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BOARD OF NATURAL RESOURCES
DEPARTMENT OF GEOLOGY, MINES, AND WATER RESOURCES
JOSEPH T. SINGEWALD, JR., *Director*

CRETACEOUS AND TERTIARY SUBSURFACE GEOLOGY

The Stratigraphy, Paleontology, and Sedimentology of Three Deep Test Wells on the Eastern Shore of Maryland

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PREFACE

This study of the Tertiary and Cretaceous Subsurface Geology of the Coastal Plain sediments of Maryland resulted from the drilling of three deep test wells for oil and gas on the Eastern Shore. Though sporadic test wells for oil and gas had been drilled in the Coastal Plain region of Maryland and in Western Maryland before, the explorations carried out by three major oil companies, the Ohio Oil Company, the Socony-Vacuum Oil Company, and the Standard Oil Company of New Jersey, during the years 1943 to 1946 were the first to utilize the most modern methods and techniques in oil-finding.

The Salisbury well and the Berlin well were drilled down to and into the basement complex, affording two complete sections of the Coastal Plain formations. The Ocean City well stopped just short of reaching the basement complex. The Salisbury well was the first one drilled. Since it was cored continuously from the depth of 1000 feet to the bottom at 5568 feet, this well furnished the most complete and accurate section. The core samples were supplemented by ditch samples over the entire depth. These samples and cores were given to the Department of Geology, Mines and Water Resources. Before the investigation of these samples was completed, the Berlin well was drilled to a depth of 7178 feet. Samples from this well, consisting of ditch samples over the entire depth and cores from a number of depths, were also given to the Department of Geology, Mines and Water Resources, providing a second complete geologic section of the subsurface of the Eastern Shore. The Ocean City well was drilled to a depth of 7710 feet before the investigation of the samples and the correlations of the first two wells were completed. The scope of the study was enlarged by the acquisition of ditch samples over the entire depth and side-wall core samples from this well, which provided a third geologic section of the subsurface of the Eastern Shore complete almost to the basement complex.

The investigation was carried out under the direction of Dr. Judson L. Anderson, Associate Professor of Geology at The Johns Hopkins University, who has had twleve years experience in all phases of petroleum geology. Dr. Anderson made a thorough analysis of the physical character of the sediments, determined their mineralogic content, interpreted and correlated the stratigraphy of the three geologic sections, and discussed their oil and gas possibilities. Dr. Robert M. Overbeck, Ground Water Geologist of the Department of Geology, Mines and Water Resources, participated in the physical analysis and sedimentary petrography of the samples from the Ocean City well and contributed to the interpretations from his knowledge of the subsurface geology of Eastern Shore water wells.

These materials offered such an unparalleled opportunity to advance the knowledge of the Cretaceous and Tertiary stratigraphy and paleontology of Maryland that Dr. John B. Reeside, Jr., Geologist in Charge of Paleontology and Stratigraphy of the United States Geological Survey, very generously arranged to have the fossils determined by the foremost paleontologic specialists of the United States Geological Survey. The Cretaceous mollusks were determined by Dr. Lloyd W. Stephenson, with the exception of a new fauna encountered in the Ocean City well which was described by Dr. Harold E. Vokes, who is also Professor of Geology at The Johns Hopkins University. The Tertiary mollusks were determined by Dr. Julia A. Gardner. The forams were determined by Dr. Joseph A. Cushman, who is also director of the Cushman Laboratory for Foraminiferal Research. A previous comprehensive study of the forams from the outcrop of the Maryland Miocene by Ann Dorsey (Mrs. Arthur W. Clapp) was utilized by Dr. Cushman and made available as a part of this report. The diatoms were studied by Mr. Kenneth E. Lohman and the ostracods by Mr. Frederick M. Swain.

Comprehensive reports on the stratigraphy and paleontology of the Tertiary and Cretaceous formations of the Maryland Coastal Plain were published years ago by the Maryland Geological Survey. They comprise a two-volume report on the Miocene in 1904, a report on the Eocene in 1901, a two-volume report on the Upper Cretaceous in 1916, and a report on the Lower Cretaceous in 1911. These reports concern the outcrops of the formations, and the correlations are based almost entirely on the macrofossils. The work was done before micropaleontology had been developed as an important basis for correlation, before sedimentary petrology had come into general use in stratigraphic interpretation, and before the needs of petroleum geology had turned the attention of geologists to subsurface investigations. This report serves, therefore, to supplement and make more complete the scope of these earlier systematic volumes.

An adjunct to this report and a further contribution to the knowledge of the Eocene stratigraphy of Maryland is an investigation by Dr. Elaine Shifflett of Eocene Stratigraphy and Foraminifera of the Aquia Formation, made in the Geological Laboratory of The Johns Hopkins University and published as Bulletin 3 of the Department of Geology, Mines and Water Resources.

To all of the above-named paleontologists, the Department of Geology, Mines and Water Resources is indebted for their valuable contributions to the completeness of this report.

JOSEPH T. SINGEWALD, JR., *Director.*

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CRETACEOUS AND TERTIARY SUBSURFACE GEOLOGY

BY

JUDSON L. ANDERSON

Scope of Report

With the entrance of the United States into the Second World War and the accompanying unrestricted submarine warfare against American shipping along the eastern seacoast, the consumers of petroleum and its products in this area were largely cut off from their source of supply. If petroleum could be found on the Eastern Shore of Maryland, the northern portion of the eastern seaboard would not be entirely dependent upon the Gulf Coast states and northern South America for their oil. Up to this period no thorough geological and geophysical studies had been conducted in this area, nor had an adequate test well been drilled. Since the general stratigraphy of Eastern Maryland is similar to that of the Gulf Coast of the United States, the Ohio Oil Company of Findlay, Ohio, one of the larger independent producers, conducted systematic studies over a portion of this region. Approximately 250,000 acres of private lands in Worcester and Wicomico counties were leased. The activity of this company soon attracted the attention of other companies, and leasing by the Pure Oil Company, the Shell Oil Company, the Sun Oil Company, the Sinclair Petroleum Company, the Socony-Vacuum Oil Company, and the Standard Oil Company of New Jersey followed.

The material collected by the Ohio Oil Company from its first well and representative samples from the well drilled jointly by the Socony-Vacuum and the Ohio Oil Companies were turned over to the Department of Geology, Mines and Water Resources for study. When the Standard Oil Company of New Jersey completed their Maryland Esso No. 1 well, they too gave to the State material for geologic studies. This report is a detailed account of the paleontology and sedimentology revealed by these samples and an application of the findings to an interpretation of the stratigraphy and petroleum possibilities of the Eastern Shore.

The report is divided into two parts. The first part contains the interpretation of the stratigraphy based on the sedimentary petrography and paleontology of the material from the three wells, followed by a discussion of the petroleum possibilities of the area. The second part contains the systematic paleontology based on a careful examination and study of all available material.

The participants in this study are all experts in their respective fields. The paleontologic investigations were carried out by Drs. Julia A. Gardner, Lloyd W. Stephenson, H. E. Vokes, Joseph A. Cushman, and Messrs. Kenneth E. Lohman and Frederick M. Swain. The sedimentary petrography was done by Dr. Judson L. Anderson. The examination of the cuttings from the Standard Oil Company of New Jersey's Maryland Esso No. 1 well was carried out by Dr. Robert M. Overbeck of the Maryland Department of Geology, Mines and Water Resources.

This comprehensive study of the subsurface geology of the Eastern Shore would not have been possible without the aid offered by the several oil companies. To the officials of the Ohio Oil Company who turned over the entire core and logs of their well, the Department of Geology, Mines and Water Resources is deeply grateful. Mr. Stanley B. White who was in charge of geologic operation for this company was extremely cooperative at all times in discussing geologic problems. Thanks are due to the officials of the Socony-Vacuum Oil Company and the Standard Oil Company of New Jersey for furnishing both samples and data from their wells. The author has also derived benefit from the discussions of geologic problems with Mr. K. D. White, geologist-in-charge of the Standard Oil Company of New Jersey's operations on the east coast, and Mr. W. B. Spangler who was geologist-in-charge at the Maryland Esso well. The Standard Oil Company of New Jersey also submitted to the Department of Geology, Mines and Water Resources of Maryland a report on the subsurface geology of the Atlantic Coastal Plain of Maryland by Mr. Walter B. Spangler. This report contains seventeen plates consisting of structure and isopach maps and cross sections, together with a text covering the interpretation of the work on the Eastern Shore of Maryland. Although the above report was submitted after this report was written, considerable benefit was derived from its contents. Thanks are also due to the Standard Oil Company of New Jersey for supplying the base map from which Figure 24 was prepared. Mr. R. W. Bishop of the Socony-Vacuum Oil Company also rendered aid in the discussion of geologic problems. Dr. John B. Reeside, Jr., of the U. S. Geological Survey, showed a keen interest in the paleontologic problems and arranged for the paleontologic studies. Dr. Joseph T. Singewald, Jr., director of the Maryland Department of Geology, Mines and Water Resources, is primarily responsible for the undertaking of this study. He recognized its importance and has rendered his support towards its completion.

PHYSIOGRAPHY

The State of Maryland is divided into three physiographic regions. They are from west to east, the Appalachian Mountains, the Piedmont Plateau, and the Coastal Plain. The Appalachian Mountain region has been carved from steeply folded beds of Paleozoic sandstone, shale, and limestone and is composed of flat-topped ridges which are separated by deep and flat-bottomed valleys. The Piedmont Plateau consists of metamorphosed sedimentary and igneous rocks penetrated by later acid and basic intrusives. The Coastal Plain is composed of the youngest sediments which consist of unconsolidated sands, gravels, clays, and marls. The sediments have been derived from the old land surface to the west.

This report deals with the Coastal Plain region, particularly the area of Worcester and Wicomico counties. This area is characterized by a featureless plain, with highest elevation in the central portion about 80 feet above sea level. It is cut by several fairly large rivers and innumerable small streams and is blanketed by terrace sands and gravels of Pleistocene age.

GEOLOGY

BASEMENT COMPLEX

The eastern margin of the Piedmont Plateau strikes in a northeasterly direction, extending from the vicinity of Washington, D. C., through Baltimore, and crossing the Susquehanna River near Perryville. The surface of the basement rock dips eastward and southeastward and provides the floor on which the younger sediments have been deposited.

The rocks of the Piedmont have had a complex history. They are composed of ancient sediments and igneous rocks that have been so highly altered through metamorphism that little of their original character remains. They now appear as schists of a wide variety, quartzites, marbles, and gneisses of both sedimentary and igenous origin. Into this old complex have been intruded granites, pegmatites, quartz veins, gabbros, peridotites, diorites, and diabase dikes. These intrusives have also suffered varying degrees of metamorphism. Two of the deep tests on the Eastern Shore encountered the basement rocks.

CRETACEOUS

Deposits of Cretaceous age crop out in a belt which varies in width from approximately 6 to 18 miles on the western shore of Chesapeake Bay and which trends in a northeast-southwest direction. These sediments have been divided into two parts, the Lower Cretaceous or Potomac Group, and the Upper Cretaceous.

Lower Cretaceous

The Potomac Group has been described in the publications of the Maryland Geological Survey as consisting of three formations known as the Patuxent, Arundel, and Patapsco. These formations are said to be unconformable to each other and also to the overlying and underlying formations (14, p. 28). On the basis of fossils from the Maryland Esso well, Vokes considers the Arundel and Patapsco formations to be of Upper Cretaceous, Cenomanian, age (Fig. 1).

The Patuxent formation on the outcrop consists essentially of cross-bedded, angular, feldspathic, and at times gravelly sands and cobbles. Clays are of much less importance than the sands. They are either white or possess mottled shades of purple, red, brown, maroon, and lavender. Lignite and carbonaceous matter have been reported from the outcrop, and the clays associated with them are usually black.

Overlying the Patuxent unconformably and apparently occupying Post-Patuxent drainage lines is the Arundel formation. This formation consists of "drab, more or less lignitic clays, carrying nodules, geodes, flakes, and ledges of earthy iron carbonate or siderite" (14, p. 64). Pyrite and gypsum are reported from these clays. The strata of the Arundel consist for the most part of "widely extended beds or lenses of clay with included beds of lignite and iron ore." Both plant and animal remains are known from the Arundel. The thickness varies from a few feet to about 125 feet, and it apparently thins seaward.

The Patapsco formation, the uppermost formation of the Potomac Group, overlies the Arundel formation unconformably. It contains lenses and beds of slightly arkosic sands and some gravels. Clays are more abundant in the Patapsco than in the Patuxent. They are characterized by their red, drab, and chocolate colors and frequently grade into sandy clays, gravels, and sands. Lignite and fossil resin are found occasionally. The thickness of the Patapsco is variable, the formation ranging upwards to 260 feet on the Western Shore. A poorly preserved fauna and an extensive flora are known from the Patapsco.

Upper Cretaceous

The Upper Cretaceous deposits of Maryland, as previously described, comprise the Raritan, Magothy, Matawan, and Monmouth formations, which form an apparently unconformable series which rests unconformably on the Patapsco formation.

The Raritan formation consists largely of white to buff sand, more common in the upper part of the formation, and variegated or white, drab, and pink clays. The strata change rapidly in character both laterally and vertically. The sands are occasionally coarse-grained and gravelly and occur as irregular lenses at various horizons. This mode of occurrence is also characteristic of the sandy clays and clays.

The maximum thickness of the Raritan on the outcrop probably does not exceed 250 feet, but this thickness decreases to about 50 feet in the southern part of the state. The Raritan beds have yielded both plant and animal remains.

The Magothy formation differs from the underlying Raritan in that it consists largely of light-colored sands which are at times coarse-grained and conglomeratic. The clays which are subordinate to the sands are usually gray or chocolate-brown in color. The dark-colored clays frequently carry finely-divided lignite. Alternating thin lamellae of sandy clay or clay and fine sand are also found. It is not uncommon to encounter leaf impressions and amber in these beds. A characteristic feature of the sands of the Magothy is the presence of pink, angular quartz, and at times much muscovite. The deposits of the Magothy, like those of the Raritan, vary both horizontally and vertically. A poorly preserved fauna, but a rich flora, has been reported from the Magothy. The thickness of this formation varies from about 10 feet to approximately 100 feet.

Unconformably overlying the Magothy formation is a series of dark-colored sandy clays and white to greenish-black sands which are referred to the Matawan formation. The color of the clays varies from light shades to black, and glauconite grains are not uncommon. The stratified character of the beds of the Matawan over extended areas contrasts with the variable lithology of the underlying formations. The thickness of the Matawan varies from 70 feet in the northern part of the Coastal Plain to 50 in the central portion, finally disappearing south of the Patuxent River. The Matawan beds have yielded only animal remains.

The Monmouth formation overlies the Matawan unconformably and consists chiefly of dark, glauconitic, green sand which at times assumes a pinkish to reddish color, probably due to the weathering of the glauconite. Alternating clays and sands and beds of clay so common to the Matawan are usually absent in the Monmouth. It is difficult to distinguish the unfossiliferous Monmouth lithologically from the overlying Aquia formation of the Eocene. The maximum thickness of the Monmouth formation is about 100 feet in the northern portion of the Eastern Shore. It thins to the southwest to about 20 feet in the central part of Prince Georges County and gradually disappears. The beds of the Monmouth are remarkably homogeneous over wide areas.

TERTIARY

Eocene

Extending southwesterly from where they enter the Eastern Shore of Maryland in Kent County is a series of deposits which, on the basis of the fauna, are referred to the Eocene. These deposits are exposed along the Chester River in Kent County, along the Magothy, Severn, South, and West Rivers in Anne Arundel County, along the Potomac River in the southwestern portion of Charles County, and in the bluffs on the Virginia side of the Potomac River. The Eocene overlies the beds of the Upper Cretaceous unconformably and is in turn unconformably overlain by the Miocene. On the basis of the fauna, the Eocene is divided into the Aquia and the Nanjemoy formations. These two formations comprise the Pamunkey Group. They are each divided into two members, the Piscataway and the Paspotansa of the Aquia and the Potapaco and the Woodstock of the Nanjemoy.

The Aquia formation is characterized by abundance of dark-green glauconite. The lowermost beds are usually argillaceous, but the remaining portion of the formation, with the exception of four hard, indurated limy bands, is composed of "greensand." The Aquia is richly fossiliferous along both Aquia and Potomac Creeks. The thickness of the Aquia is about 100 feet.

The Nanjemoy formation also contains an abundance of glauconite but on the whole is more argillaceous than the underlying Aquia and is less frequently calcareous. Certain beds are reported to contain abundant crystals and masses of gypsum. The base of the Nanjemoy is marked by a cinnamon-brown clay. The thickness of the Nanjemoy is about 125 feet.

Miocene

The deposits of Miocene age occur to the southeast of those of the Eocene and overlie these deposits unconformably. Beds of Miocene age are divided into three well-defined formations which, from the oldest to the youngest, are the Calvert, the Choptank, and the St. Marys. These three formation comprise the Chesapeake Group, named from well-exposed sections along the shores of Chesapeake Bay.

The Calvert formation is divided into two members, the lower known as the Fairhaven Diatomaceous Earth and the upper the Plum Point Marls. The Fairhaven member contains sands at its base overlain by diatomaceous earth which is greenish-gray when fresh and white and buff when weathered. The overlying Plum Point Marls consist of a series of bluish-green to grayish-brown and buff sandy clays and marls. Fossil remains are abundant. Since the Calvert is truncated by the overlying Choptank formation, its full thickness has nowhere been observed.

The Choptank formation which overlies the Calvert unconformably is composed of fine, yellow sand, bluish-green sandy clay, gray clay, and occasional ledges of indurated rock. The thickness of the Choptank is quite variable, the maximum measured being 50 feet.

The St. Marys formation overlies the Choptank unconformably and is composed of greenish-blue, fossiliferous sandy clay, clay, and sands. The thickness varies from nothing to approximately 280 feet. The formation is unconformably overlain by clays, sands, and gravels of the Pleistocene.

PLEISTOCENE

Overlying the Miocene is a series of gravels, sands, clays, and peats of Pleistocene age called the Columbia Group. The deposits form rather well-defined terraces. The Columbia Group is divided into the Brandywine, the Sunderland, the Wicomico, and the Talbot formations in the publications of the Maryland Geological Survey. Cooke (17) has defined more elaborately the terrace formations in the southeastern part of the United States as follows:

Brandywine terrace	270 above sea level
Coharie "	215 " " "
Sunderland "	170 " " "
Wicomico "	100 " " "
Penholoway "	70 " " "
Talbot "	42 " " "
Pamlico "	25 " " "

On the basis of Cooke's work the Pleistocene of the Eastern Shore includes the four terraces extending from the Pamlico through the Wicomico.

HISTORY OF PETROLEUM EXPLORATION IN MARYLAND

The search for petroleum on the Eastern Shore of Maryland may be considered to have had its beginning at the turn of the present century. Shallow wells of less than 100 feet in depth in the vicinity of Parsonsburg and Pittsville encountered gas which was used as fuel (15, p. 320). In every instance the supply exhausted itself within a period of two years. The gas encountered in these wells was high in nitrogen (77.96%) and low in methane (19.86%). It was concluded that the gas had its origin in a buried swamp of local distribution. No gas was reported below these shallow depths.

In 1914, the Wicomico Gas and Oil Company was organized, and stock was sold to promote a proposed drilling campaign in the vicinity of Parsonsburg. This company drilled a well which was abandoned in quicksand at a depth of 500 feet (75). In 1917, the St. Martins Oil and Gas Company completed the second well in the area at a depth of 1186 feet. The well is reported to have ended in the basal portion of the Miocene Calvert formation. Gas, doubtless similar to that of the early shallow wells, was encountered in both of the Parsonsburg wells, and "direct evidence" of oil in the form of "slightly petroliferous clays" was reported by Bibbins (75) in the St. Martins Oil and Gas Company's well. No oil-bearing sands were penetrated, and the waters encountered in the sands were reported to be brackish and highly mineralized.

In 1914, another attempt to strike oil on the Eastern Shore of Maryland was made by the Isle of Wight Oil Company. A well was drilled to the depth of 1706 feet on the Isle of Wight, north of Ocean City, and ended in the Calvert formation without encountering shows of petroleum. Several water horizons were passed through, and an extensive flow of mineralized artesian water was struck at 1700 feet. No further attempts were made to locate petroleum in the eastern part of the State until 1942.

Deep water wells have been drilled in various counties of the Eastern Shore, but none have reported shows of oil or gas. These wells located in Somerset, Dorchester, Talbot, and Kent Counties bottom in both the Upper and Lower Cretaceous.

In December, 1942, the Ohio Oil Company started extensive geophysical work in both Wicomico and Worcester counties. Their activity attracted the attention of other major oil companies with the result that all available land was under lease and was being explored. The Shell Oil Company did gravimeter work in the southern portion of the Eastern Shore, and the Pure Oil Company had a seismic crew working in southern Delaware.

As a result of the intensive geophysical investigations, two wells were drilled, one in 1944 by the Ohio Oil Company on the farm of Larry G. Hammond, approximately six miles east of Salisbury on the Mt. Hermon road, and the second a joint venture by the Socony-Vacuum Oil Company and the Ohio Oil Company in 1945 on the property of James D. Bethards, approximately five miles southwest of Berlin. Both of these wells failed to encounter oil or gas although both penetrated into the basement complex.

A third well, known as Maryland Esso No. 1, was drilled by the Standard Oil Company of New Jersey $4\frac{1}{2}$ miles north of Ocean City, on the west side of the Ocean City-Rehoboth highway. The well, started in October 1946, was completed in December 1946 at a total depth of 7710 feet. This venture was also a dry hole, no oil or gas sands having been penetrated.

With the failure of these three undertakings, further oil explorations ceased on the Eastern Shore.

In the 1930's, three wells were drilled in Delaware. The Sun Oil Company drilled two wells near Bridgeville, one to a depth of 2600 feet and the other to a depth of 2674 feet. Neither well reached the basement complex, and neither reported any shows of oil or gas. Another well in the Bridgeville area was drilled by the Cleveland Petroleum Corporation of Cleveland, Ohio. This well reached a depth of 3010 feet and possibly encountered the basement complex. No indications of oil or gas were reported.

Exploration for petroleum has been carried on in other sections of Maryland. A well was drilled to a depth of 1511 feet for oil and gas in Prince Georges County, one mile south of Meadows and ended in a failure. Four wells were drilled in Garrett County in Western Maryland by the New Penn Development Company to test the Paleozoic rocks. They were located a short distance west of Accident. None proved successful, although carried to depths ranging from 7000 to 8100 feet. Production of gas from the Paleozoic section in West Virginia immediately adjacent to Garrett County led the Columbia Carbon Company in June, 1947, to drill a cable tool well for gas 9 miles southwest of Oakland and $1\frac{1}{2}$ miles southwest of Redhouse. This well was abandoned as a dry hole at 5259 feet in December, 1947.

The Ohio Oil Company's Larry G. Hammond Well No. 1

INTRODUCTION

Preliminary Work

In December 1942, the Ohio Oil Company began leasing on the Eastern Shore. A total of approximately 250,000 acres were leased in Wicomico and Worcester counties.

Contract geophysical personnel, consisting of a seismograph party and a magnetometer party, under the supervision of Mr. Stanley B. White of the Ohio Oil Company, were brought in. The cost of this survey is reported to have been of the order of $10,000.00 a month. The purpose of the survey was to map the configuration of the basement rocks upon which sands and clays of the younger formations have been deposited and determine if possible whether structures favorable for oil accumulation existed in these younger formations.

Upon the basis of the geophysical surveys, the site for the first well was located on the farm of Larry G. Hammond, approximately six miles east of Salisbury, on the south side of the Mt. Hermon road. Drilling began on October 12, 1944.

Method of Drilling and Sampling

The Larry G. Hammond well was drilled by contract, and the rotary method of drilling was used. The drilling rig was powered by diesel engines and was capable of penetrating to a depth of at least 10,000 feet. Surface casing was set at 500 feet but no other casing was run into the hole. The elevation of the derrick floor was estimated to be 70 feet above sea level.

The rotary method of drilling utilizes specially treated mud to lubricate the bit, which is turned by drill-pipe lowered into the hole, to carry the cuttings produced by the bit to the surface, and to form a protective coating on the walls of the open hole in order that seepage of drilling fluid into the formation is reduced to a minimum. The drilling mud is pumped downward inside the drill pipe, and as it returns to the surface on the outside of the drill pipe it carries with it cuttings of the rocks penetrated. These cuttings, known as ditch samples, yield a geological record of the formations penetrated. Ditch samples were collected every 10 feet from the surface to the bottom of the hole in the Hammond well.

Ditch samples, due to contamination by material falling in from higher levels, are not as useful as core samples. These are cylindrical samples of the beds penetrated and are free of contamination. Coring necessitates considerable time and slows up the completion of a well. Core samples may be secured by one of three methods. First by coring until the core barrel is filled and removing the core by withdrawing the entire string of drill pipe. The core barrel and drill pipe are then run back into the hole for further coring or drilling.

The second method does not require the removal of the drill pipe but only the inner core barrel. While the core is being extracted, a second core barrel is run back inside the drilling pipe and coring continues. The second method saves considerable time in drilling. The third method secures samples of the formation by electrically discharging a small cylinder into the walls of the hole and extracting a cylindrical sample measuring approximately 1 inch in length by $\frac{1}{2}$ inch in diameter. This method is usually employed after an electrical survey of the drill hole has been made in order to secure additional information. The Ohio Oil Company took continuous cores by the second method from 1000 feet to approximately 5500 feet and by the first method from this depth to the bottom of the hole at 5568 feet.

After the well was completed a deviation survey was made, the results of which are presented in Table 1.

The samples from the Hammond well yielded the first complete geologic section on the Eastern Shore of Maryland and made possible a study of the stratigraphy, paleontology, sedimentary petrography, and economic possibilities of the Coastal Plain formations far removed from their outcrop areas.

STRATIGRAPHY AND PALEONTOLOGY

Basement Complex

The top of the basement complex in the Hammond well is characterized by the presence of a rotten schistose rock containing mica, chlorite, and feldspar and cut by small veins of pegmatite in which the feldspars are almost entirely decomposed. The top of this metamorphic horizon is at 5498 feet. The lack of core recovery between this point and 5529 feet, where the first fresh core was obtained, suggests a weathered zone approximately 31 feet in thickness. The total penetration below the top of the metamorphic rock was 70 feet.

The fresh core consists of either a biotite-rich quartzite or a mica gneiss. It is cut by veins of pegmatite containing pink orthoclase and white silicates. There is evidence of hydrothermal alteration in the bleached character of the rock and the formation of yellow epidote and pyrite. Iron garnets are occasionally present. A foliation runs roughly parallel to the length of the core.

Microscopically the rock has a granoblastic structure with a few porphyroblasts of mica and quartz. In the rock unaffected by pegmatite intrusions the following minerals were noted:

Quartz, containing numerous unoriented inclusions with index of refraction less than that of the host and also a few zircon inclusions. The quartz grains show a preferred orientation, possess a pronounced undulatory extinction, and contain in a few instances Boehm lamellae. The individuals are rounded to subangular and of more or less the same size.

Plagioclase feldspar is small and similar to quartz. It is usually untwinned, although a few Carlsbad twins were noted. The extinction angle

TABLE 1

Summary of Deviation Tests Made on Ohio Oil Company's No. 1 L. G. Hammond Well, Wicomico County, Maryland

Depth in Feet	Deviation Angle	Depth in Feet	Deviation Angle	Depth in Feet	Deviation Angle
110	¼°	2917	2½°	4050	1° 50 Min.
230	30 Min.	2949	2°	4230	2° 50 Min.
350	0°	2979	2°	4250	10 Min.
500	5 Min.	2980	4½°	4260	3° 10 Min.
750	30 Min.	3010	2½°	4288	3°
1000	30 Min.	3035	¾°	4321	2¾°
1350	1½°	3065	1° 40 Min.	4345	2¼°
1500	1¼°	3128	1½°	4381	2¾°
1750	50 Min.	3159	1¼°	4410	2°
2000	1½°	3192	2°	4445	2° 10 Min.
2097	1¼°	3255	2½°	4475	1° 50 Min.
2250	2½°	3272	50 Min.	4505	2°
2315	1¾°	3280	1° 50 Min.	4535	2°
2362	2¼°	3310	¾°	4587	2°
2420	2°	3345	1¾°	4616	2°
2487	3°	3375	1°	4645	1¾°
2454	1½°	3405	¾°	4675	2¼°
2465	2°	3435	1°	4792	1¾°
2484	2° 20 Min.	3465	1°	4829	1¾°
2486	3°	3537	2°	4859	1¾°
2487	2°	3565	1° 40 Min.	4900	1° 40 Min.
2495	3°	3596	2°	4930	1° 30 Min.
2500	3¼°	3617	1¾°	4950	1°
2515	3°	3739	2°	4980	1° 10 Min.
2557	4°	3780	2° 10 Min.	5045	50 Min.
2611	4°	3803	1¾°	5100	10 Min.
2637	3° 25 Min.	3833	2°	5170	10 Min.
2702	3°	3865	3° 10 Min.	5263	10 Min.
2753	2° 45 Min.	3895	1° 30 Min.	5300	10 Min.
2762	4°	3950	1° 10 Min.	5352	40 Min.
2827	1¾°	3955	2°	5418	1°
2857	2½°	3995	1° 50 Min.		
2887	1¾°	4020	1¾°		

measured against the (001) cleavage indicates an albite with composition near the dividing line between albite and oligoclase. Optically it is biaxial positive, with 2 V about 85°, and has pronounced dispersion. The plagioclases of the veins have a different composition from those of the host rock. On the universal stage, and employing the Rittmann method, they yielded extinction angles varying from 15°–20°, indicating a plagioclase with composition varying from Ab_{70}–Ab_{60}. They are frequently twinned after the albite law, with occasional complex albite-pericline twins.

Orthoclase occurs as small individuals and has clouded appearance. In the veins, it occurs as large anhedral masses showing extreme alteration to minute scales of sericite.

Biotite is of two types, small oriented flakes which give the rock a foliation and the large cross-cutting porphyroblasts. The crystals are pleochroic from deep chestnut-brown to colorless and have a 2 V which is almost zero. They are occasionally altered to chlorite along cleavage planes. The interference colors of the chlorite vary from deep-blue to tan.

Amphibole is of the deep-green variety and is anhedral. Inclusions of quartz, titanite, and a black opaque mineral, probably ilmenite, are numerous. Where the amphibole is in contact with orthoclase a small reaction rim has been developed, and chlorite occurs occasionally along cleavage cracks. Four crystals measured on the universal stage yielded the following constants:

2V	Z ∧ C	(110) ∧ $(1\bar{1}0)$
(−) 74°	19°	124°
(−) 78°	11°	124°
(−) 82°	13°	124°
(−) 70°	15°	125°

Winchell's table of the calciferous amphiboles (124, pp. 38–39, 42–43) shows minerals having constants similar to these. The striking feature of these data is that in nearly every instance the amphiboles contain a moderately large amount of alkalies and titanium. These elements are doubtless responsible for the large optic angles. The hornblende is considered to be the product of contact metamorphism.

A small amount of colorless pyroxene, showing in nearly every crystal a well-developed basal cleavage, is present in the vein portion of the rock. A universal stage determination of this mineral yielded the following constants.

2V	Z ∧ C	(110) ∧ $(1\bar{1}0)$
(+) 74°	50°	83°
(+) 72°	52°	86°

Judith Weiss (85, p. 1197) reports diopside from these rocks. The large optic angle and extinction angle of the minerals examined do not fit Winchell's data (123) for diopside. The properties more nearly fit those of augite, especially that variety in which TiO_2, Al_2O_3, and Fe_2O_3 are present. These oxides, according to Winchell (123, p. 230), increase the extinction angle, and the presence of alkalies increases the size of the optic angle. This mineral is a product of contact metmorphism, and all the elements necessary to effect the changes described occur in both the country rock and the veins.

Another interesting mineral formed as a result of contact action is scapolite. The grains are anhedral, colorless, are associated with pyroxene and amphibole in the veins, and possess a well-developed rectangular cleavage. Optically, they are uniaxial negative. The retardation was measured on the universal stage by placing the optic axis in a horizontal position and using a Bereck compensator. A value of 1155 mμ was obtained, indicating a scapolite whose composition according to Winchell (123, p. 294) is that of dipyre (40% meionite —$Ca_3Al_6Si_6O_{24} \cdot CaCO_3$ and 60% marialite—$Na_9Al_3Si_9O_{24} \cdot NaCl$).

Other introduced minerals are titanite, calcite, pyrite, bluish-green tourmaline, myrmekite, and garnet. Clinozoisite occurs in small amounts and results from contact action.

The mode of the least affected country rock is:

Quartz	54%
Plagioclase	17%
Orthoclase	2%
Biotite	21%
Calcite	5%
Apatite	0.4%
Chlorite	0.2%
Hornblende	0.3%
Titanite	0.3%

The mineral composition and texture of the country rock strongly suggests that it is a metamorphosed quartz-rich sediment. Rocks of this type are to be found in the Baltimore gneiss complex and are also similar to the Setters quartzite and Wissahickon schist. It is impossible to say to which of these formations the basement rock of the Hammond well belongs. Contact action as described above is commonly encountered in the Piedmont rocks, the composition of the resulting minerals depending upon the composition of the country rock.

Triassic

Newark Series

At 5363 feet, a hard, indurated quartz conglomerate containing some white feldspars and lime cement was encountered. Approximately 30 feet above this horizon the beds are hard, dark-gray shale and sandy shale and are occasionally mottled with predominating maroon tones. Above this interval the sediments are soft and only partially consolidated. Below the conglomerate the sediments are hard, reddish-brown and apple-green shales, sandy shales, and sandstones. The sandstones are medium to very coarse grained and arkosic. No fossil remains were found in these beds.

This series of beds is referred to the Triassic purely on the basis of lithologic similarity to the known Triassic of Maryland. The presence of the conglomerate at the top of the interval and the general hard, indurated character of sediments in contrast with the softness of the unconsolidated sands above precludes their being lowermost Cretaceous. The thickness of the Triassic in the Hammond well is 135 feet. No Triassic is found on the Western Shore where the Cretaceous wedges out against the metamorphics of the Piedmont.

Cretaceous

Lower Cretaceous

Patuxent Formation.—The Patuxent formation is thought to extend from 4424 to 5363 feet, a thickness of 939 feet. The top of the formation is marked by a break which is reflected both in the sedimentation and the mineralogy (Figs. 3 and 5). Deep-green sandstone with a silty glauconite matrix, and deep-green shale with some sand and shale pebbles together with laminated drab shales and very fine sands immediately overlie the Patuxent sands.

The Patuxent formation consists essentially of fine to very coarse and at times gravelly soft, white, occasionally limy, arkosic sands (Fig. 10). These sands are relatively poorly sorted, approximately 73% of those tested had a sorting factor between 1.50 and 2.00 and 4% between 2.25 and 2.75 (Fig. 6). The median diameter falls within the medium-grained class in 63% of the tests (Fig. 4).

The shales and sandy shales are usually lead-gray in color, hard, compact, and frequently mottled red, brown, yellow, purple, and green. Lignite and carbonaceous matter are fairly common (Fig. 10). Occasionally thinly laminated sandy shale and very fine grained sand are encountered. At 5027–5032 feet, a good core dip of 7 degrees was measured.

The top of the Patuxent is marked by an increase in the sorting factor and by a pronounced change in the mineralogy. These two factors indicate a break in sedimentation at the top of the Patuxent and serve to separate it from the overlying beds.

Upper Cretaceous

Patapsco-Arundel Section.—It is impossible to recognize the equivalent of the Arundel formation in this well. On the outcrop, the Arundel contains drab lignitic clays with ironstone nodules and varies in thickness from a few feet to about 125 feet. No portion of the section has these characteristics, and it is considered that the Arundel has lost its identity as it passes eastward. For this reason, the beds overlying the Patuxent formation are referred to the Patapsco-Arundel without attempting to differentiate between them. (See Vokes, this report p. 129.)

The Patapsco-Arundel section is predominately a sandy section but contains considerably more clay shale and sandy shale than the underlying Patuxent. The sands are very fine and medium-grained with coarse and gravel sizes appearing below 3800 feet. A total of 55% of the samples contain sand with median diameter in the fine sand class and 39% in the medium sand class. The color of the sands is predominately white, although occasionally olive-green. Very few kaolinized feldspars were noted.

The shales and sandy shales vary considerably in color (Fig. 10). In the uppermost 100 feet the colors are brown and lead-gray, brownish-black, and pale and dark cinnamon-brown. These are followed by highly variegated shales whose colors are olive-green and mottled gray, red, brown and green. These mottled colors continue to approximately 3950 feet, below which depth they tend to disappear and their place taken by shades of olive-green and gray.

No fossil remains were found from this portion of the section. Carbonaceous matter and lignite are sporadically present throughout the entire interval. Glauconite was found only at 3280–3285 feet.

The top of the Patapsco-Arundel section is placed at 2313 feet. Immediately above this point, the shales are dark-gray to black, whereas below olive-green shades predominate. Sands are present above and shales are common below. A change in mineralogy is also noted at this point. The thickness of the Patapsco-Arundel interval is 2111 feet.

The preceding boundaries and thicknesses of the formations of the Potomac Group are at variance with those given by Richards (85). He gives the limits for the Patapsco formation as 2267–2375 feet, for the Arundel as 2375–2560 feet, and for the Patuxent as 2560–2925 feet. He further comments that these thicknesses correspond with those found on the outcrop. This is not a valid reason for dividing the section, since all formations are thickening toward the east and lithologic correlations are not possible. It is unlikely that the formations would retain their thicknesses from the outcrop to the sites of the deep wells, and all of the section below 2925 feet in the Hammond well would be unrepresented on the outcrop. Detailed sedimentation and mineral studies reveal breaks in the Hammond section which can be picked in the other two deep wells. There is also a suggested correlation between the uppermost beds of the Patuxent formation as described in this well and those of the outcrop. This point will be discussed at length later.

Raritan Formation.—The Raritan of the Hammond well is characterized by the presence of clays and sandy clays with subordinate very fine grained sands. The upper 100 feet of the formation contains cinnamon-brown to dark brownish-black and lead-gray clays and sandy clays with occasionally interlaminated very fine white sand. Lignite and carbonaceous matter are common. Between 1700 and 1924 feet the color of the sediments changes from the shades of brown and gray above to pale green and olive-gree with brown and red mottling. Very fine grained gray and white carbonaceous sands are fairly abundant. From 1924 to 2150 feet the section is predominantly shaly, and the color has changed to pale gray with red and brown mottling. From 2150 to 2313 feet, mottled shales are very subordinate or lacking, and the colors are olive-green, lead-gray, and pale gray. Carbonaceous matter is sporadically present in this portion of the section, and very fine grained sands are well developed.

The Raritan formation extends from 1588 feet to 2313 feet, a thickness of 725 feet. This is a large increase over the maximum of about 250 feet measured on the outcrop.

Both macro-fossils and ostracods were found in the Raritan section. Stephenson notes *Breviarca* sp. (aff. *Trigonarca cliffwoodensis* Weller) "*Corbula*" aff. *C. manleyi* Weller and *Fulpia wicomicoensis* (Richards)? (95) from the depths 1588–1598 and 1598–1603 feet and suggests a correlation of this fauna with the Raritan of New Jersey. Gastropods referred to "*Cerithium* sp.," an undescribed form, were abundant in the above intervals. A poorly preserved fauna from the interval 2250–2257 feet, including *Breviarca*?, *Brachidontes*, and "*Cerithium*" (see descriptions by Stephenson, this report), suggests a faunal relationship with the Raritan. Stephenson commenting on the thickness of the interval between these fossil horizons says that the lower horizon "if not Raritan, it probably is a shallow marine or brackish-water facies of one of the formations of the Potomac group (Lower Cretaceous)." On the basis of sedimentation and mineral content this interval is placed in the Raritan formation.

Only one ostracod specimen, *Leguminocythereis*? *pustulosa*, n.sp., was found in the interval 1588–1598 feet by Swain.

One grain of amber 4 mm. in length was reported by Stephenson in the sample from 1588–1598 feet.

Magothy Formation.—Overlying the Raritan is a series of lead-gray, brownish-black, and dark cinnamon-brown clay shales with interlaminated very fine grain sands. The shales are occasionally mottled near the base of the formation. Lignite and carbonaceous matter are very common both in the sands and the shales. No coarse conglomeratic sands, common to the outcropping Magothy, were noted in the well.

The top of the Magothy is placed at 1498 feet, where a pronounced mineral change was noted (Fig. 2). Immediately above 1498 feet and extending upward to 1494 feet is a zone of reworked fossil fragments. The thickness of the Magothy formation in the Hammond well is 90 feet.

Lignitized vegetable fragments including wood, probably *Cupressinoxylon*, were identified by Roland W. Brown from 1500–1503 feet. One poorly preserved unidentified fruit was also observed. No fossil remains were noted in the Magothy beds.

Matawan Formation.—The Matawan formation in the Hammond well embraces two units. The upper unit is 30 feet thick and is composed of hard, white, silty chalk containing a small amount of glauconite and fish remains. The lower unit is a lead-gray glauconitic clay shale containing sporadic, badly mashed fossils. In the lowermost 20 feet fine sand appears and becomes conglomeratic as the basal part of the unit is reached. Pebbles measuring $\frac{1}{4}$ inch were noted.

The thickness of the Matawan formation is 105 feet. The top is placed at 1393 feet, at the top of the white chalk.

The Matawan in the Hammond well is rich in micro-fauna but contains a poor and mostly fragmentary macro-fauna. According to Stephenson, *Exogyra ponderosa* Roemer?, if correctly identified, indicates a Matawan age. Undescribed *Pecten* remains were also found in the cores. Ostracods encountered from the interval 1410–1480 feet are known from the Taylor and upper part of the Austin chalk of northeastern Texas. Foraminifera obtained from the interval 1390–1480 feet contain a number of species which are index fossils for beds of Taylor age according to Cushman.

Monmouth Formation.—The section between 1360 and 1393 feet has been assigned to the Monmouth formation. It contains beds of argillaceous glauconitic sand. The glauconite is dark-green and the argillaceous matrix is dull lead-gray.

Macro-fossils were obtained from 1362 feet. Contained in the fauna from this depth was the brachiopod *Charistothyris plicata* (Say), which according to Stephenson is known only from the Navesink marl (Monmouth group of Upper Cretaceous) of New Jersey. Associated fossils are *Exogyra costata* (Say) and *Pecten venustus* Morton. Foraminifera are well represented in the Monmouth section. At 1360–1370 feet, the ostracod *Cythereis mediocarinata*, n. sp. is reported by Swain.

Eocene

Beds assigned to Eocene on the basis of their fauna extend from 1140 feet to 1360 feet. From 1140 to 1250 feet, the section contains dull brown waxy clay shales rich in foraminifera and with a subordinate amount of fine-grained green glauconitic sand. At 1223 feet, very fine to coarse, micaceous sand, rich in glauconite and containing clay pebbles from $\frac{1}{16}$ to $\frac{1}{2}$ inches in length was noted. This appears to be a clay-pebble conglomerate. Between the depths of 1250 to 1330 feet, is hard brownish-white chalk with only a trace of glauconite at the top and bottom. From 1330 to 1360 feet, the section is rich in glauconite and varies in color from pale buff to lead-gray.

The Eocene section of the Hammond well is rich in both foraminifera and ostracods, but no diagnostic macro-fossils were obtained. According to Cushman, the foraminifera from 1140 to 1250 feet indicate a Jackson age and those from 1280 feet to 1320 feet a Claiborne age. Forms limited to the Paleocene were found between 1320 to 1350 feet. A few species found elsewhere only in the Paleocene were noted as high as 1260 feet. The exact age of the interval between 1260 and 1320 feet must, according to Cushman, remain somewhat in doubt.

The age of the Eocene of the Hammond well on basis of its foraminiferal fauna does not correspond with the age of the outcropping Eocene beds as determined by their macro-fauna. On the basis of this fauna, the outcropping beds have been referred to the Wilcox and Claiborne groups, no beds of Paleocene or Jackson age having been recognized. A recent study of the microfauna from the outcropping Eocene beds and from the Eocene encountered in water wells of the Western Shore has confirmed the age of these beds as determined by their macro-fauna (Elaine Shifflett, Maryland Department of Geology, Mines and Water Resources Bulletin 3, 1948).

Lithologically the Eocene of the subsurface differs from the Eocene of the outcrop area. In the well, glauconite is abundant only in the lower 40 feet whereas at the outcrop, the Aquia formation, which is about 100 feet thick, is richly glauconitic throughout. The portion of the well section above 1320 feet, which contains the cinnamon-brown, sparingly glauconitic clays, is lithologically more like the Nanjemoy formation than the Aquia. The massive glauconite beds of the Aquia and Potomac Creek sections, therefore, decrease in thickness towards the east in the direction of the Hammond well.

Miocene

Three formations and possibly a fourth have been recognized in the portion of the section referred to the Miocene. These formations from the oldest to youngest are the Calvert, the Choptank, the St. Marys, and possibly the Yorktown.

Calvert Formation.—This formation extends from 640 feet to 1140 feet. From 640 to 1000 feet, the portion of the section from which ditch samples were collected, the beds consist of pale-gray silty clay. In the upper 60 feet dull-gray argillaceous sands were present. Fossil fragments and glauconite were noted, the glauconite being more abundant in the interval from 810 to 820 feet. From 1000 to 1140 feet the section was cored and revealed beds consisting of pale brownish-gray silty clay. Shell fragments, fish remains, foraminifera, and diatoms were present in practically all samples.

Diagnostic macro-fossils belonging to this formation as reported by Julia A. Gardner are *Anadara subrostrata* (Conrad), *Parvilucina prunus* Dall, and *Astarte cuneiformis* Conrad. Stephenson reports *Corbula elevata* Conrad (identified by Julia A. Gardner) from 1077 and 1108 feet. Diatoms have been described by Lohman from the interval between 1000 and 1140 feet, but they probably continue as high as 800 feet according to Ruth Patrick (85, p. 1197). Foraminifera have been described by Cushman and have been further zoned by Ann Dorsey (See section on Paleontology). Ostracods have been identified in the interval from 640 to 840 feet and have been referred to the Middle Miocene by Swain who suggests a correlation with that part of the Middle Tertiary comprising the *Discorbis*, *Heterostegina*, and *Marginulina* subsurface zones of the Gulf Coast of Texas. Certain forms have been found also in the Choctawhatchee formation of Florida, according to Swain.

Choptank Formation.—This formation consists of pearl-gray to white marl and medium-grained sand. Glauconite is present but is very scarce. Fragments of macro-fossils were noted in all ditch samples.

According to Julia A. Gardner, fragments of *Pecten* sp., *Anomia* sp., barnacle plates, and echinoid tests and spines were noted in the interval from 520 feet to 540 feet. In the interval 540 to 560 feet, the small brachiopod *Discinisca lugubris* (Conrad), common only to the Choptank, was noted. A lower echinoid horizon was also noted between the depths of 630 to 640 feet. A complete list of forms and the depths at which they were encountered will be found in the discussion of the systematic paleontology by Julia A. Gardner. The foraminifera of the Choptank have been described by both Cushman and Ann Dorsey. Systematic treatment of this fauna is in the section dealing with the paleontology of the well samples. The thickness of Choptank is 125 feet, and it extends from 515 feet to 640 feet.

St. Marys Formation.—The ditch samples in the upper part of the well do not give a good picture of the lithology. In that portion of the well assigned to the St. Marys, fine to coarse sand and some gravel are very abundant. Glauconite begins at 440 feet and increases in abundance between 490 and 515 feet. Fragments of shells make their first appearance at 330 feet.

Organic remains consist of macro-fossils and foraminifera. The macrofossils *Uzita peralta* (Conrad) and *Bulliopsis quadrata* (Conrad) were encountered at several depths and are considered diagnostic forms of the St. Marys by Julia A. Gardner. Ann Dorsey notes a definite faunal change in the foraminifera at the base of the St. Marys formation. The number of species is reduced, and those that occur are characteristic of brackish water conditions.

The thickness of the St. Marys is 185 feet. The top is at 330 feet and the base at 515 feet.

Yorktown Formation (?).—The portion of the section between 130 feet and 330 feet is assigned provisionally to the Yorktown formation. At 130 feet pyrite makes its first appearance, and there are minor changes in several other mineral species (Fig. 2). No fossils were noted within this interval, which consists of yellowish-white sand and granule gravel with black chert very common. The section is probably the non-marine facies of the Yorktown formation.

Pleistocene

The Pleistocene of the Hammond well is composed of very coarse sand and gravel and extends from the surface to 130 feet.

SEDIMENTARY PETROGRAPHY

INTRODUCTION

A petrographic study of sedimentary rocks has as its object the securing of data which will lead to conclusions concerning the source of sediments, their mode of origin, and their environment of deposition. The minerals indicate the character of the source rocks, and mineral zones may be recognized which aid in correlation. Morphologic characteristics such as sphericity, etching, and inclusions are useful both in correlation and in tracing the history of the sediment. Recent advancements in the application of statistics to the study of sediments yield information concerning the mode of origin and the environment of deposition.

Methods of Analysis

Both a detailed study of the minerals and a statistical analysis of the sands were made. In the mineral study, most attention was paid to the heavy minerals. They were extracted from the sands by first splitting the bulk sample to convenient size by means of a Jones sample splitter and then separating the light constituents from the heavy with tetrabromethane after having passed the sand through a 48 mesh screen. The heavy minerals were further split by using a modified Jones splitter designed by Otto (77). Permanent mounts in Canada balsam were then prepared for examination. Approximately 300 grains per slide were counted, and their percentages determined. The results are tabulated on Figure 2.

The grain-size determinations were made by disintegrating the soft sands in a dry state and then passing them through a nest of Tyler screens shaken in a Ro-Tap machine for 15 minutes. The finest size screen used was 250 mesh with openings of 0.0625 millimeters. This is the lower limit of the very fine sand class of Wentworth (120, also 63, p. 77). The separation of the silt from the clay would have necessitated the use of wet methods, but due to the large number of samples this was not done. The results of these analyses are tabulated and discussed in a later section.

MINERALOGY OF THE SEDIMENTS

Heavy Minerals

Triassic

Newark Series.—Eight analyses were made from the sands of the Triassic. The outstanding characteristic of these sands is the large amount of tourmaline, garnet, apatite, and barite, and the moderate amount of zircon and rutile. Traces of epidote, andalusite, chlorite, and biotite were noted. A black opaque mineral, probably ilmenite, and brown iron oxides are very common to abundant.

The tourmaline grains are nearly always euhedral, and no overgrowths were noted. Brown and greenish-brown varieties greatly predominate over blue and greenish-blue types. Tourmaline continues to be abundant for about 100 feet above the top of the Triassic at which point there is a very marked decline (Figs. 2 and 3).

Garnet with a well-developed dodecahedral structure is also abundant in this part of the section. The colorless variety greatly predominates over either the pink or brown types. The grains are subangular.

Apatite occurs as small, euhedral, white, crystals, and barite in irregular, platy grains.

Zircon is fairly common, and the individual crystals have their termination rounded. Inclusions and zonal growths are common.

Rutile is of the deep orange-brown variety and occurs as small more or less rounded individuals.

Lower Cretaceous

Patuxent Formation.—The Patuxent formation may be classsified as a Garnet-Staurolite-Zircon zone. Garnet is abundant and is represented by colorless, pink and deep-brown species. The colorless and brown varieties are slightly more abundant than the pink variety. The grains are subangular and rarely exhibit dodecahedral or botyroidal structures. Staurolite is of the deep-orange type and commonly has saw-tooth edges. It is more abundant in the upper 250 feet of the formation (Figs. 2 and 3). Zircon, although present throughout the entire well section, is more abundant in certain parts than in others and is on the whole more abundant in the Patuxent than in the overlying Arundel-Patapsco section. The grains are predominately colorless, slightly rounded, and contain numerous inclusions.

Epidote minerals, pistacite and clinozoisite, begin to appear about 250 feet below the top of the formation. In this interval they are rare to fairly common until the 4424 foot level is reached where they become abruptly abundant. Pistacite is deep olive-green, irregular, and clinozoisite is pale olive-green to colorless and irregular.

Tourmaline of the brown variety with subordinate blue, bluish-green, and greenish-brown types, deep-brown rutile, and chloritoid are scarce to common. At 5267 feet a zone containing abundant euhedral to subhedral tourmaline appears. Titanite, brookite, anatase, biotite, chlorite, sillimanite, andalusite, and cyanite are very rare to scarce. Apatite and barite are sporadic in occurrence. Pyrite and ilmenite are very rare to abundant. Some ilmenite is altering to leucoxene, but usually it is fresh.

Upper Cretaceous

Patapsco-Arundel Formations.—One of the outstanding mineral characteristics of this portion of the section is the abrupt appearance of an abundance of the epidote minerals in the basal part (Figs. 2 and 3). The appearance of these minerals is considered, together with other factors, as marking the base of the Arundel-Patapsco section. They continue in abundance to the top of the Magothy formation of the Upper Cretaceous. Staurolite shows a marked decrease in passing from the Patuxent into the Patapsco-Arundel section and continues to be scarce to very common to the top of the interval. Garnet continues to be sporadically abundant for approximately 360 feet above the base of the Patapsco-Arundel section then shows a marked decrease. Colorless and pale-brown titanite grains showing very strong dispersion occur in all sands but seldom reached 11% to 13%. Cyanite is scarce to fairly common between the intervals 2313 to 3507 feet and rare to absent below. Chloritoid is fairly common throughout the entire interval as are also apatite and pyrite. Sillimanite is common above 3507 feet. Ilmenite is abundant in all sands. Traces of green hornblende, tremolite, actinolite, andalusite, muscovite, biotite, chlorite, and anatase were noted. Zircon increases in amount above 3640 feet.

The basal 350 feet of the Patapsco-Arundel section may be classified as the Epidote-Garnet-Titanite zone. From 3507 to 2313 feet, a zone containing Epidote-Titanite-Sillimanite can be recognized. Staurolite with saw-tooth edges, referred to as cleaved Staurolite, appears first at 3242 feet. This mineral is a good marker and is found in the other two wells.

At the top of the Patapsco formation, pyrite disappears and abundant siderite makes its appearance. Cyanite, garnet, and tourmaline abruptly disappear but reappear approximately 200 feet above the base of the Raritan formation. Green hornblende appears at the top of the Patapsco formation and continues into the Raritan. Brown garnet shows a marked increase at 2565 feet, but above this point it is very rare to absent. The point at which it increases in abundance has been used as an horizon marker.

Raritan Formation.—The Raritan formation is characterized by the presence of subhedral green hornblende. It makes its appearance at 1767 feet, 179 feet below the top of the formation, and continues to the base. Cyanite also comes in at the point at which hornblende first appears. In the upper 179 feet of the Raritan, cyanite is practically absent. Pyrite shows a marked decline in abundance, and in its place siderite is frequently found. The epidote minerals are very abundant, but tourmaline, staurolite, garnet and titanite have decreased in amount. Zircon is sporadic and varies from rare to abundant. Andalusite, sillimanite, biotite, chlorite, chloritoid, and apatite are rare to absent and very sporadic in their occurrence. Ilmenite is common to abundant. Below 179 feet from the top of the formation, the Raritan formation contains therefore an Epidote-Hornblende-Cyanite zone.

Magothy Formation.—The top of this formation is marked by a pronounced sedimentation break (See sample descriptions). It is at this horizon that the epidote minerals make their abrupt appearance and continue in abundance until the top of the Patuxent formation is reached. Cyanite, rutile, and titanite and pyrite are scarce to fairly common. All other minerals remain about the same as in the underlying beds of the Raritan.

Monmouth-Matawan Formations.—Only three analyses were made of the sands from this part of the section. Epidote minerals are scarce to absent. Chlorite and chloritoid are very common in the basal portion of the interval, and titanite is very rare to absent. Siderite is abundant, ilmenite is scarce to common, and pyrite is rare to scarce.

Eocene

Only four samples from the Eocene were studied. Zircon, pyrite, and siderite are abundant. Staurolite, garnet, rutile, biotite, chlorite and chloritoid are more abundant in the upper part of the section than in the lower. Ilmenite is scarce in the entire interval.

Miocene

The mineralogy of the Miocene section is not too reliable due to the contamination of the samples in the well, and much of the material of the lower levels is mixed with material from higher levels (Fig. 2). Rutile, although scarce to fairly common, is only sporadically present above the top of the Calvert formation. Green hornblende disappears shortly below 500 feet, the depth at which the casing was set. This depth is within the Choptank formation. Epidote minerals, sillimanite, and cyanite are fairly abundant in the upper portion of the Miocene but show a marked decline at the base of the Calvert. Chloritoid is scarce to rare in the upper Miocene but shows an increase in the Choptank and Calvert formations. Pyrite was noted first at the 130 foot level. Traces of other minerals were noted at various horizons (Fig. 2).

Pleistocene

Nothing diagnostic was noted in the Pleistocene that could serve to differentiate it from the underlying beds. Pyrite was not found, and tourmaline was absent except in the upper 20 feet and the lowermost 10 feet of the section. Andalusite is more abundant in the upper 40 feet, and below this point both sillimanite and rutite show a marked increase. The mineral chart (Fig. 2) shows the distribution of the other minerals.

Light Minerals

The light minerals of the samples are composed predominately of quartz and feldspars. Occasionally, on account of the specific gravity of the liquid used in the separations and also the flatness of the grains, micaceous minerals are found in the light separates.

A total of 14 examinations of light minerals from various horizons were made the results of which are as follows:

Eocene—1220–1230 feet. Quartz greatly exceeds feldspar in abundance. The feldspars are clouded and are fairly well decomposed. All feldspars have an index of refraction less than 1.55 indicating the composition of the plagioclases to be more albitic than andesine.

Upper Cretaceous—Magothy formation, 1490–1498 feet. Estimated quartz 95% and feldspar 5%. Grains are angular and quartz is clear. Feldspars are both twinned and untwinned. Albite twinning noted. Index of refraction less than 1.55. Most feldspar grains are fresh. Few are clouded.

Upper Cretaceous—Raritan formation, 1687–1697 feet. Quartz more abundant than feldspar, about 90% quartz and 10% feldspar. Quartz, clear and glassy, and contains numerous inclusions. Some grains show a cataclastic structure. Larger feldspar grains are but slightly clouded, hut smaller grains are highly decomposed. Oligoclase is more abundant than alhite, and both are more abundant than microcline-microperthite. Few albite twins were noted, most grains are untwinned.

Upper Cretaceous—Raritan formation, 1944–1954 feet. Quartz 90%; clear, glassy and numerous opaque and fluid inclusions. Feldspars: Oligoclase, Albite, Microcline-microperthite. Most feldspars are clouded, few are fresh. Muscovite is more abundant than chlorite.

Upper Cretaceous—Raritan formation (base, 2297–2307 feet. Same as Raritan above.
" " —Patapsco formation, 2709–2719 feet. Same as Raritan above.
" " —Patapsco-Arundel, 3360–3370 feet. Same as above.
" " —hasal Patapsco-Arundel, 4297–4302 feet. Quartz—Feldspar ratio about 50%–50%. Feldspars both clouded and fresh, with the clouded more abundant than the fresh. Few fresh grains noted. Indices of refraction of all grains are less than 1.55. Microcline-microperthite is very common. Small amounts of chlorite and muscovite occur.

Lower Cretaceous—Patuxent formation:	4464–4469	feet.	Same as preceding.
	4684–4689	"	" " "
	4902–4907	"	" " "
	5112–5122	"	" " "
	5307–5309	"	" " "

Triassic, 5431–5436 feet. Iron-stained quartz greatly exceeds untwinned feldspar in abundance. Several grains of albite-twinned plagioclase. Feldspars are decomposed and very clouded.

Characteristics of the Individual Minerals

Actinolite. An extremely rare mineral, occurring most persistently in the Miocene section. Scattered occurrences in the Cretaceous. Grains are pleochroic from pale yellow-green to pale yellow. Found in the metamorphic volcanic rocks of the Piedmont.

Anatase. A rare mineral in the Hammond section. Well-formed brown octahedra are more common than the royal blue variety. More commonly present in the Patuxent formation and also in the lower part of the Miocene section. An authigenic mineral.

Andalusite. Milky-white, anhedral, non pleochroic grains are more common than the pleochroic rose-red to colorless variety. Not a common mineral in the Hammond section.

More persistent in the Miocene and Patapsco-Arundel sections. Derived from argillaceous sediments which have been contact metamorphosed.

Apatite. Occurs as elongated, prismatic white grains with rounded corners. Dark inclusions common. Very common in the Triassic, scarce in the Patuxent formation, common in the Patapsco-Arundel section, but decreasing toward the top of this interval. Sporadic to absent in the upper portion of the Upper Cretaceous and overlying formations. Derived from acid igneous rocks high in alumina.

Barite. Grains are irregular and exhibit good cleavage. Milky blue-white in color and frequently stained brown. Very abundant especially in the Triassic and Patuxent intervals. Generally absent above the Patuxent formation. Usually a secondary mineral, acting as a cementing agent for sand grains.

Biotite. The micaceous minerals are not as abundant in the separations as they should be due to their tendency to float even in the heavy liquid. Sporadically present throughout the entire well section, but more commonly found in the Eocene and Miocene beds. The grains are deep-brown, non-pleochroic flakes. Derived from crystalline schists, gneisses, and acid igneous rocks.

Brookite. A titanium-bearing mineral occurring as irregular, resin-colored striated grains with an extremely strong dispersion. A very rare mineral in the well section but most frequently encountered in the middle portion of the Patuxent formation. Can be both a detrital and an authigenic mineral. Its' scarcity in the well suggests that it may be detrital.

Chlorite. Never an abundant mineral but sporadically present in all portions of the section. More common in the Eocene and uppermost Cretaceous. Occurs as thin green flakes with very low birefringence. Found in both metamorphic and igneous rocks. A secondary mineral derived from ferromagnesian minerals.

Chloritoid. Occurs as bluish-green to yellow-green plates and as prisms with pronounced pleochroism, high index of refraction, marked dispersion, and rather high birefringence. Chloritoid is present in all parts of the well section but is more common, although never abundant, in certain portions. The intervals at which it is common are the Choptank and Calvert formations of the Miocene, the Eocene, the lower part of the Patapsco-Arundel section, and Patuxent formation below 100 feet from the top. Derived from crystalline shcists.

Corundum. A very rare mineral occurring as colorless irregular plates with carbonaceous inclusions. The blue-splotched variety occurred in only one instance. More common in the Pleistocene and uppermost portion of the well section. Derived from contact metamorphosed limestones and igneous rocks.

Cyanite. A fairly common and persistent mineral in the entire well section down to 3500 feet, below which point it is very sporadic and rare. It occurs in broken colorless crystals with characteristic cleavage and extinction angle. It is derived from crystalline schists.

Enstatite. Although this mineral has been reported from the Cretaceous sediments of the western shore of Maryland (36), no definite evidence of its presence was noted in this well.

Epidote Group:

Pistacite. An abundant and important mineral especially in the Cretaceous sands. It appears abruptly at the top of the Magothy formation and abruptly decreases in amount at the base of the Patapsco-Arundel section. Abundant also in the Pleistocene and common in the Miocene. The grains are of two varieties, one a clear yellow-green prismatic and subangular type, which is considered to be of detrital origin, and the other an irregular clouded yellow-green grain, which is probably authigenic. Derived from epidote veins, altered impure limestones, and the alteration of ferromagnesian minerals.

Clinozoisite and zoisite. Both associated with the common epidote pistacite. They occur as colorless or, in the case of clinozoisite, at times pale yellow-green elongated grains. Zoisite exhibits the characteristic deep royal blue interference colors. It is very rare. Clinozoisite is also irregular in shape and shows the characteristic epidote interference colors.

Garnet. A very important mineral throughout the entire well section but more abundant at certain horizons. Three varieties are encountered, colorless, pink, and deep-brown. Occasionally a dodecahedral and botryoidal structure is noted on the grains, especially in the Triassic sands. Usually the grains are angular and without markings in the beds overlying the Triassic. Very abundant in the Patuxent formation and in the interval extending 350 feet above the top of the Patuxent (Fig. 3). The rather abrupt appearance of the deep-brown garnets is used as an horizon marker in the upper part of the Patapsco-Arundel section. Brown garnets are also abundant in the Miocene section but show a marked decline in both the Eocene and the Magothy and Raritan formations of the Upper Cretaceous (Fig. 2). Derived primarily from crystalline schists.

Gypsum. A rare mineral in the Hammond well. Found occasionally in the Patuxent sands. It occurs as colorless well-cleaved grains.

Hornblende. The yellow-green to deep-green pleochroic prismatic and somewhat worn grains are limited to certain parts of the section. It is an important and persistent mineral of the Raritan formation, and its first appearance has been used as an horizon marker. Very common in the Pleistocene terrace sands and also in the upper portion of the Miocene section, although in this instance it may represent contamination from higher levels. Usually absent in the basal part of the Miocene section, the Eocene, and Lower Cretaceous. A common mineral of the crystalline schists, igneous rocks, and meta-igneous rocks of the Piedmont. It is surprising that hornblende is not more abundant in the young sediments of the Eastern Shore.

Hypersthene. Characteristic short clear, green to reddish-brown, pleochroic grains were encountered at only two horizons in the well, though a fairly common mineral of the gabbros of the Piedmont of Maryland.

Ilmenite and Leucoxene. The bulk of the black opaque constituent of the sands is ilmenite. A strong hand magnet extracted only a negligible amount of the black opaques, indicating that magnetite was very subordinate. Numerous larger grains were picked out, and x-ray powder photographs gave "d" values definitely indicating ilmenite. This mineral is very abundant throughout the entire section and is frequently altered to the white secondary substance leucoxene. It is a primary mineral of basic and ultra-basic rocks.

Monazite. Occurs as small, somewhat rounded and egg-shaped pale-yellow grains with a black border and frequent brown stain irregularly distributed within the grain. Not a common mineral but occurs sporadically throughout the section. More persistent in the Patuxent formation.

Muscovite. Very rare and of limited occurrence due probably to the fact that the mineral tends to float in the heavy liquid.

Pyrite. Small crystals and groups of crystals commonly found throughout the section below 130 feet. Very rare in the Patuxent formation and at certain horizons higher in the section (Fig. 2).

Rutile. The deep chestnut-brown variety is the only type encountered. The crystals are small and tend to have their terminations rounded. Commonly found throughout the well section but more abundant in the Patuxent formation below 200 feet from the top.

Usually found in acid igneous rocks. Found also in the meta-basic rocks of Harford County, Maryland.

Siderite. An abundant mineral at certain horizons (Fig. 2) especially at or near the top of formations. Sideritic oolites with concentric layers and fibrous types giving a black pseudo-uniaxial interference cross are common. Occasionally well-formed rhombs were noted. An authigenic mineral.

Sillimanite. Colorless, narrow, worn, prismatic, well-cleaved grains are more commonly found in the Miocene section. Sporadic in occurrence below the Miocene and very rare to absent below the middle of the Patapsco-Arundel section. Derived from crystalline schists.

Spinel. An occasional deep-green, somewhat rounded, isotropic mineral was encountered. Very rare and not limited to any particular part of the section.

Staurolite. A very important mineral of the sands of the Hammond well. Two types were encountered. One a massive, subangular, deep-orange grain and the other a deep-orange well-cleaved variety which has saw-tooth-like terminations. Commonly found throughout the well section but more abundant in the upper 250 feet of the Patuxent formation (Fig. 3). The saw-tooth variety first appears at about 3242 feet and can be used as an horizon marker. A common mineral in certain facies of the Wissahickon schist of the Maryland Piedmont.

Titanite. Two varieties of titanite were observed, one a honey-yellow, angular type, and the other a nearly colorless variety. In both the refringence and birefringence are very high and the dispersion strong. Good biaxial figures are obtained. Never a very abundant mineral, it is more persistently present from the basal part of the Raritan formation to the base of the Patapsco-Arundel section.

Tourmaline. This mineral is commonly present throughout the well section but is abundant only in the very basal part of the Patuxent formation and in the Triassic. The brown and greenish-brown varieties are more common than the blue and bluish-green types. A mineral commonly found in the crystalline schists of the Piedmont.

Tremolite. A very rare mineral, noted only in several samples. The grains are colorless and well-cleaved, worn, and exhibit a moderate extinction angle. Found in the meta-dolomites of the Piedmont.

Zircon. The colorless variety is more abundant than the mauve-colored type. Euhedral prisms, slightly rounded and broken grains, and well rounded individuals were noted. Zircons are more abundant in certain intervals than in others especially in the fine-grained sediments. Of no value as an horizon marker in this well. The types encountered here were doubtless derived from acid igneous and old sedimentary rocks. The well-rounded types have passed through at least two cycles of sedimentation.

TEXTURE OF THE SEDIMENTS

GENERAL

A total of 227 mechanical analyses were made from the core samples distributed between the depths of 1150 to 5315 feet. The calculated weight percentage retained on each mesh screen has been tabulated in Table 3.

The grade scale used to classify the sediments according to their particle size is that proposed by Wentworth (119) and is given in Table 2.

A nest of screens was used which gave approximately the upper and lower limits of each Wentworth class below the cobble class. The weight percentages retained on these screens have been combined according to Wentworth's classification, and the results are given in Table 4. The percentage of sediment passing through the 250 mesh screen, the lower limit of the very fine sand class, is at times large and contains both the silt and clay classes. No attempt was made to separate the silt from the clay because of the necessity of using wet methods and the large number of samples.

The use of the Wentworth grade scale is rendered difficult and the calculations are cumbersome, when statistical devices are employed in the study of sedimentary data. In order to permit the direct application of statistical formulae to the study of sedimentary data, Krumbein (60) introduced a grade scale known as the "phi scale," which has integers for the Wentworth class

TABLE 2

Wentworth's Size Classification

Grade Limits (Diameters in mm.)	Name
Above 256	Boulder
256–64	Cobble
64–4	Pebble
4–2	Granule
2–1	Very coarse sand
$1-\frac{1}{2}$	Coarse sand
$\frac{1}{2}-\frac{1}{4}$	Medium sand
$\frac{1}{4}-\frac{1}{8}$	Fine sand
$\frac{1}{8}-\frac{1}{16}$	Very fine sand
$\frac{1}{16}-\frac{1}{256}$	Silt
Below $\frac{1}{256}$	Clay

limits which increase with the decrease in grain size. The conversion of the Wentworth scale to the phi scale of Krumbein is accomplished by the formula:

$$\phi = -\log_2 \xi$$

where "ξ" is the numerical value of the grain diameter in millimeters. The use of this scale eliminates the unwieldy fractions or decimals of the Wentworth classes. The phi scale and the corresponding Wentworth class units are given in Table 5.

The sedimentary data were analyzed by the methods described by Trask (103). These involve the use of the first quartile (Q_1), the median (Md), and the third quartile (Q_3) diameters and the calculation of the sorting factor. The first three factors are read directly from the cumulative curves of the individual samples.

The first quartile of any sediment is defined as that diameter which has 25 per cent of the distribution smaller and 75 percent larger than itself. It is found by intersecting the 75 percent line with the cumulative curve. The third quartile is that diameter which has 25 percent larger and 75 percent smaller than itself and is found by intersecting the 25 percent line with the cumulative curve. The median diameter is defined as that diameter which is larger than 50 percent and smaller than 50 percent of the diameters of the distribution. It is determined by intersecting the 50 percent line with the cumulative curve. These three values have been tabulated in Table 6. The three quartile values have been also converted into phi values by the use of Krumbein's conversion chart (60, p. 41), and the results are presented in Table 7.

The sorting coefficient of a sediment is defined as the square root of the third quartile divided by the first quartile and is given by the equation

$$So = \sqrt{\frac{Q_3}{Q_1}}.$$

In this case, Q_3 is the larger value and the value of So is either unity in the case of a perfectly sorted sediment or greater than unity in the case of an unsorted one. The values of So increase geometrically, hence the individual values cannot be compared directly with each other. To overcome this, the logs of So can be taken, these forming an arithmetic series, and the values than may be compared directly with each other. This transformation is accomplished by the use of the equation:

$$\text{Log}_{10}\ So = (\log Q_3 - \log Q_1)/2.$$

In order to compare the sands of the Hammond well with one another, the sample obtained from 2157–2167 feet was chosen as unity. This sample has an So-value of 1.1 and a log So-value of 0.043. By dividing the log So-values of all other samples by the unit sample, we obtain what is called the "Degree of Sorting." Hence, a sand with a degree of sorting of "5" has a spread of the grains which is five times that of the unit sand; or, in other words, the unit sand is five times as well sorted. The values for each sand analyzed have been tabulated in Table 6.

