	Barren
414-416	Clay, dark brown, compact	Barren
682-684	Clay, mottled red and gray, compact	Barren

Ohio Oil-L. G. Hammond No. 1

Operator: Ohio Oil Co.
Completion date: October, 1944
Location: Near Salisbury, Md., Wicomico Co., 38° 20.8' N, 75° 29.1' W
Elevation: 57 ft GL (depth measured from 70 ft DF)
Depth: 5568 ft
References: Anderson, 1948; Groot and Penny, 1960; core descriptions in Anderson, 1948

Depth (ft)	Lithologic summary	Spores, pollen, and marine organisms
1668-1678	Shale, dark brownish black, carbonaceous	Productive, Dinoflagellates
2363-2373	Shale, brownish gray, carbonaceous and sandy, hard	Productive, Dinoflagellates

Socony-Vacuum Oil-J. D. Bethards No. 1

Operator: Socony-Vacuum Oil Corp.
Completion date: July 5, 1945
Location: 11 mi SE of L.G. Hammond No. 1, 5 mi SW of Berlin, 3 mi due N of Newark, Worchester Co., 38° 18' 15" N, 75° 16' 30" W
Elevation: 45 ft GL
Depth: 7178 ft
References: Anderson, 1948; Doyle, 1966; sample descriptions by Doyle

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
867-100

Sampled Depth (ft)	Lithologic summary	Spores, pollen and marine organisms
2325-2340	Shale, gray, green and brown, silty, micaceous	productive, dinoflagellates
2540-2560	Shale, gray, brown, silty	productive
2735-2571	Shale, brown-gray, sandy, micaceous, friable	productive, dinoflagellates
2950-2966	Shale, light gray and brown, rusty brown	barren
3155-3171	Ċlay pebbles, medium gray, in sand, green-gray, medium grained	poor
3375-3391	Same as above	productive
3585-3601	Shale, gray, mottled with red and brown	barren
3795-3801	Shale, dark gray, green-gray, light gray	barren
4010-4025	Shale, mottled red and gray, brittle	barren
4213-4228	Shale, gray-green, brown, sandy, silty, micaceous, carbonaceous	barren
4415-5531	Shale, mottled purple, green, gray	barren
4632-4648	Sand, gray-green, fine grained, argillaceous	productive
4845-4863	Shaly sand, green	barren
5062-5082	Sand, white, coarse, argillaceous	poor
5275-5295	Shale, dark gray-green, micaceous	barren
5612-5628	Shale, dark gray, sandy, carbonaceous	productive
5832-5848	Shale, dark gray, light gray, brown, green	productive
6049-6065	Shale, gray, sandy, glauconitic	barren
6265-6281	Shale, mottled dark gray-green, brown	poor, dinoflagellates
6486-6501	Shale, chocolate brown	poor
6705-6713	Shale, gray-green, red brown, sandy, pink-gray, fine grained, arkosic	barren
6930-6947	Same as above	poor
7040-7058	Shale, dark lead-gray, silty, micaceous	productive

J and J Enterprises-E. G. Taylor 1-G

Operator: J and J Enterprises (financed by a consortium of oil companies and the USGS in cooperation with state geological surveys)
Completion date: May, 1971
Location: Near Temperanceville, Accomack Co. Va., 37°53.3'N, 75°30.9'W
Elevation: 42 ft GL (depth measurements from KB, 10.5 ft above GL)
Depth: 6272 ft
References: Onuschak, 1972; E.M. Cushing and I.H. Kantrowitz, unpublished data; sample descriptions by Perry and L.G. Wallace

Sampled depth (ft)	Lithologic summary*	Spores, pollen and marine organisms
435	Clay, medium dark gray	productive
900	Silty to sandy, medium to dark gray clay	productive

*From descriptions of well cuttings, adjusted to agree with geophysical well logs, unless otherwise stated.

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
867-100

Sampled depth (ft)	Lithologic summary	Spores, pollen and marine organisms
1030	Clay, sandy, calcareous	productive
1120	Sand, fine to medium, clayey	productive
1160	Sand, as above	productive
1270	Greensand, clayey to silty	productive
1325	Silt, argillaceous, calcareous, glauconitic	productive
1370	Clay, light gray, sandy, calcareous, and and clayey silt	productive, dinoflagellates
1388	Clay, light gray-brown to olive gray silty	productive, dinoflagellates
1430	Clay, silty, calcareous, glauconitic	productive, dinoflagellates
1450	Clay, light gray, marly, and pale gray chalk	poor, -do-
1480	Marl and chalk, glauconitic	productive, dinoflagellates
1495	Marl, as above, silty to sandy	productive
1520	Clay, calcareous, and fine to medium sand	productive, dinoflagellates
1560	Sand, fine to medium, micaceous	productive, dinoflagellates
1616	Sand, lignitic, micaceous, silty	productive
1655	Sand, and medium gray calcareous siltstone	productive
1688	Sand, slightly phosphatic, and brownish gray clay	productive, dinoflagellates
1920	Sand,silty to clayey; trace maroon clay	poor
2126	Clay, silty, light to medium gray	poor
2214	Clay, silty, light gray to maroon	productive
2440	Clay, medium gray, silty, with sand lenses	poor, dinoflagellates
2548	Clayey silt, micaceous with swelling clay	poor
2615	Clayey silt and silty clay, reddish brown and greenish gray	poor
2702	Clay and silt, as above	poor

