STRATIGRAPHIC ANALYSIS OF THE PINEY POINT FORMATION OF MARYLAND

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ABSTRACT OF THE THESIS

Stratigraphic Analysis of

The Piney Point Formation of Maryland

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The Piney Point Formation, a subsurface glauconitic sand in the coastal plain of Maryland, rests on the Eocene Nanjemoy Formation and lies below the Miocene Calvert Formation. Planktonic foraminiferal evidence shows the Piney Point to be Late Oligocene in age. This contradicts previous studies by Shifflett (1948), Otton (1955), and Brown et al. (1972) which had designated the Piney Point sediments as Middle to Late Eocene in age. The Oligocene planktonic species include *Globigerina ciperoensis*, *Globigerina officianalis*, and *Globorotalia opima opima*.

The overlying Calvert Formation appears to have a conformable relationship with the Piney Point. In addition, the updip basal beds of the Calvert show evidence of facies equivalency with the Piney Point. Thus the foraminiferal biostratigraphy and paleoecology indicates that the Piney Point Formation was deposited during a Late Oligocene transgression on truncated Middle Eocene beds of the Nanjemoy Formation.

Analysis of the depth ranges of extant Piney Point

foraminiferal species and the planktonic species diversity index of the Piney Point suggest that the formation was deposited in an inner to middle shelf environment of less than 100 m. Cluster analysis of the Piney Point benthic foraminifera separates two assemblages which represent biofacies of distinct depths (<30 to 55 m; 55 to 80 m).

The biostratigraphic and paleoecologic data on sea level change do not conform in all aspects to the curve of global cycles of sea level change for the Oligocene by Vail et al. (1977). There is no evidence of a Lower Oligocene transgressive cycle in the Maryland coastal plain.

ACKNOWLEDGEMENTS

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INTRODUCTION

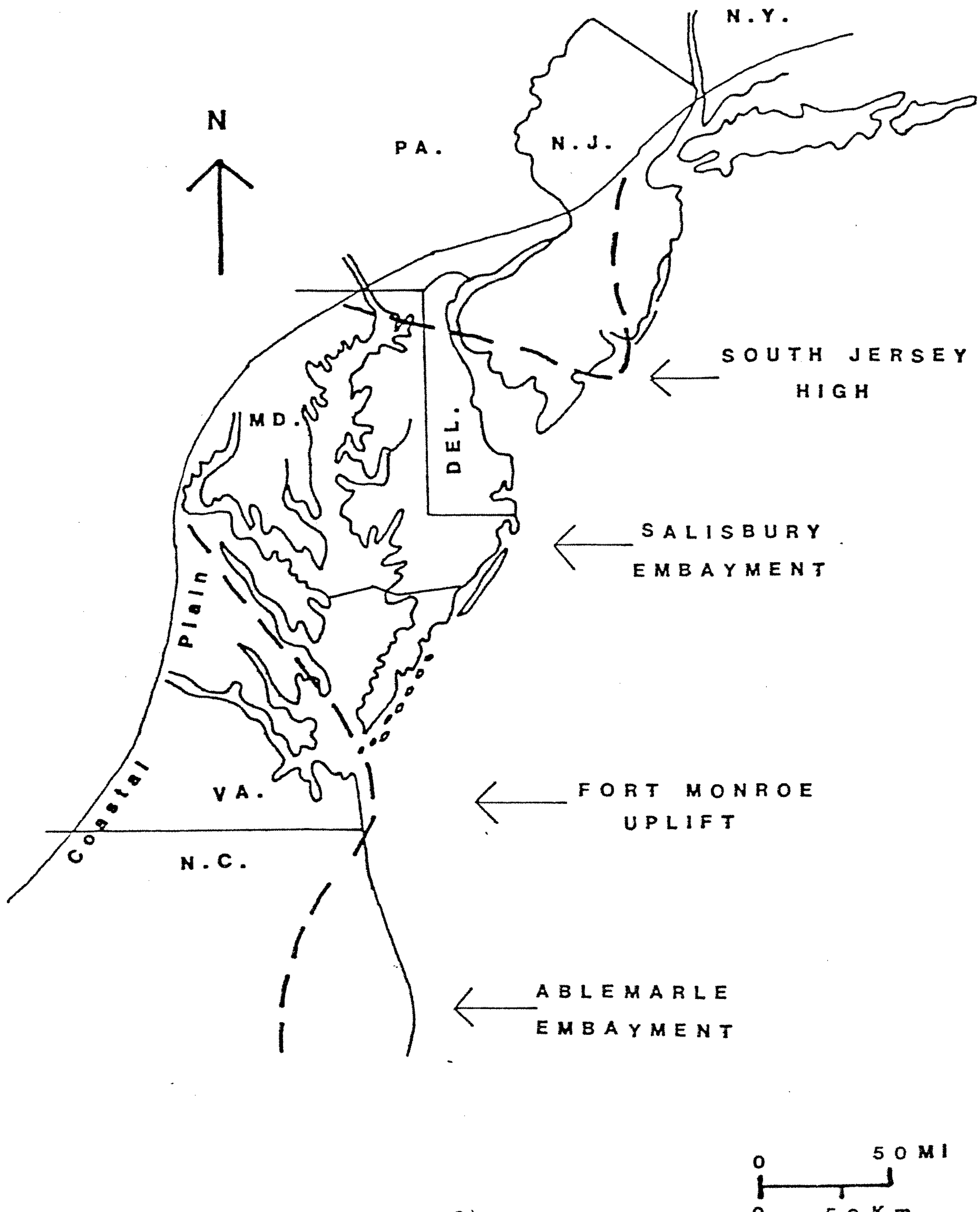
The Piney Point Formation is a glauconitic sand found in the subsurface of the Maryland coastal plain where it rests on the Eocene Nanjemoy Formation and is overlain by the Miocene Calvert Formation of the Chesapeake Group. It is part of a wedge-shaped mass of sediments which thickens and dips to the southeast. There are no outcrops of the Piney Point as it pinches out towards the northwest within the subsurface (Otton, 1955). The Piney Point is restricted to the area of the Salisbury embayment, a structural low within the basement (Balsley, 1946; Richards, 1967) (Fig. 1).

Otton (1955) named the Piney Point and assigned an Upper Eocene (Jackson) age to the formation. Shifflett (1948) had informally designated the sediments as "Jackson Eocene" based on age determination from foraminiferal evidence. Brown et al. (1972) examined the material from the type section of the Piney Point and suggested that the formation be assigned a Middle Eocene (Claiborne) age. This age determination was based on the presence of "characteristic" Clabornian ostracod species.

Olsson and Miller (1979) identified sediments of Oligocene age in the New Jersey coastal plain subsurface. Previous to this study, Oligocene sediments were not recognized in the New Jersey coastal plain (Weller, 1907; Richards, 1967). The Oligocene sediments of New Jersey,

Figure 1

Geologic Setting of the Maryland Coastal Plain



(After Olsson, 1978)

which were deposited during a transgression, were shown to trend into the Salisbury embayment (Olsson and Miller, 1979). Olsson and Miller (personal communication) also noted that the lithology and electric log signature of the Oligocene sediments of New Jersey are similar to that of the Piney Point Formation of Delaware and Maryland. The possibility exists, therefore, that the Piney Point may actually be Oligocene in age. This is of interest because sediments of Oligocene age have not been described from the Maryland-Delaware coastal plain (Otton, 1955; Richards, 1967; Cleaves et al., 1968). Shifflett's (1948) paleontological study is doubtful because the Piney Point was not formally designated when she completed her analysis. It is not clear, in fact, that the samples she used came from Piney Point intervals. In addition, the foraminiferal assemblages from the Piney Point have not been extensively analyzed and described. This study was therefore undertaken to investigate the possibility that the Piney Point is Oligocene in age by analyzing the benthic and planktonic foraminiferal assembledges contained in the formation.

The goals of this study are fivefold. They are to: (1) make a lithologic study of the Piney Point and to differentiate it from the units above and below it, (2) determine through foraminiferal evidence the age of the Piney Point and the age relationship to the units above and below it, (3) analyze the foraminiferal paleoecology of the Piney Point and identify foraminiferal biofacies through cluster analysis, (4) develop an understanding of the geological setting of the Piney Point utilizing the paleobathymetric information (biofacies), and (5) compare the findings of this study to the Vail et al. (1977) curve of global sea level change.

METHODS

Data used in this study was obtained from rotary wells, electric logs, and cores drilled by the Maryland Geological Survey. A base map (Fig. 2) and a listing of latitudes and longitudes for these wells is provided in Table 1.

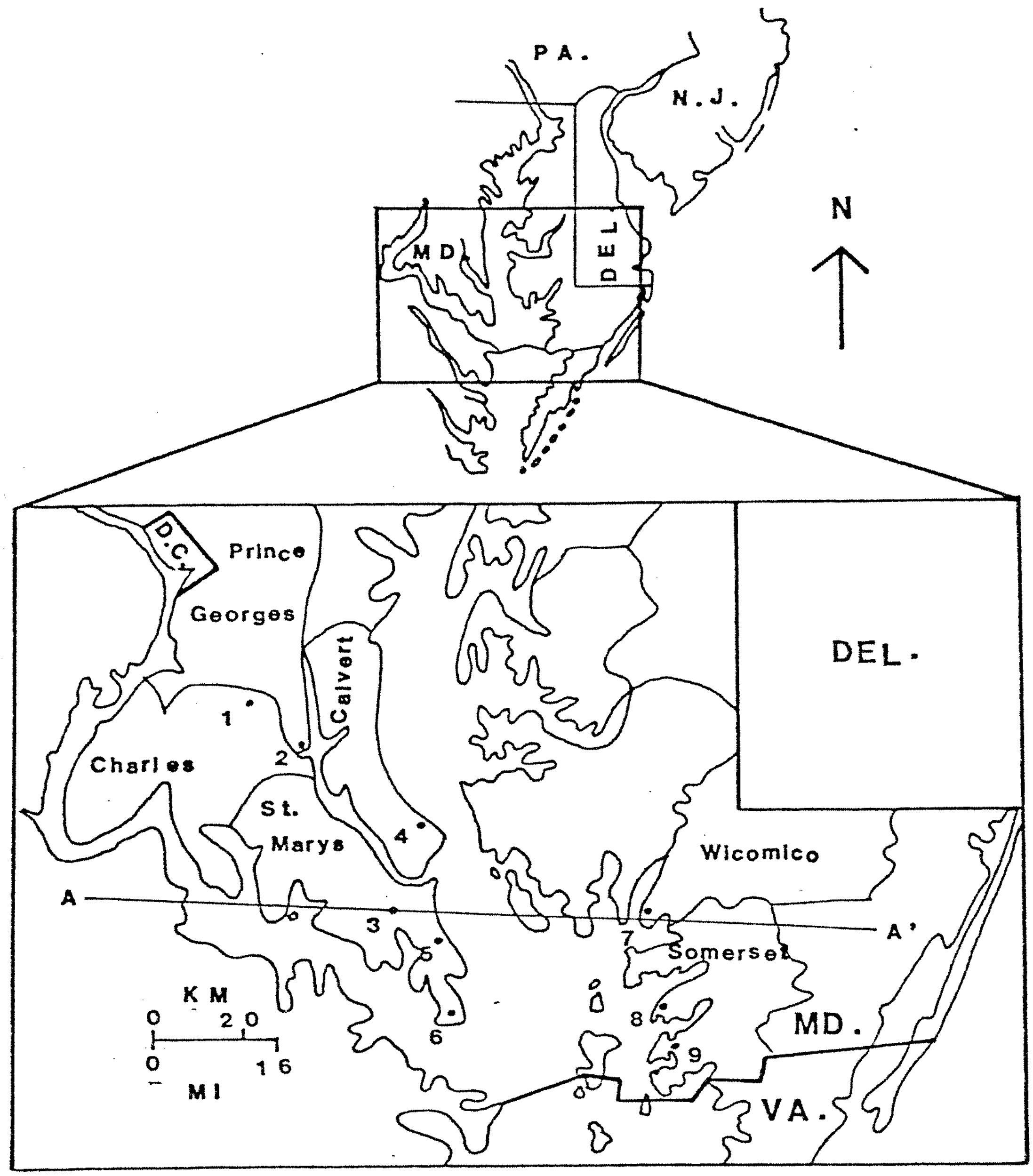
The foraminifera studied were concentrated from sediment samples using a flotation process. Scanning electron micrographs and light microscope observations were used to identify the specimens.

