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Miocene Stratigraphy of the Solomons Island, Maryland, Corehole

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MIOCENE STRATIGRAPHY OF THE SOLOMONS ISLAND, MARYLAND, COREHOLE

By THOMAS G. GIBSON and GEORGE W. ANDREWS

INTRODUCTION

The Solomons Island Corehole is located in the west-central part of the Salisbury embayment (fig. 1). The corehole penetrated the Calvert Formation approximately 12 miles south of the southern end of the type outcrop section of the formation. The Solomons Island corehole contains almost all the strata of the Calvert Formation in superposition. This is in contrast to the formation in its type area where it is comprised of numerous separated partial outcrop sections. The uppermost part of the Calvert Formation was erosionally removed at the Solomons Island site.

Core recovery of the Calvert strata in the Solomons Island corehole was good enough to allow the correlation of the lithologies, depositional discontinuities, and diatom succession with the outcropping type section of the formation. Most of the diatom zones that Andrews (1978; 1988) established in the Calvert type sections can be recognized in the Solomons Island cores. The diatom zonation is combined with depositional discontinuities and lithologic changes to correlate the corehole sequences with the four stratigraphic sequences that Kidwell (1984; 1988) recognized in the middle and upper parts of the Calvert.

Foraminifers also occur in the diatomaceous beds that form most of the lower part of the formation as well as most other intervals of the Calvert Formation in the Solomons Island corehole. Calcareous fossils, particularly foraminifers, usually are not found in outcrop sections of these diatomaceous beds, and commonly they also are absent from these beds in the subsurface. The good foraminiferal assemblages in the Calvert Formation at Solomons Island provide important information for the paleoenvironmental interpretation of Calvert depositional environments.

LOCATION AND METHODS

Dennis Duty, Donald Queen, and Cindy Crampsey drilled the Solomons Island corehole between November 7, 1986 and November 22, 1986 with Thomas Gibson as the on-site geologist. The corehole (USGS Number is CA-Gd 60) is located on the eastern side of the Calvert Marine Museum grounds at Solomons Island, Maryland, latitude 38°19'49" N, longitude 76°27'52"W. Altitude of land surface at the drill site is approximately 15 ft. The coring procedure utilized a ten-foot core barrel that was run inside the drill pipe with a wire-line retrieval system. Intervals of no recovery was run inside the drill pipe with a wire-line retrieval system. Intervals of no recovery were by convention placed at the bottom of each core run. The core has a diameter of one and 11/16 inches. Roger Starsoneck and Stephen Curtin of the Water Resources Division of the USGS ran gamma ray and resistivity logs of the hole (fig. 2).

Samples examined for diatoms were prepared by the standard procedures of the U.S. Geological Survey as outlined by Lohman (1972). Initial treatment of the rock sample with hydrochloric acid removed particulate calcareous material and finely divided iron minerals. The disintegrated sediment was washed to remove excess acid and dissolved salts. The sediment was then placed in a mildly alkaline solution to disperse the clay; both coarse and fine particles were removed by appropriate decantation techniques. As a final chemical treatment, carbonaceous organic matter was removed by heating in a solution of hydrogen peroxide. Foraminifera were prepared from approximately two to three inch long core sections. The outside rind of the core, which could contain contaminated drilling mud, was removed from core segments before processing. The sediment was washed over a 63 micrometer screen. Foraminiferal assemblages were concentrated by soap flotation from the greater than 63 micrometer sand fraction. The foraminiferal-rich concentrations then were split by a small microsplitter into an aliquot of approximately 300 or greater specimens that were picked and mounted on 60 division faunal slides.

LITHOLOGIC UNITS

Calvert Formation

The Calvert Formation is the only Neogene unit penetrated in the corehole (fig. 3). Shattuck (1902) named the Calvert Formation from the well-developed series of exposures in the Calvert Cliffs along the western shore of Chesapeake Bay in Calvert County, Maryland (fig. 1). The type exposures are a generally north-south sequence that extends over 19 miles along the Calvert Cliffs. These exposures are located from 12 to 31 miles to the north-northwest of the Solomons Island corehole.

Shattuck (1904) recognized two relatively distinctive lithologies in the Calvert Formation; he divided the Calvert into a lower Fairhaven Diatomaceous Earth Member and an upper Plum Point Marl Member on the basis of these two lithologies. The Fairhaven Member contains basal pebbly sands overlain by olive-gray to olive-green highly diatomaceous clay to fine sand. The Fairhaven varies from sandy and muddy diatomite to relatively pure diatomite where diatoms compose as much as 65 percent of the sediment (Glaser, 1971). The Plum Point Marl Member consists of olive-green to olive-brown silty and clayey fine sand beds that commonly contain molluscan shells in variable abundances.

Shattuck (1904) recognized 15 zones within the Calvert Formation. The Fairhaven Member contained Zones 1-3 and the Plum Point Member contained Zones 4-15. These zones are not paleontologic zones, but were based largely upon lithologic criteria that included the relative abundance of molluscan shells. More recent workers on the Miocene strata of this area consider the "zones" to be relatively local lithologic units, and they use other terms such as members (Gernant, 1970), beds (Gibson, 1971; 1983a) or Miocene Lithologic Units (MLU) (Andrews, 1978) for these "zones." The alternative terminologies of beds or MLU for the "zones" usually retain the numerical designation from 1 to 15 for the Calvert units. Although the lithologic characteristics of the beds may be of local development, the differences among the beds may reflect basin wide events, particularly disconformities, that would allow a correlation of the various time intervals represented by the beds across a wider region. Andrews (1978; 1988) indexed his diatom zonation to the Shattuck numerical bed sequence in its type area.

Ward (1984) and Andrews (1988) subsequently placed beds 14 and 15 into the Calvert Beach Member of Gernant (1970). The removal of these two beds from the Plum Point Marl Member, leaving it consisting of beds 4-13, is provisionally followed here.

Gibson (1983a) (this paper was in press for about five years) proposed the name Popes Creek Sand Member for the pebbly sand unit found at the base of the Calvert Formation at Popes Creek, Maryland, and other Maryland localities. Gibson designated this unit under the concept that the sand found at the base of the various Calvert sections formed a single, essentially coeval unit. The overlying diatomaceous clay was retained as the Fairhaven Member, again under the concept that all the diatomaceous beds were coeval. Andrews (1978), however, showed that Calvert diatomaceous beds along the Patuxent River near Dunkirk were of an older age than the previously considered coeval diatomaceous beds of the Calvert at Fairhaven along Chesapeake Bay. Andrews (1978; 1988) and Wetmore and Andrews (1990) suggested that diatoms and silicoflagellates from the Dunkirk diatomaceous beds indicated an age about one to two million years older than that of the diatomaceous beds present at Popes Creek and at Fairhaven. Andrews (1988) designated the older diatomaceous strata at Dunkirk as bed 3A and the younger diatomaceous strata as bed 3B (fig. 4).

As a result of Andrews (1978) dating of the two diatomites, Gibson (1982) proposed that the older diatomaceous beds present along the Patuxent River near Dunkirk, Maryland, together with the basal sand bed found there below them, composed an additional sand and diatomite sequence that was below the Popes Creek Sand and Fairhaven Members. Gibson (1982) informally called this lower diatomaceous clay and sand sequence the Dunkirk beds. The Dunkirk beds include beds 1 and 2 of Shattuck (1904), who described these lowest 2 Miocene "zones" from the Patuxent River outcrops, and Andrews diatomaceous bed 3A.

Siliceous microfossils have not been recovered from the Popes Creek Sand Member at Popes Creek or the basal sand bed at Dunkirk. Therefore, whether the Popes Creek Sand Member is coeval with the Dunkirk lower sand bed or whether it is stratigraphically between the older and younger diatomaceous beds is uncertain at this time. Wetmore and Andrews (1990) did not find an intermediate sand between beds 3A and 3B in either a split spoon cored hole or an auger hole in central Maryland.

Poag (1989) suggested a planktonic foraminiferal Zone N8 age assignment for the basal Calvert sand in the Haynesville corehole. This age assignment for the sand in the Haynesville corehole is considerably younger than the planktonic foraminiferal Zone N5/6 or older age indicated for the basal sand of the Dunkirk beds (Andrews, 1988). However, the age of the sand in the Haynesville corehole is similar to that of Andrews bed 3B (fig. 4). Poag's paleoenvironmental information suggests a deeper water origin for this basal sand than the overlying beds. This deeper water origin is similar to the paleoenvironmental pattern found in the basal sands below bed 3B in the Solomons Island (fig. 3) and BG&E coreholes (Gibson, 1983a). Therefore, the basal sand beds in these three coreholes could be coeval and younger than the sand found at the base of the Dunkirk beds, but this is uncertain at this time.

If the basal sands prove to be coeval at all the various Maryland localities, then the Popes Creek Sand Member would be a practical concept. If the Popes Creek Sand Member is found to be the basal sand of the upper diatomaceous sequence, but it is bracketed by diatomaceous beds and there is another, older, but lithologically similar sand at the base of the Dunkirk beds, then it is probably desirable to abandon the use of this unit.