Sampled depth (ft)	Lithologic summary	Spores, pollen and marine organisms
2888	Sand, fine to coarse, and gray clayey siltstone	productive
3254	Sandstone, clayey, and reddish brown clayey siltstone	barren
3270	Sandstone, as above	productive
3483	Claystone, silty, gray-green to reddish brown mottled (from core report)	barren
3493	Sand, light gray, clayey to silty	poor
3578	Claystone, dark gray to greenish gray	productive
3633	Claystone, as above, trace pyrite	productive
3652	Claystone, silty, light gray to maroon, micaceous	barren
3743	Claystone, silty, light gray to reddish gray	poor
3820	Claystone, greenish gray to brownish gray (from core report)	poor
3827	Claystone, silty, light greenish gray to maroon (possibly cavings)	productive
3963	Claystone, silty to fine sandy	productive
4370	Clay, dark gray, silty (from core report)	productive
4440	Sand, light gray, silty, argillaceous	poor
5066	Claystone, silty, grayish green	productive
5195	Claystone, silty, grayish green and dusky red	poor
5270	Clay, silty, dark brown, micaceous, lignitic (from core report)	productive
5401	Siltstone, argillaceous, grayish green, trace pyrite	productive
6058-6060	Shale, red-brown, silty, micaceous	poor
6060-6062	Siltstone, argillaceous, brownish red	poor
6062-6064	Siltstone, argillaceous, reddish gray, micaceous	poor
6064-6066	Siltstone, as above	poor

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
867-100

Sampled depth (ft)	Lithologic summary	Spores, pollen and marine organisms
6066-6068	Siltstone, light olive gray to yellow-brown, micaceous	poor
6068-6070	Siltstone, argillaceous, reddish gray to yellow-brown	poor
6070-6072	Siltstone, very argillaceous, grayish red	poor
6072-6074	Shale, silty, grayish red, and light gray, grayish green, and pale red siltstone	poor

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867-100

Appendix 2

J & J Enterprises - E. G. Taylor 1-G well; Accomack County, Virginia: Descriptions of selected well cuttings and core chips by William J. Perry, Jr., and Laure G. Wallace; Basement core data by U. S. Geological Survey personnel and Gulf Oil Company - U. S.

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867-100

J & J Enterprises - Taylor 1
Accomack County, Virginia
Descriptions of well cuttings 900-1390 feet

Depth (feet	Description *
900-10	Sand, fine to medium grained, subangular to subrounded, 60-65%; silty clay, medium gray to dark gray, 35%; heavy trace shell fragments; trace medium grained calcite and glauconite(?).
1030-40	Sand, fine to medium grained, angular to subangular, 95%; heavy trace shell fragments and glauconite(?). Electric log indicates mainly clay in interval.
1120-30	Sand, fine to medium grained, subangular to angular, 95%; heavy trace shell fragments and glauconite(?). Electric log indicates mainly clay in interval.
1160-70	Sand, fine to medium grained, few scattered coarse grains, angular to subangular, 95%+; heavy trace shell fragments. Electric log indicates clay or silt in interval.
1320-30	Clayey silt, silty clay, light olive gray, 98%; heavy trace shell fragments.
1370-80	Silt, fine, clayey light olive gray, light orange brown, 60%; sand, fine to medium grained, subrounded to subangular, 35%; trace large shell fragments; trace calcite-cemented sandstone; trace greenish-black glauconite.
1380-90	Clay, silty, light gray-brown to olive gray, glauconite, slightly calcareous, 90%; sand as above, 8%; trace shell fragments.

*Underlined components best fit geophysical log character of interval.

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867-100

J & J Enterprises - Taylor 1
Accomack County, Virginia
Descriptions of well cuttings 1420-1480 feet

Depth (feet)	Description
1420-30	Clay, slightly calcareous, light gray, with abundant, nearly black, fine to medium glauconite pellets, 70%; chalk, soft, argillaceous, pale gray to nearly white, 15%; sand, fine to medium grained, 10%; heavy trace silt and bivalve fragments; trace very glauconitic limestone; trace foraminifers. Sample examined both dry (unwashed) and wet (washed).
1430-40	Clay, silty, light gray, somewhat calcareous, glauconitic, 70%; sand and glauconite pellets as above, in equal amounts, 15%; chalk, pale gray, 10%; trace very coarse grained sand and bivalve fragments; trace foraminifers. Sample examined wet.
1440-50	Clay, as above, 50%; chalk, slightly silty, pale gray, 45%; only heavy trace sand, as above; trace foraminifers. Sample examined wet.
1450-60	Clay, calcareous (marl), and some pale gray chalk, 60%; pelletal glauconite, 20%; sand, as above, $\geq$ 5%; heavy trace sand, as above; trace foraminifers, trace pyritic sand; shell fragments, $\geq$ 5%.
1460-70	Chalk, pale gray, and slightly calcareous clay, finely micaceous, glauconitic in part, 85%; pelletal glauconite, 10%; trace bivalve and unidentified shell fragments; heavy trace very fine grained sand and silt.
1470-80	Clay, light to medium gray, silty, glauconitic, slightly micaceous, very calcareous, and some pale gray-white chalk, as above, 85%;

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867-100

J & J Enterprises - Taylor 1
Accomack County, Virginia
Descriptions of well cuttings 1480-1540 feet

Depth (feet)	Description
	pelletal glauconite, ≥ 10%; trace sand and silt, as above; with several large bivalve fragments. Sample examined both dry (unwashed) and wet.
1480-90	Clay, as above, 60%; chalk, as above, 30%; glauconite, as above, heavy trace fossil (mainly bivalve) fragments; trace sand, very fine to coarse-grained; trace forams; trace fine muscovite. Sample examined both dry and wet.
1490-1500	Clay, medium gray, silty, very calcareous (argillaceous marl); glauconite as above; trace sand, as above; heavy trace fine muscovite (sericite).
1500-10	Clay, light medium gray, calcareous, glauconitic; heavy trace sand as above; abundant bivalve fragments. Sample examined dry.
1510-20	Clay, light-medium gray, calcareous, with abundant sand to silt-sized fossil fragments, 80%; sand, fine to medium grained, 15%; heavy trace very pale gray chalk (cavings?).
8 5/8" Casing set at 1525 feet	
1520-30	Interval mainly cavings. As above but with greater amounts of quartz silt, sand, and abundant fossil fragments.
1530-40	Sand, fine to medium grained, with abundant fine to very coarse bivalve and gastropod fragments; some medium gray siltstone with abundant fine glauconite grains.