Because most samples were from rotary wells (at average intervals of ten feet), a counting method to determine species abundances was not used. Instead, a semi-quantitative ranking system similar to that used by Sancetta (1979) was employed to describe foraminiferal distribution. Because this method is a rough measure of abundance, it can handle large amounts of data in a shorter period of time than can fully quantitative descriptions. An added advantage of semiquantitative description is that it yields statistically equivalent results when subjected to the same statistical techniques as used on quantitative data (Sancetta, 1979). This study uses the semiquantitative data as a convenient method to observe the relative abundances of species and to delineate trends (Appendix I).

Problems with stratigraphically misplaced foraminifera are inherent to sample collection from rotary wells. Both the author and R.K. Olsson of Rutgers University studied the

Figure 2

Maryland Coastal Plain Base Map



WELLS

1	Ch Bf 127	6	StM Gg 14
2	PG Hf 23	7	Wi Db 56
3	StM Ef 56	8	Som Cc 5
4	Cal Fe 22*	9	Som Dc 3
5	StM Eg 27*		

* CORES

Table 1

Location of Wells, Electric Logs and Cores

Wells	Latitude	Longitude
Ch Bf 127*	N 38° 39' 10"	W 76° 52' 30"
PG Hf 23*	N 38° 32' 15"	W 76° 40' 59"
StM Ef 56*	N 38° 14' 30"	W 76° 29' 13"
StM Gg 14*	N 38° 04' 41"	W 76° 20' 02"
Wi Db 56	N 38° 18' 44"	W 75° 53' 28"
Som Cc 5*	N 38° 05' 00	W 75° 51' 53"
Som Dc 3*	N 38° 00' 29"	W 75° 50' 35"
Cores		
Cal Fe 22	N 38° 23' 24"	W 76° 24' 47"
StM Eg 27	N 38° 12' 13"	W 76° 22' 28"

* Electric logs available

foraminifera in the sample intervals above the Piney Point. Most stratigraphically misplaced species in the Piney Point were recognized by: (1) noting the location of intervals where foraminifera are abundant, (2) determining species abundance trends, and (3) comparing the rotary well samples to core materials.

LITHOLOGY

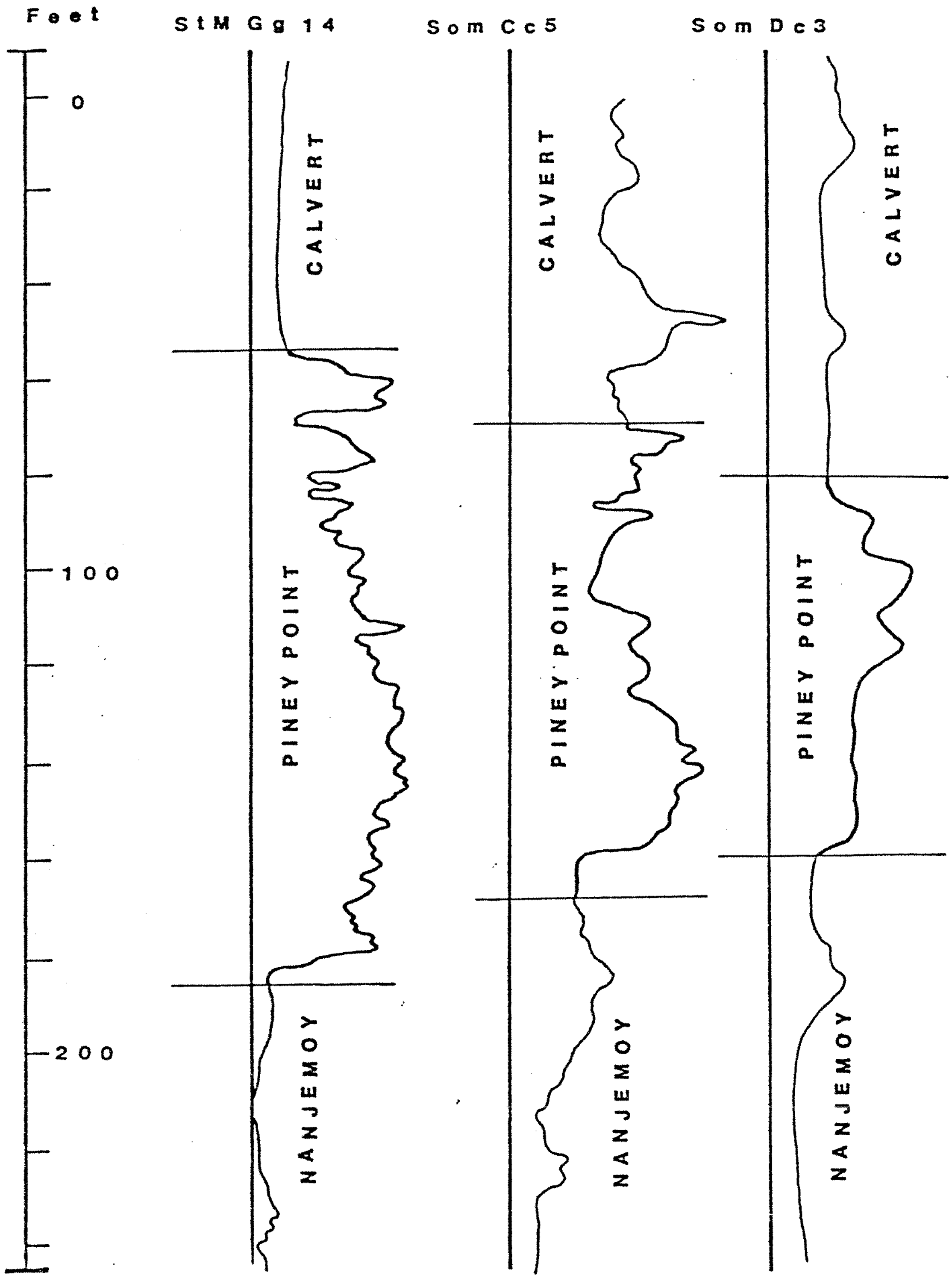
The Piney Point has a characteristic lithology that can be distinguished from the overlying Calvert and underlying Nanjemoy Formations. In general, the Piney Point is a light olive gray, slightly clayey to clayey, glauconitic, coarse to medium grained quartz sand. Some quartz sand grains in the formation are pitted and frosted, some are covered with a limonite coating, and others are unweathered and clear. Both weathered and unweathered glauconite pellets are found. The clay content varies but generally increases downdip. Amounts of fragmented shell material range from rare to abundant. The presence of weathered glauconite, pitted quartz grains, and recrystallized Eocene foraminifera (Pl. 1, Fig. 9) suggests that extensive reworking of material occurred during deposition of the Piney Point. Detailed lithologic descriptions of all well and core material containing Piney Point sediments can be found in Appendix II. The descriptions were based on microscopic observation of washed and unwashed samples.

A characteristic electric log signature is observed for the Piney Point (Fig. 3). The signature becomes less diagnostic updip where the Piney Point becomes less distinguishable from the Calvert and Nanjemoy (Appendix II).

In downdip wells, the Piney Point and Calvert are easily separated. The basal Calvert is almost entirely a

Figure 3

Piney Point Electric Log Signature



diatomaceous clay with minor amounts of coarse quartz sand and fine to silt sized glauconite pellets. The uppermost Piney Point consists of a clayey, coarse to medium quartz sand with medium to coarse glauconite pellets. The clay content ranges from 20 to 50 percent. Pitted and frosted quartz grains and grains with limonitic coatings characterize the Piney Point. Nearly all the sand in the Calvert is clear and fresh looking. Updip, the basal Calvert is a fine quartz sand. A medium to coarse quartz sand with medium grained glauconite makes up the uppermost Piney Point. The distinction between the Calvert and the Piney Point in the updip wells is not clearly defined (Appendix II). Where the Piney Point pinches out, the basal Miocene Calvert Formation overlies the Eocene Nanjemoy Formation. Here the basal Calvert (a fine quartz sand) can be easily separated from the uppermost Nanjemoy, a glauconite and quartz sand. These lithologic relationships infer that a possible facies relationship exists between the Calvert and the Piney Point.

In the downdip wells, a higher clay content and a general increase in the amount of glauconite distinguishes the Nanjemoy from the basal Piney Point. Updip, a color change from buff to light olive gray and an increase in glauconite content characterizes the change from basal Piney Point to uppermost Nanjemoy (Appendix II). Because of the high degree of reworking, the boundary between the Nanjemoy and the Piney Point is difficult to determine lithologically in the updip sections.