BIOSTRATIGRAPHIC ZONATION

The most detailed biostratigraphic subdivision of the Calvert Formation yet proposed is based upon the diatoms (Andrews, 1978; 1988). Diatoms are especially numerous in the lower part of the Calvert, the Fairhaven Diatomaceous Earth Member, but they also occur in lesser abundance in many intervals in the overlying Plum Point Marl and Calvert Beach Members. Other groups of microfossils that have been studied in the Calvert Formation, such as the foraminifers (Dorsey, 1948; Gibson, 1983b) and ostracodes (Malkin, 1953), do not produce such a fine biostratigraphic subdivision.

Some planktonic foraminiferal age assignments for Calvert beds are available. Gibson (1967; 1983b) suggested placement of bed 10 to bed 12 strata of outcrop into planktonic foraminiferal Zones N8/N9 of latest early and early middle Miocene age. Poag (1989) placed the lower sand of the Calvert into planktonic foraminiferal Zone N8 and the middle and upper parts of the Calvert in the Haynesville corehole into Zones N10-14. Andrews (1988), on the basis of the diatoms and other criteria, correlates beds 4-13 with planktonic foraminiferal Zones N8 and N9, and beds 14-16 with Zones N10 and N11 (fig. 4).

Diatom zonation

We examined 30 Calvert Formation samples from the Solomons Island corehole for diatoms. The diatom assemblages obtained from most of these samples were adequate to place them into Andrews (1978; 1988) East Coast Diatom Zones (ECDZ). The samples from the lowermost sandy beds of the formation are the only exception as no diatoms were found in them. A more detailed discussion of the Miocene diatom zonation is given in Andrews (1978; 1988).

The four-digit numbers used with the samples are USGS diatom locality numbers.

Sample depth 209'9" - no diatoms found
Sample depth 207'6" - no diatoms found
Sample depth 206'4" - no diatoms found
Sample depth 205'8" - no diatoms found

Sample #7632 - depth 203'8"
The following marker diatoms were observed:

Cocconeis costata
Delphineis ovata
Rhaphoneis scalaris
Sceptroneis caduceus

This sample showed only fair diatom preservation. The diatoms suggest correlation with East Coast Diatom Zone 2 and Lithologic Units 3B to 8 of the Calvert Formation. This was the lowermost diatom-bearing sample taken from this core.

Sample #7631 - depth 199'8"
Sample #7630 - depth 195'8"
Sample #7629 - depth 189'2"
The above three samples showed good diatom preservation. However, they are bracketed by samples of similar age and hence were not studied in detail.

Sample #7628 - depth 184'3"
The following marker diatoms were observed:

Cocconeis costata
Delphineis ovata
Rhaphoneis margaritata
Rhaphoneis scalaris

The sample showed good diatom preservation. These diatoms again suggest correlation with East Coast Diatom Zone 2 and Lithologic Units 3B to 8 of the Calvert Formation.

Sample #7627 - depth 177'9"
The following marker diatoms were observed:

Coscinodiscus lewisianus
Delphineis ovata
Rhaphoneis margaritata
Rhaphoneis scalaris

The sample showed good diatom preservation. These diatoms suggest correlation with East Coast Diatom Zone 2 and Lithologic Units 3B to 8 of the Calvert Formation.

Sample #7626 - depth 172'5"
Sample #7625 - depth 166'11"
Sample #7624 - depth 160'11"
The three above samples showed fair or good preservation of the diatoms. However, they are bracketed by samples of similar age and hence were not studied in detail.

Sample #7623 - depth 156'5"
The following marker diatoms were observed:

Coscinodiscus lewisianus
Delphineis ovata
Rhaphoneis margaritata
Rhaphoneis scalaris
Sceptroneis caduceus

The sample showed good diatom preservation, and the diatoms suggest correlation with East Coast Diatom Zone 2 and Lithologic Units 3B to 8 of the Calvert Formation.

Sample depth 128'5" - no diatoms found

Sample #7622 - depth 125'2"
Sample #7621 - depth 119'6"
Although the above two samples were processed and examined, too few diatoms were observed to permit any correlation.

Sample #7620 - depth 113'11"

The following marker diatoms were observed:

Delphineis penelliptica
Rhaphoneis fusiformis
Sceptroneis grandis

The above sample showed fair to poor diatom preservation. The diatoms suggest correlation with East Coast Diatom Zone 3 or the lower part of Lithologic Unit 11 of the Calvert Formation.

Sample #7619 - depth 108'10"

The following marker diatoms were observed:

Delphineis penelliptica
Rhaphoneis magnapunctata

The above sample showed fair to poor diatom preservation with a very few marker species. The sample probably correlates with East Coast Diatom Zone 4 and Lithologic Units 11-13 of the Calvert Formation.

Sample #7618 - depth 105.0'

The following marker diatoms were observed:

Actinoptychus virginicus
Coscinodiscus lewisianus
Delphineis angustata
Delphineis novacaesaraea
Delphineis penelliptica
Rhaphoneis gemmifera
Rhaphoneis magnapunctata
Sceptroneis sp. A

The sample showed good diatom preservation. The marker diatoms suggest correlation with East Coast Diatom Zone 5 or Lithologic Unit 14 of the Calvert Formation, with the exception of *Rhaphoneis magnapunctata* that is more characteristic of East Coast Diatom Zone 4 and Lithologic Unit 13. This species may be reworked, and this sample may approximate the base of Unit 14 of the Calvert Formation. *Sceptroneis* sp. A, above, is virtually identical to the taxon erroneously assigned to *Rhaphoneis fusiformis* by Andrews and Abbott (1985) from the Hawthorn Formation of Thomas County, Georgia.

Sample #7617 - depth 99'8"

The following marker diatoms were observed:

Actinoptychus virginicus
Delphineis angustata
Delphineis novaecaesaraea
Delphineis penelliptica
Rhaphoneis gemmifera

This sample showed fair diatom preservation. These diatoms suggest correlation with East Coast Diatom Zone 5 and Lithologic Unit 14 of the Calvert Formation.

Sample #7616 - depth 94'8"

The following marker diatoms were observed:

Actinoptychus virginicus
Delphineis angustata
Delphineis novaecaesaraea
Delphineis penelliptica
Rhaphoneis gemmifera
Rhaphoneis parilis

The sample showed fair diatom preservation. These diatoms suggest correlation with East Coast Diatom Zone 5 and Lithologic Unit 14 of the Calvert Formation.

Sample #7615 - depth 90'8"

The following marker diatoms were observed:

Actinoptychus virginicus
Delphineis angustata
Delphineis novaecaesaraea
Delphineis penelliptica
Rhaphoneis gemmifera
Rhaphoneis parilis
Sceptroneis sp. A

The sample showed fair diatom preservation. These diatoms suggest correlation with East Coast Diatom Zone 5 and Lithologic Unit 14 of the Calvert Formation.

Sample #7614 - depth 85'3"
Sample #7613 - depth 82'9"

The above two samples contain good diatom assemblages. However, they are bracketed by samples of similar age and hence were not studied in detail.

Sample #7612 - depth 76'6"

The following marker diatoms were observed:

Actinoptychus virginicus
Delphineis angustata
Delphineis novaecaesaraea
Delphineis penelliptica
Rhaphoneis gemmifera
Rhaphoneis parilis
Sceptroneis sp. A

These diatoms suggest correlation with East Coast Diatom Zone 5 and with Lithologic Unit 14 of the Calvert Formation.

Sample #7611 - depth 66'10"
Sample #7610 - depth 63'8"

These samples contained good diatom assemblages. However, they are virtually identical with sample #7612, reported on above, and also are correlated with East Coast Diatom Zone 5 and with Lithologic Unit 14 of the Calvert Formation.

Sample #7609 - depth 60'3"

The following marker diatoms were observed:

Actinoptychus virginicus
Delphineis angustata
Delphineis penelliptica
Rhaphoneis gemmifera
Rhaphoneis parilis

The diatom preservation of this sample was fair to poor, but these diatoms suggest correlation with East Coast Diatom Zone 5 and approximately the lower part of Lithologic Unit 15 of the Calvert Formation.

Sample #7608 - depth 37'8"

The following marker diatoms were observed:

Delphineis angustata
Delphineis novaecaesaraea
Delphineis penelliptica
Rhaphoneis clavata
Rhaphoneis clavata/lancettula
Rhaphoneis gemmifera
Rhaphoneis parilis
Rhaphoneis scutula

These diatoms suggest correlation with East Coast Diatom Zone 6 and with approximately the middle of Lithologic Unit 15 of the Calvert Formation.

In summary, the diatoms found in the cores suggest the following correlations with the East Coast Diatom Zones (ECDZ) and the lithologic beds of the outcropping Calvert:

203'8"-156'5"	= ECDZ2, beds 3B-8
113'11"	= ECDZ3, bed 11
108'10"	= ECDZ4, beds 11-13
105'0"-63'8"	= ECDZ5, bed 14
60'3"	= ECDZ5, bed 15
37'8"	= ECDZ6, bed 15

The diatom zonation of these strata in the Solomons Island corehole is combined with lithologic characteristics of the beds and the disconformable surfaces present to give the bed designations used in this corehole (fig. 3).