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
867-100

J & J Enterprises - Taylor 1
Accomack County, Virginia
Descriptions of well cuttings 1540-1610 feet

Depth (feet)	Description
1540-50	Sand, as above, with less fossil material than above; sand partly aggregrated, with trace siltstone, as above, and gray clay; heavy trace "books" of pale green soft micaceous mineral (vermiculite?).
1550-60	Sand, fine to medium grained, subangular to subround, partly aggregated; heavy trace soft greenish micaceous mineral in "books", as above; abundant muscovite, in fine to coarse platelets; heavy trace black carbonaceous material (lignite); trace glauconite and siltstone, as above; trace pyrite; trace macrofossil fragments.
1560-70	Sand, fine to very fine grained, subangular micaceous, with abundant silt; heavy trace macrofossil fragments; heavy trace lignite; trace glauconite.
1570-80	Sand and silt, aggregated with medium gray clay, 50%; bivalve fragments, 45%; trace lignite; trace coarse to very coarse sand.
1580-90	Sand, medium grained, subrounded and some fine to coarse with medium gray siltstone; abundant bivalve fragments; trace glauconite.
1590-1600	Sand, fine to very fine grained, 70%; silty clay and siltstone, 20%; abundant bivalve fragments; heavy trace lignite.
1600-10	As above, with coarse to very coarse mica flakes and abundant lignite and quartz silt.

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867-100

J & J Enterprises - Taylor 1
Accomack County, Virginia
Descriptions of well cuttings 1610-1680 feet

Depth (feet)	Description
1610-20	Sand, fine to medium grained, subangular, with abundant lignite and coarse muscovite; trace light gray silty clay; trace bivalve fragments (probably cavings).
1620-30	As above, but with less than 5% lignite.
1630-40	Sand, medium grained, subangular, with coarse muscovite flakes; heavy trace lignite; trace medium gray siltstone.
1640-50	(Possible all cavings) Sand, as above, 80%; cement, pale gray, 15%; trace very calcareous siltstone, with fine glauconite; trace bivalve fragments.
1650-60	(Mainly cavings?) Sand, fine to medium grained, angular, 50%; siltstone, medium gray, very calcareous, glauconitic, 20%; ankerite (ferroan dolomite?), tan-gray to medium gray and black dense, very silty to argillaceous in part, 15%; abundant very coarse bivalve fragments; cement cavings, 10%.
1660-70	Sand, as above, white-clay coated and aggregated in part, 60%; cement (cavings) 20%; lignite and plant fragments, 10-15%; abundant fine to very coarse bivalve fragments; heavy trace dark gray to tan-gray silty ankerite(?) and black phosphatic material.
1670-80	(Mainly cavings) Sand, as above, with abundant fine to coarse bivalve fragments, trace lignite; trace phosphatic grains, trace bluish-gray shale.

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
867-100

J & J Enterprises - Taylor 1
Accomack County, Virginia
Descriptions of well cuttings 1680-17 80 feet

Depth (feet).	Description
1680-90	Sand, as above, and buff, nearly white, cement (cavings). Sample examined dry.
1690-1700	Sand, fine to medium grained, subangular, micaceous; heavy trace lignite (Entire sample may be contaminated). Clay or shale by electric and IES logs.
1700-10	Siltstone, pale gray to medium gray, very calcareous, with abundant shell material--no sand; lignite, 10%; abundant cement (cavings); trace ankerite(?) as above.
1710-20	Silt and fine grained sand, light gray, somewhat argillaceous, 80%; light gray to buff silty clay, 10%; abundant lignite (5-10%); heavy trace mica; heavy trace shell fragments. Sample badly contaminated.
1720-30	As above, with about 25% lignite; abundant bivalve fragments.
1730-40	Same as 1710-20, but with very little clay, with abundant fine silt (probably a bad sample--contamination).
1740-50	As above, with abundant shell fragments.
1750-60	As above, with heavy trace soft medium to dark gray siltstone and light gray ankerite (?).
1760-80	Clay, light to medium gray, silty, and clayey silt, 85%; bivalve fragments, 5-10%; abundant fine to very fine grained sand and silt; heavy trace maroon silty clay. The clay and clayey silt may be the only indigenous part of the sample

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
867-100

J & J Enterprises - Taylor 1
Accomack County, Virginia
Descriptions of well cuttings 1790-1890 feet

Depth (feet)	Description
1790-1800	Sand, medium to fine grained, subangular, with coarse mica; trace soft light gray argillaceous siltstone and bivalve fragments. Sample possibly out of place.
1800-10	Sand, medium to fine grained, angular, and silt, light gray; heavy traces soft light-gray clayey siltstone, coarse mica flakes, and lignite; trace maroon argillaceous siltstone; trace pyrite.
1810-20	Sand, medium to fine grained, angular to subangular; silt and sandstone, as above, 5%; heavy trace sand-size mica flakes; trace lignite.
1820-30	Silt, clayey and silty clay, light gray (and heavy trace maroon silty clay); sand, fine to very fine grained, angular, 15-20%; trace shall fragments, white, badly corroded, one clearly a gastropod fragment; trace lignite; a possible tintinnid fragment; trace siderite (?).
1830-40	As above, with abundant (30-40%) very fine to fine grained sand; trace shell fragments, not corroded, as above.
1840-50	Sand, coarse to medium grained, angular to subangular, partly coated with light gray clay, 75%; silty clay and clayey silt, light gray, 10-20%; trace bivalve and other? white shell fragments; trace fine lignite (plant) fragments.
1880-90	Sand, fine to medium grained, fairly well sorted, angular to subangular, slightly argillaceous and trace light gray clayey sandstone; heavy trace coarse muscovite; rare trace fine plant fragments (fine lignite grains).