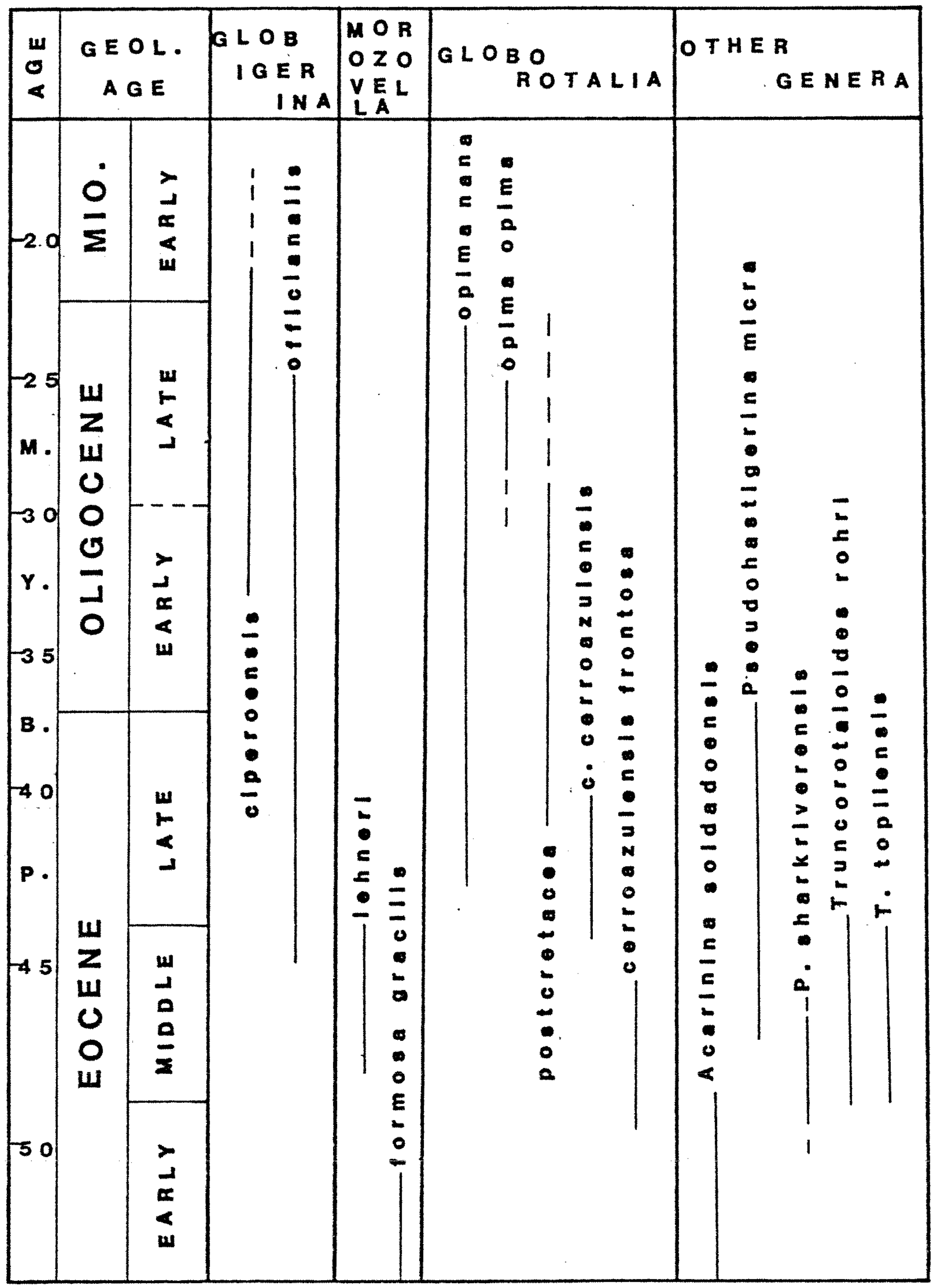
BIOSTRATIGRAPHY

Planktonic foraminifera are present in the Piney Point in small numbers. Most of these specimens are juvenile individuals or small adults. Appendix III lists the planktonic species that are identified in the Piney Point. Several of these species are useful in determining an age for the Piney Point. The presence of Globigerina ciperoensis (Pl. 1, Fig. 1) in the Piney Point is taken as a reliable guide to Oligocene age (Stainforth et al., 1975). Globorotalia opima opima is restricted to the Oligocene whereas Globorotalia opima nana and G. postcretacea range from the Upper Eocene into the Oligocene. The uppermost range of Globigerina officianalis (Pl. 1, Fig. 3) occurs in the Oligocene (Stainforth et al., 1975) (Fig. 4). Due to sparse recovery and the predominence of juvenile individuals, no foraminiferal zonation of the Piney Point is possible. However, the occurrence in the Piney Point of these planktonic species supports the assignment of an Oligocene age to the Piney Point.

In the basal portions of the Piney Point, typical Eocene foraminifers are occasionally present. These specimens are completely recrystallized (Pl. 1, Fig. 9) and are clearly distinguishable from the well-preserved indigenous forms. The underlying Nanjemoy Formation contains well-preserved Eocene foraminifera. Abundant occurrences of the

Figure 4

Planktonic Species Range Chart



(After Stainforth et al., 1975)

planktonic Genera Acarinina and Subbotina are typical of the Nanjemoy. Foraminiferal characteristics such as these clearly distinguish the Piney Point from the Nanjemoy.

The most common benthic foraminifers are Pararotalia (Pl. 1, Fig. 7) and Cibicides westi (Pl. 1, Fig. 8) both of which are characteristic Eocene forms. Except for some recrystallized Pararotalia in the basal portion, these forms are absent from the Piney Point. On this basis, the benthic foraminifera also serve to distinguish the Piney Point from the Nanjemoy.

The planktonic species that occur in the upper portions of the Nanjemoy are good indicators of a Middle Eocene age (Appendix III; Fig. 4). Morozovella lehneri (Pl. 1, Fig. 4), Truncorotaloides rohri (Pl. 1, Fig. 6), T. topilensis (Pl. 1, Fig. 9), and Pseudohastigerina sharkriverensis are all characteristic of the Middle Eocene (Stainforth et al., 1975; Berggren et al., 1967). Acarinina soldadoensis and Morozovella formosa gracilis (Pl. 1, Fig. 5) are Lower Eocene forms that are found in the basal portions of the Nanjemoy (Appendix III; Fig. 4). This infers that the age of the Nanjemoy ranges from Early to Middle Eocene. The marked differences in age between the Nanjemoy and Piney Point therefore rules out a facies relationship between the two formations.

All the benthic foraminifera indigenous to the Piney Point have been described from Oligocene or younger sediments (Appendix I). The studies by Cushman and Cahill (1933) and

Schnitker (1970) of foraminifera from the Miocene of the Atlantic coastal plain include many of the benthic species that are found in the Piney Point. This indicates that the benthic foraminifera of the Piney Point have much closer affinities to Miocene and younger benthics than to those of the Eocene.

Planktonic foraminifera indicate that the Piney Point and Calvert Formations may be conformable. Olsson (personal communication) notes that _Globigerina ciperoensis_ occurs in the basal portions of the Calvert and its equivalent, the Kirkwood Formation of New Jersey. This suggests that the Oligocene-Miocene boundary may be contained within the basal Calvert (Kirkwood). The relationship suggested here is that the Piney Point and basal Calvert are both Oligocene in age and are therefore conformable and, also that there is a facies relationship in updip sections (Fig. 5).

The above biostratigraphic and lithologic information is shown in a cross section (A-A') parallel to dip through the southern Maryland coastal plain (Fig. 2,6). Strike and dip orientation was determined graphically by the solution of a three point problem. The Calvert-Piney Point-Nanjemoy boundaries were established by the author on the basis of the preceeding paleontologic, lithologic and electric log information. All other boundaries were determined by the micropaleontological work of Dr. R.K. Olsson of Rutgers University and by electric log data (Hansen, 1968; 1974). A listing of the depths of these boundaries can be found in Appendix IV.

Figure 5

Age Assignments of Formations

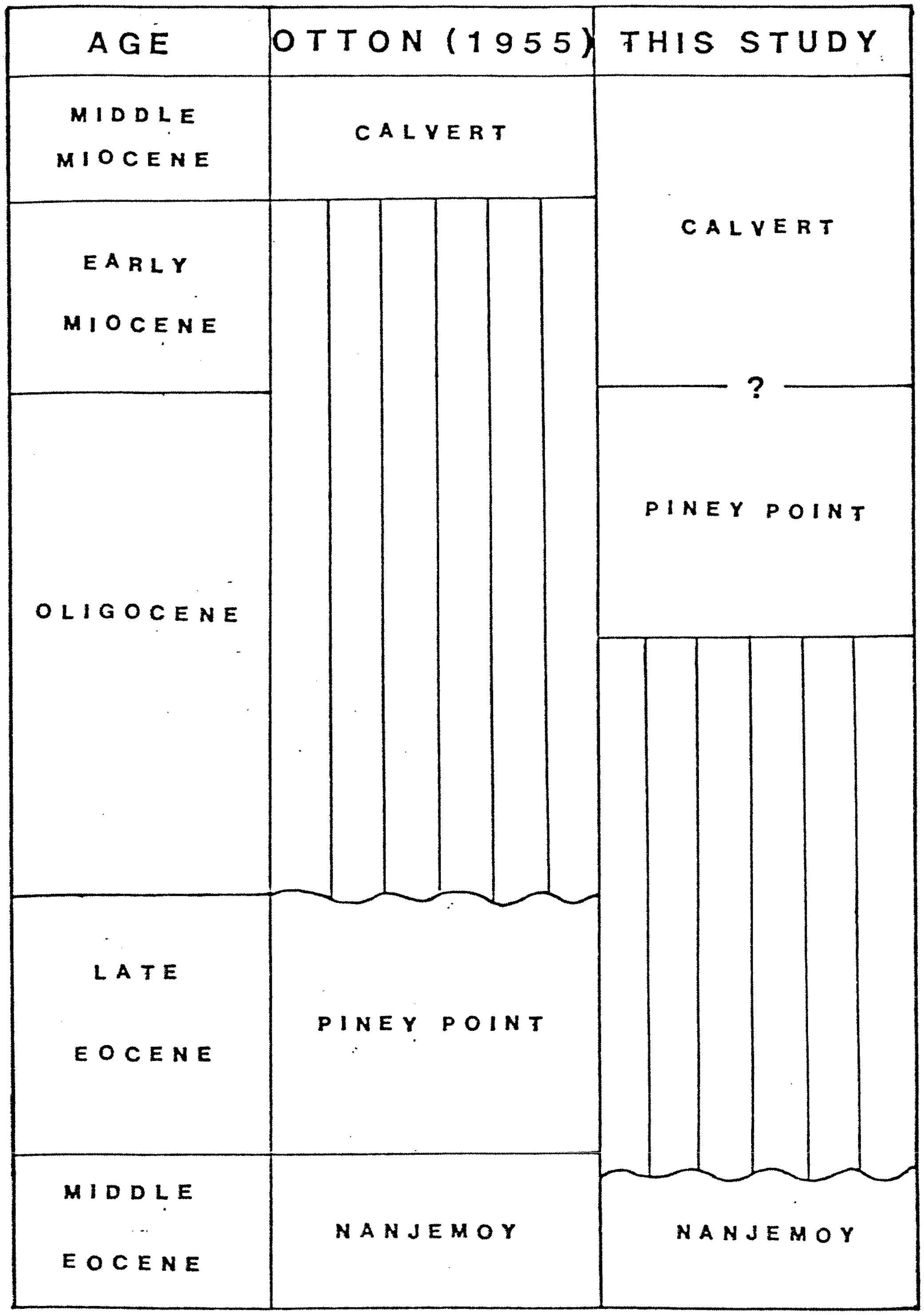
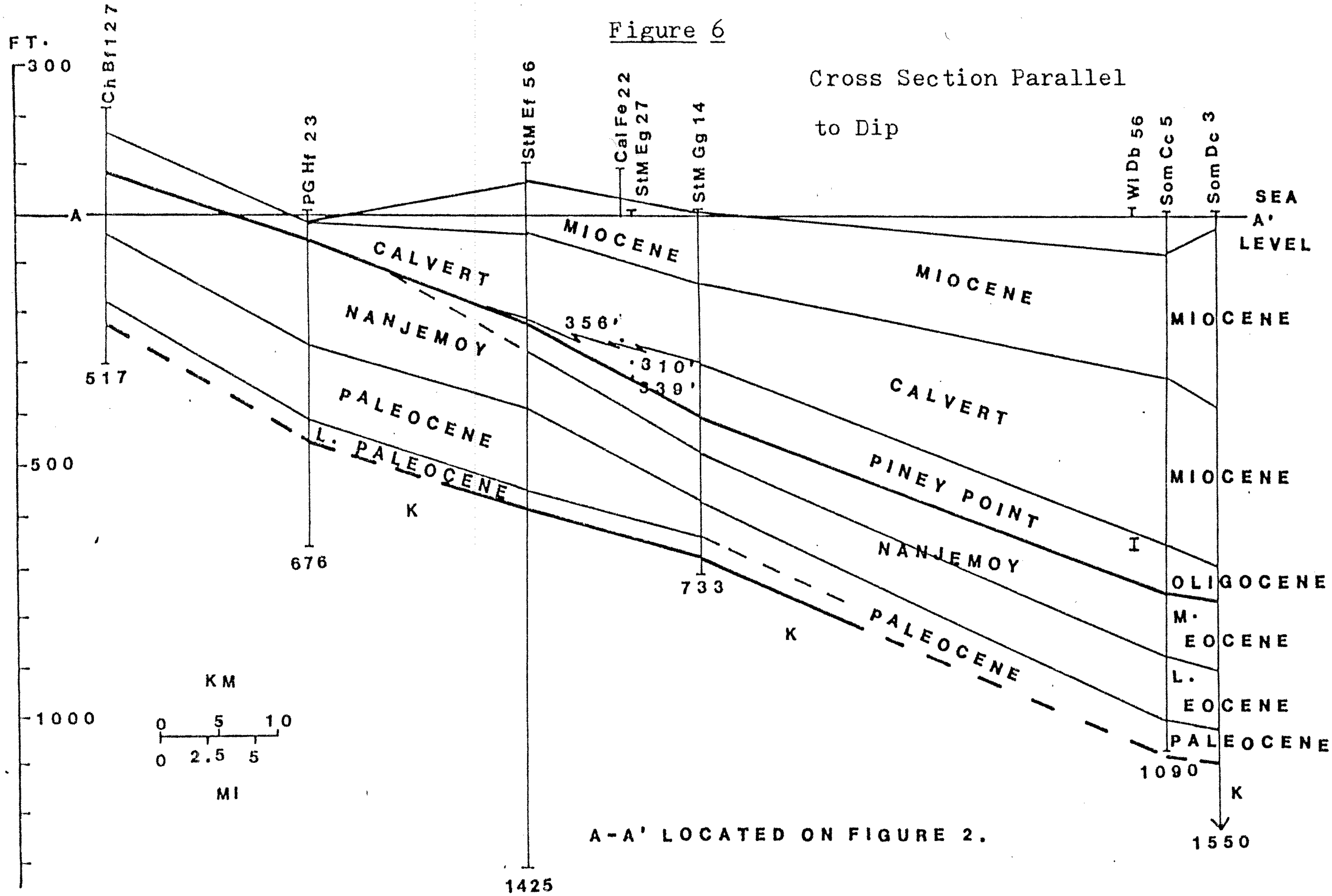


Figure 6

Cross Section Parallel to Dip



A-A' LOCATED ON FIGURE 2.