For descriptive and comparative purposes, three other statistical values have been determined. These values, proposed by Krumbein (61, p. 569), are the phi median, $Md\phi$; the phi quartile deviation, $QD\phi$; and the phi skewness, $Skq\phi$. The $QD\phi$ is given by the equation:

$$QD\phi = \frac{(Q_3\phi - Q_1\phi)}{2}$$

It is the measure of one-half the spread between the two quartiles in terms of Wentworth grades. Quartile deviations of the various sands may, therefore, be compared. For example, one sediment having a $QD\phi$ of 0.5 has one Went-

TABLE 3

Mechanical Analyses: L. G. Hammond Well No. 1, Ohio Oil Company, Salisbury, Maryland

Percentages by Weight

Depth in Feet	Retained on Mesh													Pass 250
	5	8	10	14	20	28	35	48	65	100	150	200	250	
1150–1160 Top 3 ft.			.09	.09	.09	.30	1.3	4.3	4.4	7.7	13.5	26.6	7.9	33.9
1160–1170				.05	.05	.05	.6	2.9	7.6	18.8	18.9	19.6	4.4	27.2
1220–1230				.03	.03	.03	.8	6.1	13.9	18.5	11.1	17.2	6.2	26.2
1250–1260				.03	.06	.27	3.4	16.1	25.2	22.9	9.2	6.7	1.6	15.0
1470–1480		.26	.84	2.2	4.5	8.00	10.0	9.0	10.0	28.2	5.8	5.9	7.2	7.5
1480–1490		.20	.40	.90	1.55	2.45	4.65	6.9	6.65	10.4	9.0	27.0	8.6	21.2
1490–1498					.2	.20	.20	.98	.5	4.65	14.3	27.0	13.2	39.0
1498–1508				.05	.05	.05	2.1	16.0	23.0	25.0	12.3	8.3	1.9	11.4
1508–1518				.07	.07	.14	.5	20.4	34.0	23.4	6.15	4.8	2.4	7.6
1528–1538					.07	.14	2.07	12.6	15.5	25.6	15.5	9.1	2.14	17.3
1658–1667			.04	.04	.04	.08	.59	3.34	11.1	42.0	13.1	9.55	2.45	17.8
1687–1697		.08	.03	.03	.03	.03	.19	2.06	12.8	62.0	4.1	5.1	3.1	10.7
1697–1707				.03	.03	.06	.80	4.1	8.1	22.5	23.6	18.0	5.0	18.0
1767–1777		.07	.11	.14	.53	2.34	7.65	18.3	31.0	19.0	5.5	3.9	1.25	10.4
1777–1787					.09	.09	.32	10.5	43.0	21.6	6.2	4.55	2.26	11.2
1817–1824				.04	.04	.07	1.11	13.4	30.0	26.4	8.6	5.3	1.9	13.3
1844–1854				.06	.06	.06	.62	3.2	4.0	59.7	6.8	7.7	4.4	13.2
1884–1894				.03	.03	.06	.75	2.62	3.10	39.	19.40	13.1	3.34	18.6
1904–1914		.03	.03	.03	.21	.35	1.5	11.3	31.8	25.4	6.	7.2	2.08	14.
1924–1934			.06	.11	1.13	6.50	15.2	29.2	15.8	11.1	5.2	3.54	1.13	11.
1944–1954				.04	.04	.98	6.	6.	12.5	26.4	15.	12.30	3.55	22.8
2004–2014				.06	.06	.06	.41	11.6	39.0	19.4	7.9	6.3	2.6	12.8
2014–2024 Top					.14	.14	.42	6.	20.4	34.	14.	9.	2.1	13.5
2044–2054					.03	.06	.17	2.75	3.4	43.	20.2	11.8	2.7	15.9
2157–2167					.05	.05	.20	1.37	9.3	68.	6.5	5.15	1.05	8.7
2197–2207					.04	.04	.59	11.5	43.8	19.3	3.88	10.2	1.64	9.3
2267–2277					.06	.16	.27	4.35	28.80	29.4	9.85	7.9	2.24	16.
2277–2287					.04	.08	.49	5.6	32.4	31.	4.4	10.9	2.15	12.8
2297–2307					.04	.04	.35	2.42	33.2	29.2	6.6	13.5	2.56	12.1
2323–2333					.03	.06	.7	2.73	3.3	57.	4.95	10.6	3.3	17.4
2565–2575					.17	.52	9.2	37.4	21.	13.9	5.5	3.46	1.21	7.6

2575–2585					.03	.06	2.17	49.00	6.00	19.10	5.95	5.75	1.91	9.95
2585–2595			.03	.09	.3	2.38	15.2	27.4	15.8	12.1	5.85	5.35	1.62	14.1
2595–2605				.07	.14	.28	4.05	19.9	19.5	21.	9.25	6.4	1.85	17.6
2605–2615		.04	.04	.08	.31	2.04	15.7	18.9	10.5	21.2	8.1	6.3	1.54	15.5
2615–2625			.04	.04	.18	1.90	12.8	16.0	12.2	27.5	8.25	5.6	1.56	13.8
2625–2635	.08	.22	1.04	3.06	7.2	16.7	22.4	20.	7.75	9.	3.36	1.2	.37	7.8
2679–2689			.07	.07	.07	.14	1.15	6.85	14.8	33.	12.8	8.15	2.52	20.2
2689–2699			.03	.07	.45	2.08	11.8	21.	17.3	17.1	7.2	6.2	1.66	14.9
2699–2709			.03	.07	.57	2.6	17.5	28.6	12.8	12.2	6.1	4.55	1.42	13.3
2709–2719 Top				.04	.04	.22	2.44	13.	22.2	31.4	10.5	5.86	1.34	12.9
2709–2719 Bottom					.03	.03	2.19	8.1	5.58	9.95	13.4	24.	6.75	30.
2719–2729 Top				.03	.24	1.96	16.9	20.2	12.5	15.5	5.8	8.35	3.58	14.9
2719–2729 Middle						.06	1.9	7.0	4.4	8.35	13.7	21.50	5.75	37.3
2719–2729 Bottom	.33	.04	.07	.26	.44	1.43	12.1	30.2	17.6	12.6	5.85	4.9	1.5	12.9
2729–2739	.91	.03	.03	.02	.44	.51	1.64	7.75	20.4	37.6	10.9	6.15	1.38	11.6
2739–2749 Top	.13	.13	.13	.33	1.14	3.34	10.3	24.4	19.5	15.	6.2	5.67	1.78	12.
2749–2759				.06	.06	.06	4.2	33.8	27.6	16.5	6.	3.6	1.	7.4
2759–2769				.20	.40	.20	.3	4.4	32.2	44.5	8.3	3.3	.80	5.5
2789–2794						.04	.36	2.3	7.45	35.6	19.1	12.1	3.05	20.2
2794–2801			.05	.08	.22	.51	1.51	9.55	23.5	32.8	13.6	8.1	1.35	8.71
2801–2806				.04	.12	.66	7.35	3.7	24.2	13.4	6.15	4.2	1.83	8.4
2806–2811			.07	.26	1.38	3.3	26.8	21.8	10.	11.7	6.2	4.86	1.91	11.5
2832–2837					.03	.14	3.	20.	22.8	21.	6.3	7.1	2.82	16.5
2877–2887 Bottom				.20	.20	.20	4.4	28.4	19.0	13.3	7.7	7.5	4.9	14.4
2887–2897		.10	.05	.05	.10	.24	2.9	16.6	36.4	19.4	7.35	5.15	1.62	10.4
2907–2917					.04	.04	.46	3.14	18.6	50.	6.3	8.25	2.19	11.3
2923–2932					.06	.06	.99	8.55	35.7	20.4	5.	14.5	2.78	11.8
3020–3030					.03	.14	10.1	47.	2.76	15.3	4.3	5.9	2.32	11.7
3030–3040				.12	.24	.47	8.	45.	18.4	10.6	5.4	4.	1.18	7.05
3040–3046							1.3	4.37	4.55	15.9	14.3	15.3	5.6	38.2
3101–3107	.10	.20	.05	.05	.16	.26	1.97	7.78	14.4	28.8	12.7	10.3	2.74	20.6
3117–3122						.03	.6	6.65	15.6	42.5	5.87	9.47	3.9	15.3
3122–3127					.03	.03	.73	6.30	17.9	41.5	5.75	9.65	3.47	14.5
3127–3132					.05	.12	.92	7.15	21.	34.2	10.	9.08	2.66	14.9
3183–3193					.04	.07	2.	23.	31.7	20.	6.45	5.2	1.53	9.8
3259–3269			.03	.17	1.25	10.10	25.	22.2	14.4	11.4	4.75	3.1	.91	6.8
3269–3274	.24	.18	.48	1.72	4.45	12.5	25.6	20.8	10.	9.25	4.35	3.04	.95	6.6
3274–3280	.43	.34	1.40	2.84	7.23	16.3	22.7	18.	8.	8.6	4.55	2.93	1.	6.1

TABLE 3—*Continued*

Depth in Feet	Retained on Mesh													Pass 250
	5	8	10	14	20	28	35	48	65	100	150	200	250	
3280–3285 Top		.05	.09	.28	.92	3.87	13.7	26.6	22.2	15.9	5.5	3.36	.92	6.22
3280–3285 Middle				.21	.21	.21	.63	1.89	.42	12.6	19.3	23.7	7.75	32.8
3280–3285 Bottom				.11	.22	.6	1.03	22.2	24.8	24.8	8.9	5.8	1.41	10.5
3285–3290	1.08	.06	.12	.51	2.02	9.4	26.4	24.4	10.7	11.1	4.95	2.75	.83	5.5
3290–3300	.19	.06	.16	.47	2.	10.9	31.2	20.3	9.	9.7	4.5	3.28	.88	7.2
3315–3325	6.60	1.45	.90	.66	1.13	6.23	29.4	26.	11.9	9.75	2.5	1.13	.35	2.18
3325–3335		.05	.05	.05	.11	.21	3.64	25.4	32.6	19.3	5.47	3.6	1.23	8.15
3335–3345				.05	.05	.05	.47	2.75	4.45	40.	19.8	16.	4.05	12.2
3355–3360						.04	.43	3.92	12.5	38.7	15.	15.5	3.9	10.
3360–3370			.03	.13	.26	.42	1.19	4.8	18.4	49.7	8.7	7.45	1.86	7.3
3376–3386			.05	.33	.59	1.44	6.3	22.	28.2	20.4	5.47	4.77	1.22	8.8
3386–3396		.05	.09	.24	.57	2.46	14.	30.8	22.7	14.2	5.	3.12	.85	5.87
3396–3401			.04	.04	.04	.04	.47	2.79	7.95	47.	11.7	12.3	2.32	15.3
3401–3407			.04	.11	.07	.11	1.25	5.05	15.4	46.8	12.3	8.83	1.8	7.94
3407–3417		.03	.03	.15	.30	.90	3.53	9.73	22.6	40.	3.85	6.9	1.54	10.3
3417–3427	.20	.13	.58	.77	1.54	5.95	11.5	12.00	26.6	22.9	5.7	4.	.94	7.35
3437–3447				.08	.08	.08	.30	1.00	.42	17.3	31.8	25.6	3.4	19.8
3447–3457				.03	.03	.03	.30	3.10	5.25	53.6	9.6	11.8	2.34	13.9
3457–3467		.03	.03	.13	.28	1.85	14.2	21.4	14.7	21.	9.73	6.1	1.03	9.33
3472–3477 Top					.08	.08	.84	2.95	2.62	28.	26.6	19.2	2.87	16.8
3472–3477 Bottom		.05	.05	.41	1.95	9.9	23.9	19.4	11.	17.	6.05	3.32	.82	6.1
3477–3487				.04	.47	4.33	25.6	28.3	14.7	11.9	4.43	3.03	.82	6.3
3487–3497 Top				.05	.05	1.25	21.0	38.00	16.4	10.6	3.8	2.4	.68	5.65
3487–3497 Bottom				.05	.26	1.82	18.9	33.00	13.3	12.2	5.15	4.	1.2	10.1
3497–3507		.07	.07	.07	.75	9.5	42.	21.6	4.46	7.7	3.72	2.5	.82	6.85
3512–3521					.03	.03	.78	2.24	3.3	40.5	10.8	20.5	3.5	18.4
3521–3529 Top						.04	.26	.92	.84	49.	11.8	20.5	2.02	14.8
3521–3529 Bottom						.04	.11	2.32	41.8	34.	6.06	4.75	1.54	9.2
3529–3539		.07	.04	.04	.33	4.10	14.8	25.4	24.2	13.5	5.55	3.67	1.17	7.15
3539–3549 Top	.32	.11	.53	2.98	11.	29.6	26.7	8.73	2.92	6.85	3.18	2.02	.69	4.15
3539–3549 Middle				.03	.07	.24	1.53	8.73	19.7	30.2	7.53	10.	3.75	18.2
3539–3549 Bottom				.05	.05	.05	.34	1.98	13.	52.	9.8	9.56	2.75	10.3
3549–3555					.03	.03	1.32	13.3	36.4	23.	6.6	6.25	1.87	11.1
3555–3560		.10	.20	.31	.31	.55	2.11	12.9	32.6	32.4	6.15	5.33	1.84	5.

3570–3575			.03	.05	.25	1.66	23.7	28.	15.1	13.4	4.9	4.3	1.42	7.
3575–3583		.03	.06	.15	.23	1.	11.	29.	22.5	19.	5.5	4.27	1.35	6.03
3631–3641			.04	.04	.07	.31	1.81	4.72	3.27	21.9	14.4	23.8	5.37	24.2
3712–3717				.03	.03	.03	.67	3.5	3.1	51.3	8.2	18.3	3.02	12.
3717–3722				.03	.03	.03	.62	2.29	2.67	53.	15.6	16.7	2.11	6.9
3737–3743 Top						.05	.95	8.9	22.8	33.6	10.8	8.9	2.73	11.3
3737–3743 Bottom					.03	.03	1.59	3.38	2.92	62.	7.07	10.7	2.75	9.40
3773–3778						.30	1.03	3.33	5.15	61.3	13.5	9.15	1.88	4.56
3778–3783				.04	.14	.32	1.23	11.7	44.3	28.8	6.63	4.53	.95	1.33
3783–3788	.09	.09	.19	.14	.14	.33	3.84	21.2	30.4	27.	7.3	4.4	1.14	3.93
3793–3798			.07	.07	.07	.14	3.12	25.7	33.	20.7	6.9	3.88	.68	5.65
3798–3804				.05	.26	.37	.63	2.3	16.3	31.	18.85	16.25	1.93	12.15
3804–3810				.03	.22	.48	.99	6.24	18.62	39.42	10.48	9.72	1.38	12.32
3810–3815				.05	.05	.05	.19	1.5	4.97	59.5	10.41	10.1	1.45	11.59
3815–3820			.08	.11	.11	.17	.44	7.05	41.8	33.	4.24	5.32	1.13	6.45
3820–3830 Top 1½ ft.					.05	.05	1.65	4.45	8.7	52.8	9.25	9.68	3.05	10.33
3820–3830					.03	.06	.70	20.38	37.8	27.5	6.25	4.60	1.24	1.50
3840–3850			.03	.09	.12	.56	2.64	49.	16.6	19.05	3.98	3.98	1.40	2.68
3850–3855	.42	.59	1.55	3.59	6.64	10.96	17.7	23.7	16.8	9.08	3.06	2.16	.73	2.51
3855–3865	.04	.19	.31	1.11	2.65	6.29	16.22	33.41	17.6	10.95	3.76	2.68	.73	3.91
3865–3875	.19	.13	.48	1.52	4.13	11.71	29.65	16.8	12.25	8.84	4.05	3.39	.77	6.2
3875–3880			.03	.03	.03	.17	5.43	36.	30.	15.	5.2	3.1	.83	4.1
3880–3885				.05	.05	.09	2.9	24.6	34.2	19.1	6.9	4.2	1.15	6.73
3885–3895		.26	.04	.18	.31	.83	4.54	24.	32.2	20.6	6.2	3.88	1.01	5.76
3925–3930					.04	.16	2.43	8.25	13.1	29.3	17.6	12.5	1.65	14.9
3930–3940				.05	.05	.05	1.16	3.5	9.9	38.3	22.	13.4	1.82	9.8
3940–3950				.05	.05	.05	1.04	5.2	17.6	35.7	15.4	10.6	1.69	12.5
3950–3955			.06	.06	.06	1.19	8.74	14.7	21.3	32.4	8.36	4.3	.94	7.7
3970–3980						.05	.02	2.6	11.2	45.1	19.6	10.4	1.55	9.45
3985–3990					.05	.05	.14	2.62	10.5	35.9	22.7	14.3	1.81	11.8
3990–4000 Top					.03	.09	.33	2.55	8.5	31.8	20.8	17.5	1.6	16.9
3990–4000 Bottom			.06	.11	.11	.50	3.08	16.	24.	27.	10.6	6.45	1.43	10.7
4000–4010		.05	.05	.05	.15	.40	3.	11.15	23.1	32.1	12.35	7.2	1.4	8.86
4010–4015		.05	.14	.46	.78	1.85	6.27	11.65	17.	29.2	12.60	7.9	1.08	10.8
4020–4025				.04	.04	.35	14.85	25.20	14.75	12.65	7.6	8.38	1.8	14.4
4025–4035		.08	.39	.31	.43	2.39	18.95	21.9	16.2	18.4	7.4	4.23	.98	8.45
4035–4045 Top				.05	.16	1.73	21.	33.5	13.1	13.8	5.77	3.46	.84	6.5
4035–4045 Bottom				.02	.02	.10	.87	4.8	21.2	29.6	16.8	11.25	1.37	13.8
4045–4051		.03	.17	.17	.14	.14	1.14	12.8	31.	22.1	12.5	8.	1.2	10.6

TABLE 3—*Continued*

Depth in Feet	Retained on Mesh													Pass 250
	5	8	10	14	20	28	35	48	65	100	150	200	250	
4053–4058			.05	.14	.36	1.65	16.	29.8	16.7	12.5	6.2	4.5	.84	11.2
4058–4068 Top			.04	.04	.25	2.44	13.2	28.2	18.7	13.4	6.34	4.64	.99	11.6
4058–4068 Middle	.15	.04	.15	.29	1.02	4.36	17.25	24.8	15.15	12.95	6.47	4.73	1.05	11.6
4058–4068 Bottom		.11	.41	.73	1.32	2.57	11.6	20.4	13.4	21.3	8.87	5.5	1.1	12.6
4068–4076	.51	.72	.90	1.4	2.78	8.35	25.2	23.3	8.5	9.05	4.94	3.88	.90	9.45
4976–4086 Top	3.48	.36	.54	.90	3.26	14.95	30.6	17.5	6.23	7.65	3.92	2.88	.69	7.
4076–4086 Bottom			.05	.11	.35	1.55	8.5	20.4	17.6	24.5	9.36	5.42	.97	11.2
4091–4101 Bottom		.08	.41	.66	1.34	6.73	25.7	22.5	12.	11.7	4.4	4.	1.07	9.26
4101–4107 Top		.14	.59	2.58	4.55	10.60	28.50	23.60	8.60	8.10	3.90	2.72	.80	5.45
4101–4107 Bottom				.02	.04	.04	1.75	19.15	35.7	23.2	7.06	4.82	.86	7.2
4107–4117				.03	.09	.23	5.56	27.7	30.3	20.9	5.92	3.42	.77	4.9
4117–4127 Top		.03	.03	.15	.45	2.55	12.65	23.9	24.3	19.	5.66	3.17	.78	7.34
4117–4127 Bottom		.02	.15	.36	.49	1.38	7.7	26.2	31.2	15.2	5.75	3.75	.82	6.76
4127–4137 Top			.18	.34	.47	1.29	8.27	17.	24.3	27.3	9.46	4.76	.88	5.8
4127–4137 Bottom			.03	.08	.22	1.5	8.7	26.2	22.7	22.9	6.32	3.66	.89	6.7
4137–4147		.13	.33	.80	2.56	9.93	25.3	20.2	10.7	12.15	5.17	3.64	.98	7.93
4157–4168	.27	.23	.73	1.82	5.01	14.2	27.5	19.	7.37	9.17	4.6	3.	.89	6.07
4168–4178			.08	.30	1.45	9.81	31.1	20.5	8.95	11.	4.62	3.61	1.03	7.64
4193–4199				.03	.03	.03	.31	3.93	10.4	59.	9.91	7.07	1.33	7.85
4199–4209 Top 3 ft.			.03	.03	.03	.03	.22	1.95	2.93	40.8	19.3	16.1	1.83	16.7
4199–4209 Middle				.04	.04	.04	.27	5.63	28.3	36.5	11.4	7.46	1.77	8.57
4199–4209 Bottom				.04	.04	.04	.85	15.9	36.3	26.7	7.63	4.83	.94	6.93
4209–4219		.03	.05	.20	.71	3.	9.06	20.4	25.3	16.9	6.9	5.26	.93	11.4
4219–4229	.38	.57	1.25	2.64	6.7	19.8	29.8	17.1	5.87	5.67	3.17	2.	.52	4.56
4237–4242	1.87	1.09	2.26	4.6	11.	22.5	26.9	12.5	1.87	6.16	3.35	1.56	.62	3.59
4242–4247			.05	.05	.05	.05	.54	4.37	9.1	21.8	17.2	23.4	3.51	20.
4297–4302	.13	.21	.30	1.45	3.68	10.75	21.9	18.5	9.	13.35	6.1	3.85	.98	9.7
4317–4322		.05	.05	.24	.85	5.7	26.1	29.7	10.25	8.66	4.84	3.52	1.05	9.07
4327–4332		.07	.26	.70	1.89	6.82	22.6	28.	11.9	12.	5.	3.15	.85	6.77
4347–4351		.11	.44	1.32	2.96	6.9	17.4	31.1	18.8	12.95	2.85	1.53	.44	3.29
4356–4361 Top			.04	.04	.07	.84	16.4	30.2	15.3	14.6	5.7	4.47	1.09	11.2
4356–4361 Bottom					.03	.06	2.79	22.9	22.	23.2	8.72	6.75	1.24	12.5
4361–4366			.05	.05	.14	1.05	19.6	36.3	14.6	11.1	4.77	3.24	.90	8.
4375–4380	1.43	.38	.91	2.19	6.7	20.	28.7	14.25	3.92	8.45	4.3	2.34	.60	5.8

4380–4384			.04	.41	1.71	7.1	30.	29.2	10.5	7.87	3.63	2.41	.61	6.57
4396–4401	2.46	.28	.49	.95	2.95	14.4	30.1	22.6	7.23	7.26	3.37	2.	.53	5.4
4406–4414 Bottom		.02	.02	.09	.49	3.52	15.5	25.5	17.9	15.2	6.02	4.7	.87	10.1
4414–4424		.04	.04	.18	1.12	6.06	21.2	27.	14.55	13.3	6.16	3.39	.76	6.13
4424–4434 Upper 2 ft.				.04	.17	1.3	10.1	28.6	19.95	16.7	6.93	4.87	.86	10.55
4424–4434 Bottom 8 ft.	1.94	1.17	2.93	5.72	10.15	16.65	18.5	13.9	7.95	8.37	4.10	2.52	.59	5.42
4434–4444	1.51	.85	1.63	3.33	6.35	13.	21.8	14.9	5.54	10.9	6.86	3.84	.85	8.65
4444–4454	.61	.47	1.65	4.45	8.56	17.	22.4	7.6	14.2	5.77	8.15	4.75	3.63	.77
4454–4464	2.25	.76	1.33	2.61	6.09	14.4	23.9	17.9	6.22	8.94	4.47	2.81	.70	7.48
4464–4469	3.67	2.11	3.78	5.96	9.45	14.15	19.25	13.9	2.91	8.93	4.15	2.8	.84	8.18
4500–4506	.97	.56	1.65	2.87	6.72	16.5	23.4	12.65	4.1	10.	5.1	3.72	.94	10.85
4506–4516		.07	.43	.89	2.61	7.4	13.1	22.5	16.5	15.2	6.32	4.4	1.11	9.44
4516–4521		.04	.08	.37	1.27	4.25	17.4	26.2	12.5	15.4	6.77	4.27	1.02	10.5
4521–4526		.05	.05	.09	.55	2.16	13.15	24.9	13.45	17.5	8.71	4.88	1.15	13.5
4531–4536	1.92	1.13	2.26	4.38	9.55	17.00	20.50	12.75	3.90	11.00	4.48	2.81	.79	7.57
4536–4546	.78	.20	.59	1.9	5.32	13.25	20.7	17.1	5.75	15.2	5.95	3.41	.93	9.07
4556–4566	3.32	.64	1.98	4.56	9.85	19.9	21.4	10.65	1.43	10.4	4.33	2.72	.78	8.12
4566–4576	1.45	1.08	2.21	4.56	10.05	19.05	20.6	12.35	1.39	11.05	4.5	2.85	.76	8.05
4576–4582			.65	3.37	9.25	19.9	24.	13.	.09	10.85	5.88	3.09	.94	8.96
4582–4592	.65	1.77	3.68	6.97	11.05	19.	21.6	14.2	4.84	7.44	2.90	1.79	.52	3.47
4659–4674	.11	.28	.95	3.2	8.76	17.6	18.65	12.9	4.5	13.3	5.45	3.76	1.12	9.21
4684–4689				.03	.03	.06	1.88	8.25	17.8	38.6	10.9	6.93	1.10	14.6
4747–4751					.06	.06	.89	4.17	4.17	24.5	25.5	21.4	4.24	15.05
4751–4756					.12	1.17	6.22	18.95	23.	23.4	7.18	6.43	2.09	11.4
4756–4766				.23	2.31	15.2	27.3	13.95	3.23	18.8	6.56	5.43	.69	6.24
4778–4788				.04	.04	.04	2.28	12.85	19.1	30.3	8.56	9.71	3.46	13.7
4798–4803	2.16	.28	.40	.69	1.23	3.1	10.05	23.3	18.95	20.7	3.67	9.35	1.64	4.5
4806–4813			.09	.29	.77	2.29	9.63	24.5	19.6	23.4	5.76	9.13	2.82	1.64
4813–4818			.09	.24	.93	5.34	23.7	18.25	14.6	15.2	4.43	7.56	6.27	3.2
4862–4872		.17	.50	1.55	4.04	10.01	17.45	19.15	10.9	14.7	4.93	9.03	3.38	4.1
4872–4877			.06	.06	.06	.17	4.12	17.8	17.6	34.3	7.13	13.45	2.38	2.84
4897–4902	.04	.29	.55	2.3	6.71	19.4	30.	12.85	6.71	8.	3.21	8.61	.51	.77
4902–4907	3.67	2.8	5.02	7.87	9.66	12.4	12.6	9.02	5.5	11.5	4.85	8.61	3.6	3.
4907–4912	.67	.26	1.19	2.34	3.97	9.71	22.9	18.4	9.	11.3	5.05	5.86	4.26	5.15
4917–4927	.31	.31	.78	2.03	4.54	11.5	19.1	13.95	9.99	14.3	5.21	11.5	4.3	2.14
4953–4958	.82	.28	.96	4.33	7.43	16.65	20.5	12.65	4.95	9.9	4.95	11.15	.89	4.6
4963½–4965½		.04	.04	.04	.08	.65	8.09	23.9	22.	23.58	3.77	12.65	1.22	3.49
4970–4975			.03	.05	.29	3.14	35.8	27.2	7.16	10.1	3.22	9.	1.86	2.29
4975–4980		.13	.37	1.15	3.83	10.85	14.35	15.35	16.15	20.6	4.95	8.56	2.14	1.53

TABLE 3—*Concluded*

Depth in Feet	Retained on Mesh													Pass 250
	5	8	10	14	20	28	35	48	65	100	150	200	250	
5007–5012		.09	.12	.43	1.1	5.3	22.15	30.1	12.15	12.7	2.91	10.3	.77	1.69
5027–5032 Top		.08	.12	.43	1.27	3.59	7.3	11.	14.	28.1	10.6	9.43	2.08	12.1
5027–5032 Bottom			.04	.04	.04	.15	3.44	16.75	18.9	30.	8.53	10.85	5.25	6.1
5037–5042		.04		.04	.37	2.	6.13	15.7	17.	29.2	8.42	10.7	4.47	6.
5104–5112	.45	.40	.72	1.83	4.64	10.8	15.95	16.05	14.7	15.9	3.26	9.35	2.6	3.38
5112–5122	.64	.40	.91	2.69	7.64	19.	24.4	12.15	5.5	8.27	4.07	4.47	5.06	4.78
5130–5135		.58	4.35	14.4	24.8	23.5	10.	4.08	.63	4.97	2.88	1.99	.68	7.23
5160–5165			.15	.10	.10	.10	1.67	7.65	6.8	32.1	20.7	14.4	1.32	15.
5183–5193				.09	.09	.17	4.07	7.73	7.8	37.4	13.5	9.72	3.72	15.52
5201–5213			.06	.17	.33	1.44	9.06	24.1	15.7	20.8	7.68	4.8	1.27	14.7
5307–5312		2.2	5.63	12.05	17.3	15.	10.7	6.16	.13	10.4	5.9	3.43	1.1	9.88
5312–5315			.15	.39	.62	.99	6.53	10.9	4.53	25.4	18.	11.3	1.84	19.5

TABLE 4

Classification of Sands: Ohio Oil Company, L. G. Hammond No. 1 Well

Percentages by Weight

Depth in Feet	Pebble	Granule Gravel	Very Coarse Sand	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Silt and Clay
1150–1160			0.18	0.39	5.6	12.1	48.0	33.9
1160–1170			.05	.10	3.5	26.4	42.9	27.2
1220–1230			.03	.06	6.9	32.4	34.5	26.3
1250–1260			.03	.33	19.5	48.1	17.5	15.0
1470–1480		.26	3.04	12.5	19.0	38.2	18.9	7.5
1480–1490		.20	1.30	4.0	11.55	17.05	44.6	21.2
1490–1498				0.4	1.18	5.15	54.5	39.0
1498–1508			.05	.10	18.1	48.0	22.5	11.4
1508–1518			.07	.21	20.9	57.4	13.35	7.6
1528–1538				.21	14.67	41.1	26.74	17.3
1658–1667			.08	.12	3.93	53.1	25.10	17.8
1687–1697			.06	.06	2.25	74.8	12.3	10.7
1697–1707			.03	.09	4.9	30.6	51.6	18.0
1767–1777		.07	.25	2.89	25.95	50.0	10.65	10.4
1777–1787				.18	10.82	64.6	13.21	11.2
1817–1824			.04	.11	14.51	56.4	15.8	13.3
1844–1854			.06	.12	3.82	63.7	18.9	13.2
1884–1894			.03	.09	3.37	42.1	35.84	18.6
1904–1914			.06	.56	12.8	57.2	15.28	14.0
1924–1934			.17	7.63	44.4	26.9	9.87	11.0
1944–1954			.04	.08	6.98	38.9	30.65	22.8
2004–2014			.06	.12	12.01	58.4	16.8	12.8
2014–2024				.28	6.42	54.4	25.10	13.5
2044–2054				.12	2.92	46.4	34.70	15.9
2157–2167				.10	1.57	77.3	12.70	8.7
2197–2207				.08	12.09	63.1	15.72	9.3
2267–2277				.22	4.62	58.2	19.99	16.0
2277–2287				.12	6.09	63.4	17.45	12.8
2297–2307				.08	2.77	62.4	22.66	12.1
2323–2333				.09	3.43	60.3	18.85	17.4
2565–2575				.69	46.6	34.9	10.17	7.6
2575–2585				.09	51.17	25.1	13.61	9.95
2585–2595			.12	2.68	42.6	27.9	12.82	14.1
2595–2605			.07	.42	23.95	40.5	17.40	17.6
2605–2615			.12	2.35	34.6	31.7	15.94	15.5
2615–2625			.08	2.08	28.8	39.7	15.41	13.8
2625–2635	.08	.22	4.1	23.9	42.4	16.75	4.83	7.8
2679–2689			.14	.21	8.0	47.8	23.47	20.2
2689–2699			.10	2.53	32.8	34.4	15.06	14.9
2699–2709			.10	3.17	46.1	25.0	12.07	13.3
2709–2719 Top			.04	.26	15.44	53.6	17.70	12.9
2709–2719 Bottom				.06	10.29	15.53	44.15	30.0
2719–2729 Top			.03	2.2	37.1	28.0	17.73	14.9
2719–2729 Middle				.06	8.9	12.75	40.95	37.3
2719–2729 Bottom	.33	.04	.33	1.87	42.3	30.2	12.25	12.9
2729–2739	.91	.03	.05	.95	9.39	58.0	18.43	11.6
2739–2749 Top	.13	.13	.46	4.48	34.7	34.5	13.65	12.0
2749–2759			.06	.12	38.0	44.1	10.6	7.4
2759–2769			.2	.6	4.7	76.7	12.4	5.5
2789–2794				.04	2.66	43.05	34.25	20.2
2794–2801			.13	.73	11.06	56.3	23.05	8.71
2801–2806			.04	.78	41.05	37.6	12.18	8.4
2806–2811			.33	4.68	48.6	21.7	12.97	11.5
2832–2837				.17	23.0	43.8	16.22	16.5

TABLE 4—*Continued*

Depth in Feet	Pebble	Granule Gravel	Very Coarse Sand	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Silt and Clay
2877–2887 Bottom			0.2	0.4	32.8	32.3	20.10	14.4
2887–2897		.10	.10	.34	19.5	55.8	14.12	10.4
2907–2917				.08	3.6	68.6	16.74	11.3
2923–2932				.12	9.54	56.1	22.28	11.8
3020–3030				.17	57.1	18.06	12.52	11.7
3030–3040			.12	.71	53.0	29.0	10.58	7.05
3040–3046					5.67	20.45	35.20	38.2
3101–3107	.10	.20	.1	.42	9.75	43.2	25.74	20.6
3117–3122				.03	7.25	58.1	19.21	15.3
3122–3127				.06	7.03	59.4	18.87	14.5
3127–3132				.17	8.07	55.2	21.74	14.9
3183–3193				.11	25.0	51.7	13.18	9.8
3259–3269			.2	11.35	47.2	25.8	8.76	6.8
3269–3274	.24	.18	2.2	16.95	46.4	19.25	8.34	6.6
3274–3280	.43	.34	4.24	23.53	40.7	16.6	8.48	6.1
3280–3285 Top		.05	.37	4.79	40.3	38.1	9.78	6.22
3280–3285 Middle			.21	.42	2.52	13.02	50.75	32.8
3280–3285 Bottom			.11	.82	23.23	49.6	16.11	10.5
3285–3290	1.08	.06	.63	11.42	50.8	21.8	8.42	5.5
3290–3300	.19	.06	.63	12.9	51.5	18.7	8.66	7.2
3315–3325	6.60	1.45	1.56	7.36	55.4	21.65	3.98	2.18
3325–3335		.05	.10	.32	29.04	51.9	10.30	8.15
3335–3345			.05	.10	3.22	44.45	39.85	12.2
3355–3360				.04	4.35	51.2	34.4	10.0
3360–3370			.16	.68	5.99	68.1	18.01	7.3
3376–3386			.38	2.03	28.3	48.6	11.46	8.8
3386–3396		.05	.33	3.03	44.8	36.9	8.97	5.87
3396–3401			.08	.08	3.26	54.95	26.32	15.3
3401–3407			.15	.18	6.3	62.2	22.93	7.94
3407–3417		.03	.18	1.2	13.26	62.6	12.29	10.3
3417–3427	.20	.13	1.35	7.49	23.5	49.5	10.64	7.35
3437–3447			.08	.16	1.3	17.72	60.8	19.8
3447–3457			.03	.06	3.4	58.85	23.74	13.9
3457–3467		.03	.16	2.13	35.6	35.7	16.86	9.33
3472–3477 Top				.16	3.79	30.62	48.67	16.8
3472–3477 Bottom		.05	.46	11.85	43.3	28.0	10.19	6.1
3477–3487			.04	4.8	53.9	26.6	8.28	6.3
3487–3497 Top			.05	1.3	59.0	27.0	6.88	5.65
3487–3497 Bottom			.05	2.08	51.9	25.5	10.35	10.1
3497–3507		.07	.14	10.25	63.6	12.16	7.04	6.85
3512–3521				.06	3.02	43.8	34.8	18.4
3521–3529 Top				.04	1.18	49.84	34.32	14.8
3521–3529 Bottom				.04	2.43	75.8	12.35	9.2
3529–3539		.07	.08	4.43	40.2	37.7	10.39	7.15
3539–3549 Top	.32	.11	3.51	40.6	35.43	9.77	5.89	4.15
3539–3549 Middle			.03	.31	10.26	49.9	21.28	18.2
3539–3549 Bottom			.05	.10	2.32	65.0	22.11	10.3
3549–3555				.06	14.62	59.4	14.72	11.10
3555–3560		.10	.51	.86	15.01	65.0	13.32	5.0
3570–3575			.08	1.91	51.7	28.5	10.62	7.0
3575–3583		.03	.21	1.23	40.0	41.5	11.12	6.03
3631–3641			.08	.38	6.53	25.17	43.57	24.2
3712–3717			.03	.06	4.17	54.4	29.52	12.0
3717–3722			.03	.06	2.91	55.67	34.41	6.9
3737–3743 Top				.05	9.85	56.4	22.43	11.3
3737–3743 Bottom				.06	4.97	64.92	20.52	9.4

TABLE 4—*Continued*

Depth in Feet	Pebble	Granule Gravel	Very Coarse Sand	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Silt and Clay
3773–3778				.30	4.36	66.45	24.53	4.56
3778–3783			.04	.46	12.93	73.1	12.11	1.33
3783–3788	.09	.09	.33	.47	25.04	57.4	12.84	3.93
3793–3798			.14	.21	28.82	53.7	11.46	5.65
3798–3804			.05	.63	2.93	47.3	37.03	12.15
3804–3810			.03	.70	7.23	58.04	21.58	12.32
3810–3815			.05	.10	1.69	64.47	21.96	11.59
3815–3820			.19	.28	7.49	74.8	10.69	6.45
3820–3830 Top 1½ ft.				.10	6.1	61.5	21.98	10.33
3820–3830				.09	21.08	65.3	12.09	1.5
3840–3850			.12	.68	51.64	35.65	9.36	2.68
3850–3855	.42	.59	5.14	17.6	41.4	25.88	5.95	2.51
3855–3865	.04	.23	1.42	8.94	49.63	28.55	7.17	3.91
3865–3875	.19	.13	2.00	15.84	46.45	21.09	8.21	6.2
3875–3880			.06	.20	41.43	45.0	9.13	4.1
3880–3885			.05	.14	27.5	53.3	12.25	6.73
3885–3895		.26	.22	1.14	28.54	52.8	11.09	5.76
3925–3930				.20	10.68	42.4	31.75	14.9
3930–3940			.05	.10	4.66	48.2	37.22	9.8
3940–3950			.05	.10	6.24	53.3	27.69	12.5
3950–3955			.12	1.25	23.44	53.7	22.60	7.7
3970–3980				.05	2.62	56.3	31.55	9.45
3985–3990				.10	2.76	46.4	38.81	11.8
3990–4000 Top				.12	2.88	40.3	39.90	16.9
3990–4000 Bottom			.17	.61	19.08	51.0	18.48	10.7
4000–4010		.05	.10	.55	14.15	55.2	20.95	8.86
4010–4015		.05	.60	2.63	17.92	46.2	21.58	10.8
4020–4025			.04	.39	40.05	27.4	17.78	14.4
4025–4035		.08	.7	2.82	40.85	34.6	12.61	8.45
4035–4045 Top			.05	1.89	54.5	26.9	10.07	6.5
4035–4045			.02	.12	5.67	50.8	29.42	13.8
4045–4051		.03	.34	.28	13.94	53.1	21.70	10.6
4053–4058			.19	2.01	45.8	29.2	11.54	11.2
4058–4068 Top			.08	2.69	41.4	32.1	11.97	11.6
4058–4068 Middle	.15	.04	.44	5.38	42.05	28.1	12.25	11.6
4058–4068 Bottom		.11	1.14	3.89	32.0	34.7	15.47	12.6
4068–4076	.51	.72	2.3	11.13	48.5	17.55	9.72	9.45
4076–4086 Top	3.48	.36	1.44	18.21	48.1	13.89	7.49	7.0
4076–4086 Bottom			.16	1.9	28.9	42.1	15.75	11.2
4091–4101 Bottom		.08	1.07	8.07	48.2	23.7	9.47	9.26
4101–4107 Top		.14	3.17	15.15	52.1	16.7	7.42	5.45
4101–4107 Bottom			.02	.08	20.9	58.9	12.74	7.2
4107–4117			.03	.32	33.26	51.2	10.11	4.9
4117–4127 Top		.03	.18	3.0	36.55	43.3	9.61	7.34
4117–4127 Bottom		.02	.51	1.87	33.9	46.4	10.32	6.76
4127–4137 Top			.52	1.76	25.27	51.6	15.10	5.8
4127–4137 Bottom			.11	1.72	34.9	45.6	10.87	6.7
4137–4147		.13	1.13	12.49	45.5	22.85	9.79	7.93
4157–4168	.27	.23	2.55	19.21	46.5	16.54	8.49	6.07
4168–4178			.38	11.26	51.6	19.95	9.26	7.64
4193–4199			.03	.06	4.24	69.4	18.31	7.85
4199–4209 Top 3 ft.			.06	.06	2.17	43.73	37.23	16.7
4199–4209 Middle			.04	.08	5.9	64.8	20.63	8.57
4199–4209 Bottom			.04	.08	16.75	63.0	13.40	6.93
4209–4219		.03	.25	3.71	29.46	42.2	13.09	11.4
4219–4229	.38	.57	3.89	26.5	46.9	11.54	5.69	4.56

TABLE 4—*Continued*

Depth in Feet	Pebble	Granule Gravel	Very Coarse Sand	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Silt and Clay
4237–4242	1.87	1.09	6.86	33.5	39.4	8.03	5.53	3.59
4242–4247			.10	.10	4.91	30.9	44.11	20.0
4297–4302	.13	.21	1.75	14.43	40.4	22.35	10.93	9.7
4317–4322		.05	.29	6.55	55.8	18.91	9.41	9.07
4327–4332		.07	.96	8.71	50.6	23.9	9.00	6.77
4347–4351		.11	1.76	9.86	48.5	31.75	4.82	3.29
4356–4361 Top			.08	.91	46.6	29.9	11.26	11.2
4356–4361 Bottom				.09	25.69	45.2	16.71	12.5
4361–4366			.10	1.19	55.9	25.7	8.91	8.0
4375–4380	1.43	.38	3.10	26.7	42.95	12.37	7.24	5.8
4380–4384			.45	8.81	59.2	18.37	6.65	6.57
4396–4401	2.46	.28	1.44	17.35	52.7	14.49	5.90	5.4
4406–4414 Bottom		.02	.11	4.01	41.0	33.1	11.59	10.1
4414–4424		.04	.22	7.18	48.2	27.85	10.31	6.13
4424–4434			.04	1.47	38.7	36.65	12.66	10.55
4424–4434 Bottom 8 ft.	1.94	1.17	8.65	26.8	32.4	16.32	7.21	5.42
4434–4444	1.51	.85	4.96	19.35	36.7	16.44	11.55	8.65
4444–4454	.61	.47	6.1	25.56	30.0	19.97	16.53	.77
4454–4464	2.25	.76	3.94	20.49	41.8	15.16	7.98	7.48
4464–4469	3.67	2.11	9.74	23.6	33.15	11.84	7.79	8.18
4500–4506	.97	.56	4.52	23.22	36.05	14.1	9.76	10.85
4506–4516		.07	1.32	10.01	35.6	31.7	11.83	9.44
4516–4521		.04	.45	5.52	43.6	27.9	12.06	10.5
4521–4526		.05	.14	2.71	38.05	30.95	14.74	13.5
4531–4536	1.92	1.13	6.64	26.55	33.25	14.9	8.08	7.57
4536–4546	.78	.20	2.49	18.57	37.8	20.95	10.29	9.07
4556–4566	3.32	.64	6.54	39.75	32.05	11.83	7.83	8.12
4566–4576	1.45	1.08	6.77	29.1	32.95	12.44	8.11	8.05
4576–4582			4.02	29.15	37.0	10.94	9.91	8.96
4582–4592	.65	1.77	10.65	30.05	35.8	12.28	5.21	3.47
4659–4674	.11	.28	4.15	26.36	31.55	17.8	10.33	9.21
4684–4689			.03	.09	10.13	56.4	18.93	14.6
4747–4751				.12	5.06	28.67	51.14	15.05
4751–4756				1.29	25.17	46.4	15.70	11.4
4756–4766			.23	17.51	41.25	22.03	12.68	6.24
4778–4788			.04	.08	15.13	49.4	21.73	13.7
4798–4803	2.16	.28	1.09	4.33	33.35	39.65	14.66	4.5
4806–4813			.38	3.06	34.13	43.0	17.71	1.64
4813–4818			.33	6.27	41.95	29.8	18.26	3.2
4862–4872		.17	2.05	14.05	36.6	25.6	17.34	4.1
4872–4877			.12	.23	21.92	51.9	22.96	2.84
4897–4902	.04	.29	2.85	26.11	42.85	14.71	12.33	.77
4902–4907	3.67	2.80	12.89	22.06	21.62	17.0	17.06	3.0
4907–4912	.67	.26	3.53	13.68	41.3	20.3	15.17	5.15
4917–4927	.31	.31	2.81	16.04	33.05	24.29	21.01	2.14
4953–4958	.82	.28	5.29	24.08	33.15	14.85	16.90	4.6
4963½–4965½		.04	.08	.73	31.99	45.58	17.64	3.49
4970–4975			.06	3.43	63.0	17.26	14.08	2.29
4975–4980		.13	1.52	14.68	29.7	36.75	15.65	1.53
5007–5012		.09	.55	6.4	52.25	24.85	13.98	1.69
5027–5032		.08	.55	4.86	18.3	42.1	22.11	12.1
5027–5032 Bottom			.08	.19	20.19	48.9	24.63	6.1
5037–5042		.04	.04	2.37	21.83	46.2	23.59	6.0
5104–5112	.45	.40	2.55	15.44	32.0	30.6	15.21	3.38
5112–5122	.64	.40	3.6	26.64	36.55	13.77	13.60	4.78
5130–5135		.58	18.75	48.3	14.08	5.6	5.55	7.23

TABLE 4—*Concluded*

Depth in Feet	Pebble	Granule Gravel	Very Coarse Sand	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Silt and clay
5160–5165			.25	.20	9.32	38.9	36.42	15.0
5183–5193			.09	.26	11.8	45.2	26.94	15.52
5201–5213			.23	1.77	33.16	36.5	13.75	14.7
5307–5312		2.2	17.68	32.3	16.86	10.53	10.43	9.88
5312–5315			.54	1.61	17.43	29.93	31.14	19.5

TABLE 5

Relation of Krumbein's Phi Scale to Wentworth Grades

Wentworth Grades in mm.	Phi Scale
32	−5
16	−4
8	−3
4	−2
2	−1
1	0
$\frac{1}{2}$	+1
$\frac{1}{4}$	+2
$\frac{1}{8}$	+3
$\frac{1}{16}$	+4
$\frac{1}{32}$	+5
$\frac{1}{64}$	+6
$\frac{1}{128}$	+7
$\frac{1}{256}$	+8
$\frac{1}{512}$	+9
$\frac{1}{1024}$	+10

worth grade between the quartiles, whereas a second having a $QD\phi$ of 1.00, has two Wentworth grades between its quartiles. This measure allows one to visualize the character of the frequency curves of the various sands.

The phi skewness, $Skq\phi$, is given by the equation:

$$Skq\phi = \frac{(Q_{3\phi} + Q_{1\phi}) - 2(Md\phi)}{2}$$

If the value of $Skq\phi$ is 0.0, then the frequency curve is symmetrical. If the value is negative, then the arithmetic mean of the quartiles lies to the left of $Md\phi$ or toward the smaller values of ϕ. If the value is positive, the arithmetic mean lies to the right of $Md\phi$ and the curve is skewed toward the positive values of ϕ. A sand with an $Skq\phi$ of -0.5 has its curve skewed to the left with the mean of the quartiles one half of a Wentworth unit to the left of the median. If the value were $+0.5$, then the curve would be skewed one half of a Went-

TABLE 6

Statistical Data: Ohio Oil Company, Hammond No. 1 Well

Depth in Feet	Median (mm.)	Q_1 (mm.)	Q_3 (mm.)	So	Log_{10} So	Degree of Sorting
1150–1160	0.082		0.123			
1160–1170	0.102	0.052	0.158	1.74	0.241	5.6
1220–1230	0.109	0.058	0.192	1.82	0.260	6.1
1250–1260	0.193	0.112	0.270	1.55	0.191	4.5
1470–1480	0.187	0.132	0.420	1.79	0.251	5.8
1480–1490	0.092	0.065	0.199	1.75	0.243	5.7
1490–1498	0.072		0.098			
1498–1508	0.183	0.116	0.262	1.50	0.177	4.1
1508–1518	0.219	0.159	0.284	1.34	0.126	2.9
1528–1538	0.158	0.093	0.235	1.59	0.201	4.7
1658–1667	0.158	0.091	0.185	1.42	0.154	3.6
1687–1697	0.175	0.152	0.190	1.12	0.048	1.1
1697–1707	0.122	0.077	0.165	1.46	0.165	3.8
1767–1777	0.232	0.159	0.329	1.44	0.158	3.7
1777–1787	0.216	0.148	0.261	1.33	0.123	2.9
1817–1824	0.195	0.130	0.255	1.40	0.146	3.4
1844–1854	0.168	0.101	0.179	1.33	0.124	2.9
1884–1894	0.137	0.083	0.170	1.43	0.156	3.6
1904–1914	0.198	0.120	0.255	1.47	0.164	3.8
1924–1934	0.300	0.168	0.400	1.54	0.188	4.4
1944–1954	0.134	0.068	0.187	1.67	0.220	5.1
2004–2014	0.210	0.124	0.258	1.44	0.159	3.7
2014–2024 Top	0.168	0.105	0.208	1.42	0.148	3.4
2044–2054	0.145	0.090	0.172	1.38	0.141	3.3
2157–2167	0.171	0.155	0.189	1.10	0.043	1.0
2197–2207	0.209	0.147	0.241	1.28	0.107	2.5
2267–2277	0.176	0.095	0.218	1.52	0.180	4.2
2277–2287	0.189	0.100	0.228	1.51	0.179	4.2
2297–2307	0.185	0.092	0.228	1.57	0.197	4.6
2323–2333	0.160	0.084	0.169	1.42	0.152	3.5
2565–2575	0.284	0.184	0.340	1.36	0.133	3.1
2575–2585	0.301	0.155	0.359	1.52	0.182	4.2
2585–2595	0.254	0.133	0.380	1.69	0.228	5.3
2595–2605	0.189	0.093	0.291	1.77	0.248	5.8
2605–2615	0.196	0.115	0.365	1.78	0.251	5.8
2615–2625	0.182	0.123	0.330	1.27	0.214	5.0
2625–2635	0.412	0.250	0.620	1.22	0.197	4.6
2679–2689	0.160	0.081	0.198	1.56	0.194	4.5
2689–2699	0.216	0.115	0.345	1.73	0.239	5.6
2699–2709	0.288	0.141	0.390	1.66	0.221	5.1
2709–2719 Top	0.183	0.124	0.250	1.42	0.152	3.5
2709–2719 Bottom	0.086		0.147			
2719–2729 Top	0.215	0.095	0.375	1.99	0.298	6.9
2719–2729 Middle	0.084		0.132			
2719–2729 Bottom	0.270	0.146	0.361	1.57	0.197	4.6
2729–2739	0.182	0.126	0.223	1.33	0.124	2.9
2739–2749 Top	0.248	0.143	0.357	1.58	0.199	4.6
2749–2759	0.259	0.178	0.330	1.36	0.134	3.1
2759–2769	0.191	0.163	0.229	1.19	0.074	1.7
2789–2794	0.140	0.081	0.176	1.47	0.169	3.9
2794–2801	0.180	0.125	0.236	1.37	0.138	3.2
2801–2806	0.265	0.167	0.339	1.42	0.154	3.6
2806–2811	0.310	0.149	0.432	1.70	0.231	5.4
2832–2837	0.193	0.100	0.284	1.69	0.227	5.3
2877–2887 Bottom	0.265	0.096	0.325	1.84	0.265	6.2
2887–2897	0.220	0.149	0.277	1.36	0.135	3.1

TABLE 6—*Continued*

Depth in Feet	Median (mm.)	Q_1 (mm.)	Q_3 (mm.)	So	Log_{10} So	Degree of Sorting
2907–2917	0.182	0.132	0.200	1.23	0.090	2.1
2923–2932	0.190	0.093	0.245	1.62	0.210	4.9
3020–3030	0.335	0.148	0.365	1.57	0.196	4.6
3030–3040	0.308	0.196	0.372	1.19	0.139	3.2
3040–3046	0.083		0.149			
3101–3107	0.152	0.079	0.206	1.62	0.208	4.8
3117–3122	0.173	0.095	0.199	1.45	0.160	3.7
3122–3127	0.175	0.095	0.205	1.47	0.167	3.9
3127–3132	0.169	0.099	0.215	1.47	0.168	3.9
3183–3193	0.225	0.154	0.298	1.39	0.143	3.3
3259–3269	0.340	0.196	0.472	1.55	0.190	4.4
3269–3274	0.383	0.220	0.520	1.54	0.187	4.4
3274–3280	0.414	0.240	0.630	1.62	0.210	4.9
3280–3285 Top	0.276	0.180	0.380	1.45	0.162	3.8
3280–3285 Middle	0.082		0.122			
3280–3285 Bottom	0.202	0.138	0.291	1.45	0.162	3.8
3285–3290	0.365	0.212	0.485	1.51	0.180	4.2
3290–3300	0.382	0.207	0.495	1.55	0.189	4.4
3315–3325	0.400	0.277	0.507	1.35	0.131	3.0
3325–3335	0.245	0.170	0.304	1.34	0.126	2.9
3335–3345	0.140	0.090	0.176	1.40	0.146	3.4
3355–3360	0.156	0.096	0.193	1.41	0.152	3.5
3360–3370	0.180	0.146	0.207	1.19	0.076	1.8
3376–3386	0.232	0.161	0.310	1.39	0.142	3.3
3386–3396	0.289	0.190	0.378	1.41	0.149	3.5
3396–3401	0.163	0.093	0.188	1.42	0.153	3.6
3401–3407	0.168	0.126	0.193	1.24	0.093	2.2
3407–3417	0.180	0.149	0.243	1.28	0.106	2.5
3417–3427	0.228	0.165	0.361	1.48	0.170	4.0
3437–3447	0.105	0.076	0.137	1.34	0.128	3.0
3447–3457	0.160	0.096	0.176	1.35	0.132	3.1
3457–3467	0.224	0.138	0.359	1.61	0.208	4.8
3472–3477 Top	0.120	0.084	0.158	1.37	0.137	3.2
3472–3477 Bottom	0.326	0.171	0.480	1.67	0.224	5.2
3477–3487	0.328	0.200	0.415	1.44	0.159	3.7
3487–3497 Top	0.325	0.218	0.400	1.35	0.132	3.1
3487–3497 Bottom	0.315	0.168	0.398	1.54	0.187	4.3
3497–3507	0.430	0.290	0.505	1.32	0.120	2.8
3512–3521	0.134	0.078	0.168	1.46	0.167	3.9
3521–3529 Top	0.150	0.083	0.173	1.44	0.159	3.7
3521–3529 Bottom	0.200	0.158	0.236	1.22	0.087	2.0
3529–3539	0.275	0.182	0.380	1.44	0.160	3.7
3539–3549 Top	0.546	0.370	0.710	1.39	0.142	3.3
3539–3549 Middle	0.167	0.084	0.226	1.64	0.215	5.0
3539–3549 Bottom	0.168	0.113	0.190	1.30	0.113	2.6
3549–3555	0.208	0.141	0.260	1.36	0.133	3.1
3555–3560	0.202	0.160	0.264	1.29	0.109	2.5
3570–3575	0.305	0.178	0.415	1.53	0.184	4.3
3575–3583	0.259	0.173	0.352	1.43	0.154	3.6
3631–3641	0.098	0.063	0.159	1.59	0.201	4.7
3712–3717	0.157	0.088	0.173	1.40	0.147	3.4
3717–3722	0.152	0.103	0.167	1.29	0.105	2.4
3737–3743 Top	0.172	0.115	0.221	1.39	0.142	3.3
3737–3743 Bottom	0.161	0.120	0.176	1.21	0.083	1.9
3773–3778	0.167	0.134	0.181	1.16	0.065	1.5
3778–3783	0.222	0.174	0.265	1.24	0.090	2.1
3783–3788	0.221	0.164	0.298	1.35	0.130	3.0

TABLE 6—*Continued*

Depth in Feet	Median (mm.)	Q_1 (mm.)	Q_3 (mm.)	So	Log_{10} So	Degree of Sorting
3793–3798	0.235	0.168	0.309	1.36	0.132	3.1
3798–3804	0.146	0.097	0.192	1.40	0.148	3.4
3804–3810	0.172	0.110	0.209	1.38	0.139	3.2
3810–3815	0.162	0.110	0.177	1.27	0.103	2.4
3815–3820	0.202	0.162	0.250	1.24	0.094	2.2
3820–3830 Top 1½ ft.	0.162	0.114	0.182	1.26	0.102	2.4
3820–3830	0.223	0.172	0.283	1.29	0.108	2.5
3840–3850	0.305	0.185	0.342	1.36	0.133	3.1
3850–3855	0.355	0.242	0.560	1.52	0.182	4.2
3855–3865	0.329	0.220	0.409	1.36	0.135	3.1
3865–3875	0.393	0.216	0.525	1.56	0.193	4.5
3875–3880	0.268	0.200	0.335	1.30	0.112	2.6
3880–3885	0.234	0.168	0.300	1.34	0.126	2.9
3885–3895	0.243	0.168	0.310	1.36	0.133	3.1
3925–3930	0.151	0.094	0.202	1.46	0.166	3.9
3930–3940	0.152	0.104	0.180	1.31	0.119	2.8
3940–3950	0.164	0.104	0.203	1.40	0.145	3.4
3950–3955	0.196	0.157	0.295	1.37	0.137	3.2
3970–3980	0.156	0.112	0.183	1.29	0.107	2.5
3985–3990	0.143	0.097	0.178	1.35	0.132	3.1
3990–4000 Top	0.131	0.087	0.170	1.40	0.145	3.4
3990–4000 Bottom	0.190	0.130	0.269	1.44	0.158	3.7
4000–4010	0.180	0.130	0.250	1.39	0.142	3.3
4010–4015	0.177	0.122	0.268	1.48	0.170	4.0
4020–4025	0.236	0.106	0.363	1.85	0.267	6.2
4025–4035	0.260	0.163	0.395	1.56	0.192	4.5
4035–4045 Top	0.300	0.194	0.403	1.44	0.159	3.7
4035–4045 Bottom	0.160	0.101	0.212	1.45	0.160	3.7
4045–4051	0.193	0.124	0.261	1.45	0.162	3.8
4053–4058	0.286	0.154	0.380	1.57	0.196	4.6
4058–4068 Top	0.269	0.154	0.364	1.54	0.187	4.4
4058–4068 Middle	0.284	0.152	0.400	1.62	0.210	4.9
4058–4068 Bottom	0.212	0.129	0.355	1.66	0.220	5.1
4068–4076	0.360	0.183	0.490	1.64	0.214	5.0
4076–4086 Top	0.430	0.254	0.580	1.51	0.179	4.2
4076–4086 Bottom	0.200	0.137	0.320	1.53	0.184	4.3
4091–4101 Bottom	0.344	0.175	0.450	1.60	0.205	4.8
4101–4107 Top	0.395	0.256	0.530	1.44	0.158	3.7
4101–4107 Bottom	0.222	0.162	0.280	1.31	0.119	2.8
4107–4117	0.243	0.180	0.322	1.32	0.126	2.9
4117–4127 Top	0.249	0.172	0.359	1.44	0.160	3.7
4117–4127 Bottom	0.252	0.180	0.322	1.36	0.133	3.1
4127–4137 Top	0.212	0.156	0.305	1.40	0.146	3.4
4127–4137 Bottom	0.240	0.163	0.340	1.44	0.160	3.7
4137–4147	0.342	0.181	0.480	1.63	0.218	5.0
4157–4168	0.405	0.234	0.565	1.55	0.191	4.4
4168–4178	0.370	0.200	0.500	1.58	0.199	4.6
4193–4199	0.167	0.142	0.184	1.14	0.056	1.3
4199–4209 Top 3 ft.	0.138	0.087	0.163	1.37	0.136	3.2
4199–4209 Middle	0.182	0.130	0.230	1.33	0.124	2.9
4199–4209 Bottom	0.215	0.162	0.270	1.29	0.111	2.6
4209–4219	0.234	0.146	0.330	1.50	0.177	4.1
4219–4229	0.470	0.319	0.635	1.41	0.149	3.5
4237–4242	0.541	0.368	0.760	1.44	0.157	3.7
4242–4247	0.113	0.076	0.172	1.50	0.177	4.1
4297–4302	0.324	0.170	0.500	1.71	0.234	5.4
4317–4322	0.353	0.190	0.445	1.53	0.185	4.3

TABLE 6—*Concluded*

Depth in Feet	Median (mm.)	Q_1 (mm.)	Q_3 (mm.)	So	Log_{10} So	Degree of Sorting
4327–4332	0.345	0.198	0.445	1.50	0.176	4.1
4347–4351	0.335	0.223	0.435	1.40	0.145	3.4
4356–4361 Top	0.279	0.153	0.380	1.58	0.198	4.6
4356–4361 Bottom	0.202	0.128	0.292	1.51	0.179	4.2
4361–4366	0.325	0.188	0.393	1.45	0.160	3.7
4375–4380	0.470	0.296	0.650	1.48	0.171	4.0
4380–4384	0.370	0.239	0.460	1.39	0.142	3.3
4396–4401	0.423	0.294	0.560	1.38	0.140	3.3
4406–4414 Bottom	0.269	0.162	0.380	1.53	0.185	4.3
4414–4424	0.315	0.187	0.432	1.52	0.182	4.2
4424–4434 Upper 2 ft.	0.250	0.150	0.345	1.51	0.181	4.2
4424–4434 Bottom 2 ft.	0.480	0.255	0.770	1.75	0.240	5.6
4434–4444	0.395	0.165	0.619	1.93	0.287	6.7
4444–4454	0.450	0.210	0.670	1.78	0.252	5.9
4454–4464	0.415	0.230	0.620	1.64	0.215	5.0
4464–4469	0.480	0.206	0.830	2.00	0.303	7.1
4500–4506	0.430	0.177	0.640	1.90	0.279	6.5
4506–4516	0.275	0.158	0.407	1.60	0.205	4.8
4516–4521	0.288	0.151	0.400	1.63	0.212	4.9
4521–4526	0.250	0.128	0.365	1.69	0.228	5.3
4531–4536	0.460	0.218	0.730	1.83	0.262	6.1
4536–4546	0.342	0.172	0.560	1.80	0.256	6.0
4556–4566	0.508	0.190	0.760	2.00	0.301	7.0
4566–4576	0.485	0.184	0.725	1.99	0.298	6.9
4576–4582	0.460	0.172	0.660	1.96	0.292	6.8
4582–4592	0.520	0.320	0.810	1.59	0.202	4.7
4659–4674	0.405	0.170	0.657	1.96	0.294	6.8
4684–4689	0.170	0.115	0.218	1.38	0.139	3.2
4747–4751	0.117	0.084	0.159	1.38	0.139	3.2
4751–4756	0.205	0.133	0.300	1.50	0.177	4.1
4756–4766	0.374	0.161	0.530	1.81	0.259	6.0
4778–4788	0.174	0.096	0.243	1.59	0.202	4.7
4798–4803	0.255	0.159	0.359	1.50	0.177	4.1
4806–4813	0.234	0.163	0.340	1.44	0.160	3.7
4813–4818	0.285	0.146	0.445	1.75	0.242	5.6
4862–4872	0.300	0.160	0.485	1.74	0.241	5.6
4872–4877	0.178	0.142	0.283	1.41	0.150	3.5
4897–4902	0.450	0.265	0.533	1.42	0.152	3.5
4902–4907	0.488	0.174	0.950	2.34	0.369	8.6
4907–4912	0.355	0.170	0.520	1.75	0.243	5.7
4917–4927	0.315	0.144	0.525	1.76	0.281	6.5
4953–4958	0.406	0.172	0.635	1.92	0.284	6.6
4963½–4965½	0.224	0.138	0.325	1.53	0.186	4.3
4970–4975	0.370	0.212	0.458	1.47	0.167	3.9
4975–4980	0.265	0.154	0.472	1.75	0.243	5.7
5007–5012	0.325	0.170	0.430	1.59	0.202	4.7
5027–5032	0.173	0.112	0.285	1.60	0.203	4.7
5027–5032 Bottom	0.178	0.118	0.272	1.52	0.181	4.2
5037–5042	0.182	0.124	0.293	1.54	0.187	4.4
5104–5112	0.300	0.168	0.500	1.73	0.237	5.5
5112–5122	0.447	0.200	0.640	1.79	0.253	5.9
5130–5135	0.773	0.470	1.070	1.56	0.179	4.2
5160–5165	0.145	0.093	0.175	1.37	0.137	3.2
5183–5193	0.155	0.092	0.182	1.41	0.148	3.4
5201–5213	0.210	0.135	0.337	1.58	0.199	4.6
5307–5312	0.630	0.165	1.030	2.55	0.398	9.3
5312–5315	0.144	0.085	0.200	1.53	0.186	4.3

worth unit to the right. The skewness together with the quartile deviation allows one to picture completely the general shape of the curve of a sediment. The values of these two statistical measures are found in Table 7.

THE MEDIAN DIAMETER

The distribution of the median diameters of the sands of the Hammond well has been summarized on Figs. 4 and 5. They show that 92% of all samples have median diameters which fall within the medium and fine sand classes, that is between 0.495 and 0.124 millimeters. A total of 53% of all samples have median diameters which range between 0.246 and 0.124 millimeters which are the limits of the fine sand class.

There is also a general increase in the size of the median diameter with depth as shown on Fig. 5. In the Magothy and Raritan formation of the Upper Cretaceous, the bulk of the median diameters fall within the fine sand class. In the Patapsco-Arundel section of the Upper Cretaceous, the size of the median diameter is variable, 55% of the samples having diameters falling in the fine sand class and 39% in the medium sand class (Fig. 4). In the Patuxent formation of the Lower Cretaceous, 63% of the median diameters fall in the medium sand class, 27% in the fine sand class, and 8% in the coarse sand class. The size of the median diameter is consistently larger in the uppermost 200 feet of the Patuxent formation and the lowermost 100 the Patapsco-Arundel section than in any other part of the well. Below the above mentioned point in the Patuxent formation the median diameters tend to become smaller.

THE SORTING OF THE SEDIMENTS

The distribution of the sorting factors (So-values) of the sediments of the Hammond well is shown in both Table 8 and Fig. 6. The distribution of this factor with depth together with the "degree of sorting", using the log So, have been plotted on Fig. 5.

The sands of the Upper Cretaceous Magothy and Raritan formations have a sorting factor which in 88 per cent of the samples falls between 1.25 and 1.75 (Table 8). The sorting of the sands of the Patapsco-Arundel section is similar to that of the Magothy and Raritan formations, 89 percent of the samples having a sorting factor ranging from 1.25 to 1. 75. In both cases the majority of the sands have sorting factors which are limited to the range between 1.25 and 1.50.

In the Patuxent formation, the sorting is much less uniform. Table 8 and Figure 6 show that only 21 percent of the sands have a sorting factor in the range 1.25–1.50, with 44 percent ranging from 1.50–1.75, and 31 percent between 1.75–2.00. Four percent (2 samples) were noted with So–values between 2.25 and 2.75. The increase of the sorting factor is rather abrupt at the top of the Patuxent formation as shown in Figure 5, and the factor is generally greater throughout this formation than in the overlying formations.

TABLE 7

Statistical Data: Ohio Oil Company, Hammond No. 1 Well

Depth in Feet	Median Diameter Md φ	Q3 φ	Q1 φ	QD φ	Skq φ
1150–1160	3.60		3.0		
1160–1170	3.30	4.25	2.65	0.80	+0.150
1220–1230	3.20	4.10	2.39	0.86	+0.045
1250–1260	2.38	3.19	1.90	0.65	+0.165
1470–1480	2.42	2.92	1.25	0.84	−0.335
1480–1490	3.44	3.95	2.32	0.82	−0.305
1490–1498	3.80		3.38		
1498–1508	2.43	3.10	1.94	0.58	+0.09
1508–1518	2.20	2.63	1.81	0.41	+0.02
1528–1538	2.65	3.45	2.10	0.68	+0.125
1658–1667	2.65	3.46	2.43	0.52	+0.295
1687–1697	2.52	2.70	2.40	0.15	+0.020
1697–1707	3.03	3.70	2.60	0.55	+0.120
1767–1777	2.10	2.63	1.61	0.51	+0.020
1777–1787	2.21	2.75	1.93	0.41	+0.130
1817–1824	2.35	2.95	1.97	0.49	+0.110
1844–1854	2.58	3.30	2.44	0.43	+0.290
1884–1894	2.90	3.60	2.57	0.52	+0.185
1904–1914	2.35	3.05	1.98	0.54	+0.165
1924–1934	1.75	2.60	1.32	0.64	+0.210
1944–1954	2.90	3.90	2.42	0.74	+0.260
2004–2014	2.24	3.01	1.97	0.52	+0.250
2014–2024 Top	2.60	3.25	2.24	0.51	+0.145
2044–2054	2.80	3.48	2.55	0.47	+0.215
2157–2167	2.54	2.70	2.40	0.15	+0.01
2197–2207	2.27	2.78	2.06	0.36	+0.150
2267–2277	2.50	3.40	2.21	0.60	+0.305
2277–2287	2.40	3.32	2.15	0.59	+0.335
2297–2307	2.45	3.45	2.15	0.65	+0.350
2323–2333	2.65	3.60	2.58	0.51	+0.440
2565–2575	1.81	2.45	1.55	0.45	+0.190
2575–2585	1.72	2.70	1.50	0.60	+0.38
2585–2595	2.00	2.90	1.40	0.75	+0.15
2595–2605	2.41	3.45	1.79	0.83	+0.21
2605–2615	2.35	3.10	1.46	0.82	−0.07
2615–2625	2.45	3.02	1.60	0.71	−0.14
2625–2635	1.30	2.00	0.70	0.65	+0.05
2679–2689	2.65	3.65	2.35	0.65	+0.35
2689–2699	2.20	3.10	1.55	0.78	+0.125
2699–2709	1.80	2.82	1.37	0.73	+0.295
2709–2719 Top	2.45	3.00	2.00	0.50	+0.050
2709–2719 Bottom	3.55		2.80		
2719–2729 Top	2.22	3.40	1.40	0.50	+0.180
2719–2729 Middle	3.60		2.92		
2719–2729 Bottom	1.90	2.80	1.49	0.66	+0.245
2729–2739	2.45	2.99	2.17	0.41	+0.130
2739–2749 Top	2.01	2.81	1.50	0.66	+0.145
2749–2759	1.95	2.50	1.60	0.45	+0.100
2759–2769	2.40	2.61	2.12	0.25	−0.040
2789–2794	2.82	3.65	2.52	0.57	+0.265
2794–2801	2.50	3.00	2.10	0.45	+0.050
2801–2806	1.95	2.60	1.55	0.52	+0.125
2806–2811	1.70	2.75	1.21	0.77	+0.280
2832–2837	2.35	3.32	1.81	0.76	+0.215
2877–2887 Bottom	1.95	3.40	1.61	0.90	+0.555

TABLE 7—*Continued*

Depth in Feet	Median Diameter Md ϕ	Q_3 ϕ	Q_1 ϕ	QD ϕ	Skq ϕ
2887–2897	2.20	2.72	1.88	0.42	+0.100
2907–2917	2.45	2.92	2.31	0.31	+0.165
2923–2932	2.40	3.45	2.05	0.70	+0.350
3020–3030	1.60	2.75	1.45	0.65	+0.500
3030–3040	1.70	2.35	1.42	0.47	+0.185
3040–3046	3.60		2.76		
3101–3107	2.75	3.69	2.30	0.70	+0.245
3117–3122	2.52	3.40	2.32	0.54	+0.340
3122–3127	2.53	3.40	2.30	0.55	+0.320
3127–3132	2.57	3.37	2.22	0.58	+0.225
3183–3193	2.16	2.70	1.75	0.48	+0.065
3259–3269	1.55	2.35	1.10	0.63	+0.175
3269–3274	1.40	2.20	0.95	0.63	+0.175
3274–3280	1.28	2.07	0.70	0.69	+0.105
3280–3285 Top	1.97	2.50	1.40	0.55	−0.010
3280–3285 Middle	3.60		3.05		
3280–3285 Bottom	2.32	2.85	1.81	0.52	+0.010
3285–3290	1.47	2.15	1.05	0.55	+0.180
3290–3300	1.40	2.30	1.02	0.64	+0.260
3315–3325	1.32	1.85	0.98	0.44	+0.095
3325–3335	2.03	2.58	1.72	0.43	+0.120
3335–3345	2.82	3.49	2.51	0.49	+0.180
3355–3360	2.68	3.40	2.39	0.51	+0.215
3360–3370	2.47	2.80	2.30	0.25	+0.080
3376–3386	2.10	2.64	1.90	0.37	+0.170
3386–3396	1.81	2.40	1.41	0.50	+0.095
3396–3401	2.61	3.47	2.45	0.51	+0.350
3401–3407	2.59	3.00	2.38	0.31	+0.100
3407–3417	2.49	2.75	2.05	0.35	−0.090
3417–3427	2.15	2.60	1.50	0.55	−0.100
3437–3447	3.17	3.75	2.90	0.43	+0.155
3447–3457	2.65	3.40	2.51	0.45	+0.305
3457–3467	2.17	2.85	1.50	0.68	+0.005
3472–3477 Top	3.05	3.60	2.67	0.47	+0.085
3472–3477 Bottom	1.62	2.55	1.05	0.75	+0.180
3477–3487	1.61	2.32	1.27	0.53	+0.185
3487–3497 Top	1.64	2.27	1.37	0.45	+0.180
3487–3497 Bottom	1.70	2.59	1.35	0.62	+0.270
3497–3507	1.21	1.80	0.99	0.41	+0.185
3512–3521	2.90	3.69	2.59	0.55	+0.240
3521–3529 Top	2.75	3.60	2.52	0.54	+0.310
3521–3529 Bottom	2.32	2.65	2.10	0.28	+0.055
3529–3539	1.87	2.45	1.40	0.53	+0.055
3539–3549 Top	0.89	1.43	0.50	0.47	+0.075
3539–3549 Middle	2.60	3.59	2.17	0.71	+0.280
3539–3549 Bottom	2.59	3.12	2.40	0.36	+0.170
3549–3555	2.28	2.82	1.97	0.43	+0.115
3555–3560	2.30	2.63	1.93	0.35	−0.020
3570–3575	1.70	2.50	1.28	0.61	+0.190
3575–3583	1.97	2.56	1.51	0.53	+0.065
3631–3641	3.37	4.00	2.65	0.68	−0.045
3712–3717	2.69	3.50	2.55	0.48	+0.335
3717–3722	2.70	3.30	2.60	0.35	+0.250
3737–3743 Top	2.53	3.12	2.19	0.47	+0.125
3737–3743 Bottom	2.65	3.06	2.50	0.28	+0.130
3773–3778	2.60	2.90	2.45	0.23	+0.075

TABLE 7—*Continued*

Depth in Feet	Median Diameter Md φ	Q₃ φ	Q₁ φ	QD φ	Skq φ
3778–3783	2.19	2.50	1.92	0.29	+0.020
3783–3788	2.20	2.61	1.77	0.42	−0.010
3793–3798	2.10	2.59	1.92	0.29	+0.050
3798–3804	2.80	3.40	2.39	0.51	+0.095
3804–3810	2.57	3.20	2.27	0.47	+0.165
3810–3815	2.61	3.20	2.52	0.34	+0.250
3815–3820	2.30	2.61	2.00	0.31	+0.005
3820–3830 Top 1½ ft.	2.61	3.10	2.45	0.33	+0.165
3820–3830	2.18	2.55	1.82	0.37	+0.005
3840–3850	1.72	2.45	1.55	0.45	+0.280
3850–3855	1.51	2.05	0.83	0.61	−0.070
3855–3865	1.61	2.20	1.29	0.46	+0.135
3865–3875	1.37	2.21	0.95	0.63	+0.210
3875–3880	1.91	2.35	1.60	0.38	+0.065
3880–3885	2.10	2.60	1.75	0.43	+0.075
3885–3895	2.02	2.60	1.70	0.45	+0.130
3925–3930	2.72	3.43	2.30	0.57	+0.145
3930–3940	2.71	3.28	2.47	0.41	+0.165
3940–3950	2.61	3.28	2.30	0.49	+0.180
3950–3955	2.37	2.65	1.79	0.43	−0.150
3970–3980	2.70	3.18	2.45	0.37	+0.115
3985–3990	2.81	3.38	2.50	0.44	+0.130
3990–4000 Top	2.95	3.35	2.58	0.39	+0.015
3990–4000 Bottom	2.40	2.95	1.90	0.53	+0.025
4000–4010	2.47	2.95	2.00	0.48	+0.005
4010–4015	2.50	3.03	1.89	0.57	−0.040
4020–4025	2.10	3.25	1.47	0.89	+0.260
4025–4035	1.97	2.61	1.37	0.62	+0.020
4035–4045 Top	1.77	2.38	1.30	0.54	+0.070
4035–4045	2.62	3.31	2.21	0.55	+0.140
4045–4051	2.39	3.01	1.97	0.52	+0.102
4053–4058	1.80	2.70	1.40	0.65	+0.250
4058–4068 Top	1.90	2.70	1.47	0.62	+0.185
4058–4068 Middle	1.81	2.71	1.32	0.70	+0.205
4058–4068 Bottom	2.22	2.95	1.50	0.68	+0.005
4068–4076	1.49	2.45	1.02	0.72	+0.245
4076–4086 Top	1.21	1.98	0.80	0.59	+0.180
4076–4086 Bottom	2.30	2.90	1.63	0.64	−0.035
4091–4101 Bottom	1.59	2.51	1.18	0.67	+0.255
4101–4107 Top	1.37	1.99	0.95	0.52	+0.100
4101–4107 Bottom	2.18	2.61	1.82	0.40	+0.035
4107–4117	2.02	2.47	1.63	0.42	+0.030
4117–4127 Top	2.01	2.55	1.50	0.53	+0.015
4117–4127 Bottom	1.99	2.48	1.59	0.50	+0.045
4127–4137 Top	2.22	2.70	1.70	0.50	−0.020
4127–4137 Bottom	2.06	2.61	1.58	0.52	+0.035
4137–4147	1.57	2.47	1.07	0.70	+0.200
4157–4168	1.32	2.10	0.85	0.63	+0.155
4168–4178	1.43	2.35	1.00	0.68	+0.245
4193–4199	2.60	2.81	2.45	0.18	+0.030
4199–4209 Top 3 ft.	2.86	3.52	2.61	0.46	+0.205
4199–4209 Middle	2.45	2.96	2.12	0.42	+0.090
4199–4209 Bottom	2.21	2.61	1.89	0.36	+0.040
4209–4219	2.11	2.79	1.60	0.60	+0.085
4219–4229	1.10	1.65	0.65	0.50	+0.050
4237–4242	0.90	1.44	0.40	0.52	+0.020
4242–4247	3.12	3.72	2.52	0.60	0.000
4297–4302	1.62	2.58	1.00	0.79	+0.170

TABLE 7—*Concluded*

Depth in Feet	Median Diameter Md ϕ	$Q_3\ \phi$	$Q_1\ \phi$	QD ϕ	Skq ϕ
4317–4322	1.50	2.40	1.19	0.61	+0.295
4327–4332	1.52	2.33	1.19	0.57	+0.240
4347–4351	1.59	2.18	1.21	0.49	+0.105
4356–4361 Top	1.84	2.70	1.40	0.65	+0.210
4356–4361 Bottom	2.30	2.98	1.79	0.59	+0.085
4361–4366	1.62	2.41	1.37	0.52	+0.270
4375–4380	1.10	1.78	0.62	0.58	+0.100
4380–4384	1.42	2.05	1.12	0.47	+0.115
4396–4401	1.22	1.77	0.83	0.47	+0.080
4406–4414 Bottom	1.90	2.61	1.40	0.61	+0.105
4414–4424	1.67	2.42	1.10	0.66	+0.090
4424–4434 Upper 2 ft.	2.00	2.72	1.57	0.58	+0.145
4424–4434 Bottom 8 ft.	1.05	1.99	0.40	0.80	+0.145
4434–4444	1.35	2.60	0.70	0.95	+0.300
4444–4454	1.17	2.26	0.60	0.83	+0.260
4454–4464	1.27	2.12	0.70	0.71	+0.140
4464–4469	1.05	2.30	0.30	1.00	+0.250
4500–4506	1.21	2.50	0.63	0.94	+0.355
4506–4516	1.87	2.65	1.30	0.68	+0.105
4516–4521	1.81	2.72	1.32	0.70	+0.210
4521–4526	2.00	2.98	1.70	0.64	+0.390
4531–4536	1.12	2.21	0.45	0.88	+0.210
4536–4546	1.57	2.55	0.82	0.87	+0.115
4556–4566	0.99	2.40	0.40	1.00	+0.410
4566–4576	1.02	2.45	0.47	0.99	+0.440
4576–4582	1.12	2.55	0.60	0.98	+0.455
4582–4592	0.97	1.65	0.30	0.68	+0.005
4659–4674	1.31	2.58	0.61	0.99	+0.285
4684–4689	2.58	3.11	2.21	0.45	+0.080
4747–4751	3.10	3.59	2.62	0.49	+0.005
4751–4756	2.30	2.90	1.77	0.57	+0.035
4756–4766	1.41	2.61	0.95	0.83	+0.370
4778–4788	2.52	3.40	2.02	0.69	+0.190
4789–4803	1.99	2.62	1.50	0.56	+0.070
4806–4813	2.07	2.61	1.58	0.52	+0.025
4813–4818	1.81	2.80	1.19	0.81	+0.185
4862–4872	1.75	2.62	1.05	0.79	+0.085
4872–4877	2.50	2.81	1.81	0.50	−0.19
4897–4902	1.18	1.91	0.90	0.51	+0.225
4902–4907	1.17	2.51	0.07	1.22	+0.120
4907–4912	1.50	2.58	0.96	0.81	+0.270
4917–4927	1.67	2.80	0.92	0.94	+0.190
4953–4958	1.30	2.55	0.65	0.95	+0.300
4963½–4965½	2.18	2.85	1.61	0.62	+0.050
4970–4975	1.42	2.23	1.17	0.53	+0.280
4975–4980	1.92	2.70	1.08	0.81	−0.030
5007–5012	1.61	2.58	1.11	0.74	+0.235
5027–5032	2.51	3.15	1.80	0.68	−0.035
5027–5032 Bottom	2.50	2.98	1.90	0.54	−0.060
5037–5042	2.47	3.01	1.79	0.61	−0.070
5104–5112	1.75	2.59	1.00	0.80	+0.045
5112–5122	1.18	2.32	0.65	0.84	+0.305
5130–5135	0.39	1.08	−0.10	0.59	+0.100
5160–5165	2.80	3.43	2.50	0.47	+0.47
5183–5193	2.70	3.45	2.47	0.49	+0.260
5201–5213	2.26	2.90	1.60	0.65	−0.010
5307–5312	0.67	2.60	−0.05	1.33	+0.605
5312–5315	2.80	3.58	2.32	0.63	+0.150

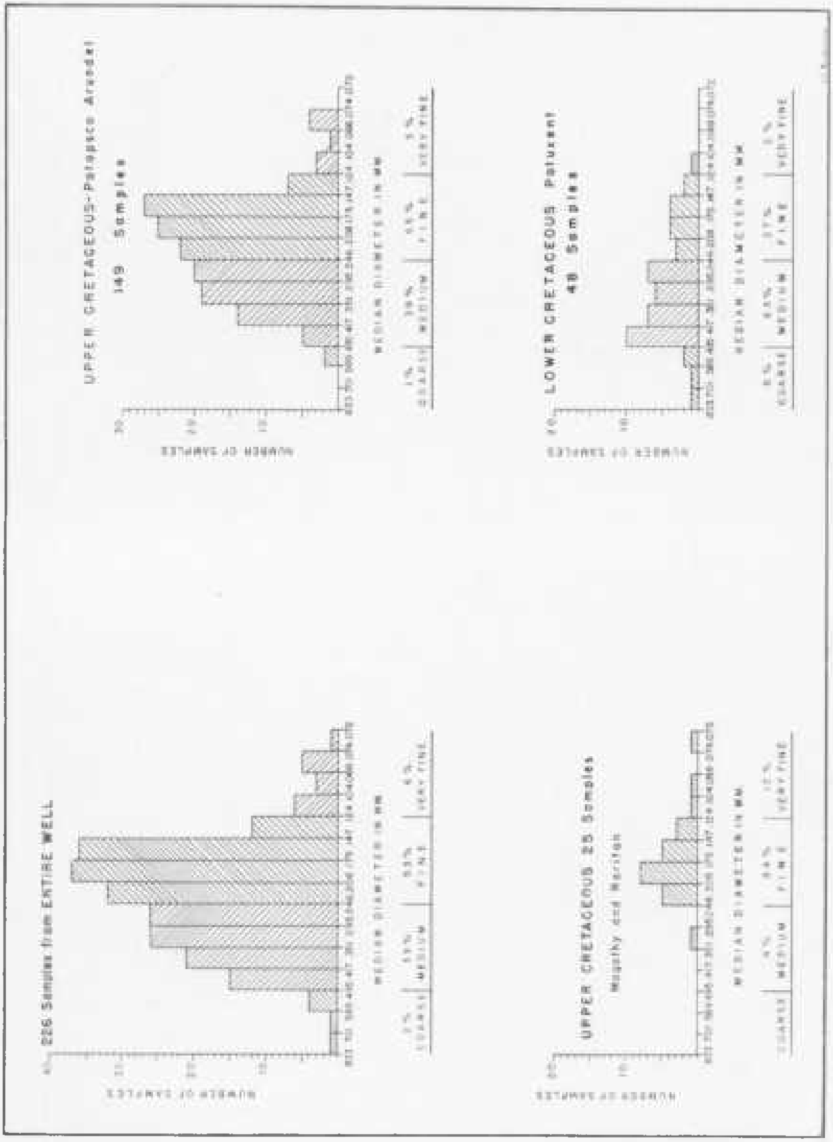

FIGURE 4. Distribution of Median Diameters of Cretaceous Sands
L. G. Hammond Well No. 1

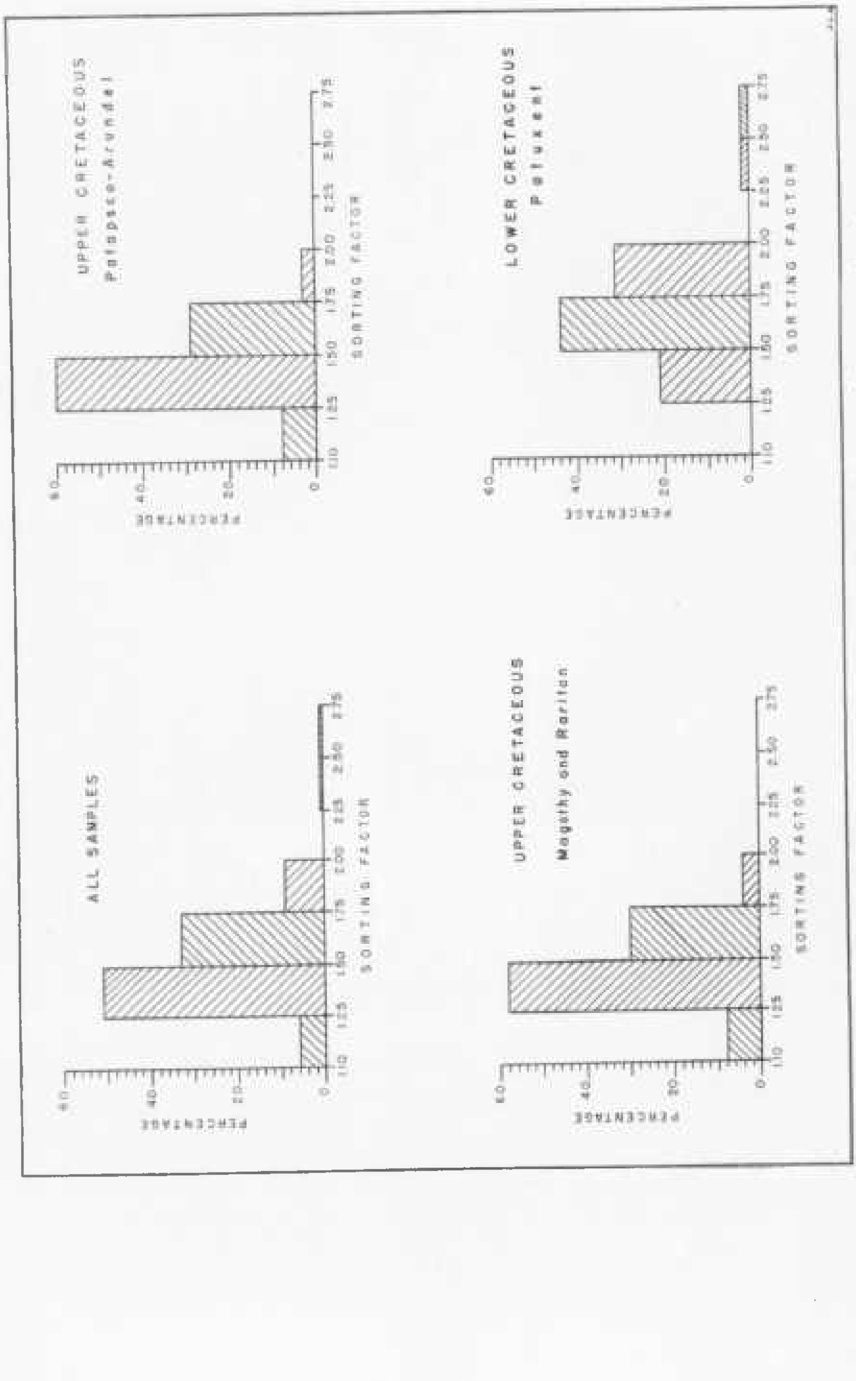

FIGURE 6. Graph Showing Distribution of Sorting Factors of Cretaceous Sands
L. G. Hammond Well No. 1

THE PHI QUARTILE DEVIATION

The phi quartile deviation of all the sands is compiled in Table 7, and a summary of these data is contained in Table 9. The distribution of this measure with depth is shown on Figure 5.