J & J Enterprises - Taylor 1
Accomack County, Virginia
Description of well cuttings 1890-1970 feet

Depth (feet)	Description
1890-1900	Clay and clayey siltstone, light medium gray and some maroon, with less than 10% fine to very fine sand; trace white shell material; trace goethite and hematite-stained material.
1900-10	Clay and clayey siltstone, as above, with trace greenish mica; trace shell fragments (some clearly bivalves, both rather thick and thin-walled fragments). Mainly sand by electric log; approximately 10 ft lag in well cuttings.
1910-20	Sand, fine-medium grained, angular to subangular, 85%; clayey siltstone and clay, light gray to medium gray, approximately 10%; trace biotite and muscovite; trace maroon clay.
1920-30	Sand, as above, 60%; silty clay and clayey silt, as above, 35%; traces of lignite, coarse mica, and maroon clay; rare trace--bivalve fragment.
1930-40	Sand, fine to very fine grained and some medium, subangular to angular, and quartz silt (approximately 10%),light gray, slightly argillaceous and micaceous, 90%; clayey siltstone and silty clay, as above, 10%.
1940-50	Sand, fine to medium grained, angular to subangular, light gray, 70%; clayey silt/silty clay, 25%; heavy trace coarse mica; trace fine lignite (organic material); rare trace--bivalve fragment.
1950-60	Sand/silty clay, as above, 60/40%; trace lignite.
1960-70	Fine to very fine grained sand, silt, and clay, light gray, and trace pale maroon-gray clay.

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J & J Enterprises - Taylor 1
Accomack County, Virginia
Descriptions of well cuttings 1970-2040 feet

Depth (feet	Description
1970-80	Sand, silt and clay (less than 15%), as above, light gray and trace maroon-gray clay.
1980-90	Clay, silty and clayey silt, light and some medium gray, trace pale maroon gray; trace sand, as above; trace lignite; trace poorly preserved shell fragments.
1990-2000	Clay, silty, and some soft clayey siltstone, light gray, and some pale maroon-gray, 70%; sand, very fine to coarse grained, angular to subangular, 20%; heavy trace shell fragments (including bivalves).
2000-10	Silt and very fine to fine grained sand, argillaceous, 60%; clay, silty, light gray and some pale maroon-gray, 35%; trace muscovite, biotite, and chlorite(?) flakes; trace lignitic material; trace dark yellow green epidote(?); trace bivalve fragments.
2010-20	Sand, fine to very fine grained, silty, argillaceous, 75%; clayey silt, and clay 20%; heavy trace black lignitic(?) material; trace mica flakes and shell fragments, as above, trace black lignitic material.
2020-30	Clay, light gray to pale maroon, 80%; abundant bivalve fragments, including a complete valve; some silty clay and clayey silt. Top of sand 2028 ft by electric log.
2030-40	Silt, clayey light gray with fine to very fine sand, with lignite (in relatively large fragments); trace pale maroon-gray clay, probably cavings; trace mica.

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867-100

J & J Enterprises - Taylor 1
Accomack County, Virginia
Descriptions of well cuttings 2040-2120 feet

Depth (feet)	Description
2040-50	Sand, very fine to fine grained, silty, clayey, as above, with shell fragments common, trace lignite.
2050-60	Sand, fine to very fine grained, subangular, with flakes of mica; trace light gray to pale maroon clay and soft siltstone.
2060-70	Sand, fine to very fine grained, subangular, argillaceous, silty ["dirty" sand], with abundant light gray sandy clay and silt; trace mica, as above; trace lignite.
2070-80	Sand, fine to very fine grained, and silt, as above with mica flakes; trace glauconite; trace lignite; trace shell fragments (including a foraminifer simmilar to Globigerina sp.).
2080-90	Sand, very fine to fine grained and silt, as above with mica flakes, with approximately 15% light gray clay; traces of glauconite, lignite, and shell fragments; heavy trace pale maroon-gray to brick red clay.
2090-2100	Same, with some medium to coarse subangular sand (no efforvescence with dilute HCL).
2100-10	Sand, medium to fine and some coarse grained subangular, approximately 20% silt and clay, as above, (probably cavings); trace shell material in coarse to very coarse fragments. Sand 2095-2101 ft by electric log.
2110-20	Silt and clay, light gray, silty, 60%; sand fine to very fine grained and some medium subangular, 40%; mica flakes common; trace shell fragments; rare trace glauconite.