PALEOECOLOGY

Current approaches to foraminifera paleoecology are largely based on concepts borrowed from modern ecology. Relationships such as species diversity and abundance trends and species depth biofacies have been widely applied as paleoecologic tools, especially in estimating paleo-bathymetry. The use of modern faunal concepts to interpret fossil faunas are based on the assumption that modern distributional patterns are analogous to those of the past. Paleodepth estimates based on extant species assumes that species depth habitats have not changed significantly with time. The general correlation of form, structure and environment observed in modern and fossil faunas support these assumptions (Douglas, 1979).

Thirty-four species of benthic foraminifera were identified from the Piney Point (Appendix I). Many of these are extant species. Phleger and Parker (1951), Phleger (1960), Smith (1964), Murray (1973), and others have studied the ecology of living foraminifera. Studies such as these were used to find depth ranges for the extant benthic foraminifera of the Piney Point. Table 2 lists these species and their bathymetric range. The Piney Point foram-iniferal assemblage suggests a paleodepth of less than 100 meters (Fig. 7).

Planktonic foraminifera are sparse in the Piney Point. Less than 5 percent of the total foraminiferal population

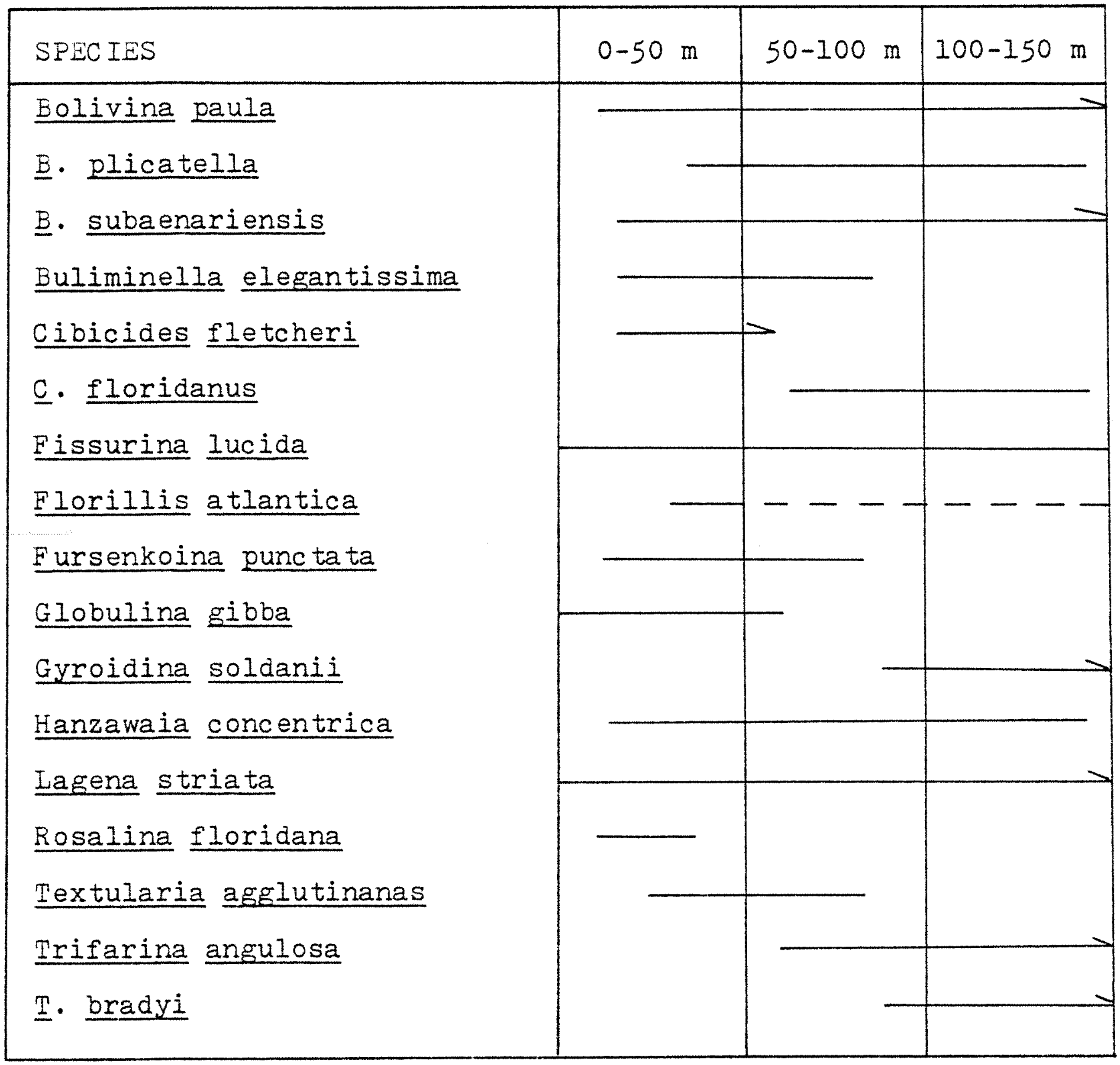
Table 2

Bathymetric Ranges of Extant Species

SPECIES	DEPTH	REFERENCE
Bolivina paula	12-793 m	Wilcoxon, 1964
Bolivina plicatella	37-140 m	Smith, 1964
Bolivina subaenariensis	18-155 m	Wilcoxon, 1964
Buliminella elegantissima	20-82 m	Smith, 1964
Cibicides fletcheri	18-57 m	Walton, 1955
	occurs at 55+ m	Phleger, 1960
Cibicides floridanus	64-144 m	Smith, 1964
Fissurina lucida	0-150 m	(Generic) Murray, 1973
Florilis atlantica	30-530 m (most common 50 m)	Phleger, 1960
Fursenkoina punctata	15-80 m	Murray, 1973
Globulina gibba	0-60 m	(Generic) Murray, 1973
Gyroidina soldanii	90-300 m	Phleger, 1960
Hanzawaia concentrica	37-144 m	Smith, 1964
	15-90 m off the Atlantic coast	Phleger, 1960
Lagena striata	0-180 m	(Generic) Murray, 1973
Rosalina floridana	10-30 m	Phleger, 1956
Textularia agglutinans	25-80 m	Smith, 1964
Trifarina angulosa	60-250 m	Smith, 1964
Trifarina bradyi	90-300 m	Phleger & Parker, 1951

Figure 7

Extant Species Depth Range Chart



are planktonic and the planktonic diversity is low (less than 5 species). Phleger (1960) cites an overall trend for decreasing planktonic diversity and abundance with shallowing of shelf conditions. Diversities of less than 7 planktonic species in depths less than 73 meters and complete absence of planktonics in depths less than 24 meters are noted by Phleger (1960). Whelan (1954) lists diversities of less than 7 planktonic species in depths of less than 58 meters for the modern Delaware Bay shelf. A general paleodepth of less than 75 meters can be inferred from these planktonic diversity studies.

Cluster Analysis

Species composition within the studied interval of the Piney Point is variable (Appendix I). A statistical method is needed to find meaningful patterns from this large data set. Mello and Buzas (1968) and Hazel (1970) have shown the validity of cluster analysis as a method of data reduction in foraminiferal studies. The Jaccard Coefficient of similarity $S_j = \frac{S_c}{(S_1 + S_2 - S_c)}$ (where S_j = Jaccard coefficient, S_c = number of species in common, and S_1, S_2 = number of species in each sample under comparison), a binary coefficient, is the most widely used clustering coefficient (Hazel, 1970). It is based on the presence or absence of species in the samples under comparison. In this study, the Q-mode type of cluster analysis was used. The Q-mode relates sampling intervals to each other on the basis of species in common (Hazel, 1970). A program written by Hazel (1970) and modified by Dr. R. Holzer (unpublished) was used to compute the similarity matrices and dendrograms used in this study.

The data from the studied intervals (Appendix I) was put in a presence/absence format and modified so meaningful results could be obtained. Of the thirty-four benthic species identified, only eighteen were used in the cluster analysis. Because of the nature of rotary sampling, the distribution of rarer species was generally inconsistent. Therefore, these species were not included in the analysis. Cases where intervals of high relative abundance for a particular species was followed down hole by intervals of markedly lower abundances needed to be considered. Such instances indicate specimens misplaced by drilling. Table 3 shows the species used in the cluster analysis along with the corresponding presence/absence data and semiquantitative rankings. Comparison of the rankings in Appendix I with the presence/absence data in Table 3 indicates the basis on which misplaced (therefore absent) species were determined in the intervals for cluster analysis. Some intervals were not used in the analysis because of sparse foraminiferal recovery.

Examination of the computer generated Q-mode dendrogram shows the samples clustered into three distinct groupings (Fig. 8). Sample 3 remotely clusters with group I but may stand by itself.