In the Upper Cretaceous Magothy and Raritan formations 84 percent of all the sands have a Mdϕ which falls within the fine sand class, and of these, 76 percent have a phi quartile deviation ranging from 0.4 to 0.7. This means that there are from 0.8 to 1.4 Wentworth grades between the quartiles of these sands.

In the Patapsco-Arundel section, 39 percent of the sands have a Mdϕ value which falls within the medium sand class, and of these, 98 percent have a QDϕ value which ranges from 0.4 to 0.8 (Table 9). In the sands with Mdϕ

TABLE 8

Distribution of Sorting Factors of Sediments of Ohio Oil Company's L. G. Hammond Well No. 1

Percentages

Sorting Factors	Entire Well		Upper Cretaceous				Lower Cretaceous	
			Magothy and Raritan		Patapsco-Arundel		Patuxent	
	No. of Samples	%	No. of Samples	%	No. of Samples	%	No. of Samples	%
1.10–1.25	14	6	2	8	12	8	—	—
1.25–1.50	111	51	14	58	87	60	10	21
1.50–1.75	73	33	7	30	42	29	21	44
1.75–2.00	20	9	1	4	4	3	15	31
2.00–2.25	—	—	—	—	—	—	—	—
2.25–2.50	1	0.5	—	—	—	—	1	2
2.50–2.75	1	0.5	—	—	—	—	1	2

value within the fine sand class, the QDϕ values show a greater spread, ranging from 0.1 to 0.9 The bulk of the values, however, lie between 0.3 and 0.6.

The sands of the Patuxent formation have 90 per cent of the Mdϕ values in the medium and fine sand classes. Those of the medium sand class show a range of QDϕ values from 0.5 to 1.2, with the bulk (61%) ranging from 0.8 to 1.0. The sands whose Mdϕ values fall within the fine sand class have QDϕ values which lie entirely with the limits 0.4 to 0.7. In general, the finer sands have less spread between the quartiles than the coarser varieties.

THE PHI SKEWNESS

The phi skewness of the sands of the Hammond well is presented in Table 7, and its variation with depth is shown on Figure 5. This graph also reveals the relation between the phi skewness and the phi quartile deviation, the phi

TABLE 9

Percentage Distribution of QD φ with Respect to Md φ: Ohio Oil Company's L. G. Hammond No. 1 Well

		Md φ	Percentage of Samples	QD φ 0.1 to 0.2	0.2 to 0.3	0.3 to 0.4	0.4 to 0.5	0.5 to 0.6	0.6 to 0.7	0.7 to 0.8	0.8 to 0.9	0.9 to 1.0	1.0 to 1.1	1.1 to 1.2	1.2 to 1.3
Eocene (3 samples)		0φ–1.00φ													
		1.00φ–2.00φ													
		2.00φ–3.00φ													
		3.00φ–4.00φ	100					1 sample		2 samples					
Upper Cretaceous	Magothy and Raritan	0φ–1.00φ													
		1.00φ–2.00φ	4					1 sample							
		2.00φ–3.00φ	84	9		5	24	38	14	3	5				
		3.00φ–4.00φ	12					1 sample			1 sample				
	Patapsco-Arundel	0φ–1.00φ	1				1 sample	1 sample							
		1.00φ–2.00φ	39			2	20	27	38	13					
		2.00φ–3.00φ	55	1	8	17	27	27	7	8	4				
		3.00φ–4.00φ	5				2 samples		2 samples						
Lower Cretaceous	Patuxent	0φ–1.00φ	8					1 sample	1 sample				1 sample		1 sample
		1.00φ–2.00φ	63					10	7	14	36	2^5	4	4	
		2.00φ–3.00φ	27				20	33	47						
		3.00φ–4.00φ	2				1 sample								

median diameter, the sorting factor, and the degree of sorting of each sample with depth.

The phi skewness, with few exceptions, has a positive value. This indicates that the arithmetic mean of the quartiles lies to the right or the fine-grained side of the phi median diameter, that is the curves are skewed toward the right. The bulk of the values lie between zero and $+0.2\phi$. When the values are negative, they range between zero and -0.335. The highest negative values were obtained at 1470–1480 feet. At this point the phi quartile deviation, the sorting factor, and the degree of sorting show an increase. The same is true of the values at 2300 feet, the base of the Raritan formation. At the base of the Patapsco-Arundel section between 4300 and 4400 feet and at the top of the Patuxent formation, the positive phi skewness values show a marked increase. Here the phi quartile deviation, the phi median diameter, the sorting factor, and the degree of sorting all increase. This indicates that the sands are rather poorly sorted; the spread between the quartiles shows a marked increase, and the curves are skewed toward the right or in the direction of the smaller sand diameters. The statistical constants show marked changes at formational breaks. This is especially true at the top of the Patuxent formation of the Lower Cretaceous.

INTERRELATION OF THE PROPERTIES OF THE SEDIMENTS

Median Diameter: Sorting

Figures 7, 8, and 9 show the relationships between the sorting factor, phi quartile deviation, phi skewness, and median diameter of the Upper and Lower Cretaceous sediments. With few exceptions, the bulk of the sediments show sorting factors less than 1.75. This indicates that the Cretaceous sediments as a whole can be classified as well sorted. This conclusion applies to the sands with median diameters larger than 0.10 mm. Hough (48, 49) has shown that the sediments of both Buzzards Bay and Cape Cod Bay become less sorted when the median diameter falls below 0.062 mm. A similar condition in the case of the sediments of the Hammond well cannot be demonstrated since no sediments with median diameters less than 0.062 mm. were studied.

The limited number of sands from the Magothy and Raritan formations available for study do not justify definite conclusions concerning the variation of the sorting factor with decrease in the median diameter. A line indicating the trend of the distribution of the sorting factors of Figure 7 would suggest that the sorting becomes slightly better with a decrease of median diameter down to 0.12 mm.

The sediments of the Patapsco-Arundel section and the Patuxent formation show a definite trend toward better sorting with decreasing median diameter down to 0.105 mm as revealed by Figures 8 and 9. The coarse-grained sediments

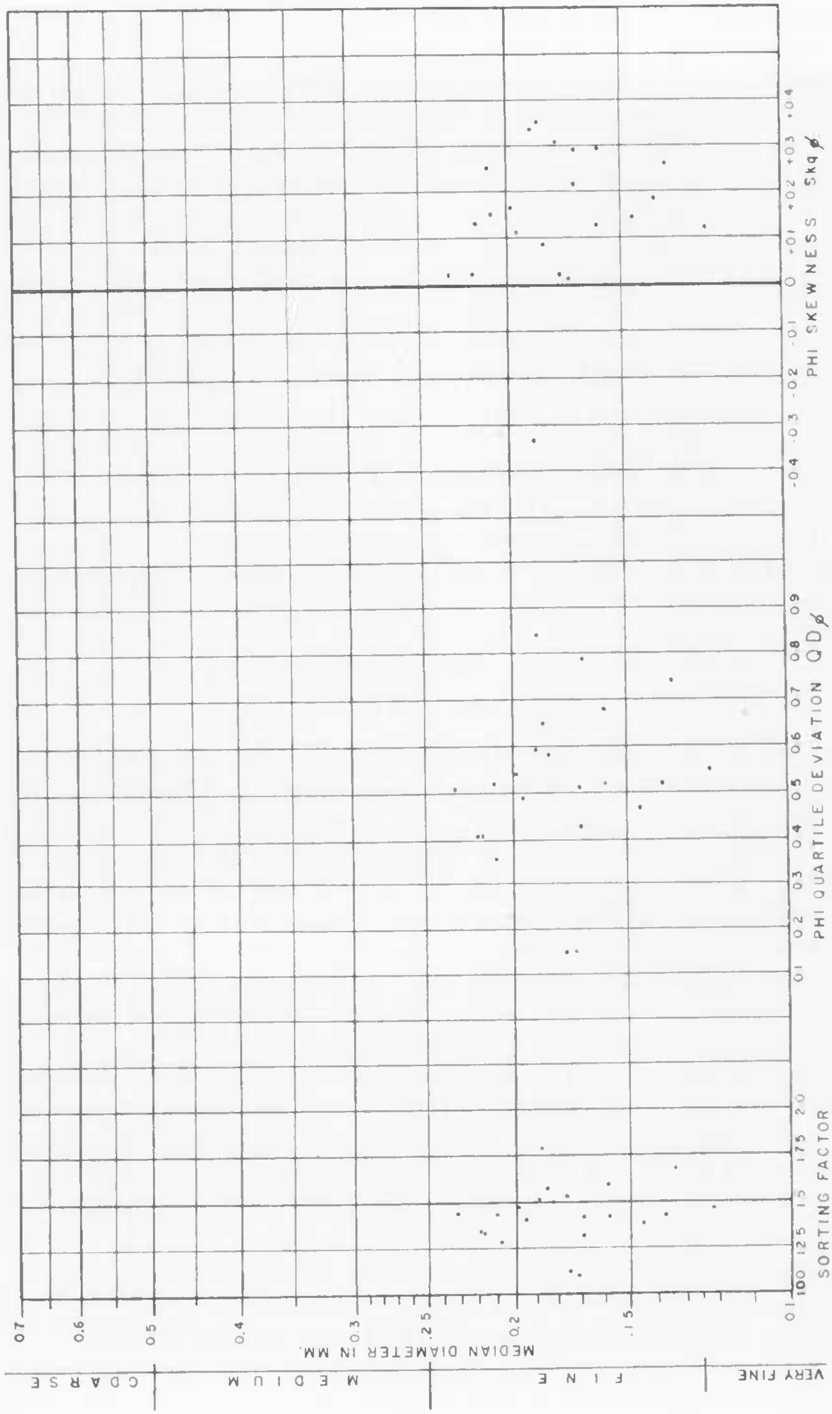

FIGURE 7. Relation between Median Diameter and Sorting Factor, Phi Quartile Deviation, and Phi Skewness
Upper Cretaceous, Raritan formation. L. G. Hammond Well No. 1

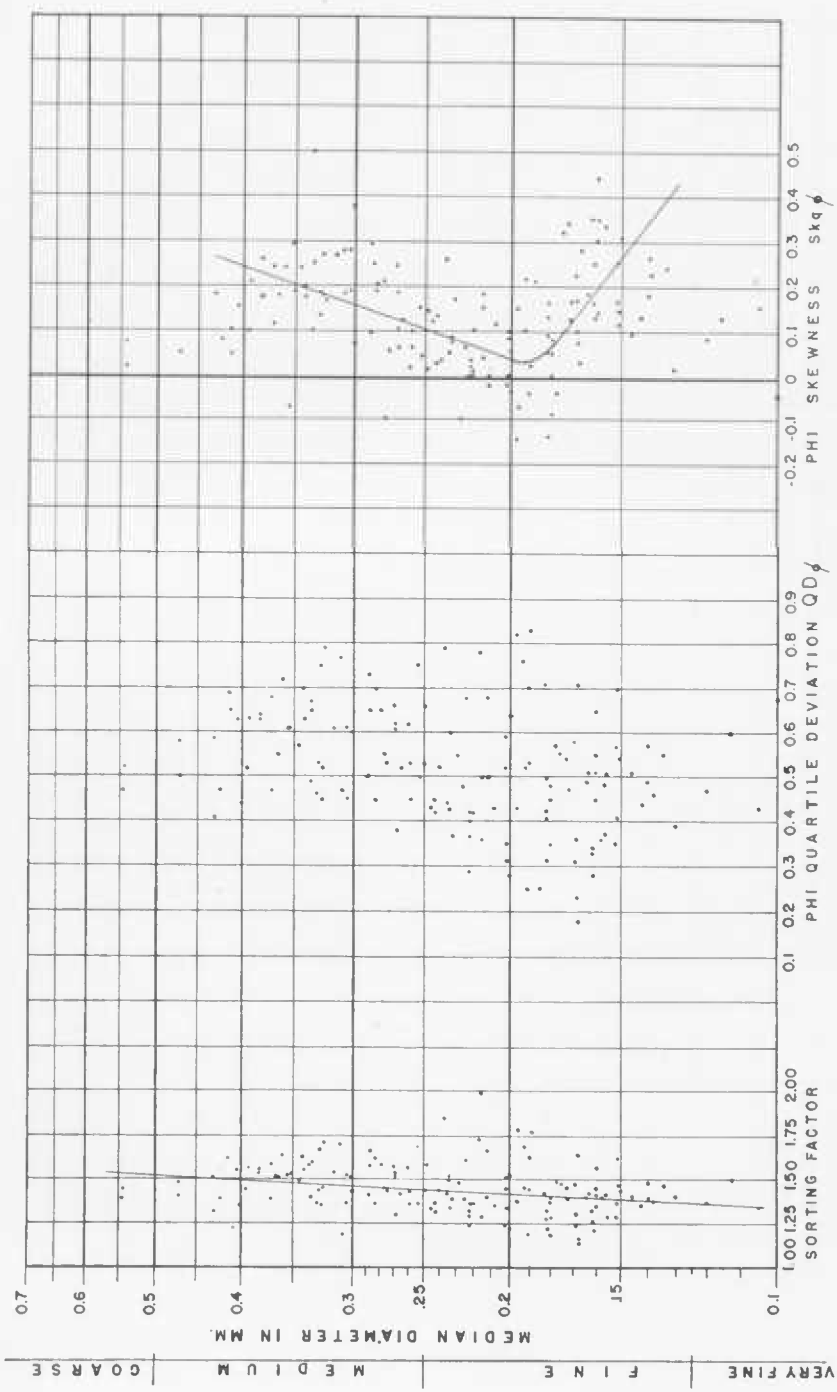

FIGURE 8. Relation between Median Diameter and Sorting Factor, Phi Quartile Deviation, and Phi Skewness Upper Cretaceous Patapsco-Arundel Section. L. G. Hammond Well No. 1

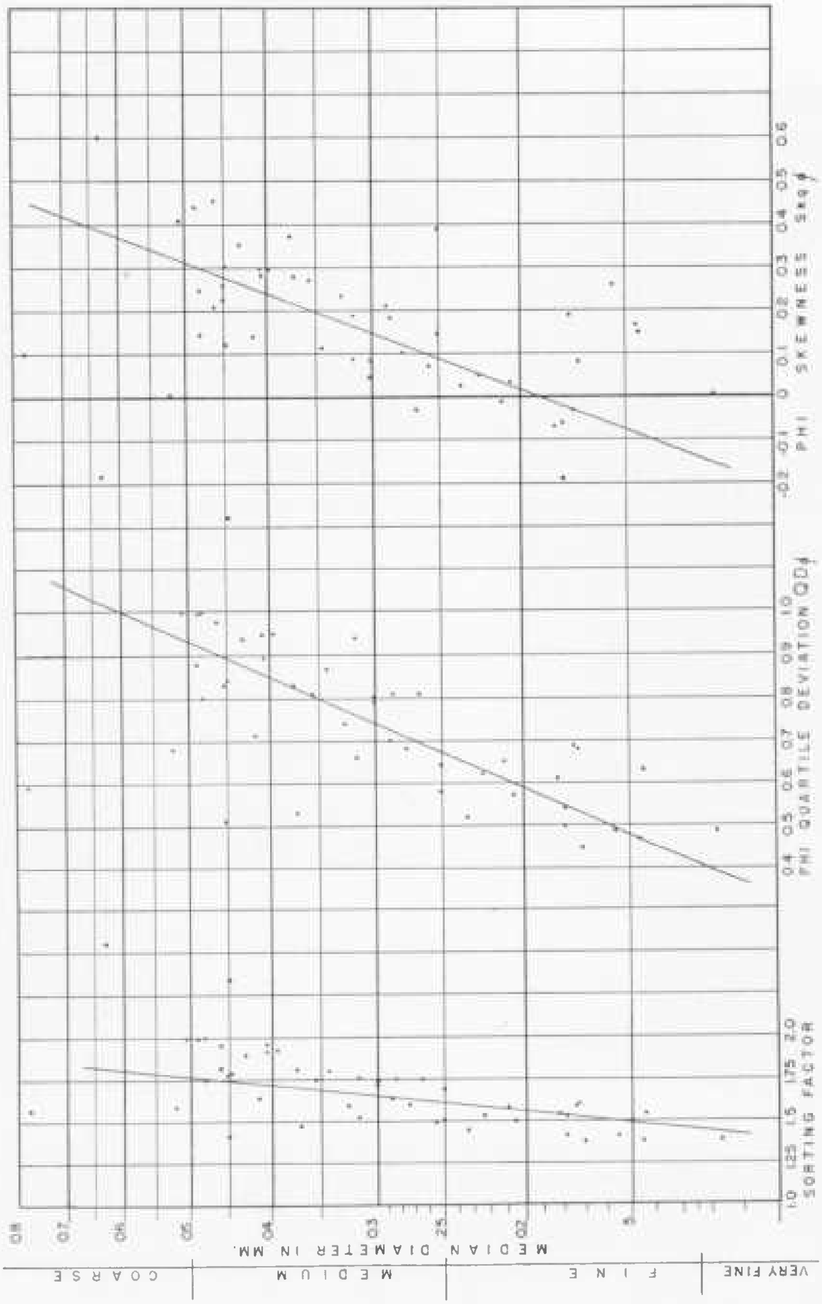

FIGURE 9. Relation between Median Diameter and Sorting Factor, Phi Quartile Deviation, and Phi Skewness Lower Cretaceous Patuxent formation. L. G. Hammond Well No. 1

of the Patuxent formation generally show a lower degree of sorting than those of the overlying Patapsco-Arundel section, but the general trend is the same.

Median Diameter: Phi Quartile Deviation

The distribution of the points indicating the phi quartile deviation of the Magothy and Raritan sediments is too great to warrant drawing any conclusions. This is generally true also for the sediments of the Patapsco-Arundel section. On the other hand, the sands of the Patuxent formation show a decided decrease in $QD\phi$ values with a decrease in the median diameter.

Median Diameter: Phi Skewness

Figures 8 and 9 show the relationships between the median diameter and the phi skewness for the samples of the Patapsco-Arundel section and those of the Patuxent formation. The line showing the general trend of the distribution of the points in the Patapsco-Arundel section indicates that the $Skq\phi$ values vary from moderately high positive in the coarser grades to almost zero in the sands with median diameters of approximately 0.19 mm. With a decrease in median diameter below this point, the line turns, and the general trend is toward increasing positive skewness with decreasing median diameter.

In the sands of the Patuxent formation, the coarser grades show slightly larger $Skq\phi$ values than do those of the Patapsco-Arundel section. The general trend indicates a decrease in the skewness with a decrease in median diameter and passing to negative values at approximately 0.19 mm. There is a suggestion that the trend may have reversed, as in the sediments of the Patapsco-Arundel section, if more analyses of the finer grained sands had been available.

The variation of the sorting factor, the median diameter, the quartile deviation, and the skewness of each sample with depth is shown on Figure 5.

SHAPE OF THE MINERAL GRAINS

As pointed out by Wadell (114, 115, 116) there is a difference between shape and roundness of grains. Roundness deals with the sharpness of the edges and corners, whereas shape refers to the form of the grain and is independent of the sharpness. Various methods have been proposed for the determination of the shape or sphericity of grains. Some are exact methods and others are less exact (63, p. 277). The less exact method suggested by Rittenhouse (87) was employed. This quicker method, which is based on Wadell's projected sphericity, was chosen because the large number of samples precluded the use of exact methods.

Rittenhouse's method employs the visual estimation of grain sphericity. His chart enables one to arrive at the approximate sphericity of the grains.

The sphericity of the grains in the sediments of the Hammond well varied from 0.51 to 0.85, with the smaller grains showing a higher sphericity. The majority of the grains had a sphericity of approximately 0.75. No pronouned changes in the sphericity of the grains were noted as formational contacts were approached.

Two types of zircons and garnets were noted in the sediments. One type of zircon shows little rounding of the corners and is euhedral in form. The second type is well-rounded and possesses a sphericity of approximately 0.85. One type of garnet has an estimated sphericity of 0.85, whereas the second type is of the magnitude of 0.55.

The heterogeneity of the sphericities would suggest that some of the particles of the sediments of the Hammond well had undergone erosion in more than one sedimentary cycle. On the other hand, the majority of the particles exhibit a sphericity of approximately 0.75, a relatively low roundness, and a fairly high degree of sorting. This would suggest that the sediments of the Hammond well had been only slightly affected by abrasion, and that the majority were involved in only one erosion cycle.

SOURCE OF THE SEDIMENTS

It seems reasonable to conclude that the source rocks of the sediments of the Eastern Shore of Maryland are to be found in the Piedmont region to the west. This complex area has all the various types of rocks necessary to yield the minerals found in the younger sediment.

The detrital minerals of the Hammond well section are those characteristically derived from a terrain consisting of igneous rocks and metamorphosed igneous and sedimentary rocks. The variation in abundance of the individual species with depth (Fig. 2) suggests that either different rock types were being eroded at different times or that the transportation of the minerals was affected by changes in the transporting medium.

The schists and gneisses seem to have been an important source of the sediments. Minerals characteristic of these rocks are garnet, staurolite, tourmaline, cyanite, chloritoid, sillimanite, chlorite, muscovite, biotite, quartz, albite, and oligoclase. This is a typical metamorphic suite, and all of these minerals are to be found in the various facies of the Wissahickon schist. Tremolite, although scarce, indicates the meta-dolomites as a source rock.

It is surprising that more amphiboles and pyroxenes were not found in the Hammond well sediments. Basic and ultra-basic igneous rocks are common to the Piedmont complex and are well exposed at many places. Hornblende is fairly common in the upper portion of the well but is absent in the Lower Cretaceous. Pyroxenes are conspicuous by their absence. It is hardly likely that the amphiboles and pyroxenes were entirely decomposed either during or after deposition, because the feldspars are not too highly altered. It is quite possible that the basic rocks were not uncovered and subjected to erosion during the Lower Cretaceous and much of the Upper Cretaceous.

Igneous rocks and pegmatite dikes were minor sources of supply. Euhedral zircons of both the colorless and mauve varieties, monazite, titanite, rutile, biotite, muscovite, apatite, corundum, ilmenite, clear quartz, microcline are typical minerals. The epidote minerals were probably derived from both epidote veins and meta-basic igneous rocks. Cross-cutting epidote veins are fairly common in certain areas of the Piedmont, especially in the Potomac river area of Montgomery County, Maryland. Much of the epidote of the well section is authigenic. Its clouded appearance and irregular outline suggest that it is of secondary origin. It may have been derived from the decomposition of plagioclase feldspar.

The rather well-rounded grains of zircon, garnet, and tourmaline are subordinate to the fairly angular minerals enumerated above. These rounded minerals were doubtless derived from either old sedimentary rocks lying to the west of the Piedmont area or from the metamorphosed sedimentaries which are found within the Piedmont itself.

Attention should be called to the persistence and at times abundance of garnet in the Hammond well section. This mineral reaches its greatest abundance in the basal part of the Patapsco-Arundel section and in the upper portion of the Patuxent formation. Careful study of these Cretaceous beds both from the outcrop and in shallow water wells of the Baltimore area failed to reveal the presence of garnet. Dryden (26) has noted a similar condition and has ascribed the absence of garnet to its weathering. The mineral would, therefore, not become available for transportation. This explanation fails in the case of the Cretaceous sands of the Hammond well where garnet is fresh and fairly abundant. The Wissahickon schist has not been studied systematically to delineate its facies. It is possible that the source rock of these Cretaceous sediments in the vicinity of Baltimore was not the garnet facies of the Wissahickon schist. Staurolite is abundant in the Patuxent formation both from the outcrop and from the subsurface. If weathering destroyed garnet it would also tend to destroy staurolite, since on the basis of Dryden's resistance values of the various minerals, staurolite immediately precedes garnet. It is probable that the material of these Cretaceous sediments in the Baltimore area and in the area near the Hammond well was derived from different metamorphic facies of the Wissahickon schist.

ENVIRONMENT OF DEPOSITION

GENERAL

Twenhofel's classification (104, p. 784) of the environments of deposition of the sedimentary rocks has been adapted for use in this discussion. It divides the environments into Continental, Mixed Continental and Marine, and Marine. The evidence derived from the lithologic, paleontologic, and statistical study of the sediments will be used to postulate the type of environment under which the sediments in the vicinity of the Hammond well were laid down.

THE LOWER CRETACEOUS

Evidence Derived from the Lithology of the Sediments

The sediments of the Lower Cretaceous are composed predominantly of fine to coarse-grained and at times gravelly sands which contain feldspars in various stages of decomposition and whose color is usually white. Clay shales are subordinate below 3800 feet but increase in thickness above this depth. The color of shales from 5362 to 4700 feet is predominantly lead-gray with subordinate brownish-gray, dark cinnamon-brown, pale gray, and pale green colors. Between 4600 and 4700 feet mottling of the shales is very pronounced, and the predominant gray color is mixed with red, brown, and green shades. Pale-green clay shales occur at the top of the Patuxent formation (Fig. 10). Carbonaceous matter and fragments of lignite are frequently found in the sands and as thin partings in the sandy shales. Sideritic hard shales and occasionally hard limy sands are found in the basal portion of the Patuxent formation.

It is important to note that the mineral pyrite is very rare to absent in all but the uppermost 150 feet of the section. Here it increases in amount and ranges from scarce to common.

The lithology of the Lower Cretaceous sediments indicates that they were not deposited in a marine environment. The large quantity of sand with relatively undecomposed feldspar, the predominant lead-gray color of the subordinate clay shales followed by highly mottled green and gray shales suggests that the environment was one which favored the rather rapid deposition of sands and the partial oxidation of the iron-bearing minerals of the clay shales.

Evidence Derived from the Paleontology of the Sediments

Careful search for fossil remains failed to reveal the presence of either well-preserved or reworked forms. The environment therefore in which the Lower Cretaceous sediments were deposited was not suited to the development or preservation of animal life and hence was not marine.

Evidence Derived from the Statistical Study

The sorting factor of the sediments of the Patuxent formation ranges from 1.25 to 2.75 with the bulk falling with the limits 1.50 to 2.00. Trask (103, p. 72) classifies as well-sorted those sediments whose So factor is less than 2.5, normally sorted sediments with So values of about 3.0, and poorly sorted sediments with values above 4.5. On this basis, the Patuxent sands would be classified as well sorted. Stetson and Shalk (98, p. 42), on the other hand, point out that their experience with many samples indicates that beach sands give an average So value of 1.25 and that near-shore sediments have average values of

1.45. Figs. 5 and 6 show that the bulk of the So values of the Patuxent sands lies between 1.50 and 2.00. This would suggest, therefore, that most of the Patuxent sediments were not laid down as either beach sands or near-shore deposits.

Mohr (74) studied sediments from different environments in the East Indies and presented the results in the form of histograms. Similar studies were carried on by Thoulet (102) in the Gulf of Lyon and by Sudry. A few selected histograms from these localities are submitted on Figure 19. Mohr points out, what is generally well known, that beach sands are very well sorted and that off-shore deposits are as well sorted but of finer grain. Lagoonal deposits, subjected to weaker wave action, are less sorted. River deposits are poorly sorted, and their curves show an abrupt rise on the left and a gentle fall on the right. Delta deposits show the combined effect of stream action with a certain amount of sorting. The information obtained from the histograms is obtainable also from the statistical constants of the sediments. The quartile deviation and the skewness of the curves are given in mathematical expressions which can be compared with one another. Histograms give pictures of the size distribution of the grains.

Certain conclusions concerning the environments of deposition of the Patuxent sediments may be drawn from the histograms of Figs. 17, 18, and 19. The curves with a few exceptions show no pronounced maxima. Those that do show maxima, for example the samples from 4684 to 4689 feet and 4970 to 4975 feet, have also a fair amount of fine sand, silt, and clay. This is not characteristic of beach sands but of shallow-water, off-shore deposits. The sample from 4813 to 4818 feet has the characteristics of a river deposit, the curve showing an abrupt rise on the left and a gradual falling off on the right. The histograms as a whole are similar to those of sediments from both deltas and lagoons.

The changes in the character of the histograms from the bottom to the top of the formation, indicate changes in the environment of deposition. From the base upward, the sedimentation seems to have taken place in a marginal type lagoon or bay where at first rather rapid deposition of material by streams was followed by the development of deltaic type deposits. The sorting of the material brought in by the streams was relatively poor, indicating that wave and current action were relatively unimportant factors. As deposition progressed, the environment into which the material was being brought changed periodically. The histograms indicate periods during which the sediments were affected by current action and became well sorted. The immediate environment would be one which would favor the development of off-shore, shallow-water sediments. There are also indications that periodically streams brought rather coarse, poorly-sorted material into the delta. The environment may be classified, therefore, as continental, no evidence of marine conditions having been noted.

THE UPPER CRETACEOUS

Evidence Derived from the Lithology of the Sediments

Sands and shales are about equally distributed in the lower portion of the Upper Cretaceous section, but shales become more abundant toward the top (Fig. 10).

Above 4300 feet in the Patapsco-Arundel section, there is a marked change in color of the clay shales. Lead-gray and brownish-gray tones become subordinate to olive-green and pale gray. The shales are highly mottled in red, brown, and yellow shades. Lignite and carbonaceous matter are fairly abundant and are associated with thinly laminated sandy shales and paper thin sands.

Within the basal 200 feet of the Raritan formation, the color of the shales is predominantly lead-gray and olive-green with subordinate shades of brown. The sands are white and olive-green. Above the basal 200 foot section and extending upwards for about 400 feet, the shales become highly mottled in shades of gray, red, brown, and green. Above this portion of the section, and continuing upwards to the top of the Upper Cretaceous, shades of brown and lead-gray are the principal colors (Fig. 10).

Carbonaceous matter and lignite, associated both with the fine sands and the sandy shales, are abundant in certain intervals (Fig. 10 and Sample descriptions). They continue upward from the base of the Raritan to the top of the Magothy formation at about 1500 feet. Above this point they are lacking.

Deep-green, botryoidal and oolitic, glauconite is common only in the upper 100 feet of the Upper Cretaceous (Fig. 10). At several lower horizons, green-brown pellets of glauconite and silty glauconitic sand occur, but the glauconite is always less abundant than in the upper portion of the section.

From the standpoint of lithology, the environment of deposition may be postulated as one in which a slight subsidence occurred at the close of Patapsco time. The environmental conditions favored the formation of shales with somber colors, which reveal no effects of oxidation, and which are marine in the basal portion. Carbonaceous matter and lignite became abundant at this time. This interval was followed by one during which the shales again became oxidized. This was accomplished either through slight elevation or through sedimentation reaching the profile of equilibrium. Marine conditions set in at the top of the Upper Cretaceous, at the base of the Matawan formation, as revealed by the abundance of deep-green glauconite. Marine conditions continued uninterrupted into the Tertiary.

Evidence Derived from the Paleontology of the Sediments

Marine fossils make their first appearance at 2257 feet in the basal part of the Raritan formation. No other fossiliferous horizons were encountered in the

Raritan until the top was reached at 1588 feet. The Raritan formation, with the exception of the tongue of marine fossiliferous shales at the base of the formation and again at the top, was deposited under non-marine conditions. The Magothy formation was deposited under non-marine conditions similar to those under which the Raritan formation was laid down.

Above 1480 feet, the section becomes richly fossiliferous and microforms make their first appearance. The environment of deposition has changed from a deltaic type to an open-water marine type which favored the formation of glauconite and the preservation of marine forms.

Evidence Derived from the Statistical Study

In the Patapsco-Arundel section, the sorting of the sands becomes better, 60 percent having So values between 1.25 and 1.50 and approximately 30 percent between 1.50 and 1.75. Also 8 percent of the samples have So values lying between 1.10 and 1.25 (Figs. 5 and 6). This indicates a high degree of sorting accomplished by current or wave action. The histograms of Figures 12, 13, 14, 15, 16, and 17 indicate that the curves begin to show pronounced maxima, a characteristic of sorted sediments. On the other hand, deltaic features, such as the mixture of coarser and finer grades with the predominant class, are still in evidence. It is obvious, therefore, that the Cretaceous delta was subsiding at a rate which was not balanced by deposition. More open-water conditions, where wave action and current action were active, prevailed as revealed, for example, by the histograms of samples from 4193 to 4199 feet. Evidence of stream depositions is still present, as revealed by the samples from 4020 to 4035 feet and others. Even though there is evidence of subsidence accompanied by better sorting, there still is no evidence of a true marine environment of deposition in the vicinity of the Hammond well during Cretaceous time. The somber-colored shales and sandy shales followed by rather highly oxidized mottled shales, the presence of carbonaceous matter and pyrite, and the relatively poorly-sorted abundant sands all suggest a changing, but non-marine, deltaic environment. Farther towards the east where the Maryland Esso No. 1 well was drilled, brackish-water conditions existed at times during the lower part of the Upper Cretaceous.

The sands of the Magothy and Raritan formations closely resemble those from the Patapsco-Arundel section (Fig. 6). Approximately 90 percent have an So value rangingfrom 1.25 to 1.75 and 8 percent with values falling between 1.10 and 1.25. These sands are therefore well sorted sands, and 84 percent of the samples have median diameters which fall in the fine sand class.

The histograms of the Upper Cretaceous sediments still show the characteristics of delta deposits, but the environment of deposition was probably somewhat removed from the delta proper where current action was able to affect a fairly high degree of sorting. Off-shore marine environments are suggested at several horizons, especially at 1687 to 1697 feet and from 2151 to 2307 feet, by the occurrence of highly-sorted fine sands.

The environment of deposition of the Upper Cretaceous was therefore deltaic during the time the lowermost beds were being laid down. Current action was pronounced and occasional marine invasions took place. The environment was probably lagoonal in character at the top of the Magothy and at the base of the Matawan. Above this horizon the environment changed to an open-water marine type favoring the formation of glauconite and the development of marine life. These conclusions are in agreement with those of Goldman (36) from his study of the outcropping Upper Cretaceous rocks of Maryland.

THE TERTIARY

Evidence Derived from the Lithology of the Sediments

The environment in which the Tertiary sediments were laid down was one in which oxidizing conditions were lacking. On the whole it was a marine environment which favored the accumulation of shales whose colors are shades of gray and brown. There is a suggestion that there was a slight change in the environment toward a slightly shallower water type favoring the accumulation of carbonaceous matter and the formation of a clay-pebble conglomerate at 1220 to 1230 feet. The marine environment continued to the top of the St. Marys formation, above which the sediments become coarse and pyrite is lacking. From 330 to 120 feet, the sediments were deposited in a non-marine environment.

Evidence Derived from the Paleontology of the Sediments

Both macro- and micro-fossils are present in the Tertiary, but the micro-forms are more abundant. The presence of large numbers of barnacle plates together with echinoid tests and spines led Julia A. Gardner to suggest that at least a portion of the Tertiary sediments were laid down in shallow waters.

Evidence Derived from the Statistical Study

Only four samples from the Eocene section were studied (Fig. 11). With the exception of the sample from 1250 to 1260 feet, all show rather poor sorting. The sediments are composed almost entirely of fine and very fine sand, silt, and clay. The general lack of sorting indicates that current action must have been weak in a marine environment.

CONCLUSIONS

The sediments of the Hammond well can be divided into four types on the basis of the size of the median diameters. Within each type, the arrangement depends on the increasing size of the sorting factor (Table 10). There is no

TABLE 10

Statistical Comparison of Sedimentary Types of the Hammond Well

		Depth in Feet	Median Diameter in mm.	Md ϕ	Sorting Factor	Skq ϕ	
Eocene		1250–1260	0.193	2.38	1.55	+0.165	Type III
		1160–1170	0.102	3.30	1.74	+0.150	Type IV
		1220–1230	0.109	3.20	1.82	+0.045	
Upper Cretaceous	Magothy and Raritan	1924–1934	0.300	1.75	1.54	+0.210	Type II
		2157–2167	0.171	2.54	1.10	+0.010	Type III
		1904–1914	0.198	2.35	1.47	+0.165	
		1470–1480	0.187	2.42	1.79	−0.335	
		1480–1490	0.092	3.44	1.75	−0.305	Type IV
	Arundel-Patapsco	3855–3865	0.329	1.61	1.36	+0.135	Type II
		4237–4242	0.541	0.90	1.44	+0.020	
		3477–3487	0.328	1.61	1.44	+0.185	
		4091–4101(B)	0.334	1.59	1.60	+0.255	
		4297–4302	0.324	1.62	1.71	+0.170	
		4193–4199	0.167	2.60	1.14	+0.030	Type III
		2759–2769	0.191	2.40	1.19	−0.040	
		2907–2917	0.182	2.45	1.23	+0.165	
		3875–3880	0.268	1.91	1.30	+0.065	
		4000–4010	0.180	2.47	1.39	+0.005	
		3990–4000	0.190	2.40	1.44	+0.025	
		4076–4086(B)	0.200	2.30	1.53	−0.035	
		2832–2837	0.193	2.35	1.69	+0.215	
		4020–4025	0.236	2.10	1.85	+0.260	
		3437–3447	0.105	3.17	1.34	+0.155	Type IV
		3631–3641	0.095	3.37	1.59	−0.045	
Lower Cretaceous	Patuxent	5130–5135	0.773	0.39	1.56	+0.100	Type I
		5307–5312	0.630	0.67	2.55	+0.605	
		4970–4975	0.370	1.42	1.47	+0.280	Type II
		4414–4424	0.315	1.67	1.52	+0.090	
		5007–5012	0.325	1.61	1.59	+0.235	
		4756–4766	0.374	1.41	1.81	+0.370	
		4434–4444	0.395	1.35	1.93	+0.300	
		4464–4469	0.480	1.05	2.00	+0.250	
		4902–4907	0.448	1.17	2.34	+0.120	
		5160–5165	0.145	2.80	1.37	+0.470	Type III
		5027–5032(B)	0.178	2.50	1.52	−0.060	
		5201–5213	0.210	2.26	1.58	−0.010	
		4747–4751	0.117	3.10	1.38	+0.005	Type IV

relation between the decrease in the size of the median diameter and the sorting of the sediments. Although the sediments may be classified as well sorted, very few show the effects of pronounced wave or current action. The environment therefore was one in which sediments were deposited on the whole removed from the sorting effects of currents.

All the important characteristics of the Hammond sediments suggest that the initial deposits were laid down by streams flowing into a bay or inland sea. It is impossible to ascertain the nature of the body of water into which the material was brought from the study of one complete section. On the other hand, it is obvious that the sediments were not laid down as beach deposits where they would be subjected to strong wave and current action. Hence, it is safe to say that the Lower Cretaceous sediments were deposited in a non-marine environment.

The evidence suggests a deltaic environment of deposition for the Lower Cretaceous and most of the Upper Cretaceous. The generally better-sorted nature of the sediments in the upper portions of the section suggest off-delta conditions and subsidence with occasional inter-tonguing of marine shales. As subsidence continued, the site of the Hammond well became a marine environment during uppermost Upper Cretaceous and Tertiary times. The sea withdrew toward the close of the Miocene and non-marine deposits were again laid down.

There is a similarity between the sediments of the Hammond well area and those described by R. J. Russell and R. D. Russell (87) from the delta of the Mississippi River. In the Mississippi delta, sorting varies from very poor to extremely good. The poorly-sorted sediments are located in channels and on bars, and the well-sorted types are found in beach, dune, and open-water sands. Marine sediments interfinger with those of the delta in both areas. Between the natural levees of the Mississippi delta complex are marshes, lakes, and bays. There are indications that lagoonal environments existed at certain times during the deposition of the Hammond well sediments.

EVIDENCE OF PETROLEUM

THE CORE SAMPLES

A careful examination of the sand cores of the Hammond well failed to reveal the presence of petroleum. Acetone tests were made on sands that had the slightest suggestion of petroleum, but all tests were negative. No chemical tests for chlorides were made, but practically all sands had a saline taste. All the sands of the Cretaceous and the Tertiary are barren of petroleum and are salt-water bearing.

THE ELECTRIC LOG

Upon the completion of the Hammond well an electrical survey of the hole was made for the Ohio Oil Company by the Schlumberger Well Survey Corporation. One of the principal objects of such a survey is the location of sand beds and the determination of the fluid content of the sands. The electric log of the survey is reproduced in Figures 10 and 20.

Electric logs, as taken in oil field areas, show two principal curves, a potential curve occupying the left side of the graph, and a resistance curve on the right side.

The Potential Curve

The potential log is made by lowering an electrode into the well and measuring the difference in potential between the well electrode and a ground electrode located at the surface. The potentials existing in an oil well are thought to be due to several causes.[1] One cause is natural potentials which result from potential differences set up at the boundaries of dissimilar geologic bodies. A second cause is filtration potential. Depending on the pressure differential existing in a drill hole, there is movement of fluid either from the well into the porous medium or from the porous medium into the well. This causes a potential difference, which in oil wells is usually small. A third cause is solution concentration potentials. In an oil well the salt water associated with oil in the sands has a higher concentration than the water used in drilling the well. The water of the drilling fluid has, therefore, a negative potential with respect to the water of the sand. The potential log is the algebraic sum of these three potentials.

The Interpretation of the Potential Curve

Potential values are recorded on the logs on the left side of the line representing the well. The base line from which these values are measured is as a rule known as the "shale base line", since shales usually show the same potential throughout the well. A millivolt scale showing positive and negative directions together with the value of the divisions is plotted.

The potential of sandy horizons is almost always more highly negative than that of shales. Sand bodies will therefore stand out as peaks or maxima on the potential log in contrast with shales which show up as nearly straight lines. In general, one can, therefore, distinguish lithologic units by means of the potential curve.

The Resistance Curve

The resistance curve is obtained by introducing a current of constant voltage into the ground by means of an electrode in the well and measuring the amount of current flowing between this electrode and a second electrode at the surface. The current does not flow directly from one electrode to the other but spreads out equally in all directions. The potential difference is highest in the vicinity of the well electrode, and it has been determined that the material within a foot of the electrode causes most of the fluctuation in the resistance curve. As the electrode is lowered into the well, the resistance to the current flowing between

[1] For a complete discussion of electric logging and its interpretation reference should be made to a series of articles by H. Guyod on Electric Well Logging, Oil Weekly, vols. 114, 115, 116, 1944; and Electric Log Interpretation, Oil Weekly, vol. 120, 1945.

the well electrode and the surface electrode will be determined largely by the resistivity of the material in the vicinity of the electrode in the well. If alternating current is used, both the potential and resistance curves can be obtained at the same time.

The fact that the material within a foot of the well electrode causes most of the changes in the resistance curve is frequently a disadvantage. If a sand body opposite an electrode has a low pressure relative to the hydrostatic pressure of the drilling fluid, there will be a migration of water from the well into the sand body causing a contamination of the sand. The resistance measurement will not be that caused by the original fluid of the sands but of the introduced water. This has been overcome by lowering three or more electrodes, spaced at definite intervals, into the hole. The introduced current flows from the lowermost electrode toward the surface, spreading out equally in all directions, and a portion will flow through the strata opposite the upper electrodes. The drop in potential opposite the two upper electrodes is a measure of resistance of the strata between these two points, and as far back into the formation as the distance between the bottom electrode and the next highest. By this means, the original fluid content of the sands can be measured, and the infiltration of drilling fluid is not a controlling factor.

Resistance changes are largely caused by water contained in the rock pores. Most sediments contain salt water in varying amounts. Since salt water is a good conductor of electrical currents, a sediment containing a large amount of salt water should have a low resistivity, and its resistance curve would either be a straight line or contain a small peak. Shales usually have a high porosity and a large content of trapped connate water. They will therefore produce nearly straight lines on the resistance curve of the log. Oil, gas and fresh water have high resistivities and will therefore produce maxima on the resistance curve.

Both the pressure of the water in the drill hole and its salinity will affect the resistance measurements. This is especially true if the formation pressure is less than the hydrostatic head of the drilling fluid, water of a lower salinity than that of the formation being introduced into the sand. In this case, a salt-water sand may be interpreted as an oil sand unless a third or fourth resistance curve is available, in which case the infiltration effects are not important.

The Interpretation of the Resistance Curve

The resistance curve is difficult to interpret because of the variables which affect it. The salinity and the amount of original water in the formation, the salinity of the drilling fluid, the size of the drill hole, and the degree of infiltration of drilling fluid into the formation all have pronounced effects on the resistance curve which is the algebraic sum of all these variables. In general, shales which have very low permeabilities are not affected by infiltration and will have low resistance values on the curve due to the large connate water content. The curve produced by shales can, therefore, be taken as a base line.

Sand horizons containing salt water or brackish water, or oil and gas sands with much salt water will show a low resistance on the resistance curve. Oil and gas sands, fresh water sands, limestone, or oil and gas sands flushed by fresh water will show a high resistance on the curve. Sandy shales, thin sands, and oil and gas sands with small amounts of infiltered fresh water will show moderately high resistances. The potential curve should always be studied together with the resistance curve when a knowledge of the fluid content of the strata is desired.

The Electric Log of the Hammond Well

The electric log of the Hammond well is reproduced on Figures 10 and 20 and shows the second curve or resistance curve as a solid line and the third curve (resistance) as a dotted line on the right side of the log. The third curve was obtained by the use of multiple electrodes and reveals the true resistivity of the beds.

Sand horizons are indicated by the maxima of the potential curve on the left side of the log. Shale horizons are shown by straight or nearly straight lines.

The first resistance curve shows a series of small peaks between 1400 and 1800 feet, but below this horizon the curve is nearly a straight line down to 4750 feet. Below 4750 feet the curve has a series of peaks indicating an increase in resistivity. This increase in resistivity may be due to oil or gas or to the infiltration of less saline water from the drilling fluid. If the second resistance curve (dotted curve) or the "third curve" as it is known, is considered, it is evident that the formation fluid possesses a low resistivity since the curve is nearly a straight line. The formation fluid is therefore salt or brackish water and not oil or gas. The sands below the 4750 foot level are all soft, partially consolidated, and poorly sorted and doubtless possess a relatively high permeability. This would favor the infiltration of drilling fluid.

In the upper portion of the hole, up to approximately 2200 feet, the sands all show a low resistance both on the first and second resistance curves. Infiltration is not important in this portion of the section, and the fluid content of the sands is either salt or brackish water.

The second resistance curve ("third curve") does not indicate that petroleum is present in any portion of the section.

CONCLUSIONS

As a result of the study of the core samples supplemented by the interpretation of the electric log, the Ohio Oil Company abandoned the Hammond test as a "dry hole," on January 13, 1945. No evidence of petroleum could be found in any of the sands.