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867-100

J & J Enterprises - Taylor 1
Accomack County, Virginia
Descriptions of well cuttings 2120-2190 feet

Depth (feet)	Description
2120-30	Sand, medium to coarse grained, subangular, 40%; clay, silty, light to medium gray. 40%; bivalve fragments, 15%; trace glauconite in irregular botryoidal clumps; trace lignite (probably cavings).
2130-40	Silt, sandy and clayey, light gray, to very fine - fine silty sand, micaceous, with lignite fragments (carbonized wood)ccommon; trace shell material, as above
2140-50	As above, with trace medium to coarse grained sand.
2150-60	As above, with about 20% medium to coarse sand, and abundant shell fragments; with greater than 20% light gray to pale maroon-gray clay; trace glauconite.
2160-70	Silt, sandy and clayey, light gray, with lignite (carbonized wood) fragments common. Sand 2158 to 2168 by IES log.
2170-80	As above, with abundant fine to very fine sand.
2180-90	Sand, medium to very fine grained, subangular, silt, and some light gray clay; with heavy trace botryoidal glauconite; trace mica flakes; trace shell fragments; trace maroon to brick-red clay.

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867-100

J & J Enterprises - Taylor 1
Accomack County, Virginia
Descriptions of well cuttings 2190-2260 feet

Depth (feet)	Description
2190-2200	Sand, fine to very fine grained, and some medium, subangular, silty, clayey; with light gray to pale maroon gray clay and clayey silt, 30%; with heavy trace mica flakes; trace lignite; rare trace shell fragments.
2200-10	Sand, fine to medium grained and some very fine, subangular, 75%; clay, light gray to pale maroon-gray and some greenish-gray, 20%; traces glauconite, shell fragments, mica flakes.
2210-20	Sand, as above, 55%; clay and clayey silt, light gray to pale maroon-gray and trace dark gray, 40%; trace mica flakes and glauconite.
2220-30	Sand, as above, 70%; clay and clayey silt, as above 20%; feldspar grains common in sand; mica flakes common; trace red clay.
2230-40	As above, clay partly coating everything; with heavy trace lignite.
2240-50	Sand, medium to fine grained, subangular, 45%; clay and clayey silt, light gray to maroon-gray, 45%; some clay very limonitic; trace altered biotite; mica flakes common; trace glauconite, some vermiform.
2250-60	Clay and clayey silt, light gray, 50%; sand, as above, 40%; mica flakes common; trace shell fragments; trace glauconite.

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567-100

J & J Enterprises -Taylor 1
Accomack County, Virginia
Description of well cutting 2260-2310 feet

Depth (feet)	Description
2260-70	Clay, and clayey silt, light gray (cavings) 70%; sand, very fine to medium, subangular, 25%; lignite (carbonized plant material) common; mica flakes common; trace glauconite (cavings).
2270-80	Sand, very fine to medium, subangular, 65%; clay and clayey silt, as above, 30%; mica flakes and lignite common; trace glauconite (cavings); trace red hematitic clay; rare trace shell fragments (cavings).
2280-90	Sand, as above, 45%; clay and clayey silt, as above, 40%; mica flakes and lignite common.
2290-2300	Clay and clayey silt, light gray, 60%; sand, as above 35%; mica flakes and lignite common; trace limonite and hematite-stained clay.
2300-10	Sand, medium to very fine grained, subangular, 65%; clay and clayey silt, as above, and some maroon to brick-red, 30%; mica flakes common; heavy trace shell material; trace glauconite; trace lignite.
2310-20	Sand, fine to medium grained, angular to subangular, approximately 75%; silty clay, pale gray and some pale reddish gray; traces of bivalve shell fragments, coarse muscovite flakes, clayey hematite nodules, and glauconite (probably cavings).

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867-100

J & J Enterprises - Taylor 1
Accomack County, Virginia
Descriptions of well cuttings 2320-2390 feet

Depth (feet)	Description
2320-30	Sand, as above, with mica flakes, about 80%; silty clay, light to medium gray, 15%; heavy trace light reddish-gray silty clay and hematitic to limonitic nodules; trace shell material (abraided), one broken fragment filled with medium gray silty clay.
2330-40	Sand and clay, as above; with trace weathered glauconite, crab(?) fragments.
2340-50	Sand, poorly sorted, medium to very fine grained, angular to subangular, with medium to coarse muscovite flakes, 70%; clay, silty, light gray to light reddish-gray, 25%; trace shell material (finely broken), bone fragment(?), weathered glauconite.
2350-60	As above, with trace grayish-red and yellowish-green silty clay.
2360-70	Sand, fine to very fine grained, silty, angular to subround, approximately 55%; buff to light gray silty clay, with two bivalve impressions and attached fragments, 35%; muscovite and biotite flakes common; trace lignite; trace glauconite; heavy trace shell material.
2370-80	As above, with more silt than clay.
2380-90	Sand, fine to medium grained and some very fine, fair sorting, subangular, with medium to coarse muscovite flakes, 80%; clayey silt and silty clay, pale buff, light to medium gray, grayish-red and greenish-gray, about 15%; heavy trace lignite; trace weathered glauconite.

J & J Enterprises - Taylor 1
Accomack County, Virginia
Descriptions of well cuttings 2390-2460 feet

Depth (feet)	Description
2390-2400	Sand, fair sorting, medium to fine grained, angular to subangular, with mica flakes, 70%; clay, silty, light gray to medium gray, some pale gray to pale reddish-gray, 25%; trace shell material and bone(?) finely broken; trace weathered and unweathered glauconite (cavings?), altered biotite; trace sand-sized hematitic pellets.
2400-10	Clay, light gray, silty, and clayey silt, 40%; sand, medium to fine grained, angular, 40%; clay, reddish gray to grayish red, 10%; heavy trace medium gray clay; heavy trace lignite and shell fragments; trace coarse muscovite flakes.
2440-50	Sample appears badly contaminated with tan drilling mud. Sand, medium to very fine grained coarse silt, subangular to subrounded, 75%; trace medium gray silty clay; heavy trace sand-sized mica (some soft, greenish); trace cement, trace shell fragments; apparently abundant heavy minerals including magnetite or ilmenite, kyanite(?), epidote; trace shell material; heavy trace hematitic material.
2450-60	Sand and silt, as above, 60%; clay, silty, light to medium, brownish gray and some light reddish gray, and soft clayey siltstone, 30%; trace mica, as above; trace shell fragments, finely broken; trace black opaque grains (possibly including carbonaceous material.