In group I (samples 1,2,8,9,10,11,12) Buliminella elongata,

Table 3

Presence/Absence and Ranking Data
For Species Used for Cluster Analysis

SPECIES	WELL StM Gg 14	320'-330'	330'-340'	335'-340'	340'-350'	350'-360'	360'-370'	370'-380'
Bolivina directa		5	4	5				
B. paula		4	3	4				
Buliminella elegantissima		5	5	5				
B. elongata		5	5	6				
Cibicides fletcheri				5	3	2		
C. ornatus			2	4	2	1		
Epistominella pontoni		5	5	6				
Florilis atlantica		2	3	4	3	2	2	2
Gavelinella? americanus		2	1	4	2	2		
Gyroidina soldanii				5	4	2	1	
Hanzawaia concentrica		4	3	5	3	3	1	
Melonis affine				5				
Spiroplectammina gracilis				5	3	2	1	
Textularia agglutinans				5	4	2	2	1
Trifarina angulosa								
Uvigerina carapitana		1	1	1				
U. juncea		1	1	2	1	1		
Valvulineria floridana		3	2	3				

RANKING: 1 = 1-11 specimens
2 = 11-25 "
3 = 25-50 "
4 = 50-100 "
5 = 100-500 "
6 = 500+

Table 3 (contd)

SPECIES	WELL Som Cc 5	670'-680'	680'-690'	690'-700'	700'-710'	710'-720'	720'-730'	730'-740'	740'-750'	750'-760'	Wi Db 56	666'-686'
Bolivina directa		4	4	3	3	3	3	3	1			
B. paula		3	3	4	4	4	4	4	1	4		
Buliminella elegantissima		1	1	1	1	1						
B. elongata		4	3	5	4	4	3	3	3	2		
Cibicides fletcheri												2
C. ornatus				1	1	1	2	2	1			1
Epistominella pontoni		3	3	4	3	2	3	3	2	3		
Florilis atlantica		3	3	3	3	3	3	2	2	1		5
Gavelinella? americanus		2	1	2	1	2	1					1
Gyroidina soldanii			1	1	1	1	1	1	1	1		1
Hanzawaia concentrica		3	2	3	3	3	2	2	2	2		1
Melonis affine										1		
Spiroplectammina gracilis		1	1	1	1	1	1	2	1	1		2
Textularia agglutinans		2	1	1	2	1						1
Trifarina angulosa							1	1	1	1		
Uvigerina carapitana												1
U. juncea		1	1	2	2	1	1	1	1			
Valvulineria floridana				3	2	2	2	2	1			

RANKING:
1 = 1-11 specimens
2 = 11-25 "
3 = 25-50 "
4 = 50-100 "
5 = 100-500 "
6 = 500+

INTERVALS:

StM Gg 14 380'-390'
390'-400'
400'-410'
410'-420'
420'-430'
430'-440'

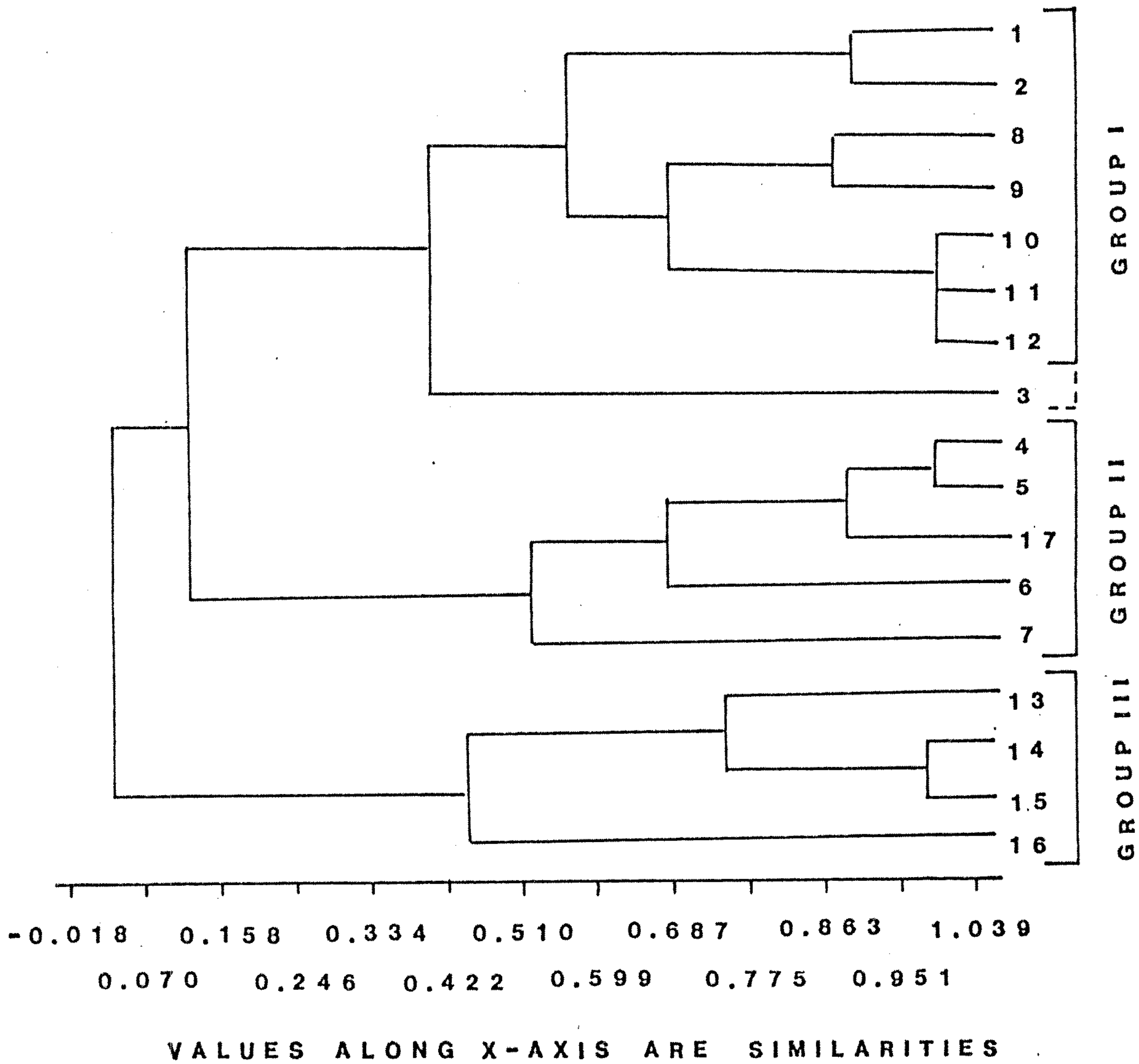
Som Cc 5 760'-770'

StM Eg 27 310'-320'
339'

Were not used for cluster analysis due to sparse foraminiferal recovery.

Figure 8

Q-mode Analysis Dendrogram



SAMPLE #	INTERVAL (ft)
StM Gg 14	
1	320-330
2	330-340
3	335-340
4	340-350
5	350-360
6	360-370
7	370-380
Som Cc 5	
8	670-680
9	680-690
10	690-700
11	700-710
12	710-720
13	720-730
14	730-740
15	740-750
16	750-760
WIDb 56	
17	666-686

(Pl. 2, Fig. 7), B. elegantissima (Pl. 2, Fig. 8), Bolivina directa (Pl. 2, Fig. 6), B. paula (Pl. 2, Fig. 10) and Epistominella pontoni (Pl. 2, Fig. 9) dominate the fauna. Other species characteristic of or unique to this group are Uvigerina carapitana, Rosalina floridana, Valvulineria floridana, Globulina gibba, Nonionella auris, and Spirobolivina sp. The appearance of the Genus Spirobolivina (Pl. 2, Fig. 5) and the abundant occurrence of Buliminella elegantissima are typical of the upper portions of the formation. Table 4 shows the bathymetries of extant species characterizing or unique to group I. From these depth ranges, a paleodepth of <30-55 m is inferred.

Group II (samples 4,5,6,7) and group III(samples, 13, 14,15,16) are located stratigraphically beneath group I but occur in separate wells. Sample 17 is a solitary sample from a third well that clusters within group II (Fig. 8). These two cluster groupings probably represent equivalent assemblages in terms of paleodepth which can be inferred from their stratigraphic position in relation to group I. The combined group II and III is characterized by Cibicides ornatus (Pl. 3, Fig. 2,3), C. fletcheri (Pl. 3, Fig. 5,6), C. floridanus (Pl. 3, Fig. 7,8), C. lobatulus, Gyroidina soldanii (Pl. 3, Fig. 9), Melonis affine, Spiroplectammina gracilis (Pl. 3, Fig. 1), Textularia agglutinans, and Trifarina angulosa (Pl. 3, Fig. 4). The bathymetries of extant species in group II-III suggest a paleodepth range of 55-80 m (Table 4).

Table 4

Paleobathymetry

Fauna 1 Estimated paleobathymetry <30-55 m.

Extant Species

Species	Depth	Reference
Buliminella elegantissima	20-82 m.	Smith, 1964
Fursenkoina punctata	15-80 m	Murray, 1973
Globulina gibba	0-60 m.	(Generic) Murray, 1973
Rosalina floridana	10-30 m.	Phleger, 1956
Other Studies		
Bolivina directa	all occur	Schnitker, 1970
B. paula	in Miocene	
Nonionella auris	sediments	
	deposited in	
	20-35 m.	
Buliminella elongata	30-35 m. (most abundant)	Olsson and Miller, (personal communication)
Epistominella pontoni	45-80 m	" "

Fauna 2 Estimated paleobathymetry 55-80 m.

Extant Species

Species	Depth	Reference
Cibicides fletcheri	18-57 m.	Walton, 1955
	occurs 55^{+} m.	Phleger, 1960
C. floridanus	64-144 m.	Smith, 1964
Gyroidina soldanii	90-300 m.	Phleger, 1960
Textularia agglutinans	25-80 m.	Smith, 1964
Trifarina angulosa	60-250 m	Smith, 1964
Other Studies		
Cibicides ornatus	50-80 m.	Olsson and Miller, (personal communication)
Gyroidina soldanii	35-60 m.	" "
Melonis affine	50-80 m.	" "
Spiroplectammina gracilis	50-80 m.	" "

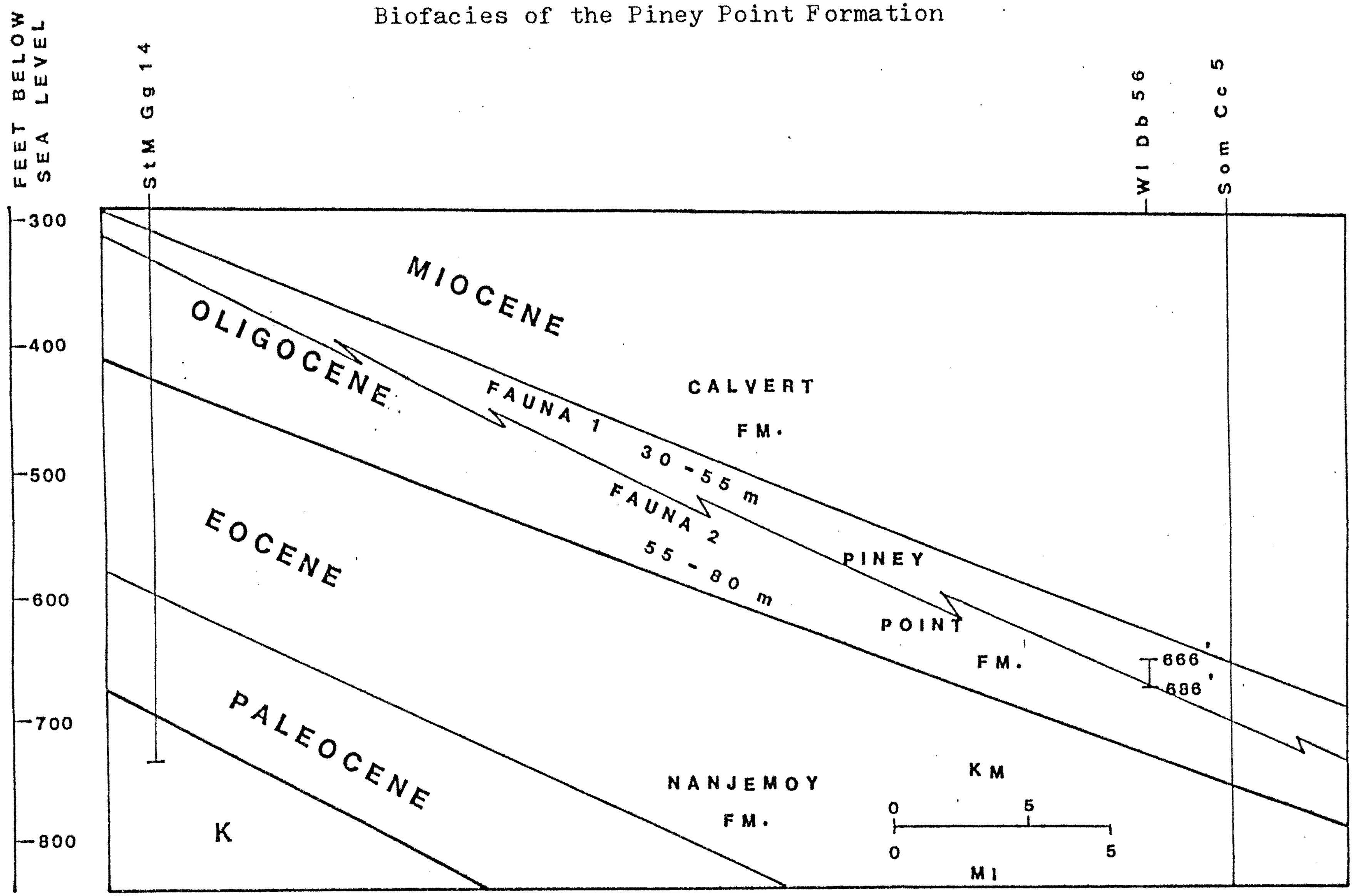
Sample 3 has remote affinities to group I. Presence/absence data used for cluster analysis (Table 3) shows that Sample 3 has elements common to both group I and group II. It is possible Sample 3 represents a transitional fauna between these two assemblages.