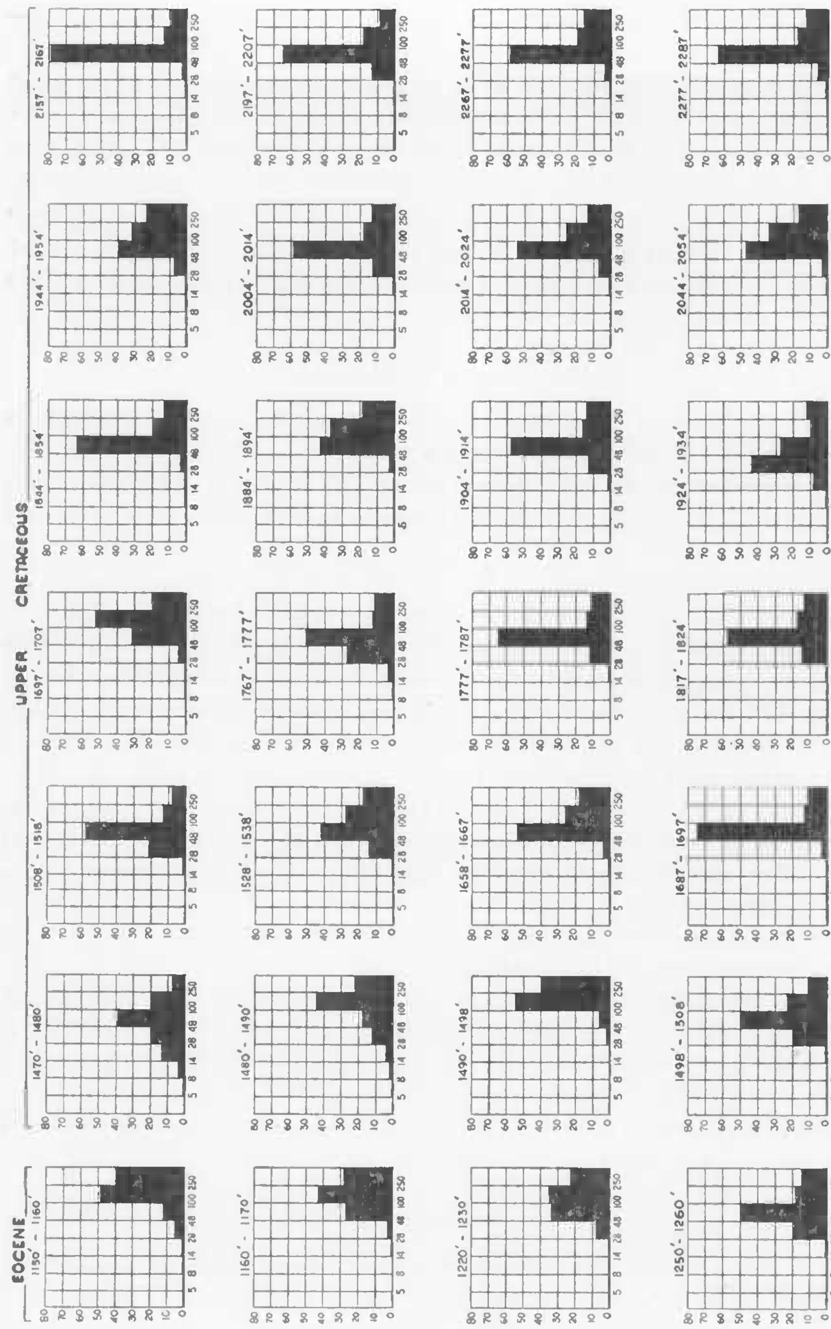

FIGURE 11. Eocene and Upper Cretaceous Histograms. L. G. Hammond Well No. 1

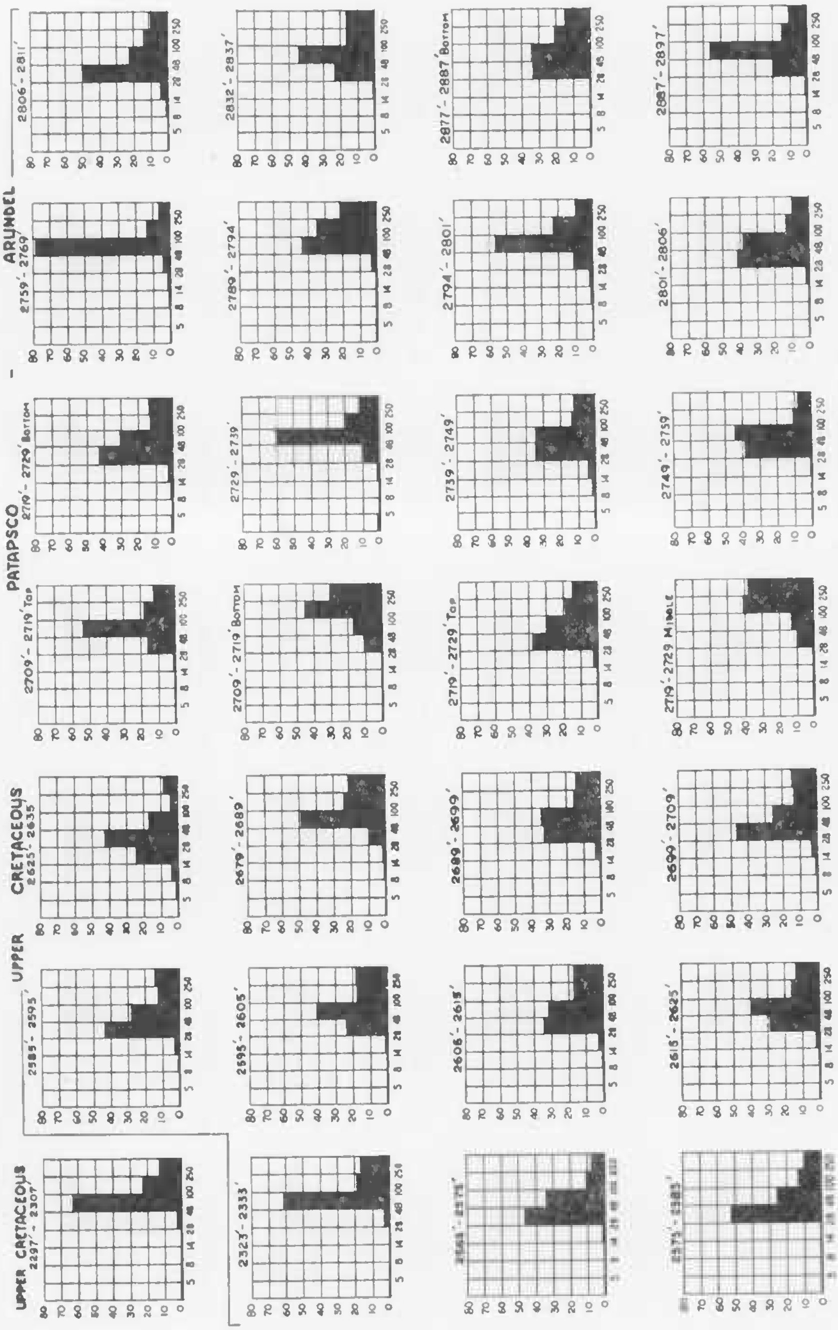

FIGURE 12. Upper Cretaceous Histograms. L. G. Hammond Well No. 1

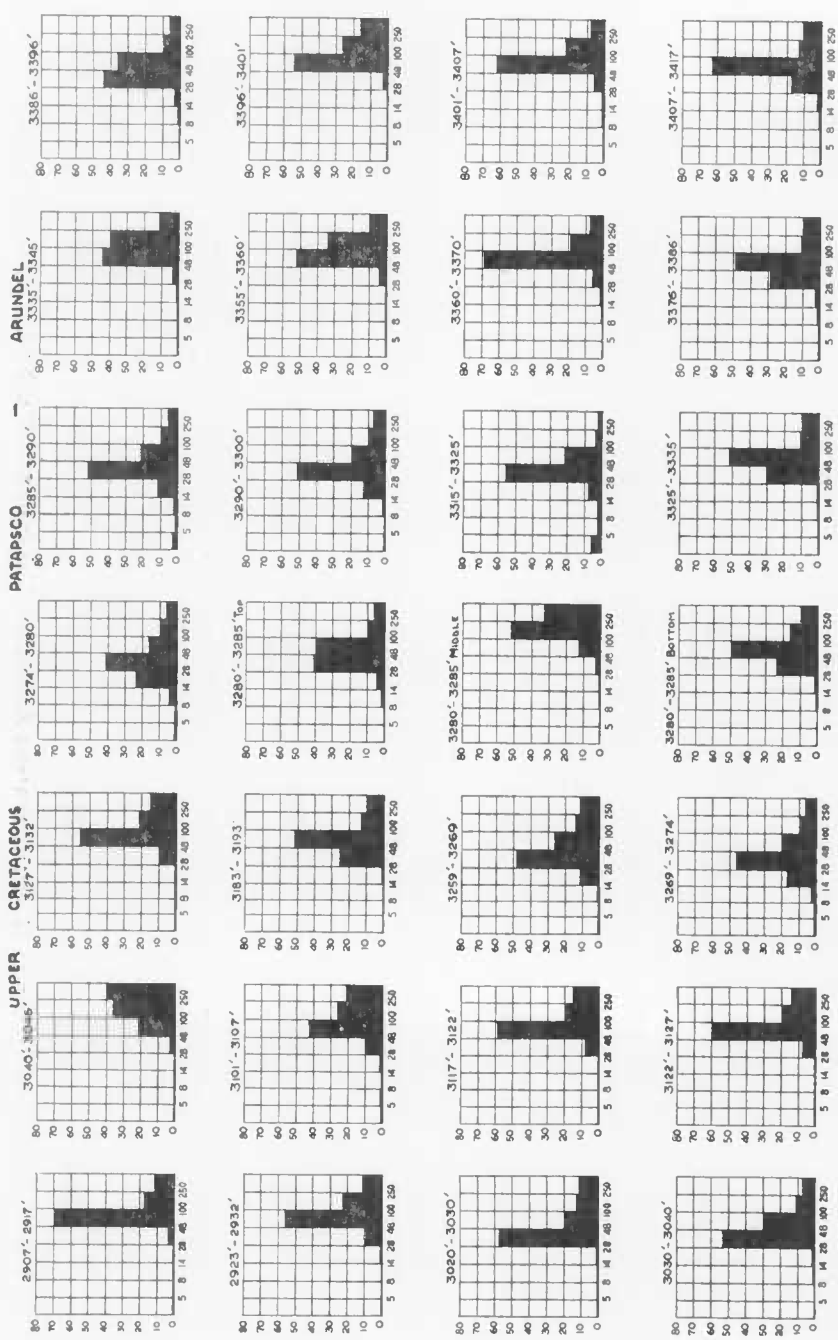

FIGURE 13. Upper Cretaceous Histograms. L. G. Hammond Well No. 1

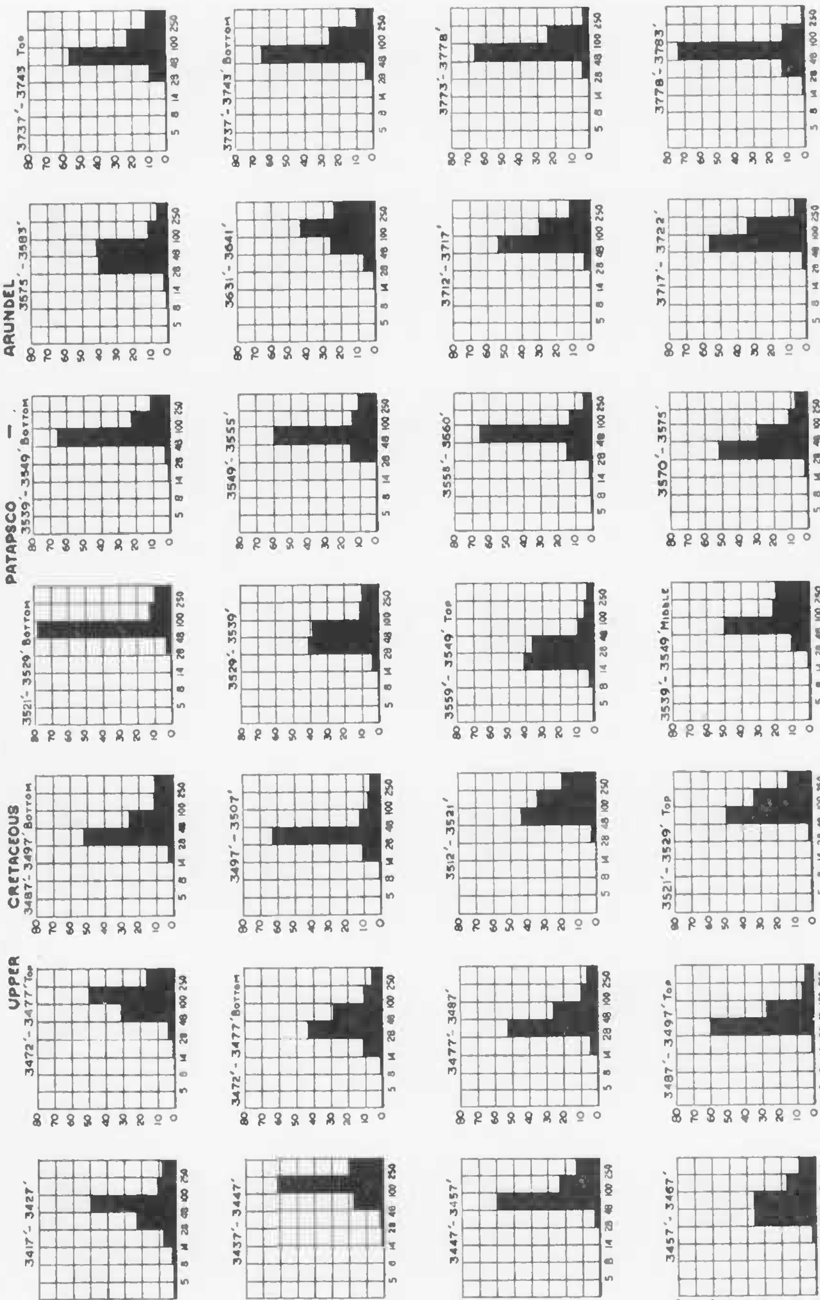

FIGURE 14. Upper Cretaceous Histograms. L. G. Hammond Well No. 1

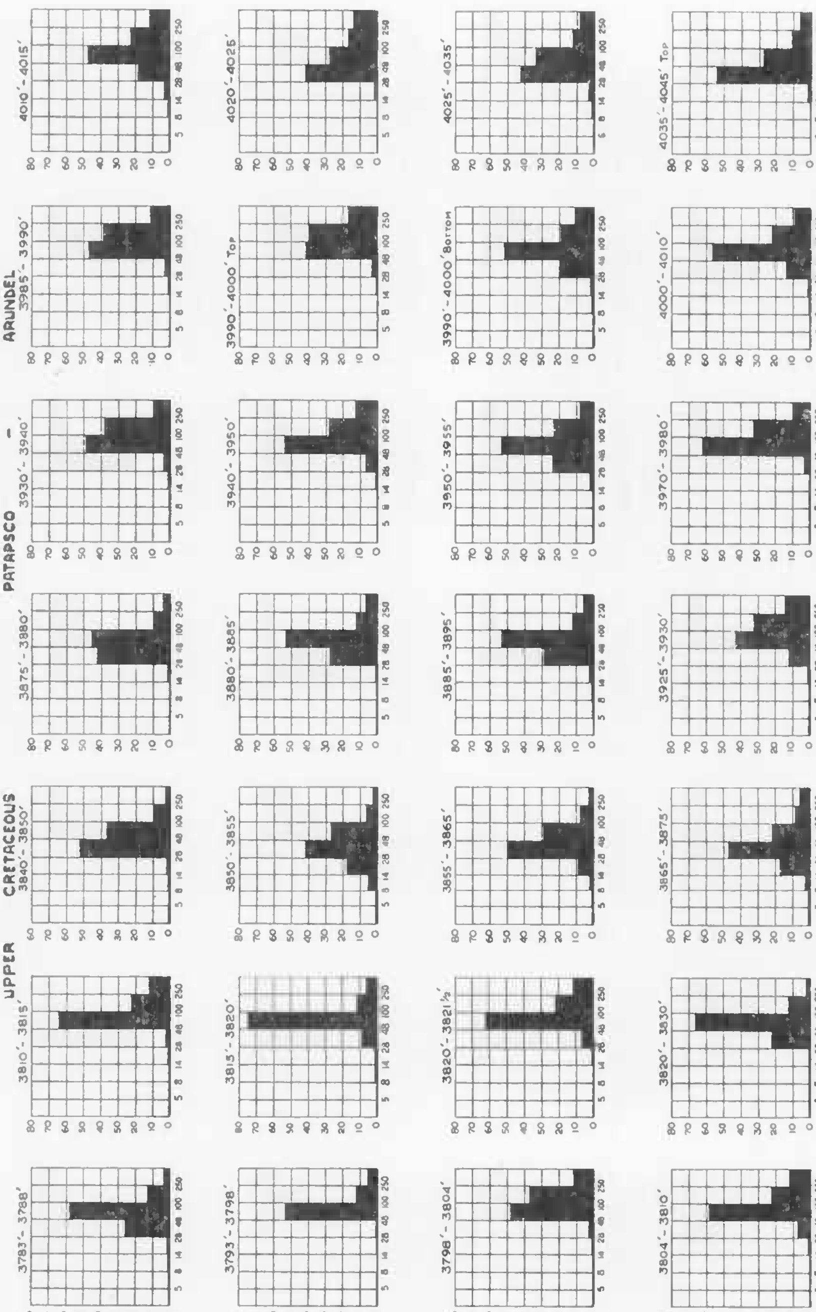

FIGURE 15. Upper Cretaceous Histograms. L. G. Hammond Well No. 1

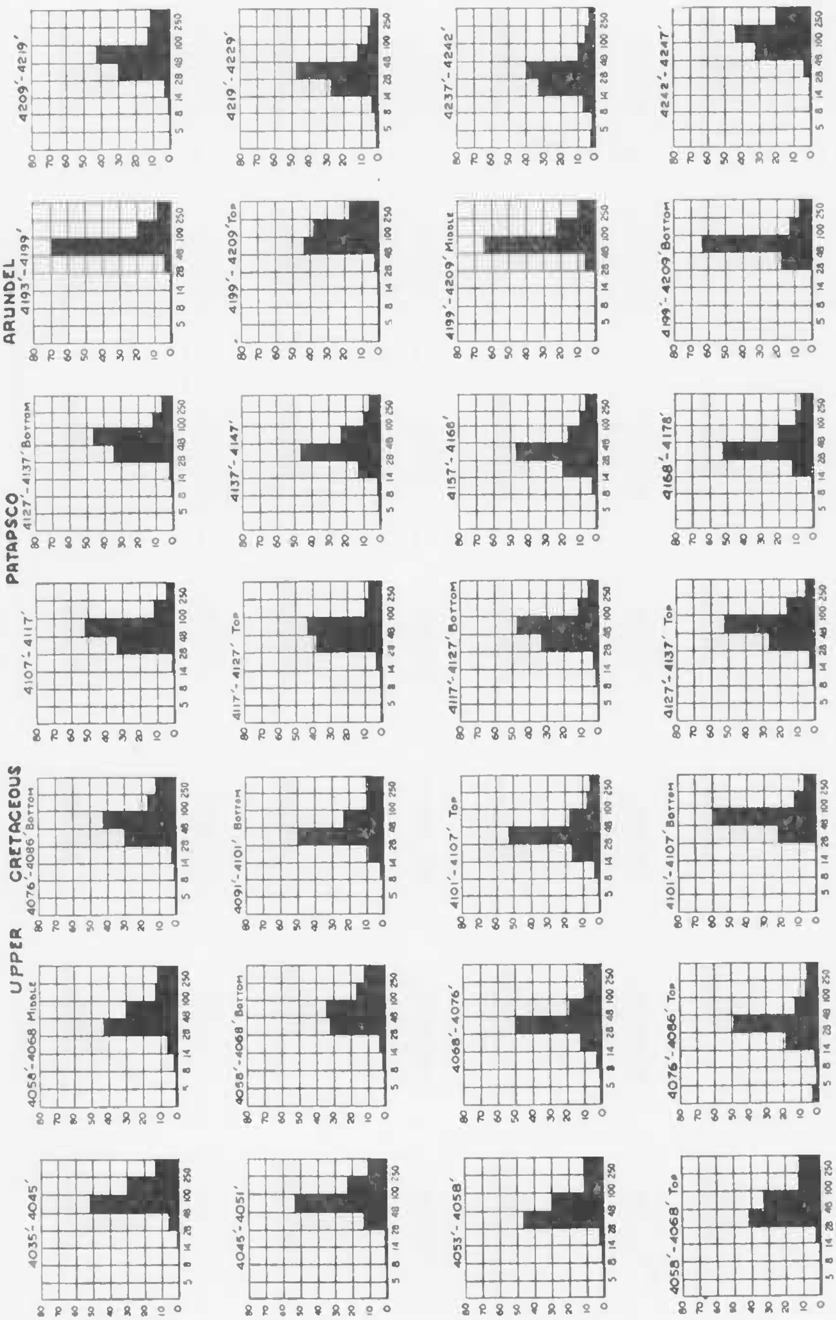

FIGURE 16. Upper Cretaceous Histograms. L. G. Hammond Well No. 1

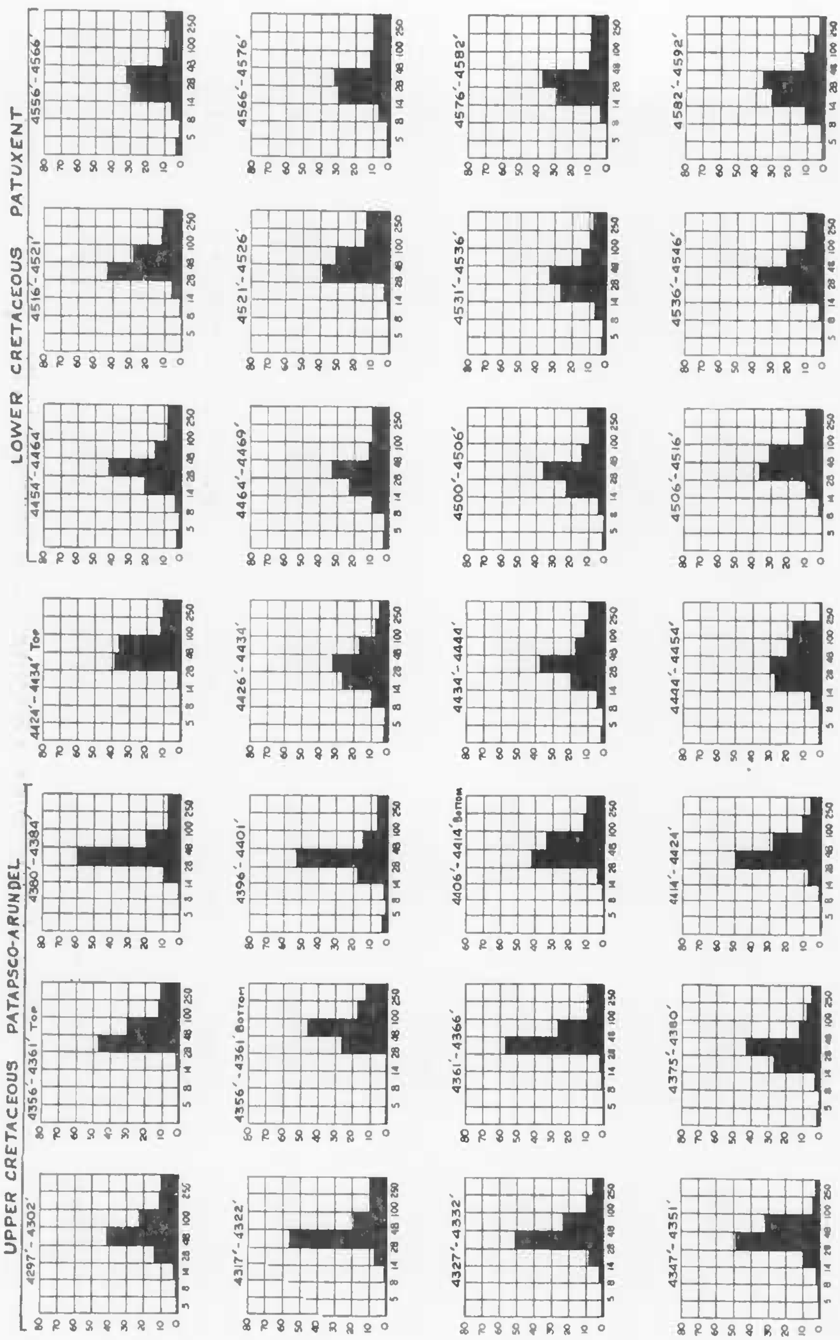

FIGURE 17. Upper and Lower Cretaceous Histograms. L. G. Hammond Well No. 1

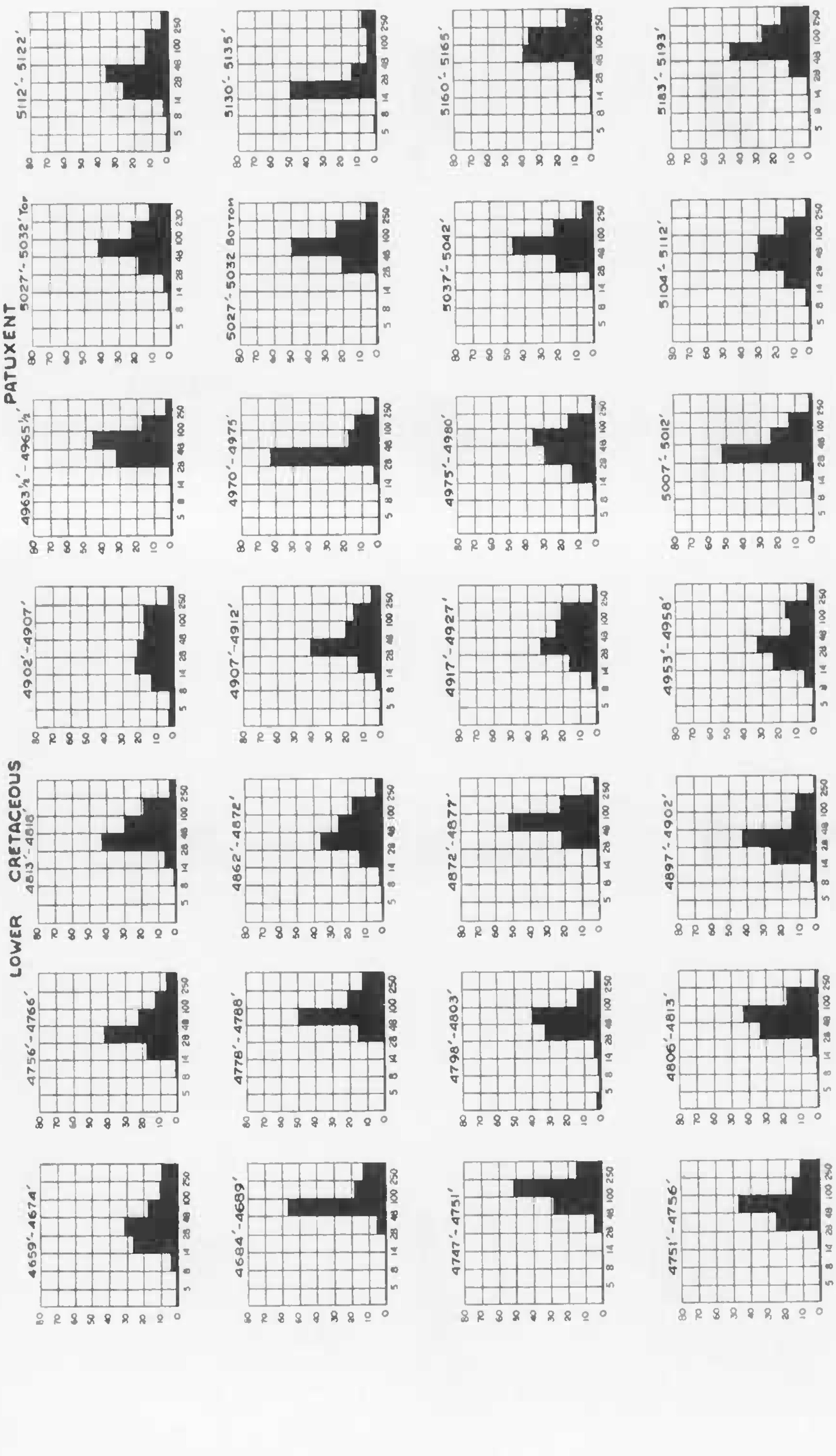

Figure 18. Lower Cretaceous Histograms. L. G. Hammond Well No. 1

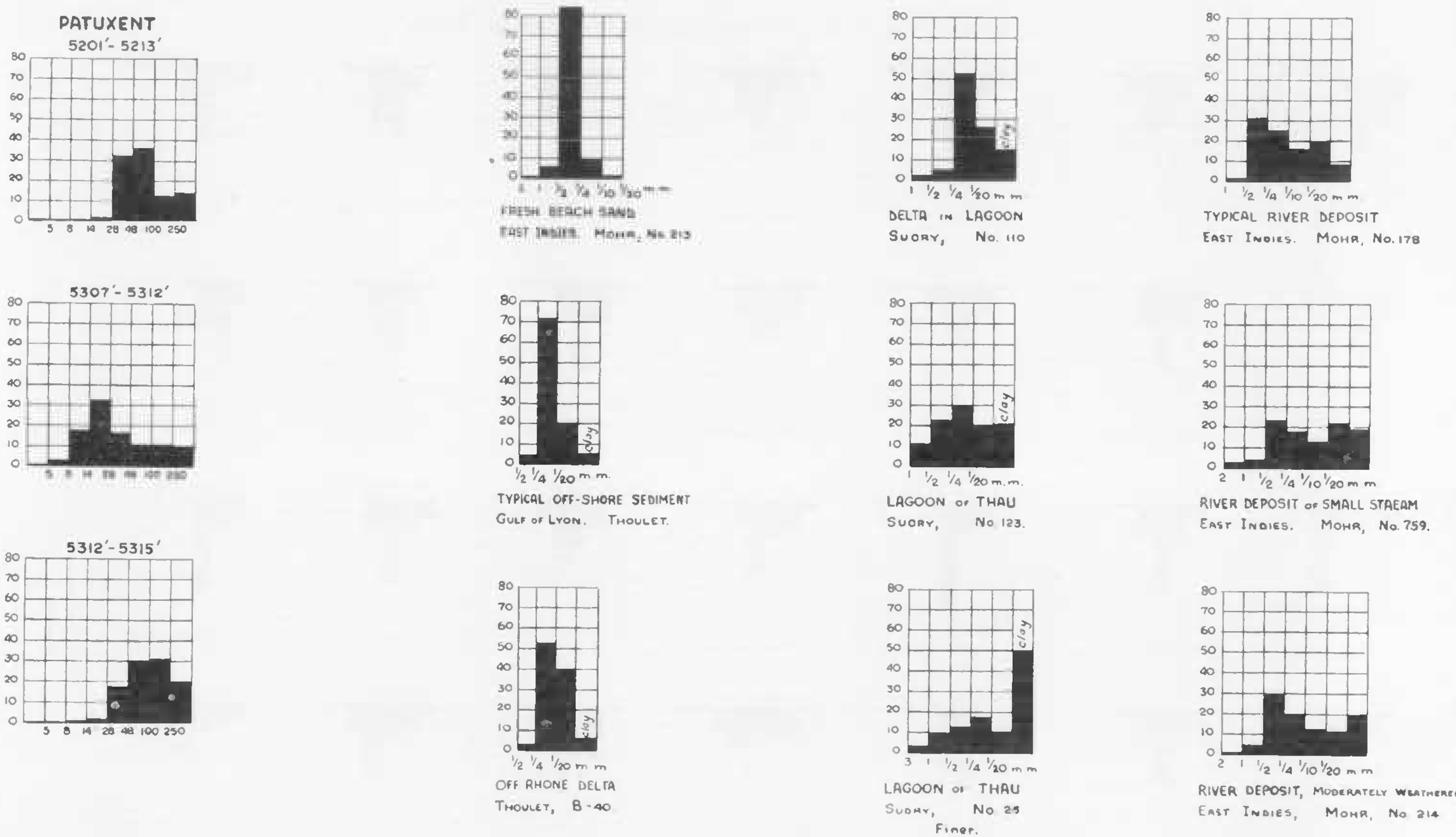

FIGURE 19. Lower Cretaceous and Miscellaneous Histograms

Method of Abandonment

The surface casing which was set at 550 feet was left in the hole. The well was plugged from 600 feet to 347 feet with 180 sacks of Portland cement, and the top of the hole was cemented off with 20 sacks of cement. Since the company failed to discover petroleum in this well, the lease under which the well was drilled, was surrendered to its owner, Larry G. Hammond.

The Socony-Vacuum Oil Company's James D. Bethards No. 1 Well

Introduction

Preliminary Work

The James D. Bethards No. 1 well was a joint venture by the Socony-Vacuum Oil Company and the Ohio Oil Company. The peliminary geological and geophysical work was carried out by the Ohio Oil Company, and the well was drilled on a lease held by this company.

The well was located on the property of James D. Bethards in Worcester County, Maryland. It was 11 miles southeast of the Hammond well of the Ohio Oil Company, approximately 5 miles southwest of Berlin, $3\frac{1}{2}$ miles northwest of Ironshire, and slightly more than 3 miles almost due north of Newark. The well was spudded in on July 5 and was plugged and abandoned on August 26, 1945.

Method of Drilling and Sampling

The Bethards well was drilled by contract, and rotary tools were used from the surface to the total depth of 7178 feet. A total of 31 conventional cores was taken between 1709 feet and the bottom of the hole. After the electrical log was run, a series of 27 Schlumberger side-wall cores were taken at selected horizons between 1955 and 6434 feet. Ditch samples were collected every 10 feet from the surface to the bottom of the hole. A representative cut from all of the ditch samples, except those between 100 and 790 feet, and all core samples including those taken by the Schlumberger method were turned over to the Department of Geology, Mines, and Water Resources for study. A description of these samples is contained in the appendix to this report.

The well has a string of 20-inch conductor pipe set at 39 feet and 923 feet of $10\frac{3}{4}$-inch casing cemented in with 775 sacks of cement. No other casing was run in the hole, and all pipe was left in when the well was abandoned.

Stratigraphy and Paleontology

The Basement Complex

The top of the basement complex was first definitely recognized in the core sample taken at 7157 feet. The ditch sample from 7140–7150 feet contained a few rather soft fragments of a dark-green basic igneous rock, and the core from 7111–7120 feet was conglomerate with pebbles measuring up to $1\frac{1}{2}$ inches. From the electric log, the top of the basement is chosen at 7130 feet. The well penetrated approximately 48 feet into the basement, to a total depth of 7178 feet.

The rock at the bottom of the well is dark greenish-black, similar to rocks in the vicinity of Baltimore and Washington which have been mapped as gabbros. The grain size varies from medium to fine. In places the rock is jointed, with the joint planes dipping at 75 degrees and occasionally filled with carbonates. Brecciation was noted at 7168 feet. Pyrite and serpentine are common.

A total of seven thin sections from different portions of the rock were studied. Metamorphism has not entirely obliterated the original rock texture, and the remains of what was originally an ophitic texture are still evident. The rock, therefore, possesses a blastophitic texture. The original light minerals have been altered both in composition and texture. They now have a granoblastic texture.

Microscopically, amphibole, plagioclase, quartz, clinozoisite, biotite, apatite, ilmenite, leucoxene, titantite, chlorite, and calcite were noted.

The amphibole occurs as subhedral to anhedral individuals, that are occasionally well-twinned and frequently are frayed and rod-like. Basal sections show the characteristic amphibole cleavage. Some cleavage lines are not smooth and continuous but tend to be somewhat broken and interrupted. The outlines of one basal section suggested a pyroxene, but the poorly developed cleavage was that of an amphibole. Hence the rock may have originally contained some pyroxene, but no definite pyroxene crystals were found in any of the slides.

The amphiboles are strongly pleochroic as follows:

Z = bluish-green
Y = pale yellow
X = deep yellow-green

The extinction angle and the size of 2V are:

$$Z \wedge c = 13° - 14°$$
$$2V(-) = 72°$$

The relatively large optic angle and the moderately large extinction angle suggest that the mineral might belong to the group of calciferous amphiboles containing alkalies and titanium described by Winchell (124). The two optical constants do not correspond to those of either the actinolite or hornblende series.

Plagioclase feldspar and quartz form a granoblastic groundmass for the amphibole crystals. The composition of the plagioclase is that of oligoclase with indexes of refraction less than quartz. One grain showed faint albite twinning and a suggestion of a zonal growth. With this exception, all of the oligoclase is untwinned. The association of clinozoisite with both oligoclase and quartz indicates that the original plagioclase was rich in anorthite. Through metamorphism the anorthite was changed into the more acid plagioclase and an epidote mineral.

Accessory minerals are biotite, less than 1 percent; ilmenite, altering to leucoxene and titanite; and apatite.

Secondary minerals are chlorite, calcite, and serpentine. The first two are associated with amphibole. Serpentine is the result of hydrothermal alterations and occurs adjacent to the veins containing pyrite, ilmenite, and carbonates.

The approximate composition of the rock is 75 percent amphibole and 25 percent mostly plagioclase and quartz. It represents an igneous intrusion whose mineralogy suggests a hornblende gabbro. The body has suffered only a moderate degree of metamorphism which has not obliterated entirely its original ophitic texture. The original plagioclases have disappeared, and in their place occurs an annealed mass of oligoclase and quartz and associated clinozoisite. The rock should therefore be classified, according to Eskola (29, p. 355–359), as an Epidote Amphibolite, to bring out its metamorphic characteristics.

Triassic

Newark Series

It is difficult to accurately select the top of the Newark series due principally to the lack of continuous cores. There seems to be a change in lithology between the cored intervals of 6486 to 6501 feet and 6705 to 6713 feet. Below this latter depth, the character of the beds is highly suggestive of the Triassic. The ditch sample from the depth of 6610 to 6620 feet contains coarse sand and reddish-brown shale, the reddish-brown shale increasing in amount below this horizon. The electric log shows a pronounced lithologic change at 6566 feet, from sands above to sandy shales and shales below. The top of the Triassic has therefore been placed at 6566 feet. The total thickness of the sediments referred to the Triassic is therefore approximately 585 feet.

The basal part of the Triassic of the Bethards well is conglomeratic. In the core from the interval 7111 to 7120 feet are pebbles of quartzite, pegmatite, serpentine measuring up to 3 inches and rounded milky-quartz pebbles up to 1½ inches. Overlying this basal conglomerate, and extending upwards to about 6850 feet, is a series of coarse to fine-grained, mottled reddish-brown and bottle-green sandstones and chocolate-brown shales and sandy shales with occasional intercalations of lead-gray sands and shales. Above 6850 feet, and extending upwards to the top of the series, is silty reddish-brown shale with a minor amount of greenish-gray shale. Fine-grained sand is very subordinate in this part of the section.

Cretaceous

Lower Cretaceous

Patuxent Formation.—The portion of the section assigned to the Patuxent formation is characterized by the extensive development of fine to very coarse-grained and at times pebbly, soft, white, highly arkosic sands. Shales are subordinate to the sands and are hard, lead-gray, and frequently mottled in shades of reddish-brown, lavender, and green. Lignite and carbonaceous matter are sparingly present in the ditch samples.

The electric log indicates the top of the Patuxent formation at 4876 feet, although the coarse to pebbly sand did not show up in the ditch samples above 4930 feet. This is probably due to the lag in return of the cuttings from that depth to the surface. Mineralogically, the break occurs between the sample from 4890 feet and that from 5062 to 5082 feet. This is the same mineral change noted in the Hammond well. The thickness of the Patuxent formation in the Bethards well is, therefore, approximately 1690 feet.

Upper Cretaceous

Patapsco-Arundel Section.—The lack of critically placed core samples makes it very difficult to pick accurately the top of the Patapsco-Arundel section. The core from 2540 to 2560 feet is lithologically similar to sediments of the Raritan formation in the Hammond well. Lithologically, the core from 2950 to 2966 feet indicates that it is from the Patapsco formation. The core from 2735 to 2751 feet, may be from either the lowermost Raritan beds or the uppermost Patapsco. In the Hammond well, the mottled shales begin approximately 100 feet below the top of the Patapsco-Arundel section. In the Bethards well they first appear in the ditch sample from 2860 feet. On the basis of the lithologic similarity of the sediments from the two wells, the top of this section is placed at 2770 feet. A lithologic correlation is not the most accurate, especially when dealing with sediments whose environment of deposit changes as rapidly as that of the Eastern Shore area. On the other hand, the lack of more definitive data makes a more accurate correlation impossible.

The section between 2770 and 3440 feet is predominantly sandy. The sands are fine to medium-grained, micaceous, and at times silty. The color varies from shades of gray to grayish-green with occasional mottling. Rarely are the sands coarse, and large feldspar grains seem to be lacking. Intercalated shales show a variety of colors ranging from dark-gray slightly mottled to reddish-brown highly mottled.

Below 3440 feet the section becomes predominantly shaly. The shales are still highly mottled and reddish-brown colors predominate. Occasional sands are fine to coarse-grained, rarely limy, and at times micaceous. No fossil remains were noted from this portion of the section.

The thickness of the Patapsco-Arundel section of the Bethards well is approximately 2105 feet. This is very nearly the same thickness as the equivalent section of the Hammond well.

Post-Patapsco Section.—The character of the well samples does not permit an accurate division of the upper part of the Upper Cretaceous into formational units. On foraminiferal evidence, Cushman has placed the Eocene-Cretaceous boundary in the interval represented by the ditch sample from 1670 to 1680 feet. The core sample from 1709 to 1728 feet contained Cretaceous foraminifera. On this basis, the Upper Cretaceous of the Bethards well above the Patapsco-Arundel section is about 1060 feet thick.

The core sample from the interval 1894 to 1914 feet was studied by L. W. Stephenson. The upper two feet of this core contains a macro-fauna which is similar to that found in the Hammond well at 1588 feet (See section on systematic paleontology). This would indicate that the Raritan formation of the Bethards well extends from 2770 to 1894 feet, a thickness of 876 feet.

The electric log indicates that the basal 450 feet of the Raritan formation is composed of intercalated thin sands and shales. The sands are fine-grained, micaceous, and occasionally lignitic. Their color varies from grayish-brown to greenish-gray. The shales are lead-gray in the basal part of the interval and mottled in shades of gray, brown, and green in the upper part. In the upper portion of the Raritan thicker bodies of sand and shale are developed.

It is not possible to delineate the formations above the Raritan. The section is predominantly shaly and thin sands are only rarely present. The shales are brownish-gray in color and glauconite is very common to abundant. A white chalky clay with some glauconite was first noted at 1800 feet but disappears in the samples below 1840 feet.

Macro-fossils from the cored interval 1894 to 1914 feet were determined by L. W. Stephenson. Shells referred to *Brachidontes* appear to be related to *B. filisculptus* (Cragin) from the Lewisville formation (Upper Woodbine) of Texas. "*Corbula*" aff. "*C.*" *manleyi* Weller is closely related to the species described by Weller from the Raritan formation of New Jersey. Three species of "*Cerithium*" are common to the lower part of the Lewisville formation of Texas (See systematic paleontology). The fossil evidence therefore indicates that the section represented by the above core is of Raritan or late Cenomanian age.

Foraminifera from the core at 1709 to 1728 feet were determined by J. A. Cushman. All forms with the exception of one are known from the Upper Cretaceous Navarro of the Gulf Coast area.

Eocene

Samples are lacking from the interval 1110 to 1270 feet, the interval within which the top of the Eocene is located. On foraminiferal evidence, the sample from 1100 to 1110 feet belongs in the Miocene, but the sample from 1270 to 1280 feet contains Jackson Eocene forms. The top of the Eocene, therefore, must be between 1140 feet, the top in the Hammond well, and 1270 feet. The Eocene section of the Bethards well is, therefore, between 400 and 530 feet thick, with approximately 450 feet as a closer figure.

The lithology of the available samples indicates that the Eocene is composed primarily of dark grayish-brown clay with a small amount of fine sand. The sample from 1270 to 1280 feet is only sparingly glauconitic, but glauconite becomes common below 1500 feet.

Miocene

It is not possible to divide the Miocene into its formational units. The samples collected are all from the Calvert formation. No samples were secured between the depths of 100 and 790 feet. The Miocene probably extends upward to about 130 feet.

The lithology of the samples from the Calvert formation indicates that it consists primarily of pale-gray to grayish-white silty clay with occasional streaks of fine to medium-grained sand. Traces of glauconite, lignite and shell fragments were noted.

Pleistocene

The samples from 40 to 100 feet indicate that the Pleistocene is composed of medium to very coarse sand containing rounded quartz pebbles up to $\frac{1}{8}$ inch in diameter. They contain occasional pecten fragments.

MINERALOGY

A total of 40 mineral analyses were made from the core samples of the Bethards well. Since the mineralogy of the Bethards sediments is similar to that of the Hammond well, it will not be discussed in detail. Table 11 shows the distribution of the various mineral species. The six mineral zones which were recognized in the Hammond well were also recognized in the Bethards well. A summary of these zones follows.

The Epidote Zone

This zone in which the epidote minerals pistacite and clinozoisite are very abundant and which marks the top of the Magothy formation in the Hammond well was observed in the first core sample at 1894 to 1914 feet. The ditch samples locate the top of this zone within the interval 1780–1870 feet. It could not be tied down closer because of the lack of sand in the samples. The electric log suggests that the top is close to the 1800 foot level. On this basis the top of the Epidote Zone is approximately 300 feet lower in the Bethards well that in the Hammond well.

The Hornblende Zone

Subhedral green hornblende, which appears abruptly in a fairly common amount 179 feet below the top of the Raritan formation in the Hammond well, was also noted in the Bethards samples. It was first encountered in the sample from 2170 feet. In the Bethards well, the top of the zone lies 276 feet below the top of the Raritan formation.

The Brown Garnet Zone

The deep-brown variety of garnet makes its first appearance in the core sample from 2894 to 2897 feet (Table 11). It is lacking in the 2735 to 2751 foot core and also in the ditch sample from 2790–2800. The top of the zone is doubtless in the top of the sand body at 2870 feet (See Figure 20).

The Cleaved Staurolite Zone

Staurolite grains with well-defined saw-tooth edges and sharp planes which traverse the grains were first encountered in the core sample from 3764 to 3767 feet. The ditch samples above this depth do not contain this type of crystal. The top of this zone, which lies within the Patapsco-Arundel section, is about 1035 feet below the top of the Patapsco. In the Hammond well, it was located 887 feet below the top of the Patapsco formation.

The Lower Staurolite-Garnet Zone

Figures 2 and 3 of the Hammond well indicate that the basal Patapsco-Arundel section is characterized by an increase in both garnet and staurolite. The Bethards samples (Table 11) show a similar increase in staurolite at 4845 feet. A marked decline in the amount of staurolite was noted in the sample from 5152 feet. This decline is also similar to that noted in the Hammond well. The marked increase in the amount of garnet in the basal Patapsco-Arundel of the Hammond well could not be detected in this well due to the lack of critically placed cores. There is a noticeable increase in garnet at the top of the Patuxent formation, but the large increase occurs at 5062 to 5082 feet. From this horizon to 6281 feet, garnet is very abundant but declines in amount from 6281 to 6930 feet. Below this horizon it again becomes abundant and continues to be abundant until the bottom of the hole is reached. The staurolite-garnet characteristics are so similar to those of the uppermost Patuxent formation of the Hammond well that a direct correlation is possible.

The Tourmaline Zone

A marked increase in euhedral to subhedral brown and greenish-brown tourmaline was noted about 785 feet below the top of the Patuxent formation in the

TA

Mineral Analyses: Socony-

Percentag

Depth in Feet	1894–1914	1955–1958	1965–1967	2110–2125	2195	2205	2288	2325–2340	2540–2560	2735–2751	2894–2897	2904–2906	3155–3171	3232	3320	3375–3391	3375–3391 Bottom 8 ft.	3764–3767
Zircon	11	10	14	22	2	3	8	36	17	27	8	4	14	3	2	3	3	22
Colorless	10	9	14	21	2	3	6	34	16	26	6	4	12	3	2	2	2	20
Mauve	1	1		1	tr		2	2	1	1	2	tr	2	tr	tr	1	1	2
Monazite	1	2	1			1	2	3			tr	1	2	tr	tr		tr	2
Tourmaline	2	7	3	8	1	2	5	3	2	4	tr	1	2		tr		1	tr
Brown	1	6	2	5	1	1	2	2	1	3	x	tr	1		x		1	tr
Green-Brown	1	1	tr	3	tr	1	3	1	1	1		1	1				tr	1
Blue						tr	tr				x							
Blue-Green			1								x							tr
Staurolite	3	38	14	33	2	5	6	4	3	16	7	4	7	6	2	7	6	3†
Garnet	1	4	11	1	2	4	2	1	3	4	7*	5*	8	6	4	8	10	12
Colorless	1	3	9	1		3	1	1	3		4	2	4	3	2	5	6	9
Pink		tr									1	1	tr	1		1	1	tr
Brown		1	2			1	1				2	2	4	2	2	2	3	3
Rutile	4	6	4	6	1	1		5	2	3	1	1	1	tr	tr	tr	tr	3
Titanite	1	1	2		3	2			tr	1	3	2	3	2	3	6	3	1
Brookite								tr										
Anatase			tr	tr				tr										
Blue																		
Brown			x	x				x										
Hornblende	1	1	2		11	4	2	tr			1	tr	tr		1		tr	tr
Green	1	1	2			4												
Brown		tr				tr												
Actinolite			tr		1													
Tremolite								tr										
Hypersthene													tr					
Epidote	34	9	10		20	24	26	15	14	13	25	26	24	34	27	38	34	25
Clinozoisite	34	8	17	tr	54	49	38	29	55	23	43	52	31	46	54	35	39	24
Zoisite	4	1	tr		2	5	2	1	1		1	tr	1		1			
Andalusite		2	tr	6			tr					tr	tr				tr	
Pleochroic		1																
Non-Pleo		1	x	6			x					tr	x				x	
Sillimanite	1	1		4	tr		2	tr			tr	tr	1	tr				
Cyanite	2	4	3	10	1	1	2	1	1		1	3	1	tr	1	1	1	
Biotite		3	3							3	tr			tr	2		tr	
Muscovite																		
Chlorite	tr	1	2			1	tr		1	4		tr	tr				1	tr
Chloritoid	tr	3	2			tr			tr	2		tr	1			tr	1	tr
Apatite	tr						1	tr			1	1	1	1	2	1		4
Barite				5														
Gypsum			10	1														C
Siderite		tr							VA									
Pyrite	S		S	VC				S	R	S			R		R			
Green Isotropic																		
Black Opaque	VC	C	C	S	S	S	C	C	C	C	C	S	C	S	S	C	C	C
Leucoxene			S	VC	S	R	R	S	R	R	S	R	S	R	R	R	R	1
Brown Opaque										VA								

* Deep brown garnet.
† Staurolite shows cleavage.
‡ Garnet increase.
§ Staurolite not cleaved.
** Staurolite well cleaved.
†† Epidote with carbonate overgrowths.

VA = very abundant.
A = abundant.
VC = very common.
C = common.
S = scarce.
R = rare.
VR = very rare.
tr = trace.

…uum Bethards No. 1 Well

…Weight

	4415–4431	4632–4648	4845–4863	4890	5062–5082	5152	5248	5488	5735	5808	5832–5848	5986	6049–65 Top	6049–65 Bot.	6265–6281	6434	6486–6501	6705–13 Top	6930–47 Top	6930–47 Bot.	7040–7058
	31	16	13	13	7	7	30	20	49	20	9	8	48	27	44	12	25	12	13	3	16
	31	13	12	11	7	7	28	19	47	19	8	7	48	27	44	12	25	12	13	3	16
		3	1	2	tr		2	1	2	1	1	1	tr	tr							
		2	1	tr	2	1	5	2	2	1	tr	2	tr	tr	8		2				
	2	1	2	2	1	2	7	8	4	6	3	2	13	15	24	8	39	3	43	12	25
	1		1	tr		1	2	6	2	4	3	2	7	9	14	7	23	1	28	6	8
	1	1		tr		tr	5	2	2	1	tr	1	5	5	10	tr	14	1	13	5	14
			1	tr						1	tr			1	tr		t		tr	tr	5
	tr			2		1							1			1	t	1	2	1	tr
	10	4	15	19	11	20	2	2	5	6	5	7	9	19	2	58§	20**	tr	1	15	6
	8	7	12	15	60‡	55	33	30	27	35	63	50	6	28	13	6	4	t	22	56	21
	6	5	7	9	22	35	21	21	20	25	46	30	5	13	11	5	2		21	37	16
		tr	1	1	17	7		1	tr		5	4	tr	1						9	1
	2	2	4	5	21	13	12	8	7	10	12	16	1	14	3	1	2		1	10	4
	5	1	1	1	1	tr	4	11	8	9	5	4	10	3	5	1	6	2	4	2	tr
	9	6	4	4	5	4	1	1	tr				tr					3			1
								tr			1	3			tr						
								1	tr	1	3	16									
								1	x	1	3	16									
	1			3		2	3	5		4		tr				5					
	9	34	35	24	7	3	1	1		3	tr	tr			tr	tr	tr	16††			1
	15	21	15	10	2	1	1				1				tr	tr		1			
					tr					2	tr	tr								2	
					x					2	x	x								2	
				1		tr	tr			1											
tr			t	tr		tr	tr														
tr	1		1		1	tr	2	6	tr	1	3	1	1	2	1	5	2	tr	1	1	3
	tr																				
3	6	tr		3	tr		5	3	1	1	1	1	4	tr		2		1			1
3		1	1	3	2	2	6	6	3	8	1	1	7	4		1		tr			
	2	5	tr		3	2	3	3		3	3	3		tr			2	4	15	3	24
																VA	C	C		5	
C				C			C	A		C											
								R													
A	VR	R		C	C			A		R	S			C							
				tr							2				tr						tr
S	A	C	R	C	S	S	R	S	C	S	C	S	VC	S	C		C	S	C	S	S
R	R	S	VR	S	S	R	C	C	C	C	S	C	S	C	S		S	C	S	S	R
			A																		

Hammond well. This mineral, which was scarce to rare above this horizon, suddenly becomes abundant and continues relatively abundant on into the Triassic (Fig. 3). A similar change was noted in the Bethards well at 6049 feet, which is approximately 1175 feet below the top of the Patuxent formation. This zone affords another tie to the Patuxent formation of the Hammond well.

EVIDENCE OF PETROLEUM

The Core Samples

The sands of the Schlumberger side-wall samples and the sands of the conventional cores were all tested by the Socony-Vacuum Oil Company. No evidence of petroleum was obtained from any of the sands.

The Electric Log

The Schlumberger Well Surveying Corporation made an electrical survey of the hole for the Socony-Vacuum Oil Company. Figure 20 is a reproduction of the log. The potential curve indicates the distribution of sand and shale, and the two resistance curves reveal the character of the fluid content.

The Eocene section shows a negligible development of sand. The first resistance curve has several very small peaks, but the second resistance curve (known as the "third curve") is a straight line opposite these peaks. The conclusion is that these small, poorly developed sandy horizons contain salt water and no oil or gas.

The Upper Cretaceous contains a better development of sand that the overlying horizons. The first resistance curve shows the effects of infiltration of water from the drilling fluid in the sands between 1850 and 2000 feet. The character of the second resistance curve, which does not show corresponding peaks, indicates that the sands contain a fluid which has a low resistivity. The conclusion is that the sands are salt water bearing. The same conditions are present in all remaining sands of the upper part of the Upper Cretaceous.

The second resistance curve of the Patapsco-Arundel section shows few fluctuations from a generally straight line graph, and the first resistance curve contains very few peaks. Infiltration was not important in this portion of the section, and the fluid content again was one having a low resistivity. The conclusion is that the sands of the Patapsco-Arundel interval are salt-water bearing.

In the Patuxent formation, sand bodies are highly developed and infiltration of drilling water is very pronounced as revealed by the large peaks on the first resistance curve. The second resistance curve, although sinuous, has none of the pronounced peaks characteristic of oil and gas sands. The conclusion is that these sands, too, contain salt water.

CONCLUSIONS

The lack of any indications of petroleum in the sand cores together with the salt-water character of the sands as revealed by the electric log led the Socony-Vacuum Oil Company to abandon the James D. Bethards well as a "dry hole." The well was abandoned by placing 15 sacks of cement at the bottom of the $10\frac{3}{4}$ inch casing at 923 feet and 10 sacks of cement at the surface in the $10\frac{3}{4}$ inch casing.

Standard Oil Company of New Jersey's Maryland Esso No. 1 Well

INTRODUCTION

Preliminary Work

In 1945, the Standard Oil Company of New Jersey leased from the State of Maryland 82,310 acres of State-owned land consisting of the inland waterways in the bays along the Atlantic Coast, a strip $\frac{1}{2}$ mile wide consisting of 10,240 acres extending from the beach outward into the Atlantic Ocean, the Pocomoke State Forest Reserve consisting of 3,680 acres, and the Scarboro Game Refuge consisting of 550 acres. The initial payment for these leases was $20,577.50 or $.25 per acre. The lease requires a yearly payment of $20,577.50 while drilling operations are not in progress and the further payment to the State of a $\frac{1}{8}$ royalty on each barrel of oil produced. The lease is to run for a period of ten (10) years unless otherwise cancelled, and the Standard Oil Company of New Jersey agreed to drill a well within 18 months after the signing of the lease to a depth of at least 5000 feet or until oil or gas was encountered.

The Maryland Esso well No. 1 was not drilled on State land but on a lease located $4\frac{1}{2}$ miles north of Ocean City, Maryland, on the Ocean City-Rehoboth highway and on the west side of the highway between the Assawoman Bay and the Atlantic Ocean. The exact location of the well as given by the company is latitude 38°24′ and longitude 75°03′33″. It is not known whether the Standard Oil Company of New Jersey carried on any preliminary geophysical surveys in this area.

Drilling and Sampling

The Maryland Esso well was drilled by contract for the Standard Oil Company of New Jersey by the Noble Drilling Company of Tulsa, Oklahoma, and cost the company approximately $125,000 or $16.20 per foot. A 127-foot L. C. Moore jackknife derrick and diesel rig, shipped in from Oklahoma, were used in drilling the well. Rotary tools employing $4\frac{1}{2}$ inch drill pipe were also used. Drilling operations began on October 1, 1946, and were completed on December 14, 1946. Two cores were taken during the drilling of the well, one from 4600 to 4607 feet and the other from 4875 to 4885 feet. Ditch samples were collected every 10 feet from the surface to the bottom at 7710 feet. A total of 18 Schlumberger sidewall cores were taken from 1565 to 7702 feet, only 13 of which were recovered. The Schlumberger sidewall cores and a representative cut from all other samples were turned over to the Maryland Department of Geology, Mines, and Water Resources for study. The sidewall cores were studied and described by J. L. Anderson and the other samples were examined and described by R. M. Oberbeck. A description of these samples is found in the appendix of this report.

The results of a straight hole survey are shown in Table 12.

TABLE 12

Straight Hole Survey: Lease and Well No. Md. Esso No. 1: Field, Worcester County

Deviation in Degrees at	Depth in feet	Deviation in Degrees at	Depth in feet
0	250	1/2	3950
1/2	843	1/2	4250
1/2	1050	1/2	4500
1/2	1500	1/4	4750
0	1750	1	5000
0	2000	1/2	5250
1/2	2190	3/4	5500
1/4	2440	3/4	6050
3/4	2710	1/2	6540
1/4	2950	0	6850
1/4	3150	0	7230
1/4	3400	1/4	7540
1/4	3700		

The geological work pertaining to the drilling of the Maryland Esso well was done under the supervision of Mr. K. D. White. Mr. W. B. Spangler was directly responsible for the geological work at the well site.

STRATIGRAPHY AND PALEONTOLOGY

General

The Maryland Esso well, though 7710 feet deep, did not encounter the basement complex, nor did it enter the red-bed series of the Triassic. The well was completed in the basal part of the Lower Cretaceous, at an undetermined point above the bottom of the Lower Cretaceous.

Lower Cretaceous

Patuxent Formation.—The large increase in staurolite, characteristic of the top of the Patuxent formation, in both the Hammond and Bethards wells, was first noted in the sample from 5400 to 5410 feet. The Patuxent formation therefore extends from 5400 feet to below the bottom of the hole at 7710 feet, a thickness of more than 2310 feet.

The section revealed by the electric log is composed of thick bodies of sand with subordinate intercalated shales which become thicker in the basal part of the section. The sand varies in size from very coarse grained with subordinate gravel and pebbles in the lower part of the section to predominantly coarse-grained with subordinate medium and very coarse grained in the upper part (Fig. 20). Kaolinized feldspars are present in the sidewall cores. The shales are light olive-gray, pale yellowish-green, medium greenish-gray and weak brown in color. Occasional hard, calcareous beds are intercalated. The highly mottled red, brown, lavender, green, and gray shales of the Hammond and Bethards sections are largely missing in the Patuxent of the Esso well.

Upper Cretaceous

Patapsco-Arundel Section.—The top of the Patapsco-Arundel section is placed at 3330 feet at the base of the very thick green-colored sand which is considered as belonging in the Raritan formation of the Upper Cretaceous. The thickness of this section is of the magnitude of 2070 feet.

Sand bodies are not as well developed in this portion of the well section as in the underlying Patuxent formation (Fig. 20). Shale bodies are thicker, especially in the upper 900 feet. The sands vary from fine to coarse-grained, are angular to subrounded, and contain mostly quartz with subordinate kaolinized feldspars. The shales show a variety of colors ranging from light mottled shales in the upper part through pale-brown and light brownish-gray to darker shades of brown in the lower part.

All ditch samples are contaminated with foraminifera from higher horizons. The core taken at 4875 to 4885 feet contained a macro-fauna composed of pelecypods and gastropods, which according to L. W. Stephenson is apparently new and undescribed. Two species of gastropods appear to be related to two as yet undescribed genera and species in the Woodbine (Upper Cretaceous) of Texas. This fauna has been studied by H. E. Vokes (see section on paleontology) who established its age as Cenomanian and possibly lowermost Upper Cretaceous. The Upper Cretaceous is much thicker than has heretofore been considered, and the Patapsco-Arundel section is Upper Cretaceous; and only the Patuxent formation is Lower Cretaceous. K. D. White (personal communication) was of this opinion during the drilling of the Esso well.

Post-Patapsco Section.—It is difficult, if not impossible, to correctly subdivide the section above the Patapsco-Arundel into its formational units. On the basis of lithology the contact between the Eocene and Upper Cretaceous is placed within the interval 2100 and 2150 feet.

The top of the Epidote zone, marking the top of the Magothy formation, falls within the interval 2290 and 2400 feet, with the top probably coming at 2360 feet. The electric log indicates a well-developed sand section with subordinate shales between 2360 and 2480 feet. This interval might represent the Magothy formation. If 2480 feet marks the base of the Magothy formation, then the underlying Raritan formation is 850 feet thick. The section above the top of the Magothy formation which contains the Matawan and Monmouth equivalents is between 210 and 250 feet thick.

The basal 600 feet of the Raritan formation is composed almost entirely of medium to coarse pale olive-green sand and pale-brown to dark-gray shales. Occasional lime fragments, siderite spherules, and lignite are present. The upper portion of the Raritan formation is composed of light yellowish-brown shale and a subordinate amount of fine sand.

In that portion of the section assigned to the Magothy formation, sands are more abundant than yellowish-gray clay shales. Overlying the Magothy formation and extending upwards to the Eocene contact, pale-brown and olive-gray clay shales are more abundant than fine-grained sands. Glauconite is fairly abundant below 2170 feet.

Eocene

The top of the Eocene on the basis of the foraminifera is placed within the interval 1650 to 1670 feet by Cushman. The thickness of the Eocene section is, therefore, of the magnitude of 500 feet.

The Eocene is composed almost entirely of pale-brown foraminiferal clay containing a subordinate amount of glauconite, and a small amount of fine to medium-grained, rarely coarse, light olive-gray sand. The heavy glauconite zone which is characteristic of the lower half of the Eocene on the western shore and the basal 40 feet in the Hammond well seems to be entirely missing in the Esso well.

Miocene

The top of the Miocene is placed approximately at 200 feet which gives a thickness of about 1450 feet for the Miocene.

Lithologically the Miocene section has been divided into the following units by R. M. Overbeck. These units are not formational units.

200–780	Chiefly light olive-gray and brownish-gray sand varying from medium to very coarse grained. A minor amount of clay and sandy marl.
780–1160	Abundant hard, calcareous beds, shell fragments, and pale-olive to olive-gray sand.
1160–1500	Predominantly yellowish-gray and pale-brown clay. Some fine to coarse sand and hard, calcareous beds. Shell fragments. Glauconite appears in the cuttings between 1010 and 1220 feet. Diatoms present.

1500–1650 Chiefly pale-brown clay. Foraminifera suggest that this interval corresponds to the Calvert formation of the Hammond well. Heavy diatom bed occurs at 1610–1650 feet and possibly represents the Fairhaven member.

Pleistocene

The contact between the Miocene and Pleistocene has been tentatively placed at 200 feet by Overbeck. The Pleistocene samples are largely sandy and contain minor amounts of clay. The lower portion of the interval carries heavy gravel. At 200 feet a color change occurs. Below this horizon clear quartz, which is commonly found in the Miocene, is present.

MINERALOGY

The lack of core samples at critical horizons makes it very difficult to accurately correlate the Esso well with the two other wells. The ditch samples were utilized when possible and several of the zones encountered in the Hammond and Bethards wells were located.

The Epidote Zone

The zone of abundant epidote marking the top of the Magothy formation was located within the interval of 2300 and 2400 feet. From the electric log, the sand development begins at 2350 and the top of the Epidote zone probably falls at or near this horizon. On this basis, the top of the Magothy formation in the Esso well is approximately 550 feet lower than in the Bethards well (Fig. 20).

The Hornblende Zone

The hornblende zone in the Raritan formation of the Hammond and Bethards wells was not definitely located in the Maryland Esso well. At 2790 feet, a large quantity of chlorite and small amount of hornblende was encountered for the first time. This horizon is within a sand body whose top is at 2760 feet. The top of this sand may coincide with the top of the hornblende zone. There appears to be a satisfactory electric log correlation between the Bethards and Esso wells, the top of the sand at 2170 feet in the Bethards well being equivalent to the top of the sand at 2760 feet in the Esso well.

The Brown Garnet Zone

The brown garnet zone, occurring in the uppermost part of the Patapsco-Arundel section, was not located. If present, it should be encountered in the sand which begins at 3460 feet. There is an excellent electric log correlation of the sands and shales above and below this horizon in both the Bethards and Esso wells.

The Cleaved Staurolite Zone

The ditch samples from the depths of 4220 and 4290 feet were examined for cleaved staurolite. None was found in the first sample, but it occurred in the sample from 4290 feet. Checking the lithology of the ditch samples against that of the electric log, Overbeck found an apparent lag of about 50 feet in the ditch samples. If this is the case, then the top of the cleaved staurolite zone might be located in the top of the sand body which begins at 4210 feet. On this basis, the top of this zone is about 450 feet lower than the top of the same zone in the Bethards well.

The Lower Staurolite-Garnet Zone

A marked increase in staurolite accompanied by abundant garnet, characteristic of the top of the Patuxent formation in both the Hammond and Bethards wells, was noted in the sample from 5460 feet. Allowing for the apparent lag in the samples, this would place the top of the Patuxent at about the 5400 foot horizon. On this basis, the top of the Patuxent in the Esso well is 525 feet lower than in the Bethards well. The electric log correlation confirms this (Fig. 20).

The Tourmaline Zone

This zone, which was found in the basal part of the Patuxent formation in both the Hammond and Bethards wells, was also encountered in the side-wall core sample from the Maryland Esso well at a depth of 7136 feet. This horizon is located within a massive sand, the top of which is at 7124 feet. It is probable that the tourmaline zone reaches to the top of this sand body. No tourmaline was noted in the ditch samples above 7090 feet.

The top of the tourmaline zone in the Bethards well was encountered 517 feet above the top of the Triassic. In the Maryland Esso well, the top is located 586 feet above the bottom of the hole at 7710 feet. The top of the Triassic dips 110 feet per mile between the Hammond and Bethards wells (Table 14). If this dip were maintained between the Bethards and Esso wells, the top would be expected at about 7670 feet. The lithologic character of the sediments in the bottom portion of the Esso well is different from that of both the Hammond and Bethards wells. It is concluded that the Esso well ended in the very basal portion of the Patuxent formation very close to the top of the Triassic.

EVIDENCE OF PETROLEUM

The Well Samples

All samples were carefully checked at the well site by the company geologist using an ultra violet ray lamp. No indications of either oil or gas were noted in any of the samples.

The Electric Log

The first resistance curve shows large peaks both in the Upper and Lower Cretaceous sections (Fig. 20). This is probably due to the infiltration of water from the drilling fluid. A second resistance curve was run and, with several exceptions, all peaks either disappeared or decreased in magnitude. The character of the second resistance curve was suggestive of oil or gas in one or two places. In order to determine if oil or gas were present, a third resistance curve was run. This curve definitely indicates that no oil or gas horizons were encountered.

CONCLUSIONS

The Maryland Esso well, after failing to find oil or gas, was abandoned on December 14, 1946. The 24 inch, 16 inch, and $10\frac{3}{4}$ inch casing were left in the hole. The well was filled with mud from 7710 to 1132 feet and a cement plug extending from 1132 to 1057 feet was placed within the $10\frac{3}{4}$ inch casing. A mud column extending from 1057 to 170 feet was capped by a cement plug which extended from 170 feet to the surface. A total of 115 sacks of cement were used by the Noble Drilling Corporation.

CORRELATION OF THE THREE DEEP TESTS

GENERAL

The correlation of the three oil tests based on paleontologic, mineralogic, and lithologic evidence is shown in Figure 20. A suggested relation of these three wells with the subsurface section in the vicinity of Baltimore is given on the geologic cross-section of Figure 21. Tables 13 and 14 summarize the information obtained from the complete study of the three wells.

RELATION OF THE HAMMOND SECTION TO THOSE OF THE BETHARDS AND ESSO WELLS

General

One of the most outstanding features revealed by Figures 20 and 21 is the increase in thickness of the Mesozoic and Tertiary sections on passing eastward from the Hammond well. In the Hammond well, the section above the basement complex is 5498 feet thick and has increased to about 7130 feet in the Bethards well. The Esso well with 7710 feet of section was still in the Lower Cretaceous when completed.

Another important fact brought out by the correlation between these wells is the attitude of the basement complex. This surface dips 150 feet per mile between the Hammond and the Bethards wells, and the Bethards well is 1664 feet lower than the Hammond well. It is not known whether this surface is a peneplane or whether it is characterized by marked relief. If it is a peneplane, its dip must flatten out somewhere between the Hammond well and the outcrop,

TABLE 13

Correlation of Formations, Mineral Zones, and Faunal Zones in the Deep Tests, Eastern Shore of Maryland

	Outcrop	Hammond Well		Bethards Well		Md. Esso Well	
	Maximum Thickness	Top	Thickness	Top	Thickness	Top	Thickness
Miocene	500 – ?	130	1010	130±	1010–1140	200	1450
Yorktown	—	130	200	—	—	?	
St. Marys	280	330	185	—	—	?	450
Choptank	50	515	125	—	—	?	
Calvert	100±	640	500	—	—	650?	1000
Siphogenerina lamellata	—	1010	—	—	—	1310	—
Eocene	225	1140	220	1225?	445±	1650	430
Jackson	?	1140	110	—	—	—	—
Claiborne	?	1250	70 (max.)	—	—	—	—
Paleocene	?	1320 or 1260 (?)	40 or 100 (max.)	—	—	—	—
Upper Cretaceous	905	1360	3064	1670	3206	2080	3320
Monmouth	100	1360	33	1670	70	2080	
Globotruncana Canaliculata	—	1360	—	1670	—	2110	
Matawan	70	1393	105	1740	60	?	270
Planulina taylorensis	—	1400–1410	—	1750	—	2140	
Kyphopyxa christneri	—	1433	—	—	—	2400 (probably too low)	
Magothy	100	1498	90	1800	88	2350	140
Epidote zone	—	1498	2926	1800	?	2350	—
Planulina texana	—	1500	—	—	—	—	—

Raritan	250	1588	725	1888	882	2490	840
Upper Woodbine macro-fauna	—	1588–1603	—	1894–1914	—	—	—
Hornblende zone	—	1767	545±	2170	—	2760	—
Patapsco-Arundel	385	2313	2111	2770	2106	3330	2070
Brown Garnet zone	—	2565	—	2870	—	—	—
Cleaved staurolite zone	—	3242	—	3764	—	4210	—
Cenomanian macro-fauna	—	—	—	—	—	4875–78	—
Lower Cretaceous	350	4424	939	4876	1694	5400	Depth penetrated 2310
Patuxent	350	4424	939	4876	1694	5400	2310
Staurolite zone	—	4424	250±	4876	—	5400	—
Tourmaline zone	—	5267	231	6049	—	7136	—
Triassic	—	5363	135	6570	560	—	—
Basement Complex	—	5498	70 penetrated	7130	48 penetrated	—	—

otherwise it would be exposed to the east of the Chesapeake Bay (Fig. 21). The change in dip might be explained by either a hinging of the basement or erosion which carved out a canyon through which some pre-Mesozoic stream flowed.

The Triassic

In the Hammond well, the Triassic section is 135 feet thick (Table 13), and in the Bethards well 560 feet. The dip on the top of the Triassic is 110 feet per mile, and the increase in thickness is at the rate of 39 feet per mile. Structurally the top of the Triassic is 1207 feet lower in the Bethards well than in the Hammond well. Shales are more abundant in the Bethards well than in the Hammond section. This would suggest that the Triassic basin of deposition lay to the east of the Hammond well. No Triassic beds were reached in the Esso Well.

TABLE 14

Structural Data, Deep Tests, Eastern Shore, Maryland

	Hammond—Bethards			Bethards—Esso		
	Differences in Elevation Corrected for Topography	Dip in feet per Mile on Top of Formation	Increase in Thickness in Feet per Mile	Difference in Elevation Corrected for Topography	Approximate Dip in Feet per Mile on Top of Formation	Approximate Increase in Thickness in Feet per Mile
Miocene	—	?	8	—	—	38
Eocene	100±	9±	20±	470	43	Nil
Upper Cretaceous	322	29	12	455	46	11
Magothy	314	29	Nil	595	60	5
Raritan	312	28	14	647	65	Nil
Patapsco-Arundel	469	43	Nil	605	61	Nil
Lower Cretaceous	464	42	69	569	57	62±
Patuxent	464	42	69	569	57	62±
Triassic	1219	110	39	—	—	—
Basement Complex	1644	150	—	—	—	—

The Lower Cretaceous

The excellent mineralogic and lithologic (electric log) correlation at the top of the Patuxent formation serves to establish accurately the top of this horizon. Below this point sands predominate in all three sections, but it is not possible to correlate individual sand bodies. There is a very marked thickening of the Patuxent formation from west to east; ranging from 939 feet in the Hammond well, to 1694 feet in the Bethards well, to over 2300 feet in the Esso well. This increase in thickness between the Hammond and Bethards wells is at the rate of 69 feet per mile, and the dip of the top of the formation is at the rate of 42 feet per mile. The thickness of the Patuxent formation in the three wells is in marked contrast with the maximum thickness of about 350 feet measured on the outcrop. There is, therefore, a progressive overlapping of the beds of the Patuxent formation from bottom to top and a suggestion that marine or near shore conditions existed in the vicinity of the Esso well. The top of the Patuxent is 464 feet lower in the Bethards well than in the Hammond well and 569 feet lower in the Esso well than in the Bethards well.

The Upper Cretaceous

It is impossible to recognize the lithologic equivalent of the Arundel formation in any of the wells. The section in both the Hammond and Esso wells is much sandier than it is in the Bethards well. In the Bethards section, well-developed sand bodies occur mostly in the uppermost and lowermost parts. The top of the Patapsco-Arundel section is 469 feet lower in the Bethards well than in the Hammond well and 605 feet lower in the Esso well than in Bethards well. This represents a dip of 43 feet per mile between the Hammond and Bethards wells and 61 feet per mile between the Bethards and Esso wells. The thickness of this section is about 2100 feet in the three wells. It is in marked contrast to the thickness of 385 feet measured on the outcrop.

The top of the Cleaved Straurolite zone remains nearly parallel with both the top and base of the section, but the Brown Garnet zone shows a flattening in dip. Evidence of brackish-water conditions is revealed by the presence of fossiliferous shales at 4875 to 4885 feet in the Esso well. No evidence of similar conditions was noted in either the Hammond or Bethards wells.

The top of the Upper Cretaceous is accurately established in both the Hammond and the Bethards wells and fairly accurately located in the Esso well (Table 13). The top of the Upper Cretaceous in the Bethards well is 322 feet lower than in the Hammond well and approximately 455 feet structurally higher than in the Esso well. Between the Hammond and Bethards wells, the Upper Cretaceous surface dips at the rate of 29 feet per mile and the increase in thickness is at the rate of approximately 12 feet per mile. Between the Bethards and Esso wells the dip is about 46 feet per mile and the increase in thickness is approximately 11 feet per mile. The top of both the Magothy and Raritan formations between the Hammond and Bethards wells conforms very closely to the dip of the Upper Cretaceous surface, but the rate of increase in thickness of the Raritan is 14 feet per mile whereas the Magothy shows no appreciable change (Table 14). The thickness of the outcropping Upper Cretaceous is approximately 900 feet, which is less than one third the thickness noted in the three wells.

The large well-developed sand bodies of the Esso well are in marked contrast with the thin sands and interlaminated shales of the Bethards well and poor development of sands in the Hammond well. The top of both the Raritan and the Magothy formations is well established in the Hammond and Bethards wells but only approximately located in the Esso well. Both paleontologic and mineralogic data were used in this correlation. The Matawan and Monmouth formations could not be accurately located in either the Bethards or Esso wells. The interval represented by these two formations is 138 feet thick in the Hammond well, approximately 130 feet thick in the Bethards well, and approximately 270 feet thick in the Esso well.

The Eocene

The top of the Eocene is accurately located by paleontologic evidence in both the Hammond and Esso wells but only approximately in the Bethards well. The top of the Eocene in the Bethards well is approximately 100 feet lower than in the Hammond well and about 470 feet higher than in the Esso well. The dip on the top of the Eocene is roughly 9 feet per mile between the Hammond and Bethards wells, and the increase in thickness is roughly 20 feet per mile. Between the Bethards and Esso wells, the dip is 43 feet per mile and the thickness remains nearly constant.

The Eocene section is marine, but the micro-fauna was systematically studied only in the Hammond section. The maximum thickness of the outcropping Eocene is nearly that observed in the Hammond well, but in the Bethards and Esso wells the Eocene thickness is about twice as great.

The Miocene

The formational units of the Miocene were distinguished only in the Hammond well. The thickness of the Miocene in this well is 1010 feet, but in the Bethards well it has increased to a maximum of 1140 feet, and in the Esso well to about 1450 feet. The rate of increase between the Hammond and the Bethards wells is of the magnitude of about 8 feet per mile. There is also a decided increase in thickness of the Miocene from the outcrop area eastward to the Hammond well.

SUGGESTED CORRELATION WITH WATER WELLS OF THE BALTIMORE AREA

An attempt has been made, through the study of the mineral content of the Cretaceous sediments, to establish a correlation between the section exposed on the outcrop and that encountered in the Hammond well. It is obvious that such a correlation based solely on mineralogy might not be a reliable one because of the distance involved and possibility of different provinces contributing to beds in question. Nevertheless, mineral analyses were made of the samples from two water wells and an outcropping section of the Patapsco formation in the vicinity of Baltimore. The results are compiled in Table 15.

The most important facts brought out by these analyses is the abundance of staurolite in the Patuxent formation and its scarcity in the sands of the

Patapsco, and the lack of garnet in both formations. Tourmaline is commonly present in both formations, but cyanite is much more common in the Patuxent than in the Patapsco. Chloritoid is found only in traces.

Comparing the minerology of the Patuxent formation of the Hammond section with that of the wells of the Baltimore area, it will be noted that staurolite shows a marked increase at the top of the Patuxent in the Hammond well and continues to be abundantly present for about 250 feet. A marked decrease in the amount of staurolite was noted when passing upward into the Patapsco formation. Both formations in the wells of the Baltimore area are different from those of the Hammond section in that garnet is absent in the former but abundantly present in the latter. This has been commented on in a previous discussion. Tourmaline, which is abundant in the Baltimore sections, is very scarce in the Patapsco and upper Patuxent formations in the Hammond well. Cyanite which is commonly present in the Patuxent of the Baltimore area is very rare to absent in this formation in the Hammond section. There are many mineralogic dissimilarities between the two sections, but the abundance of staurolite in the Patuxent formation of both sections suggests a correlation on this basis. If this correlation be accepted, then the outcropping beds of the Patuxent formation are represented by the uppermost 250 feet of section in the Hammond well, the basal portion of the Hammond section not being represented on the outcrop.

PETROLEUM POSSIBILITIES OF THE EASTERN SHORE AREA

GENERAL

Origin and Accumulation of Petroleum

Geologic experience has indicated that most of the rocks from which petroleum is derived are of marine origin and that petroleum comes from the organic material contained in sediments. As Trask has pointed out (103, p. 240), the organic content of recent marine sediments, such as those of the Channel Islands region of California, ranges upwards to 7 percent and that in the richest deposits only about 25 percent of the organic matter is converted into petroleum. On this basis, only a small amount of organic matter, approximately 2 percent, is required to furnish petroleum.

Several factors affect the accumulation of organic matter. Trask (103, p. 230) points out that the configuration of the sea bottom strongly influences the amount of organic material in sediments, more accumulating in depressions and closed basins than on adjoining ridges and slopes. Fine-textured sediments such as clays and shales are higher in organic matter than coarser-grained sediments. Organic material varies roughly with the supply of plankton in the surface water. Near-shore sediments contain more organic matter than deep-sea deposits, and in regions of upwelling of deep water to the surface the organic content is high.

TABLE 15

Estimated Percentages of Heavy Minerals in Coastal Plain Sediments in the Baltimore area, Maryland

Source	Depth below Land Surface (feet)	Zircon	Tourmaline	Staurolite	Garnet	Rutile	Titanite	Brookite	Anatase	Hornblende	Actinolite	Hypersthene	Augite	Epidote	Clinozoisite	Andalusite	Sillimanite	Cyanite	Chloritoid	Chlorite	Biotite	Muscovite	Siderite	Geologic Formation
Well 3S5E-30, Federal Yeast Co., Dundalk district, altitude 15 ft.	16.8–18.8	1	1	30	tr	1				35	10			1	15	tr	2	2	2					Pleistocene
	57 – 61	5	35	30	tr											3	7	20						Patapsco
	106.7–116.7	50	40		5	1		1										1		tr	1			Patapsco
	116.7–121.7	55	40		1	tr													tr		tr			Patapsco
	126.7–131.7	55	40		1	tr	tr	tr											tr		tr			Patapsco
	142.2–147.2	70	27	tr		tr	tr	1	tr	tr								tr	1		tr			Patapsco
	236.6–241.6	20	40	35		tr	tr										1	3	tr					Patuxent
	242.6–246.6	10	15	44		5		1									5	20						Patuxent
	255 –257	32	20	30		2		tr		tr							tr	15	tr					Patuxent
	267 –269	60	15	10		10		tr						tr			1	4						Patuxent
	279.7–285.7	40	15	30		5											5	5						Patuxent
	297.7–298.2	40	30	10		10		2	tr					tr			2	6						Patuxent
	310.2–312.2	10	24	40		10		1									5	10						Patuxent
	322.8–326	9	15	30				1									20	25						Patuxent
	328.8–330.8	50	20	15		10			2								2	1						Patuxent
	363 –363.8	2	2	60		1											10	25				tr		Patuxent
	365.8–369.8	1	tr	60		1											3	35						Patuxent
	377.8–379.8	tr	tr	50		tr				tr							7	40			tr	tr		Patuxent
	386.3–390.3	1	1	50		1		tr									20	25	tr					Patuxent
	392.3–394.3	p	p	p													p	(Poor separation)						Patuxent

Well Bal-Gf 194, Bethlehem Steel Co., Sparrows Point district, altitude 10 ft.	35 - 40	3	1	9	tr	tr	tr			40	20	tr		5	15	tr	2	1	3					Pleistocene
	75 - 80	tr		3	10					tr				tr	tr		tr	2		tr			85	
	80 - 85		tr	tr	25					35	5		tr	5	18			1					10	
	95 -100	tr		20	20					30	5	tr		2	15		2	3			tr	tr	2	
	110 -115	1	1	1	1					50	5			5	25		10		1					
	115 -120	tr	1	10	2		1			50	12				20	tr	2	1						
	140 -150	55	30	3			2			9				1		tr			tr					Patapsco
	162	55	30	3		2	tr			9							1							
	175.8-180	50	30	10		2				3				tr				2					2	
	190 -195	43	44	2		5		2	tr					tr	2			tr	2				tr	
	205.8-209.3	45	25	3		3			tr	15	1			2	3			1					1	
	219.3-224.3	55	25	3		tr	tr	tr	tr	10	2			tr	3								1	
	303 -311	5	4	8			tr	tr		3	2			2	3		1	2					70	
Samples from outcrop of Patapsco formation, Curtis Bay district, Cherry Hill Road	Sample																							Patapsco
	1	66	20	1		10		2						tr	tr			tr				tr		
	2	60	30	1	tr			8	1					tr										
	3	47	36	3		5		5	3						tr			tr				tr		
	4	45	35	3		7		5	2					tr	1		tr	1				tr		
	5	51	40	2		2		3	1						tr									
	6	75	15	1		6		2	tr					1										
	7	65	30			4		tr	tr					tr										
	8	60	35	1		3								tr								tr		

p = present.

Marine clays and shales are not the only potential source rocks of petroleum. Limestones are frequently source rocks, and occasionally continental sediments such as lake deposits contain sufficient organic matter to produce petroleum.

There is no general agreement at present concerning the manner in which the organic matter of sediments is transformed into protopetroleum or petroleum and the time at which such transformations take place. Various theories have been advanced, some of which advocate that protopetroleum is formed very soon after the deposition of the enclosing sediments, whereas other theories postulate a relatively late origin associated with deformation. Whichever theory is accepted, it must explain the manner in which the oxygen, nitrogen, phosphorous, and sulphur are removed from the organic matter in order to increase relatively the amounts of carbon and hydrogen, the essential constitutents of petroleum.

One of the most recent theories dealing with the origin of petroleum is that advanced by Zobell as a result of his micro-biological work at the Scripps Institution of Oceanography. Zobell has shown that certain types of bacteria, acting on either plant or animal matter in an oxygen free (anaerobic) environment, can liberate the oxygen, nitrogen, phosphorous and sulphur, and concentrate the carbon and hydrogen. This transformation is thought to take place in a relatively low temperature environment and coincident with the deposition of the fine-grained sediments. The place of accumulation of the petroleum is considered to be near the locality at which it was formed. The hydrocarbon thus produced is not the ultimate form which it may assume. Reactions with minerals and salts in sediments and the mixing of different hydrocarbons during migration will result in the formation of an oil such as that produced from any oil structure.

There is no general agreement concerning the mode of accumulation of petroleum. There is evidence to prove that some deposits of petroleum are indigenous to the formations in which they are found, whereas in others there is evidence to indicate that petroleum must have migrated into the reservoir bed from a considerable distance.

Petroleum Structures

One of the necessary requisites for the accumulation of petroleum is a geologic trap. Petroleum cannot accumulate into commercial deposits unless it is trapped in its subsurface migration. This migration takes place in porous media such as sandstones or limestones and is the result of gases generated during the formation of the oil and the circulation of underground fluids caused by compaction of sediments. The pressure thus produced, acting on the oil and subsurface waters, causes them to migrate. If the oil is not stopped in its subsurface migration and if the sedimentary strata through which it is passing are inclined, it may migrate to the surface and escape. The geologic traps necessary to effect the accumulation of oil into commercial pools can be classified under two main types, one known as structural traps and the other as stratigraphic traps.

Structural Traps.—Deformation of the rocks of the earth's crust produces in them folds and fractures which are able to halt the general migration of oil and to cause it to accumulate in commercial quantities. The most important structural traps are anticlines and domes, faults, monoclines, and salt domes. Traps of lesser importance are terraces, fissures, synclines, and igneous intrusions. All traps of the structural type must possess a closure otherwise the petroleum would not accumulate. In the case of folded beds, some horizon or horizons must completely encircle the structure thus producing a closed structure capable of holding petroleum. If the beds are faulted, some horizon or horizons must close against the fault in order to trap the oil.

Stratigraphic Traps.—In contrast with the structural type of trap, which is caused by deformation, is the geological structure known as the stratigraphic trap. This type is the result of changes in sedimentation which are affected to a certain degree by deformation. Important traps of the stratigraphic type are unconformities, sandstone lenses, shoe-string sands, old shore lines, overlaps, and buried hills. Of lesser importance are up-dip wedging sands and up-dip decrease of porosity. Early geological search for petroleum-bearing structures was confined to the location of the more obvious types such as the structural traps. With the advent of geophysical methods and the advances in sedimentation and paleogeography, the stratigraphic trap has assumed greater importance. Much of our future supply of petroleum will doubtless be found in stratigraphic traps.

SUBSURFACE STRUCTURES OF THE EASTERN SHORE

The attitude of the basement complex upon which the Mesozoic and Tertiary sediments have been deposited is important from the standpoint of possible petroleum accumulation. The seismic work of Ewing and others (31, 32, 33, 34) along the Atlantic Coastal Plain, together with the results of the deep drilling, indicate that a regional low or basin structure exists in the basement complex along the Eastern Shore of Maryland, extending northward into southeastern Delaware and southward into the northern coastal plain of Virginia (Fig. 24). This depression extends westward toward the fall-line. The oil test drilled one mile south of Meadows in Prince George's County, Maryland, penetrated to a depth of 1522 feet without encountering the basement. Another well drilled at Fort Washington was carried to 1000 feet without reaching the basement, but a well drilled at Indian Head, Charles County, Maryland, reached the crystallines at 741 feet. Ewing's (34) seismic survey shows the basement to be at depths of 3050 and 2950 feet below the level of Chesapeake Bay near the Patuxent River. The extraordinary thickness of the Coastal

Plain sediments in the two wells mentioned above led Clark (15) to postulate that they were located along an old stream channel, probably the pre-Cretaceous Potomac River. Regionally, therefore, we are dealing with a basin structure, the axis of which extends in a slightly northwest-southeasterly direction and dips to the southeast.

Geophysical work, including seismograph, magnetometer, and gravity meter

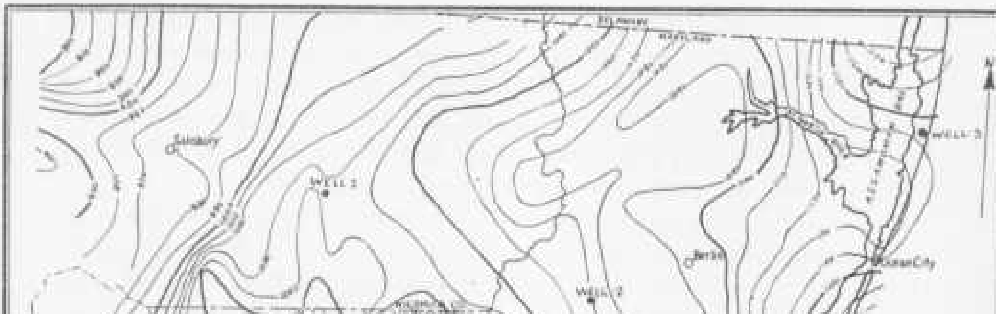

FIGURE 22. Reproduction of U.S.G.S.-U. S. Navy Airborne Magnetometer Contour Map

surveys, was undertaken by several oil companies, the United States Navy, and United States Bureau of Mines. The Navy made an airborne magnetometer survey of Worcester and part of Wicomico county, the results of which are contained in Preliminary Map No. 46 of oil and gas investigations of the United States Geological Survey. The Bureau of Mines made a ground magnetometer survey of Worcester county, and the results are discussed in a report by Kuehn and Dent (64). The maps of these two surveys are reproduced in Figures 22 and 23.

Both magnetometer surveys show two magnetic "highs," one near the town of Girdletree and the other approximately eight miles to the northwest. However the apex of the "high" near Girdletree on the Navy's map is about two miles southeast of the apex of the same "high" on the Bureau of Mines' map. The "high" to the northwest very nearly coincides on the two maps. Both maps indicate a general rise in the magnetic contours between Wells 2

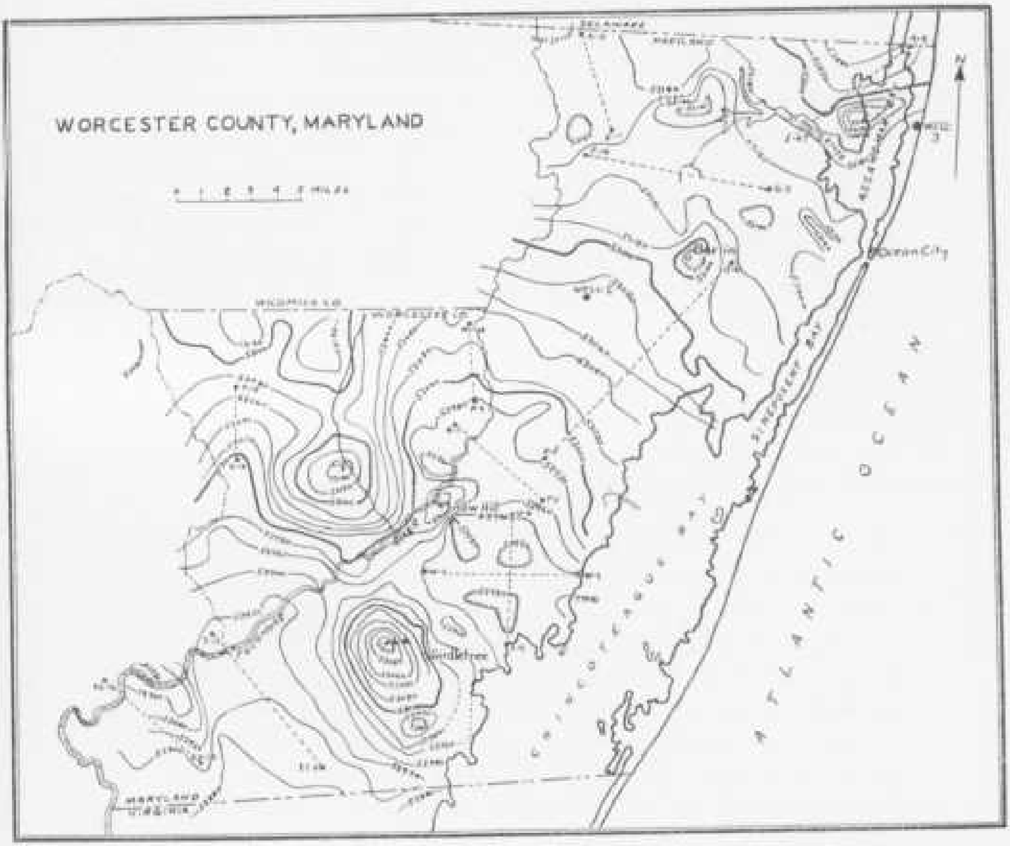

FIGURE 23. Reproduction of U. S. Bureau of Mines Ground Magnetometer Contour Map with Cheltenham Corrections

(Bethards) and 3 (Esso). This magnetic rise could hardly be due to a change in topography in the basement complex since the basement in Well 2 was encountered at 7140 feet and Well 3 at a total depth of 7710 feet was still in the unconsolidated sands and clays of the lower Cretaceous.

The magnetic "highs" may owe their origin to either changes in elevation of the basement or to changes in the mineralogic character of the rocks of the basement or possibly both. As pointed out by the authors of Map 46, basic intrusions, such as the one encountered in the bottom of the Bethards well (Well 2), or basic dikes in the Triassic and the basement, may produce such anomalies. It is hardly conceivable that the basement complex is a plane surface, hence these two pronounced anomalies may owe their origin to both a change in topography and a change in rock type. Seismic surveys would largely reveal the character of the surface of the basement in this area.

From the standpoint of potential oil structures, these two anomalies are important if they are topographic "highs" in the basement complex. Younger sediments would lap against their sides and be deposited over them. Compaction over their tops, caused by the weight of the overlying sediments, would produce stratigraphic traps on the flanks of the highs. These would be ideal traps for petroleum.

Aside from the traps produced by topographic expressions in the basement, are the stratigraphic traps which result from changes in sedimentation. In the Eastern Shore area, one of the most important types of stratigraphic trap is the overlap. Figures 20 and 21 show the effect of the overlapping in the Mesozoic and Tertiary sediments, resulting in a marked thinning from east to west. Formational unconformities and lensing sands would also be important petroleum structures. There is no concrete evidence to indicate that deformation has produced structures in the Mesozoic and Tertiary rocks of the area, therefore, traps caused by changes in sedimentation should be the most important structures for petroleum accumulation in this area.