DEPOSITIONAL SEQUENCES

Kidwell (1984; 1988) recognized four depositional sequences in the Plum Point Marl Member (herein equals Plum Point and Calvert Beach Members) of the Calvert Formation in the Calvert Cliffs sections. Each of her sequences are disconformity bounded. Kidwell interpreted these four sequences as transgressive-regressive cycles that were present over much of the Maryland and Virginia Coastal Plain. Her lowest sequence, termed PP-0, was separated from the underlying Fairhaven Member by a disconformity, and it consisted of Shattuck's beds 4-9 (she re-named the beds, but her terms are not used herein). The next higher sequence, PP-1, consisted of Shattuck's beds 10-11; the next higher, sequence PP-2, consisted of Shattuck's beds 12-13, and the highest one, sequence PP-3, consisted of Shattuck's beds 14-15.

Most of these sequences can be recognized in the Solomons Island corehole. Kidwell's lowest disconformity, PP-0, which is located at the top of the Fairhaven Member, is strongly developed at 182.7 ft in the Solomons Island core. Sequence PP-0 extends from its base at 182.7 ft to somewhere in the 147-156 ft interval where there was no core recovery. Sequence PP-1 starts in this 147-156 ft interval and extends to a disconformity at 110.0 ft, which appears to be Kidwell's disconformity PP-2. Kidwell's sequence PP-2, however, which is quite thick in outcrop, is very thin and poorly represented in the Solomons Island corehole. A thin interval from 110.0 ft to no higher than 105 ft is provisionally assigned to this sequence. Kidwell's disconformity PP-3 is not noticeable in the Solomons Island core, but a thick series of deposits belonging to her sequence PP-3 is present from 105 ft to 37-28 ft.

PALEOENVIRONMENTS

A generalized paleobathymetric history of the Calvert Formation in the Solomons Island corehole is constructed from the foraminiferal assemblages. The paleobathymetric trends are shown (fig. 3) by the use of the *tau* index (Gibson, 1988). *Tau* values are the mathematical product of the number of benthic foraminiferal species times the percentage of planktonic specimens in the total foraminiferal assemblage in a sample.

Buzas and Gibson (1969) and Gibson and Buzas (1973) showed that although the number of benthic species (S) exhibits a general increase from inner neritic depths into abyssal depths along the U.S. Atlantic margin, the increase is not necessarily a continually progressive one. The S values generally increase from inner neritic to outer neritic depths, but S values on the upper continental slope may be lower than those found on outer parts of the shelf. An increase in S values begins again on the middle and lower parts of the slope and this increase continues into abyssal regions. This pattern places limits on the use of S for interpretation of slope paleoenvironments.

The planktonic proportion of the foraminiferal assemblage, however, generally continues to increase across the shelf and upper and middle slope environments (Grimsdale and Van Morkhoven, 1955; Gibson, 1989). Therefore, Gibson (1988) proposed the index *tau*, which is the product of the number of benthic species times the percentage of planktonic specimens in the total foraminiferal assemblage of a sample. The values of this index continue to increase across the shelf, down the slope, and into abyssal regions. Gibson (1988, fig. 11) showed that Parker's (1954) data from the northeastern Gulf of Mexico region gives *tau* values of 1-100 in waters less than 130 ft deep. The *tau* values continue a general increase with depth and reach 10,000 in water depths around 3,000 ft. There is not an exact correlation between any particular *tau* value and a particular water depth, but various depth interval categories and paleobathymetric trends can be recognized. The *tau* values also may vary between different sedimentary basins because of particular environmental conditions, but the plotting of *tau* values through a section in a single sedimentary basin commonly highlights the paleobathymetric trends.

Because the species, as well as genera, composing the foraminiferal assemblages vary both in their proportions and in their presence or absence with changes in bathymetry and other environmental complexes, the taxonomic composition of the assemblages is an additional valuable tool for the interpretation of the paleoenvironmental changes. I am preparing a much more extensive paleontologic manuscript that contains detailed lists and illustrations of the foraminiferal taxa in the Calvert Formation in the Solomons Island corehole and discussions of their paleoenvironmental significance.

The deepest water Calvert deposits are present in the basal sandy beds of the formation (fig. 3). The *tau* values reflect the high proportion of planktonic specimens and high diversity of benthic species that are characteristic of more off-shore areas. These beds suggest deposition in inner-middle to middle neritic depths of about 250-300 ft. Gibson (1983a) and Poag (1989) also found the deepest water environments in the Calvert in these basal sands in Maryland and northern Virginia.

The overlying diatomaceous beds were deposited in considerably shallower environments, probably about 100 ft deep, into which very little coarse clastic material was transported (table 1, fig. 5). Shallow marine environments with waters about 100 ft deep also were present during the deposition of the lower part of the Plum Point Marls. Gibson (1983a) found similar environments in these age strata both in the outcrops and BG&E corehole.

Water depths increased to inner-middle neritic depths approaching 250 ft during deposition of the strata assigned to bed 10. A similar pattern of somewhat deeper environments in this sequence was found both in outcrop and the BG&E corehole (Gibson, 1983a).

Shallow, open-marine environments of 100 ft or less characterize the Calvert Beach Member in the Solomons Island corehole. Poag (1989) suggests similar shallowing to water depths of around 125 ft in the Calvert Beach age sequence in the Haynesville corehole.

An unusual characteristic common to all the Calvert assemblages in the Solomons Island corehole is the domination of the fauna by the genera *Bolivina* spp., *Bulimina* spp., *Buliminella* spp., *Epistominella* spp., and *Pseudononion* spp. These taxa usually compose 70 percent or higher of the assemblages. All of these taxa are characteristic of high nutrient/low oxygen environments. In the Solomons Island samples they are associated with abundant diatoms and radiolarians. The general absence of carbonaceous debris in these deposits suggests that a high influx of nutrients probably was not coming in from terrestrial sources. The most likely explanation for these characteristics is that marine upwelling was taking place along the Maryland and Virginia margin during the deposition of these beds; this upwelling resulted in high productivity of marine plankton such as diatoms and radiolarians. This high productivity resulted in large amounts of organic matter being carried to the sea-floor and caused an oxygen deficiency in the bottom waters and sediments. Poag (1989) suggests a similar scenario for the Calvert deposits of the Haynesville corehole.

REGIONAL STRATIGRAPHIC ASPECTS OF THE CALVERT FORMATION

Several other continuously cored drillholes have penetrated the Calvert Formation in Maryland and northern Virginia in the central part of the Salisbury embayment. In addition, numerous non-cored drillholes, such as the deep drillhole at Lexington Park, Maryland (Hansen and Wilson, 1984), which is located about four miles south of Solomons Island, have penetrated this section. Gibson (1983a) described the lithofacies and biofacies of the Calvert Formation from some partially cored drillholes on the Eastern Shore of Maryland. However, a detailed examination of diatom and foraminiferal assemblages for biostratigraphic and paleoenvironmental purposes as well as the detection of discontinuities in the strata is largely restricted to uncontaminated samples from continuously cored holes.

Examination of the relative thicknesses of the different Calvert Formation subdivisions in this area highlights an interesting regional pattern. The corehole studies have utilized both a bipartite or a tripartite division of the Calvert Formation, but all coreholes can be compared as they refer the deposits to the beds of Shattuck (1904).

In the type area outcrops in Calvert County, Maryland, the thickness of the Calvert is estimated at 160 to 180 ft by superposition of the discontinuous sections of Shattuck (1904). Here, the Fairhaven Member contains basal pebbly sands that are overlain by diatomaceous clay to fine sand. This member is approximately 60 to 70 ft thick. The silty and clayey fine sands of the Plum Point Member (herein beds 4-13) reach a total thickness of approximately 72 to 82 ft, and beds 14 and 15 of the Calvert Beach Member total approximately 25 ft.

The Baltimore Gas and Electric Company (BG&E) Calvert Cliffs nuclear power plant site (fig. 1) is about five miles south of the southernmost Calvert outcrops, and it is presumably obliquely downbasin. Andrews (1978) discussed the diatom biostratigraphy of this corehole. The BG&E corehole penetrated about 195 ft of the Calvert Formation (Gibson, 1983a). The members here have lithologies similar to those found in outcrop. The Calvert Beach Member is 22 ft thick and the Plum Point Member is 61 ft thick (Fig. 6). The thicknesses of these members in the BG&E corehole are similar to their thicknesses in outcrop. The Fairhaven Member, however, is about 112 ft thick in the BG&E corehole in comparison to the 60 to 70 ft thickness reported in outcrop. The difference in thickness of the Fairhaven between outcrop sections and the BG&E site may reflect the original depositional thickness, subsequent differential erosion between the different areas, or the difficulty in obtaining the true thickness of this relatively uniform member within the series of discontinuous outcrops. Which of these possibilities is the most important or only cause of the difference in thickness is uncertain at the present time.