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867-100

J & J Enterprises - Taylor 1
Accomack County, Virginia
Descriptions of well cuttings 2470-2550 feet

Depth (feet)	Description
2470-80	Silt, clayey and silty clay, light brownish gray to gray-brown, sandy, micaceous, with some brownish red silty clays; trace yellowish green (weathered?) glauconite pellets and shell material and heavy trace lignite.
2480-90	Clay, silty and clayey silt, as above, with heavy trace lignite, (weathered?), glauconite (cavings?) and one or tow medium sand-sized shell fragments (possibly cavings).
2500-10	Unwashed--clayey silt, and heavy trace silty clay, grayish green, reddish brown, 95%; sand, fine to medium grained, subangular, and silt, trace mica, shell fragments. Washed sample--clayey silt and silty clay, as above, 70%; sand and silt 25%; trace mica and shell fragments. Light tan material which appears as clay in dry sample comprises extensive amounts of the sample, it disintegrates immediately in water and is most likely drilling mud. Loss of clays occurs during washing.
2540-50	Unwashed--clayey silt and silty clay, reddish brown and greenish gray, 90%; snad, fine to medium grained, subrounded; trace of pyrite, shell fragments and mica. Washed--clayey silt, silty clay, as above 50%; sand and siltstone, 45%; traces, as above. Loss of extensive drilling mud and swelling clays give the % difference in washed sample.

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
867-100

J & J Enterprises - Taylor 1
Accomack County, Virginia
Descriptions of well cuttings 2600-2910 feet

Depth (feet)	Description
2600-20	Unwashed--clayey silt and silty clay, 75%; sand, medium to coarse grained, subrounded, 25%; Washed--clayey silt and silty clay, greenish-gray, yellow-orange some reddish-brown, 60%; sand and silt, 40%; trace shell fragments, mica, pyrite. Loss of clays and drilling mud during wash.
2610-20	Sand, medium to coarse grained, subrounded, 90%; in washed samples; silty clay and clayey silt, reddish-brown and grayish green, 4%; trace shell fragments, pyrite and mica.
2650-60	Sand, fine to medium grained, subangular to subrounded, 60-70% in washed samples; clayey silt, grayish green to reddish brown; trace pyrite, mica; trace siderite, garnet, ilmenite or magnetite, on heavy mineral separation.
2700-10	Sand, medium to coarse grained, subrounded to subangular, 55%; silty clay and clayey silt, reddish brown, greenish gray, 40%; trace pyrite, muscovite, biotite, shell fragments. Appears to be 60% clayey silt in dry sample.
2880-90	Sand, subangular, fine to coarse grained 95%;heavy trace clayey silt, greenish gray; trace biotite and muscovite.
2900-10	Sand, medium to coarse grained, subrounded to subangular, 95%; heavy trace clay or silty clay; trace feldspar.

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
867-100

J & J Enterprises - Taylor 1
Accomack County, Virginia
Description of well cuttings 2920-3260 feet

Depth (feet)	Description
2920-30	Sand, fine to coarse grained, subrounded to subangular, 95%; heavy trace clayey silt, reddish brown, greenish gray; trace magnetite, pyrite, garnet, olivine (?), feldspar, ilmenite (?), on heavy mineral separation.
2940-50	Sand, medium to coarse grained, subrounded to subangular, 85%; silty clay to clayey silt, greeninh gray (5G 5/2)*, 15%; trace feldspar and pyrite.
2960-70	Sand, medium to coarse grained, subrounded to subangular, 85%; clayey silt and silty clay, reddish brown, grayish green, 15%; trace pyrite, fossil fragments.
2980-90	Sand, medium to coarse grained, rounded to subangular, 85%; clayey silt, grayish green, 15%; trace shell fragments, pyrite, feldspar.
3000-10	Sand, medium to coarse grained, subangular to subrounded, 95%; heavy trace clayey silt and silty clay, grayish grain, reddish brown; trace pyrite, shell fragments, feldspar.
3250-60	Sand, fine to coarse grained, subrounded to subangular, 55%; clayey silt to silty clay, greenish gray, reddish brown, 40%; trace mica, shell fragments, pyrite. Dry sample appears to be equally sand and clayey silt.

*Goddard, E. N., and others, 1948, Rock-color chart: Washington, D. C., National Research Council, 6 p.; repub. Geol. Soc. America, 1963.

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867-100

J & J Enterprises - Taylor 1
Accomack County, Virginia
Descriptions of well cuttings 3270-3750 feet

Depth (feet)	Description
3270-80	Clayey silt and silty clay, reddish brown, grayish green, 70%; sand, medium to coarse grained, subrounded, 25%; trace shell fragments, mica, feldspar.
3480-90	Sand, very coarse grained, subround, 60%; clayey silt, and silty clay, reddish-brown and greenish gray, 35%; trace feldspar.
3490-3500	Clayey silt and silty clay, reddish-brown, light grayish green, 60%; sand, medium to very coarse, subrounded to subangular, 40%.
3570-80	Silty clay and clayey silt, reddish-brown and greenish-gray, as above, 95%, in washed sample; sand, very coarse grained, subrounded, 5%; clays appear well aggregated in dry sample but swell rapidly and disaggregate with addition of water.
3630-40	Sand, very coarse to medium grained, subangular to angular, 65%; claystone, silty, maroon, reddish-gray and light (greenish) gray, 30%; trace pyritized wood fragments; sand grains are clay-coated in part.
3650-60	Sand, coarse to medium and some very coarse grained, subangular to subrounded, 60%; claystone light gray to maroon, silty, 40%; (clayey fine sericitic siltstone at 70x magnification).
3740-50	Claystone, maroon, light reddish gray, light gray, silty and clayey siltstone, 80%; sand, very coarse to medium grained, angular to subangular, 18%; trace gray-white silty claystone.