Results of the paleobathymetric study compare favorably with the work of Olsson and Miller (1979; personal communication) on the Oligocene sediments in the New Jersey coastal plain. Table 4 lists some of the paleodepths determined by Olsson and Miller for species common to both studies.

The above paleobathymetric information supports the assignment of an inner neritic, inner to middle shelf environment for this portion of the Piney Point. A plot of the biofacies (Fig. 9) suggests deposition during a transgressive phase followed by a regressive event.

Figure 9

Biofacies of the Piney Point Formation

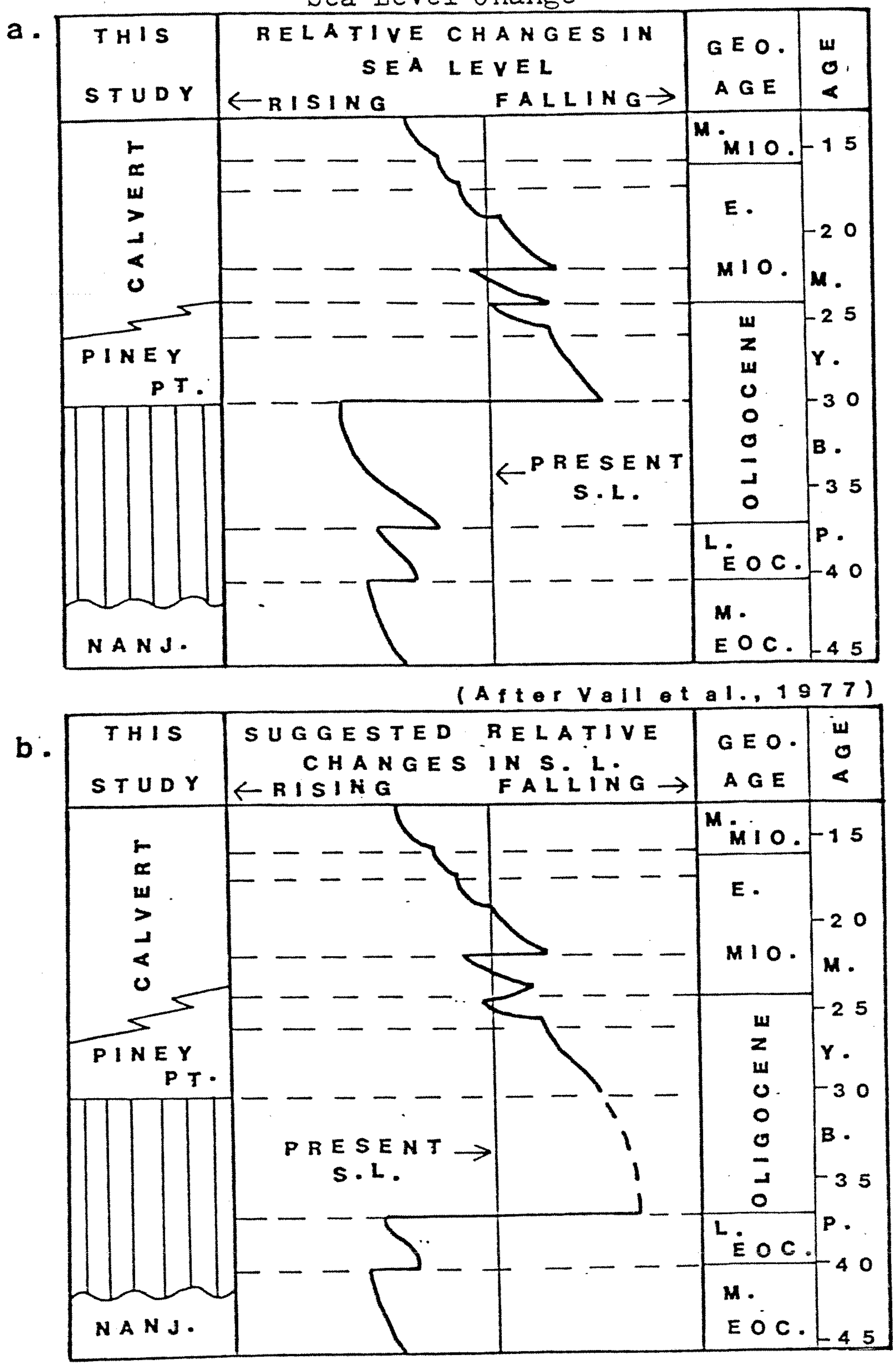


COMPARISON WITH THE VAIL ET AL. CURVE

Recently, Vail et al. (1977) produced a curve showing global cycles of sea level change for the Cenozoic (Fig. 10a). The curve, which has received a great deal of interest in the scientific community, shows a major regressive event occurring during Middle Oligocene time after a major Early Oligocene transgression. A transgression follows in the uppermost Oligocene and in turn a regression at the base of the Miocene is followed by a Lower Miocene transgression. Evidence from this study would suggest that revisions are warranted in the curve of Vail et al. for this part of the geologic column. This study shows that the Piney Point Formation was deposited during a Late Oligocene transgression on an eroded Eocene surface. In the Maryland coastal plain, only Middle Eocene sediments are present below the Piney Point. A similar stratigraphic setting occurs in the New Jersey coastal plain (Olsson and Miller, 1979). According to Olsson and Miller, Upper Eocene sediments occur beneath the Atlantic shelf off New Jersey in the COST B-2 well but Lower Oligocene strata are absent there. It appears more likely that a major regression took place near the end of Eocene time which in turn led to the erosion of the exposed Eocene beds. The Piney Point was deposited on this eroded surface during a subsequent transgression. It may be that the Early Oligocene transgression shown in the curve of Vail et al. should be placed in the Upper Eocene (Fig. 10b).

Figure 10

Suggested Revisions of the Vail et al. Curve of Global Sea Level Change



Despite these discrepancies, this study compares rather favorably with the curve of Vail et al.. The transgression that occurs during the Upper Oligocene corresponds to the Piney Point transgressive event. Vail et al. show that a minor regression occurs during earliest Miocene time. This also agrees with the findings of this study. However, evidence from this study suggests that an additional change in the curve be made. The portion of the curve including and above the Upper Oligocene (Fig. 10b) should be moved to the left to show that the Piney Point and Calvert sediments were deposited during transgressions somewhat more extensive than shown in the curve by Vail et al. (1977).

CONCLUSIONS

The Piney Point Formation can be distinguished from the underlying Nanjemoy and overlying Calvert Formations on the basis of lithology and paleontology. Planktonic foraminifera were studied to determine the age of both the Piney Point and the underlying Nanjemoy. Characteristic Oligocene planktonic foraminifers are present in the Piney Point Formation indicating an Oligocene age. Foraminiferal evidence shows that an Early to Middle Eocene age can be assigned to the Nanjemoy.

Lithologic and paleontologic evidence suggests that the Piney Point is conformably overlain by the Miocene Calvert Formation. The possibility that the basal Calvert is Oligocene in age is indicated by recent foraminiferal studies by Olsson (personal communication). This relationship suggests that the Piney Point and Calvert are conformable and also that a facies relationship exists in updip sections. This updip facies relationship can also be inferred from the lithology. Because of their marked difference in age, a facies relationship between the Piney Point and Nanjemoy can be ruled out.

A paleoecologic analysis of the Piney Point was made based on bathymetric information from extant benthic foraminifera and planktonic species diversity. The resulting interpretation of paleodepth suggests a general bathymetry of less than 100 m for the Piney Point. Cluster analysis of benthic foraminifera defines two distinct biofacies in the Piney Point. One assemblage (group I) occurs in the upper portions of the Piney Point and indicates a paleodepth of less than 30 to 55 m. A stratigraphically lower, second assemblage (group II-III) suggests a paleodepth of 55 to 80 m. This bathymetric interpretation supports the assignment of an inner neritic, inner to middle shelf environment for the Piney Point.

A revision of the Vail et al. (1977) curve of global cycles of sea level change is suggested for the Oligocene. Biostratigraphic and paleoecologic data shows no evidence of a Lower Oligocene transgressive cycle in the Maryland coastal plain. The findings of this study also suggest that the Piney Point and Calvert sediments were deposited during transgressions somewhat more extensive than those shown by Vail et al. (1977) (see Fig. 10b).

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APPENDIX I

DISTRIBUTION OF BENTHIC SPECIES IN THE PINEY POINT

StM Gg 14

SPECIES (WELL)	320'-330'	330'-340'	335'-340'	340'-350'	350'-360'	360'-370'	370'-380'	380'-390'	390'-400'	400'-410'	410'-420'	420'-430'	430'-440'
Bolivina cookei	1		1		1							1	
B. directa	5	4	5		1	1	1	1	1		1	1	
B. subaenariensis							1	1	1			1	
B. paula	4	3	4	1	3	1	1	1	1		1	1	1
B. plicatella	1						1	1					
Buliminella elegantissima	5	5	5	1	2	1	1	1	1	1	1	1	1
B. elongata	5	5	6	1	3	2	3	2	2	1	3	3	2
Cibicides fletcheri			5	3	2		1					1	1
C. floridanus													
C. lobatulus					1		1						
C. ornatus		2	4	2	1		1	1	1	1	1	1	1
Epistominella pontoni	5	5	6		2	1	1	1	1	1		1	
Fissurina lucida								1					
Florilis atlantica	2	3	4	3	2	2	2	1	1	1		2	
Fursenkoina punctata	1												1
Gavelinella? americanus	2	1	4	2	2	1	1		1	1	1	1	1
Globulina gibba	1		1	1	1	1							1
Guttulina austriaca					1	1			1				
Gyroidina soldanii			5	4	2	1	2	1	1		1	1	1
Hanzawaia concentrica	4	3	5	3	3	1	2	1	2	1	1	2	1
Lagena pseudosulcata													
L. striata					1	1	1		1				
Lenticulina a.americana	1	1	1	2	1	1	1					1	
Loxostomium gunteri													
Melonis affine		1	5	1	2	1	1		1		1	1	
Nonionella auris	1	1			1								
Rosalina floridana	1							1					
Spirobolivina sp.	1												
Spiroplectammina gracilis	1	1	5	3	2	1	2	1	1	1	2	2	1
Textularia agglutinans	1	1	5	4	2	2	1	1	1	1	1		1
Trifarina angulosa													
T. bradyi		1		1									1
Uvigerina carapitana	1	1	1										
U. juncea	1	1	2	1	1		1				1		
Valvulineria floridana	3	2	3	1	1	2	1		1	1	1	1	1

RANKING:
- 1 = 1-11 specimens
- 2 = 11-25 "
- 3 = 25-50 "
- 4 = 50-100 "
- 5 = 100-500 "
- 6 = 500+ "