At Well 220 (fig. 1), approximately 20 miles to the east of the BG&E site, Gibson (1983a) found lithologies and thicknesses for the Calvert Formation and its members that were similar to those in the BG&E corehole. A significant change both in thickness and lithology of the Calvert Formation, however, is present in the Hammond Well, which is located 30 miles east of Well 220 on the Maryland Eastern

Shore. The Hammond Well was not cored through the Calvert interval, but the thickest section of Calvert yet reported, 500 ft, was penetrated here (Anderson, 1948). The members of the Calvert are not distinguishable here as the entire formation consists of brown to gray silty clay and very fine sand.

A much more rapid change in thickness of the members is seen to the south of the BG&E corehole. The Solomons Island corehole is about eight miles south-southwest of the BG&E corehole. The lithologies of the Calvert members at Solomons Island are still similar to those found in the BG&E corehole. Highly diatomaceous sediments are confined to the Fairhaven Member, and sparsely to moderately shelly clayey sand dominates the Plum Point and Calvert Beach Members. At Solomons Island, however, the Fairhaven Member thins considerably to only 39 ft. While the Plum Point Member retains a similar thickness of 77 ft, beds 14 and 15 of the Calvert Beach Member thicken considerably to between 68 and 78 ft (fig. 6).

The thickness of the Fairhaven Member and the lithology of the Plum Point and Calvert Beach Members is very different in the 132.3 ft of Calvert strata found in the Haynesville corehole in northern Virginia (fig. 1) (Mixon and others, 1989). Andrews (in Mixon and others, 1989) discussed the Calvert diatom biostratigraphy and Poag (1989) described the foraminifera from the Calvert Formation in the Haynesville corehole. Mixon and others (1989) found an 11 ft thick basal pebbly sand unit that was considered to belong to either the upper part of the Fairhaven Member or the lower part of the Plum Point Member. However, it is lithologically similar to the sands that are at the base of the Fairhaven Member and no evidence is presented as to why it was not considered correlative with this bed. No other Fairhaven beds were found here, showing a considerable thinning of this unit from the Solomons Island corehole (Fig. 6). Beds referred to the Plum Point Member are 57 ft thick, somewhat thinner than that found to the north. The Calvert Beach is very similar in thickness (at 65 ft) to that found at Solomons Island. However, both the Plum Point and Calvert Beach Members are finer grained and considerably more diatomaceous in the Haynesville corehole than in southern Maryland.

Whether the north-south differences in thickness of the members are primary depositional ones or later erosional ones, or some combination of these two causes and others, is uncertain. Shattuck's (1904) sections for bed 15 in the Calvert Cliffs suggest that significant amounts of erosion have occurred in that area. The Calvert Beach Member has much thicker sections in the two more southerly coreholes (fig. 6). However, an examination of Shattuck's (1904) outcrop sections of beds 14 and 15 of this member indicates that there is significant local thickness variation that is best attributed to erosion. Although beds 14 and 15 generally have a combined thickness of 14 to 26 ft in the outcrops, Shattuck localities V to VIII, all within a 2.5 mile distance along the Calvert Cliffs, have thicknesses of 0, 9, 9, 19, 19, and 48.5 ft for bed 15. Using the one thick section of beds 14 and 15, which totals 55.5 ft, produces a section that is similar to the thicknesses both in Solomons Island and Haynesville coreholes. Thus, this north-south thickness difference does not seem to be due to a southward movement in the locus of deposition, but mainly seems to be a function of greater post-Calvert erosion along the Calvert Cliffs area.

The Oak Grove corehole, which is farther upbasin in Virginia than the Haynesville corehole (fig. 1), contains 99 ft of the Calvert Formation. Andrews (in Gibson and others, 1980) studied the Calvert diatoms, but foraminifera and other calcareous fossils were not present in the Calvert beds in this corehole. Only two Calvert intervals in the Oak Grove corehole produced diagnostic diatom assemblages. A diatom assemblage indicative of Calvert beds 3B-8 was present in a 17 ft interval near the base of the Calvert section, and an assemblage indicative of Calvert beds 14 and 15 was present in a 24 ft interval near the top of the Calvert. The Oak Grove corehole contains a 10-ft-thick basal sand that is overlain by a 10-ft-thick highly diatomaceous silt-clay (Reinhardt and others, 1980). These lower two units probably represent a basal Calvert sand and a relatively thin section of bed 3B of the Fairhaven diatomite. No biostratigraphic information was available on the thick middle section of the Calvert Formation beneath the section that would correlate with Calvert Beach Member beds elsewhere. Because of the absence of stratigraphic control in this section, it is not utilized on the cross-section.

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REFERENCES

Anderson, J.L., 1948, Cretaceous and Tertiary subsurface geology: Maryland Department of Geology, Mines, and Water Resources Bulletin 2, p. 1-113.

Andrews, G.W., 1978, Marine diatom sequence in Miocene strata of the Chesapeake Bay region, Maryland: Micropaleontology, v. 24, p. 371-406.

Andrews, G.W., 1988, A revised marine diatom zonation for Miocene strata of the southeastern United States: U.S. Geological Survey Professional Paper 1481, 29 p.

Andrews, G.W., and Abbott, W.H., 1985, Miocene diatoms from the Hawthorn Formation, Thomas County, Georgia: Bulletins of American Paleontology, v. 87, no. 321, p. 53-109.

Buzas, M.A., and Gibson, T.G., 1969, Species diversity: benthonic foraminifera in western North Atlantic: Science, v. 163, p. 72-75.

Dorsey, Ann, 1948, Miocene Foraminifera, Chesapeake Group: Maryland Department of Geology, Mines, and Water Resources Bulletin No. 2, p. 268-321.

Gernant, R.E., 1970, Paleoecology of the Choptank Formation (Miocene) of Maryland and Virginia: Maryland Geological Survey Report of Investigations No. 12, 90 p.

Gibson, T.G., 1967, Stratigraphy and paleoenvironment of the phosphatic Miocene strata of North Carolina: Geological Society of America Bulletin, v. 78, p. 631-650.

Gibson, T.G., 1971, Miocene of the Middle Atlantic Coastal Plain: Maryland Geological Survey Guidebook No. 3, p. 1-15.

Gibson, T.G., 1982, Depositional framework and paleoenvironments of Miocene strata from North Carolina to Maryland: Florida Department of Natural Resources Special Publication 25, p. 1-22.

Gibson, T.G., 1983a, Stratigraphy of Miocene through Lower Pleistocene strata of the United States Central Atlantic Coastal Plain: *in* Geology and Paleontology of the Lee Creek Mine, North Carolina, I, C.E. Ray (ed.), Smithsonian Contributions to Paleobiology Number 53, p. 35-80.

Gibson, T.G., 1983b, Key Foraminifera from Upper Oligocene to Lower Pleistocene strata of the Central Atlantic Coastal Plain: *in* Geology and Paleontology of the Lee Creek Mine, North Carolina, I, C.E. Ray (ed.), Smithsonian Contributions to Paleobiology Number 53, p. 355-453.

Gibson, T.G., 1988, Assemblage characteristics of modern benthic foraminifera and application to environmental interpretation of Cenozoic deposits of eastern North America: Revue de Paleobiologie, Special Volume 2, Benthos '86, p. 777-787.

Gibson, T.G., 1989, Planktonic benthonic foraminiferal ratios: modern patterns and Tertiary applicability: Marine Micropaleontology, v. 15, p. 29-52.

Gibson, T.G., Andrews, G.W., Bybell, L.M., Frederiksen, N.O., Hansen, Thor, Hazel, J.E., McLean, D.M., Witmer, R.J., and Van Nieuwenhuise, D.S., 1980, Biostratigraphy of the Tertiary strata of the core, *in* Geology of the Oak Grove core: Virginia Division of Mineral Resources Publication 20, Part 2, p. 14-30.

Gibson, T.G., and Buzas, M.A., 1973, Species diversity: patterns in modern and Miocene foraminifera of the eastern margin of North America: Geological Society of America Bulletin, v. 84, p. 217-238.

Glaser, J.D., 1971, Geology and Mineral Resources of Southern Maryland: Maryland Geological Survey Report of Investigations No. 15, 84 p.

Grimsdale, T.R., and Van Morkhoven, F.P.C.M., 1955, The ratio between pelagic and benthonic Foraminifera as a means of estimating depth of deposition of sedimentary rocks: IV World Petroleum Congress, Proceedings, section I/D, Report 4, p. 473-491.

Hansen, H.J., and Wilson, J.M., 1984, Summary of hydrogeologic data from a deep (2,678 ft.) well at Lexington Park, St. Mary's County, Maryland: Maryland Geological Survey Open File Report 84-02-1, 61 p.

Kidwell, S.M., 1984, Outcrop features and origin of basin margin unconformities in the Lower Chesapeake Group (Miocene), Atlantic Coastal Plain: *in* Schlee, J.S. (ed.), Interregional unconformities and hydrocarbon accumulation, American Association of Petroleum Geologists Memoir 36, p. 37-58.

Kidwell, S.M., 1988, Reciprocal sedimentation and noncorrelative hiatuses in marine-paralic siliciclastics: Miocene outcrop evidence: Geology, v. 16, p. 609-612.

Lohman, K.E., 1972, A procedure for the microscopical study of diatomaceous sediments: Nova Hedwigia, v. 39, p. 267-283.