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867-100

J & J Enterprises - Taylor 1
Accomack County, Virginia
Descriptions of well cuttings 3820-4210 feet

Depth (feet)	Description
3820-30	Sand, medium to fine and coarse to very coarse grained, 80%; claystone silty, light greenish gray to maroon, 19%; rare trace shell fragments (cavings?); rare trace lignite.
3960-70	Sand, medium to coarse grained, angular to subangular, grains partly coated with clay (drilling mud?) 95%; claystone, silty to fine sandy, buff to light gray, 5%; trace maroon claystone (cavings?); trace opaque minerals (coarse black subequant grains with shiny surfaces). Drilling mud coatings removed in the wash. Heavy trace feldspar; trace carbonate-cemented sandstone, glauconite, chloritic quartz, metamorphic rock fragments.
4000-10	Sand, medium to coarse, some very coarse,grained subangular, 90%; claystone silty, maroon to greenish gray, 10%; in wet examination, claystone swells and disaggregates to show 5% in washed sand fraction; trace feldspar. Top of sand at 4006 ft by IES log.
4100-10	Sand, fine to medium grained, angular to subangular, 80%; claystone, silty greenish-gray to maroon, 20%; trace 0.8 mm altered chlorite? (or biotite) flakes; trace chalcedony(?).
4200-4210	Sand, medium to fine and some coarse grained, and some coarse grained, angular to subangular, 90%; claystone, silty, gray-green to brownish red, 8%; trace medium to dark gray shale; trace feldspar (both sand and claystone in interval accords with IES log).

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
867-100

J & J Enterprises - Taylor 1
Accomack County, Virginia
Descriptions of well cuttings 4360-4490 feet

Depth (feet).	Description
4360-70	Sand, coarse to medium grained, angular to subangular, 90%; claystone, silty, greenish gray to maroon, less than 10%; (about 5% of the sand grains have cleavage surfaces and are probably nearly fresh feldspar).
4400-10	Sand, coarse to medium grained, subangular, 70%; silty clay, light brown, grayish green, dusky red, pale green and light gray; and clayey silt, light to medium gray. Rapid expansion of clays in water in the interval from 4400-5700; all samples examined both dry (unwashed) to determine percentage clay, and wet (washed) to determine color and minor constituents (feldspar, etc.).
4440-50	Sand, coarse to medium grained, subangular to angular, 90%; clayey silt and silty clay, grayish green, grayish red, reddish brown, light brown, and pale brown, 10%.
4470-80	Sand, medium to coarse grained with a few very coarse grains, subangular to angular, 85%; clayey silt and silty clay, dusky red, grayish green, light green, pale brown, light and dark gray, 15%; traces of shells, feldspar including microcline, and pyrite.
4480-90	Sand, medium to coarse grained with a few very coarse grains, 85%; silty clay, and clayey silt, as above, 15%; noted increase in the amount of shell material and a greater proportion of greenish gray silty clay; heavy mineral separation showed traces of magnetite, ilmenite, garnet, olivine.

J & J Enterprises - Taylor 1
Accomack County, Virginia
Descriptions of well cuttings 4560-5410 feet

Depth (feet)	Description
4560-70	Sand, medium to coarse grained, subangular, a few very coarse grains, 85%; silty clay and clayey silt, greenish gray and dusky red, 15%; traces of shell fragments, pyrite and feldspar.
5060-70	Siltstone, clayey and silty clay, grayish green predominantly, also dusky red, dark yellowish orange, 65-70%; sand, coarse to very coarse grained, subrounded to subangular, 30%; traces of very coarse feldspar grains.
5190-5200	Siltstone, silty clay and clayey silt, grayish green, and dusky red, 90-95%; sand, coarse to very coarse grained, subrounded, 5-10%.
5230-40	Sand, predominantly coarse and some fine grained, subangular to angular, 70-80%; clayey silt, gray and dusky red; traces of shell fragments and feldspar. Analysis of grains smaller than 63 microns shows little evidence of clay in the silt.
5250-60	Sand, fine to medium, coarse grains occasionally, subangular, 50%; silt, greenish gray, dusky red, and dark yellow orange, 48%; traces of shell fragments, feldspar, and mica flakes.
5270-80	Siltstone, grayish green with some yellow orange and dusky red, 50%; sand, medium to coarse grained with some fine and very coarse grained, subangular, less than 50%.
5400-10	Siltstone, grayish green, 60%; sand, coarse to very coarse, subangular, 40%; traces of shell fragments and pyrite.