APPENDIX I

DISTRIBUTION OF BENTHIC SPECIES IN THE PINEY POINT

	WELL	Som Cc 5								
SPECIES	670-680	680-690	690-700	700-710	710-720	720-730	730-740	740-750	750-760	760-770
Bolivina cookei	1	1	1	1	1	2	1	1	1	1
B. directa	4	4	3	3	3	3	3	1	2	2
B. subaenariensis	2	3	3	2	3	2	3	1	2	1
B. paula	3	3	4	4	4	4	4	1	4	2
B. plicatella	1	1	1	1	1	1	1	1	2	1
Buliminella elegantissima	1	1	1	1	1			1	1	
B. elongata	4	3	5	4	4	3	3	3	2	2
Cibicides fletcheri										
C. floridanus		1					1	1		1
C. lobatulus						1				
C. ornatus			1	1	1	2	2	1	1	1
Epistominella pontoni	3	3	4	3	2	3	3	2	3	1
Fissurina lucida		1	1		1	1			1	
Florilis atlantica	3	3	3	3	3	3	2	2	1	1
Fursenkoina punctata		1		1						
Gavelinella? americanus	2	1	2	1	2	1	1	1	1	1
Globulina gibba	1			1					1	
Guttulina austriaca						1		1		
Gyroidina soldanii		1		1	1		1		1	1
Hanzawaia concentrica	3	2	3	3	3	2	2	2	2	1
Lagena pseudosulcata										
L. striata		1	1	1	1	1	1			
Lenticulina a. americana	1	1	1	1	1	2	1	1	1	
Loxostomium gunteri										
Melonis affine									1	1
Nonionella auris										
Rosalina floridana		1	1	1	1					
Spirobolivina sp.	1						1			
Spiroplectammina gracilis	1	1	1		1	1	2	1	1	1
Textularia agglutinans	2	1	1	2	1	1			1	
Trifarina angulosa						1	1	1	1	
T. bradyi										
Uvigerina carapitana	1	1	1	1	1	1				
U. juncea	1	1	2	2	1	1	1	1		
Valvulineria floridana	1	1	3	2	2	2	2	1	1	1

RANKING: 1 = 1-11 specimens
2 = 11-25 "
3 = 25-50 "
4 = 50-100 "
5 = 100-500 "
6 = 500+ "

APPENDIX I

DISTRIBUTION OF BENTHIC SPECIES IN THE PINEY POINT

SPECIES	StM Eg 27 310'-320'	StM Eg 27 339'	Wi Db 56 666'-686'
Bolivina cookei			
B. directa	2		1
B. subaenariensis	2		1
B. paula			1
B. plicatella			
Buliminella elegantissima	1		1
B. elongata	2	1	2
Cibicides fletcheri			2
C. floridanus			
C. lobatulus			
C. ornatus			1
Epistominella pontoni		1	
Fissurina lucida	1		
Florilis atlantica			5
Fursenkoina punctata			
Gavelinella? americanus			
Globulina gibba			1
Guttulina austriaca			
Gyroidina soldanii			1
Hanzawaia concentrica	2	1	1
Lagena pseudosulcata	1		
L. striata			
Lenticulina a. americana			1
Loxostomium gunteri	1		
Melonis affine			2
Nonionella auris			1
Rosalina floridana			
Spirobolivina sp.			
Spiroplectammina gracilis	1		2
Textularia agglutinans	1		1
Trifarina angulosa			1
T. bradyi			
Uvigerina carapitana			1
U. juncea			4
Valvulineria floridana			

RANKING:
1 = 1-11 specimens
2 = 11-25 "
3 = 25-50 "
4 = 50-100 "
5 = 100-500 "
6 = 500+ "

APPENDIX II

LITHOLOGIC DESCRIPTIONS

Well: StM Ef 56	Depth (feet)
BASAL CALVERT	
White, slightly clayey, fine to medium quartz sand	302 - 312
White, sl. clayey, fine to v. fine quartz sand; shell fragments	312 - 322
PINEY POINT	
Buff, sl. glauconitic medium to coarse quartz sand; minor amounts of clay; abundant shell fragments; extensive reworking of Eocene foraminifera	322 - 332
NANJEMOY	
Lt. olive gray, sl. clayey, glauconitic coarse to medium quartz sand; 20 percent green and brown (weathered) glauconite; less than 10 percent clay and shell fragments	332 - 342
Lt. olive gray, glauconitic, medium quartz sand; 20 percent green and brown glauconite, minor amounts of silt and clay	342 - 352

Well: StM Gg 14	
BASAL CALVERT	
Yellow gray, diatomaceous clay	300 - 310
V. lt. gray, clay; minor amounts of coarse to medium quartz sand; shell fragments	310 - 320

Well: StM Gg 14 (contd.)	Depth (feet)
PINEY POINT	
V. lt gray, glauconitic, sandy, clay; 50 percent clay; coarse to medium quartz sand; 10 percent, fine, glauconite; shell fragments	320 - 330
White to lt. gray, clayey, sl. glauconitic, coarse sand; 20 percent clay; abundant shell fragments.	330 - 340
Med. gray to pale yellow brown, sl. clayey, sl. glauconitic, coarse to medium quartz sand; 10 percent clay; shell fragments.	340 - 350
Lt. gray, tan, and buff, glauconitic, coarse quartz sand, limonite staining; 10-15 percent brown and green, coarse to fine glauconite; minor amounts of clay; shell fragments.	350 - 400
Tan and yellow gray, sl. clayey, glauconitic, medium quartz sand; sand is stained with limonite; 10-20 percent green and brown, medium and fine glauconite; 10 percent clay; shell fragments.	400 - 420
Tan and lt. olive gray, clayey, glauconitic, coarse to medium quartz sand, stained; 20 percent green and brown, medium and fine glauconite; 25 percent clay; minor amounts of shell fragments.	420 - 440
NANJEMOY	
Olive gray and tan, clayey, sl. sandy, coarse to medium glauconite sand; glauconite is green and brown; 50 percent glauconite; coarse to medium quartz sand; shell fragments.	440 - 460

Well: Wi Db 56	
PINEY POINT	
Lt. olive gray, clayey, glauconitic, medium quartz sand; 40 percent clay; 10 percent medium to fine glauconite, some weathering; abundant shell fragments.	666 - 686

Well: Som Cc 5	Depth (feet)
BASAL CALVERT	
Yellow gray, sandy clay; coarse to fine quartz sand; minor amounts of glauconite, shell fragments.	650 - 660
Yellow gray, sl. sandy clay; coarse quartz sand; minor amounts of glauconite, shell fragments.	660 - 670
PINEY POINT	
Lt. olive gray, clayey, glauconitic, coarse to medium quartz sand; 20 percent medium to fine glauconite; rare shell fragements.	670 - 690
Lt. olive gray, clayey, glauconitic, coarse to medium quartz sand; 20 percent green and brown, medium to coarse glauconite; shell fragments.	690 - 700
Lt. olive gray, clayey, sandy, glauconite sand; 50 percent medium to coarse glauconite; 20 percent medium to fine quartz sand; rare shell fragments.	700 - 710
Lt. olive gray, clayey, sandy, coarse to medium glauconite; 20 percent coarse to medium quartz sand; shell fragments.	710 - 720
Lt. olive gray, clayey, glauconitic, coarse quartz sand; 20-30 percent green and brown, coarse to medium glauconite; minor amounts of shell fragments.	720 - 760
Lt. olive gray, glauconitic coarse quartz sand; 20 percent green and brown, coarse to medium glauconite; abundant shell fragments.	760 - 770
NANJEMOY	
Lt. olive gray, sandy, glauconitic, clay; 20 percent coarse quartz sand; 20 percent green and brown, coarse to medium glauconite; shell fragements.	770 - 790

Well: Som Dc 3	Depth (feet)
BASAL CALVERT	
Yellow gray, diatomaceous clay; rare amounts of coarse to medium quartz sand, glauconite, and shell fragments.	700 - 720
PINEY POINT	
Lt. olive gray, clayey, glauconitic, coarse to medium quartz sand; 20-25 percent clay; 10 percent green and brown, coarse to fine glauconite; rare shell fragments.	720 - 730
Lt. olive gray to olive gray, clayey, glauconitic, coarse quartz sand; 10 percent clay; 25-40 percent green and brown, medium to fine glauconite; rare shell fragments.	730 - 760
Olive gray, v. glauconitic, coarse to medium quartz sand; 40 percent medium to fine glauconite, some weathered; rare shell fragments.	760 - 770
Olive gray, v. glauconitic, coarse quartz sand; 35-50 percent coarse to medium glauconite, some weathered; rare shell fragments.	770 - 780
Olive gray, v. sandy, coarse to medium glauconite sand; 40-50 percent coarse quartz sand; rare shell fragments.	780 - 790
NANJEMOY	
Olive gray, clayey, sandy, medium glauconite sand, some weathered; 50-60 percent glauconite; 10-20 percent coarse to medium quartz sand; rare shell fragments.	790 - 810

Core: Cal Fe 22

BASAL CALVERT	
Lt. gray to yellowish gray, clayey, v. sl. glauconitic, medium quartz sand; less than one percent silt sized glauconite; 50 percent shell fragments.	356 - 357

Core: StM Eg 27	Depth (feet)
PINEY POINT	
Yellow gray to lt. olive gray, glauconitic coarse quartz sand; 10 percent green and brown, coarse to medium glauconite; shell fragments.	310 - 320
Yellow gray to lt. olive gray, clayey, glauconitic, coarse to medium quartz sand; 10-20 percent clay; 20 percent green and brown, medium to coarse glauconite; clumps of quartz sand and glauconite in a calcified matrix; shell fragments.	339

APPENDIX III

DISTRIBUTION OF PLANKTONIC SPECIES

SPECIES	WELL StM Gg 14	WELL Som Cc 5
Acarinina soldadoensis+	488'-498'	
*Chiloguembelina cubensis**		670'-680' 760'-770'
*Globigerina anguliofficianalis**	335'-340'	
*G. angustiumbilicata**	320'-330' 360'-370' 410'-420'	
*G. ciperoensis**	320'-330' 360'-370' 390'-400'	
*G. officianalis**	335'-340'	670'-680'
*G. praebulloides**	380'-390' 390'-400'	
Globorotalia cerroazulensis+ *cerroazulensis*		
G. cerroazulensis frontosa+		790'-800'
G. cf *opima nana**	380'-390'	
G. opima opima		
*G. postcretacea**	430'-440'	690'-700' 770'-780'
Morozovella formosa gracilis+		840'-850'
M. lehneri+		
Pseudohastigerina micra+	450'-460'	
P. sharkriverensis+		790'-800'
Truncorotaloides rohri+	440'-450'	
T. topilensis+	370'-380'*	

+ Found in the Nanjemoy Formation
* Found in the Piney Point Formation

Appendix III (Contd)

SPECIES	WELL Som Dc 3
Acarinina soldadoensis+	
*Chiloguembelina cubensis**	
*Globigerina anguliofficianalis**	
*G. angustiumbilicata**	720'-730'
*G. ciperoensis**	760'-770'
*G. officianalis**	790'-800'
*G. praebulloides**	720'-730' 730'-740' 750'-760' 760'-770' 780'-790'
Globorotalia cerroazulensis+ *cerroazulensis*	810'-820'
G. cerroazulensis frontosa+	830'-840'
G. cf *opima nana**	
*G. opima opima**	730'-740'
*G. postcretacea**	
Morozovella formosa gracilis+	
M. lehneri+	830'-840'
Pseudohastigerina micra+	
P. sharkriverensis+	
Truncorotaloides rohri+	820'-825' 830'-840' 840'-850'
T. topilensis+	820'-825'

+ Found in the Nanjemoy Formation
* Found in the Piney Point Formation

APPENDIX IV

SUBSURFACE DATA

Depth to top of series in well

WELL	O	ME	LE	P	LP	K	Elev.
Ch Bf 127	-	-	130	260	390	430?	215
PG Hf 23	-	-	60	270	420	460?	5
StM Ef 56	322	332	390	500	670	700	110
StM Gg 14	320	420	490	600	670	700	10
Som Cc 5	670	770	910	1020	-	-	5
Som Dc 3	720	790	940	1050	-	1130?	5

Depth to top of series, Datum S.L.