CONCLUSIONS RESULTING FROM THE DRILLING OF THE THREE DEEP TESTS

The detailed section of the Hammond well together with the logs and samples from the other wells permit certain general conclusions to be drawn concerning the petroleum potentialities of the various sections. The presence of salt water and the lack of petroleum in the three widely separated wells might suggest that the area as a whole is not structurally suited for the accumulation of petroleum. On the other hand, there is a possibility that the wells were not located on suitable structures or too far down on potential structures. More detailed geophysical work would doubtless eliminate this possibility. Another important factor is the generation of petroleum. Do source beds capable of producing petroleum exist in the area? The examination of the characteristics of the various sections may answer these questions.

Potentialities of the Cretaceous Section

The Lower Cretaceous of the Hammond well has been shown to be primarily of continental origin. Coarse, arkosic, rather poorly sorted sands and subordinate mottled shales were deposited by streams flowing into the basin. As deposition continued, deltaic conditions developed, but no definite marine sediments were laid down. Fine-grained deposits capable of containing organic matter are largely lacking, which means that potential source beds are absent in the Lower Cretaceous of the Hammond and Bethards areas. The shales show the effects of oxidation, hence the environment in which they were laid down was not suited to the generation of protopetroleum. This does not entirely eliminate the possibility of petroleum accumulating in the area of these two wells. If marine source beds were present farther to the east, oil could migrate up dip in the abundant porous beds of the Lower Cretaceous and accumulate in suitable stratigraphic traps. Although there is a decided overlapping of the Lower Cretaceous beds from east to west, large continuous shale units seem to be lacking in all three sections. These would be necessary in order to seal the porous sands and prevent the escape of oil which would migrate into the traps.

If petroleum were forming during Lower Cretaceous times, then its formation would have had to have taken place at some distance east of the present coast line on the then existing continental shelf. Bottom conditions favorable to the accumulation of fine-grained sediments and an anaerobic environment suitable for the decomposition of organic matter would have been necessary. The absence of petroleum in the Lower Cretaceous of the three test wells and the lack of oil seepages in this part of the section along the fall line would suggest that the necessary conditions for petroleum generation were lacking during these times. Trask (103, p. 239) points out that the production of organic matter in a marine deposit depends largely on the upwelling of deep water bringing nutrients for the plankton. This upwelling occurs chiefly near the coast and is caused by off-shore winds. Trask states that, at present, the sediments along the Atlantic coast are poor in organic matter.

The lowermost Upper Cretaceous section of the Esso well indicates near-shore and at intervals, brackish-water conditions there. It is quite possible that the Esso well is located where off-delta conditions prevailed during the beginning of Upper Cretaceous time. If this be true, then the environment would not be a suitable one for the generation of petroleum.

Marine and shallow-water sediments appear for the first time as a tongue in the basal portion of the Raritan formation of the Hammond well. They are not thick and do not appear again until the upper part of the section is reached. Slightly deeper water conditions probably existed in the areas of the Bethards and Esso wells. Large sand bodies which could serve as reservoirs and thick shale units which are seals for the underlying sands are present in the Esso well. Passing westward, the sands and shales become thinner and interlaminated. The Upper Cretaceous sediments in the vicinity of the Hammond and Bethards wells do not seem to be suited to the formation of petroleum, but those of the Esso well suggest that, if bottom conditions were right, petroleum could have been generated. Although overlap in the Upper Cretaceous is not as pronounced as in the Lower Cretaceous, there is sufficient to form a stratigraphic trap. The presence of salt water in the sands of the Upper Cretaceous indicates that, if petroleum had been formed, either it has migrated away from this general area or that the wells were located off-structure. This latter explanation does not appear to be a satisfactory one, since there is no evidence to suggest the presence of structural traps. If petroleum were trapped due to the overlapping of the beds of the Upper Cretaceous then it would have to be present to the west of the Hammond area. Deep water wells on the east side of Chesapeake Bay have encountered both fresh and brackish water in the uppermost beds of the Upper Cretaceous. On the western shore of the Bay, the Upper Cretaceous contains fresh water sands. From a consideration of all the factors, it seems very unlikely that petroleum ever existed in the sands of the Upper Cretaceous.

Potentialities of the Eocene Section

The Eocene section of the Eastern Shore, as revealed by the samples from the three tests, is a marine section rich in micro-fossils. Shales are very abundant, but very fine sands which could serve as reservoir beds within the section are rare. The Eocene shows a marked thinning in a northwesterly direction (Fig. 21) and is nowhere buried very deeply. If petroleum can form from the remains of micro-fossils, then the shales of the Eocene must be considered as a potential source bed. No indications of oil were noted in any of the Eocene shales. If oil exists, it would have to be found to the east of the present coastline where a more complete section could be developed at greater depths.

Potentialities of the Miocene Section

The Miocene section is truncated and overlain by Pleistocene deposits. It thins rapidly westward and is present at very shallow depths even in the Esso well. Even though the beds were laid down in a shallow-water marine environment and sands are rather well developed, it is hardly likely that any beds from this shallow section would contain petroleum of a very good quality. The thickening of the section at the rate of about 8 feet per mile would be sufficient to provide stratigraphic traps; but, if petroleum is to be found, it probably would be located far to the east of the present shore line.

SUMMARY

The subsurface material obtained from the drilling of the three deep tests on the Eastern Shore of Maryland has given geological information on the Mesozoic and Tertiary sections far removed from the outcrop. Paleontologic studies have revealed new species not known from either the outcrop or the subsurface of the Gulf Coast. On the basis of paleontologic evidence, the formations in the upper part of the wells have been delineated. Petrographic

studies have revealed the presence of mineral zones which serve to correlate the completely cored Hammond section with those of the Bethards and Esso wells. The detailed statistical studies have yielded information which has led to the conclusion that the beds of the Hammond well were first deposited in a continental environment which changed gradually to deltaic, and finally to marine. Progressive overlapping of the beds toward the west is more pronounced in the Lower Cretaceous and less pronounced in the upper part of the well section. Evidence of brackish-water conditions is noted in the lower part of the Upper Cretaceous of the easternmost well. Intraformational unconformities as well as formational unconformities occur.

Geophysical data suggest the presence of topographic "highs" in the basement which could serve, through the compaction of the sediments over them, as traps for petroleum. Stratigraphic traps such as overlaps, lensing sands, and unconformities are present. Reservoir beds are well developed, but thick shales which would serve as seals are lacking in the Lower Cretaceous. Source beds are not in evidence in the Lower Cretaceous and only occasionally present in the Upper Cretaceous. The Cretaceous section of the Eastern Shore, although suited for the accumulation of petroleum, is not very favorable for the generation of petroleum. If any oil is to be found in Cretaceous sediments, it will probably have to be found to the east of the present coast line where suitable marine conditions would occur. The Eocene and Miocene sections although marine are considered to be of little value due to their shallow depth. No evidence of petroleum was found in any of the sands of the three wells. The results of the drilling has discouraged further search for oil in this region for the present.

PALEONTOLOGY

TERTIARY MOLLUSCA FROM DEPTHS OF 330 TO 990 FEET IN THE HAMMOND WELL

BY

JULIA A. GARDNER

Only coarse sand and gravel including a few fragments of carbonized wood are found in the samples from 10 feet to 330 feet.

The samples from 330 feet to 510 feet are referred to the St. Marys formation without reservation. *Uzita peralta* (Conrad) and *Bulliopsis quadrata* (Conrad) occur at several depths within the interval and are considered diagnostic; in Maryland, the genus *Bulliopsis* and the rare forms, *Terebra simplex* Conrad, *Terebra curvilirata* Conrad and *Acteon pusillus* Forbes are restricted in their known range to the St. Marys formation.

The two samples from 510 feet to 520 feet are confusing; the first, from 510 feet to 515 feet, includes among the half dozen organisms a young *Uzita* resembling the St. Marys species, *Uzita peralta*, although the possibility that it may be the young of the rare *U. peraltoides* of the Choptank and Calvert formations has not been eliminated. In the second sample, from 510 feet to 520 feet, no fragments suggesting diagnostic species of the St. Marys formation were observed and echinoid fragments make their first appearance. Possibly the contact between the St. Marys and the Choptank falls close to 515 feet; the first sample may then be from the St. Marys formation and the second sample, if taken from the lower part of the interval, may be of Choptank age.

The faunas from 520 feet to 540 feet are meager assemblages of fragments of echinoid tests and spines, *Pecten* sp., *Anomia* sp. and barnacle plates and seem to indicate a near-shore fauna. In the surface outcrops of the Chesapeake Group in Maryland, echinoid faunas have been recognized only in the basal Choptank. That horizon is apparently represented in the sample from 630 feet to 640 feet. The higher echinoid horizon is probably uppermost Choptank rather than basal St. Marys, for *Discinisca lugubris* (Conrad), a small brachiopod which is common only in the Choptank, was recovered from the samples from 540 feet to 560 feet, and an echinoid spine was noted in association with the brachiopod in the sample from 550 feet to 560 feet. No species peculiar to the Choptank have been recognized between this depth and the lower echinoid horizon at 630 feet to 640 feet, a zone which may well be the equivalent of the *Echinocardium orthonotum* (Conrad) zone in Calvert Cliffs and in the lower bed at Jones Wharf on the Patuxent River in St. Marys County.

Fragments of the diagnostic Calvert species, *Anadara subrostrata* (Conrad) probably appear for the first time in the sample from 640 feet to 650 feet. *Parvilucina prunus* Dall, another diagnostic Calvert species, is present in the, sample from 650 feet to 660 feet. A third zone marker, *Astarte cuneiformis* Conrad, was recovered from a depth of 660 feet to 670 feet. The most common and widely distributed species, *Chlamys* (*Lyropecten*) *madisonia* (Say), is common to the Calvert and the Choptank. It is recorded at various depths from 590 feet to 850 feet. The lowest samples examined, from 850 feet to 990 feet, include barnacle plates in extraordinary numbers, a possible indication of the shoaling of the waters. However, barnacles are common throughout the Chesapeake Group and are in all the samples from 540 feet down to 990 feet.

ST. MARYS FORMATION

Depth in Feet

330–340
- **Nucula sinaria* Dall (Pl. I, figs. 1, 4)
- "*Cardium*" sp.
- *Turritella plebeia* Say? R
- *Lunatia* sp. cf. *L. heros* (Say) R
- *Uzita peralta* (Conrad)
- *Uzita?* sp.
- *Bulliopsis?* sp. R
- Barnacle plates
- Vertebrate fragments

340–350
- *Nucula sinaria* Dall?
- Mactroids

350–360
- *Nucula* sp. cf. *N. sinaria* Dall
- *Nucula* sp.
- "*Cardium*" sp.
- *Mactra clathrodon* Lea R
- Mactroids
- *Venus* sp.
- *Barnea?* sp.
- *Turritella* sp. cf. *T. plebeia* Say R
- *Lunatia* sp. cf. *L. heros* (Say)
- *Uzita peralta* (Conrad)
- Barnacle plates

360–370
- *Nucula sinaria* Dall

Depth in Feet
- Mactroids
- Scaphopod
- *Lunatia* sp. cf. *L. heros* (Say)
- Barnacle plate

370–380
- *Nucula* sp. cf. *N. sinaria* Dall
- "*Arca*" sp.
- "*Pecten*" sp.
- **Mactra clathrodon* Lea R (Pl. I, figs. 2, 3)
- Mactroids
- *Turritella* sp.
- *Uzita* sp. cf. *U. peralta* (Conrad)

380–390
- *Nucula* sp. cf. *N. sinaria* Dall
- Mactroid
- *Turritella* sp. cf. *T. variabilis* Conrad
- *Sinum?* sp.

390–400
- *Nucula sinaria* Dall R
- *Nucula* sp. cf. *N. sinaria* Dall
- **Nuculana concentrica* (Say)? R (Pl. I, figs. 5, 10)
- Fragment of large "*Arca*" ribs R
- *Mactra clathrodon* Lea R
- Mactroids
- *Corbula* sp.

* Figured.

R Loaned through the kindness of Horace G. Richards.

ST. MARYS FORMATION—*Continued*

Depth in Feet

**Dentalium caduloide* Dall R (Pl. I, fig. 11)
Turritella sp. cf. *T. plebeia* Say R
Lunatia heros (Say) R
Naticoid
Uzita peralta (Conrad)
Barnacle plate

400–410
Nucula sinaria Dall R
Nucula sp. cf. *N. sinaria* Dall
Nuculana concentrica (Say)?
"*Arca*" sp.
Mactroids
Pholad
Scaphopod
Turritella sp. cf. *T. variabilis* Conrad
Lunatia? sp. cf. *L. heros* (Say)
Uzita sp. cf. *U. peralta* (Conrad)

410–420
Nucula sp. cf. *N. sinaria* Dall
"*Leda*"*?* sp.
Nuculana concentrica (Say)? R
"*Arca*" sp. cf. "*A.*" *idonea* Conrad R
Mactra clathrodon Lea R
Mactroid
Pholad
Dentalium attenuatum Say? R
**Bulliopsis quadrata* (Conrad) R (Pl. I, fig. 27)
**Cymatosyrinx limatula* (Conrad) R (Pl. I, fig. 13)

420–430
Nucula sinaria Dall? R
Nucula sp.
"*Cardium*" sp.
Mactra clathrodon Lea
Mactroid
**Turbonilla* (*Pyrgiscus*) sp. R (Pl. I, figs. 18, 19)
**Turritella* sp. cf. *T. variabilis* Conrad R (Pl. 1, fig. 22)
Turritella sp. cf. *T. variabilis* Conrad
**Uzita peralta* (Conrad) R (Pl. I, figs. 25, 26)
**Terebra simplex* Conrad R (Pl. I, fig. 16)

Depth in Feet

**Terebra curvilirata* Conrad R (Pl. I, figs. 23, 24)

430–440
Nucula sinaria Dall R
Nucula sp.
**Bulliopsis quadrata* (Conrad) R (Pl. I, fig. 17)
Terebra sp. cf. *T. curvilirata* Conrad R

440–450
Nucula sinaria Dall R
Nucula sp.
Nuculana concentrica (Say)? R
Mactra clathrodon Lea R
Dentalium caduloide Dall
Otolith

450–460
Nucula sp.
Nuculana concentrica (Say)
Corbula sp.
Naticoid
Barnacle plates
Otoliths

460–470
Nucula sp.
Nuculana sp. cf. "*N.*" *concentrica* (Say)
"*Arca*" sp.
Mactroid
Venus sp.
Scaphopod

470–480
Nucula sp. cf. *N. sinaria* Dall
Mactroid
Turritella sp.
Uzita sp. cf. *U. peralta* (Conrad)

480–490
Nucula sp.
Ostrea sp.
Mactroid
Dentalium? sp.
Naticoid

490–500
Nucula sp.

Depth in Feet

"*Cardium*" sp.
Barnacle plate

500–510
Nucula sinaria Dall
Nuculana concentrica (Say)?
Anadara sp. cf. *A. idonea* (Conrad) and *A. staminea* (Say)
Mactroids
Venus sp.
Scaphopods
Turritella sp. cf. *T. variabilis* Conrad
Uzita sp.
cf. *Bulliopsis* sp.
**Acteon* sp. cf. *A. pusillus* Forbes (Pl. I, figs. 20, 21)

ST. MARYS FORMATION?

Depth in Feet

510–515
Nucula sp.
Anadara sp. cf. *A. idonea* (Conrad) and *A. staminea* (Say)
Mactroids
Turritella sp.
Uzita sp.
Barnacle plates

CHOPTANK FORMATION?

Depth in Feet

510–520
Echinoid fragments
"*Pecten*" sp.
Mactroids
Dosinia sp.
Barnacle plates

520–530
Echinoid fragments
"*Pecten*" sp.
Barnacle plates
Echinoid fragments
"*Pecten*" sp.
Anomia sp.
Barnacle plates

CHOPTANK FORMATION

Depth in Feet

540–550
Discinisca lugubris (Conrad)
Mactroid
Barnacle plates

550–560
Echinoid spine
Discinisca lugubris (Conrad)
Barnacle plates

560–570
Barnacle plates

570–580
"*Pecten*" sp.
Anomia sp. cf. *A. aculeata* Gmelin
Barnacle plates

580–590
"*Pecten*" sp. cf. *Chlamys* (*Lyropecten*) sp.
Anomia sp. cf. *A. aculeata* Gmelin
Pedalion? sp.
Discinisca sp.
Barnacle plates

590–600
"*Pecten*" sp.
**Chlamys* (*Lyropecten*) sp. cf. *C.* (*L.*) *madisonia* (Say) (Pl. I, fig. 6)
**Chlamys* (*Lyropecten*) *madisonia* Say? juv. R (Pl. I, fig. 8)
**Anomia aculeata* Gmelin? R (Pl. I, figs. 9, 14)
Anomia sp. cf. *A. aculeata* Gmelin
Pedalion? sp.
Ecphora sp.
Barnacle plates

600–610
"*Pecten*" sp.
Anomia sp. cf. *A. aculeata* Gmelin
Ostrea sp. juv. R
Pedalion sp.
Barnacle plates

Depth in Feet

610–620

Chlamys (*Lyropecten*) sp. in part *C.* (*L.*) *madisonia* (Say)
Anomia aculeata Gmelin
Pedalion? sp.
Venus sp.
Barnacle plates
Crab finger

620–630

Chlamys (*Lyropecten*) sp. in part *C.* (*L.*) *madisonia* (Say)
Pedalion? sp.
Turritella sp. cf. *T. plebeia* Say
Barnacle plates

630–640

Echinoid fragments
Nuculanid
Chlamys (*Lyropecten*) sp. in part *C.* (*L.*) *madisonia* (Say)
Cadulus sp.
Turritella sp. cf. *T. plebeia* Say
Barnacle plates

CALVERT FORMATION

Depth in Feet

640–650

Anadara sp. cf. *A. subrostrata* (Conrad)
Chlamys (*Lyropecten*) sp. cf. *C.* (*L.*) *madisonia* (Say)
Pedalion? sp.
Venerids
Dentalium sp.
Turritella sp.
Barnacle plates

650–660

Nuculanid
Chlamys (*Lyropecten*) sp. cf. *C.* (*L.*) *madisonia* (Say)
Pedalion sp.
**Parvilucina prunus* Dall? (Pl. I, fig. 15)
Venerid
Cadulus sp.
Epitonium sp.
Barnacle plates

660–670

Anadara subrostrata (Conrad)?
Chlamys (*Lyropecten*) *madisonia* (Say)?
Astarte cuneiformis Conrad
Turritella plebeia Say
Barnacle plates
Crab finger

670–680

No fossils recorded

680–690

Chlamys (*Lyropecten*) *madisonia* (Say)
Barnacle plates
Otolith

690–700

Echinoid fragment
Chlamys (*Lyropecten*) *madisonia* (Say)?
Barnacle plates

700–710

Chlamys (*Lyropecten*) *madisonia* (Say)?
Pedalion? sp.
Venerids
Barnacle plates

710–720

**Chlamys* (*Lyropecten*) *madisonia* (Say)? (Pl. I, figs. 7, 12)
Pedalion? sp.
Crassatellites? sp.
Uzita? sp
Barnacle plates

720–730

Chlamys (*Lyropecten*) *madisonia* (Say)?
Venerid
Epitonium? sp.
Barnacle plates

730–740

Barnacle plates

740–750

Barnacle plates
Fragment of vertebrate jaw

Depth in Feet

750–760
Chlamys (*Lyropecten*) *madisonia* (Say)?
Barnacle plates

760–770
Chlamys (*Lyropecten*) *madisonia* (Say)?
Chlamys (*Lyropecten*)? sp.
Barnacle plates

770–780
"*Pecten*" sp.
Barnacle plates

780–790
Chlamys (*Lyropecten*) sp.
Barnacle plates

790–800
"*Pecten*" sp.

800–810
Nucula sp.
"*Pecten*" sp.
Anomia aculeata Gmelin?
Barnacle plates

810–820
Nucula sp.
Chlamys (*Lyropecten*) *madisonia* (Say)?
Chlamys (*Lyropecten*) sp.
Barnacle plates

820–830
Chlamys (*Lyropecten*) sp. cf. *C.* (*L.*) *madisonia* (Say)
Barnacle plates

830–840
Chlamys (*Lyropecten*) sp.
Astarte? sp.
Barnacle plates

840–850
Chlamys (*Lyropecten*) sp. cf. *C.* (*L.*) *madisonia* (Say)
Chione sp.
Barnacle plates

850–860
Chlamys (*Lyropecten*) sp.
Barnacle plates

860–870
"*Pecten*"? sp.
Naticoid
Barnacle plates

870–880
Barnacle plates
Fish tooth

880–890
Discinisca? sp.
Barnacle plates
Fish vertebra

890–900
Pedalion? sp.
Barnacle plates
Fish tooth

900–910
No molluscan remains

910–920
"*Pecten*"? sp.
Turritella sp.

920–980
No molluscan remains

980–990
"*Pecten*"? sp.
Nassoid
Barnacle plates

TERTIARY AND CRETACEOUS MOLLUSCA FROM DEPTHS OF 1040 TO 2257 FEET IN THE HAMMOND WELL

BY

LLOYD W. STEPHENSON

Depth 1040 feet; light-gray calcareous diatomaceous earth.
  Fragment of a flattish bivalve
    Age: Miocene (Calvert formation).
Depth 1077 feet; light-gray, slightly calcareous diatomaceous earth.
  Corbula elevata Conrad (identified by Julia A. Gardner)
    Age: Miocene (Calvert formation).
Depth 1108 feet; light-gray, slightly calcareous diatomaceous earth.
  Corbula elevata Conrad (identified by Julia A. Gardner)
    Age: Miocene (Calvert formation).
Depth 1220 feet; brownish-gray calcareous sandy clay.
  Lima sp. (probably undescribed)
  Dentalium sp. (small fragment)
  Otolith?
    Age: ?, probably Tertiary.
Depth 1245 feet; brownish-gray shaly, calcareous, finely micaceous clay.
  Lima sp.
  Foraminifera (numerous, well preserved)
    Age: ?, probably Tertiary.
Depth 1319 feet; very light greenish-gray chalk
  Rich microfauna (Ostracoda and Foraminifera)
    Age: ?
Depth 1320 feet; very light greenish-gray chalk with scattered grains of glauconite.
  Rich microfauna (Ostracoda and Foraminifera)
  Small fish scales and bones
  Small shark tooth
    Age: ?
Depth 1325 feet; very light greenish-gray chalk with abundant glauconite grains.
  Microfauna (Foraminifera and Ostracoda)
  Small fish scales and bones
    Age: ?
Depth 1362 feet; dark greenish-gray calcareous greensand; glauconite predominates.
  Molluscoidea:
    Choristothyris plicata (Say), (= *Terebratella plicata* (Say) = *Terebratula plicata* Say), (pl. 1, figs. 32–34)
  Mollusca:
    Exogyra costata Say (fragments)
    Pecten venustus Morton (pl. 1, fig. 28)
    Pecten (*Camptonectes*) sp. (juvenile)
      Age: Upper Cretaceous (Navesink marl = part of Monmouth formation or group of Maryland).

Depth 1380 feet; gray marl with a large percentage of dark-green glauconite; contains a few small dark-green phosphatic (?) pebbles.

Pecten sp. (probably new)
Spondylus sp. (fragment)
Paranomia scabra (Morton) (pl. 1, figs. 29, 30)
Age: Upper Cretaceous (Navesink marl = part of Monmouth formation or group of Maryland).

Depth 1382 feet; gray marl with a large percentage of dark-green glauconite; contains a few small dark-green phosphatic (?) pebbles.

Pecten sp. (incomplete, probably undescribed), (pl. 1, fig. 31)
Age: Upper Cretaceous.

Depth 1405 feet; light-gray, almost white chalk with scattered grains of glauconite.

Microfauna (Foraminifera and Ostracoda)
Inoceramus sp. (small fragments)
Small fish bones
Age: Upper Cretaceous.

Depth 1409 feet; light-gray chalk.

Microfauna (Foraminifera and Ostracoda)
Pecten sp. (small fragment)
Age: Upper Cretaceous.

Depth 1415 feet; light-gray chalk.

Microfauna (Foraminifera and Ostracoda)
Echinoid spine (small fragment)
Ostrea? sp.
Pecten sp. (cf. *P. simplicius* Conrad), (juvenile)
Fish scales and small bones
Age: Upper Cretaceous.

Depth 1466 feet; dark greensand with sandy marl matrix.

Exogyra ponderosa Roemer? (fragments)
Age: Upper Cretaceous (probably Matawan).

Depth 1471 feet; coarse glauconitic, calcareous sand with small pebbles.

Cliona? sp. (sponge borings in shell of *Exogyra*)
Exogyra ponderosa Roemer? (fragment of thick left valve)
Pecten sp. (fragment, probably undescribed)
Age: Upper Cretaceous (probably Matawan).

Depth 1476 feet; medium-dark greenish-gray, coarsely sandy, glauconitic, micaceous marl.

Exogyra ponderosa Roemer? (young shells and framgnets of large thick shells), (pl. 2, figs. 1–5)
Age: Upper Cretaceous (probably Matawan).

Depth 1483 feet; dark greenish-gray coarsely sandy, glauconitic marl.

Inoceramus sp. (fragments)
Ostrea sp. (fragments)
Pecten (*Neithea*) sp. (fragment)
Age: Upper Cretaceous.

Depth 1491 feet; fine medium-gray, strongly micaceous, calcareous, argillaceous sand.

Ostrea sp. (juvenile)
Exogyra sp. (juvenile)
Age: Upper Cretaceous.

Depth 1496 feet; medium-gray, fine, strongly micaceous, strongly calcareous sand.

Exogyra? sp. (fragments)

Veniella? sp. (badly corroded and crushed)
Unidentified bivalves
Age: Upper Cretaceous.

Depth 1500–1503 feet; light-gray, medium to coarse, poorly sorted, argillaceous, noncalcareous sand with interbedded thin layers of finely sandy clay.

Lignitized vegetable fragments including wood, probably *Cupressinoxylon* (identified by R. W. Brown); also one poorly preserved unidentified fruit
Age: Upper Cretaceous.

Depth 1588–1598 feet; medium-gray, finely sandy, shaly clay, noncalcareous except for shell content; shells numerous, soft, mostly small, poorly preserved.

Pelecypoda:
Breviarca? sp. (aff. *Trigonarca cliffwoodensis* Weller), (pl. 2, figs. 6–9)
Brachidontes cf. *B. filisculptus* (Cragin)
Brachidontes sp. (small)
"*Laternula*" sp.
Cuspidaria sp. (small)
"*Cyprina*" sp. (small fragment)
Fulpia wicomicoensis (Richards)? (pl. 2, figs. 10–14)
"*Corbula*" aff. *C. manleyi* Weller (pl. 2, figs. 16–20)
"*Corbula*" sp. (4 or 5 species)

Gastropoda:
"*Cerithium*" sp. *a* (small, incomplete), (pl. 2, fig. 21)
Natica? sp. (small)
A gastropod similar to an undescribed genus in the Lewisville member of the Woodbine formation of Texas
Several unidentified gastropods

Plantae:
Grain of amber 4 mm. long
Age: Upper Cretaceous (Raritan formation).

Depth 1598–1603 feet; medium-gray, finely sandy, shaly clay, noncalcareous except for shell content; shells numerous, mostly poorly preserved.

Pelecypoda:
Breviarca? sp. (aff. *Trigonarca cliffwoodensis* Weller), (pl. 2, figs. 6–9)
Ostrea sp. (small, fragmentary)
Brachidontes sp. (aff. an undescribed species in the Lewisville of Texas)
Fulpia wicomicoensis (Richards)? (pl. 2, figs. 10–14)
"*Corbula*" aff. *C. manleyi* Weller (pl. 2, figs. 16–20)
"*Corbula*" sp.
"*Corbula*" sp.

Gastropoda:
"*Cerithium*" sp. *a* (small, incomplete), (pl. 2, fig. 21)
A gastropod related to an undescribed species in the Lewisville of Texas
Age: Upper Cretaceous (Raritan formation).

Depth 2173 feet; medium-dark-gray, finely sandy, finely micaceous, noncalcareous shale and argillaceous sand.

Molluscoidea:
Lingula sp. (poorly preserved, mostly fragmentary)

Mollusca:
A small, smooth bivalve (fragment) with hinge missing; attached to it is a tiny fragment of *Brachidontes* sp.

Age: Upper Cretaceous (possibly Raritan formation).

Depth 2250–2257 feet; medium-dark-gray, finely micaceous, in part slightly calcareous shale with interbedded lighter gray finely micaceous sand.

Pelecypoda:

Barbatia? sp. (small, both valves present)

Breviarca? sp.

Ostrea sp. (thin fragments)

Brachidontes sp. (poor)

Fulpia sp. (pl. 2, fig. 15)

"*Corbula*" sp.

Unidentified bivalves

Gastropoda:

"*Cerithium*" sp. (similar to but more slender than the species in samples from 1588 to 1603 feet)

A small turreted, noded gastropod related to an undescribed genus in the Lewisville of Texas

Age: Upper Cretaceous (possibly Raritan formation).

NOTES ON CORRELATIONS

Samples at depths of 1040, 1070, and 1108 feet consist of light-gray diatomaceous earth. Two of these (depths 1070 and 1108 feet) each yielded a poorly preserved right valve of *Corbula elevata* Conrad, a common species in the Calvert formation (Miocene) of Maryland and not recorded outside of that formation.

No diagnostic macrofossils were recognized in the samples from depths between 1220 and 1325 feet. An abundant microfauna is present in several of these samples.

The only previously known occurrences of the brachiopod, *Choristothyris plicata* (Say), found in the sample from a depth of 1362 feet, are in the Navesink marl (Monmouth group of Upper Cretaceous) of New Jersey. The associated fossils, *Exogyra costata* Say and *Pecten venustus* Morton, though having a somewhat greater vertical range in the Upper Cretaceous, afford no evidence contradictory to the Navesink age of the sample.

The samples from depths of 1380 and 1382 feet are lithologically like the one from a depth of 1362 feet, and are believed to represent the Navesink marl. *Paranomia scabra* (Morton), from 1380 feet, is definitely an Upper Cretaceous species.

The samples of chalk from depths of 1405, 1409, and 1415 feet yielded no diagnostic macrofossils but contain an abundant microfauna. The position of this chalk below the Navesink marl suggests that it corresponds in age to the upper part of the Matawan group of New Jersey, Delaware, and Maryland (= age of Taylor marl of Texas). No chalk has been recognized in outcrop in the Upper Cretaceous of those States.

The dark greensands, marls, and sands composing the seven samples between depths of 1466 and 1503 feet yielded only a few poor and mostly fragmentary fossils having no value in close zonation of the beds. The position of these samples between the Navesink marl above and the Raritan formation below determines their Upper Cretaceous age, and *Exogyra ponderosa* Roemer, in samples at depths of 1466, 1471, and 1476 feet, if correctly identified, indicates the Matawan age of this part of the section.

The sandy, noncalcareous, shaly clay, composing the samples taken between depths of 1588 to 1603, contains an abundance of soft, poorly preserved, mostly small mollusks. In the sample from a depth of 1588–1598 feet *Breviarca* sp. (aff. *Trigonarca cliffwoodensis* Weller) and "*Corbula*" aff. *C. manleyi* Weller seem to relate this fauna to that of the Raritan formation of New Jersey. That the New Jersey species is incorrectly referred to *Trigonarca* is indicated by the central position of the beak and the weak development of the carina bordering its posterior adductor scar. The "*Corbula*" is closely related to Weller's species *manleyi*, but it appears to be more elongated and narrower in its posterior extension and should probably be treated as a variety or as a separate species. Several elements in this fauna suggest a relationship to undescribed genera and species in the Lewisville fauna of Texas, which I am now monographing. This is particularly true of the bivalve *Fulpia wicomicoensis* (Richards). *Brachidontes* cf. *B. filisculptus* (Cragin) is another of these elements. There is nothing in the fauna that suggests an age younger than the Raritan or the Lewisville.

The assemblage of fossils in the sample from a depth of 1598–1603 feet is very much like that in the preceding sample. The form *Breviarca* sp. is related to an undescribed species in the Lewisville member.

The small, frail gastropod in the two preceding samples, which I have referred to "*Cerithium*" sp., is present in considerable numbers, and is apparently characteristic of this faunal zone. It is believed to be an undescribed species.

The poorly preserved fauna contained in the sample from a depth of 2250–2257 feet is not adequate to permit a satisfactory correlation. However, several of its elements, including *Breviarca*, *Brachidontes*, and "*Cerithium*", suggest a faunal relationship with that in the samples correlated with the Raritan formation from depths of 1588 to 1603. The two faunas are separated by nearly 650 feet of sediments, an apparently excessive thickness for the Raritan formation. The recorded maximum estimated thickness of the formation in the belt of outcrop is 300 feet. If not Raritan it probably is a shallow marine or brackish-water facies of one of the formations of the Potomac group (Lower Cretaceous).

CRETACEOUS MOLLUSCA FROM DEPTHS OF 1894 TO 1896 FEET IN THE BETHARDS WELL

BY

LLOYD W. STEPHENSON

Mollusca (Pelecypoda):
- *Breviarca* sp. (probably new)
- *Ostrea* sp. (small)
- *Anomia* sp. (fragments)
- *Brachidontes* aff. *B. filisculptus* (Cragin)
- *Fulpia wicomicoensis* (Richards)?
- "*Corbula*" aff. *C. manleyi* Weller
- "*Corbula*" (numerous, 6 or more species, probably some of them new)
- *Parmicorbula* sp.

Mollusca (Scaphopoda):
- *Dentalium*? sp. (fragments of a small smooth tube)

Mollusca (Gastropoda):
- "*Cerithium*" sp. *a*
- " sp. *b*
- " sp. *c*

Arthropoda:
- A small, smooth species

NOTES

The fossiliferous core consists of more or less finely arenaceous gray shale. The shells are small and are present in great numbers. On a freshly split surface of the core many of the shells appear well preserved, but actually they are very soft and fragile, some are partly crushed, and most of them have incipient cracks, so that when the matrix is soaked and decanted only a few of them remain whole. By soaking with diluted glue the shells exposed on a broken surface, allowing them to dry and harden, and picking them out with a needle, a goodly number were obtained in a fairly good state of preservation.

The shells referred to *Brachidontes* appear to be related to *B. filisculptus* (Cragin), from the Lewisville member of the Woodbine formation of Texas. They may be the same as Richards' *Mytilus salisburyensis*, the published description of which is inadequate to permit certain identification (see Richards, Bull. Am. Assoc. Petroleum Geologists, vol. 29, no. 8, p. 1202, 1945).

Fulpia wicomicoensis (Richards) (*idem*, p. 1202) is closely related to *F. pinguis* Stephenson. (See Jour. Paleontology, vol. 20, no. 1, pp. 68–71, 1946.)

One of the species of the family Corbulidae here identified as "*Corbula*" aff. "*C*". *manleyi* Weller is closely related to Weller's species from the Raritan formation of New Jersey.

Richards' species *Corbula whitei* (*idem*, p. 1202) may be represented among the several species of shells that I have listed as "*Corbula*", but I have not been able to identify it.

The three species listed as "*Cerithium*" sp. *a*, sp. *b*, and sp. *c* appear to belong to an as yet undescribed genus in the family Cerithiidae, common in the lower part of the Lewisville member of the Woodbine formation of Texas.

The faunal evidence seems to indicate that this core corresponds in age to the Raritan formation of New Jersey and to the Lewisville member of Woodbine formation of Texas. In terms of European time units this would mean late Cenomanian.

The horizon represented by this core appears to be the same as that penetrated in the Hammond well at a depth of 1588 to 1603 feet. Several of the species listed are common to the two wells.

CRETACEOUS MOLLUSCA FROM DEPTHS OF 4875 TO 4885 FEET IN THE MARYLAND ESSO WELL

BY

HAROLD E. VOKES

INTRODUCTION

This fauna was obtained from a core taken between the depths of 4,875 feet and 4,885 feet in the Maryland Esso No. 1 well of the Standard Oil Company of New Jersey. Seven feet of core were recovered from this interval. The uppermost three feet consisted of dark gray, micaceous siltstone crowded with fossils. The remaining portion consisted of three feet of green shale and one foot of green,fine sandstone.

Dr. Lloyd W. Stephenson of the United States Geological Survey made a preliminary examination of the fossils and reported:

> "The fauna is a rather new and strange one to me. I have not been able to match it with any of the known faunal assemblages from either the Upper or the Lower Cretaceous series of the Atlantic and Gulf Coastal Plain. Several of the species are to be referred to known genera, whereas others probably belong to undescribed genera. Apparently all of the species in the assemblage are undescribed. Two of the species of gastropods appear to be related to two as yet undescribed genera and species in the Woodbine formation (early Upper Cretaceous) of Texas, but I am not prepared to say that this relationship indicates equivalence in age. . . . I am inclined to the opinion that this zone is of Cretaceous age, and not younger than early Upper Cretaceous."

The press of other commitments prevented Dr. Stephenson from undertaking the detailed study of this fauna, and at his suggestion, the following discussion and description of this unusual assemblage has been prepared.

COMPOSITION OF THE FAUNA

The fauna is predominantly a molluscan assemblage. Pelecypoda dominate in number of species and genera, but are outnumbered by the gastropoda in specimens present. A few poorly preserved fragments of Pteropods occur, but all are too incomplete to permit more than a suggestion as to possible generic position. Arthropoda are represented by a single fragment of a small decapod cheliped; and the vertebrate record consists only of rare teleost scales, a small fin spine, and a fragmentary bit of bone that is possibly an element of the jaw.

The following molluscan forms have been recognized:

Pelecypoda:
- *Barbatia assawomanensis* new species
- Arcidae species indeterminate (2 species)
- *Ostrea* species indeterminate
- *Anomia urbismarina* new species
- *Inoceramus* (?) species indeterminate
- *Brachidontes stephensoni* new species
- *Nemocardium marinum* new species
- *Eomiodon maretesta*, new species
- "*Corbula*" *tethys* Stephenson
- *Parmicorbula* species
- *Ursirivus oceanus* new species
- *Ursirivus atlanticus* new species
- Corbulidae indet. (3 species ?)
- Pelecypoda indeterminate (a tellinid and a lucinid ? form)

Gastropoda:
- *Euspira parvissima* new species
- *Anteglosia essoensis* new genus, new species
- *Plesiopotamides marinus* new genus, new species
- *Cassiope marylandensis* new species
- *Metacerithium oceanum* new species
- Gastropoda genus and species indeterminate

Plesiopotamides marinus is the most abundant form, and there are probably more relatively complete, though crushed specimens of this form than of all the other species. *Anteglosia essoensis* is second only to *P. marinum*, but the form is so small and inconspicuous as to be easily overlooked. *Cassiope marylandensis* and the two species of *Ursirivus* are also quite abundantly represented, but the specimens of *Cassiope* are for the most part immature or juvenile forms with only one fragment of what is, apparently, a fully adult individual. The species of *Ursirivus*, on the other hand, are relatively large and have suffered much from crushing, as well as, apparently, from breakage due to wave action before final entombment. The species of *Barbatia*, *Ostrea*, *Anomia*, and *Euspira* are each represented by a number of examples, and

Eomiodon maretesta is abundant on one bedding plane only. The other forms are rare, and each is represented by only two or three specimens.

ECOLOGIC OBSERVATIONS

The dominance of the cerithiaceid genera *Plesiopotamides* and *Anteglosia*, and the presence of the genus *Cassiope*, among the gastropoda, and of the two species of *Ursirivus* among the pelecypoda seems clearly to indicate an essentially brackish water environment for the fauna. *Ursirivus* is otherwise known, in literature, only from the Bear River formation of the western interior Cretaceous, where the associated fauna suggests an exceedingly low saline content (121), and from the Dunvegan formation of the Cretaceous of Alberta, Canada (70, pl. 18). The genus is also represented in the fauna of the Lewisville member of the Woodbine formation, basal upper Cretaceous of Texas, where it occurs in an assemblage of brackish water types.

The most notable feature of the species representative of previously described genera is their small size. The fauna definitely shows the effects of some dwarfing influence. With respect to those types that are usually developed in waters of normal salinity, the species of the Arcidae, *Anomia*, *Inoceramus*, *Nemocardium*, *Astarte* and *Euspira* may possibly reflect the reduced salinity of the environment. With respect to the species of *Ursirivus* and *Ostrea* the picture is not so clear. The Bear River form of *Ursirivus* attains a shell size that is at least twice that of any specimen in the present collection, and the shell is always proportionately much thicker and heavier. It may be that the smaller size of the present forms reflects a greater salinity than that of the Bear River environment, a feature also attested to by the associated species in the Bear River assemblage. But the dwarfing of the ostreids does not readily admit of explanation. The brackish condition of the water would seem to be essentially the optimum condition required by this genus, and the explanation for their small size must be sought elsewhere. It may lie in the fineness of the matrix, a silty substratum lacking large shelled forms or other solid material to which the shell could be attached may have resulted in the animals being readily covered with mud and killed off before they could attain a large size. The absence of most types that normally are burrowing species may also be explainable on this basis.

The dark gray color of the matrix attests to the presence of considerable organic material, and there is a very minor amount of an iron sulphide mineral, probably marcasite, that suggests the presence of some H_2S in the bottom muds. However, it does not appear probable that there was sufficient amount to be a factor in the dwarfing of the fauna; and the abundant evidence afforded by the broken shells suggests that wave action was sufficiently strong to have kept the bottom free of any accumulations of foul water such as might otherwise affect the general ecology of the fauna.

The general absence of a trace of fresh water types, together with the presence of dwarfed examples of normal marine forms, leads to the very tentative suggestion that this part of the section may have been deposited in an on-shore lagoon facies, somewhat similar to that existing along the present Maryland coast, with a bar, or other obstruction, that prevented the normal mixing of marine and fresh waters. Small streams entering this lagoon, in regions somewhat away from the site of the Ocean City well, would lessen the salinity of the waters in the lagoon, but would not add to this fauna the remains of animals that may have lived within their waters.

AGE OF THE FAUNA

The position of the fossiliferous core in the well section indicates that it occurs well down in the Cretaceous section. In the cores from the Hammond well, Stephenson identified fossils that indicate that the beds encountered between 1588 and 2313 feet are of Raritan age. No faunas were found below this depth; but, on the basis of lithologic characteristics and of the heavy mineral content of the core and outcrop sections, the section between 2313 and 4424 feet is assigned to the "Patapsco-Arundel" formation. The lack of cores from the Ocean City well has prevented precise paleontological correlations based on megafossils, and caving of the upper levels so contaminated the microfaunas as to make their use difficult. On the basis of the information that could be obtained from this source, however, together with the study of the sediments, the section between the depths of 3330 and 5400 feet is correlated with that which was assigned to the Patapsco-Arundel in the Hammond well. The only core taken in this interval in the Ocean City well was that between 4875 and 4885 feet which contained the fauna here described.

A noteworthy feature of the section in all of the wells is the absence of strata that can be considered as representing the lithologic equivalent of the Arundel formation. This formation was described from the outcrop area as consisting of "drab, more or less lignitic clays, carrying nodules, geodes, flakes, and ledges of earthy iron carbonate or siderite" (14, p. 64). These clays rest unconformably upon the Patuxent formation, "occupying what appear to be old drainage lines therein, but extending beyond these to the seaward where they spread into a more or less continuous sheet" (14, p. 66). The strata were also considered as being overlain unconformably by the Patapsco formation, with the contact being marked by a band of pebbles or a bed of broken and redeposited ironstone crusts.

The sedimentation studies by Dr. Anderson have indicated that the top of the Patuxent section in the wells is marked by a zone containing a great abundance of staurolite fragments. This zone is also found in, and is confined to, the Patuxent formation in the outcrop sections. In none of the well sections is this zone immediately overlain by clays or shales of the Arundel type. When they occur, they are all found higher in the section, but in no two of the wells are they found at the same stratigraphic horizon.

This is not a surprising development considering the fact that the Arundel of the outcrop section is clearly a deposit formed within a swamp area. Similar swamp deposits may well be expected to occur at other horizons in a sequence of deposits being formed upon a low-lying coastal plain area. Furthermore, any one of the deposits will be of essentially local extent, and would not occur in sections as far apart as the three wells in question and the area of outcrop of the Cretaceous formations.

Nevertheless, since the present fauna occurs low in the section that is assigned in this report to the "Patapsco-Arundel" formation, the possibility of its being an age equivalent to the Arundel must be considered. It is quite possible that the presence of the Arundel swamps on the landward side of the area in which the wells are located, resulted in the trapping of the sediments in the Arundel basin and that no deposits of that age occur within the well cores. If that be the case the problem of the age of the Arundel is a purely academic one so far as this study is concerned. If, on the other hand, the lower part of the well sections contains strata that are the age equivalents of the Arundel formation, it is most probable that this Esso well core section occurs in the Arundel formation.

The outcrop sections of the Arundel have yielded a considerable number of species of fossil plants and a few fragmentary reptilian remains including Crocodilia, Dinosauria and Testudinata. Berry (14) found 33 species of fossil plants in the Arundel flora, all but 5 of which also occurred within the larger Patuxent flora which included approximately 100 species. In addition, the Patuxent and Arundel floras contain 14 species that are absent from the Patapsco flora, which, according to Berry, numbers 82 species. Only two forms occur in the Arundel and Patapsco floras that are not also present in the Patuxent. Furthermore, the appearance of 42 new species in the Patapsco flora, including 25 angiosperms, a type not certainly known from the older floras, led Berry to conclude that "it is perfectly apparent that the Arundel flora is closely allied to the flora which preceded it, and the interval separating the two floras, if there was such an interval, was one of short duration" (14, p. 155). Concerning the relations with the Patapsco flora, Berry states (14, p. 156), "The Patapsco flora, on the other hand, is decidedly different from the flora of the underlying Arundel formation, and this difference is not so much an extinction of earlier forms, although the extinction may have been considerable, as it is an introduction of higher forms of a decidely Neocretaceous facies."

Concerning the age of these floras, Berry states (14, pp. 160, 161):

"Sixteen Patuxent species, some of which are doubtful determinations, are present in the European Wealden floras, while three additional species are recorded from floras which are classed as Neocomian. There are, in addition, 12 species which are very similar to foreign

Wealden and Neocomian types. . . . There are 13 species present in the foreign Barremian, and 11 additional species which are closely allied to Barremian types. . . . When these facts are considered along with these furnished by the Arundel reptilia, and when the Patuxent-Arundel floras are studied in comparison with those from other American Lower Cretaceous localities, the conclusion is reached that the Patuxent and Arundel formations considered as a unit represent all except possibly the earliest part of the Neocomian and all of the Barremian of the standard European section.

"Turning to the Patapsco flora it may be noted that none of the species which are peculiar to this flora, when compared with the underlying Patuxent-Arundel floras, occur in the European Cretaceous except *Cissites parvifolius*, which is found in the Albian of Portugal. A considerable number, however . . . are represented by closely allied species in the Albian of Portugal. Moreover, the latter flora closely parallels the Patapsco, in that both mark the first abundant appearance of undoubted dicotyledons and a persistence of a considerable number of earlier Cretaceous types, which survive in both the Patapsco flora and that of the Albian of Portugal.

"On the basis of the close similarity between these two floras on opposite sides of the Atlantic . . . and the further fact that the Patapsco formation is overlain unconformably by the Raritan formation carrying an abundant and unmistakably Cenomanian flora, the Patapsco formation is considered of Albian age. The unconformity which separates the Patapsco formation from the underlying Potomac beds is believed to represent all or nearly all of the time interval represented by the Aptian stage of European geology."

There can be no doubt but that Berry's age determinations of his flora were to some extent influenced by the results of Lull's study of the reptilian remains that were recovered from the Arundel clays (14, p. 173–178). Lull, largely on the basis of the presence of fragmentary remains of Sauropod dinosaurs, correlated this fauna with that of the Morrison formation of the western American section. At that time, higher Cretaceous sauropods were unknown, and the correlation seemed quite obvious. Gilmore later (35, p. 581) restudied the Maryland faunas and reached the following conclusions:

"The evidence apears to show—first, that the vertebrate fauna as a whole is not to be closely correlated with that of the Morrison formation of the West; second, that it contains forms having undoubted Upper Cretaceous affinities; third, that it consists of a combination of dinosaurian forms hitherto unknown in any fauna of this continent—that is, the intermingling of Sauropodous dinosaurs with those having Upper Cretaceous affinities."

Gilmore was much influenced in his conclusions by the presence in the fauna of a number of Theropod types that were all of Upper Cretaceous affinities.

"On the other hand (we have) the presence of an Ornithomimid dinosaur pertaining to the family Ornithomimidae, which has never before been known below the Upper Cretaceous (Belly River); an armored dinosaur, *Priconodon crassus*, which Lull, correctly, recognizes as having its closest affinities with *Palaeoscincus* of the Upper Cretaceous; a carnivorous dinosaur having a caudal vertebra most nearly resembling the Upper Cretaceous *Dryptosaurus* from New Jersey; and the smaller Theropod *Coelurus ? gracilis* based on a claw of the fore foot, that except for its much smaller size has its exact counterparts in the collections from the Belly River formation." (35, pp. 591–592).

The more recent discovery of Upper Cretaceous Sauropods in the North Horn formation of the Wasatch Mountains of Utah, and in the region of the Big Bend National Park of Texas, would seem to confirm Gilmore's emphasis upon the significance of the Theropod types, and to justify his final conclusions that "Imperfect as it is, the weight of the vertebrate evidence would appear to favor a higher position in the geological scale than has been attributed to this fauna in the past" (35, p. 592).

If the deposits in which this molluscan fauna occurs are equivalent to those of the Arundel formation of the outcrop areas, the evidence of the present molluscan fauna serves to confirm the age identification suggested by the reptilian fauna. The affinities seem clearly to lie with the fauna of the Woodbine sand of Texas of which the former Lewisville formation is considered a member. The genus *Ursirivus*, represented in this fauna by two species, also occurs in the Lewisville member of the Woodbine formation of Texas and in the Bear River and Dunvegan formations of the western interior Cretaceous. All three of these formations are considered to be of lowermost Upper Cretaceous age in the American sense equivalent to the basal part of the Gulf Series, a horizon somewhat higher than the base of the Cenomanian, the bottom of the Upper Cretaceous in the European standard. If the identification of a minute, rather poorly preserved corbulid as *"Corbula" tethys* Stephenson, a species dredged from Banquereau, Nova Scotia, in a faunal assemblage correlated by Stephenson (93, pp. 385–386) with the Woodbine sand, is correct, this is additional evidence favoring the correlation of this fauna. It should be noted, furthermore, that Stephenson, in his preliminary report on this fauna noted that "two of the species of gastropods appear to be related to two as yet undescribed genera and species in the Woodbine formation of Texas."

Five species, therefore, out of a total of thirteen that are specifically identifiable, suggest an early Upper Cretaceous age for the fauna. There are no forms that are known only from Lower Cretaceous horizons, and none that are particularly comparable with Lower Cretaceous forms.

The extent to which this apparent correlation is influenced by the lack of knowledge of faunas of a similar facies in the Lower Cretaceous is difficult to determine at this time, but a much older age assignment seems a doubtful possibility; and the fauna, if not strictly contemporaneous with the Woodbine sand, is probably still to be assigned to some horizon within the Lower Cenomanian. This latter assignment gains added probability on the basis of the fact that the Raritan formation, which unconformably overlies the Potomac series is usually correlated with the Woodbine on, however, rather meagre faunal evidence.

It should be noted, however, that the typical Raritan, as developed in the State of New Jersey, varies in outcrop thickness up to 500 feet, whereas the strata in Maryland that are referred to this formation have an outcrop thickness not exceeding 100 feet, and usually are considerably thinner.

Berry was clearly much influenced in his assignment of the Patapsco flora to the Albian, by the fact that the Raritan of New Jersey contained a Cenomanian flora, and that the Raritan of Maryland unconformably overlies the Patapsco. Neither fact would seem to require that the Patapsco be no higher than Albian in age. It is widely recognized that the unconformity between the Comanche and Gulf Series of the American Cretaceous section occurs within the time interval of the European Cenomanian. Therefore the Patapsco formation might well lie below this unconformity and still have a Lower Cenomanian age.

Another possibility that cannot be overlooked is that the Raritan of Maryland is equivalent only to the higher Raritan of the New Jersey section, that the unconformity separating the Patapsco and the Maryland Raritan is not co-equal with that separating the Comanche and Gulf Series, but is somewhat younger, and that the Patapsco is, at least in part, equivalent to the basal portion of the Raritan formation of New Jersey. There is no method by which this can be checked at the present time, but if so, the Arundel formation might well also be of Cenomanian age.

SYSTEMATIC PALEONTOLOGY

Pelecypoda

Family ARCIDAE

Genus BARBATIA Gray, 1842

Barbatia Gray, 1842, Synopsis Contents British Museum, 44th ed., p. 81.
Genotype, by subsequent designation, Gray, 1847, *Arca barbata* Linnaeus. Recent, Mediterranean Sea.

There seems little doubt but that many, if not most of the Cretaceous species that have been referred to *Barbatia* should be considered at least subgenerically distinct from the typical form of that genus. All that they have in common is a relatively straight hinge line, umbones that are relatively closely approximate for an arcid genus, and an ornamentation consisting of fine radial ribbing. This form, for example, judging from the single, very imperfect hinge that was recovered, has heavier and longer teeth than are typical, and if the material was adequate for a careful study, would seem to be clearly not a representative of *Barbatia* in the strict sense. Since, however, the mateial is imperfect, and the ligamental area cannot be observed, it is referred to this genus.

Barbatia, sensu lato

BARBATIA ASSAWOMANENSIS, new species

(Plate III, figs. 9–11)

Holotype, U.S.N.M. 104416a; length 8.4 mm.; height 4.0 mm.; diameter (right valve) ca. 1.8 mm.
Paratype, U.S.N.M. 104416b; length 14.8 mm.; height 7.7 mm.; diameter (left valve, crushed) ca. 2.5 mm.
Paratype, U.S.N.M. 104423; incomplete mold showing hinge.

The core samples show numerous fragments, and a few relatively complete examples, of a small arcid species characterized by a relatively straight hinge line crossed by numerous teeth. These are markedly oblique at the extremities of the hinge area and transversely cross the hinge beneath the umbones.

Externally the valves are markedly inequilateral with broad, relatively inflated umbones situated approximately at the anterior third of the length. The dorsal margin is straight, and the ventral nearly so, but with a very shallow inconspicuous median concavity that is reflected in a flattening of the top of the umbones. The posterior margin is relatively straight and is angulate dorsally. The posterior ventral margin is rounded, reflecting the very low, and feebly developed posterior umbonal ridge. The anterior margin is broad and regularly rounded. The surfaces of the valves are almost smooth. Microscopic examination reveals the presence of fine radial riblets on the anterior and posterior slopes; the median area being almost unornamented.

The ligamental area has not been observed in sufficient detail to permit its description, although some evidence suggests the presence of typical *Barbatia*-type of ligamental grooves. The muscle scars and interior of the valves are unknown.

The weak development of the surface ornamentation is the most distinguishing feature of this species, the relatively unornamented median surface of the valve being a character that apparently has not been described on any other American Cretaceous species of this type.

ARCID species indeterminate

(Plate III, fig. 8)

Figured Specimen, U.S.N.M. 104419; length 1.2 mm.; height 0.8 mm.

Two minute specimens of an arcid species are right valves of a small form with markedly anterior umbones and a sharp posterior umbonal ridge. A fairly strong concentric ribbing is present over the entire surface, but is particularly well marked along the area of the shell posterior and dorsal to the umbonal ridge. In general shape they agree fairly well with that of *Barbatia assawomanensis*, except that the umbones are more anterior, and are narrower and relatively higher than in that species. It may be that they represent extremely immature specimens of that form. Lacking intermediate types it has seemed best not to make any definite specific assignment at this time.

In addition to these forms, there is another very minute specimen that was tentatively considered by Stephenson in his preliminary examination as possibly representing a minute example of *Breviarca*. The shape is entirely different from that of the above species, with nearly central, highly inflated umbones and an almost smooth shell surface. The specimen is too obviously immature to merit description.

Family ANOMIIDAE

Genus ANOMIA Linnaeus, 1758

Anomia Linnaeus, 1758, Systema naturae . . ., ed. 10, pp. 700–703.
Genotype, by subsequent designation, Schmidt, 1818, *Anomia ephippium* Linnaeus. Recent, Mediterranean Sea?

ANOMIA URBISMARINA, new species

(Plate III, figs. 24, 25)

Holotype, U.S.N.M. 104413; left valve, length 9.9 mm.; height 8.7 mm.; diameter 2.0 mm.
Paratype, U.S.N.M. 104415; left valve, length 4.9 mm.; height 4.4 mm.; diameter 1.1 mm.

A relatively small, transversely ovate species of *Anomia* is represented by approximately a dozen specimens that are, apparently, all left valves. All are more or less crushed; in addition to these, there are numerous shell fragments. In the less distorted left valves, the shell appears to be relatively thin, approximately equilateral, and to vary in ventricosity from almost flat to strongly convex. The umbone is small, relatively compressed, and generally submarginal. The surface of the smaller specimens is finely sculptured by numerous minute, round-topped, low, beaded, radial ribs that are separated by round-bottomed, shallow interspaces that are usually approximately as wide as the ribs. In the larger, and presumably adult specimens, this radial ornamentation has become so fine as to be very difficultly observable.

No adequately preserved left interiors were found. Enough can be seen to indicate that the byssal, adductor, and retractor muscle scars are so closely approximate, each to each, as to seem to be merged into one. They are, however, but feebly impressed. This small species seems probably to be related to the ubiquitous Upper Cretaceous species *Anomia argentaria* Morton (76, p. 293, pl. 5, fig. 10). It shows a similar high convexity of the right valve, although in both forms the degree of this convexity may vary within wide limits, and both are characterized by the general silvery luster of the shell. The two may be separated by the more marginal umbones of *A. argentaria*, the lack of raised concentric lamellae in the present species, and by the fact that the radial ornamentation consists of raised riblets in *A. urbismarina* rather than striations as in *A. argentaria*.

A. perlineata Wade (113, p. 69, pl. XXIII, figs. 1, 2) from the Ripley formation, has a similar type of radial ornamentation on the outer parts of the shell, but differs in that the earlier portion is smooth.

The most nearly comparable European species seems to be *A. pseudoradiata* d'Orbigny (78, vol. 2, p. 84) (126, p. 27, pl. V, figs. 1a-c, 2, 3). This form also has radial ribbing over the entire surface, but the ribbing is clearly of two orders of strength, with secondary riblets between the stronger primary ones. Furthermore, the shell is higher than long, and also shows a greater tendency toward irregularities in outline. Judging from the published illustrations it does not attain as great a degree of convexity of the right valve as is found in this species

Family MYTILIDAE

Genus BRACHIDONTES Swainson, 1840

Brachidontes Swainson, 1840, Treatise on Malacology, p. 384.
Genotype by monotypy, *Brachidontes sulcata* Swainson [? = *Brachidontes modiolus* (Linnaeus) *fide* Hanley, 1855]. Recent, Indian Ocean.

BRACHIDONTES STEPHENSONI, new species

(Plate III, figs. 17–19)

Holotype, U.S.N.M. 104403; left valve, length 5.3 mm.; height 3.2 mm.; diameter 0.8 mm.
Paratype, U.S.N.M. 104396; right valve, length 5.3 mm.; height (incomplete) 26 mm.; diameter 0.8 mm.

This small species is represented by an internal mold of a right valve together with fragments of the original shell of this valve; an external mold of a left valve; and three additional shell fragments from other specimens. All show a small form characterized by a distinctive sculpture pattern consisting of eighteen prominent, sub-rounded, almost flat-topped, broad, radial ribs separated by slightly narrower interspaces. These ribs are confined to the posterior area of the valve between the posterior ventral umbonal ridge and the posterior dorsal margin. Anterior to this area the surface of the valve is marked by strong, rounded, semi-concentric corrugations separated by round-bottomed interspaces of approximately equal width. Superficially, this anterior ornamentation appears to be wholly concentric, but actually their number increases toward the medial part of the valve. This increase is both by intercalation and by bifurcation, with the ribs in bifurcation trending, for a short part of their length, at an angle to the true concentric.

The posterior ribbing also tends to increase by both bifurcation and intercalation. This increase takes place toward the posterior end of the ribbed area, with the result that at the extreme posterior margin of the holotype there are approximately 30 radial ribs rather than the primary 18. Bifurcation is of much more common occurrence than intercalation, the latter occurring only three times on the holotype.

The valve is subrectangular and typically volsellid in outline, with the greatest length about two and one-half times the extreme width. The latter is found just in advance of the posterior extremity. The dorsal margin is straight, the anterior sharply rounded ventrally and more broadly rounded dorsally. The ventral margin is slightly sigmoidal, being gently convex anteriorly, but having a shallow and inconspicuous medial concavity that extends to the regularly rounded posterior ventral margin. The dorsal half of the posterior margin is almost straight, and is sharply angulate at the dorsal margin.

The valves appear to have been less strongly inflated than in most species of the genus, and the umbos, as a consequence are broad and low. They are typically anterior in position.

This species is particularly marked by the development of semi-concentric ribbing on the anterior portion of the valve. Radial ribbing is characteristically present in this genus, but it usually tends to be reduced in strength, and gradually die out toward the anterior end, leaving the latter area smooth and devoid of ornamentation. Rarely is it confined to the posterior area, as in these specimens. Apparently no other form has it so confined, and at the same time of equal strength, and sharply delimited from the rest of the surface area of the shell. This, together with the semi-concentric ribbing, will serve to distinguish this species from all other described Cretaceous representatives of the genus.

Family INOCERAMIDAE

Genus INOCERAMUS Parkinson, 1819.

Inoceramus Parkinson, 1819, Trans. Geol. Society, vol. 5, pp. 55, 59, pl. 1, fig. 3.
Genotype, by subsequent designation, Stoliczka, 1871, *Inoceramus "cuvierianus"* Sowerby (*I. cuvieri* Sowerby in Parkinson). Cretaceous (Turonian-Senonian), England.

INOCERAMUS (?) species indeterminate

(Plate III, fig. 12)

Figured Specimen, U.S.N.M. 104425; height 6.7 mm.; width 7.7 mm.

Two small crushed specimens are suggestive of the genus *Inoceramus*. Both are very small, almost circular, and marked by an ornamentation of even concentric waves. The shell material was apparently very thin, and the ornamentation seems as strongly apparent on what is apparently an internal mold as it is on an external one. If these forms are correctly referable to *Inoceramus*, they would seem to represent very young individuals.

Family OSTREIDAE

Genus OSTREA Linnaeus, 1758

Ostrea Linnaeus, 1758, Systema Naturae . . ., ed. 10, p. 696.
Genotype, by subsequent designation, Children, 1823, *Ostrea edulis* Linnaeus. Recent, Coasts of Europe.

OSTREA species indeterminate

(Plate III, figs. 31-33)

Figured Specimen, U.S.N.M. 104399; left valve, length 10.4 mm.; height 8.8 mm.
Figured Specimen, U.S.N.M. 104424; left valve, length 8.2 mm.; height 8.4 mm.

Numerous small specimens of *Ostrea* are quite variable in shape, but most tend to be elongate, moderately broad ventrally, with a narrow umbone marked by a proportionately broad ligamental groove. Some, however, are almost circular. The left valves are strongly ventricose; the right are almost flat. The form is too generalized and the specimens too small to permit their certain assignment to any described species.

Family CARDIIDAE

Genus NEMOCARDIUM Meek, 1876

Nemocardium Meek, 1876, Rept. U. S. Geol. Surv. Territories (Hayden), vol. 9, pp. 167, 173. Genotype, by virtual monotypy, and subsequent designation, Sacco, 1889, *Cardium semiasperum* Deshayes. Eocene, Paris Basin, France.

Nemocardium is a genus that includes, for the most part, species of Eocene and Oligocene age, but it has been reported from strata as low as the Neocomian of Europe ("*Cardium*" *subhillanum* d'Orbigny, [79, p. 19, pl. 239, fig. 7, 8] which was associated with *Nemocardium* by Meek). The genus is, however, but rarely represented in the Cretaceous. The Aptian species from the Republic of Lebanon, "*Cardium*" *birdanum* Whitfield (122, p. 385, 405, pl. 6, figs. 7–10) has been referred to this genus by the writer (112, p. 185, pl. 7, figs. 22–25). Stewart (99, p. 273) indicates that "*Cardium*" (*Nemocardium*) *bisolaris* Cragin (23, p. 6, pl. 1, fig. 16) from the Cretaceous of Kansas is also a representative of this genus.

The genus is characterized by the presence of fine radial riblets over the anterior and median surfaces of the valve with stronger, finely tuberculate radial ribs behind the posterior angulation. The tubercles in the posterior area are upon the ribs, rather than in the interspaces, as in *Brevicardium* Stephenson (94, p. 203). Both types of radial ribs are reflected in the crenulate internal margins of the shell, the strength of the crenulations being in agreement with the strength of the ribbing on the surface. The hinge is characterized by the unequal development of the cardinal teeth, with the right anterior and the left posterior cardinals greatly reduced and the opposite cardinals greatly enlarged.

NEMOCARDIUM *sensu lato*

The specimens differ from typical *Nemocardium* in having the radial ribs unusually well-developed on the anterior and median portions of the valve, though not quite as strongly as on the posterior area. The surface of the valve of the only entire specimen is strongly abraded, but traces of tuberculations are preserved upon the posterior ribs, with no suggestions of their presence on the ribbing over the rest of the surface. The posterior angulation is but weakly developed, but is present. No trace of such angulation can be observed upon specimens of "*Cardium*" *formosum* Deshayes, the genotype of *Loxocardium* Cossmann, 1886 which the present species rather suggests in the relative strength of the ribbing. The ribs in *L. formosum*, furthermore, are finely tuberculate over the entire surface of the shell.

NEMOCARDIUM MARINUM, new species

(Plate III, figs. 13, 14)

Holotype, U.S.N.M. 104401; left valve, length 10.7 mm.; height, slightly crushed, 9.6 mm.; diameter 3.4 mm.

This new species is represented by a complete, though somewhat abraded left valve together with a partial external natural mould of this specimen; a fragment of a right valve preserving the umbo and a portion of the anterior dorsal margin; and a fragment of the posterior portion of a left valve, preserving the posterior area and the ventral portion of the median surface.

The shell is relatively thin, with a sub-rectangular outline, a little longer than high, moderately inflated with comparatively small, and high, relatively prominent, slightly prosogyrate umbones situated near the midlength of the valve. The posterior umbonal ridge is prominent, subangular, and delimited by a relatively strong, but narrow, radial rib. The posterior margin is but slightly convex and trends almost directly vertical above the posterior-ventral end of the umbonal ridge. The ventral margin is broadly and regularly rounded, passing without any sharp delimitation into the rounded anterior end. The dorsal margin is broadly arched and subangulate at both anterior and posterior extremities.

The surface of the valve is ornamented with radial riblets. Approximately 55 may be observed on the anterior and median portion of the shell; these are relatively broad and are separated by linear interspaces. The top of each rib is grooved, and on the abraded surface of the holotype this results in an apparent doubling of the number of ribs. The posterior area is sculptured by 11 narrow, raised ribs, separated by interspaces approximately as wide as the ribs; each rib bearing, on its surface, small, rounded tubercles. The anterior dorsal area of the valve is smooth, the ribbing extending in an arc from the beak to the anterior end of the valve.

Imperfect hinges of both right and left valves have been obtained. That of the left valve shows a very large, triangular, anterior cardinal tooth, in which the posterior margin is essentially vertical with the main mass of the tooth anterior to the apex Its anterior dorsal margin is curved dorsally around the linear socket that receives the right anterior cardinal. The anterior cardinal is rudimentary and located essentially upon the margin of the valve. The socket for the reception of the posterior cardinal of the right valve is moderately broad and long. Anterior and posterior lateral teeth are distant, relatively thin and elongate, being located upon the margins of the valve. The right valve shows a moderately broad, triangular posterior cardinal tooth that is proportionally narrower than the left anterior cardinal, and, in complement to the latter, has a straight anterior margin. The anterior cardinal is broken away, but judging from the socket for its reception in the left valve must have been relatively long, thin, and low. The anterior lateral clasper is unusually long, and deep, very narrow towards the umbone, and expanding in width toward the anterior margin. The posterior lateral clasper has been broken away.

The inner margins of the valve appear to have been crenulated.

There appears to be no American Cretaceous species with which this form may be readily compared. "*Cardium*" *ibbetsoni* Forbes from the Lower Greensand of England seems to have a somewhat comparable ornamentation, but that species may be readily separated by its much narrower, less inflated, and higher umbones and more rounded outline (126, pl. XXXII, figs. 7a–f, 8, 9, 10).

Family CYPRINIDAE ?

Genus EOMIODON Cox, 1935

Eomiodon Cox, 1935, Paleontolog. Indica, n.s., vol. 20, no. 5, p. 6.
Genotpye, by original designation, *Eomiodon indicus* Cox. Jurassic (Bathonian), Attock District, India.

Judging from the illustrations of the hinge of the form referred by Chavan (12, p. 64, text fig. 10) to this genus under the designation, *Eomiodon dieulafaiti* (Gourret), the following species seems to be closely allied to this Jurassic genus. The original illustrations given by Cox of the hinge of the genotype species (21, pp. 6–8, text figs. 1a, b) are too indefinite for precise comparison. The hinge of the left valve, as shown by Chavan includes a single, long and sinuous anterior lateral, A_{II}, and a distant posterior lateral, P_{II}, that is essentially but a swelling on the posterior end of the dorsal margin of the valve. The cardinals consist of a relatively broad triangular 2, and a thin, elongate 4b; the right valve has paired anterior and posterior laterals. Of the anterior pair, A_I and A_{III}, the latter is continuous posteriorly with a small anterior cardinal 3a; the posterior laterals, P_I and P_{III}, are distant from the rest of the hinge elements at the posterior end of the dorsal margin. In addition to the small 3a, there is a broadly triangular 3b and a very short 5b that is located on the anterior end of the nymph plate.

In addition to this tooth pattern, Chavan's figures indicate that *E. dieulafaiti* has a rather broad, deep escutcheon, a narrow, elongate lunule, and an external sculpture marked by distant raised lamellae. Cox indicates that these external features are to be considered as being characteristic of the genus, which is a brackish water form in its typical Jurassic development.

Cox believes that *Eomiodon* is ancestral to the Wealden genus *Neomiodon* Fischer, a form that is smooth externally, and has paired anterior and posterior laterals on the left hinge, with a single posterior lateral and a long A_I with a shorter A_{III}, or an exceptionally elongate 3a dorsal to it, on the right.

The following species has a left hinge that is identical with that figured by Chavan for *Eomiodon dieulafaiti*, and in addition possesses the lunule, escutcheon, and type of sculpturing that are, according to Cox, characteristic of the genus. In outline, the present form seems to be more sub-ovate and less Pitaroid than is characteristic of the Jurassic forms, and it is clearly less strongly inflated. Nevertheless, there seems little doubt but that it represents a persistent radical of the *Eomiodon* line that has lingered on in the brackish water environment, similar to that which was occupied by that genus during the Jurassic.

Another Cretaceous form that may well be derived from *Eomiodon* is the marine genus *Protocyprina* Vokes (112, pp. 170–172, pl. 5, fig. 1–12). This is a much larger form whose hinge differs primarily in the absence of well-defined anterior laterals on the right valve. The long, sinuous lateral of the left valve is received, instead, in a well-defined groove on the hinge plate, and there is no raised structure margining it on either side.

These forms are here referred to the Cyprinidae, particularly on the basis of the resemblance of *Protocyprina* to some variants of *Cyprina* itself (112, p. 172). Cox, however, has recently (22, p. 141) explicitly excluded both *Eomiodon* and *Neomiodon* from this family, although he has not stated his reasons for so doing.

EOMIODON MARETESTA, new species

(Plate III, figs. 27–30)

Holotype, U.S.N.M. 104410*a*; length 13.1 mm.; height 11.7 mm.
Paratype, U.S.N.M. 104410*c*; length (incomplete) 12.6 mm.; height (incomplete) 9.5 mm.
Paratype, U.S.N.M. 104410*b*; incomplete anterior end of a right valve.

This species is represented by a number of badly crushed individuals crowded upon a single bedding plane in the core (Pl. III, fig. 30) and by a few fragments in the immediately overlying matrix. It is confined to this one horizon and there is no trace of the form in any other part of the core.

The shell is transversely ovate in outline, a little longer than high, and apparently was but moderately inflated. No free specimens are available, but the matrix filling the interior of the holotype, a left valve, shows a diameter of but 2.3 mm., and the shell material being thin, the diameter of this specimen is clearly less than 3 mm. The ornamentation consists of prominent, raised, concentric lamellae which though thin are raised well above the surface of the valve itself. On the figured paratype these lamellae are 0.5 to 0.75 mm. apart; the interspaces being flat-bottomed and marked only by lines of growth. The lunule of the right valve is long and exceptionally narrow, marked by an impressed line. The escutcheon is not well shown on any of the specimens, but so far as observed was relatively narrow and moderately deep. The lunule and escutcheon of the left valve are not known.

Internally, the hinge of the left valve consists of two cardinals and a long, narrow and curved, anterior lateral. The anterior cardinal is triangular in shape, moderately long and straight; the posterior cardinal is thin and elongate and closely appressed to the nymph plate at its posterior end but separating from this structure anteriorly to permit the development of a slender, rather shallow socket. Posterior to the nymph, the hinge plate itself is narrow and becomes raised to form a posterior lateral tooth, which is received within well-developed claspers on the right valve. (Traces of these structures may be seen in figure 30, Plate III.) Anteriorly, the left hinge plate is broadened, with a long, slender curved lateral tooth on its inner margin paralleling the edge of the plate. Dorsal to this tooth is a broad "socket" whose dorsal margin is defined by the raised margin of the valve. Fragments of the anterior end of the right hinge show a well-defined anterior lateral tooth, A_{III}, that is received in this socket; and in addition a second tooth, A_{I}, directly on the raised ventral margin of the hinge plate, the two forming a socket for the reception of the left anterior lateral.

The inner margins of the valve are smooth. The muscle scars cannot be certainly observed. They appear to have been relatively large with the anterior adductor extending anteriorly to a position immediately ventral to the end of the anterior lateral tooth.

The species has been compared above with *Protocyprina libanotica*, the genotype species. No other similar Cyprinid species occurs in the American Cretaceous section.

Family CORBULIDAE

Genus CORBULA Lamarck, 1799

Corbula Lamarck, 1799, Mém. Soc. Hist. Nat., Paris, p. 81.
Genotype, by subsequent designation, Schmidt, 1818, *Corbula sulcata* Lamarck. Recent, coast of Senegal.

Corbula sensu lato

A diverse group of species has, in the past been referred to the genus *Corbula* (111) and at least 25 generic and subgeneric groups may be recognized in a discriminating study of the assemblage.[1]

"CORBULA" TETHYS Stephenson

(Plate III, fig. 22)

Corbula tethys Stephenson, 1936, Bull. Geol. Soc. Amer., vol. 47, p. 398, pl. 5, figs. 4–7.
Hypotype, U.S.N.M. 104412; length (incomplete) 1.8 mm.; height 1.3 mm.; diameter 0.7 mm.

An imperfect right valve agrees rather closely in general shape and ornamentation with the form described by Stephenson from boulders dredged near Banquereau, Nova Scotia, as *Corbula tethys*. The present specimen is slightly less than half the size of Stephenson's type, a condition which is readily explainable on the basis of the dwarfing of all of the elements in this assemblage.

Stephenson compared his form to "*Corbula*" *crassiplica* Gabb, a form that has been demonstrated to possess the triangular siphonal plates of *Caestocorbula* (110). The species also rather resembles the type species of *Varicorbula* (*Flexicorbula*), mentioned above, which, however, lacks siphonal plates. A precise generic reference of this species is, therefore, not possible at this time.

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[1] In the preparation of the report on the "Supraspecific groups of the Pelecypod family Corbulidae" (111), the genus *Phaenomya* Weaver and Palmer (117, p. 26, pl. 9, figs. 6–8) (genotype *P. vaderensis* W. and P.) from the Eocene of Washington was overlooked. In addition, a recently published report by Chavan includes the description of a new subgenus of *Varicorbula*, *Flexicorbula* (13, p. 173–5, pl. 3, figs. 26–29) (genotype *Varicorbula* (*Flexicorbula*) *vokesi* Chavan) from the Campanian of Palestine.

Genus PARMICORBULA Vokes, 1944

Parmicorbula, Vokes, 1944, Amer. Jour. Sci., vol. 242, pp. 629, 621, pl. 1, figs. 7–18.
Genotype, by original designation, "*Corbula*" *neaeroides* Blanckenhorn, Cretaceous (Aptian), Lebanon Mountains, Lebanon.