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867-100

J & J Enterprises - Taylor 1
Accomack County, Virginia
Descriptions of well cuttings and core chips 5700-6069 feet

Depth (feet).	Description
5700-10	Sand, coarse to very coarse grained, subrounded to subangular, 55%; silt, predominantly grayish green and gray, some brownish orange and red, slight expansion of clays with water, 40%; traces of shell fragments, feldspar and pyrite.
5950-60	Sand, coarse to medium grained, subrounded to subangular, 98%; clayey silt and silty clay reddish brown and dark gray green, 1-2%; trace fossil fragments.
6050-60	Silty claystone and clayey siltstone, moderate reddish brown (10R 4/6) and grayish green (5G 5/2); sand, subangular to angular, fine to coarse grained, 30- 35%; trace feldspar.
	CORE CHIPS
6059-60	Siltstone, very argillaceous, medium brownish red, micaceous.
6060-61	Siltstone, argillaceous, light brownish red, finely micaceous, with darker brownish red claystone clasts inbedded in siltstone.
6063-64	Siltstone, reddish gray, very fine sandy, very micaceous.
6065½-66	Siltstone, argillaceous, light brownish gray to grayish-red, muscovite, and biotite prevalent; few claystone clasts, very friable.
6067-68	Siltstone, light olive gray (5Y 6/1), moderate yellow brown (10YR 5/4), abundant fine micaceous particles.
6068-69	Siltstone, light olive gray and moderate yellow brown, as above, abundant fine micaceous particles, not as friable as 6065½-66.

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
867-100

J & J Enterprises - Taylor 1
Accomack County, Virginia
Descriptions of core chips and well cuttings 6069-6250

Depth (feet)	Description
6069-70	Siltstone, with increasing clay content, pale reddish gray to yellowish brown. Thin bedded material: a firm micaceous siltstone layer grades into thin layer of argillaceous siltstone with clay clasts.
6070-71	Siltstone, light gray (N7), light brownish gray (5YR 6/1), and pale red (5R 6/2), brownish gray (5YR 4/1), and grayish red (10 4/2), with wavey hematitic laminae. Siltstone micaceous throughout, fairly firm becoming very friable in argillaceous layers when wet.
6071-72	Siltstone, highly argillaceous, highly micaceous, grayish red (5R 4/2) - (10R 4/2).
6072-72½	Shale, silty, grayish red (10R 4/2), on shiny surfaces of claystone laminae, fissle (platy fracture). Compositionally a siltstone, in part grayish green (5GY 6/1).
6072½-73	Siltstone, grayish green (5GY 6/1), tinted grayish red (5R 4/2); calcareous material in matrix; with a few coarse sand grains.
6073-74	Siltstone, with a few coarse sand grains, pale red (5R 6/2) to medium light gray (N6), reacts only in a few small areas to HCL; (slightly calcareous) slightly argillaceous, becomes more friable with the addition of water.
	WELL CUTTINGS
6250	Metasiltstone, calcareous, light gray to dark gray with porphyroblasts of biotite, in part, 45%; silts and clayey siltstone cavings, grayish green, not as expandable as clay, above.

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867-100

J & J Enterprises - Taylor 1
Accomack County, Virginia
Description of well cutting 6250 feet

Depth (feet)	Description
6250	5700 feet, 35%; sand, coarse, subangular, 15%; traces of feldspar, fossil fragments, two unbroken gastropods, and pyrite (cavings).

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867-100

J & J Enterprises - Taylor No. 1-G
Accomack County, Virginia
Basement core data

Geophysical well logs indicate that basement rocks were encountered from 6186 to 6272 feet TD. These are variously described as "dark-gray porphyroblastic argillite" (Onuschak, 1972), calcareous metasiltstone (this report, p. 57), and impure marble or calcareous gneiss (petroleum industry). Core photographs indicate an inhomogeneous, finely crystalline, foliated 'gneissic' rock. Light, apparently carbonate-rich bands, occur in a generally dark gray, apparently more micaceous and quartzose rock-type. X-ray identification of fine-grained phases in a core chip (from 6280 ft) by Mary Mrose indicates the presence of calcite, quartz, plagioclase feldspar (near andesine) and a $2M_1$ muscovite with *d* (060) = 1.50Å. A semi-quantitative emission spectrographic analysis of this chip is:

SiO_2	56.7%
Al_2O_3	16.7%
Fe_2O_3	5.9%
MgO	3.5%
CaO	14.1%
Na_2O	$>$0.4%
K_2O	$>$1.2%
TiO_2	0.7%
P_2O_5	$<$0.1%
MnO	0.1%

Velocities recorded by F.T. Lee from a basement core-sample are:

V_p = 19,100 ft/sec
V_s = 10,750 ft/sec

The following core report by Gulf Oil Company was kindly provided

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J & J Enterprises - Taylor No. 1-G
Accomack County, Virginia
Basement core data

by James L. Calver, State Geologist of Virginia, and is reproduced with his permission and that of Gulf Oil Company - U. S.

"A portion of basement core from the interval 6,265' to 6,280' was examined using potassium-argon and petrographic methods.

Petrographic Examination

Planar banding, apparently bedding, is distinguishable in the sample by both megascopic and petrographic examinations. Light-gray carbonate-rich bands are intercalated with dark gray, clastic-rich bands. Thin-section examination indicates the amount of carbonate varies from band to band ranging from 10% to 85%. Roughly 40% of the total thin section is carbonate.

Fine-grained biotite porphyroblasts comprise roughly 15% to 20% of the thin section. Biotite occurs in each band, but is more sparse in the carbonate-rich ones.

Very fine-grained white mica laths make up 5% of the thin section. Orientation of the laths defines a faint chevron folding in several bands; apparent axial orientation is grossly perpendicular to the bedding. The remainder of the thin section is very fine-grained quartz and feldspar with roughly one per cent opaque accessories.

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867-100

J & J Enterprises - Taylor No. 1-G
Accomack County, Virginia
Basement core data

Potassium-Argon Radioactive Dating

A total-rock age determination was first made although the core material was observed to be inhomogeneous. The rock is indicated to be 245 x 10^6 (Permian) in age. Removal of carbonate by acid treatment was then attempted. Data from this second run indicated a loss of argon during the acid treatment and this resulted in a meaningless date. The possibility of relict argon precludes a reliable age assignment."

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