Malkin, Doris, 1953, Biostratigraphic study of Miocene Ostracoda of New Jersey, Maryland, and Virginia: Journal of Paleontology, v. 27, p. 761-799.

Mixon, R.B., Powars, D.S., Ward, L.W., and Andrews, G.W., 1989, Lithostratigraphy and molluscan and diatom biostratigraphy of the Haynesville cores - Outer Coastal Plain of Virginia: U.S. Geological Survey Professional Paper 1489-A, p. A1-A48.

Parker, F.L., 1954, Distribution of the foraminifera in the Northeastern Gulf of Mexico: Museum of Comparative Zoology (Harvard) Bulletin 111, No. 10, p. 453-588.

Poag, C.W., 1989, Foraminiferal stratigraphy and paleoenvironments of Cenozoic strata cored near Haynesville, Virginia: U.S. Geological Survey Professional Paper 1489-D, p. D1-D20.

Reinhardt, Juergen, Newell, W.L., and Mixon, R.B., 1980, Tertiary lithostratigraphy of the core, *in* Geology of the Oak Grove core: Virginia Division of Mineral Resources Publication 20, Part 1, p. 1-13.

Shattuck, G.B., 1902, The Miocene Formation in Maryland: Science, v. 15, p. 906.

Shattuck, G.B., 1904, Geological and paleontological relations, with a review of earlier investigations, *in* Clark, W.B., Shattuck, G.B., and Dall, W.H., The Miocene deposits of Maryland: Maryland Geological Survey, p. 33-94.

Ward, L.W., 1984, Stratigraphy of outcropping Tertiary beds along the Pamunkey River-central Virginia Coastal Plain, *in* Ward, L.W., and Krafft, Kathleen, eds., Stratigraphy and paleontology of the outcropping Tertiary beds in the Pamunkey

River region, central Virginia Coastal Plain (Guidebook for Atlantic Coastal Plain 1984 field trip): Atlantic Coastal Plain Geological Association, p. 11-77.

Wetmore, K.L., and Andrews, G.W., 1990, Silicoflagellate and diatom biostratigraphy in successive Burdigalian transgressions, middle Atlantic coastal Plain: Micropaleontology, v. 36, p. 283-295.

APPENDIX 1. On-Site Core Description of Miocene strata.

Depth (ft):

0-28 ft: No coring. Descriptions from rotary drilled cuttings.

0-1 ft - gray clay, massive, with about 10 percent fine to coarse grained quartz sand.

1-8 ft - brownish-gray clayey sand becoming coarser grained toward the bottom.

16-26 ft - becomes more sandy, with gray, very fine sand and gravel.

26-28 ft - light-greenish-gray, very fine sand with abundant shell.

Started coring at 28-ft depth.

RUN 1, 28-37 ft:

9-ft core run, 0.2-ft recovery.

28-28.2 ft:
indurated sand that blocked core barrel.

28.2-37 ft: No recovery.
drilling bit at end of barrel contained bluish clay suggesting that probably entire run was through Miocene beds.

RUN 2, 37-47 ft:

10-ft core run, 2-ft recovery.

37--39 ft:
SAND, very fine to fine, slightly clayey, massively bedded with abundant shell material; barnacle fragments most abundant, but has clams that look like *Ensis*; several inch-long pieces of wood near bottom; medium-gray-green.

39-47 ft: No recovery.

47-60 ft:
Drillers reamed out hole, mistakenly went 10 ft past targeted depth of 50 ft, no samples over this interval.

RUN 3, 60-66 ft:

6-ft core run, 3-ft recovery.

60-63 ft:
SAND, very fine, clayey, silty, massively bedded, with bioturbated fabric, fairly abundant shell; shells generally in lenses 1/2 to 1 inch thick; some pecten shells that are probably *Chesapecten nefrens* and also some *Turritella*; medium-dark-gray-green.

63-66 ft: No recovery.

RUN 4, 66-76 ft:

10-ft core run, 1-ft recovery.

66-67 ft:
SAND, very fine, clayey, silty, massively bedded; scattered fine shell; medium-dark-gray-green.

67-76 ft: No recovery.

RUN 5, 76-86 ft:

10-ft core run, 9.3-ft recovery.

76-85.3 ft:
SAND, very fine, silty, clayey; highly bioturbated fabric; very scattered shell in upper 5 ft, more shell in lower four ft, both scattered and in layers, including abundant *Turritella*; medium-gray-green.

85.3-86 ft: No recovery.

RUN 6, 86-96 ft:

10-ft core run, 7-ft recovery.

86-89 ft:

SAND, very fine, clayey, silty; some scattered shell; bioturbated fabric; bed appears to be continuation of above unit, has large *Turritella* at top; medium-gray-green; this interval appears to represent a transition to finer grained sediments below that are darker in color and do not have any shell material.

89-93 ft:
CLAY, very fine sandy and silty, massively bedded; no shells; medium-dark-gray-green; unit is both darker in color and lacks the bioturbated fabric of the above unit.

93-96 ft: No recovery.

RUN 7, 96-106 ft:

10-ft core run, 10-ft recovery.

96-101 ft:
SILT, clayey with some silty clay intervals, massively bedded; common *Turritella* is scattered throughout core, not in layers, and it has some smaller clams; medium-dark-grayish-green; compared to above unit it is both more olive and somewhat lighter in color and it is highly bioturbated and has a fair amount of shell.

101-106 ft:
SAND, silty, clayey. massively bedded; highly bioturbated fabric; common *Turritella* scattered through core; medium-dark-gray-green.

RUN 8, 106-111 ft:

5-ft core run, 5-ft recovery.

106-110 ft:
SAND, very fine, silty, clayey, massively bedded; common *Turritella* scattered through core; carbonaceous debris in lower 2 ft; medium-dark-gray-green.

-------- burrowed surface at 110 ft with underlying more olive unit

110-111 ft:
CLAY, silty; bioturbated fabric; few shells; possible clay clasts; olive-green.

RUN 9, 111-119 ft:

8-ft core run, 7.6-ft recovery.

111-117.6 ft:
CLAY, silty, massively bedded; highly bioturbated fabric; no shell; clay clasts in upper 3 ft; continuation of unit seen in bottom of above run, which becomes darker and more olive with lighter gray-green bioturbation fabric; olive-green.

117.6-118.6 ft:
SAND, very fine, clayey, massively bedded; sparse poorly preserved shell; carbonaceous debris at 118.3 ft; more gray-green.

118.6-119.0 ft: No recovery.

-------contact at 119 ft, appears to be burrowed surface

RUN 10, 119-126 ft:

7-ft core run, 7-ft recovery.

119-123 ft:
CLAY, sandy, with some highly sandy intervals; highly bioturbated fabric with silty pods in clayey matrix; a few shell fragments in upper part; olive-green mottled in medium-gray-green; appears to have burrows from overlying unit.

123-126 ft:
SAND, fine, clayey, massively bedded; very few shell fragments; medium-dark-gray-green.

RUN 11, 126-136 ft:

10-ft core run, 3.5-ft recovery.

126-129.5 ft:
SAND, fine, clayey, massively bedded; small amount (1-2 percent) of fine to medium-grained glauconite; small amount of scattered shell with few larger clams of *Astarte*?; bioturbated fabric with lighter colored more silty and sandy areas of dusky-yellow-green (5 GY 5/2) mottled with darker more clayey sand of grayish-olive-green (5 GY 3/2).

129.5-136 ft: No recovery.

RUN 12, 136-146 ft:

10-ft core run, 2.9-ft recovery.

136-138.9 ft:
SAND, very fine to fine, slightly clayey, but with some intervals having considerable clay, massively bedded with bioturbation fabric containing sandy pods; no shell; olive-gray (5 Y 3/2); color considerably different from above run.

138.9-146 ft: No recovery.

RUN 13, 146-156 ft:

10-ft core run, 0.5-ft recovery.

146-146.5 ft:
SAND, very fine to fine, clayey, some more clayey laminae about 1/4 inch thick; parts between laminae are highly bioturbated; no shell; olive-gray (5 Y 3/2); bed is possibly near the base of a cycle as it is much more sandy and more olive in color than the next run.

146.5-156 ft: No recovery.

RUN 14, 156-166 ft:

10-ft core run, 9.5-ft recovery.

156-163.5 ft:
CLAY, silty, very fine sandy, with some intervals grading to clayey silt to very fine sand, massively bedded; bioturbation fabric; few scattered shell fragments; phosphatic brachiopods; fish scales; diatomaceous; dusky-yellow-green (5 GY 5/2); this run is slightly darker in color and slightly less bioturbated than run below.

163.5-165.5 ft:
SAND, very fine, clayey, massively bedded; bioturbation fabric; no shells; diatomaceous; dusky-yellow-green (5 GY 5/2).

165.5-166 ft: No recovery.

RUN 15, 166-176 ft:

10-ft core run, 9.3-ft recovery.

166-172.3 ft:
SAND, very fine, clayey; heavily bioturbated fabric with lighter colored sand; massive bedding; about 1 percent very fine grained glauconite; no calcareous shells but some phosphatic brachiopods; dusky-yellow-green (5 GY 5/2) mottled with lighter grayish-yellow-green (5 GY 7/2).