PARMICORBULA species

(Plate III, fig. 20)

Figured specimen, U.S.N.M. 104394; length 4.7 mm.; height 3.1 mm.; diameter (slightly crushed) 0.9 mm.

A single imperfect right valve with a well-defined rostral "snout" of the type characteristic of the genus *Parmicorbula*, and with the main surface of the valve ornamented with relatively coarse concentric ribs that die out before reaching the rostrum in the manner typical of that genus probably represents an undescribed species, but in itself is not adequate for the diagnosis.

The inflated shell is characterized by its high, relatively narrow umbones and steeply sloping anterior and posterior dorsal slopes. The latter is sharply angulate at midlength where the posterior end assumes an almost horizontal position along the dorsal side of the rostrum. The anterior end is relatively sharply rounded, and the ventral margin is strikingly regularly and evenly rounded. The surface of the rostrum is divided into a dorsal, relatively flat area, and a ventral one that is rather broadly convex. Both are smooth except for relatively rugose growth lines. The main area of the valve surface is ornamented by moderately coarse concentric ribs that tend to be slightly narrower than the round-bottomed interspaces between them.

The most distinguishing feature of this form seems to be the bipartite nature of the rostral surface. No similar detail has been observed on any of the species heretofore referred to this genus; the general shape of the present species is, however, so similar to that of these other species as to leave no doubt as to the generic identification.

Genus URSIRIVUS Vokes, 1945

Ursirivus Vokes, 1945, Bull. American Mus. Nat. Hist., vol. 86, Art. 1, pp. 15–16, pl. 3, figs. 8–10. [New name for *Anisorhynchus* Conrad *in* Meek, 1871; *not* Schoenherr, 1842 (Coleoptera)].
Genotype, by original designation (Monotype of *Anisorhynchus* Conrad *in* Meek) *Corbula* (*Potamomya*?) *pyriformis* Meek. Cretaceous, Bear River Group, southwestern Wyoming.

URSIRIVUS OCEANUS, new species

(Plate III, figs. 1–4)

Holotype, U.S.N.M. 104432 a, b, c; left valve, length 25.1 mm.; height 15.5 mm.; diameter, ca. 3.8 mm.
Paratype, U.S.N.M. 104406; left valve, length (incomplete) 22.8 mm.; height 15.7 mm.; diameter, ca. 3.6 mm.

This species is represented by four incomplete left valves, two preserving the hinge structure and anterior end, a third showing the posterior half of the valve, and the fourth, a relatively complete, juvenile individual; and by two badly crushed right valves. In addition, there is an almost complete external mold of the holotype, the larger and more complete of the two valves that show the hinge structure and anterior end. A number of fragments that clearly represent this species suggest it was one of the most abundant pelecypod species in the fauna.

The shell is relatively large for a member of the Corbulidae, though smaller and less inflated than the genotype of *Ursirivus*. In the present species the ratio of the diameter of the left valve to the height is 1:4, whereas in the left valves of the genotpye species the ratio averages approximately 1:2. The shape and external ornamentation of the valves are characteristic of the genus. The shell is moderately elongate and sub-pyriform with the sharp, pointed umbones situated at the anterior third of the length. The anterior third of the length is also the point of the greatest curvature of the ventral margin and both dorsal and ventral margins slope with rather regularly decreasing convexity to the produced, sharply rounded anterior end. The anterior margin, in contrast, is broadly and regularly rounded. A well-defined, broad, impressed escutcheon marks the posterior dorsal area, and is set off by a narrow, raised ridge. A lunular area is pronounced, but in contrast to the genotype species, is raised, rather than depressed, being delimited from the rest of the valve by a shallow, but distinct groove. Surface ornamentation consists of coarse, concentric lines.

The hinge of the left valve is less massively developed than that of *U. pyriformis*, and the chondrophore tends to be broader with the adjacent anterior cardinal socket proportionally narrower. The latter is floored ventrally, and broadly open dorsally, and curves posteriorly so that the dorsal end of the socket is distinctly behind the posterior limit of the ventral edge. The chondrophore is but slightly projecting, somewhat longer than wide, and lightly asymmetric in shape, with the greatest projection posterior to the middle of the depressed, spoon-shaped ligamental attachment area.

The genus *Ursirivus* is known, in literature, solely from the genotype species, which occurs in the Bear River formation of Wyoming and Idaho, and in the Dunvegan formation of the Cretaceous of Alberta, Canada. In addition, Stephenson has described, in manuscript, two species referrable to this genus from the Lewisville member of Texas.

The species being described by Stephenson are, like this form, less strongly inflated than the genotype species. The fauna of the Bear River formation contains a number of fresh-water faunal types that are absent in both the Lewisville and this fauna. It may be that the greater convexity of the shells of *U. pyriformis* can be attributed, in part at least, to a response, on the part of that species, to the lesser salinity that must have characterized the waters in the environment in which the Bear River formation was deposited.

URSIRIVUS ATLANTICUS, new species

(Plate III, figs. 5-7)

Holotype, U.S.N.M. 104422; right valve, length, 26.9 mm.; height, 18.2 mm.; diameter (crushed).
Paratype, U.S.N.M. 104429; right valve, length, 15.3 mm.; height, 10.5 mm.; diameter (crushed) 1.7 mm.
Paratype, U.S.N.M. 104420; left valve, imperfect specimen, showing hinge.

This form, which is almost as abundantly represented as is the preceding species, was at first thought to represent a variety of *U. oceanus* distinguished by the presence of a surface ornamentation consisting of raised fine concentric ribbing. Careful comparison, however, has failed to reveal any specimens intermediate between the two; all of the examples referred to *U. oceanus* are smooth over the entire surface of the valve, and all referred to this form exhibit the characteristic ribbing over the entire area except the posterior dorsal margin.

The general shape and low degree of inflation are similar to those of *U. oceanus;* in general the present species is somewhat smaller, though not markedly so. The hinge is typical of the genus.

The representatives of this species and those of *U. oceanus* are mutually exclusive of each other in the core section, and it is to be assumed that one species is older than the other. The core had been split for examination before the present study, so that it was impossible to determine the relative stratigraphic position of the two forms.

CORBULIDAE indeterminate, species A

(Plate III, fig. 15)

Figured Specimen U.S.N.M. 104417; length 2.1 mm.; height 1.7 mm.

A single poorly preserved left valve characterized by an unusually high, thin umbone is not readily referrable to any described species, and the generic assignment within the family Corbulidae is wholly uncertain. It might represent the left valve of the species here referred to the genus *Parmicorbula*, in which event it represents a much smaller individual, even though the left valve of Parmicorbula is notably smaller than the right. The specimen is ornamented by relatively fine concentric ribbing separated by interspaces that are approximately as wide as the ribs. There is a distinct posterior umbonal ridge delimiting a narrow rostral area.

CORBULIDAE indeterminate, species B

(Plate III, fig. 21)

Figured Specimen U.S.N.M. 104393; length 2.3 mm.; height 1.3 mm.

A finely oramented right valve that is notably elongate with a relatively small and but moderately inflated umbone is somewhat reminiscent of "*Corbula*" *manleyi* Weller (118, p. 636, pl. 62, figs. 1–8) a species from the Raritan formation of New Jersey. The umbone of the present specimen, however, tends to be lower and relatively less inflated than those of Weller's species and the concentric ribbing is finer and less strongly developed.

CORBULIDAE indeterminate, species C

(Plate III, fig. 26)

Figured Specimen U.S.N.M. 104414; length 4.0 mm.; height 2.7 mm.

A somewhat crushed corbulid right valve of relatively large size, so far as the present collection is concerned, is marked by a particularly prominent posterior umbonal ridge, and a notably broad, straight, posterior end. The surface is almost smooth, although traces of concentric ornamentation may be noted under microscopic examination. Its relationships are entirely unknown.

Pelecypoda, Genera and Species indeterminate

(Plate III, figs. 16, 23)

In addition to the forms described above, there are fragmentary specimens representing several species of pelecypoda that are too incomplete for certain generic identification. One of these, shown on plate III, figure 16, has a shape that is reminiscent of certain pectinid genera, but lacks any trace of the auricles. The presevation of the shell material is quite similar to that which marks the specimens referred to the genus *Ostrea*, and it may well be that this form represents a member of that group. It is, however, so strikingly different from any of the forms that are now known to occur in the core that it clearly must be referred to a species other than that shown on plate III, figures 31–33.

A second form, illustrated on plate III, figure 23, has weakly developed concentric ornamentation, a moderately inflated umbone, and is sub-circular in outline. The form is so generalized that, lacking any evidence of hinge structures, no provisional generic identification can be made.

A third, badly abraded specimen suggests the anterior end of a smooth tellinid. Another, characterized by coarse, distant, concentric lamellae, might conceivably represent a second species of *Eomiodon*. There appears to have been a well developed escutcheon, but the shell is much higher, in proportion to its length than *E. maretesta*, or than any of the Jurassic species referred to this genus. It may with equal propriety be compared with several of the Jurassic and Cretaceous forms that are commonly referred to the genus *Astarte*, although these differ markedly from the typical species of that genus.

Gastropoda

Family NATICIDAE

Genus EUSPIRA Agassiz, 1839

Euspira Agassiz, 1839 *in* Desor, French translation of Sowerby, Min. Conch. of Great Britain. pp. 14, 15, 16.

Genotype, by subsequent designation, Dall, *Natica glaucinoides* Sowerby, not Deshayes. Eocene, England.

EUSPIRA PARVISSIMA, new species

(Plate IV, figs. 25, 26)

Holotype, U.S.N.M. 104430; length 3.1 mm.; diameter 3.5 mm.
Paratype, U.S.N.M. 104431; length (incomplete) 4.1 mm.; diameter (crushed) 4.0 mm.

A minute naticoid species is represented in the cores by several specimens, all more or less distorted by crushing.

The shell is typically naticoid in outline with a relatively high spire. There are five whorls present on the holotype, the most perfect specimen available for study; others show but four whorls. The whorls are distinctly shouldered, moderately rounded in outline below the shoulder, and relatively flat above. The suture is linear. The aperture is semi-lunate, angulate posteriorly and broadly rounded anteriorly extending to the median axis of the shell. The outer lip is simple, the inner lip very thinly callused, the callus extending partly across the moderately wide umbilical chinck.

The very small size is the most distinguishing feature of this shell, and the specific name is given in allusion to this characteristic. In its essential specific characters it is a generalized representative of the genus, and might well represent a dwarfed form of any one of several Cretaceous species.

Family MELANOPSIDAE

Genus CASSIOPE Coquard, 1865

Cassiope Coquand, 1865, Mém. Soc. Émul. Provence, vol. 3, p. 247 (new name for *Glauconia* Giebel, 1852, *not* Gray, 1845 [Reptilia]).
Genotype, (Type of *Glauconia*, Giebel) *Turritella kefersteini* Goldfuss. Cretaceous (Turonian), Gosau region, Austria.

The following form is tentatively referred to this genus although it does not concur in all its characters whith those to be observed on the genotpye species. In the latter form the apical angle is quite consistently of the general magnitude of 32 to 35 degrees, the early post-nuclear whorls are ornamented by spiral ribs that show one primary band near mid-whorl height that is heavier than the others from its inception and is, at all stages visible on the species available for study, definitely nodose. Later in the development, a second spiral immediately above the suture also tends to become noded, but at all stages seems to remain less strongly noded than the initial band. None of the specimens of *Cassiope kefersteini* available for study possess a well-preserved aperture and the whorl-base is worn on all. According to Cossmann (20, pp. 167–168) the "Dernier tour égal au tiers environ de la hauteur totale, circonscrit par une carène à la périphérie de la base qui est un peu convexe, souvent marquée de carènes et de filets spiraux, excavée et perforée au centre par une étroite fente ombilicale. . . ."

In the following species the apical angle is considerably smaller, being of the magnitude of 25 to 27 degrees; the early post-nuclear whorls are ornamented by spiral ribs only, having a distinctly turritelloid appearance, and when noding does appear it occurs first upon the spiral that is directly below the suture, and later on one that is directly above the suture. The median spiral, which is initially, as in *C. kefersteini*, of primary strength, becomes weakened and reduced in importance, rather than dominating the ornamentation. More significant, perhaps, is the absence of any trace of umbilical perforation or excavation other than a slight detachment of the peristome of the inner lip from the base of the body whorl.

A species that appears to have a very similar type of ornamentation, as well as the same general history of development of noding, occurs in the lower Aptian of the Lebanon Mountains. Described as *Turritella damesi* Blanckenhorn, it was recently referred to under the inadmissable hybrid generic combination of "*Turritella-Glauconia*" by Delpey (24, p. 99, text figs. 70, 71, 72). Judging from the rather unsatisfactory line drawings of this species, it has an apical angle of approximately 30 degrees, and a non-umbilicate base. Concerning the pattern of the ornamentation Delpey observes: "A quel phénomène ce dimorphisme est-il dû? On pourrait penser à du gérontisme. Mais l'ornamentation perlée dure parfois pendant plus de 3 ou 4 tours. Il est probable que le milieu a agi sur cette forme, qui est l'un des termes de transition entre les genres *Turritella* et *Glauconia*."

In this connection it should be pointed out that while the ornamentation is seemingly transitional in type between that characteristic of *Turritella* and that which marks the typical form of *Cassiope*, the general species-group that might be so ornamented cannot be considered as being actually so transitional. Typical *Cassiope* ornamentation occurs on forms that are stratigraphically older, as for example, on *C. strombiformis* (Schlotheim) from the "Wealden" of northern Germany and the Neocomian of Spain. It seems more probable that the present group is to be interpreted as a distinctive offshoot from the main *Cassiope* sequence, and might well be distinguished by a new subgeneric name. The present material, however, is not sufficiently complete to permit the adequate characterization of such a group at the present time.

CASSIOPE MARYLANDENSIS, new species

(Plate IV, figs. 1-8)

Holotype, U.S.N.M. 104408; length (incomplete) 14.0 mm; diameter (crushed) 5.0 mm. (greatest diameter across flattened surface).
Paratype, U.S.N.M. 104392; length (incomplete apically) 13.3 mm.; diameter (as above) 6.4 mm.
Paratype, U.S.N.M. 104391; length (incomplete) 18 mm.; diameter (as above) 14.6 mm. (fragment of adult whorls).
Paratype, U.S.N.M. 104421; length (incomplete) 8.8 mm.; diameter 3.4 mm.
Paratype, U.S.N.M. 104397; length (incomplete) 7.5 mm.; diameter (as above) 5.4 mm.
Paratype, U.S.N.M. 104418; length 17.3 mm.; diameter (slightly crushed) 8.8 mm.
Paratype, U.S.N.M. 104387; length (incomplete) 7.3 mm.; diameter (as above) 3.2 mm. (showing apical whorls).

An unusually slender species of *Cassiope*, this form is represented by a number of fairly complete examples showing the early post-nuclear whorls together with a single crushed adult that is fragmentary and incomplete (Pl. IV, fig. 8). The holotype is the only specimen that shows both early post-nuclear ornamentation and the change toward that on the typical adult form.

The change between the immature and adult ornamentation is a most striking one. In the early stages of development the whorls are marked by a *Turritella*-like development, both in form and in ornamentation. The latter consists of four revolving spiral threads, the anterior pair of which are much more strongly developed than the posterior ones. The whorl profile is angulate at each of the anterior primaries and is sharply concave between them. Above the upper of this pair of spirals the whorl slopes toward the suture to give a broad whorl shoulder, below the lower it slopes abruptly to the suture. On all whorls the sutures are linear.

On the early post-nuclear whorls the upper of the two primary ribs occurs at approximately the mid-height of the whorl and the lower at approximately the anterior quarter of the height. As growth continues the lower primary assumes a position directly above the suture; whereas the upper, somewhat weakened in strength, tends to maintain its position at, or just anterior to, the mid-height, but loses its importance as a site for the angulation of the whorl.

The posterior pair of spirals, on the other hand, remain relatively close together, but the upper spiral progressively increases in strength while the lower (anterior) one becomes progressively finer and less prominent.

At, or about, the tenth spire whorl the posterior rib begins to develop a longitudinally nodose condition, and as growth continues the nodes become progressively heavier and broader until on the late whorls of the only adult fragment in the collection, they have become almost round and are the dominant feature of the ornamentation. In this relatively adult fragment, the anterior primary spiral has also broken up into nodes, apparently beginning to do so at about the fifteenth post-nuclear whorl. At this stage the other spiral ribs have become so weak as to be observed with difficulty, and the ornamentation consists of a heavy sub-sutural row of nodes and a weaker nodose row immediately above the suture, with an essentially flat-sided whorl area between.

No complete aperture has been available for study. The growth lines show a typical *Cassiope* shape, reflecting a posterior emargination of the outer lip with its apex located approximately at mid-height of the spiral whorls; a patulate projection of the lip below the anterior primary spiral, approximately along the line of the suture of the spire whorls, and a second, shallower, emargination near the middle of the whorl base. The inner lip of the aperture is relatively thinly callused, the callus being appressed to the whorl base posteriorly, becoming semi-detached toward the base. The base of the body whorl of the only specimen in which this feature is well-preserved (Pl. IV, figs. 1, 2) shows a single heavy spiral immediately at the suture with two minute threads above between this spiral and the anterior primary spiral of the whorl-side ornamentation, and several secondary spirals between the sutural rib and the aperture. This specimen is an immature individual, and the nature of the adult ornamentation of the whorl base is unknown at this time.

Among the described North American species of this genus, "*Vicarya*" *branneri* Hill, as restricted by Stanton (92, p. 77, pl. 57, figs. 1–6) from the Glen Rose limestone of Texas and the Dierks and DeQueen limestones of Arkansas, has a very similar adult sculptural pattern. The early post-nuclear ornamentation, however, has 3 or 4 spiral ribs, with only the anterior spiral of primary strength. The whorl-side above this spiral slopes evenly and regularly up to the suture, and there is no trace of the second angulation at a second primary spiral such as occurs in the present species.

In his recent monograph on Comanche pelecypods and gastropods (92, pp. 77–79, pl. 57, figs. 1–10, 12, 13, 17–19) Stanton describes or discusses five species of *Cassiope*. Of these, *Cassiope branneri* clearly belongs to the same group of species of *Cassiope*, s.l. as does the present form; *C. paluxiensis* Stanton, *C. hyatti* Stanton, and *C. zebra* (Gabb) should be referred to *Gymnentome* Cossmann, 1909; *C. burnsi* Stanton seems to be referrable to *Cassiope* s.s., although the apical angle appears to be somewhat smaller than is typical.

Family LITIOPIDAE (?)

Genus ANTEGLOSIA, new genus

Genotype, *Anteglosia essoensis*, new species.

There are so many genera of small, more or less smooth, turrited gastropods that it is only after considerable study, and with much hesitation that another is added to the list. No category can be found, however, to which the following species, together with the forms described by Wade as *Rissoina tennesseensis* (113, p. 167, pl. LVIII, figs. 26, 27) and *Rissoina subornata* (113, p. 168, pl. LVIII, figs. 23, 24) can be referred.

Rissoina inca d'Orbigny, monotpye of the genus *Rissoina* d'Orbigny, 1840, to which Wade referred his species, is marked by strong axial ornamentation and by an aperture that is constricted anteriorly by a swelling at the apertural base so as to simulate an anterior canal. The growth line appears to have a sigmoidal trend.

The species here being considered are almost smooth, but possess a very weak spiral lineation, observable on Maryland specimens only under favorable light and relatively high magnifications, and present only on the penultimate and ultimate whorls of the Coon Creek species; they lack all trace of axial ornamentation other than incrementals. The latter are markedly sigmoidal in trend across the whorl, and this is, perhaps, the most striking and diagnostic feature in the genus. Also characteristic is the nature of the aperture, with the base of the whorl produced anteriorly so that the callused inner lip is appressed to it for its entire length.

The Upper Jurassic species, *Glosia potamidula* Cossmann, genotype of *Glosia* Cossmann (20, p. 57, pl. II, figs. 79–82; pl. III, fig. 7) has a similarly sinuous growth line, and a general shape that is somewhat similar, although the individual whorls are proportionately shorter, giving the shell a more stubby appearance. The base of the body whorl is said to be subperforate, and the ornamentation is described as consisting of "nombreuses costules obliquement inclinés en avant, minces, que croissent souvent d'imperceptibles filets spiraux, parfois effacés" (20, p. 58). Later Cossmann states that the ornamentation and proportions of the genotype species are very variable, and figures (pl. II, figs. 81, 82) a specimen that seems to be almost devoid of axial ornamentation.

In consideration of the possibility that the present species may have been developed from a form similar to that of *Glosia potamidula* through the suppression of the axial ornamentation, and a slight lengthening of the base of the body whorl, so that the inner lip of the aperture was appressed for its entire length, the new generic name *Anteglosia* is proposed for the present Cretaceous species.

ANTEGLOSIA ESSOENSIS, new species

(Plate IV, figs. 9–12)

Holotype, U.S.N.M. 104404a; length 3.4 mm.; diameter (crushed) 1.3 mm.
Paratype, U.S.N.M. 104404b; length 3.1 mm.; diameter (crushed) 1.2 mm.
Paratype, U.S.N.M. 104404c; length 2.4 mm.; diameter (crushed) 1.1 mm.
Paratype, U.S.N.M. 104407; incomplete, apical whorls only.

This form is second only to *Plesiopotamides marinus*, new species, in its abundance in the fauna, but the minute shell is so fragile that only a few specimens adequate for study have been obtained.

The shell is small and turrited, consisting of a somewhat submerged nucleus and five, smooth, post-nuclear whorls. Only one nucleus has been observed. This is not sharply delimited from the post-nuclear whorls (pl. IV, fig. 10), although there is a slight discontinuity in the shell surface suggesting that the exposed portion of the nucleus includes but slightly more than one-half a whorl. The post-nuclear whorls are evenly convex, with linear sutures that tend to become slightly appressed between the penultimate and ultimate whorls. The surface of the shell is smooth and polished, marked by prominent, sigmoidal growth lines, but with a faint suggestion, under magnification, of a spine spiral lineation. The growth lines are concave, with relationship to the plane of the aperture on the posterior half of the spire whorls, and convex on the anterior part. The point of maximum convexity lies approximately at the line of sutural contact between adjacent whorls.

The base is imperforate, and is produced anteriorly so that the callused inner lip of the aperture is appressed to it for its entire length. The aperture is entire, broadly and regularly rounded anteriorly, but acutely angulate posteriorly.

Anteglosia essoensis, new species differs from *Anteglosia tennesseensis* (Wade) the only closely comparable form, in its smaller size and much weaker spiral ornamentation that can be observed only under favorable light at relatively high magnification.

Family POTAMIDIDAE?

Genus PLESIOPOTAMIDES new genus

Genotype *Plesiopotamides marinus*, new species.

A small species of general cerithiopsid aspect, but lacking the anterior canal of that genus and possessing a markedly sinuous outer lip that is produced and patulate anteriorly, and strongly concave above does not appear to be referrable to any described genus, although the Eocene species "*Melania*" *rigida* Sowerby figured by Cossmann (20, pl. IV, figs. 7, 15) as a "génoplésiotype" of *Tarebia* H. and A. Adams, seems to be quite possibly a congeneric form. No specimens have been available for comparison, and a certain assignment to the present genus cannot be made at this time. The Recent species, *Melania granifera* Lamarck, the actual genotype of *Tarebia*, is a very different type of sub-fusiform shape with an elongate aperture, and a relatively straight growth line.

Among described genera, the Tertiary genus *Potamides* Brongniart, 1810, seems most closely related. *P. lamarcki* Brongniart, the monotype species, has a similarly sinuous outer lip and growth line, although the apex of the upper concavity is somewhat higher on the whorl and the patulous projection of the lip is closer to the columella, giving a narrower, and proportionately deeper, anterior basal notch. The two forms seem clearly relatively closely related, and the present genus is probably ancestral to the Tertiary form.

PLESIOPOTAMIDES MARINUS, new species

(Plate IV, figs. 14-20)

Holotype, U.S.N.M. 104400a; length, 4.0 mm.; diameter, 1.6 mm.
Paratype, U.S.N.M. 104400b; length, 8.0 mm.; diameter, 2.9 mm.
Paratype, U.S.N.M. 104400e; length, 7.1 mm.; diameter, 2.6 mm.
Paratype, U.S.N.M. 104400d; length, 4.7 mm.; diameter, 1.7 mm.
Paratype, U.S.N.M. 104400c; length, 5.9 mm.; diameter, 2.3 mm.
Paratype, U.S.N.M. 104400f; length, 2.6 mm.; diameter, 1.2 mm.
Paratype, U.S.N.M. 104428; fragment with aperture.

This small species is the most abundant form in the collection, and is common throughout all parts of the core. Despite its abundance no complete specimens have been obtained; the most perfect show eight whorls, but lack the nuclear region. Smaller specimens in which the latter whorls are preserved permit the suggestion that the complete shell consisted of approximately eleven post-nuclear whorls and a small, smooth nucleus of one and one-half turns.

The shell is small, slender, and turrited, with an apical angle of 14 degrees. The ornamentation of the later whorls consists of four approximately equidistant broad spiral ribs that are strongly noded where crossed by low, broad and rounded sinuous axials. The number of these axials varies between 17 and 25, with 19 or 20 the usual number. Axial ornamentation is absent on the early post-nuclear whorls, the first two of which are bicostate, and sharply angulate at the costae. The third spiral, at first of secondary strength, appears above the primary pair on the third post-nuclear whorl, which also bears the first faint traces of axial ornamentation. A fourth spiral appears above the third on the fifth post-nuclear whorl. On the last three or four whorls all four of the spirals tend to be of equal strength, although a few specimens show a tendency for the upper of the initial primary spirals to be heavier than the other three. In extreme cases, they may be as much as twice the width of the rest.

In addition to these major spiral ribs there is a microscopically fine spiral ornamentation in the interspaces. This consists of five to seven, sub-equally spaced, non-nodose, tertiary riblets. These are so fine as to be observable only under favorable light at relatively high magnifications.

The base of the body whorl is ornamented by three revolving ribs, the outer being sharp and carinate, delimiting the base from the sides of the whorl. The innermost rib is mostly covered by callus on the inner lip of the aperture.

The suture is linear, with the adjacent whorls meeting at the line of the outer carinate spiral of the whorl base.

The aperture is ovate to sub-rounded, with a simple outer lip and a moderately heavy callus on the inner one. The callus is sharply delimited from the imperforate whorl base. There is a shallow, moderately broad and short notch at the base of the aperture.

The growth line is markedly sigmoidal, being concave above, with respect to the plane of the aperture, and convex anteriorly. The point of greatest concavity occurs approximately at the upper of the two primary spiral ribs, just below the mid-height of the whorl side, while the greatest convexity occurs approximately at the second of the basal spiral riblets. The apertural notch is largely defined by the re-entrant formed between the furthest anterior projection of this convexity and columellar lip.

This species appears to be unique among described American Cretaceous forms.

Family PROCERITHIIDAE

Genus METACERITHIUM Cossman, 1906

Metacerithium Cossmann, 1906, Ess. Paleoconch. Comp., vol. 7, p. 54.
Genotype, by original designation, *Cerithium trimonile* Michelin Cretaceous (Albian), France and Switzerland.

A small, narrowly turbinate form with a sharp peripheral keel and a relatively flat imperforate base is tentatively referred to this Cretaceous genus. No complete apertures are available so that an exact generic assignment is impossible at this time.

METACERITHIUM OCEANUM, new species

(Plate IV, figs. 21–23)

Holotype, U.S.N.M. 104395; length (slightly incomplete apically) 4.5 mm.; diameter 2.3 mm.
Paratype, U.S.N.M. 104405a; length 5.0 mm.; diameter (crushed, greatest diameter measured) 2.6 mm.
Paratype, U.S.N.M. 104405b; length (slightly incomplete) 5.9 mm.; diameter (slightly crushed) 3.1 mm.

The types are the only known representatives of this small, distinctive species. The form is narrowly turbinate with an apical angle of 31 degrees, and is composed of flat-sided whorls that are sharply carinate at the periphery, with adjacent whorls meeting just below the carinae to result in a straight-sided shell. The two paratypes each show nine whorls to the shell; the holotype is incomplete apically and has but eight.

The ornamentation consists of three primary spiral ribs on the whorl sides above the peripheral carina. On the holotype and paratypes these three spirals are present on the last six whorls in essentially equal strength. On the earlier whorls the upper and lower of these spirals are most strongly developed and the median rib is very weak. On all whorls the upper spiral is finally longitudinally nodose. On the holotype the second spiral becomes nodose on the penultimate whorl, and the lower one shows a tendency toward the development of the nodose condition on the ultimate whorl. The larger of the two paratypes shows the median spiral becoming nodose on the fifth of the nine preserved whorls, and the lower spiral begins to develop nodes on the seventh whorl. The strong peripheral carina does not at any stage show any tendency toward the development of nodes.

In addition to these primary spirals there is a well developed secondary spiral ornamentation. A single, narrow and sharp secondary spiral lies between the upper primary and the somewhat impressed suture. Three secondary spirals, of which the median one is at times the stronger, lie between each of the primaries, as well as between the lowermost primary and the peripheral carina. The latter is also ornamented by three secondary spirals, the median one lying upon the apex of the carina and thus assuming a prominence out of keeping with its true strength.

The flattened imperforate base is sharply angulate at the periphery of the body whorl, its general slope making an angle of almost 110 degrees with the general slope of the sides of the shell. It is subangulate along a strong spiral rib approximately one-third of the width from the periphery, with three additional primary spirals between the angle and the columella. In addition there are numerous fine secondary spirals, five or six, of which the median one, or two, are slightly stronger than the others, lying between the angulation and the whorl periphery, and two or three, between each of the spirals on the base inside of the angulation.

No complete aperture is available. The columella appears to have been straight throughout its length, and there is a suggestion of a short anterior canal. If there was a callus on the inner lip it must have been exceedingly thin. Growth lines are not well defined, but there appears to have been a broad, shallow concavity on the side of the whorl, and a fairly strong patulous projection on the base. This latter projection was sharply recurved towards the columella, suggesting the presence of an anterior canal. The general shape of the aperture must have been subrectangular.

In general sculpture pattern this form is somewhat reminiscent of "*Cerithium*" *weeksi* Wade (113, p. 154, pl. LIV, figs. 1, 2). But on that form the noding on the spirals is a reflection of rounded axials that traverse the whorl sides and occasionally rise to form irregular varices, and the shape of the two forms is entirely different. The genotype species, *Metacerithium trimonile* Michelin, from the Albian of France and Switzerland, differs in all details of ornamentation, there being but two primary spirals above the peripheral carina; both spirals and carina are noded.

Gastropoda, genus and species indeterminate

(Plate IV, fig. 13)

Figured specimen, U.S.N.M. 104398; length 1.8 mm.; diameter 0.8 mm.

A single minute representative of a high-spired gastropod with rounded whorl profile and an ornamentation of relatively distant spiral threads and traces of broad axial swellings cannot be referred to any genus. The aperture is not exposed, and it may even be that the form possesses a long anterior canal.

Pteropoda

A few fragmentary Pteropod remains were found. The most abundant forms are fragments of broad, rounded plates that are suggestive of the genus *Cavolina* Abilgaard, 1791, a genus that is unknown before the Miocene. The true relationships of this species are unknown, and the material is too fragmentary to permit a certain identification.

A single fragment, better preserved and more complete than the rest, appears to represent a crushed *Vaginella*. In general proportions it is very similar to *Vaginella venezuelana* Collins (16, p. 219, pl. XIV, figs. 18–20), although somewhat shorter and proportionately stouter than that species.

The presence of these Pteropods is a striking feature, especially when it is remembered that no trace of foraminifera or of ostracoda was found in the core, although special search was made for both.

CRUSTACEA

Decapoda

A single minute fragment of what appears to be a propodal segment was found. The form is smooth and unornamented save for a fairly well-developed marginal rim. It is a relatively flat segment, with a greatest width approximately 1.8 mm. The small size may reflect a small individual, although the test appears to be moderately thick. It may likewise reflect a dwarfing of the Decapod fauna similar to that which is so marked in the mollusca.

"PISCES"

Fish remains are rare. The largest, a bone fragment, has a length of 6 mm. It may represent the proximal end of a ventral rib. Another fragment 1.7 mm. in length and less than 0.3 mm. in greatest width, appears to represent a portion of a fin spine. Only one scale has been noted; it also is of very small size, being 1.1 mm. long and 0.9 mm. wide. It is ornamented by very fine concentric sculpture in an irregular pattern that is rather suggestive of that of a fingerprint.

MIDDLE MIOCENE DIATOMS FROM THE HAMMOND WELL

BY

KENNETH E. LOHMAN[1]

This report is based upon a series of 8 core samples from depths of 1000 to 1140 feet in the Hammond well. The sample numbers, the depths from which obtained, and their permanent U. S. Geological Survey diatom locality numbers are listed in Table 16.

All of the samples are of similar lithologic composition, a gray, fairly compact silty clay. In each sample, diatoms were visible on broken surfaces under a low-power binocular microscope. The samples were prepared for study using a procedure described briefly several years ago (67, p. 65). Every effort was made to prevent contamination between samples and to treat each sample alike in the cleaning process, in order that the same degree of concentration could be expected. Thus the relative abundance terms have very nearly the same meaning for each sample.

A diatom flora of 89 species and varieties, 11 of which are described as new, was obtained. The list of species and their distribution in the core is given in Table 17. The following symbols are used for relative abundance: R = rare, F = frequent, C = common, and A = abundant.

The age significance of the 89 species is shown in Table 18.

Twelve species, included in the 37 extinct species known only from middle

[1] Published with the permission of the Director, U. S. Geological Survey.

Miocene rocks, are known only from the Calvert formation of the Atlantic Coastal Plain. If the 11 new species are eliminated as obviously not previously recorded, 61 out of the remaining 78 species, or 78 percent, have been previously recorded from the Calvert formation. This diatom flora is strikingly similar to floras obtained from the Calvert formation exposed at Fairhaven, Anne Arundel County (zones 1 to 3 of Maryland Geological Survey) and along the Calvert Cliffs from Chesapeake Beach, Calvert County, southward. No hesitation is felt in correlating the beds in the well between the depths of 1000 and 1140 feet with the Calvert formation of middle Miocene age at its type locality. The middle Miocene diatom floras from many widely separated areas are well known, are remarkably similar, and contain numerous genera and species known only from rocks of that age.

TABLE 16

Diatom Locality Numbers, L. G. Hammond Well No. 1

Core Sample No.	Depth in Feet	U.S.G.S. Diatom Locality No.
1	1000–1010	3074
2	1020	3075
3	1020–1030	3076
4	1030	3077
5	1040	3078
6	1077	3079
7	1108	3080
8	1130–1140	3081

The Calvert formation of middle Miocene age has been mapped and its fauna and flora described by a group of specialists in the Miocene volume of the Maryland Geological Survey, published in 1904. In this early work, the Calvert formation was divided into 15 zones based upon faunal and lithologic differences, which can be traced along the Calvert Cliffs on the western shore of Chesapeake Bay, and from similar exposures long the Patuxent and Potomac Rivers. The chapter on diatoms by Charles S. Boyer has been of material help in the present study. The rich and spectacular diatom flora of the Calvert formation has been of interest to students of diatoms all over the world for over 100 years, and many of its species have been originally described from exposures of this formation in Richmond and Petersburg, Virginia; in Nottingham, Pope's Creek, Patuxent River, and Calvert Cliffs, Maryland; and from the deep well (1200 feet) drilled in Atlantic City, New Jersey in 1888. The author had measured sections and made collections of diatoms from the 15 zones of the Calvert formation in many localities in Maryland and Virginia, and also from the overlying Choptank and St. Marys formations. This

TABLE 17

Diatom Species and Their Distribution in the L. G. Hammond Well No. 1

	Sample Number							
	1	2	3	4	5	6	7	8
Melosira complexa Lohman, n. sp.	...	...	F	...	...	F	R	R
sulcata (Ehrenberg) Kützing	A	A	A	A	A	A	A	A
Endictya robusta (Greville) Hanna and Grant	F	F	F	...	...	C	...	F
Stephanopyxis corona (Ehrenberg) Grunow	...	F	C	...	...	C	...	...
grunowii Grove and Sturt	...	...	...	...	...	F	F	...
joynsonii Schmidt	...	...	R	...	...	R	...	...
lineata (Ehrenberg) Forti	...	...	...	...	...	...	...	F
turris (Greville and Arnott) Ralfs	F	F	F	...	...	F	...	C
Coscinodiscus apiculatus Ehrenberg	F	F	C	C	F	...	...	...
arcus Lohman, n. sp.	...	R	F	...	...	R	...	...
asteroides Truan and Witt	...	F	...	...	...	F	...	F
asteromphalus Ehrenberg	F	C	...	...	F	C	...	F
centralis Ehrenberg	...	R	...	...	...	...	...	...
convexus Schmidt	...	R	F	...	F	F	...	...
crassipunctatus Forti	...	F	...	...	...	...	...	...
curvatulus Grunow	...	R	R	...	...	...	...	...
curvatulus var. *minor* (Ehrenberg) Grunow	...	R	...	...	...	R	...	...
excentricus Ehrenberg	F	F	F	...	F	...	...	F
kützingi Schmidt	...	R	...	...	...	...	...	...
lewisianus Greville	R	...	R	...	R	R	...	R
lewisianus var. *similis* Rattray	...	...	...	...	...	...	...	R
lineatus Ehrenberg	R	...	F	...	...	C	F	F
marginatus Ehrenberg	F	F	F	F	F	C	C	C
monicae Grunow	...	...	...	R	...	...	...	...
obscurus Schmidt	C	C	C	C	...	C	C	...
oculus-iridis Ehrenberg	F	...	...	...	F	C	...	F
perforatus Ehrenberg	F	C	F	C	C	C	C	...
perforatus var. *cellulosa* Grunow	...	F	F	R	R	F	F	R
radiatus Ehrenberg	F	F	...	...	F	...	...	F
salisburyanus Lohman, n. sp.	R	...	...	...	...	R	...	...
stellaris Roper	...	...	...	...	R	R	F	F
Liradiscus bipolaris Lohman, n. sp.	...	...	...	...	...	R	...	...
minimus Lohman, n. sp.	...	...	...	...	...	...	...	R
Cestodiscus marylandicus Lohman, n. sp.	...	...	...	...	...	...	...	R
Craspedodiscus coscinodiscus Ehrenberg	R	R	...	...	...	...	R	...
elegans Ehrenberg	...	...	...	...	...	...	...	R
Actinocyclus octonarius Ehrenberg	...	C	F	C	C	...	F	A
partitus Grunow	...	...	...	R	...	...	...	...
Stictodiscus kittonianus Greville	...	R	...	...	R	R	R	F
Cladogramma dubium Lohman, n. sp.	...	...	...	...	...	...	R	...
ellipticum Lohman, n. sp.	R	...	...	...	...	...	...	R
Actinoptychus heliopelta Grunow	...	...	R	...	...	...	...	...
kymatodes Pantocsek	...	R	...	...	...	...	...	...
senarius (Ehrenberg) Ehrenberg	...	C	C	F	F	...	R	C
splendens (Shadbolt) Ralfs	...	...	...	...	...	R	R	...
Cymatogonia amblyoceras (Ehrenberg) Hanna	...	...	...	...	...	...	...	F
Asterolampra marylandica Ehrenberg	...	F	R	...	R	...	R	...
Aulacodiscus argus (Ehrenberg) Schmidt	...	R	...	...	...	...	...	...
rogersii (Bailey) Schmidt	...	F	...	...	...	...	...	...
sollitianus Norman	...	R	...	R	...	F	...	...
Auliscus caballi Schmidt	R	...	...	...	...	...	...	...
pruinosus Bailey	...	...	...	...	...	...	R	...

TABLE 17—*Concluded*

	Sample Number							
	1	2	3	4	5	6	7	8
Pseudauliscus spinosus (Christian) Rattray		R				R		
Biddulphia decipiens Grunow		F	C		F	C	F	F
semicircularis (Brightwell) Boyer					R			R
tuomeyi (Bailey) Roper		F			R			
Zygoceros quadricornis Grunow					R			
Triceratium americanum Ralfs		R						
argus Janisch						R		
interpunctatum Grunow	R	F	F	R		F		
kainii Schultze							R	R
tessellatum Greville					F	R	R	F
Hemiaulus bipons (Ehrenberg) Grunow		F	F		R	F	R	F
polymorphus Grunow							C	F
Ploiaria petasiformis Pantocsek					R		R	
Mastogonia crux Ehrenberg		F	R				F	
Stephanogonia actinoptychus (Ehrenberg) Grunow		F						
Periptera tetracladia Ehrenberg					R			
Goniothecium rogersii Ehrenberg		F	R	R	R	F		
Dossettia lacera (Forti) Hanna	R					R	R	R
Xanthiopyxis oblonga Ehrenberg						R		R
Pseudopyxilla capreolus var. *gracilior* Forti								R
Rhaphoneis amphiceros Ehrenberg					R			F
angustata Pantocsek	F	F						F
elegans Pantocsek and Grunow		C			R			
gemmifera Ehrenberg	R	C	F	F	F	F	F	
immunis Lohman, n. sp.		F						
parilis Hanna			R					
scalaris Ehrenberg	R	F		F	R			F
wicomicoensis Lohman, n. sp.					R			
Sceptroneis caducea Ehrenberg			F			F	R	
Dimerogramma novae-caesareae Kain and Schultze			F				R	R
Thalassiothrix longissima Cleve and Grunow	F	F	F		F		F	F
Cocconeis costata Gregory		F	R		F	F	F	C
Navicula lyra Ehrenberg					R		R	R
Raphidodiscus marylandicus Christian							R	
Diploneis prisca (Schmidt) Cleve	R		R		R	R	F	F
subcincta (Schmidt) Cleve								F
Pleurosigma affine var. *marylandica* Grunow	R		R		F	F	R	

TABLE 18

Age Significance of Diatom Species of the L. G. Hammond Well No. 1

	Number	Percent
New species	11	12.5
Extinct species, known only from middle Miocene rocks	37	41.5
Extinct species with long geologic ranges	5	5.5
Long-ranging species represented in living floras	36	40.5
	89	100.

material has been of considerable help in making both the age assignment and the correlation of this core.

SYSTEMATIC DESCRIPTIONS

The classification of the diatoms has been fairly stable since 1896, when Schütt proposed a reasonable and workable classification, published in Engler and Prantl's Naturliche Pflanzenfamilien. In his scheme, the diatoms are divided into two suborders, the Centricae, in which the structure and markings are related to a central point, and the Pennatae, in which the structure and markings are related to a longitudinal line. Aside from minor changes in the naming of the suborders and slight rearrangement of families, little real change and almost no improvements have been introduced during the 40 years following the first appearance of Schütt's classification. In 1937 Hendey (47, p. 199) proposed a new classification based in part on Schütt's earlier one, but eliminating the twofold separation into centric and pennate forms. As Hendey has pointed out, such genera as *Biddulphia*, *Chaetoceros*, *Rhizosolenia*, *Anaulus*, and *Triceratium* do not fall into either of Schütt's major divisions. For convenience, Schütt and all who have followed him have included the above genera, as well as others equally unfit, in the Centricae. Hendey considers the diatoms as a class of Algae, Bacillariophyceae, comprising 1 order, Bacillariales, which is divided into 10 suborders. The 10 suborders are again divided into families and subfamilies in the customary manner. The scheme is simple and workable and removes many of the anomalies and ambiguities inherent in the older system.

Complete synonymies have not been attempted, as to do so would have lengthened the report out of all proportion. For the same reason, descriptions have been given only for species that were considered to be new or inadequately described elsewhere. All of the species for which adequate specimens were available have been illustrated. The magnifications given in the explanations to the plates have been rounded slightly and may be in error by a few percent due to slight dimensional changes resulting from the various printing processes. The dimensions given, however, are as exact as possible and should be used to obtain precise magnifications on the final printed page, when and if such information is needed.

With the single exception of *Sceptroneis caducea* Ehrenberg, (Pl. XI, fig. 7) all of the photomicrographs were made from specimens from the Hammond core. In this case, no complete, well-oriented specimen could be found in the material from the core, therefore a satisfactory specimen was selected from a collection from the Calvert formation, the locality data for which is given in the discussion of the species and in the explanation of the plate.

ALGAE

Class BACILLARIOPHYCEAE

Order BACILLARIALES

Suborder DISCINEAE

Family COSCINODISCACEAE

Subfamily MELOSIROIDEAE

Genus MELOSIRA Agardh, 1824

Melosira complexa Lohman, n. sp.

(Plate V, figs. 1-7)

Valve circular, convex, 40 to 70μ in diameter. Margin complex, divided into outer, intermediate, and inner zones. Outer zone, $2\frac{1}{2}$ to 5μ wide with irregular, dominantly radial striae, 5 to 8 in 10μ; intermediate zone 3 to $4\frac{1}{2}$μ wide, composed of a single annular ring of radial areolae, 6 to 7 in 10μ, underlain by the inner zone 4 to 5μ wide, composed of fine puncta, 11 to 18 in 10μ, arranged in curved, decussating rows. Central portion hyaline with domed center, with or without irregularly scattered puncta, and sometimes with an annular zone about 25μ in diameter and 2μ wide composed of radial costae, 11 in 10μ.

Holotype: U.S.G.S. diatom catalog no. 2363-37, diameter, 67μ (Pl. V, figs. 4, 5). U.S.G.S. diatom locality no. 3076, sample 3 from depth of 1020-1030 feet in Ohio Oil Company, Larry G. Hammond No. 1 well, near Salisbury, Wicomico County, Maryland. Calvert formation, middle Miocene.

Paratypes: U.S.G.S. diatom catalog no. 2377-8, diameter 65μ (Pl. V, figs. 6, 7). U.S.G.S. diatom locality no. 3080, sample 7 from depth of 1108 feet in above well. U.S.G.S. diatom catalog no. 2368-62, diameter 42μ (Pl. V, figs. 1, 2, 3). U.S.G.S. diatom locality no. 3081, sample 8 from depth of 1130-1140 feet in above well.

A number of views are needed to adequately illustrate this complex and variable species. The outer zone is best shown in the holotype (Pl. V, fig. 4). The intermediate zone is well shown in the same specimen at a different focus, (Pl. V, fig. 5) and in both paratypes (Pl. V, figs. 2, 6). The central portion is one of the most variable parts of this tiny species. Some specimens (Pl. V, figs. 4-7) have the central area irregularly covered with large puncta with a domed hyaline mound about 1 radius in diameter. Others have the annular zone shown in Plate V, figure 1. This annular zone is very similar to a zone characteristic of *M. sulcata* (Ehrenberg) Kützing. The single annular zone of areolae constituting part of the intermediate zone is also suggestive of *M. sulcata*, but the outer zone is totally different.

Found frequently in samples 3 and 6 and rarely in samples 7 and 8.

Melosira sulcata (Ehrenberg) Kützing

Gaillonella sulcata Ehrenberg, Die Infusionsthierchen als vollkommene Organismen, p. 170, pl. 21, fig. 5, 1838.

Melosira sulcata (Ehrenberg) Kützing, Die Kieselchaligen Bacillarien oder Diatomeen, p. 55, pl. 2, fig. 7, 1844.

Schmidt, Atlas der Diatomaceenkunde, pl. 178, figs. 1-5, 7-19, 22-24, 1893.

Lohman, U. S. Geol. Survey Prof. Paper 196-B, p. 64, pl. 12, fig. 1, 1941.

Paralia sulcata (Ehrenberg) Cleve, K. svenska akad. Handl., Bihang, Band 1, no. 13, p. 7, 1873.

Boyer, Maryland Geol. Survey, Miocene, p. 491, pl. CXXXV, fig. 9, 1904.

This variable species was found abundantly in all of the samples from the core. Its known geologic range covers all of the Tertiary and a variety has been reported from the Cretaceous.

Subfamily SKELETONEMOIDEAE

Genus ENDICTYA Ehrenberg, 1845

Endictya robusta (Greville) Hanna and Grant

(Plate VI, fig. 4)

Coscinodiscus robustus Greville, London Micr. Soc. Trans., new ser., vol. 14, p. 3, pl. 1, fig. 8, 1866.
Schmidt, Atlas der Diatomaceenkunde, pl. 62, figs. 16, 17, 1878.
Endictya robustus (Greville) Hanna and Grant, California Acad. Sci. Proc., 4th ser., vol. 15, no. 2, p. 144, pl. 16, figs. 2, 3, 1926.

Although this species is still living, it reached its heyday in upper Miocene time, where it was much more abundant than in the middle Miocene Calvert formation. Boyer (8, p. 506) did not record it from the Calvert, although he did report *Coscinodiscus marginatus* Ehrenberg, with which it is frequently confused.

Diameter of figured specimen (U.S.G.S. diatom catalog no. 2362–32), 68μ, from sample 2.

Found frequently in samples 1, 2, 3, 8 and commonly in sample 6.

Genus STEPHANOPYXIS Ehrenberg, 1844

Stephanopyxis corona (Ehrenberg) Grunow

Systephania corona Ehrenberg, K. Akad. Wiss. Berlin, Ber., p. 272, 1844.
Ehrenberg, Mikrogeologie, pl. 33, group XV (Hollis Cliff, Virginia), fig. 22, 1854.
Stephanopyxis corona (Ehrenberg) Grunow, in Van Heurck, Synopsis des diatomées Belgique, pl. 83ter, figs. 10, 11, 1881.
Schmidt, Atlas der Diatomaceenkunde, pl. 123, figs. 10–17, 19, 20; pl. 130, figs. 13, 16, 17, 36, 1888.
Boyer, Maryland Geol. Survey, Miocene, p. 490, pl. CXXXV, fig. 13, 1904.

Found frequently in sample 2, and commonly in samples 3 and 6.

Stephanopyxis grunowii Grove and Sturt

Stephanopyxis grunowii Grove and Sturt, in Schmidt, Atlas der Diatomaceenkunde, pl. 130, figs. 1–5, 1888.

Since its original description from the Oligocene diatomite in Oamaru, New Zealand, this diatom has been reported from the Upper Cretaceous Moreno shale of California by Hanna, (42, p. 33, pl. 4, fig. 12) to Recent by Van Heurck (109, p. 31, pl. 6, fig. 89) although the recent material was dredged and thus may have come from a submarine outcrop of unknown age.

Found frequently in samples 6 and 7.

Stephanopyxis joynsonii Schmidt

Stephanopyxis joynsonii Schmidt, Atlas der Diatomaceenkunde, pl. 123, fig. 9, 1888 (Barbadoes).
Tempère and Peragallo, Diatomées du Monde Entier, 2nd Ed., p. 374, 1907 (Pope's Creek, Md., Calvert formation).

The specimens found in the core agree with Schmidt's original figure, except that my specimens have a faintly striated border, whereas Schmidt's figure shows the border completely hyaline.

Found rarely in samples 3 and 6.

Stephanopyxis lineata (Ehrenberg) Forti

(Plate VI, fig. 3)

Stephanodiscus? lineatus (= *Peristephania lin.?*) Ehrenberg, Mikrogeologie, pl. 33, group XIII (San Francisco, Calif.), fig. 22, 1854.
Stephanopyxis lineata (Ehrenberg), Forti, Nuova Notarisia, 1912, p. 83.
Forti, R. ist. veneto sci. Atti, vol. 72, pt. 2, p. 1547, pl. 11, figs. 21, 23; pl. 12, fig. 3, 1913.
Hanna, California Acad. Sci. Proc., 4th ser., vol. 20, p. 219, pl. 16, figs. 9, 10, 11, 1932.

The specimens from the core are identical with Ehrenberg's original figure and could easily be confused with *Coscinodiscus lineatus* Ehrenberg (Pl. VII, fig. 2) except for the high marginal spines characteristic of *S. lineata*. This similarity has been pointed out by Hanna, but his figure 9 has the more nearly radial arrangement of the areolae characteristic of *S. corona*. His figures 10 and 11 are undoubtedly *S. lineata*. This species is characteristic of the middle Miocene from all over the world.

Diameter of figured specimen (U.S.G.S. diatom catalog no. 2368–57), 61μ. From sample 8, where it occurs frequently.

Stephanopyxis turris (Greville and Arnott) Ralfs

Creswellia turris Greville and Arnott, Royal Soc. Edinburgh Trans., vol. 21, pt. 4; p. 64, pl. 6, fig. 109, 1857.
Stephanopyxis turris (Greville and Arnott) Ralfs, in Pritchard, A., History of the Infusoria, 4th ed., p. 826, pl. 5, fig. 74, 1861.
Schmidt, Atlas der Diatomaceenkunde, pl. 130, figs. 42, 43, 1888.

Many of the specimens found were whole frustules, with the two valves tightly joined and spines intact. This species has a long geologic range, from Cretaceous (90, p. 397) to Recent (72, p. 145).

Frequent in samples 1, 2, 3, and 6 and common in sample 8.

Subfamily COSCINODISCOIDEAE

Genus COSCINODISCUS Ehrenberg, 1838

Coscinodiscus apiculatus Ehrenberg

(Plate VI, fig. 2)

Coscinodiscus apiculatus Ehrenberg, K. Akad. Wiss. Berlin, Ber., 1844, p. 77.
Ehrenberg, Mikrogeologie, pl. 18, fig. 43, 1854 (Richmond, Va.)
Schmidt, Atlas der Diatomaceenkunde, pl. 64, fig. 5–9, 1878.
Boyer, Maryland Geol. Survey, Miocene, p. 503, pl. CXXXIV, fig. 13, 1904. (Calvert formation, Maryland).
Hanna, California Acad. Sci., 4th ser., vol. 20, p. 178, pl. 6. fig. 1, 1932 (Temblor formation, middle Miocene, California).

This is one of the most abundant and characteristic species of the Calvert formation along the Atlantic Coastal Plain and the Middle Miocene part of the Temblor formation in California. It is often confused with *Coscinodiscus perforatus* Ehrenberg which has more obvious radial rows of areolae becoming smaller toward the margin. *C. perforatus* also has a secondary structure of the areolae, which is well shown by Hustedt's (53, p, 445, fig. 245) figure. Although its geologic range is lower Miocene to Recent, it is most abundant in the middle Miocene.

Frequent in samples 1, 2, 5, and common in samples 3 and 4.

Dimensions of figured specimen (U.S.G.S. diatom catalog no. 2373–38), 77μ, from sample 3.

Coscinodiscus arcus Lohman n. sp.

(Plate VI, fig. 1)

Valve circular, 60 to 85μ in diameter, flat except for slightly raised annular zone about $\frac{1}{3}$ of the radius from the margin; polygonal areolae, 6 to 7 in 10μ at semiradius, somewhat closer toward center and margin; areolae in poorly defined fasciculi with rows parallel to center radial row in each fasciculus; secondary oblique rows very evident, especially in the central portion. No rosette or central space. Marginal zone $3\frac{1}{2}\mu$ wide containing fine areolae, 12 to 13 in 10μ in oblique, decussate rows forming a series of overlapping cusps or arcs; marginal apiculi 6 to 7μ apart; marginal striae very fine, 20 to 10μ.

Holotype: U.S.G.S. diatom catalog no. 2376-14, diameter 80μ. U.S.G.S. diatom locality no. 3079, sample 6 from depth of 1077 feet in Ohio Oil Company Larry G. Hammond No. 1 well, near Salisbury, Wicomico County, Maryland. Calvert formation, middle Miocene.

The absence of definite fasciculi and the presence of the marginal zone of fine decussating areolae forming cusps or arcs and culminating in fine marginal apiculi separate this species from *C. subtilis* Ehrenberg and the group centered around *C. rothii* (Ehrenberg) Grunow.

Found rarely in samples 2 and 6 and frequently in sample 3.

Coscinodiscus asteroides Truan and Witt

(Plate VII, fig. 1)

Coscinodiscus asteroides Truan and Witt, Die Diatomaceen der Polycystinenkreide von Jeremie in Hayti, p. 13, pl. 3, fig. 2, 1888.
Rattray, Royal Soc. Edinburgh Proc., vol. XVI, p. 522, 1889.
Boyer, Maryland Geol. Survey, Miocene, p. 504, pl. CXXXIV, fig. 14, 1904.

This large and striking diatom occurs frequently in Miocene strata in the West Indies, the central Atlantic Coastal Plain, and in Japan (10, p. 70), but has not been reported in rocks of the same age in the Western United States. It is a good marker species for the Calvert formation of Maryland and Virginia.

Diameter of figured specimen (U.S.G.S. diatom catalog 2372-1), 181μ, from sample 2.

Found frequently in samples 2, 6, and 8.

Coscinodiscus asteromphalus Ehrenberg

Coscinodiscus asteromphalus Ehrenberg, K. Akad. Wiss. Berlin, Ber., 1844, p. 77, 1845.
Ehrenberg, Mikrogeologie, pl. 18 (Richmond, Va.), fig. 45; pl. 33, group 15 (Hollis Cliff, Va.), fig. 7, 1854.
Schmidt, Atlas der Diatomaceenkunde, pl. 63, fig. 12, 1878; pl. 113, fig. 22, 23, 1888.
Lohman, U. S. Geol. Survey Prof. Paper 196-B, p. 70, pl. 13, fig. 11, 1941.

For a discussion of the geologic range of this species, see the last reference above. Frequent in samples 1, 5, 8 and common in samples 2 and 6.

Coscinodiscus centralis Ehrenberg

Coscinodiscus centralis Ehrenberg, K. Akad. Wiss. Berlin, Abh., 1838, p. 129.
Ehrenberg, Mikrogeologie, pl. 18 (Richmond, Va.), fig. 39, 1854.
Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 444, fig. 243, 1928.

This very large diatom, which often attains a diameter of $\frac{1}{3}$ mm., was represented by rare fragments only in sample 2. The long, radial hyaline spaces (well shown in Hustedt's figure) make it possible to identify this species with only a marginal fragment.

Its known geologic range is Miocene to Recent.

Coscinodiscus convexus Schmidt

Coscinodiscus convexus Schmidt, Atlas der Diatomaceenkunde, pl. 60, fig. 15, 1878.
Hanna, California Acad. Sci. Proc., 4th ser., vol. 20, p. 179, pl. 6, figs. 2, 3; pl. 7, fig. 1, 1932.

The earliest recorded occurrence of this large and distinctive diatom is from the Upper Cretaceous Moreno shale in California (68, p. 103). Its known upper limit is Miocene. It has not been reported previously from the Calvert formation, but it occurs frequently in samples 3, 5, and 6, and rarely in sample 2. It occurs frequently to commonly in the middle Miocene part of the Temblor formation in a number of localities in California, notably on Phoenix Ridge, 8 miles north of Coalinga, Fresno County. It appears probable that this species has not been reported from the Calvert formation previously because it has been confused with *C. asteromphalus* Ehrenberg. It is very much more convex and does not have the highly developed central rosette characteristic of *C. asteromphalus*.

Coscinodiscus crassipunctatus Forti

(Plate VI, fig. 5)

Coscinodiscus rhombicus var. *crassipunctatus* Forti, R. ist. veneto sci. Atti, Tome 72, part 2, p. 1570, pl. 3, fig. 23, 24, 1913.
Laporte and Lefébure, Diatomées rares et curieuses, vol. 1, pl. 3, fig. 29, 1929.

Valve rhomboidal in outline, with rounded angles; puncta coarse, scattered without order, 2½ to 5 in 10μ, becoming closer toward margin; marginal striae, 10–11 in 10μ. Length, 60–110μ; width, 30 to 45μ.

Grunow (39, pl. 129, fig. 3, 1883) and Castracane (11, p. 164, pl. 22, fig. 11) independently used the name *Coscinodiscus rhombicus* for two species which have the same rhomboidal shape, but have many differences that are here considered sufficient to place them in different species. Grunow's *C. rhombicus* has priority, making *C. rhombicus* Castracane a homonym. Forti named a much more coarsely marked form a variety *crassipunctata* of Castracane's species, to which it is definitely related. As Forti's diatom came from the Miocene of Italy, and Castracane's came from the Sea of Japan and is therefore presumably Recent, it appears preferable to avoid the genetic anomaly of having a Miocene variety of a Recent species by raising *crassipunctata* to specific rank.

Kain and Schultze (58, p. 74) listed *C. rhombicus* Castracane from the northern extension of the Calvert formation in the Atlantic City, New Jersey, well. It seems probable that the diatom they found there was actually *C. crassipunctatus*. If so, it constitutes the earliest record of this diatom.

The specimens in the core appear to be identical with those from the Miocene of Italy, thus making this another species with a short geologic range and extensive geographic distribution.

Length of figured specimen (U.S.G.S. diatom catalog 2372–3), 63μ; width, 30μ.

Found frequently in sample 2.

Coscinodiscus curvatulus Grunow

Coscinodiscus curvatulus Grunow, in Schmidt, Atlas der Diatomaceenkunde, pl. 57, fig. 33, 1878.
Lohman, U. S. Geol. Survey Prof. Paper 196-B, p. 74, pl. 15, fig. 8, 1941.

This species is known from the whole Tertiary and the Recent. It was found rarely in samples 2 and 3.

Coscinodiscus curvatulus var. minor (Ehrenberg) Grunow

Coscinodiscus minor Ehrenberg, K. Akad. Wiss. Berlin, Physikal. Abh. 1838, p. 129, pl. 4, fig. 12e, 1840.

Coscinodiscus curvatulus var.? *minor* (Ehrenberg) Grunow, Akad. Wiss. Wien, Math.-naturwiss. Kl., Denkschr., Band 48, p. 83, pl. 4 (D), figs. 8–10, 1884.
Lohman, U. S. Geol. Survey Prof. Paper 196-B, p. 75, pl. 15, fig. 3, 1941.

The geologic range of this tiny variety is similar to that of the type, with which it is frequently associated.

Found rarely in samples 2 and 6.

Coscinodiscus excentricus Ehrenberg

Coscinodiscus excentricus Ehrenberg, K. Akad. Wiss., Berlin, Physikal. Abh., 1839, p. 146, 1841.
Schmidt, Atlas der Diatomaceenkunde, pl. 58, figs. 46–49, 1878.
Lohman, U. S. Geol. Survey Prof. Paper 196-B, p. 67, pl. 12, fig. 7; pl. 13, fig. 8, 1941.

This is one of the most common diatoms known and one very frequently mis-identified. Its surface is usually flat, or very nearly so, and the areolae are only slightly smaller near the margin than at the center. The marginal apiculi are frequently lacking, particularly in worn specimens, causing confusion with the center of *Planktoniella sol* (Wallich) Schütt.

Found frequently in samples 1, 2, 3, 5, and 8.

Coscinodiscus kützingi Schmidt

Coscinodiscus kützingi Schmidt, Atlas der Diatomaceenkunde, pl. 57, figs. 17, 18, 1878.
Rattray, Royal Soc. Edinburgh, Proc. vol. 16, p. 481, 1889.
Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 398, fig. 209, 1928.

Hustedt's figure is the best available, from which these specimens differ in having more numerous and narrower fasciculi. The highly characteristic marginal zone of fine areolae arranged in quincunx with the narrow striated border is present, exactly as in Hustedt's figure. Schmidt's original figures do not show the submarginal apiculi, which are present in these specimens and in Hustedt's figure.

The finding of this diatom in the part of the core assigned to the Calvert formation represents its earliest known occurrence. It occurs rarely to frequently in the Pliocene part of the Tulare formation and the Pliocene San Joaquin formation in the Kettleman Hills, California (66, p. 82).

Found rarely in sample 2.

Coscinodiscus lewisianus Greville

(Plate VI, fig. 7)

Coscinodiscus lewisianus Greville, Trans. Micr. Soc. London, 1866, p. 78, pl. 8, figs. 8–10.
Schmidt, Atlas der Diatomaceenkunde, pl. 66, fig. 12, 1881, (Nottingham, Md.)
Rattray, Royal Soc. Edinburgh, Proc., vol. 16, p. 598, 1889.
Boyer, Maryland Geol. Survey, Miocene, p. 505, pl. CXXXIV, fig. 16, 1904.
Reinhold, Nederland en Koloniën, Geol.-Mijnbouwk, Genootschap, Verh., Geol. Ser., Deel 12, p. 96, pl. 8, fig. 11, 1937.

This distinctive diatom is a good marker species for the Miocene along the Atlantic Coastal Plain. It has never been reported from rocks older or younger than Miocene. The round markings are dominantly arranged in rows parallel to the long axis of the valve, whereas in *C. rhomicus* Grunow, the only species with which it might be confused, the markings are arranged almost at random and never even approximate parallel rows.

Found rarely in samples 1, 3, 5, 6, and 8.

Length of figured specimen (U.S.G.S. diatom catalog 2366–21), 62μ, from sample 6.

Coscinodiscus lewisianus var similis Rattray

(Plate VI, fig. 6)

Coscinodiscus lewisianus var *similis* Rattray, Royal Soc. Edinburgh Proc., vol. 16, p. 598, pl. III, fig. 10, 1889.

Boyer (8, p. 505) favored lumping this variety with the type, with which I cannot agree. The rhombic shape of this variety distinguishes it at once from the rounded, elliptical shape of the type. Consistent, easily recognizable differences of this kind are extremely useful when these microfossils are used in zoning and correlation. The variety was found only in sample 8, at the base of the Calvert formation.

Length of figured specimen (U.S.G.S. diatom catalog 2378–12), 68μ.

Coscinodiscus lineatus Ehrenberg

(Plate VII, fig. 2)

Coscinodiscus lineatus Ehrenberg, K. Akad. Wiss. Berlin, Physikal. Abh. 1838, p. 129, 1839.
Ehrenberg, Mikrogeologie, pl. 18, fig. 33; pl. 22, fig. 6; pl. 35A, group 16, fig. 3; group 17, fig. 7, 1854.
Rattray, Royal Soc. Edinburgh Proc., vol. 16, p. 472, 1889.
Boyer, Maryland Geol. Survey, Miocene, p. 506, pl. CXXXV, fig. 1, 1904.

This is a cosmopolitan species with a known geological range of Cretaceous (90, p. 390) to Recent.

Found rarely in sample 1, frequently in samples 3, 7, 8, and commonly in sample 6.

Diameter of figured specimen (U.S.G.S. diatom catalog no. 2377–43), 88μ, from sample 7.

Coscinodiscus marginatus Ehrenberg

(Plate VII, fig. 4)

Coscinodiscus marginatus Ehrenberg, K. Akad. Wiss. Berlin, Physikal. Abh. 1841, p. 142, 1843.
Ehrenberg, Mikrogeologie, pl. 18, fig. 44; pl. 33, group 12, fig. 13; pl. 38B, group 22, fig. 8, 1854.
Lohman, U. S. Geol. Survey Prof. Paper 196-B, p. 71, pl. 14, figs. 1, 6, 1941.

This is another very long ranging species, having been reported from the Cretaceous (68, p. 104, pl. 16, fig. 13) to the Recent (47, p. 248). It is quite variable and included in the species are forms with discrete, separated, rounded areolae, as in the example chosen to illustrate this paper, and also forms with touching hexagonal areolae, as, for example, fig. 1, in the last reference in the synonymy.

Diameter of figured specimen (U.S.G.S. diatom catalog no. 2369–23), 55μ, from sample 1.

Found frequently in sample 1 to 5, inclusive, and commonly in samples 6 to 8, inclusive.

Coscinodiscus monicae Grunow

(Plate VII, fig. 6)

Coscinodiscus janischii var.? *monicae* Grunow, Akad. Wiss. Wien, Math.-naturwiss. Kl. Denkschr., Band 48, p. 76, 1884.
Coscinodiscus monicae Grunow, Rattray, Royal Soc. Edinburgh Proc., p. 563, 1889.
Schmidt, Atlas der Diatomaceenkunde, pl. 63, fig. 10, 1878 (no name).
Hanna, California Acad. Sci. Proc., 4th ser., vol. 20, p. 182, pl. 9, fig. 2, 1932.

Found rarely in sample 4. Diameter of figured specimen (U.S.G.S. diatom catalog 2377–44), 154μ, from sample 4.

Coscinodiscus obscurus Schmidt

(Plate VII, fig. 3)

Coscinodiscus obscurus Schmidt, Atlas der Diatomaceenkunde, pl. 61, fig. 16, 1878.
Rattray, Royal Soc. Edinburgh Proc., vol. 16, p. 513, 1889.
Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 418, fig. 224, 1928.

Hustedt's figure and description are the best published. The small clear spaces at the origins of the shorter radial rows of areolae are especially noteworthy and diagnostic, but may not be visible in my illustration. The size of the central space is quite variable; the specimen figured is average.

This is one of the dominant species, being common in six out of eight samples. It has been reported from the Calvert formation (101, 2nd ed. p. 163) of Maryland and I have found it in Miocene and Pliocene deposits in California.

Diameter of figured specimen (U.S.G.S. diatom catalog no. 2369–1), 102μ, from sample 1.

Found commonly in samples 1, 2, 3, 4, 6, and 7.

Coscinodiscus oculus-iridis Ehrenberg

Coscinodiscus oculus-iridis Ehrenberg, K. Akad. Wiss. Berlin, Abh., 1839, p. 147.
Ehrenberg, Mikrogeologie, pl. 18, fig. 42; pl. 19, fig. 2; pl. 21, fig. 3, 1854.
Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 454, fig. 252, 1928.

This large diatom is another species with a long geologic range covering the whole of the Tertiary and with a wide distribution in modern seas.

Found frequently in samples 1, 5, 8, and commonly in sample 6.

Coscinodiscus perforatus Ehrenberg

Coscinodiscus perforatus Ehrenberg, K. Akad. Wiss. Berlin, Ber., 1844, p. 78.
Ehrenberg, Mikrogeologie, pl. 18, fig. 46, 1854.
Schmidt, Atlas der Diatomaceenkunde, pl. 64, figs. 12–14, 1878.
Rattray, Royal Soc. Edinburgh, Proc., vol. 16, p. 571, 1889.
Boyer, Maryland Geol. Survey, Miocene, p. 506, pl. CXXXV, fig. 2, 1904.
Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 445, fig. 245, 1928.

This is another common species characteristic of the Calvert formation. It is often confused with *C. apiculatus* Ehrenberg, although the differences between the two are real and consistent. *C. apiculatus* has coarser, more uniform and simple areolae. In *C. perforatus* the areolae are smaller near the margin and near the central space; the areolae are not simple, but have a complex secondary structure (well shown in Hustedt's figure), and small puncta occur at the origin of the shorter radial rows of areolae.

The known geologic range of this species is Miocene to Recent.

Found commonly in samples 2, 4, 5, 6, 7, and frequently in samples 1 and 3.

Coscinodiscus perforatus var. cellulosa Grunow

(Plate VIII, fig. 3)

Coscinodiscus perforatus var. *cellulosa* Grunow, K. Akad. Wiss. Wien, Math.-naturwiss. Kl. Denkschr., Band 48, p. 75, 1884.
Schmidt, Atlas der Diatomaceenkunde, pl. 114, fig. 5, 1888.
Rattray, Royal Soc. Edinburgh, Proc., vol. 16, p. 572, 1889.
Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 447, fig. 246, 1928.

The forms assigned to this variety deviate from the original description of Grunow and the subsequent descriptions of Rattray and Hustedt in having a few free, rounded areolae near the margin on one side. The agreement in all other respects is very good, particularly such features as the size and distribution of the areolae, the small puncta at the origin of the shorter radial rows of areolae, the presence of the central space, and the absence of a rosette.

Coscinodiscus kurzii Grunow (41, pl. 113, fig. 17) might be confused with this variety, as one of the most characteristic features of *C. kurzii* is the presence of free rounded areolae near the margin on one side. In *C. kurzii*, however, the hexagonal areolae are much larger at the semiradius than at the margin or center, whereas in the variety *cellulosa* they are virtually constant between $\frac{1}{10}$ and $\frac{9}{10}$ of the radius.

Rattray listed this variety from a number of localities, including Nottingham, Maryland (most certainly the Calvert formation), Japan, Oamaru, New Zealand (Oligocene), and several Recent occurrences.

Diameter of figured specimen (U.S.G.S. diatom catalog no. 2372–27), 79μ, from sample 5.

Found frequently in samples 2, 3, 6, 7, and rarely in samples 4, 5, and 8.

Coscinodiscus radiatus Ehrenberg

Coscinodiscus radiatus Ehrenberg, K. Akad. Wiss. Berlin, Abh., 1839, p. 148, pl. 3, fig. 1 A-C.
Lohman, U. S. Geological Survey Prof. Paper 196-B, p. 73, pl. 14, figs. 7, 8, 1941.

This widespread and common species was found frequently in samples 1, 2, 5, and 8.

Coscinodiscus salisburyanus Lohman, n. sp.

(Plate VII, fig. 5)

Valve circular, flat, with small, irregular central space 4 to 5μ in maximum dimension; 2 to 4 irregularly rounded granules occupy this space. Hexagonal areolae in very definite fasciculi, with straight rows parallel to a radius constituting one side of each fasciculus; areolae 6 to 7 in 10μ near the margin and near the central space, 5 in 10μ at the semiradius. Margin very narrow, with radial striae 13 in 10μ; immediately inside of the margin is a single circular row of round puncta, 14 in 10μ. Diameter, 43μ.

Holotype: U.S.G.S. diatom catalog no. 2370–16, diameter, 43μ. U.S.G.S. diatom locality no. 3074, core sample 1 from Ohio Oil Co., Larry G. Hammond No. 1 well, near Salisbury, Wicomico County, Maryland. Depth 1000–1010 feet; Calvert formation, middle Miocene.

Two identical specimens of this diatom were found in the samples from the well, one at a depth of 1000 feet (the holotype) and the other at a depth of 1077 feet (sample 6). *Coscinodiscus nodulifer* Schmidt (89, pl. 59, figs. 20-23, 1878), with which this species may be confused, has non-fasciculate areolae and the prominent central nodule. *Coscinodiscus aeginensis* Schmidt (89, pl. 133, figs. 13, 14, 1888) another diatom which is closely related to this species and which might be confused with it, has coarser markings, the fasciculation is irregularly curved when present, and the marginal striae are very much coarser.

Coscinodiscus stellaris Roper

Coscinodiscus stellaris Roper, Quart. Jour. Micr. Sci., vol. 6, p. 21, pl. 3, fig. 3, 1858
Rattray, Royal Soc. Edinburgh Proc., vol. 16, p. 493, 1889.
Schmidt, Atlas der Diatomaceenkunde, pl. 164, fig. 4, 1891.
Lohman, U. S. Geol. Survey Prof. Paper 196-B, p. 68, pl. 13, fig. 2, 1941.

The last reference contains a discussion of the nomenclatorial tangle involving this species. Its geologic range of Miocene to Recent makes it of little value as a stratigraphic marker.

Found rarely in samples 5, 6, and frequently in samples 7 and 8.

Genus LIRADISCUS Greville, 1865

Liradiscus bipolaris Lohman n. sp.

(Plate VIII, fig. 5)

Valve oblong with rounded ends, sometimes very slightly constricted in center; valve flat with two low and gentle elevations or poles about 20μ from each end; curved, linear anastomosing markings radiating from the two elevations, although sometimes feebly; interspaces hyaline; margin narrow, hyaline. Length, 40 to 50μ; width 14 to 19μ.

Holotype: U.S.G.S. diatom catalog no. 2366–29, length 49μ, width 19μ. U.S.G.S. diatom locality no. 3079, sample 6 from depth of 1077 feet in Ohio Oil Company Larry G. Hammond No. I well, near Salisbury, Wicomico County, Maryland. Calvert formation, middle Miocene.

This distinctive species has been found in the "Indicator bed" in the middle Miocene part of the Temblor formation in Oil Canyon, 8 miles north of Coalinga, Fresno County, California. The bipolar arrangement of the markings is more evident in the California specimens than in those from the Hammond well, otherwise the two are identical.

Found rarely in sample 6.

Liradiscus minimus Lohman n. sp.

(Plate VIII, fig. 4)

Valve circular, very slightly convex, with narrow, hyaline margin; linear or curved anastomosing markings forming irregular network; at half the radius the markings form a ring concentric with the margin; interspaces hyaline; a poorly defined annulus between the concentric ring and the central markings, which form a somewhat closer mesh than those near the margin. Diameter of valve, 17μ.

Holotype: U.S.G.S. diatom catalog no. 2368–6, diameter 17μ. U.S.G.S. diatom locality no. 3081, sample 8 from depth of 1130–1140 feet in Ohio Oil Company, Larry G. Hammond No. 1 well, near Salisbury, Wicomico County, Maryland. Calvert formation, middle Miocene.

Less than a dozen species have been assigned to Greville's genus *Liradiscus* and this one is quite different from any of them, and very much smaller.

Found rarely in sample 8.