WELL	O	ME	LE	P	LP	K	Elev.
Ch Bf 127	-	-	+85	45	175	215?	215
PG Hf 23	-	-	55	265	415	455?	5
StM Ef 56	212	222	280	390	560	590	110
StM Gg 14	310	410	480	590	660	690	10
Som Cc 5	665	765	905	1015	-	-	5
Som Dc 3	715	785	935	1045	-	1125?	5

O = Top of Piney Point (Oligocene)
ME = " Middle Eocene
LE = " Lower Eocene
P = " Paleocene
LP = " Lower Paleocene
K = " Cretaceous

All depths are in feet.

Explanation of Plate 1

Fig. 1 -- *Globigerina ciperoensis* Bolli, StM Gg 14 360'-370', umbilical view, X 425.

2 -- *Globigerina praebulloides* Banner & Blow Som Dc 3 730'-740', umbilical view, X 340.

3 -- *Globigerina officianalis* Subbotina, Som Cc 5 670'-680', umbilical view, X 340.

4 -- *Morozovella lehneri* Cushman & Jarvis, Som Dc 3 830'-840', umbilical view, X 204.

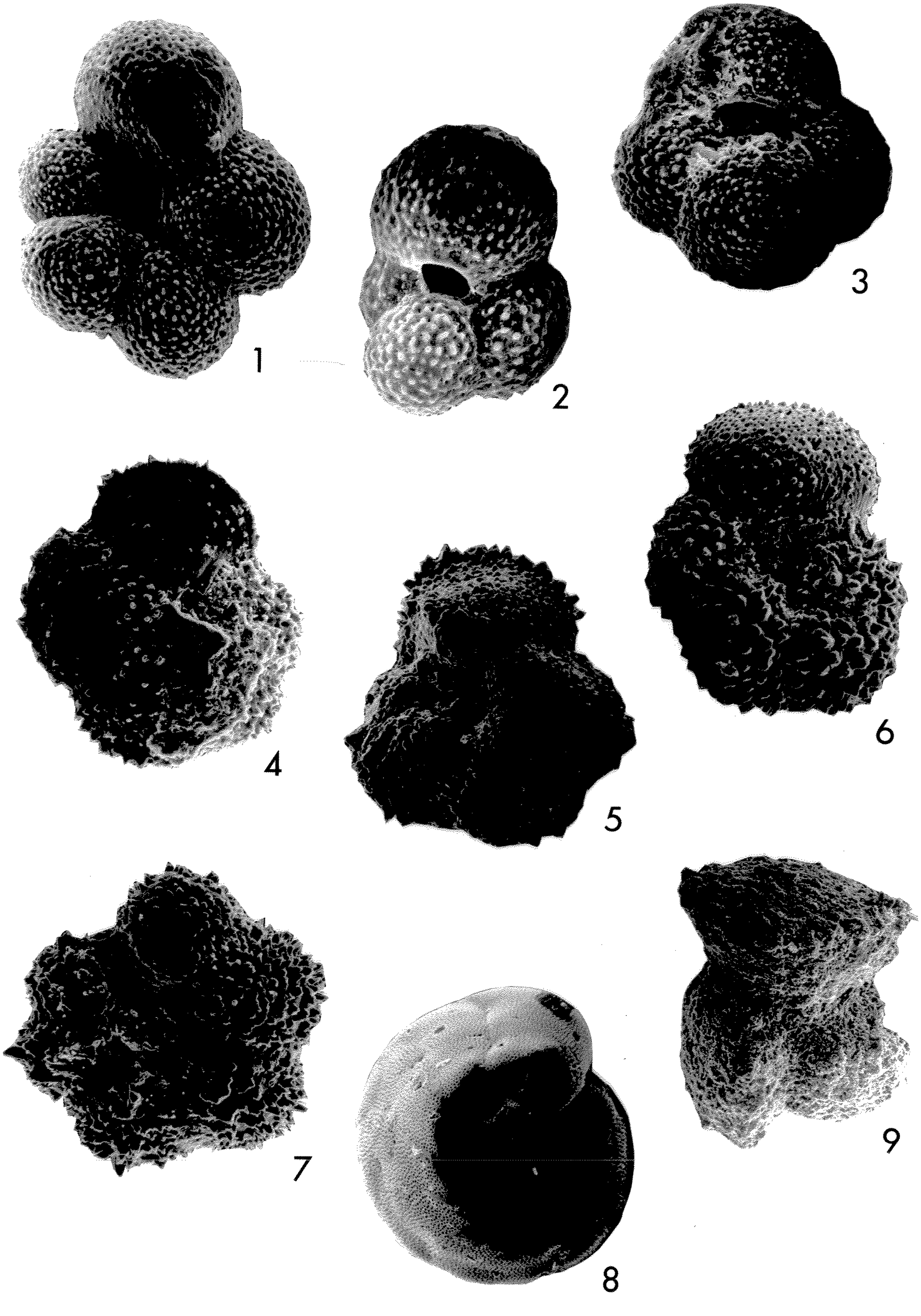
5 -- *Morozovella formosa gracilis* Bolli, Som Cc 5 840'-850', umbilical view, X 170.

6 -- *Truncorotaloides rohri* Bronnimann & Bermudez, Som Dc 3 820'-825', umbilical view, X 195.

7 -- *Pararotalia* sp. Y. Le Calvez, Som Dc 3 830'-840', umbilical view, X 340.

8 -- *Cibicides westi* Howe, Som Cc 5 810'-820', umbilical view, X 153.

9 -- *Truncorotaloides topilensis* (Cushman), StM Gg 14 370'-380', recrystallized, side view, X 110.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Explanation of Plate 2

Fig. 1 -- _Uvigerina juncea_ Cushman & Todd, StM Gg 14 335'-340', side view, X 85.

2 -- _Hanzawaia concentrica_ (Cushman), StM Gg 14 320'-330', dorsal view, X 144.

3 -- _Bolivina plicatella_ Cushman, StM Gg 14 420'-430', side view, X 170.

4 -- _Florilis atlantica_ (Cushman), StM Gg 14 335'-340', side view, X 170.

5 -- _Spirobolivina_ sp. Hofker, StM Gg 14 320'-330', side view, X 425.

6 -- _Bolivina directa_ (Cushman), Som Cc 5 720'-730', side view, X 178.

7 -- _Buliminella elongata_ (d'Orbigny), StM Gg 14 320'-330', side view, X 119.

8 -- _Buliminella elegantissima_ (d'Orbigny), StM Gg 14 320'-330', side view, X 178.

9 -- _Epistominella pontoni_ (Cushman), StM Gg 14 320'-330', ventral view, X 340.

10 -- _Bolivina paula_ (Cushman), StM Gg 14 320'-330', side view, X 161.


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Explanation of Plate 3

Fig. 1 -- *Spiroplectammina gracilis* (von Muenster), StM Gg 14 335'-340', side view, X 93.

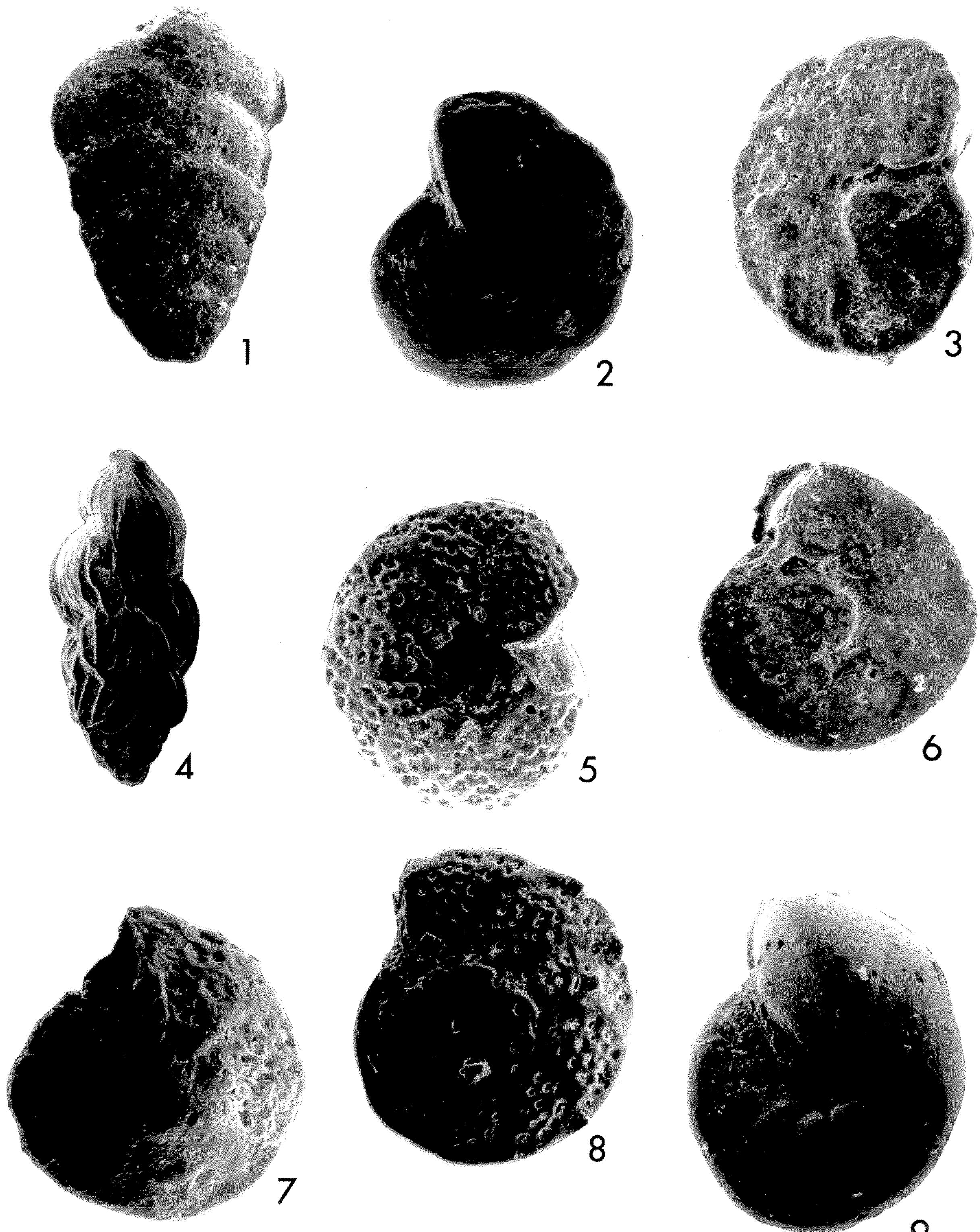
2,3 -- *Cibicides ornatus* (Cushman), 2, StM Gg 14 335'-340', ventral view, X 272, 3, StM Gg 14 340'-350', dorsal view, X 212.

4 -- *Trifarina angulosa* (Williamson), Som Cc 5 740'-750', side view, X 144.

5,6 -- *Cibicides fletcheri* Galloway & Wissler, 5, StM Gg 14 335'-340', ventral view, X 144 , 6, StM Gg 14 335'-340', dorsal view, X 127.

7,8 -- *Cibicides floridanus* (Cushman), 7, StM Gg 14 380'-390', ventral view, X 246 , 8, StM Gg 14 380'-390', dorsal view, X 204.

9 -- *Gyroidina soldanii* (d'Orbigny), StM Gg 14 335'-340', umbilical view, X 161.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VITA

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1973-1977	Attended the University of Maryland, College Park, Maryland; Majored in Geology.
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