172.3-175.3 ft:
CLAY, silty, very fine sandy, some intervals with a lot of very fine sand; bioturbated fabric, but also contains some more sandy laminae about 1 inch thick; no shells; grayish-olive-green (5 GY 3/2); possibly a burrowed contact at 172.3 ft or possibly just a lithologic and color change to finer grained sediments with a darker green and less olive color.

175.3-176 ft: No recovery.

RUN 16, 176-186 ft:

10-ft core run, 10-ft recovery.

176-182.7 ft:
CLAY, silty, very fine sandy, massively bedded; bioturbated fabric; 1 percent very fine grained glauconite; slightly diatomaceous; a few small shell fragments; dusky-yellow-green (5 GY 5/2).

-----sharply burrowed contact at 182.7 ft with 0.7 ft relief

182.7-186 ft:
CLAY, silty, massively bedded; bioturbation fabric; diatomaceous; no shell; grayish-olive-green (5 GY 3/2).

RUN 17, 186-190 ft:

4-ft core run, 4-ft recovery.

186-190 ft:
CLAY, silty, massively bedded; bioturbation fabric of light olive-gray (5 Y 5/2) with yellowish-gray (5 Y 7/2); diatomaceous; no shell, echinoid spines abundant.

RUN 18, 190-196.5 ft:

6.5-ft core run, 6.5-ft recovery.

190-196.5 ft:

CLAY, silty, mostly massive bedding but has some thin, 1 mm thick silty laminae, otherwise has bioturbated fabric, very diatomaceous; no shell; light-olive-gray (5 Y 5/2).

RUN 19, 196.5-206.0 ft:

9.5-ft core run, 9.5-ft recovery.

196.5-204.9 ft:

CLAY, silty, massively bedded; faint bioturbation fabric; very diatomaceous; no shell, continuation of above unit; light-olive-gray (5 Y 5/2).

-----GRADATIONAL CHANGE across 0.5 ft from 204.4 to 204.9

204.9-206 ft:

SAND, medium to coarse, some angular phosphate; abundant shells, some look like large oysters; at base is coarse sand with no shell; grayish-olive-green (5 GY 3/2).

RUN 20, 206-216 ft:

10-ft core run, 3.3-ft recovery.

206-208.3 ft:

SAND, fine to medium, clayey, some phosphatic fine gravel, massively bedded; bioturbated fabric; micaceous; abundant thick oyster and clam shells; dusky-yellow-green (5 GY 5/2).

-----GRADATIONAL CHANGE across 0.2 ft from 208.1 to 208.3 ft

208.3-209.3 ft:

SAND, slightly clayey, massively bedded, a few fine grained glauconite grains; few shells; this interval has less clay and shell than immediately above; grayish-olive-green (5 GY 3/2).

209.3-216 ft: No recovery.

RUN 21, 216-226 ft:

10-ft core run, 3-ft recovery.

216-217.5 ft:

SAND, bimodal sediment distribution with abundant medium- to coarse-grained sand and fine quartz gravel mixed with some clay, massively bedded, less than 1 percent glauconite; some shell; dusky-yellow-green (5 GY 5/2); is basal part of Calvert Formation.

217.5-221 ft: No recovery.

-----MAJOR LITHOLOGIC CHANGE at 221 ft.

221-222.5 ft:

SANDSTONE, fine- to medium-grained quartzose; 10-20 percent glauconite; abundant clam shell molds; light-olive-gray (5 Y 6/1); hard bed is top of Piney Point Formation.

222.5-226 ft: No recovery.

Table 1. Sand percentages of selected samples.

Depth (ft)	Sand percentage
45.7	76.1
61.5	58.7
66.1	74.6
78.9	21.5
84.3	35.4
91.0	27.6
92.6	32.2
96.7	36.1
102.0	10.6
108.5	30.6
114.3	3.1
120.0	30.4
126.9	55.0
129.0	74.8
144.6	69.3
146.3	79.7
156.7	12.7
161.3	7.3
165.3	19.3
170.1	40.5
174.8	31.7
178.4	35.5
181.5	24.6
184.5	0.1
188.0	0.1
189.6	0.1
194.7	0.5
199.8	0.3
203.8	0.4
206.0	38.1
206.7	55.8
207.3	44.7
207.8	50.7
220.0	65.2

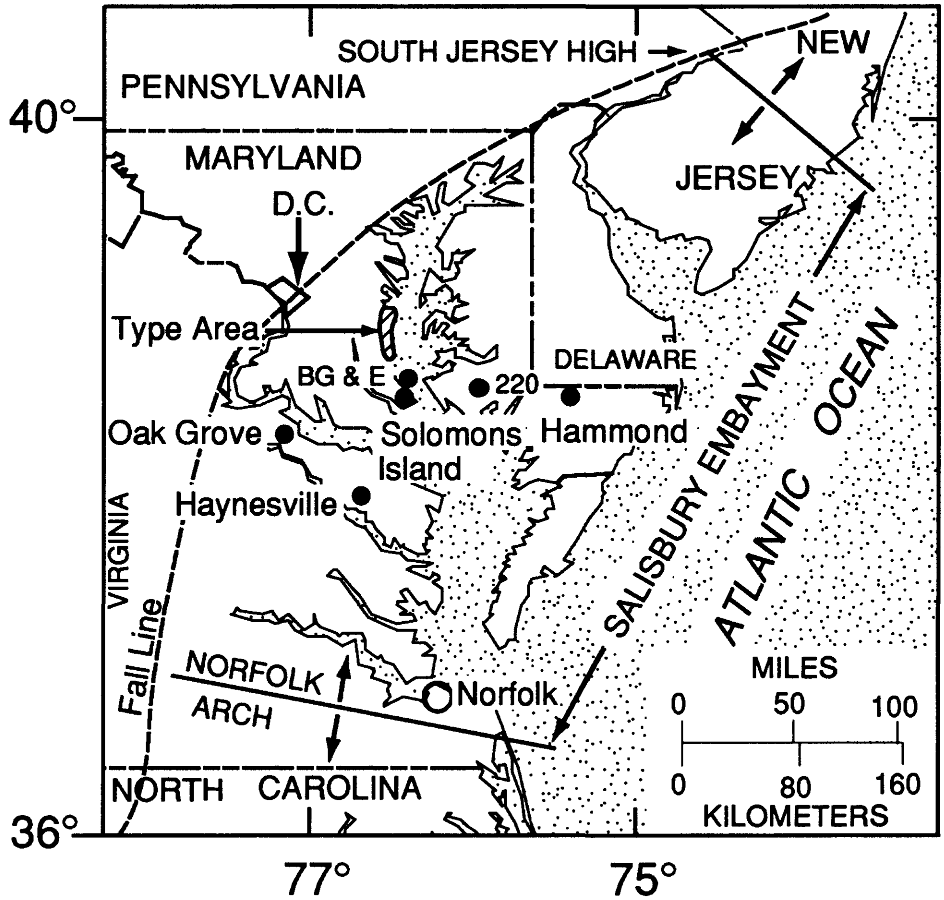

Figure 1. Map of Salisbury embayment showing location of Solomons Island corehole, other coreholes discussed in text, and type area of the Calvert Formation.