Genus CESTODISCUS Greville 1865

Cestodiscus Greville, London Micr. Soc. Trans., new ser., vol. 13, p. 48, pl. 5, figs. 8, 9, 1865.
Grunow, in Van Heurck, Synopsis diatomées Belgique, pl. 126, 1883.
Castracane, Challenger Repts., Botany, vol. 2, p. 122, 1886.
De Toni, Sylloge Algarum, vol. 2, p. 1308, 1894.
Van Heurck, Treatise on the Diatomaceae, p. 491, 1896.
Reinhold, Nederland en Koloniën Geol.—Mijnbouwk. Genootschap Verh., Geol. Ser., Deel 12, p. 89, 1937.
Coscinodiscus (*Cestodisci*) Pantocsek, Fossilen Bacillarien Ungarns, Teil 1, p. 73, 1886.
Coscinodiscus (*Cestodiscoidales*) Rattray, Royal Soc. Edinburgh, Proc., vol. 16, p. 457, 1889.
De Toni, Sylloge Algarum, vol. 2, p. 1206, 1894.

Greville's genus *Cestodiscus* appears to be quite as distinct as other discoid genera, such as *Craspedodiscus*, *Actinocyclus*, etc., and should certainly not be lumped with *Coscinodiscus*. The circle of short, radial, usually hyaline markings, always at some distance inside the margin, but never extending to the center, clearly separate this genus from *Coscinodiscus*. Both Pantocsek and Rattray, who combined the two genera, were so impressed by the distinctness of *Cestodiscus* that they made a subgenus of it. De Toni was apparently even more confused, as on page 1206 of his Sylloge Algarum, vol. 2, he followed Rattray's lead in making a section of subgeneric rank called *Cestodiscoidales*. On page 1308 of the same volume he recognized 8 species and one variety of *Cestodiscus*.

In view of the need for more sharply defined limits for the genus *Coscinodiscus*, it seems wise to separate Greville's distinctive genus from it. With the exception of the six species assigned to this genus by Castracane, all presumably living species, most members of the genus are extinct and therefore valuable in stratigraphy.

Cestodiscus marylandicus Lohman n. sp.

(Plate VIII, figs. 1, 2)

Valve circular, convex, 40 to 50μ in diameter, divided into four annular zones: a central zone, about 20μ in diameter, with coarse, rounded punctate areolae, 6 to 7 in 10μ, arranged in radial rows; a second annular zone 5 to 7μ wide with punctuate polygonal areolae, 6 to 7 in 10μ, arranged in quincunx; a third annular zone 4 to 5μ wide containing fine puncta, 13 in 10μ arranged in radial rows, 13 in 10μ; and a fourth or marginal zone 3μ wide with prominent radial striae 12 to 13 in10μ. At the sharp dividing line between the third and fourth zones is a series of thick processes, 15 to 18μ apart extending inward from the outer part of zone 3. The topography of the valve is as follows: assuming the margin to be the datum, the 2nd annular zone is 5μ high, and the center is depressed to 4μ high.

Holotype: U.S.G.S. diatom catalog no. 2368–54, diameter 46μ. U.S.G.S. diatom locality no. 3081, core sample no. 8 from Ohio Oil Company, Larry G. Hammond No. 1 well, near Salisbury, Wicomico County, Maryland. Depth 1130–1140 feet. Calvert formation, middle Miocene.

The two figures give some idea of the topography of this complex species. In figure 1, the central zone and the prominent puncta on the bottom of the polygonal areolae of zone 2 are in focus. The polygonal areolae in zone 2 are out of focus and cannot be seen. Zone 3 is partly in focus in both figures but cannot be focussed simultaneously over its entire width as it slopes very steeply. The submarginal processes in zone 3 and the margin, or zone 4, are well shown in figure 2.

Found rarely in sample 8.

Genus CRASPEDODISCUS Ehrenberg, 1845

Craspedodiscus coscinodiscus Ehrenberg

(Plate VIII, fig. 6)

Craspedodiscus coscinodiscus Ehrenberg, K. Akad. Wiss. Berlin, Ber., 1844, p. 266, 1845.
Ehrenberg, Mikrogeologie, pl. 33, group 15, fig. 8, 1854.
Schmidt, Atlas der Diatomaceenkunde, pl. 66, figs. 3, 4, 1881.
Boyer, Maryland Geol. Survey, Miocene, p. 500, pl. CXXXV, fig. 3, 1904.
Craspedodiscus microdiscus Ehrenberg, Mikrogeologie, pl. 33, group 17, fig. 4, 1854.

This and the following are two excellent marker species for the Calvert formation. Both the species and the genus were originally described from exposures of this formation in Virginia.

Diameter of figured specimen (U.S.G.S. diatom catalog no. 2377–22), 114μ, from sample 7.

Found rarely in samples 1, 2, and 7.

Craspedodiscus elegans Ehrenberg

(Plate VIII, fig. 7)

Craspedodiscus elegans Ehrenberg, K. Akad. Wiss. Berlin, Ber., 1844, p. 266, fig. 12, 1845.
Ehrenberg, Mikrogeologie, pl. 33, group 18, fig. 2, 1854.
Schmidt, Atlas der Diatomaceenkunde, pl. 66, fig. 1, 1881.
Boyer, Maryland Geol. Survey, p. 501, pl. CXXXV, fig. 4, 1904.

The nearly complete specimen used to illustrate this species was chosen on account of a large air bubble covering most of the central zone. The difference in refraction between air and the mounting medium makes it possible to get the center of this huge diatom in fair focus at the same time as the outer zone. The intermediate zone is completely out of focus, as it rises to a higher elevation than either the marginal or central zones. The dark, eccentric, circular area in the central zone is the air bubble, within which the areolation is sharply defined.

Diameter of figured specimen (U.S.G.S. diatom catalog no. 2378–23) 224μ, from sample 8.

Found rarely in sample 8.

Genus ACTINOCYCLUS Ehrenberg, 1838

Actinocyclus octonarius Ehrenberg

(Plate VIII, fig. 8)

Actinocyclus octonarius Ehrenberg, Die Infusionsthierchen als vollkommene Organismen, p. 172, pl. 21, fig. 7, 1838.
Hendey, Discovery Repts., vol. 16, p. 262, 1937.
Lohman, U. S. Geol. Survey Prof. Paper 196-B, p. 77, pl. 16, fig. 4, 1941.
Actinocyclus ehrenbergii Ralfs, in Pritchard, A History of Infusoria, 4th ed., p. 834, 1861.
Boyer, Maryland Geol. Survey, Miocene, p. 502, 1904.

See the 2d or 3d citation above for reasons for returning to Ehrenberg's original name and abandoning the time-honored *A. ehrenbergii*.

This is one of the commonest species in the core and was found frequently in samples 3 and 7, commonly in samples 2, 4, and 5, and abundantly in sample 8.

Its known geologic range is Miocene to Recent.

Diameter of figured specimen (U.S.G.S. diatom catalog no. 2378–21), 130μ, from sample 8.

Actinocyclus partitus Grunow

(Plate IX, fig. 1)

Actinocyclus (*Ralfsii* var.) *partitus* Grunow, in Van Heurck, Synopsis diatomées Belgique, pl. 132, fig. 10, 1885 (Nottingham, Md.)
Actinocyclus partitus (Grunow), Rattray, Queckett Micr. Club Jour., ser. 2, vol. 4, p. 153, 1890.
De Toni, Sylloge algarum, vol. 2, p. 1169, 1894.

This striking species was originally described from the Calvert formation exposed near Nottingham, Maryland, and has never been recorded from any other locality, although it has been known for 61 years. The figure is incomplete, but is much more complete than the original and the only other known illustration. The ragged, hyaline annulus at the semiradius is one of the most striking features of this species.

Diameter of figured specimen (U.S.G.S. diatom catalog no. 2374–8), 62μ, from sample 4.

Found rarely in sample 4.

Family ACTINODISCACEAE

Subfamily STICTODISCOIDEAE

Genus STICTODISCUS Greville, 1861

Stictodiscus kittonianus Greville

(Plate IX, fig. 2)

Stictodiscus kittonianus Greville, London Micr. Soc. Trans., new ser., vol. 9, p. 77, pl. 10, figs. 2, 3, 1861.

Schmidt, Atlas der Diatomaceenkunde, pl. 74, figs. 16–18, 1882. (Nottingham, Md.)
Hanna, California Acad. Sci. Proc., 4th ser., vol. 20, p. 219, pl. 16, fig. 12, 1932. (Temblor formation, middle Miocene, California).

Many students of diatoms all over the world have studied and reported on the diatoms from the Calvert formation from various localities in Virginia, Maryland, and New Jersey, and in practically every list of species this small diatom has been represented. It is usually reported as rare and yet has a very wide distribution in rocks of middle Miocene age. It is also widespread and rare in the middle Miocene part of the Temblor formation in California.

The only time this species has been reported living has been by Mann (71, p. 269) who found it in a dredging from Station 4029H, Bering Sea. Hanna (45) later studied Mann's complete diatom flora from this one sample and came to the entirely defensible conclusion that the dredging, taken at a depth of 913 fathoms, actually broke off a piece of Miocene sediment.

It remains an excellent guide fossil for the Miocene.

Diameter of figured specimen (U.S.G.S. diatom catalog no. 2372–68), 37μ, from sample 2.

Found rarely in samples 2, 5, 6, 7, and frequently in sample 8.

Genus CLADOGRAMMA Ehrenberg 1844

Cladogramma dubium Lohman, n. sp.

(Plate IX, fig. 5)

Cladogramma californicum Ehrenberg, Grunow in Van Heurck, Synopsis diatomées Belgique, pl. 83, bis, figs. 18, 19, 1882.
Cladogramma cebuense Grunow, Van Heurck, A Treatise on the Diatomaceae, p. 502, fig. 246, 1896.

Valve circular, with center raised to form a low rounded peak about 8μ in diameter covered with faint liradiscoid markings; irregularly spaced radial costae sometimes bifurcating toward margin; interspaces hyaline or occasionally containing scattered puncta; margin narrow and hyaline. Diameter, 31 to 34μ.

Holotype: U.S.G.S. diatom catalog no. 2377–2, diameter 34μ. U.S.G.S. diatom locality no. 3080, sample 7 from depth of 1108 feet in Ohio Oil Company, Larry G. Hammond No. 1 well, near Salisbury, Wicomico County, Maryland.

Grunow, who first figured this tiny species, confused it with *C. californicum* Ehrenberg (28, pl. 33, group 13, fig. 1) to which it bears only a superficial resemblance. Grunow prepared three figures of this genus for plate 83 Bis of Van Heurck's Synopsis. Figures 18 and 19 (mentioned above) he assigned to *C. californicum* Ehrenberg and figure 20 became the original figure of his new species *C. cebuense* Grunow. In selecting figures for his "Treatise on the Diatomaceae", Van Heurck used many of the figures which Grunow and he had prepared for the Synopsis. By some mischance, he chose figures 18 and 19 from plate 83 bis of the Synopsis, and there plainly mislabeled *C. californicum*, to become figure 246 on page 502 of the Treatise, where he completed the confusion surrounding these figures by labeling them *C. cebuense* Grunow. Unfortunately the error was perpetuated by Peragallo (81, p. 181) and Mills (73, p. 404).

Known only from the Miocene of California, Virginia and Maryland.

Found rarely in sample 7.

Cladogramma ellipticum Lohman n. sp.

(Plate IX, fig. 4)

Valve elliptical with center raised to form a rounded peak 6 to 8μ in diameter and about 5μ higher than the margin. Markings in the center are liradiscoid and discontinuous. Radial costae averaging 6 in 10μ at the semiradius cover the space between the central peak and the narrow, hyaline margin. Length 40 to 50μ; width 20 to 25μ.

Holotype: U.S.G.S. diatom catalog no. 2368–20, length 41μ; width 22μ. U.S.G.S. diatom locality no. 3081, sample 8 from depth of 1130–1140 feet in Ohio Oil Company, Larry G. Hammond No. 1 well, near Salisbury, Wicomico County, Maryland. Calvert formation, middle Miocene.

This is the first noncircular *Cladogramma* that has been described and illustrated. De Toni (25, p. 1422) listed as the 4th and last species of this genus, *C. ovale* Grunow in Cleve and Möller Diatom Type slide no. 215, but as neither a description or a figure of this diatom has ever been published it must remain a *nomen nudum*. The name suggests the possibility that it may have been the form here described.

Found rarely in samples 1 and 8.

Subfamily ACTINOPTYCHOIDEAE

Genus ACTINOPTYCHUS Ehrenberg, 1843

Actinoptychus heliopelta Grunow

(Plate IX, fig. 3)

Heliopelta Euleri Ehrenberg, K. Akad. Wiss. Berlin, Ber., 1844, p. 268.
Ehrenberg, Mikrogeologie, pl. 33, group 18, fig. 6, 1854.
Heliopelta Ehrenbergii Ralfs, in Pritchard, A History of Infusoria, 4th ed., p. 840, 1861.
Actinoptychus heliopelta Grunow, in Van Heurck, Synopsis diatomées Belgique, pl. 123, fig. 3, 1883 (Nottingham, Md.).
Schmidt, Atlas der Diatomaceenkunde, pl. 109, fig. 2, 1886; pl. 153, fig. 22, 1890.
Wolle, Diatomaceae of North America, pl. 92, fig. 1; pl. 103, fig. 2, 1894 (Nottingham, Md.).
De Toni, Sylloge algarum, vol. 2, p. 1377, 1894.
Boyer, Maryland Geol. Survey, Miocene, p. 499, pl. CXXXIV, fig. 3, 1904.

Ehrenberg and others set up a total of 9 species of his genus *Heliopelta* to take care of subvarietal differences, such as the number of sectors, etc. Ralfs, probably using the same argument he appears to have used in the case of *Actinocyclus* (see remarks under *A. octonarius* Ehr. in this report), lumped them all together and called them *Heliopelta ehrenbergii* (2d citation above). It remained for Grunow, over twenty years later, to place them all under one species, *heliopelta*, in the sound genus *Actinoptychus*.

This species is one of the best markers for the Calvert formation, and in the 102 years that have passed since it was first described it has been recorded countless times, but never from any other stratigraphic horizon.

Diameter of figured specimen (U.S.G.S. diatom catalog no. 2373–25), 110μ, from sample 3, where it occurred rarely. This specimen is the best and most nearly complete found in the core.

The lowest diatomite (zone 3 of the Calvert formation, as defined by the Maryland Geological Survey in 1904) exposed in the quarry on the east bank of the Patuxent River opposite the town of Nottingham, contains countless numbers of perfect specimens of this diagnostic species.

Actinoptychus kymatodes Pantocsek

(Plate IX, fig. 6)

Actinoptychus kymatodes Pantocsek, Fossilen Bacillarien Ungarns, Teil 1, p. 62, pl. 23, fig. 213 1886.
De Toni, Sylloge algarum, vol. 2, p. 1380, 1894.

My specimen has the outer margin missing, but the balance of the valve is identical with Pantocsek's original description and figure. The "moiré silk" interference pattern caused by the combination of fine oblique markings and the alternating concavity and convexity of the sectors is particularly striking and distinctive. This species has hitherto been reported only from Miocene rocks in Hungary and Italy.

Diameter of figured specimen (U.S.G.S. diatom catalog no. 2371–30), 110μ, from sample 2, where it was found rarely.

Actinoptychus senarius (Ehrenberg) Ehrenberg

Actinocyclus senarius Ehrenberg, Die Infusionsthierchen als vollkommene Organismen, p. 172, pl. 21, fig. 6, 1838.
Actinoptychus senarius (Ehrenberg) Ehrenberg, Berlin K. Akad. Wiss. Physikal. Abh., 1841, p. 400, pl. 1, fig. 27, 1843.
Hendey, Discovery Repts., vol. 16, p. 271, 1937.
Lohman, U. S. Geol. Survey Prof. Paper 196-B, p. 80, pl. 16, fig. 9, 1941.
Actinoptychus undulatus (Kützing) Ralfs, in Pritchard, A history of Infusoria, 4th ed., p. 839, pl. 5, fig. 88, 1861.

For a fairly complete synonymy of this widespread and widely misnamed species see my paper listed above. This is another long-ranging species, having been reported from Cretaceous to Recent strata.

Found commonly in samples 2, 3, 8, frequently in samples 4 and 5, and rarely in sample 7.

Actinoptychus splendens (Shadbolt) Ralfs

Actinosphaenia splendens Shadbolt, London Micr. Soc. Trans., new ser., vol. 2, p. 16, 1854.
Actinoptychus splendens (Shadbolt) Ralfs, in Pritchard, A history of Infusoria, 4th ed., p. 840, 1861.
Schmidt, Atlas der Diatomaceenkunde, pl. 153, figs. 3, 7–10, 12, 16, 17, 19–21; pl. 154, fig. 3, 8; pl. 156, fig. 12, 13, 1890.
Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 1, p. 478, fig. 265, 1928.

Forms here referred to this species vary between 70 to 80μ in diameter, which is the lower usual limit for the species. In these specimens, the marginal apiculi are bifurcated along an extension of the radial hyaline space. In Hustedt's figure this radial hyaline space is shown as straight and of uniform width. In these specimens the hyaline space is much less prominent, and tends to waver toward a weak finish at the margin.

Found rarely in samples 6 and 7.

Genus CYMATOGONIA Grunow, 1883

Cymatogonia amblyoceras (Ehrenberg) Hanna

(Plate IX, fig. 7)

Triceratium amblyoceras Ehrenberg, K. Akad. Wiss. Berlin, Ber., 1844, p. 88.
Ehrenberg, Mikrogeologie, pl. 18, fig. 51, 1854.
Cymatogonia amblyoceras (Ehrenberg) Hanna, California Acad. Sci. Proc. 4th ser., vol. 20, p. 186, pl. 10, fig. 5, 1932 (Temblor formation).
Triceratium amblyoceras var. *nankoorensis* Grunow, Reise der österreichischen Fregatte Novara, Bot. Teil, Band I, p. 103, 1870.
Schuettia ? amblyoceras (Ehrenberg) De Toni, Sylloge algarum, vol. 2, pp. 1393, 1396, 1894.
Actinoptychus amblyoceras (Ehrenberg) Schmidt, Atlas der Diatomaceenkunde, pl. 1, fig. 25, 1874 (Richmond, Va.); pl. 155, fig. 13, 1890 (Sendai, Japan).
Pantocsek, Fossilen Bacillarien Ungarns, Teil 1, p. 60, pl. 13, fig. 110, 1886.

This species is an excellent marker for the middle Miocene all over the world. On some forms the sides are concave, others convex. The hexagonal areolae in these specimens are 10 to 11 in 10μ. Hanna's specimens from the Temblor formation of California are somewhat more finely marked, the areolae being 12 to 14 in 10μ. His specimens also have usually smaller central areas than the eastern ones, but numerous specimens from exposures of the Temblor formation on Phoenix Ridge, 8 miles north of Coalinga, Fresno County, California, have the large hyaline central area and hexagonal areolae 10 to 11 in 10μ as in the eastern forms from the Calvert formation. I therefore agree with Hanna that the two forms are identical.

Found frequently in sample 8.

Length of one side of figured specimen (U.S.G.S. diatom catalog no. 2378-11), 90μ, from sample 8.

Subfamily ASTEROLAMPROIDEAE

Genus ASTEROLAMPRA Ehrenberg, 1844

Asterolampra marylandica Ehrenberg

Asterolampra marylandica Ehrenberg, K. Akad. Wiss Berlin, Ber., 1844, p. 76, fig. 10, 1845.
Schmidt, Atlas der Diatomaceenkunde, pl. 137, figs. 19–21, 1889.
Rattray, Royal Soc. Edinburgh Proc., vol. 16, p. 641, 1889.
Hendey, Discovery Repts., vol. 16, p. 268, 1937.
Asterolampra septenarius Johnson, Am. Jour. Sci., 2d ser., vol. 13, p. 33, 1852.
Asterolampra impar Shadbolt, London Micr. Soc. Trans., new ser., vol. 2, p. 17, pl. 1, fig. 14, 1854.
Asterolampra hexactis Ehrenberg, K. Akad. Wiss. Berlin, Abh., 1872, p. 392, pl. 9, fig. 1, 2.

Originally described from strata later named the Calvert formation in Maryland, this species has been reported from many localities, both fossil and Recent, all over the world. Many fragments were found, but not one whole specimen was recovered from the core.

Found frequently in sample 2, and rarely in samples 3, 5, and 7.

Suborder AULACODISCINEAE

Family EUPODISCACEAE

Subfamily AULACODISCOIDEAE

Genus AULACODISCUS Ehrenberg, 1845

Aulacodiscus argus (Ehrenberg) Schmidt

Tripodiscus argus Ehrenberg, K. Akad. Wiss. Berlin, Ber., 1839, p. 159, pl. 3, fig. 6 a-c, 1841.
Aulacodiscus argus (Ehrenberg) Schmidt, Atlas der Diatomaceenkunde, pl. 107, fig. 4, 1886.
Rattray, Royal Micr. Soc. Jour., 2nd ser., vol. 8, p. 373, 1888.
Eupodiscus argus (Ehrenberg) Smith, A Synopsis of the British Diatomaceae, vol. 1, p. 24, pl. 4, fig. 39, 1853.
Van Heurck, Synopsis diatomées Belgique, p. 209 (1885), pl. 117, fig. 3–6, 1883.
Schmidt, Atlas der Diatomaceenkunde, pl. 92, fig. 7–11, 1886.

This species has a long geologic range and is widespread geographically.

Found rarely in sample 2.

Aulacodiscus rogersii (Bailey) Schmidt

Podiscus rogersii Bailey, Am. Jour. Sci., 1st ser., vol. 46, p. 137, pl. 3, fig. 1, 2, 1844.
Aulacodiscus rogersii (Bailey) Schmidt, Atlas der Diatomaceenkunde, pl. 107, fig. 3, 1886.
Rattray, Royal Micr. Soc. Jour., 2nd ser., vol. 8, p. 372, 1888.
Boyer, Maryland Geol. Survey, Miocene, p. 497, pl. CXXXIV, fig. 5, 1904.
Eupodiscus rogersii (Bailey) Ehrenberg, K. Akad. Wiss. Berlin, Ber., 1844, p. 81, 1845.
Schmidt, Atlas der Diatomaceenkunde, pl. 92, fig. 5–6, 1886.
Hanna and Grant, California Acad. Sci. Proc., 4th ser., vol. 15, p. 144, pl. 16, fig. 6–7, 1926.
Tripodiscus rogersii (Bailey) Mann, Contr. U. S. Nat. Herbarium, vol. 10, part 5, p. 281, 1907.

The known geologic range of this species is from Miocene to Recent.
Found frequently in sample 2.

Aulacodiscus sollitianus Norman

(Plate IX, fig. 8)

Aulacodiscus sollitianus Norman, London Micr. Soc. Trans. new ser., vol. 9, p. 7, pl. 2, fig. 5, 1861.
Schmidt, Atlas der Diatomaceenkunde, pl. 33, fig. 10–13, 1876.
Rattray, Royal Micr. Soc. Jour., 2nd ser., vol. 8, p. 377, 1888.
De Toni, Sylloge Algarum, vol. 2, p. 1125, 1894.

In addition to the figures listed above, Schmidt, in his atlas, gave two additional figures (plate 102, figure 5, and plate 103, figure 3) which he assigned to this species. I question these two figures, as in both the areolae extend entirely to the narrow margin. In Schmidt's figures listed in the above synonymy, there is a marginal zone about $\frac{1}{10}$ of the radius broad containing radial striae which are extensions of rows of areolae and which are 4–6 in 10μ. Areolae average 4 in 10μ.

Hanna (43, p. 110) has reported a fragment of this species from the Kreyenhagen shale of Eocene or Oligocene age on Domengene Ranch, north of Coalinga, California. This is the oldest known occurrence of this species, all those listed in the above synonymy being from the Calvert formation (middle Miocene) from Nottingham, Maryland. Kain and Schultze (58, p. 208) also reported it from what is most probably a northern extension of the Calvert formation at a depth of 387 to 677 feet in a well drilled at Atlantic City, N. J. Tempere and Peragallo (101, p. 121) have reported this species from a "fossil marine earth" from Mejillones, Bolivia. It has never been reported living, and its known geologic range is probably confined to the lower Tertiary.

Found rarely in samples 2 and 4 and frequently in sample 6.

Diameter of figured specimen (U. S. diatom catalog no. 2376–13), 177μ, from sample 6.

Suborder AULISCINEAE

Family AULISCACEAE

Subfamily AULISCOIDEAE

Genus AULISCUS Ehrenberg, 1844

Auliscus caballi Schmidt

Auliscus caballi Schmidt, Atlas der Diatomaceenkunde; pl. 32, figs. 1, 2, 1875.
Rattray, Royal Micr. Soc. Jour., 2nd ser., vol. 8, p. 866, 1888.
Hanna and Grant, California Acad. Sci. Proc., 4th ser., vol. 15, p. 129, pl. 13, fig. 7, 1926.

This small delicately marked species has a known geologic range of Miocene to Recent. Found rarely in sample 1.

Auliscus pruinosus Bailey

Auliscus pruinosus Bailey, Smithsonian Contr. Knowl. vol. 7, p. 5, pl. 1, figs. 5–8, 1854.
Schmidt, Atlas der Diatomaceenkunde, pl. 31, figs. 6, 7, 11, 13–15; pl. 32, fig. 5, 1875; pl. 108, fig. 10, 1886.
Rattray, Royal Micr. Soc. Jour., 2nd ser., vol. 8, p. 882, 1888.
Mann, Contr. U. S. Nat. Herbarium, vol. 10, part 5, p. 283, 1907.

Mann considered that a great state of confusion existed between this species and *A. punctatus* Bailey (4, p. 5, pl. 1, fig. 9), although both Bailey's figures and descriptions are quite distinct. It seems quite possible that many forms referred to *A. pruinosus* should have been called *A. punctatus.* My specimen has no apiculi and fits both Bailey's and Rattray's desciiptions very well. On the basis of the material from the core, the two species are considered distinct. Its geologic range is Miocene to Recent.

Found rarely in sample 7.

Genus PSEUDAULISCUS Schmidt, 1875

Pseudauliscus spinosus (Christian) Rattray

(Plate X, fig. 1)

Auliscus spinosus Christian in Schmidt, Atlas der Diatomaceenkunde, pl. 125, fig. 2, 1888.
Kain and Schultze, Torrey Bot. Club Bull., vol. 16, p. 73, pl. 92, fig. 2, 1889.
Pseudauliscus spinosus (Christian) Rattray, Royal Micr. Soc. Jour., 2nd ser., vol. 8, p. 904, 1888.
Boyer, Maryland Geol. Survey, Miocene, p. 497, pl. CXXXV, fig. 10, 1904.

This very distinctive species is known only from the Calvert formation in Maryland and its northern equivalent in New Jersey, where it was recovered (2d citation above) at depths from 387 to 638 feet from a well at Atlantic City. It is an excellent marker for the middle Miocene on the Atlantic Coastal Plain. Only one complete specimen could be found in the samples, from the core, and it was so poorly oriented in mounting that the incomplete one here shown was chosen for the photomicrograph.

Found rarely in samples 2 and 6.

Diameter of figured specimen (U.S.G.S. diatom catalog no. 2376-16), 86μ, from sample 6.

Suborder BIDDULPHINEAE

Family BIDDULPHIACEAE

Subfamily BIDDULPHIODEAE

Genus BIDDULPHIA Gray, 1831

Biddulphia decipiens Grunow

(Plate X, fig. 6)

Biddulphia decipiens Grunow in Van Heurck, Synopsis diatomées Belgique, pl. 100, figs. 3, 4, 1882.
Wolle, Diatomaceae of North America, pl. 98, figs. 5, 6, 1894.
Boyer, Philadelphia Acad. Nat. Sci. Proc., 1900, part III, p. 716, 1901.
Boyer, Maryland Geol. Survey Miocene, p. 493, pl. CXXXIV, fig. 8, 1904.
Amphitetras (Biddulphia) alternans, H. L. Smith, The Microscope, 1887, p. 67, fig., p. 113.

This is another species which has been reported only from the Calvert formation of Maryland and its northern equivalent in New Jersey (58, p. 73). These specimens do not have the sides quite so deeply indented as previous authors have indicated, otherwise there is no hesitancy in assigning them to this species. In addition to being an excellent marker for the middle Miocene, this species is easy to identify and occurs with dependable frequency.

Found frequently in samples 2, 5, 7, 8 and commonly in samples 3 and 6.

Length of figured specimen (U.S.G.S. diatom catalog no. 2368-43), 64μ, from sample 8.

Biddulphia semicircularis (Brightwell) Boyer

Triceratium semicirculare Brightwell, Royal Micr. Soc. Jour., 1853, p. 252, pl. 4, fig. 21.
Biddulphia semicircularis (Brightwell) Boyer, Philadelphia Acad. Nat. Sci., Proc., 1900, part III, p. 726, 1901.
Boyer, Maryland Geol. Survey, Miocene, p. 294, pl. CXXXIV, fig. 10, 1904.
Triceratium obtusum Ehrenberg (in part), Mikrogeologie, pl. 18, fig. 49 (not fig. 48), 1854.
Euodia brightwellii Ralfs in Pritchard, A History of Infusoria, 4th ed., p. 852, 1861.
Van Heurck, Synopsis diatomées Belgique, pl. 126, fig. 20, 1883.

Ehrenberg, probably seeing this diatom for the first time, may have thought that it was an aberrant form of the triangular specimen (his figure 48) he was naming *Triceratium obtusum*, and hence included it with that species. Mann (71, p. 293) perpetuated Ehrenberg's error when he included both figures in making *T. obtusum* a synonym of *Trigonium parallelum*, when he should have considered only figure 48.

Kain and Schultze (58, p. 76, pl. 89, figs. 6, 6a), have reported this species from the northern equivalent of the Calvert formation in the Atlantic City well at a depth of 387 to 638 feet, and Woolman (127, p. 423) has reported it from the Dismal Swamp in Virginia and North Carolina. Woolman considered that this species as well as several others were eroded from outcrops of the Calvert formation in Richmond and vicinity and carried to the Dismal Swamp by the James River. If Woolman is correct, this species remains a good marker for the middle Miocene Calvert formation.

Found rarely in samples 5 and 8.

Biddulphia tuomeyi (Bailey) Roper

Zygoceros Tuomeyi Bailey, Am. Jour. Sci., vol. 46, pl. 138, pl. 3, fig. 3–9, 1844.
Biddulphia Tuomeyi (Bailey) Roper, Royal Micr. Soc. Trans., vol. 7, p. 8, pl. 1, figs. 1, 2, 1859.
Van Heurck, Synopsis diatomées Belgique, pl. 98, figs. 2, 3, 1882.
Schmidt, Atlas der Diatomaceenkunde, pl. 118, figs. 1–7; pl. 119, figs. 1–5; 1888.
Biddulphia tridens Ehrenberg, K. Akad. Wiss. Berlin, Ber., 1840, p. 205.
Boyer, Philadelphia Acad. Nat. Sci. Proc., 1900, part III, p. 695, 1901.

The synonymy of this long-ranging and widespread diatom could be extended to several pages without exhausting the possibilities or contributing anything to this investigation.

Bailey, on page 141 of the same paper in which he originally described and figured this species, added a note in which he said "I also found that rare and beautiful form, *Biddulphia pulchella*, and was struck with its *generic* resemblance to the above-mentioned *Zygoceros tuomeyi*. It is possible that the latter should be referred to the genus *Biddulphia*."

Boyer's action in placing this well-known species in *B. tridens* Ehrenberg seems to be unsound, as Ehrenberg's bare description does not sufficiently depict this complicated species, whereas Bailey's excellent description and 7 figures identify it beyond all doubt.

This variable species is known from rocks of Cretaceous (90, p. 387) age to the Recent.

Found frequently in samples 2 and 8 and rarely in sample 5.

Genus ZYGOCEROS Ehrenberg 1841

Zygoceros quadricornis Grunow

Zygoceros? quadricornis Grunow in Van Heurck, Synopsis diatomées Belgique, pl. 105, figs. 5, 6, 7, 1883. (Nottingham, Md., Calvert formation).
Zygoceros quadricornis Grunow. Pantocsek, Fossilen Bacillarien Ungarns, Teil 1, p. 46, pl. 26, fig. 248, 1886 (Szakal, Hungary).
De Toni, Sylloge algarum, vol. 2, p. 887, 1894.
Hanna, California Acad. Sci. Proc. 4th ser., vol. 20, p. 228, pl. 18, figs. 8, 9, 1932. (Temblor formation, middle Miocene).
Biddulphia quadricornis (Grunow) Boyer, Philadelphia Acad. Nat. Sci. Proc. 1900, part III, p. 713, 1901.

I agree with Hanna that Grunow was probably correct in questioning the placing of this species in *Zygoceras*. These specimens, like Hanna's, are incomplete and one hesitates to either create a new genus for it or change its original assignment. It is not likely to belong in the hodge-podge that Boyer attempted to make of the genus *Biddulphia*.

This is another species recorded only from the Miocene, but from widely scattered localities, indicating its value as a marker species.

Found rarely in sample 5.

Subfamily TRICERATIOIDEAE

Genus TRICERATIUM Ehrenberg, 1841

Triceratium americanum Ralfs

Triceratium americanum Ralfs in Pritchard, A History of Infusoria, 4th ed., p. 855, 1861 (Richmond, Va.).
Schmidt, Atlas der Diatomaceenkunde, pl. 76, fig. 27, 1882 (Nottingham, Md.).
Hanna, Jour. Paleontology, vol. 1, p. 122, pl. 21, fig. 3, 1927. (Phoenix Canyon, California, lower Miocene).
Hanna, California Acad. Sci. Proc. 4th ser., vol. 20, p. 220, 1932 (Temblor formation, California, middle Miocene).
Biddulphia americana (Ralfs) Boyer, Philadelphia Acad. Nat. Sci. Proc. 1900, part 3, p. 721, 1901.

Although Boyer's attempt to place this species in *Biddulphia* is not agreed with, his note at the bottom of page 721 of his paper is strongly recommended. It removes much of the confusion that formerly surrounded the name of this species.

The known geologic range of this species is probably lower Miocene (or Oligocene ?) to middle Miocene. It is an excellent marker for the Calvert formation on the Atlantic Coastal Plain from southern Virginia (type locality in Richmond, Va.) to Atlantic City, New Jersey, where it was found by Kain and Schultze (58, p. 76) at a depth of 387 to 638 feet.

Found rarely in sample 2.

Triceratium argus Janisch

Triceratium argus, Janisch, in Schmidt, Atlas der Diatomaceenkunde, pl. 81, fig. 12, 1885.
De Toni, Sylloge algarum, vol. 2, p. 948, 1894.

Only one specimen, comprising a whole frustule, was found (in sample 6). This small species has only been reported previously from a sample collected from some unknown location by the Gazelle Expedition. It is closely related to *T. interpunctatum* Grunow and possibly should be combined with it.

Triceratium interpunctatum Grunow

(Plate X, fig. 2)

Triceratium interpunctatum Grunow, in Schmidt, Atlas der Diatomaceenkunde, pl. 76, fig. 7, 1882 (Nottingham, Md.).
Biddulphia interpunctata (Grunow) Boyer, Philadelphia Acad. Nat. Sci. Proc. 1900, part III, p. 722, 1901.
Boyer, Maryland Geol. Survey, Miocene, p. 494, pl. CXXXIV, fig. 9, 1904.

Valve triangular, sides straight to somewhat undulating, angles rounded. A large flat triangular area, only slightly smaller than the valve, is depressed 1 to $1\frac{1}{2}\mu$ below the marginal elevated zone, which averages 5 to 7μ wide. Surface covered with rounded puncta, 4 to 5 in 10μ, arranged in radial rows. Occasional very small puncta occur between rows of larger puncta in random arrangement. Margin very narrow. Length of side, 70 to 120μ.

Boyer erroneously states that the surface is flat, although his own figure clearly shows the triangular depressed area.

This species is another good marker for the Calvert formation along the Atlantic Coastal Plain, being known only from this formation.

Altitude of figured specimen (U.S.G.S. diatom catalog no. 2372–35), 74μ, from sample 2. Found frequently in samples 2, 3, 6, and rarely in samples 1 and 5.

Triceratium kainii Schultze

(Plate X, figs. 4, 5)

Triceratium kainii Schultze, Torrey Bot. Club. Bull., vol. 16, p. 76, pl. 89, fig. 5, 1889.
De Toni, Sylloge algarum, vol. 2, p. 963, 1894.
Wolle, Diatomaceae of North America, pl. 104, fig. 8; pl. 105, figs. 15, 16; 1894.
Triceratium multifrons Brun, Genève Soc. Phys. Hist. Nat. Mém., tome 30, no. 9, p. 63, pl. 6, fig. 2, 1889.
Schmidt, Atlas der Diatomaceenkunde, pl. 168, fig. 3, 1891.
De Toni, Sylloge algarum, vol. 2, p. 962, 1894.
Biddulphia kainii (Schultze) Boyer, Philadelphia Acad. Nat. Sci. Proc., 1900, part 111, p. 718, 1901.

Valve triangular with sides straight or concave. Angles obtusely cuneate to rounded; separated from balance of valve by strong costae, equidistant between apices and center. Surface flat, with puncta 7 to 9 in 10μ, radiating from a hyaline center to margins and costae. From costae to apex, puncta are somewhat coarser, 6 to 7 in 10μ, arranged in rows parallel to a line from each apex to the center of the valve. In some forms, the puncta between the costae and the center are only faintly radiate and occasionally are scattered. The hyaline central area is about $\frac{1}{6}$ the diameter of the valve. Length of side, 50 to 140μ.

The degree of concavity of the sides of this diatom varies from straight (fig. 5) to deeply concave (fig. 4). Schultze's variety *constrictum* should probably remain separate and not be combined with the type as Boyer has suggested.

This is another of the species that appear to be excellent markers for the Calvert formation along the Atlantic Coastal Plain. Brun has found this species in calcareous Tertiary beds near Tokyo, Japan, which are probably equivalent to the Calvert formation in age.

Length of 1 side of figured specimens: fig. 5 (U.S.G.S. diatom catalog no. 2377–9), 69μ; fig. 4 (U.S.G.S. diatom catalog no. 2368–50), 57μ.

Found rarely in samples 7 and 8.

Triceratium tessellatum Greville

(Plate X, fig. 3)

Triceratium tesselatum Greville, Royal Micr. Soc. Trans., vol. 9, p. 71, pl. 8, fig. 14, 1861.
Schmidt, Atlas der Diatomaceenkunde, pl. 76, fig. 33, 1882.
De Toni, Sylloge algarum, vol. 2, p. 939, 1894.
Biddulphia tessellata (Greville) Boyer, Philadelphia Acad. Nat. Sci. Proc. 1900, part III, p. 723, 1901.
Boyer, Maryland Geol. Survey, Miocene, p. 495, pl. CXXXIV, fig. 12, 1904.
Triceratium robustum Greville, Royal Micr. Soc. Trans., vol. 9, p. 71, pl. 8, fig. 15, 1861.
Triceratium amoenum Greville, Royal Micr. Soc. Trans., vol. 9, p. 75, pl. 9, fig. 7, 1861.

When the genus *Triceratium* is revised, this species may be placed in *Biddulphia*, as Boyer has done. Certainly Greville's three species *tessellatum*, *robustum*, and *amoenum* are the same, regardless of the genus to which they are assigned.

This is another species which is confined to the Calvert formation in Maryland and its northern equivalent in New Jersey, where it was found in the Atlantic City well at a depth of 387 to 638 feet (58, p. 76).

Length of one side of figured specimen (U.S.G.S. diatom catalog no. 2368–21), 46μ, from sample 8.

Found frequently in samples 5 and 8 and rarely in samples 6 and 7.

Subfamily HEMIAULOIDEAE

Genus HEMIAULUS Ehrenberg 1845

Hemiaulus bipons (Ehrenberg) Grunow

(Plate X, fig. 7)

Zygoceros bipons Ehrenberg, K. Akad. Wiss. Berlin, Ber., 1844, p. 273.
Hemiaulus bipons (Ehrenberg?) Grunow, in Van Heurck, Synopsis diatomées Belgique, pl. 103, figs. 6, 7, 8, 9, 1882 (Nottingham, Md.).
Grunow, Akad. Wiss. Wien, Math.—naturwiss. Kl., Denkschr., Band 48, p. 65, 1884.
Boyer, Philadelphia Acad. Nat. Sci. Proc., 1900, part III, p. 740, 1901.

This tiny species has a geologic range from middle Miocene (Calvert formation, Nottingham, Md.) to Recent (Arctic Sea) (9, p. 141).

Length of figured specimen (U.S.G.S. diatom catalog no. 2368-61), 37μ.

Found frequently in samples 2, 3, 6, 8, and rarely in samples 5 and 7.

Hemiaulus polymorphus Grunow

Hemiaulus polymorphus Grunow, Akad. Wiss. Wien, Math.—naturwiss. Kl., Denkschr., Band 48, p. 66, 1884.
Schmidt, Atlas der Diatomaceenkunde, pl. 143, figs. 11–13, 1888.
De Toni, Sylloge Algarum, vol. 2, p. 851, 1894.

As its name implies this is a variable form, and it appears quite probable that the long geologic range (Cretaceous to Recent) assigned to it reflects some of the confusion regarding the limits of the species and its varieties. At present it is useless for the purpose of stratigraphic correlation.

Found commonly in sample 7 and frequently in sample 8.

Genus PLOIARIA Pantocsek 1889

Ploiaria petasiformis Pantocsek

Hemiaulus? petasiformis Pantocsek, Fossilen Bacillarien Ungarns, Teil 1, p. 50, pl. 29, fig. 295, 1886.
Ploiaria petasiformis Pantocsek, Fossilen Bacillarien Ungarns, Teil 2, p. 84, pl. 28, figs. 403, 405, 1889.
Boyer, Philadelphia Acad. Nat. Sci. Proc., 1900, part III, p. 742, 1901.
Mann, Contr. U. S. Nat. Herbarium, vol. 10, part 5, p. 313, 1907.

This species has been found only in Miocene strata, in Maryland, in the Atlantic City, New Jersey, well and in Hungary, where it was discovered originally. Mann found it at station 4029-H in the Bering Sea, the sample from which was later shown by Hanna (45) to have come from an outcropping of Miocene strata on the sea floor. It is an excellent marker for the Calvert formation on the Atlantic Coastal Plain.

Found rarely in samples 5 and 7.

Family CHAETOCERACEAE

Subfamily CHAETOCEROIDEAE

No specimens of the genus *Chaetoceros* were found, although several closely allied genera were well represented. Among them are *Mastogonia*, *Stephanogonia*, *Periptera*, *Goniothecium*, *Dossettia*, and *Xanthiopyxis*. Some, and possibly all, of these genera are probably resting spores of various species of *Chaetoceros*, and their validity as genera is therefore questionable. Nevertheless, the fact remains that in each case these genera have been established from fossil material, under which circumstances it is virtually impossible to determine which species of *Chaetoceros* is the parent. Many species of *Chaetoceros* are so slightly silicified that they are poorly preserved or not preserved at all in sediments. A relatively large number of specimens of these doubtful genera were found in the samples, but not one fragment of any species of *Chaetoceros* was found.

It seems best, therefore, to continue to regard them as separate genera and species until direct lines of descent can be established. Obviously, this can be done only with those long-ranging species which are represented in living floras. Although their position in the scheme of classification is subject to these uncertainties, they remain very useful fossils, and from the point of view of the stratigraphic paleontologist they deserve as careful consideration as any other group of diatoms.

Genus MASTOGONIA Ehrenberg 1845

Mastogonia crux Ehrenberg

(Plate X, fig. 8)

Mastogonia crux Ehrenberg, K. Akad. Wiss. Berlin, Ber., 1844, p. 269, 1845.
Ehrenberg, Mikrogeologie, pl. 33, group 18, fig. 8, 1854.
De Toni, Sylloge algarum, vol. 2, p. 1013, 1894.
Möller, Lichtdrucktafeln Möllerscher Diatomaceen-Präparate, pl. 25, row 8, figs. 5, 6, 1891.
Mastogonia heptagona Ehrenberg, K. Akad. Wiss. Berlin, Ber., 1844, p. 269, 1845.
Mastogonia quinaria Ehrenberg, K. Akad. Wiss. Berlin, Ber., 1844, p. 269, 1845.
Mastogonia rota Ehrenberg, K. Akad. Wiss. Berlin, Ber., 1844, p. 269, 1845.

Van Heurck's (108, pl. 83-ter, fig. 1) figures of this species are far from satisfactory and are apparently drawn to show both valves of the frustule drawn in the same plane. Möller's figures, which are the only previous photographs published of this diatom, are identical with these specimens.

This is another species known only from the Calvert formation of Maryland and Virginia, and from rocks of equivalent age in Hungary (80).

Diameter of figured specimen (U.S.G.S. diatom catalog no. 2377–20), 77μ, from sample 7.

Found rarely in sample 3, and frequently in samples 2 and 7.

Genus STEPHANOGONIA Ehrenberg 1845

Stephanogonia actinoptychus (Ehrenberg) Grunow

Mastogonia actinoptychus Ehrenberg, K. Akad. Wiss. Berlin, Ber., 1844, p. 269, 1845.
Ehrenberg, Mikrogeologie, pl. 18, figs. 109a, b; pl. 33, group 13, fig. 16, 1854.
Stephanogonia actinoptychus (Ehrenberg) Grunow in Van Heurck, Synopsis diatomées Belgique, pl. 83ter, figs. 2–4, 1882.
Hanna, California Acad. Sci. Proc. 4th ser., vol. 20, p. 217, 1932. (Temblor formation, middle Miocene).

Known only from the Miocene along both the Pacific and Atlantic Coasts, this species is a useful guide fossil.

Found frequently in sample 2.

Genus PERIPTERA Ehrenberg 1845

Periptera tetracladia Ehrenberg

Periptera tetracladia Ehrenberg, K. Akad. Wiss. Berlin, Ber., 1844, p. 270, 1845.
Ehrenberg, Mikrogeologie, pl. 33, group 18, fig. 9, 1854 (Bermuda = Nottingham, Md., middle Miocene).
Grunow in Van Heurck, Synopsis diatomées Belgique, pl. 83ter, figs. 7–9, 1882 (Nottingham, Md., middle Miocene).
Hanna, California Acad. Sci. Proc. 4th ser., vol. 20, p. 205, pl. 13, fig. 8, 1932 (Temblor formation, middle Miocene).

Hanna's figure agrees perfectly with the specimen found in the core. The multibranching spines shown in Grunow's figure 8 are rarely seen; they are probably broken off in compaction of the sediment or in mounting.

The known geologic range of this species is from middle Miocene to Pliocene (66, p. 83).

Found rarely in sample 5.

Genus GONIOTHECIUM Ehrenberg 1843

Goniothecium rogersii Ehrenberg

Goniothecium rogersii Ehrenberg, K. Akad. Wiss. Berlin Abh., 1841, pp. 401, 416, 1843.
Ehrenberg, Mikrogeologie, pl. 18, figs. 92, 93, 1854.
Hanna, California Acad. Sci. Proc. 4th ser., vol. 20, p. 192, pl. 11, figs. 4–6, 1932.

Originally described from strata exposed at Richmond, Virginia, and later assigned to the Calvert formation, this species has been reported from its northern equivalent in New Jersey (58, p. 75) and from material reworked from the Calvert formation in the Dismal Swamp, Virginia and North Carolina (127, p. 423). Hanna found this species in the middle Miocene Temblor formation in California and the youngest rocks from which it has been reported are in the Pliocene San Joaquin formation in the Kettleman Hills, California (66, p. 83) where it occurred rarely.

Found frequently in samples 2, 6, and rarely in samples 3, 4, and 5.

Genus DOSSETIA Azpeitia 1911

Dossetia lacera (Forti) Hanna

Xanthiopyxis lacera Forti, in Tempere and Peragallo, Diatomées du Monde Entier, 2nd ed., p. 197, 1909 (Marmorita, Italy, middle Miocene).
Forti, R. ist. veneto sci. Atti, vol. 69, part 2, p. 1311, 1910; vol. 72, part 2, p. 1555, pl. 12, figs. 14–18, 1913.
Dossetia lacera (Forti) Hanna, California Acad. Sci. Proc. 4th ser., vol. 20, p. 190, pl. 11, fig. 3, 1932 (Temblor formation, California, middle Miocene)

This species has not been reported previously from the Calvert formation or anywhere in eastern United States. Its previous occurrences have been in rocks of Calvert age in Italy and California.

Found rarely in samples 1, 6, 7, and 8.

Genus XANTHIOPYXIS Ehrenberg 1845

Xanthiopyxis oblonga Ehrenberg

Xanthiopyxis oblonga Ehrenberg, K. Akad. Wiss. Berlin, Ber., 1844, p. 273, 1845.
Ehrenberg, Mikrogeologie, pl. 33, group 17, fig. 17, 1854 (Rappahannock Cliff, Virginia, Calvert formation).
Cleve, Queckett Micr. Club Jour., ser. 2, vol. 2, p. 175, pl. 13, figs. 18a, b, 1885 (Brünn Tegel (Marl), Moravia, Miocene or Pliocene).
Mann, Contr. U. S. Nat. Herbarium, vol. 10, part 5, p. 389, 1907 (Station 4029H, Bering Sea, Miocene).
Hanna, California Acad. Sci. Proc. 4th ser., vol. 20, p. 226, 1932 (Temblor formation, California, middle Miocene).

X. panduriformis Pantocsek (80) which Mann threw into synonymy as belonging to this species should be kept separate as the central constriction is a distinctive and consistent feature.

This species has a recorded geologic range of lower Miocene (43, p. 124) to Pliocene (66, p. 83), but apparently reached its heyday in middle Miocene time. Mann found it at Station 4029 H, Bering Sea, but this sample has since been shown to be from a submarine outcrop of Miocene sedimentary rock. See discussion of Station 4029 H under *Stictodiscus kittonianus* Greville on page 168.

Found rarely in samples 6 and 8.

Family RHIZOSOLENIACEAE

Subfamily RHIZOSOLENIOIDEAE

Genus PSEUDOPYXILLA Forti 1909

Pseudopyxilla capreolus var. gracilior Forti

Pseudopyxilla capreolus var. *gracilior* Forti, La Nuova Notarisia, ser. 20, Anno 24, p. 31, pl. 1, fig. 5, 1909.

Forti's original specimen came from Maryland "earth", almost certainly the Calvert formation. My specimen agrees with his description and photograph in every respect.

Found rarely in sample 8.

Suborder ARAPHIDINEAE

Family FRAGILARIACEAE

Subfamily FRAGILAROIDEAE

Genus RHAPHONEIS Ehrenberg 1845

Eight species of this genus were found in the samples from the core and all but *R. amphiceros* are known only from Miocene strata. One species, *R. parilis*, originally described from marine middle Miocene rocks in California, has not been reported previously from any other locality. *R. moravica* and *R. angustata* were originally described and previously known only from marine Miocene rocks in Hungary and Moravia.

Rhaphoneis amphiceros Ehrenberg

Rhaphoneis amphiceros Ehrenberg, K. Akad. Wiss. Berlin, Ber., 1844, p. 87, 1845.
Ehrenberg, Mikrogeologie, pl. 33, group 14, fig. 22, 1854.
De Toni, Sylloge algarum, vol. 2, p. 699, 1892.
Van Heurck, Synopsis diatomées Belgique, p. 147, 1885; pl. 36, figs. 22, 23, 1881.
Hustedt, Die Kieselalgen Deutschlands, Österriechs, und der Schweiz, Teil 2, p. 174, fig. 680, 1931.
Hanna, California Acad. Sci. Proc. 4th ser., vol. 20, p. 211, pl. 15, figs. 3, 4, 5, 1932.

Ehrenberg's figure 22 from Norwich, Connecticut (2d citation above) shows the radial rows of small puncta characteristic of this species. His figure 20 of group 15 from Hollis Cliff, Virginia, was questioned by Ehrenberg himself in his explanation of the plate and is considered to be more applicable to *R. gemmifera*. It has the coarser markings arranged normal to the transapical axis characteristic of the latter.

This species has a geologic range of Miocene to Recent.

Found rarely in sample 5 and frequently in sample 8.

Rhaphoneis angustata Pantocsek

(Plate XI, fig. 11)

Rhaphoneis angustata Pantocsek, Fossilen Bacillarien Ungarns, Part 1, p. 33, pl. 11, fig. 97; pl. 30, fig. 313, 1886.
De Toni, Sylloge algarum, vol. 2, p. 703, 1892.

The specimens of this species are shorter and wider than Pantocsek's, but since he gave dimensions of one individual only, it appears that these specimens would fall within the limits of variation of the species. They varied as follows: length, 22 to 49μ; width 5 to 8μ; transverse rows of puncta 6.5 to 7.6 in 10μ. Pantocsek's figures are: length, 60μ; width, 3μ; transverse rows of puncta 6 in 10μ.

Pantocsek's specimens came from Miocene rocks exposed at Kekko and Szakal, in Hungary, and the species had not hitherto been reported from any other locality.

Dimensions of figured specimen (U.S.G.S. diatom catalog no. 2368–28), length, 32μ; width, 7μ; traverse rows of puncta, 6.5 in 10μ; from sample 8.

Found frequently in samples 1, 2, and 8.

Rhaphoneis elegans Pantocsek and Grunow

(Plate XI, fig. 2)

Rhaphoneis gemmifera var. *elegans* Pantocsek and Grunow, in Pantocsek, Fossilen Bacillarien Ungarns, Part I, p. 34, pl. 2, fig. 21; pl. 20, fig. 179; pl. 27, fig. 264; pl. 30, fig. 317, 1886.
De Toni, Sylloge algarum, vol. 2, p. 706, 1892.
Rhaphoneis elegans Pantocsek and Grunow. Hanna, California Acad. Sci. Proc., 4th ser., vol. 20, p. 213, pl. 15, figs. 5, 6, 7, 1932.
Rhaphoneis amphiceros var. *gemmifera* Peragallo. Mills, Index to the genera and species of the Diatomaceae, part 18, p. 1392, 1934.

The expanded central portion and the produced, parallel-sided apices distinguish this species from *R. gemmifera*. It is another species known only from the Miocene.

Dimensions of figured specimen (U.S.G.S. diatom catalog no. 2372–70), length, 82μ; width, 29μ; puncta, 3.5 to 4.5 in 10μ; from sample 2.

Found commonly in sample 2 and rarely in sample 5.

Rhaphoneis gemmifera Ehrenberg

(Plate XI, fig. 1)

Rhaphoneis gemmifera Ehrenberg, K. Akad. Wiss. Berlin, Ber., 1844, p. 87, 1845.
Van Heurck, Synopsis diatomées Belgique, pl. 36, fig. 30, 1881.
De Toni, Sylloge algarum, vol. 2, p. 706, 1892.
Boyer, Maryland Geol. Survey, Miocene, p. 488, pl. CXXXV, fig. 11, 1904.
Rhaphoneis amphiceros var *gemmifera* (Ehrenberg) Peragallo, Diatomées marines de France et des districts maritimes voisins, pl. 83, figs. 11–14, 1901.
Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 2, p. 175, fig. 681, 1931.
Rhaphoneis amphiceros? Ehrenberg, Mikrogeologie, pl. 33, group 15, fig. 20, 1854.

Hustedt, following Peragallo's lead in making *R. gemmifera* a variety of *R. amphiceros*, hurt his case somewhat by allowing four figures of *R. amphiceros* (Fig. 680), one figure of *R. belgica* (figure 682), and one figure labelled *R. amphiceros* var *gemmifera* (fig. 681) (all drawn at the same magnification) to be printed on the same page (p. 175). It is immediately apparent that there is a real, fundamental, difference between *R. amphiceros* and *R. gemmifera* that is much greater than the relatively slight difference between *R. amphiceros* and *R. belgica*. The differences are summarized in Table 19, all of the data for which have been taken from Hustedt's figures and descriptions.

In *R. gemmifera*, the valve is much larger, the markings coarser and the length/width ratio much greater. Hustedt's figure referred to in the above table is broader than typical specimens from the Calvert formation, where the length/width ratio varies from 4 to 7. The puncta are large and pearly, varying from 3.5 to 4.5 in 10μ in typical specimens. This species thus appears to be quite distinct on purely morphological grounds and worthy of retention as a separate species. Furthermore, *R. gemmifera* is known only from the Miocene, whereas the other two have known ranges of Miocene to Recent.

Dimensions of figured specimen (U.S.G.S. diatom catalog 2377–19), length, 93μ; width, 20μ; length/width ratio, 4.6; puncta 3.5 to 4.5 in 10μ. The slight curvature about a longitudinal axis has no significance and merely represents a slight deformity. Although many specimens were found very few were sufficiently whole and flat to permit a satisfactory photomicrograph to be made.

Found commonly in sample 2, frequently in samples 3 to 7, and rarely in sample 1.

Rhaphoneis immunis Lohman n. sp.

(Plate XI, fig. 6)

Valve narrow, flat, lanceolate, with rostrate apices. A single row of marginal areolae, 8 in 10μ, short, but definitely elongated parallel to the transapical axis; a second row of round areolae, $5\frac{1}{2}$ in 10μ, parallel to and inside of the marginal row, with no apparent relation between the two rows; the second, interior row of areolae sometimes continues into the apices, sometimes stops short, leaving the apices hyaline. Pseudoraphe very wide, forming a lanceolate hyaline central area reaching a maximum width in the central part of half the width of the valve. Length of valve, 70 to 75μ; width, 8μ.

Holotype: U.S.G.S. diatom catalog no. 2371-20, length 71μ. U.S.G.S. diatom locality no. 3075, core sample no. 2 from Ohio Oil Company, Larry G. Hammond No. 1 well, near Salisbury, Wicomico County, Maryland. Depth, 1020–1030. Calvert formation, middle Miocene.

The complete independence of the two rows of areolae is the most distinguishing feature of this species. In most members of this genus, the markings form continuous transverse rows on each side of the pseudoraphe. *R. gemmifera* var. *parcepunctata* Pantocsek and Grunow (80) bears a superficial resemblance to this species, but has capitate apices and has a single marginal row of round areolae, except in the central, expanded portion of the valve, where there are irregular beginnings of a second similar row.

TABLE 19

Comparison of Rhaphoneis amphiceros, R. gemmifera, and R. belgica

	R. amphiceros	*R. gemmifera*	*R. belgica*
Length	14 to 60μ	113μ	67μ
Width	10 to 23μ	31μ	24μ
Length/width ratio	1.4 to 2.6	3.6	2.8
Puncta	6–7 in 10μ	4 in10μ	7–9 in 10μ
Arrangement of rows of puncta	Radial, curved in center of valve	Dominantly straight and normal to transapical axis	Straight and normal to transapical axis

Found frequently in sample 2.

Rhaphoneis parilis Hanna

(Plate XI, fig. 10)

Rhaphoneis parilis Hanna, California Acad. Sci. Proc., 4th ser., vol. 20, p. 214, pl. 16, figs. 2, 3, 4, 1932.

One nearly perfect specimen of this species was found in sample 3, which fits Hanna's description and figures perfectly. Hanna's specimens came from the Temblor formation (middle Miocene), Sharktooth Hill, Kern County, California. This formation is the California equivalent of the Calvert formation in Maryland and contains a remarkably similar diatom flora.

Dimensions of figured specimen (U.S.G.S. diatom catalog no. 2363-7), length, 39μ; width 9μ; transverse rows of puncta, 7 in 10μ.

Found rarely in sample 3.

Rhaphoneis scalaris Ehrenberg

(Plate XI, fig. 3)

Rhaphoneis scalaris Ehrenberg, K. Akad. Wiss. Berlin, Ber., 1844, p. 271, 1845.
Van Heurck, Synopsis diatomées Belgique, pl. 36, fig. 32, 1881 (Calvert formation, Rappahannock, Va.).
Kain and Schultze, Torrey Bot. Club Bull., vol. 16, p. 76, 1889 (Atlantic City, N. J. well).
Boyer, Maryland Geol. Survey, Miocene, p. 489, 1904. (Calvert formation, Maryland).

This striking little species is another one that is known only from the Calvert formation of Maryland and Virginia and its northern equivalent in New Jersey. Its elongate, anastomosing puncta and its lanceolate outline are its chief differentiating characteristics.

Dimensions of figured specimen (U.S.G.S. diatom catalog no. 2374–10), length, 78μ; width, 9μ, from sample 4.

Found rarely in sample 1 and 5 and frequently in samples 2, 4, and 8.

Rhaphoneis wicomicoensis Lohman n. sp.

(Plate XI, fig. 9)

Valve lanceolate with rostrate apices; a single row of oval areolae, 4 in 10μ, along each margin; long axis of areolae parallel to transapical axis and about $\frac{1}{3}$ the width of the valve at that point; central lanceolate hyaline area occupying about $\frac{1}{3}$ width of valve; margin very narrow, hyaline. Length 40 to 50μ; width, 11 to 12μ.

Holotype: U.S.G.S. diatom catalog no. 2375–44, length 43μ; width 11μ. U.S.G.S. diatom locality no. 3078, core sample no. 5 from Ohio Oil Company, Larry G. Hammond No. 1 well, near Salisbury, Wicomico County, Maryland. Depth 1040 feet. Calvert formation, middle Miocene.

The only diatom with which this might be confused is *R. gemmifera* var.? *moravica* Grunow (40, p. 34, pl. 30, fig. 322) from which it differs by having oval instead of round areolae. Grunow apparently entertained some doubt in making *moravica* a variety of *R. gemmifera*. The variety *moravica* should be raised to specific rank, as it is one of the most distinctive members of the whole genus *Rhaphoneis* and is certainly not even closely related to *R. gemmifera*. It is much more closely related to the species here described, but the pronounced difference in the type of areolation separates them.

Found rarely in sample 5.

Genus SCEPTRONEIS Ehrenberg 1845

Sceptroneis caducea Ehrenberg

(Plate XI, fig. 7)

Sceptroneis caducea Ehrenberg, K. Akad. Wiss. Berlin, Ber., 1844, p. 264, 1845. ("Bermuda tripoli"—Nottingham, Md.).
Bailey, Am. Jour. Sci., 1st ser., vol. 48, p. 326, pl. 4, fig. 11, 1845.
Ehrenberg, Mikrogeologie, pl. 33, group 17, fig. 15, 1854 (Rappahannock Cliff, Va.).
Van Heurck, Synopsis diatomées Belgique, Atlas, pl. 37, fig. 5, 1881.
Kain and Schultze, Torrey Bot. Club Bull., vol. 16, p. 76, 1889. (Well at Atlantic City, N. J., Miocene).
Boyer, Maryland Geol. Survey, Miocene, p. 489, pl. CXXXV, fig. 12, 1904 (Calvert formation, middle Miocene).
Hustedt, Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 2, p. 130, fig. 651, 1931.
Hanna, California Acad. Sci. Proc., 4th ser., vol. 20, p. 216, pl. 16, figs. 5, 6, 7, 1932. (Temblor formation, California, middle Miocene).
Rhaphoneis caduceus (Ehrenberg) Van Heurck, Synopsis diatomées Belgique, Texte, p. 147, 1885.

This species was originally described from the Calvert formation at Nottingham, Maryland, (erroneously called "Bermuda tripoli" due to a confusion arising from an old name of "Bermuda Hundred" for the region surrounding Nottingham.) Gregory (38, p. 531, pl. 14, fig. 106) reported it from Loch Fine but indicated that the identification was uncertain, as only a fragment was found. Hustedt has reported it as always rare along the Atlantic and Mediterranean coasts of Europe. In view of the abundance of this species in middle Miocene strata in many localities, it appears that either all of the reported Recent occurrences are questionable, or that it has been reworked from Miocene strata, or that its geologic range is actually middle Miocene to Recent. The last explanation appears to be the least likely of the three for the following reasons: Diatom-bearing rocks of upper Miocene (65, pp. 114 to 115; 44, pp. 969 to 983) and Pliocene (125; 66, pp. 81 to 102, pl. 20 to 23) age have been studied in localities near similar rocks of middle Miocene age. The middle Miocene rocks have yielded large numbers of specimens of *S. caducea* (Hanna, in above synonymy) whereas the upper Miocene and Pliocene diatom-bearing formations have never yielded one specimen. It would appear most amazing for a species as distinctive as this one to be abundant in middle Miocene time, totally absent in the same or any other region during upper Miocene, Pliocene and Pleistocene times, and then suddenly reappear (always rarely) in Europe at the present time. One doubtful occurrence has been given by Tempère and Peragallo (101, pp. 115 to 117) as "Santa Cruz, Colorado", which was ably investigated by Hanna (46, p. 184) who searched for material which might have the diatom flora listed by Tempère and Peragallo. He says, "Eventually a portion of the Tempère sample was purchased in Paris and a careful study of this with the lists has convinced me that it is a mixture from more than one locality. The presence therein of Temblor, middle Miocene, distinctive species indicates that some of it may have come from Santa Cruz Island. Also, the presence of some characteristic Pliocene forms such as *Lithodesmium cornigerum* Brun, is equally convincing that part of the sample came from the vicinity of 'Santa Ynez, California.' " According to all of the evidence presented so far, *S. caducea* is doubtless restricted to the middle Miocene.

Although a fairly large number of specimens of this species were found in the core, none was in a satisfactory state for photographing. Therefore, a specimen was selected from U.S.G.S. diatom locality 2385, 4½ feet, stratigraphically above the base of zone 3 of the Calvert formation (as defined by the Maryland Geological Survey in 1904) exposed in the quarry on the east bank of the Patuxent River opposite the town of Nottingham, Maryland, where the species occurs in great abundance.

Length of figured specimen (U.S.G.S. diatom catalog no. 2177-1, locality 2385), 126μ.

Found frequently in samples 3, 6, and rarely in sample 7.

Genus DIMEROGRAMMA Ralfs, 1861

Dimerogramma novae-caesareae Kain and Schultze

(Plate XI, figs. 4, 5)

Dimerogramma novae-caesareae Kain and Schultze, Torrey Bot. Club Bull., vol. 16, p. 74, pl. 89, figs. 1, 1b, 1889.
De Toni, Sylloge algarum, vol. 2, p. 714, 1892.
Wolle, Diatomaceae of North America, pl. 5, fig. 16, 22, 1894.

Valve linear, with slight central inflation, inflated, acute apices; transverse striae moniliform, marginal, 7.5 to 9 in 10μ, parallel to transverse axis; central space hyaline, about ⅓ width of valve; length of valve, 50 to 75μ; width (center), 6μ; width (across expanded apex), 7–8μ.

The inflation of the central portion is very slight to nonexistent in these specimens, otherwise they agree with the original description and figure. In some instances, as in figure 5 on plate XI, the transverse striae are not resolved into beads, but are really short costae.

This is another species which is known only from the Calvert formation of Maryland and its northern equivalent exposed in the Atlantic City, New Jersey, well.

Dimensions of figured specimens

	USGS diat. cat. no.	Length	Width		Trans. striae
			Center	Apices	
Plate XI, fig. 4	2363-9	52μ	6μ	8μ	7.5 in 10μ
5	2363-28	71μ	6μ	7μ	8.8 in 10μ

Found frequently in sample 3 and rarely in samples 7 and 8.

Genus THALASSIOTHRIX Cleve and Grunow 1880

Thalassiothrix longissima Cleve and Grunow

Synedra thalassiothrix Cleve, K. svenska vetensk akad. Handl, Bihang, Band 1, no. 13, p. 22, pl. 4, fig. 24, 1873.
Thalassiothrix longissima Cleve and Grunow, K. svenska vetensk. akad. Handl., Band 17, no. 2, p. 108, 1880.
Hustedt, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Teil 2, p. 247, fig. 726, 1932.

This hairlike diatom, with a width of 3 to 4μ and a length up to 4 mm. has a geologic range of middle Miocene to Recent.

Found frequently in samples 1, 2, 3, 5, 7, and 8.

Suborder MONORAPHIDINEAE

Family ACHNANTHACEAE

Subfamily COCCONEIOIDEAE

Genus COCCONEIS Ehrenberg 1838

Cocconeis costata Gregory

(Plate XI, fig. 12)

Cocconeis costata Gregory, Quart. Jour. Micr. Sci., vol. 3, p. 39, pl. 4, fig. 10, 1855.
Van Heurck, Synopsis diatomées Belgique, pl. 30, figs. 11-17, 1881.
Mann, Contr. U. S. Nat. Herbarium, vol. 10, part 5, p. 329, 1907. (Very good synonymy).

Only the upper valves, those with no raphe, were found in the samples. The form figured here is typical. The various figures published for this species vary greatly in details, suggesting that either this is an unusually variable species, or, what appears more probable, several species have been combined to form a complex known as *Cocconeis costata*. This may also account for its long geologic range—Miocene to Recent.

Dimensions of figured specimen (U.S.G.S. diatom catalog no. 2368-53), length, 46μ; width, 37μ; costae, 4.5 in 10μ, from sample 8.

Found rarely in sample 3, frequently in samples 2, 5, 6, 7 and commonly in sample 8.

Suborder BIRAPHIDINEAE

Family NAVICULACEAE

Subfamily NAVICULOIDEAE

Genus NAVICULA Bory 1824

Navicula lyra Ehrenberg

Navicula lyra Ehrenberg, K. Akad. Wiss. Berlin, Phys. Abh., 1841, p. 419, pl. 1, group I, fig. 9a, 1843.

Schmidt, Atlas der Diatomaceenkunde, pl. 2, figs. 4, 5, 8, 9, 16, 18, 1875.
Cleve, K. svenska vetensk. akad. Handl. Band 27, no. 3, p. 63, 1895.
Mann, Contr. U. S. Nat. Herbarium, vol. 10, part 5, p. 347, 1907 (good synonymy).
Mills, Index to the Diatomaceae, p. 1086, 1934.

With a known geologic range of Eocene to Recent, and a world wide geographic range, this species is of little value as a stratigraphic guide.

Found rarely in samples 5, 7, and 8.

Genus RAPHIDODISCUS H. L. Smith

Raphidodiscus marylandicus Christian

(Plate XI, fig. 13)

Melonavicula marylandica Christian, Am. Monthly Micr. Jour. vol. 7, p. 218, 1886 *nomen nudum*.
Raphidodiscus marylandica Christian, The Microscope, vol. 7, p. 66, first fig., 1887.
Vorce, The Microscope, vol. 9, no. 5, p. 132, pl. 6, fig. 5, 1889.
Van Heurck, Treatise on the Diatomaceae, pl. 35, fig. 913a, 1896.
Hanna, California Acad. Sci. Proc. 4th ser., vol. 20, p. 208, pl. 14, figs. 3, 4, 1932. (Temblor formation, middle Miocene).
Raphidodiscus febigerii Christian, The Microscope, vol. 7, p. 66, 3 figs., 1887.
Vorce, The Microscope, vol. 9, p. 132, pl. 6, figs. 1, 2, 1889.
Van Heurck, Treatise on the Diatomaceae, pl. 35, fig. 913b, 1896.
Raphidodiscus christianii Gascoyne in Vorce, The Microscope, vol. 9, p. 132, pl. 6, fig. 4, 1889.
Raphidodiscus bogus Ward in Vorce, The Microscope, vol. 9, p. 132, 1889.
Van Heurck, Treatise on the Diatomaceae, p. 236, fig. 33, 1896.
Diploneis mikrotatos var. *christianii* Cleve, K. svenska vetensk. akad. Handl. Band 26, no. 2, p. 96, pl. 2, fig. 1, 1894. (Cambridge, Md., Calvert formation)
Boyer, Maryland Geol. Survey, Miocene, p. 487, pl. CXXXV, fig. 5, 1904 (Calvert formation, middle Miocene).
Cocconeis febigerii Brun, in Schmidt, Atlas der Diatomaceenkunde, pl. 193, fig. 58, 1894 (Richmond, Va., Calvert formation).

I agree fully with Hanna that the genus *Raphidodiscus* should be preserved. It is difficult to understand how Boyer, who must have had hundreds of specimens of the species available for study, could have followed Cleve in assigning it to *Diploneis*. The fundamental differences between this genus and *Diploneis* are as great as those between it and *Coscinodiscus*. The name *Raphidodiscus* suggests that H. L. Smith came to a somewhat similar conclusion before naming it.

This is one of the most valuable guide fossils among all of the diatoms recovered from the core samples. It is known only from the middle Miocene in such widely separated localities as Trinidad, Maryland and Virginia, and California.

Dimensions of figured specimen (U.S.G.S. diatom catalog no. 2377–18), length, 52μ; width, 54μ; transverse rows of beads at oval line opposite central nodule, 10 to 13 in 10μ.

Found rarely in sample 7.

Genus DIPLONEIS Ehrenberg 1845

Diploneis prisca (Schmidt) Cleve

(Plate XI, fig. 8)

Navicula prisca Schmidt, Atlas der Diatomaceenkunde, pl. 12, figs. 66 to 69, 1875, Richmond, Va., and Nottingham and Piscataway, Md. (Calvert formation).
De Toni, Sylloge algarum, vol. 2, p. 85, 1891.
Diploneis prisca (Schmidt) Cleve, K. svenska vetensk. akad. Handl. Band 26, no. 2, p. 103, 1894.

The double rows of puncta, about 16 in 10μ, which alternate with the costae are difficult to see, unless an oil-immersion objective is used and carefully focused. The ease with which they may be seen varies between different valves and even between different parts of the same valve, suggesting that they constitute a surficial membrane easily attacked by corrosive agents.

This species is another excellent marker for the Calvert formation, as it is known only from that formation in Virginia, Maryland and New Jersey.

Dimensions of figured specimen (U.S.G.S. diatom catalog no. 2368-49), length 64μ; width, 23μ; width at constriction, 19μ; costae, 6.3 in 10μ, from sample 8.

Found rarely in samples 1, 3, 5, 6, and frequently in samples 7 and 8.

Diploneis subcincta (Schmidt) Cleve

Navicula subcincta Schmidt, Grundproben der Nordseefahrt, Diatomaceen, p. 87, pl. 2, fig. 7, 1874.
Schmidt, Atlas der Diatomaceenkunde, pl. 13, fig. 41, 1875; pl. 69, fig. 32, 1881.
Diploneis subcincta (Schmidt) Cleve, K. svenska vetensk. akad. Handl. Band 26, no. 2, p. 86, 1894.
Boyer, Philadelphia Acad. Nat. Sci. Proc. vol. 79, suppl., p. 349, 1927.

This species has a geologic range of Miocene to Recent.

Found frequently in sample 8.

Genus PLEUROSIGMA Wm. Smith 1852

Pleurosigma affine var. marylandica Grunow

Pleurosigma affine var. *marylandica* Grunow, in Cleve and Grunow, K. svenska vetensk. acad. Handl., Band 17, no. 2, p. 51, 1880. (Nottingham, Md., Calvert formation).
Peragallo, Le Diatomiste, vol. 1, no. 4, p. 10, pl. 4, fig. 15, 1891.
De Toni, Sylloge algarum, vol. 2, p. 234, 1891.
Mills, Index of the Diatomaceae, part 18, p. 1324, 1934.
Pleurosigma normanii var. *marylandica* (Grunow) Cleve, K. svenska vetensk. acad. Handl. Band. 26, no. 2, p. 40, 1894.
Boyer, Maryland Geol. Survey, Miocene, p. 488, 1904 (Calvert formation).

I agree with Mills when he said "Cleve (Nav. 1 p. 40) appears to have given the specific name of *P. normanii* to two different forms and caused some confusion. It is better to drop Ralf's species and retain Grunow's, though more recent, as has been done by Peragallo."

This variety was represented in many of the samples by fragments of varying size, but usually large enough for accurate identification. It is known only from the Calvert formation of Maryland.

Found rarely in samples 1, 3, 7, and frequently in samples 5, 6, and 8.

OSTRACODA FROM THE HAMMOND WELL

BY

FREDERICK M. SWAIN

The ostracodes obtained from this well include 24 previously described Upper Cretaceous, Eocene and Miocene forms, together with 17 species that are new.

Publications relating to Cretaceous and Tertiary Ostracoda from the Eastern United States and Florida include: Upper Cretaceous, Berry (6); Coryell, Sample, and Jennings (19); Jennings (55); Eocene, Ulrich (105); Jennings (55); Swain (100); Oligocene, Swain (100); Miocene, Ulrich and Bassler (106); Howe et al. (50); Stephenson (96); Edwards (27).*

In the Hammond Well, the interval from 640 to 1130 feet has been identified as the Calvert formation, Middle Miocene, and in it the following ostracode species were obtained:

	Feet
Cytheridea (Haplocytheridea) israelskyi Stephenson	640–650
Cythereis martini (Ulrich and Bassler)	640–660
Cytheretta plebia (Ulrich and Bassler)	640–690
Cythereis evax (Ulrich and Bassler) and var. oblongula (Ulrich and Bassler)	640–820
Cytheridea (Haplocytheridea) obovata Swain, n. sp.	650–660
Leguminocythereis clarkana (Ulrich and Bassler)	650–690
Cythereis exanthemata (Ulrich and Bassler)	650–900
Cytherideis longula Ulrich and Bassler	680–690
Cytherideis ashermani Ulrich and Bassler	680–920
Cythereis (Pterygocythereis) cornuta var. americana (Ulrich and Bassler)	730–950
C. martini var. punctopustula Swain, n. var.	740–750
Cytheretta inaequivalvis (Ulrich and Bassler)	790–890
Bythocypris? wicomicoensis Swain, n. sp.	830–840

The occurrence of *Haplocytheridea israelskyi* Stephenson in the Calvert formation suggests a correlation with that part of the Middle Tertiary comprising the *Discorbis*, *Heterostegina* and *Marginulina* zones of the subsurface Gulf coastal plain of Texas. *Cytherideis ashermani* Ulrich and Bassler, *C. longula* Ulrich and Bassler, *Cythereis exanthemata* (Ulrich and Bassler), and *C.* (*Pterygocythereis*) *cornuta* var. *americana* (Ulrich and Bassler) are found also in the Choctawhatchee formation of Florida (50). *Cytherideis ashermani* and *Cythereis exanthemata* have been recorded by Edwards from the Duplin marl of North Carolina.