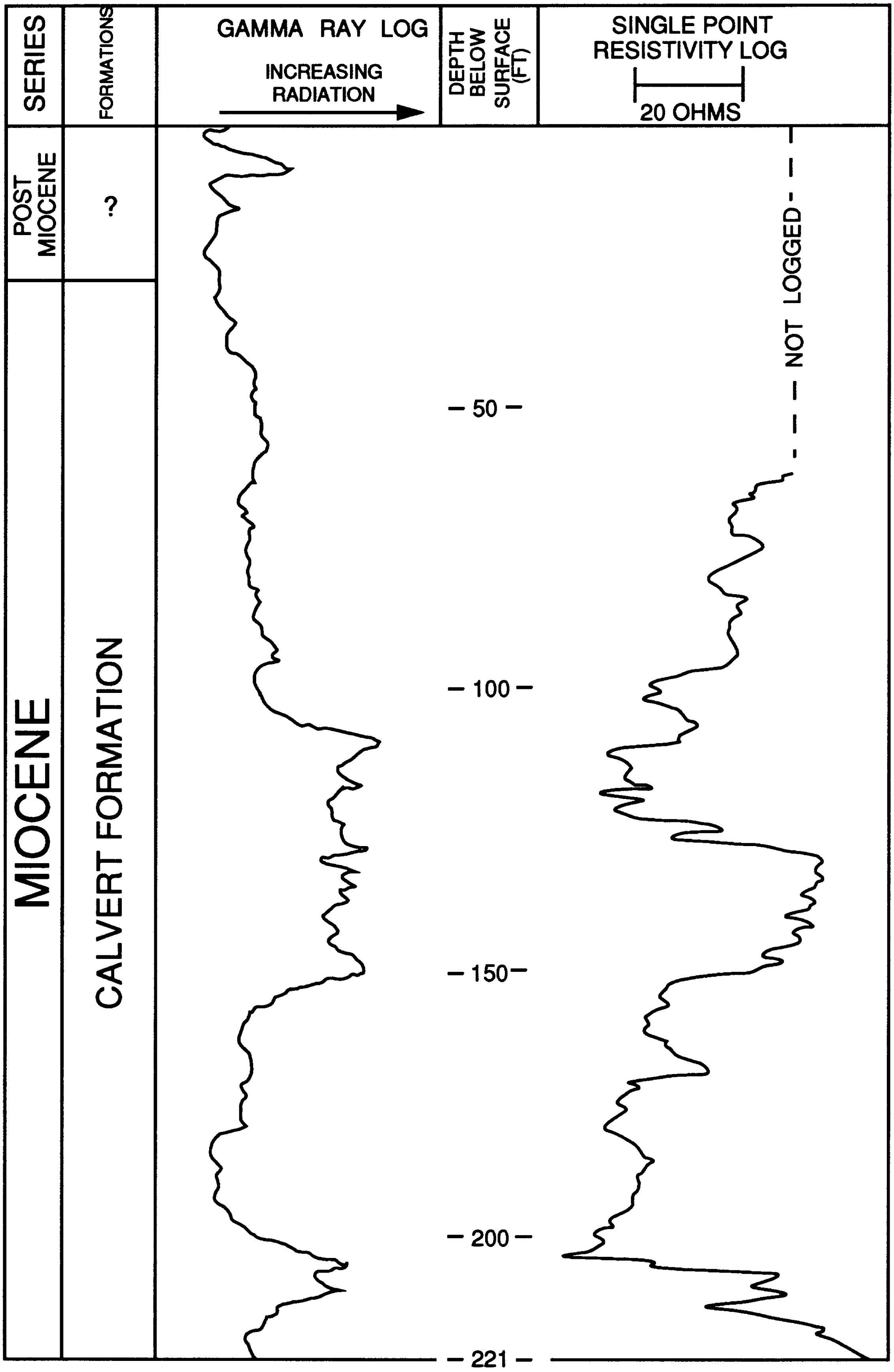

Figure 2. Gamma ray and single point resistivity logs of Miocene strata in Solomons Island corehole (USGS well CA-Gd 60). Altitude of ground surface is 15 ft.

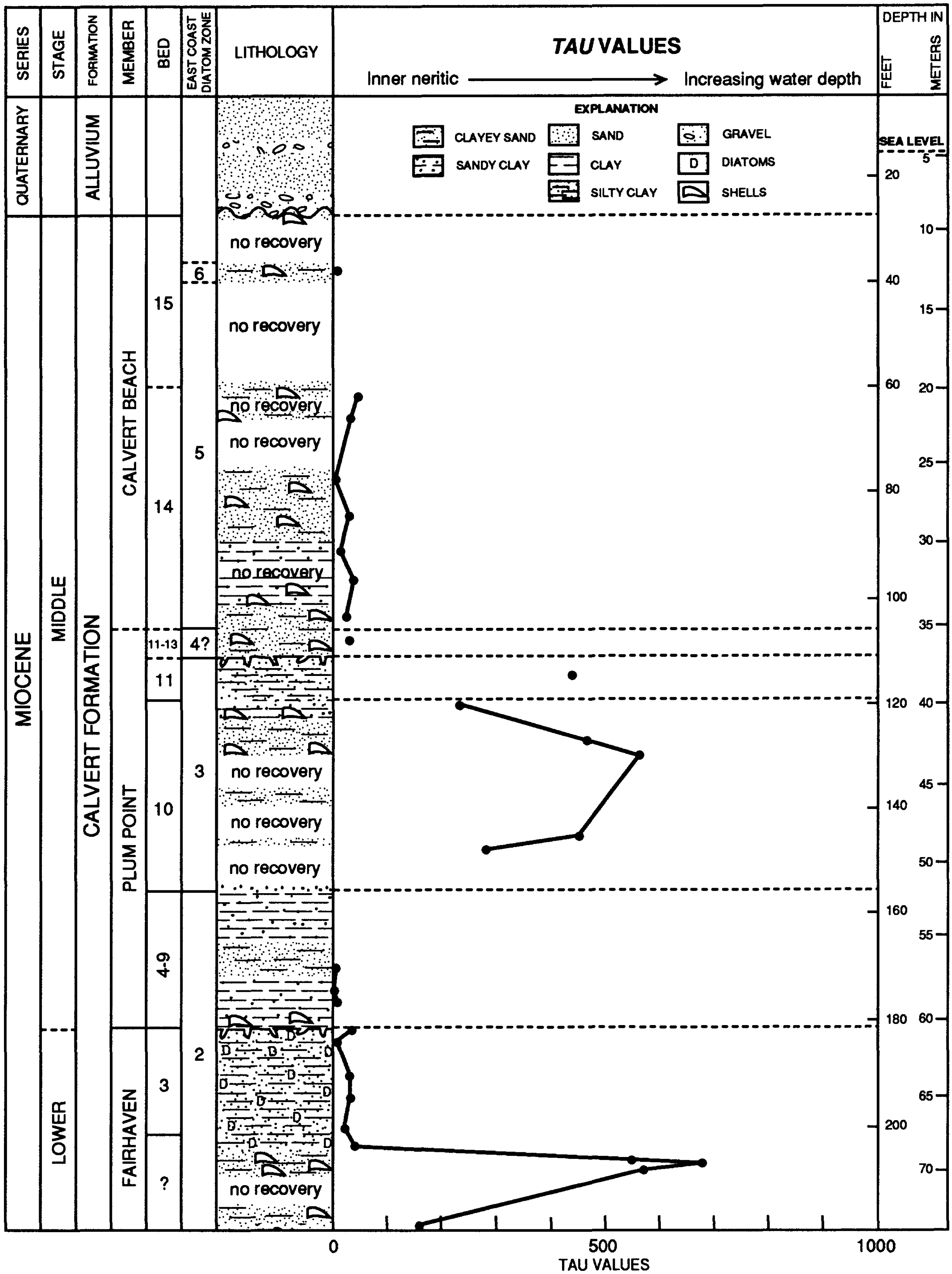

Figure 3. Stratigraphic column of Miocene strata of Solomons Island corehole (USGS well CA Gd 60) and *tau* values. Land surface elevation is 15 ft. Dashed lines represent cycle boundaries.

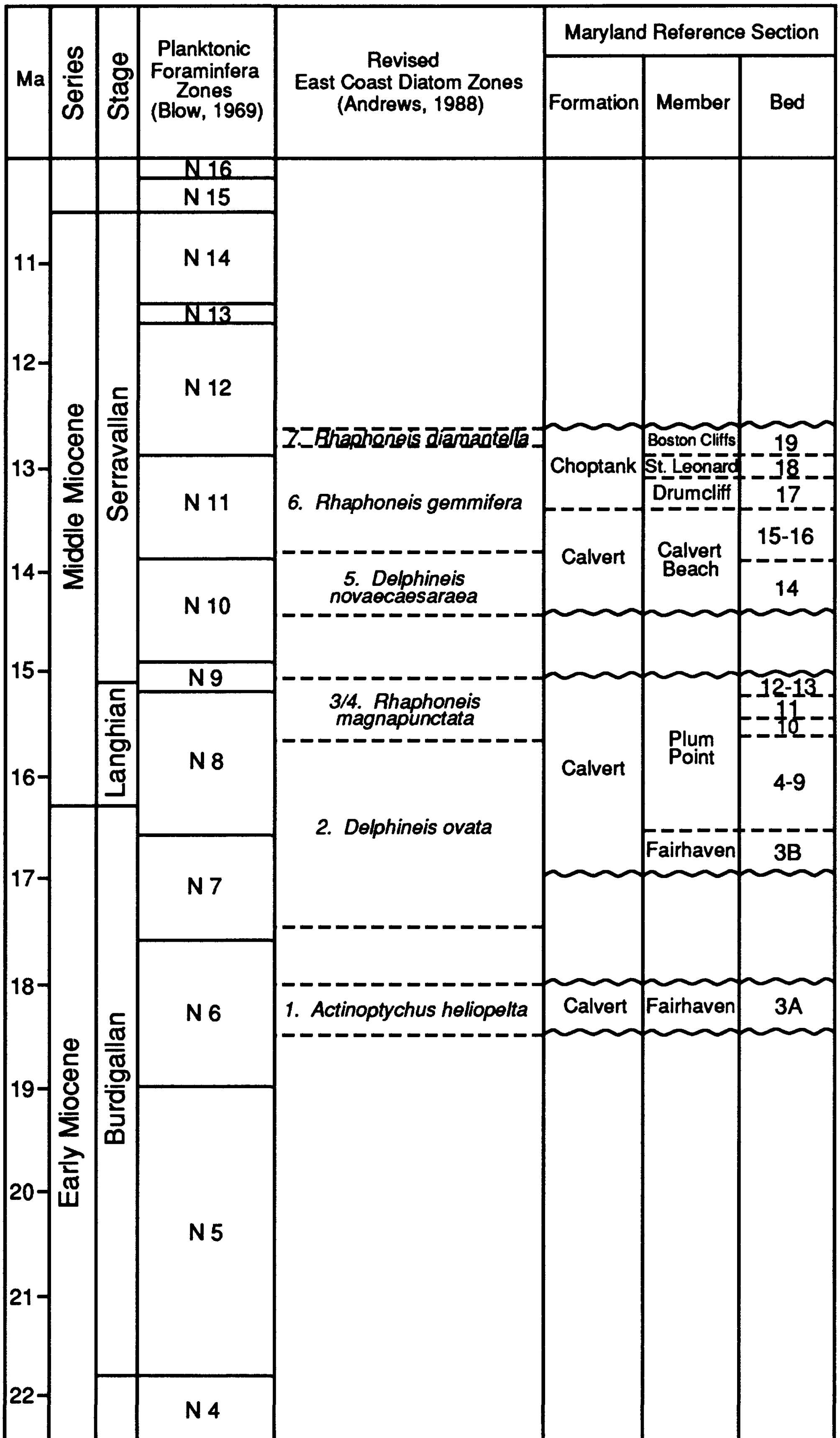

Figure 4. Correlation chart of lower and middle Miocene strata of central Salisbury embayment (from Andrews, 1988 and Wetmore and Andrews, 1990).

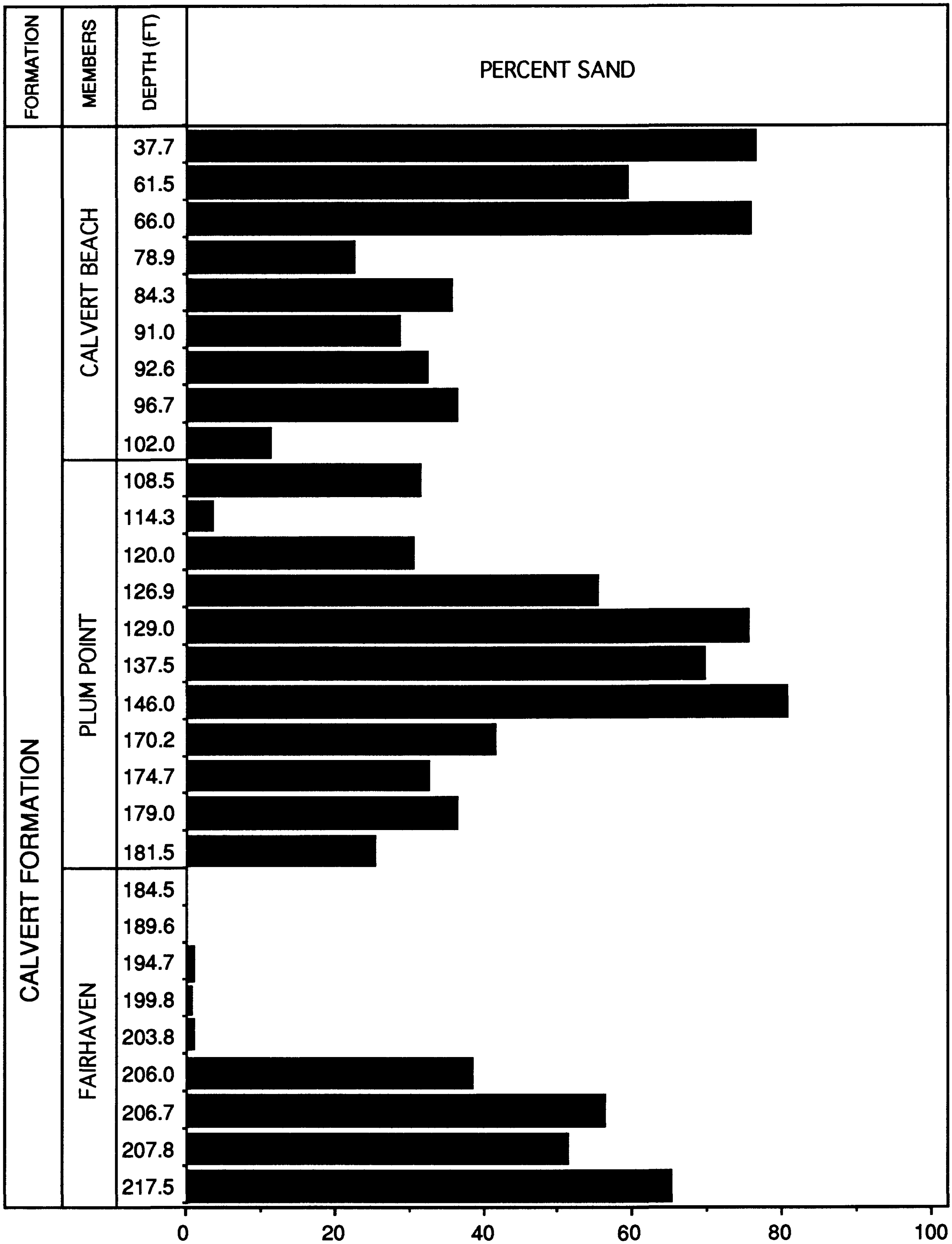

Figure 5. Percentage of sand in selected samples from Calvert Formation in Solomons Island Corehole.

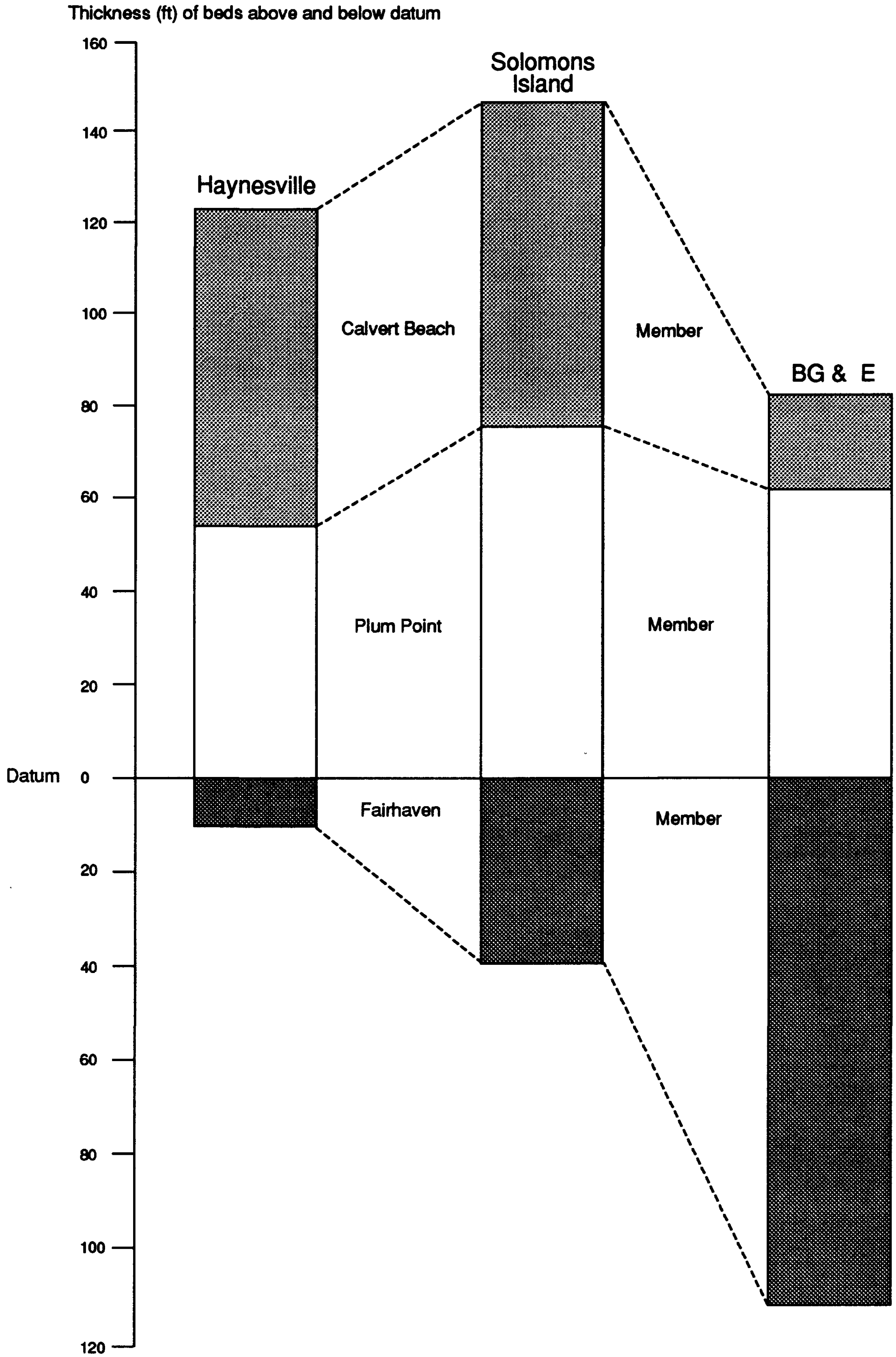

Figure 6. North-south stratigraphic cross-section showing thicknesses of the three Calvert Formation members in three coreholes.