The interval from 1130 feet to 1360 feet has been designated as Eocene. This part of the well was cored continuously so that the depths given for the various species are fairly accurate. The following ostracodes were obtained:

	Feet
Cytherelloidea howei Swain, n. sp.	1220–1230
Bytheocypris subaequata Ulrich	" "
Loxoconcha cf. L. creolensis Howe and Chambers	" "
Cythereis bassleri Ulrich	" "

* This article was submitted to the U. S. Geological Survey, November 20, 1945. A recent comprehensive paper by Ruth A. M. Schmidt (Journal of Paleontology, vol. 22, 1948, pp. 389–431) describes many additional ostracode species from the outcropping Upper Cretaceous and Lower Eocene of the Middle Atlantic States. A publication by W. A. Van den Bald (Contribution to the Study of Ostracoda, Amsterdam, 1946) describes Upper Cretaceous and Tertiary forms that are common to the Atlantic coast and the Carribbean regions.

	Feet
Cythereis marginoreticulata Swain, n. sp.	1220–1230
Cythereis pellucinoda Swain, n. sp.	" "
Brachycythere betzi Jennings	" "
Cytheridea (Clithrocytheridea) aquia Swain, n. sp.	" "
Cythereis goochi Swain, n. sp.	1240–1330
Loxoconcha? postdecliva Swain, n. sp.	1250–1260
Cythereis splendens Sutton and Williams	1260–1270
Cythereis reticulodacyi Swain, n. sp.	1270–1280
Cythereis parwinniana Swain, n. sp.	" "
Cythereis dorsopleura Swain, n. sp.	1280–1290
Cythereis cf. hysonensis Howe and Chambers	" "
Cytherella submarginata Ulrich	1290–1300
Argilloecia alexanderi Swain, n. sp.	" "
Cythereis cf. spiniferrima Jones and Sherborn	1300–1310
Eucythere spp.	1310–1320
Bairdia postextensa Swain, n. sp.	1320–1330
Cythereis ventroconvexa Swain, n. sp.	" "

A zonal relationship of the species listed above appears to be possible, but additional collections must be studied before such zonation can be established. *Brachycythere betzi* Jennings (55) occurs in the Hornerstown formation of the Wilcox Eocene of New Jersey. The other previously described species in this interval indicate an Eocene age, but their arrangement is not such as to permit recognition of the various standard Eocene subdivisions.

The interval between 1360 feet and 1390 feet is believed to represent the Monmouth group of Navarro age. *Cythereis* (*Pterygocythereis*) cf. *C. communis* Israelsky, occurring in samples from 1360–70 feet and from 1410–20 feet is the only ostracode seen in the Monmouth beds, and it apparently occurs also in the upper part of the underlying Matawan formation. The species is much like if not identical to a form identified by Alexander (1) from the Navarro formation of northeastern Texas as *Cythereis communis* Israelsky. *C. communis* as described by Israelsky from rocks equivalent to the Navarro and Taylor formations in Arkansas differs in several ways from both the Texas and the Maryland examples. Jennings (55) recorded *C. communis* from the Mount Laurel and Navesink formations of the Monmouth group of New Jersey. The example from New Jersey is apparently conspecific with the forms described here. Unfortunately, the interval representing the Monmouth group in the Hammond well did not yield any of the other Monmouth species that were described by Jennings.

The Matawan formation, according to information other than that furnished by the ostracodes, occurs between 1390 feet and 1480 feet. The following ostracode species were found in this interval:

	Feet
Paracypris sp. aff. P. angusta Alexander	1410–1420
Cythereis (Pterygocythereis) communis Israelsky	" "

	Feet
Cytheridea (Haplocytheridea) cf. monmouthensis Berry	1410-1420
Cythereis reesidei Swain, n. sp.	1433-1440
Bairdia cf. rotunda Alexander	1440-1450
Cytheridea? sp. aff. C. perforata (Roemer)	" "
Cythereis paraustinensis Swain, n. sp.	1470-1480
Cythereis cf. bicornis Israelsky	" "
Cytheridea (Haplocytheridea) parvasulcata Swain, n. sp.	" "

The above species indicate a late Upper Cretaceous age for the containing sediments. *Paracypris angusta* Alexander, *Bairdia rotunda* Alexander and *Cytheridea perforata* (Roemer) are found in the Taylor formation of northeastern Texas. *Cythereis bicornis* Israelsky occurs in the upper part of the Austin formation and in the Taylor formation. *Cythereis paraustinensis*, n. sp. is much like *C. austinensis* Alexander, a characteristic species of the Austin formation.

Below 1480 feet only one ostracode specimen has been obtained, namely, *Leguminocythereis? pustulosa*, n. sp. from a core sample at 1588-98 feet. On the basis of other information this level is believed to represent the Raritan formation of early Upper Cretaceous Woodbine age.

SYSTEMATIC DESCRIPTIONS

Subclass OSTRACODA Latreille

Order PLATYCOPA Sars

Family CYTHERELLIDAE Sars

Genus CYTHERELLA Jones, 1849

Cytherella cf. C. submarginata Ulrich

(Plate XII, fig. 4)

Cytherella submarginata Ulrich, 1901, Maryland Geol. Surv. Eocene volume, p. 118, pl. XVI, figs. 14, 15.

Shell ovate in lateral view; highest one-third to one-half from anterior end; dorsal margin of right valve strongly arched, that of left valve less arched; ventral margin of right valve strongly convex, that of left valve moderately convex; anterior margin broadly rounded with a narrow rimlike elevation; posterior margin more narrowly rounded, most extended below, subtruncate above. Right valve larger than left, extending strongly beyond the other mid-dorsally and mid-ventrally. Greatest convexity in posterior one-third. Surface smooth.

Remarks.—The specimens have a somewhat different outline than the single example of *C. submarginata* figured by Ulrich, but otherwise are similar to that species and are compared with it.

Occurrence.—Core sample at 1290-1300 feet.

Figured Specimen.—U.S.N.M. 559890.

Genus CYTHERELLOIDEA Alexander, 1929

Cytherelloidea howei Swain, n. sp.

(Plate XII, fig. 5)

Shell suboblong in lateral aspect; dorsal margin of right valve nearly straight, that of left valve slightly sinuate; ventral margin of each valve nearly straight and subparallel to dorsum;

anterior margin broadly and uniformly rounded; posterior margin broadly rounded, truncate medially. Greatest convexity at posterior extremity. Right valve larger than left, overlapping it around entire periphery; overlap greater along mid-dorsal section than elsewhere.

Surface of each valve bears a sulcus that rises from a dorso-median pit, extends dorsally, then bends sharply backward to about one-fifth from posterior end where it narrows and dies out; a longitudinal furrow lying ventrad of midheight extends for about two-thirds length of shell; on either side of furrow is a broad longitudinal ridge. Anteriorly and ventrally there is a marginal swelling; dorsally, swelling less defined, and posteriorly it is lacking. Internal features not observed.

Dimensions.—Length of holotype 0.81 mm., height 0.46 mm., thickness 0.21 mm.

Relationships.—In the character of its surface ornamentation this species is much like the group of *C. vicksburgensis* Howe, including *C. chawneri* Howe and Law, *C. byramensis* Howe and Law, and *C. byramensis* var. *conecuhensis* Howe and Law, all from the Oligocene Vicksburg group of the Gulf region. In all of these species the longitudinal ridges appear to be narrower and the dorso-median sulcus differently shaped and bounded dorsally by an oblique ridge. In *C. danvillensis* Howe from the Upper Eocene Jackson group, the longitudinal ridges are relatively narrow and there is a conspicuous, broad, dorso-median depression that is bounded above by a narrow ridge. *C. spiralia* Jennings from the Mount Laurel and Navesink formations, Upper Cretaceous, of New Jersey, is very close to the species under discussion, but possesses a distinct marginal swelling around the posterior as well as the anterior end.

Occurrence.—Core sample 1220–30 feet.

Holotype.—U.S.N.M. 559891.

Family CYPRIDAE BAIRD, 1846

Genus BYTHOCYPRIS BRADY, 1880

Bythocypris subaequata Ulrich

(Plate XII, figs. 2, 3)

Bythrocypris subaequata Ulrich, 1901, Maryland Geol. Survey, Eocene vol., p. 116, pl. XVI, figs. 1–4.

A single example having the valve surfaces much recrystallized, has an outline similar to Ulrich's species from the Aquia formation at Upper Marlboro, Maryland. The individual figured here is from core sample at 1220–30 feet. It is subelliptical in lateral view; anterior end uniformly rounded; posterior end slightly truncate above; dorsal margin slightly convex; ventral margin nearly straight, subparallel to dorsum; valves nearly equal in size, the left slightly the larger. Viewed from above, the hinge margin is slightly sinuate. Internal features not seen.

Plesiotype.—U.S.N.M. 559892.

Bythocypris? wicomicoensis Swain, new species

(Plate XII, fig. 1)

Shell elongate-reniform in lateral aspect; dorsal margin moderately convex, with greatest height lying about one-third from anterior end; ventral margin slightly concave; anterior margin narrowly rounded, more extended below; posterior margin sharply rounded and strongly extended below. Left valve larger than right, overlapping it strongly along the dorsal two-thirds and along the ventral one-third, less conspicuously elsewhere.

The species is based upon a single complete shell in which the internal features unfortunately could not be ascertained.

Dimensions.—The holotype measures length 1.01 mm., height 0.46 mm., thickness 0.46 mm.

Relotionships.—The shape and overlap relationships of the species ally it to *Bythocypris* Brady, but owing to incomplete knowledge of the internal characters, its generic status is questionable. In its details of shape, particularly of the posterior outline, *wicomicoensis* differs slightly from other described species.

Occurrence.—The holotype is from sample at 830–40 feet.

Holotype.—U.S.N.M. 559893.

Genus PARACYPRIS Sars, 1865

Paracypris aff. P. angusta Alexander

(Plate XII, fig. 6)

Paracypris angusta Alexander, 1929, Univ. Texas Bull. 2907, p. 67, pl. IV, figs. 3, 7.

Shell subtriangular-acuminate in lateral view; highest about one-third from anterior end; hinge margin straight, equal to about half shell length; ventral margin slightly concave, converging posteriorly with respect to dorsum; anterior margin the more broadly rounded, truncated above; posterior margin acuminate, extended below. Left valve larger than right, overlapping and extending beyond the other around entire periphery. Surface smooth.

Hinge simple, the edge of the right valve fitting into a groove along the hinge margin of the left; other internal features not seen.

Occurrence.—The species was originally described as occurring in the lower one-fourth of the Taylor group in northeastern Texas (1, p. 67). The specimen here described and illustrated from the sample at 1410–20 feet is believed to be related to *P. angusta.*

Figured Specimen.—U.S.N.M. 103947.

Genus ARGILLOECIA Sars, 1865

Argilloecia alexanderi Swain, new species

(Plate XII, fig. 7)

Shell elongate-subreniform in lateral aspect; highest medially; dorsal margin strongly convex; ventral margin of right valve slightly convex, that of left valve nearly straight, slightly concave medially; anterior margin the more broadly rounded, most extended medially; posterior margin narrowly rounded, subacuminate. Right valve larger than left, overlapping and extending beyond the other around entire periphery, the greatest such extension being ventral in position. Surface smooth.

Hinge surface curved, equal to about one-half shell length; along the hinge, the slightly extended edge of the left valve fits into a narrow groove on the right valve. Muscle scar consists of a compact group of three spots, lying at midlength; there are two anterior spots, together with a larger postjacent spot.

Dimensions.—Length 0.51 mm., height 0.25 mm., thickness 0.20 mm.

Relationships.—In the nature of its shape and overlap, and the character of its hinge and muscle scar, this species is related to *Argilloecia* Sars. No other described species was noted that exactly matches the specimens here described.

Occurrence.—Core sample at 1290–1300 feet.

Holotype.—U.S.N.M. 559894.

Family BAIRDIIDAE Sars, 1887

Genus BAIRDIA McCoy, 1884

Bairdia postextensa Swain, n. sp.

(Plate XII, fig. 10)

Shell subtriangular in lateral view; greatest height slightly less than half the distance from anterior end; dorsal margin strongly convex; ventral margin moderately convex in left valve, moderately convex and partly sinuate in right valve; anterior margin rounded, extended medially, the anteroventral marginal bend slightly angulated; posterior margin narrowly rounded, much extended medially. Left valve larger than right, extending beyond the other around entire periphery; greatest extension along ventrum. Greatest convexity slightly anteromedian in position. Surface smooth. Internal features not observed.

Dimensions.—Length of holotype 0.97 mm., height 0.59 mm., thickness 0.46 mm.

Relationships.—In the marked extension of its posterior margin, this species resembles *B. comanchensis* Alexander (1) from the Lower Cretaceous deposits of Texas, and it is also similar to *Bairdia* sp. figured by Howe and Chambers (51) from the Eocene Jackson group of Louisiana. In *B. comanchensis* there is much greater dorsal overlap of the left valve, and in the example from Louisiana, the right valve margin is longer and straighter. The new species is more narrowly rounded and extended posteriorly than is *Bairdioppilata delicatula* Jennings from the Hornerstown formation of New Jersey.

Occurrence.—Core sample 1320–30 feet.

Holotype.—U.S.N.M. 559895.

Bairdia cf. B. rotunda Alexander

(Plate XII, fig. 11)

Bairdia rotunda Alexander, 1929, Univ. Texas Bull. 2907, p. 62, pl. III, figs. 2, 6.

A single example in the collection appears to belong to this species. The shell is subtriangular in lateral outline; greatest height slightly post-median; dorsal margin strongly convex; ventral margin gently convex, straight medially; anterior margin extended medially, truncate above; posterior margin extended and acuminate ventro-medially, the right valve posterior termination pointed. Left valve much larger than right, overlapping and extending strongly beyond the other dorsally and ventrally, less strongly at the ends. Greatest convexity slightly post-median. Surface bears scattered, tiny, inconspicuous pits.

Occurrence.—Core sample at 1440–50 feet. Alexander (1, p. 62) states the species occurs in the upper part of the Austin group and in the lower two-thirds of the Taylor group in Texas.

Figured Specimen.—U.S.N.M. 103948.

Family CYTHERIDAE Baird, 1850

Genus EUCYTHERE Brady, 1866

Eucythere spp.

(Plate XII, figs. 8, 9)

Two shells are thought to belong to this genus. Both are imperfectly preserved, and fail to exhibit internal characters, so that formal description of them is not made.

One example is subtriangular, highest antero-medially, relatively short, with a very strongly arched dorsal margin. The broadly rounded anterior end is more extended below, and the posterior end is narrowly rounded, subacuminate, most extended ventrally. Ventral margin nearly straight. Left valve larger than right, overlapping it around entire margin. Surface smooth.

In shape this example resembles *E. midwayensis* Alexander from the Paleocene Midway group of Texas, *E. chickasawhayensis* Howe and Law from the Oligocene Vicksburg group of Louisiana, and *E. brightsealensis* (Berry) from the Upper Cretaceous Monmouth formation of Maryland. In comparison to these, however, the present specimen is relatively shorter and more strongly arched dorsally.

The second example, here tentatively ascribed to *Eucythere* is elongate-subtriangular in side view; highest about one-third from anterior end; dorsal margin strongly arched; ventral margin moderately concave; anterior end broadly rounded, most extended medially; posterior end very narrowly rounded, acuminate, much extended ventrally. Left valve larger than right, overlapping it. Surface smooth.

This specimen is comparable in outline to *E. brownstownensis* Alexander from the Upper Cretaceous of Texas, but is even more extended and more acuminate posteriorly than is that species.

Occurrence.—Core sample at 1310–20 feet.

Figured Specimens.—U.S.N.M. 559896.

Genus LOXOCONCHA Sars, 1865

Loxoconcha cf. L. creolensis Howe and Chambers

(Plate XII, fig. 13)

Loxoconcha creolensis Howe and Chambers, 1935, Louisiana Dept. Cons. Geol. Bull. 5, pp. 40, 41, pl. V, fig. 13.

Shell very small, subovate-elliptical in side view; highest near anterior end; dorsal margin only slightly convex; ventral margin converges strongly backward with respect to dorsum, but this feature obscured in lateral view by the pronounced sub-alate overhang of the post-ventral expanded valve surface; a prominent, narrow marginal rim present around free margins; surface reticulately pitted.

Internal features not observed.

Remarks.—The specimens at hand are comparable to *L. creolensis* Howe and Chambers from the Eocene Jackson group of Louisiana. One of the individuals is rather more elongate and more coarsely pitted than the others, and may represent either a distinct variety or a dimorphic example.

Occurrence.—Core sample at 1220–30 feet.

Figured Specimen.—U.S.N.M. 559897.

Loxoconcha? postdecliva Swain, new species

(Plate XII, fig. 12)

Shell subelliptical in lateral view; highest about one-fourth from anterior end; dorsal margin nearly straight, about four-fifths shell length; ventral margin slightly sinuate; anterior margin broadly rounded, more extended below; posterior end slightly compressed terminally, its margin more narrowly rounded than the other, truncate above, slightly produced in ventral one-half. Left valve larger than right, but scarcely extending beyond the other except at the post-dorsal marginal bend.

Prominent short keels occur near valve edges, just behind post-ventral marginal bend.

Medially, there is a short groove or sulcus that begins about one-third distance from dorsal margin and terminates just ventrad of valve middle. Posterior portion of valve surface strongly swollen and declining rapidly to narrow, compressed posterior termination, so that greatest convexity lies about one-third from posterior end. Shell surface ornamented by reticulate, curving ridges that are more or less irregularly disposed, but which, near anterior end, tend to run parallel to that margin.

Hingement and other internal features not observed.

Dimensions.—The holotype measures length 0.73 mm., height 0.38 mm., thickness 0.32 mm.

Relationships.—In general shape and in the presence of a median-vertical sulcus, this species resembles *Loxoconcha prava* Alexander (3) from the Paleocene Midway group of Texas. The latter, however, has a pronounced post-terminal flange, a more subdued, although somewhat coarser pattern of reticulate surface ornamentation, a medially concave dorsum, and a less swollen posterior portion. Lack of knowledge about internal features makes generic designation of *postdecliva* somewhat insecure, but its general shape and post-ventral marginal keels ally it to *Loxoconcha*.

Occurrence.—The holotype is from core sample at 1250–60 feet.

Holotype.—U.S.N.M. 559898.

Genus CYTHERIDEIS Jones, 1856

Cytherideis ashermani Ulrich and Bassler

(Plate XIII, fig. 1)

Cytherideis ashermani Ulrich and Bassler, 1904, Maryland Geol. Surv., Miocene vol., p. 126 pl. XXXVII, figs. 10–16.
Cytherideis ashermani Ulrich and Bassler, Howe, Henry V. et al, 1935, Fla. Geol. Surv. Bull. 13, p. 14, pl. III, figs. 8–10.

This species occurs in the Middle Miocene Calvert formation of Maryland, and in the Middle and Upper Miocene Choctawhatchee formation of Florida. It is present in samples ranging in depth from 680 feet to 920 feet.

The shell is elongate-ovate in lateral view; highest about one-third from anterior end; dorsal margin gently convex, with the middle portion nearly straight; ventral margin nearly straight, slightly concave medially; anterior margin the more broadly rounded, extended below; posterior margin narrowly rounded, extended below. Left valve slightly larger than right. Surface bears large pits, with interspaces having width about equal to diameter of pits.

Plesiotype.—U.S.N.M. 559899.

Cytherideis longula Ulrich and Bassler

(Plate XIII, fig. 2)

Cytherideis longula Ulrich and Bassler, 1904, Maryland Geol. Surv. Miocene vol., p. 128, pl. XXXVII, figs. 21–27.

Relatively much more elongate than *C. ashermani*, this species is otherwise similar to it in surface ornamentation. Previously described by Ulrich and Bassler from the Middle Miocene Choptank and Calvert formations of Maryland, it occurs in the sample at 680–90 feet.

Plesiotype.—U.S.N.M. 559900.

Genus CYTHEREIS Jones, 1849

Cythereis martini (Ulrich and Bassler)

(Plate XII, figs. 16, 17)

Cythere martini Ulrich and Bassler, 1904, Maryland Geol. Surv. Miocene vol., p. 112, pl. XXXVI, figs. 11–15.

The following description is part supplements that of Ulrich and Bassler.

Shell oblong-subquadrate in lateral aspect; hinge margin nearly straight, slightly arched medially, and about five-sevenths of shell length; ventral margin nearly straight and converging slightly toward dorsum in a posterior direction; greatest height about two-sevenths from anterior end; anterior margin truncate above, extended below, and bending sharply to meet ventral margin; about 10 short spines lie along ventral half of anterior margin; posterior margin more uniformly, but also more narrowly, rounded than the other, and subtruncated medially, provided with a few short spines along ventral half. Left valve larger than right, especially at ends of hinge margin.

Anterior end with a marginal rimlike elevation that bears two narrow grooves parallel to margin; grooves continue part way along ventrum, but marginal rim is not appreciably elevated here; posterior end with a narrow marginal rim. Just anterior to valve middle is a node-like swelling; dorsal and ventral to swelling are oblique, depressed areas. Middle two-thirds of valve surfaces reticulately ornamented; in some specimens, low nodes are developed at junction of reticulate ridges in posterior part of shell. A small eyespot occurs just beneath anterodorsal marginal bend on each valve.

Hinge of right valve consists of an anterior, strongly elevated, pointed tooth, a postjacent rounded socket, a posterior, strongly elevated, pointed tooth, in front of which is a small, subtriangular, shallow socket, and between these terminal dental areas, the valve edge bears a very faint groove. Hinge of left valve not seen, but is presumed to be a counterpart of that of right. Marginal pore canals arranged in pairs, about 30 on each end. Inner lamellae fairly broad, the inner margin and line of concresence coinciding. Muscle scar lies anterior to midlength, and consists of a compact group of four spots; additional spots may be present dorsal and anterior to the main group, but could not be observed clearly.

Remarks.—This species, originally placed with *Cythere* by Ulrich and Bassler, is more nearly similar to *Cythereis.* As compared to species considered to be more typical of *Cythereis* (37), *martini* lacks dorsal and ventral post-median nodelike elevations, so that its classification remains somewhat questionable.

Occurrence.—In samples from 640 feet to 660 feet and from 990 to 1000 feet. It was originally described as occurring in the Miocene Choptank and Calvert formations of Maryland and the Chesapeake group of Virginia.

Plesiotypes.—U.S.N.M. 559901, 559902.

Cythereis martini var. punctopustula Swain, new variety

(Plate XII, fig. 18)

General outline and major features of shell as in *C. martini*; characteristic antero-median elevation well developed, as is the post-ventral protuberance of the surface of the right valve. Four or five low nodes present along dorsum. Surface depressed into broad, longitudinal furrows above and below antero-median swelling, thereby defining a low, longitudinal, submedian ridge. Small marginal spines occur along ventral half of ends of both valves, but are only feebly developed on posterior end of left valve. Surface of valves raised into three or four broad, pustule-like elevations, that are deeply pitted, and provide the varietal name.

Dimensions.—The holotype measures length 0.84 mm., height 0.49 mm., thickness 0.43 mm.

Remarks.—Three specimens are believed to be this variety. One is relatively much more elongate than the other two and may represent a dimorphic individual, perhaps a male. The elongate example is much like *Cythereis producta* (Ulrich and Bassler) in outline, but that species as illustrated, appears to lack the two longitudinal depressed areas that define a low submedian ridge.

Occurrence.—The holotype is from the sample at 740–50 feet.

Holotype.—U.S.N.M. 559903.

Cythereis bassleri Ulrich

(Plate XIII, fig. 7)

Cythereis bassleri Ulrich, 1901, Maryland Geol. Surv., Eocene vol., p. 120, pl. XVI, figs. 19–21.

Shell small, suboblong in lateral outline; highest about one-sixth from anterior end; dorsal margin nearly straight for most of its length, arched at anterior end; ventral margin nearly straight, slightly sinuate, converging backward with respect to dorsum; anterior margin rounded, more extended below, slightly truncate above, fringed with small spines; posterior end compressed, its margin narrowly rounded, slightly angulated medially, concave above, convex below, its ventral half bearing three or four blunt spines on each valve. Left valve larger than right, overlapping the other most noticeably at antero-cardinal angle.

A narrow, marginal rim is developed terminally and ventrally, its anterior portion faintly reticulate, and its inner side bounded by a rather deep groove that is broader terminally than ventrally. An antero-median swelling is defined posteriorly by a curved, narrow depression. On ventral part of valve surface is a longitudinal ridge that extends from the antero-ventral angle back to about one-fourth from posterior end where it bends dorsally, almost at a right angle, to meet a ridge that parallels and lies close to the dorsum; dorsal ridge extends forward to about one-third from anterior end where it dies out. Entire surface lying within marginal rims coarsely pitted in a reticulate pattern.

Variation among the specimens at hand is evidenced by differences in relative elongation, and in the strength of the longitudinal ridges, the antero-median tubercle, and the surface pits.

Hinge of left valve consists of the following elements: an anterior rounded socket with postjacent, triangular, shallow, depressed area, a narrow bar, formed of the thickened and rounded valve edge, and a posterior rounded socket. Hinge of right valve not seen, but is presumably the antithesis of the left. Line of concresence and inner margin not quite coinciding terminally. Marginal pore canals rather widely spaced but fairly numerous; 15 to 20 occurring on the anterior end. Muscle scar not seen.

Remarks.—This species is somewhat like *C. claibornensis* Gooch and *C. collei* Gooch both from the Eocene Cook Mountain formation of Louisiana. In both of the latter, however, the inner ridges are more elevated, and the pattern of surface ornamentation appears to be coarser than in *C. bassleri*.

Occurrence.—The species occurs in core samples from 1220 to 1330 feet. Originally described from the Eocene Aquia formation of Maryland, it is also reported to occur in the Wilcox and Claiborne groups of Texas, Louisiana, and Alabama (3, p. 220).

Plesiotype.—U.S.N.M. 559904.

Cythereis marginoreticulata Swain, new species

(Plate XIII, fig. 12)

Shell elongate-ovate in lateral view; highest near anterior end; dorsal margin nearly straight but with strongly elevated antero-cardinal angle; ventral margin nearly straight for most of its length, converging moderately backward with respect to dorsum; anterior margin broadly rounded, extended below, and bears numerous small spines; posterior end compressed, its margin narrowly rounded, angulated dorso-medially, and with several short, blunt spines. Left valve slightly larger than right, overlapping it most conspicuously at the cardinal angles.

Terminal and ventral margins provided with a distinct and elevated rim; mid-ventrally the rim is narrower and less elevated; anteriorly, the rim is broad and is bounded on its inner side by a deep groove; its surface bears seven or eight polygonal pits that supply the specific name. Posteriorly, the marginal rim is bounded on its inner side by a deep groove, and bears several pustules on its surface. A small nodelike swelling lies on valve surface in an antero-median position. Surface reticulately pitted, with small nodes prominently developed at the intersections of many of the reticulating ridges. Along dorsum, four small nodes project above that margin as viewed laterally.

Internal features not observed.

Dimensions.—The holotype measures length 0.78 mm., height 0.43 mm., thickness 0.32 mm.

Relationships.—This species is close to *C. bassleri* with which it is associated in this material. As compared to *bassleri*, the new species lacks an angulated inner ridge, has a reticulate or pitted anterior border, bears four conspicuous nodes along the dorsum, and is more acuminate posteriorly.

Occurrence.—The holotype and only known example is from the core sample 1220–30 feet.

Holotype.—U.S.N.M. 559905.

Cythereis dorsopleura Swain, new species

(Plate XIII, fig. 8)

Shell subquadrate in side view; highest about one-fifth from anterior end at position of anterior cardinal angle; dorsal margin nearly straight, slightly sinuate; ventral margin nearly straight, converging moderately backward with respect to dorsum; anterior margin broadly rounded, slightly more extended below, its ventral half provided with four or five short, blunt, broad spines; posterior end compressed, its margin narrowly rounded, angulated medially, and dorsally, curving uniformly into that margin. Left valve larger than right, but extending beyond the other only at the antero-cardinal angle.

Entire margin of each valve bears a distinct, elevated rim; just behind antero-ventral bend, a strong, short ridge arises from the marginal rim and runs posteriorly to about one-fifth from that end where it terminates in an elevated node. Along dorsum, several short, stout, ridge-like processes project ventrally from the inner side of the marginal rim. Antero-median, rounded node distinct; a broad median-longitudinal ridge lies posterior to the node and is connected to it. Surface marked by scattered, widely spaced pits, that on the posterior, compressed portion are only about half the diameter of the more anterior pits. Shell surface, as a whole, smooth and shiny.

Internal features mostly not observed; along anterior end, marginal pore canals occur in pairs on ventral half, where they number 12 to 14; in dorsal half of anterior end only one or two widely spaced pore canals are visible.

Dimensions.—The holotype measures length 0.59 mm., height 0.32 mm., thickness 0.25 mm.

Relationships.—This species is very similar to *Cythereis prestwichiana* Jones and Sherborn as illustrated by Alexander from the Midway group of Texas (3, p. 220, pl. 32, figs. 14, 15). *C. prestwichiana*, however, lacks spurlike extensions from the inner part of the dorsal marginal rim, has the posterior end of the post-median longitudinal ridge bent dorsally to connect with the marginal rim, and its surface pits have scalloped edges.

Occurrence.—Core sample at 1280–90 feet.
Holotype.—U.S.N.M. 559906.

Cythereis reesidei Swain, new species

(Plate XIV, fig. 3)

Shell subovate in lateral aspect; highest about one-third from anterior end; dorsal margin nearly straight in left valve slightly convex in right valve; ventral margin nearly straight to slightly sinuate, converging strongly backward with respect to dorsum; anterior margin broadly rounded; posterior margin more narrowly rounded and bearing a few small spines. Left valve larger than right, but projecting beyond the other, conspicuously, only at antero-cardinal angle.

Anterior end provided with a narrow marginal rim that continues around antero-dorsal bend to about midlength where it dies out; a narrow, curved ridge begins below dorsal margin and slightly antrad of midlength from which position it rises to the dorsal margin, continues backward and terminates about one-fourth from posterior end. Antero-median node prominent, bounded posteriorly and ventrally by a narrow groove. Surface of valves ornamented by strongly developed, reticulating ridges, except on the marginal areas, on the antero-median node, and on the compressed posterior end, all of which are smooth. Greatest convexity about one-third from posterior end; behind, the surface slopes steeply to the compressed terminal portion.

Hinge of right valve consists of an anterior pointed tooth with postjacent shallow socket, a narrow median groove, and a posterior pointed tooth. Hinge of left valve consists of an anterior socket with postjacent, inconspicuous tooth, a median knife-edged bar formed of the extended valve edge, and a small rounded posterior socket. Inner lamellae fairly broad; inner margin and line of concresence coincide except at posterior marginal bend. A rounded depression that is the internal expression of the antero-median node contains the muscle scar, but details of the musculature could not be ascertained.

Dimensions.—The holotype measures length 0.57 mm., height 0.35 mm., thickness 0.32 mm.

Relationships.—In its general shape, and the reticulation of its valve surfaces, this species is close to *Cythereis pellucinoda*, n. sp. It differs from that form in that it lacks a ventro-median longitudinal ridge, has the posterior surface of the valves sloping more gently to the compressed end, has little or no angulation of the posterior lateral outline, and lacks a lucid antero-median node. The new species is also somewhat like *Cythereis mahonae* Alexander (1) from the Lower Cretaceous of Texas, but that form is more elongate, has a sharply angulated posterior margin, bears a prominent median-longitudinal ridge, and lacks a well-defined antero-median node.

Occurrence.—The holotype and only known example is from the core sample at 1433–40 feet.

Types.—Holotype, U.S.N.M. 103949; paratype, 103950.

Cythereis paraustinensis Swain, new species

(Plate XIII, fig. 9)

Shell subovate-elongate in side view; highest about one-fourth from anterior end, at position of antero-cardinal angle; dorsal margin nearly straight, a little more than three-fifths shell length; ventral margin nearly straight, slightly concave medially, converging backward with respect to dorsum; anterior margin broadly rounded, slightly more extended below, bearing numerous small spines; posterior end compressed, narrowly rounded, angulated medially, its ventral portion bearing several blunt spines. Left valve larger than right, but extending beyond the other only at the antero-cardinal angle.

Anterior marginal rim distinct, formed of two, narrow, parallel ridges; posterior marginal rim distinct but narrow, with smooth surface. A rather ill-defined ridge parallels dorsal margin. Antero-median node elevated, elongated longitudinally; to its post-dorsal portion is attached a short, longitudinal ridge. Ventrally, there is a pronounced longitudinal ridge that, along its posterior part, forms the crest of a short post-ventral alate expansion. Other than on the ridges and on the terminal rims, surface coarsely pitted.

Internal features mostly not observed; marginal pore canals on posterior end numerous; in ventral half they apparently occur in pairs.

Dimensions.—The holotype measures length 0.56 mm., height 0.32 mm., thickness 0.28 mm.

Relationships.—This example is very similar to *Cythereis austinensis* Alexander (1) from the middle Upper Cretaceous Austin group of northeastern Texas. The Austin species has a short oblique ridge that connects the posterior end of the median-longitudinal ridge with the dorsum, and as described, it lacks spines on the anterior margin.

Occurrence.—The holotype is from the core sample at 1470–80 feet.

Holotype.—U.S.N.M. 103951.

Cythereis pellucinoda Swain, new species

(Plate XIV, figs. 1, 2)

Shell subquadrate in lateral view; highest about one-fourth from anterior end at position of antero-cardinal angle; dorsal margin nearly straight; ventral margin nearly straight to slightly sinuate, converging backward rather strongly with respect to dorsum; anterior margin broadly rounded, most extended and slightly produced antero-ventrally; posterior end compressed, its margin narrowly rounded, angulated medially, truncate above. Left valve slightly larger than right, but projecting beyond the other only at the antero-cardinal angle.

Anterior marginal rim narrow, well defined, and continuing ventrally and posteriorly to beginning of posterior valve-compression; posterior marginal rim narrower than the other and with several small pustules. Antero-median node well defined, but not greatly elevated; over surface of node the shell is very thin so that the muscle scar is visible from the exterior. Dorsally, a ridge arises near post-cardinal angle and runs obliquely forward to a little in front of midlength where it dies out; a short extension projects ventrally from the posterior end of the ridge; ventrally, there is a second longitudinal ridge that forms the crest of a short post-ventral alate expansion. Remainder of shell ornamented by low narrow ridges that are connected at frequent intervals by cross ridges to produce a reticulate pattern. Post-ventral surface flattened owing to the short alae; greatest convexity about median. Muscle scar consists of four small spots arranged within the area of the antero-median node. There is a group of two spots together with two more anterior separated spots.

Dimensions.—The holotype measures length 0.62 mm., height 0.38 mm., thickness 0.28 mm.

Relationships.—The form here described is very close to *Cythereis? weaveri* Howe and Law from the Oligocene Vicksburg group of Louisiana. In that species, however, the antero-cardinal angle on the left valve is more elevated, the posterior end is more spinose and has a broader marginal rim, and the surface is pitted rather than provided with reticulate ridges. The exceptional thinning of the shell over the antero-median node occurs in both valves of each of the two specimens of *C. pellucinoda* at hand, and apparently is characteristic of the species.

Occurrence.—Core sample at 1220–30 feet.

Holotype and Paratype.—U.S.N.M. 559907.

Cythereis cf. C. bicornis Israelsky

(Plate XIII, figs. 15, 16)

Cythereis bicornis Israelsky, 1929, Arkansas Geol. Surv. Bull. 2, pp. 19, 20, pl. IV A, figs. 10 a–c.
Cythereis bicornis Israelsky, Alexander, 1929, Univ. Texas Bull. 2907, p. 100, pl. VIII, figs. 4, 5.

Shell subquadrate in lateral view; highest anteriorly at position of antero-cardinal angle; dorsal margin nearly straight, about two-thirds shell length, slightly concave medially; ventral margin slightly convex, subparallel to dorsum; anterior margin broadly rounded, slightly more extended below, bearing several small spines; posterior end compressed, narrowly rounded, angulated medially, concave above, convex below; its ventral portion bears a few small spines. Left valve larger than right, projecting beyond it conspicuously at cardinal angles, less noticeably elsewhere.

Anterior end with well-defined, high, narrow marginal rim; dorsally, this rim is interrupted at cardinal angle by a small eye tubercle, then continues back nearly two-fifths from anterior end where it dies out. A second, ventrally offset, mid-dorsal ridge extends back to beginning of posterior valve-compression, then bends ventrally for a short distance; at its bend there is a node-like elevation; short spurlike extensions project ventrally from inner side of ridge. Ventrally, the antero-marginal rim extends back, paralleling valve-edge, to beginning of posterior valve-compression, where it terminates in a high, blunt, spinelike elevation that has a base much broader than the width of the rim; on inner side of rim are several short spurlike extensions. Posterior end with a narrow marginal rim. Antero-medially there is a prominently elevated node, posterior to which, and connected with it by a saddle, is a narrow, sinuous, median-longitudinal ridge, that bears short, spurlike extensions on either side. Viewed from below, mid-ventral surface flattened, triangular, owing to alate expansions of the surface; large shallow excavations occur near the apices of the alae. Surface otherwise smooth and shiny.

Internal features mostly not seen; marginal pore canals fairly numerous, occurring singly.

Remarks.—The illustrated example is from the core sample at 1470–80 feet. It agrees with the descriptions of Upper Cretaceous forms from the Tokio formation and from the lower part of the Taylor group and the upper part of the Austin group in southern Arkansas and northeastern Texas respectively (54, 1).

Figured Specimen.—U.S.N.M. 103952.

Cythereis cf. C. hysonensis Howe and Chambers

(Plate XIII, fig. 10)

Cythereis hysonensis Howe and Chambers, 1935, Louisiana Dept. Cons. Geol. Bull. 5, pp. 31, 32, pl. I, fig. 8, pl. VI, figs. 23, 24.

Shell subquadrate in lateral aspect; highest anteriorly at position of anterior cardinal angle; dorsal margin straight, about five-sixths shell length; ventral margin nearly straight to slightly sinuate, converging moderately backward with respect to dorsum, and slightly produced downward at its anterior bend; anterior margin broadly rounded, slightly more extended below, bearing small spines; posterior end compressed, its margin narrowly rounded, angulated medially, truncate to slightly concave above; prominent, short, spinelike extensions occur at postventral marginal bend. Left valve slightly larger than right, its antero-cardinal angle projecting strongly above that of right; posteriorly this extension is much less marked.

Entire margin of each valve bears an elevated rim, widest terminally, very narrow, almost knifelike ventrally. Median node well defined, and located about two-fifths from anterior end. Prominent longitudinal ridges that are about one-half shell length lie near dorsal and ventral margins; each becomes increasingly elevated posteriorly and terminates in a spinose process. A low, anteriorly curved ridge connects the posterior ends of the two longitudinal ridges. Viewed from below, the ventral surfaces are produced into short angular alae; ventro-medially, the valve edges are strongly impressed. Small eye tubercles are present at antero-cardinal angles. Surface bears a few, scattered, rather large pits.

Hingement and musculature not observed. In the single complete example at hand, the anterior marginal pore canals begin just beneath the cardinal angle and number about 15, in part occurring in pairs. On posterior end, the pore canals begin below the marginal angulation and number six, occurring in pairs.

Dimensions.—The figured specimen measures length 0.51 mm., height 0.32 mm., thickness 0.20 mm.

Relationships.—The example in this collection is so nearly like *C. hysonensis* Howe and Chambers from the Eocene Jackson group of Louisiana that separation from that species is not possible. As illustrated by Howe and Chambers, the Jackson form is not so high anteriorly, has a less angulated posterior margin, and bears two post-ventral spines, instead of one, but is otherwise similar to the specimen discussed here.

Occurrence.—Core sample at 1280–90 feet.

Figured Specimen.—U.S.N.M. 559908.

Cythereis reticulodacyi Swain, new species

(Plate XIII, figs. 13, 14)

Shell subquadrate in lateral view; highest anteriorly at position of anterior cardinal angle; dorsal margin nearly straight, except at anterior marginal bend, where the cardinal angle is strongly elevated; ventral margin slightly convex, merging gradually into posterior margin; anterior margin broadly and rather uniformly rounded; posterior end compressed, most extended and slightly angulated about one-fourth from dorsal margin.

Anterior end, including the well-defined marginal rim, bears three rows of closely-spaced small spines; marginal rim of posterior end bears two rows of spines; a double row of spines occurs along dorsum. Surface reticulately ornamented with a pattern of ridges, at the junctions of which there are blunt spinelike projections. About two-fifths from anterior end, and in a median position, is a cluster of small nodes that represents the antero-median swelling. Ventral marginal areas flattened as seen in end view, but ventral surface not appreciably alate. Medially, the ventral valve edges are impressed for a short distance.

Hinge of left valve, the holotype, consists of an anterior rounded socket supported behind and below by a thickening of the shell, a long median bar, formed of the thickened edge of the valve, and a large, rounded posterior socket. Hinge of right valve not seen. Within left valve interior, a deep, rounded, antero-median depression, corresponding to the external cluster of nodes, bears the muscle scar impression. The scar consists of a compact group of three, elongate spots, oriented parallel to shell-length, together with a single, more anterior rounded spot that lies in the depth of the depression. Line of concrescence and inner margin apparently coincide; marginal pore-canals very numerous and closely spaced.

Dimensions.—The holotype measures length 0.70 mm., height 0.43 mm.

Relationships.—In its general aspect, this species is very close to *Cythereis dacyi* Howe and Law from the Oligocene Vicksburg group of Louisiana. It differs in having a reticulate pattern of surface ornamentation, and in being less sharply rounded posteriorly, as seen in side view.

Occurrence.—The holotype and only known example is from the core sample at 1270–80 feet.

Holotype.—U.S.N.M. 559909.

Cythereis parwinniana Swain, new species

(Plate XIII, figs. 17, 18)

Shell oblong-subquadrate in side view; highest at anterior cardinal angle; dorsal margin nearly straight; ventral margin nearly straight, converging slightly to posterior with respect to dorsum; anterior margin broadly rounded, slightly more extended below, fringed ventrally with small spinelets; posterior end compressed, narrowly rounded, gently angulated medially, concave above, convex below, with several small spines on ventral portion. Valves of approximately equal size; at antero-cardinal angle the left projects slightly above the right. Viewed from beneath, ventral valve edges strongly impressed for a short distance anteromedially.

Shell surface shiny. Terminal and ventral margins of each valve provided with well defined rims; ventrally the rim is much narrower and knife-edged. Antero-median, rounded, nodelike swelling prominent, bounded behind by a shallow furrow Ventro-medially, surface of each valve raised into an alate expansion; a ridge forms the crest of the expansion, and extends anteriorly nearly to marginal bend; posteriorly, the ridge terminates in a prominent node; a short ridgelike extension runs dorsally from the node and terminates at midheight; the ventro-longitudinal ridge is bounded on either side by a row of coarse pits. Dorsally, a ridge rises just above antero-median swelling and extends posteriorly nearly to cardinal angle, where it terminates in a prominent node; ventrally this ridge is bounded by a row of coarse pits. Prominent, small, lucid eye spots occur at antero-cardinal angles on both valves. Greatest convexity of surface about median. Ventral surface, except for marginal rims, nearly flat, owing to the alate expansions.

Hingement and other internal features not observed.

Dimensions.—The holotype measures length 0.65 mm., height 0.32 mm., thickness 0.10 mm.

Relationships.—This form is very close to *Cythereis winniana* Gooch from the Eocene Cook Mountain formation of central Louisiana. It differs from *winniana* in that it lacks a complete post-median vertical ridge connecting the prominent dorsal and ventral post-median nodes, its eyespots are smaller, the antero-cardinal angle is less elevated, and on the anterior end, the marginal spines are more numerous and are confined to the ventral two-thirds of that margin.

Occurrence.—Core samples at 1270-80 feet (holotype), and at 1280-90 feet.

Holotype.—U.S.N.M. 559910.

Cythereis goochi Swain, new species

(Plate XIII, figs. 19, 20)

Shell ovate-acuminate in lateral view; highest near anterior end; dorsal margin straight, but with elevated antero-cardinal marginal bend; ventral margin slightly convex; anterior margin broadly and rather uniformly rounded, slightly extended below, its ventral portion bearing numerous tiny spines; posterior end compressed, its margin acuminate, terminating in a small spinelike extension; along its ventral portion is a ridge bearing several blunt nodes, and its dorsal portion is provided with two or three small spines. Left valve larger than right, most noticeably so at the cardinal angles.

Anterior end and the anterior four-fifths of ventral margin bear a narrow, elevated, smooth-crested rim; posteriorly the rim ends at the beginning of the compression of that portion of shell, and at its termination it is relatively more elevated to form a node. Just behind antero-cardinal angle, a ridge arises and runs posteriorly, parallel to dorsum; at about midlength, ridge is divided and offset ventrally; at the position where the posterior compression of the valve begins, the ridge bends ventrally for a short distance, then terminates; at its bend a small node is formed. Small but prominent antero-median nodes present on valve surfaces; a second, smaller, and much less distinct node lies on surface of each valve about at midheight and three-fifths from anterior end. Remainder of surfaces of valves deeply pitted, and having the pits fringed with numerous tiny spinules. Viewed dorsally, the hinge-margins are somewhat impressed; viewed ventrally, the valve edges are slightly impressed, and there are low, rimlike swellings along the ventrum; ventral surface relatively flat, the prominent ventral longitudinal ridges forming alate expansions.

Hingement and other internal features unknown.

Dimensions.—The holotype measures length 0.73 mm., height 0.40 mm., thickness 0.32 mm.

Relationships.—The species here described is very close to *Cythereis howei* Gooch (37) from the Eocene Cook Mountain formation of Louisiana. In that species, however, the posterior end is somewhat more extended and lacks terminal spines, the post-median node is more distinct, and the surface pits lack the fringing spinules found in *C. goochi*.

Occurrence.—Core samples at 1240–50 feet (holotype), at 1300–10 feet, and at 1320–30 feet.

Holotype.—U.S.N.M. 559911.

Cythereis exanthemata (Ulrich and Bassler)

(Plate XII, figs. 14, 15)

Cythere exanthemata Ulrich and Bassler, 1904, Maryland Geol. Surv., Miocene vol., p. 117, pl. XXXVI, figs. 1–5.

Several examples of this coarsely spinose form are present in the material at hand. The following observations serve to supplement the original description.

Contact margins of valves slightly impressed around entire periphery. Left valve a little larger than right, but overlapping it conspicuously only at ends of hinge. Eye tubercles distinct, lying at position of antero-dorsal marginal bend.

Several specimens in the present collection are relatively more elongate than the one chosen as being typical of the species, according to features described by Ulrich and Bassler. These more elongate examples are possibly male dimorphs, while the relatively higher shells perhaps may be the female dimorphs. In addition, the latter are somewhat thicker post-medially, although the surface spines tend to mask this relationship.

Internal features not observed, so that nothing can be added to that pictured in the original figures.

Occurrence.—Samples ranging in depth from 650 feet to 900 feet Elsewhere, it occurs in the middle Miocene Choptank and Calvert formations of Maryland and Virginia.

Plesiotypes.—U.S.N.M. 559912, 559913.

Cythereis evax (Ulrich and Bassler) and var. oblongula (U. & B.)

(Plate XII, figs. 19, 20)

Cythere evax Ulrich and Bassler, 1904, Maryland Geol. Surv., Miocene vol., p. 119. pl. XXXVI, figs. 6–8, 9, 10.

Shell oblong-subquadrate in lateral outline, highest anteriorly; dorsal margin nearly straight; ventral margin slightly convex, converging posteriorly with respect to dorsum; anterior margin broadly rounded, extended below; posterior margin narrowly rounded, slightly extended medially. Left valve a little larger than right, but overlapping it conspicuously only at ends of hinge.

Entire surface, including marginal areas, provided with small blunt spines. A prominent nodelike swelling lies just anterior to midlength and slightly dorsal to midheight; an oblique, curved furrow defines node posteriorly; posterior to this furrow is a short longitudinal ridge; on either side of the node and postjacent ridge is a broad, shallow, longitudinal furrow, the more ventral one the longer. Marginal rim developed around entire periphery, broadest anteriorly, and not greatly elevated at any position. Contact edges of valve somewhat impressed.

Internal features not observed in these specimens.

Remarks.—The general outline, the highly ornamented surface, the antero-median nodelike swelling on each valve, and the marginal rims, ally this form to *Cythereis*, as that genus is understood at present, rather than to *Cythere*, where it was originally placed by Ulrich and Bassler. Lack of knowledge of the hingement, however, makes its generic status somewhat uncertain.

A larger and relatively more elongate example in the collection agrees otherwise with more typical *evax* and is thought to represent the variety *oblongula* (Ulrich and Bassler) (Pl. XII, fig. 20). In view of what has been observed in the similar and associated species *C. exanthemata* (Ulrich and Bassler), the elongate examples may represent male dimorphs and the shorter, higher ones female dimorphs. In the case of *exanthemata*, however, the elongate forms that were observed are simply lower and not longer than their dimorphs. Unti more specimens of *evax* have been studied, it seems best to retain *oblongula* as a variety because of its relatively larger size, as well as its pronounced elongation.

Occurrence.—Samples ranging in depth from 640 feet to 820 feet. The species was originally described from the middle Miocene Calvert formation at Plum Point, Maryland.

Plesiotypes.—U.S.N.M. 559914, 559915.

Cythereis cf. C. spiniferrima Jones and Sherborn

(Plate XIV, fig. 8)

Cythereis spiniferrima Jones and Sherborn, 1889, Suppl. Monogr. Tertiary Entomostraca England, Paleontol. Soc. London, p. 34, text-figure 3.
Cythereis spiniferrima Jones and Sherborn, Alexander, 1934, Jour. Paleontology, vol. 8, no. 2, p. 220, pl. 32, fig. 11.

A somewhat poorly preserved specimen is tentatively referred to this species. The dorsal margin is straight, the ventral margin converges strongly backward with respect to dorsum. The anterior margin is broadly rounded, extended below, and bears numerous spines; posterior end compressed, its margin narrowly rounded, angulated medially, and bears a number of spines. Entire surface covered with small, closely spaced spines, that, in several instances, bifurcate near their terminations. It is present in a core sample from 1300-10 feet. Alexander (3) has described it from the Midway group of Texas.

Figured Specimen.—U.S.N.M. 559916.

Cythereis cf. C. splendens Sutton and Williams

(Plate XIV, fig. 11)

Cythereis splendens Sutton and Williams, 1939, Jour. Paleontology, vol. 13, no. 6, p. 563, pl. 63, figs. 12-14.

Shell elongate in lateral view; highest near anterior end at position of antero-cardinal angle; hinge margin nearly straight, about two-thirds shell length; ventral margin nearly straight to somewhat sinuate, rising rather strongly backward with respect to dorsum; anterior margin broadly rounded, slightly more extended below, truncate above in right valve, and fringed with numerous small spines; posterior end compressed, its margin narrowly rounded, bearing blunt spines along ventral portion. Left valve larger than right, extending beyond the other most noticeably at the cardinal angles.

Anterior end provided with well defined marginal rim; entire surface ornamented with elevated nodes or blunt spines of medium size and having rather irregular distribution; a subvertical row of spines is developed at anterior margin of compressed posterior portion of valve; a row of blunt spines arranged along dorsum projects slightly above that margin. Slightly anterior to midlength of valve surface is a cluster of nodes, that is bounded posteriorly by a furrow and represents the antero-median node. Ventral surface flattened, as viewed from below, but not conspicuously alate.

Hingement and other internal features not seen.

Dimensions.—The figured specimen measures length 0.81 mm., height 0.46 mm., thickness 0.32 mm.

Remarks.—The specimen illustrated here appears to be the same as *C. splendens* Sutton and Williams from the Eocene Weches formation of Texas. It is similar to *C. parexanthemata* Swain (100) from the lower part of the Ocala limestone formation of Florida, but in that species the shell is relatively higher, more alate, and lacks the prominent, post-median, vertical row of spines on the valve surfaces.

Occurrence.—Core sample 1260–70 feet.

Figured Specimen.—U.S N.M. 559917.

Cythereis ventroconvexa Swain, new species

(Plate XIV, figs. 9, 10)

Shell ovate-subacuminate in side view; greatest height near anterior end, at position of anterior cardinal angle; hinge margin nearly straight, about three-fourths shell length; ventral margin rather strongly convex, especially so about one-third from posterior end; anterior margin broadly rounded, most extended below, and fringed with numerous small spines along ventral two-thirds; posterior end compressed, its margin narrowly rounded, angulated medially, the ventral portion bearing small spines. Left valve larger than right, extending beyond the other most conspicuously at antero-cardinal angle; ventrally, the left overlap is strong.

Anterior marginal rim only weakly elevated, its inner portion marked by a row of small spinelike nodes. Three longitudinal rows of nodes are present on valve surfaces; one along the dorsum, a second sub-median in position, and a third lying ventral to midheight; at anterior end of sub-median row of nodes is a small asteriform elevation, representing the antero-median node Surface of valves just behind anterior marginal rim roughly reticulate. Ventral surface flattened but not appreciably alate; medially the ventral valve edges are impressed for a short distance. Small lucid eye spots are present at antero-cardinal angles.

Internal features unknown.

Dimensions.—The holotype measures length 0.70 mm., height 0.42 mm., thickness 0.35 mm.

Relationships.—In its general outline, and particularly in the marked convexity of its ventral margin as viewed laterally, the species under discussion is similar to *Cythereis ciliata* Jones (= *C. ornatissima* (Reuss)) from the Cretaceous of England, but the latter is much more alate ventrally, has an irregular distribution of surface spines, and a broader anterior marginal rim.

Occurrence.—Core sample at 1320–30 feet.

Holotype.—U.S.N.M. 559918.

Subgenus PTERYGOCYTHEREIS Blake, 1933

Cythereis (Pterygocythereis) cornuta var. americana Ulrich and Bassler

(Plate XIV, fig. 4)

Cythereis cornuta var. *americana* Ulrich and Bassler, 1904, Maryland Geol. Surv., Miocene vol., p. 122, 123, pl. XXXVII, figs. 27–33.

Cythereis cornuta var. *americana* Ulrich and Bassler, Howe et al, 1935, Fla. Geol. Surv. Bull. 13, p. 26, pl.II, figs. 19, 21–24, pl. IV, fig. 24.

Two moderately well preserved specimens belonging to this variety are present in the collection. The similarity of the Maryland forms to those described and illustrated by Jones (57) from the Tertiary beds of England is very striking. The English examples are, perhaps, slightly less elongate and have a more truncate antero-dorsal marginal slope.

Occurrence.—Samples at 730–40 feet and at 940–50 feet. Originally described from the middle Miocene Calvert formation at Plum Point, Maryland, the form has also been reported to occur in the middle and upper Miocene Choctawhatchee formation of Florida.

Plesiotype.—U.S.N.M. 559919.

Cythereis (Pterygocythereis) cf. C. (P.) communis Israelsky

(Plate XIV, figs. 5-7)

Cythereis communis Israelsky, 1929, Ark. Geol. Sur., Bull. 2, p. 14, pl. 32, figs. 9–13.
Cythereis communis Israelsky, Alexander, 1929, Univ. Tex. Bull., 2907, p. 101, pl. IX, fig. 18.
Cythereis communis Israelsky, Jennings, 1936, Bull. Am. Paleont., vol. XXIII, no. 78, p. 52, pl. 7, fig. 3.
Cythereis communis Israelsky, Schmidt, Jour. Paleon. vol. 22, p. 419, pl. 61, figs. 11–13.

Shell elongate-subquadrate in side view; highest about one-fifth from anterior end at position of anterocardinal angle; dorsal margin nearly straight to slightly convex; ventral margin nearly straight, converging moderately backward with respect to dorsum; anterior margin broadly rounded, bearing on its ventral portion several short thick spines; posterior margin compressed, its margin narrowly rounded, and, ventrally, bearing three thick, short spines. Left valve larger than right, projecting beyond the other conspicuously at anterocardinal angle.

Dorsal and terminal margins provided with moderately broad, smooth, elevated rim. Anteromedian node prominent and extended posteriorly as a short ridge; ventrally there is a pronounced median-longitidunal ridge, the ventral and posterior surface of which is strongly elevated to form an ala. Viewed from beneath, midventral section flat and sharply triangular as a result of the alation; along this section valve edges slightly impressed. Eye tubercles weakly developed at anterocardinal angles.

Hingement and musculature not observed; anterior marginal pore canals number 14 to 16 and occur in parts.

Dimensions.—Length of holotype 0.81 mm., height 0.43 mm., thickness 0.36 mm.

Relationships.—This species is close to a form described as *Cypridina serratula* Bosquet (7, p. 370, pl. IV, figs. 3a–d) from the Cretaceous of France. The latter lacks a median longitudinal ridge, has serrate marginal ridges, and is more elongate. The present species probably belongs to the general group of *Cythereis cornuta* (Roemer) and *C. alata* (Bosquet) (56), but is distinguished by its median longitudinal ridge. An example figured by Alexander (1) as *Cythereis communis* Israelsky appears to be nearly identical to the species under discussion, but with perhaps a slightly narrower dorsal marginal ridge. As figured by Israelsky (54) *C. communis* is more nearly rectangular in outline, and has nodose or serrate marginal rims.

Occurrence.—Core samples 1370–80 feet and 1410–20 feet; Navarro, Taylor and Austin formations of northeastern Texas and Arkansas, Mount Laurel and Navesink formations of New Jersey, Marshalltown formation of Delaware.

Figured Specimens.—U.S.N.M. 103953, 103954.

Genus LEGUMINOCYTHEREIS Howe, 1936

Leguminocythereis clarkana (Ulrich and Bassler)

(Plate XIII, fig. 6)

Cythere clarkana Ulrich and Bassler, 1904, Maryland Geol. Surv. Miocene vol., p. 98, 99, pl. XXXV, figs. 1–10.

This species is well represented. The fol owing descriptions of internal features serve to supplement the original diagnosis.

Hinge of left valve consists of the following elements: a small, deep, rounded, anterior socket, supported ventrally by a pronounced, ridgelike, subvertical shell-thickening; a larger, deep, rounded, posterior socket; and an intervening heavy bar, formed of the thickened valve edge, bluntly club-shaped at its posterior end, expanded and with slightly depressed surface at its posterior end; dorsally, the ridge is defined by a weak furrow. Hinge of right valve not observed here, but according to Ulrich and Bassler, it consists of terminal, rounded teeth connected by a bar; the relationship of the connecting bars is not clear, but it appears that in the right valve, the thin valve-edge slightly overlaps the strong bar on the left valve.

Muscle scar slightly anterior to midlength; it consists of a curved, subvertical row of four spots, together with two more anterior spots that lie adjacent to one another; between the two groups of spots is a deep, rounded pit. Inner surface bears numerous, small, rather widely spaced pits that represent the positions of the pore canals. Marginal pore canals numerous; inner margin and line of concrescence not quite coinciding, either terminally or ventrally. Ventral margin of left valve impressed medially, where it seems to be overlapped slightly by the edge of the right valve.

Several of the specimens are relatively shorter, higher, and slightly more convex posteriorly than are the more typical representatives of the species. These are thought to belong to Ulrich and Bassler's variety *miniscula*, which may possibly represent female dimorphs.

Remarks.—The bean-shaped carapace, the type of muscle scar pattern, and the hingement of this species ally it to *Leguminocythereis* Howe rather than to *Cythere*, where it was originally placed by Ulrich and Bassler.

Occurrence.—Samples ranging in depth from 650 feet to 690 feet. The species was originally described from the middle Miocene Calvert formation at Plum Point, Maryland.

Plesiotype.—U.S.N.M. 559920.

Leguminocythereis? pustolosa Swain, new species.

(Plate XIII, fig. 11)

Shell subovate in lateral view; highest at position of anterior end of hinge, about one-fourth from anterior end; hinge margin nearly straight, scarcely concave medially, and about half shell length; ventral margin straight and subparallel to dorsum; anterior margin rounded, extended medially, slightly truncate above; posterior margin rounded, extended below. Left valve slightly larger than right.

Marginal areas of valves smooth; mid-portion of valves ornamented with closely spaced nodes that are more or less concentrically arranged in rows about an antero-median area that, on the inner surface, marks the position of the muscle scar.

Hinge of left valve consists of a posterior pointed tooth, an anteriorly adjoining, long, median bar, that is slightly expanded at its anterior end, and a shallow anterior socket; dorsal to the median bar is a narrow groove that presumably is for the reception of the edge of the right valve. Hinge of right valve not seen. Muscle scar consists of an antero-medially placed, subvertical row of four small pits, together with a more anterior, compact group of three very small spots. Inner lamellae rather narrow; terminally, the inner margin and line of concrescence do not coincide. Pore canals widely spaced, forming small pits where they open into shell interior.

Dimensions.—The holotype measures length 0.70 mm., height 0.38 mm.

Relationships.—In its shape and nature of muscle scar, this species is related to *Leguminocythereis* Howe. Its hingement is different from that described for the genus, and in this feature is more nearly like *Loxoconcha* Sars, except that the posterior socket occurring in the left valve of that genus was not observed in the specimen under discussion.

The holotype and only known example, originally a complete shell, has been taken apart in order that the internal character might be studied.

Occurrence.—Core sample at 1588–98 feet.
Figured Specimen.—U.S.N.M. 103955.

Genus BRACHYCYTHERE Alexander, 1933

Brachycythere betzi Jennings

(Plate XIV, figs. 12, 13)

Brachycythere betzi Jennings, 1936, Bull. Am. Paleont., vol. XXIII, no. 78, p. 47, pl. 6, figs. 12a–c.

Shell subovate in lateral view; highest anteriorly; dorsal margin nearly straight; ventral margin moderately convex, converging strongly backward with respect to dorsum; anterior margin broadly rounded, slightly more extended below, and finely spinose along ventral half; posterior margin narrowly rounded, bearing several short spines on ventral portion. Left valve extends slightly beyond right along dorsum; ventrally and terminally, right valve slightly larger than left and overlapping it. As viewed ventrally, valve edges impressed for a short distance in front of midlength.

Greatest convexity about one-third from posterior end; anterior end compressed and provided with a narrow marginal rim; posterior end strongly compressed behind area of greatest convexity; ventral surface swollen medially and nearly perpendicular to valve margins. Most of surface of valves, except anterior portion, coarsely but rather weakly reticulate, forming shallow pentagonal pits with narrow interspaces. Small, lucid eye-tubercles occur at anterocardinal angles.

Internal features mostly not clearly observed; on anterior end are about 35 marginal pore canals that tend to occur in pairs.

Dimensions.—Length of figured specimen 0.90 mm., height 0.59 mm., thickness 0.51 mm.

Relationships.—This species is close to *Brachycythere interrasilis* Alexander (3) of the Midway group of northeastern Texas, judging by the general outline, inflated ventrum, reticulate ornamentation, and dorsal overlap of left valve over right. On the other hand, it is unlike *Brachycythere* in the small degree of the dorsal left valve projection above the right, and in the apparent ventral and terminal right valve overlap. In *Brachycythere* the marginal pore canals are described by Alexander (2, p. 205, pl. 25, figs. 3a–c) as being in part branching and anastomosing and in having bulbous expansions at their midportions. In this species, the pore canals tend to occur in pairs, and they apparently lack bulbous expansions. The differences from typical *Brachycythere*, together with lack of knowledge of the other internal characters, makes generic designation of the species rather insecure. As compared to *B. interrasilis*, the species lacks a longitudinal ridge on the ventral surface and has different overlap relationships.

Occurrence.—The figured specimen is from the core sample 1220–30 feet. The species was originally described by Jennings from the Hornerstown formation of New Jersey.

Figured Specimen—U.S.N.M. 559921.

Genus CYTHERIDEA Bosquet, 1850

Cytheridea? sp. aff. C. perforata (Roemer)

(Plate XIV, fig. 16)

Cytherina perforata Roemer, 1838, Neues Jahrb. f. Min., etc., p. 516, pl. 6, fig. 11.
Cytheridea perforata (Roemer), Alexander, 1929, Univ. Texas Bull. 2907, p. 72, pl. V, figs. 1, 2. (A more complete synonymy given here.)

Shell subtriangular-acuminate in lateral view; highest about one-third from anterior end; dorsal margin strongly convex; ventral margin nearly straight to slightly concave; anterior margin broadly rounded, extended medially; posterior margin narrowly rounded, acuminate, extended below. Left valve larger than right, extending beyond the other around entire periphery. Surface finely punctate.

Hingement and other internal features not observed.

Remarks.—In general shape, ornamentation, and the absence of terminal marginal spines, this example is similar to *C. perforata* (Roemer), but differs in being more elongate, and in having the greatest height more anterior in position. Lack of knowledge of its hingement prevents accurate generic allocation, but it is *Cytheridea*-like in appearance.

Occurrence.—Core sample at 1440–50 feet. In Texas, *C. perforata* occurs in the Upper Cretaceous Taylor group (1, p. 73).

Figured Specimen.—U.S.N.M. 103956.

Subgenus HAPLOCYTHERIDEA Stephenson, 1936

Cytheridea (Haplocytheridea) israelskyi Stephenson

(Plate XIV, fig. 18)

Haplocytheridea israelskyi Stephenson, 1944, Jour. Paleontology, vol. 8, no. 2, p. 159, pl. 28, fig. 1.

Shell elongate-ovate-acuminate in side view; dorsal margin moderately convex, with greatest height about two-fifths from anterior end; ventral margin gently convex; anterior margin narrowly rounded, extended below, and bearing about 15 tiny spines along ventral half; posterior margin more sharply rounded, rather strongly extended below. Left valve the larger and receiving the edge of the right in a rabbet-type groove that extends from the ends of the hinge around, and just within, entire remaining shell margin. Surface bears widely spaced, fairly large pits.

Hinge of left valve consists of an anterior, elongate, denticulate socket, a posterior, narrower and shorter, elongate, denticulate socket, and an intervening narrow, faintly denticulate groove. The anterior socket bears 10 transverse denticulae, and the posterior socket, 7. At its anterior end, the surface of the connecting groove is about level with the socket; at its posterior end, the surface of the groove is truncated above the level of the socket. Hinge of right valve not observed, but presumably is a counterpart of that of the left. A shallow, but well defined, groove, apparently independent of the hingement, lies on the surface of the left valve just dorsal to the long hinge-groove, and is of corresponding length.

Muscle scar, as seen in left valve, consists of a subvertical row of four small, rounded spots lying in an antero-median position, ventrad of the anterior hinge socket.. An accessory, rounded muscle spot lies just antrad of the most dorsal spot of the main group, and an additional, subcrescentic spot is present antrad of the lower end of the main group.

Remarks.—The specimen figured here conforms in appearance to *Haplocytheridea israelskyi* Stephenson from that portion of the Middle Tertiary strata comprising the *Discorbis*, *Heterostegina*, and *Marginulina* zones of the subsurface of Jefferson County, Texas (97, p. 156). It is slightly longer and with a more narrowly rounded anterior end than the holotype of *israelskyi*, but is otherwise so similar that separation is not now feasible.

Occurrence.—A single example was obtained from the sample at 640–650 feet.

Plesiotype.—U.S.N.M. 559922.

Cytheridea (Haplocytheridea) obovata Swain, new species

(Plate XIV, fig. 15)

Shell subovate in lateral view; dorsal margin moderately convex, with greatest height about median; ventral margin slightly convex, but becoming straightened for a short distance just antrad of midlength; anterior margin rather narrowly rounded, most extended below, its ventral portion bearing about 15 short, small spines; posterior margin the more broadly rounded, the right valve bearing four small spines around its post-ventral bend. Greatest convexity in posterior half. Left valve larger than right, overlapping and extending beyond the other around entire periphery. Valve surfaces bear small, widely spaced pits.

Hingement not satisfactorily observed in the single complete example at hand, owing to conditions of preservation, but apparently consists of terminal elongate, crenulate teeth in the right valve and corresponding sockets in the left valve. Between the terminal teeth, the hinge surface is questionably crenulate. Muscle scar not observed.

Dimensions.—The holotype measures length 0.98 mm., height 0.56 mm., thickness 0.46 mm.

Relationships.—The hingement of the species allies it to the subgenus *Haplocytheridea* Stephenson, 1936. The details of shape, particularly the relatively narrowly rounded anterior margin, separates *obovata* from other species known to the author. It is close to *Cytheridea subovata* Ulrich and Bassler (106) from the Miocene Calvert formation of Maryland and the Shoal River formation of Florida, and to the similar species *C. floridana* Howe and Hough from the Miocene Choctawhatchee formation of Florida, but is more acute in anterior outline and bears more numerous, smaller, marginal spines than either of these two species.

Occurrence.—The holotype and only known example is from the sample at 650–60 feet.

Holotype.—U.S.N.M. 559923.

Cytheridea (Haplocytheridea) parvasulcata Swain, new species

(Plate XIV, fig. 17)

Shell ovate in lateral aspect; greatest height slightly anterior to midlength; dorsal margin of left valve strongly convex, that of right valve moderately convex; ventral margin of left valve moderately convex, that of right valve less convex, somewhat sinuate; anterior end broadly and uniformly rounded; posterior margin more narrowly rounded, most extended medially. Left valve larger than right, overlapping and extending beyond the other around entire periphery, and having the greatest extension along the dorsal and ventral margins. Greatest convexity just posterior to valve middle.

A small, elongate, antero-cardinal swelling is present on right valve, but was not observed on left valve. Ventral and slightly posterior to the swelling on the right valve is a short, broad, shallow, subvertical depression. Valve surfaces smooth except for scattered, widely spaced, inconspicuous pits.

Hinge surface curved, occupying middle seven-tenths of shell. In the left valve, the hinge consists of terminal, elongate, taxodont sockets, connected by a finely serrate groove; hinge of right valve consists of terminal taxodont teeth, connected by a finely serrate bar. Muscle scar not clearly seen, but consists of a subvertical row of four small spots, and at least one additional, more anterior, spot. Inner lamellae rather broad, especially at anterior end. Line of concresence and inner margin apparently coincide, except along middle part of anterior end. Marginal pore canals very numerous, and closely spaced.

Dimensions.—The holotype measures length 0.52 mm., height 0.38 mm., thickness 0.27 mm.

Relationships.—In outline, this species is like *C. amygdaloides* (Cornuel) which occurs in the Lower Cretaceous Kiamichi formation of northeastern Texas (1, pp. 69, 70). That species, however, lacks an antero-cardinal swelling and associated subvertical depression.

Occurrence.—Core sample at 1470–80 feet.

Holotype.—U.S.N.M. 103957.

Cytheridea (Haplocytheridea) cf. C. monmouthensis Berry

(Plate XIV, fig. 14)

Cytheridea monmouthensis Berry, 1925, Am. Jour. Sci., Ser. 5, vol. 9, p. 486, fig. 10.
Cytheridea monmouthensis Berry, Alexander, 1929, Univ. Texas Bull. 2907, p. 74, pl. V, figs. 11–14.

A single example, here compared to *C. monmouthensis*, is present in the core sample at 1410–20 feet. Berry originally described it from the Monmouth formation, Upper Cretaceous, at Brightseat, Maryland, and Alexander reports its occurrence in the upper two-thirds of the Navarro group in northeastern Texas.

The species is characterized by a small, winglike expansion at the post-ventral marginal bend. The shape and hingement exhibited in this specimen relate it to the subgenus *Haplocytheridea* Stephenson.

Figured Specimen.—U.S.N.M. 103958.

Subgenus CLITHROCYTHERIDEA Stephenson, 1936

Cytheridea (Clithrocytheridea?) aquia Swain, new species

(Plate XIV, fig. 19)

Shell subreniform-acuminate in side view; highest about three-tenths from anterior end; hinge margin nearly straight, about one-half shell length; ventral margin very slightly concave; anterior end broadly rounded, more extended below; posterior end more narrowly rounded, extended below, truncate above. Left valve larger than right, overlapping it more noticeably at ends of hinge.

Antero-ventral and post-ventral marginal areas with a narrow rimlike elevation. A broad but well-defined ridge, beginning at antero-cardinal angle, runs parallel to anterior margin, then bends posteriorly along ventral margin nearly to posterior end; along its anterior course it is bounded behind by a furrow that dies out about one-fifth from anterior end; behind this the ridge broadens abruptly and is bounded dorsally by a second groove that is postmedian in position; dorsal to the groove is a second longitudinal, median ridge. A small nodelike swelling lies at the anterior end of the median groove, and slightly in front of valve middle. Posterior end slightly compressed as viewed dorsally; greatest convexity about median.

Internal features unknown.

Dimensions.—The holotype measures length 0.55 mm., height 0.32 mm., thickness 0.20 mm.

Relationships.—The figured specimen is like *Clithrocytheridea* Stephenson in outline, but inasmuch as that subgenus was established as distinct from *Cytheridea* proper on the basis of details of hingement, the example considered here does not offer means of direct comparison. Its surface ornamentation bears resemblance to *Clithrocytheridea ruida* Alexander from the Paleocene Midway group of Texas, and to *C. gosportensis* Stephenson from the Eocene Claiborne group of Alabama, but the surface ridges in both of those species are narrower, and there are other finer details of ornamentation that are lacking on the specimen under consideration.

Occurrence.—The holotype and only known example is from the core sample at 1220–30 feet.

Holotype.—U.S.N.M. 559924.

Genus CYTHERETTA Mueller, 1894

Cytheretta plebia (Ulrich and Bassler)

(Plate XIII, figs. 3, 4)

Cythere plebia Ulrich and Bassler, 1904, Maryland Geol. Surv., Miocene vol., pp. 102, 103, pl. XXXV, figs. 20–29.

This species is represented by several specimens, one of which is believed to belong to the variety *modica* (Ulrich and Bassler) as it is relatively shorter and has more distinct pitting. Another example, having preserved only traces of fine pitting in a post-median area of the shell surface, and bearing three or four short spines on the posterior extremity of each valve, may represent the variety *capax* (U. & B.).

Originally placed with *Cythere* by Ulrich and Bassler, this species seems clearly to belong with *Cytheretta* Mueller, as it shows the typical anterior and antero-ventral configuration of the inner margin (plate XIII, figure 4), has a heavy adult shell, and strong projection of the left valve over the right ventrally and at the ends of the hinge.

Occurrence.—Samples ranging in depth from 640 to 690 feet. The species was originally described from the middle Miocene Calvert formation at Plum Point, Maryland, and from the Chesapeake group of Virginia.

Plesiotypes.—U.S.N.M. 559925, 559926.

Cytheretta inaequivalvis (Ulrich and Bassler)

(Plate XIII, fig. 5)

Cythere inaequivalvis Ulrich and Bassler, 1904, Maryland Geol. Surv., Miocene vol. pp. 101, 102, pl. XXXV, figs. 15–17.

Several individuals are recognized as belonging to this species, and the following observations of inner structure are offered as supplementary to the original description.

Hinge long, equal to about seven-tenths shell length; hinge of left valve consists of terminal deep sockets that open below into shell concavity, together with an intervening narrow bar that is very faintly marked by extremely fine, closely spaced, transverse denticulations. Hinge of right valve consists of strongly elevated, pointed, terminal teeth, between which lies a narrow very finely denticulate groove.

Muscle scar lies considerably anterior to midlength, and consists of a subvertical row of four, very small, closely spaced pits, together with two additional, more anterior, separated pits. Between the two groups of pits is a deep, rounded depression, just dorsal to which is a small spot that may represent part of the muscle scar. Anteriorly, the inner lamella is rather broad, and just behind the antero-ventral bend the lamella is sinously curved, as is typical of the genus.

Occurrence.—Samples ranging in depth from 790 feet to 890 feet. The species was originally described from the middle Miocene Calvert formation at Plum Point, Maryland.

Plesiotype.—U.S.N.M. 559927.

FORAMINIFERA FROM THE HAMMOND WELL

BY

JOSEPH A. CUSHMAN

The samples in some parts of the well section contain abundant and well-preserved foraminifera, including species which are definitely known to be of restricted ranges. A study of these shows that beds of Miocene, Eocene, and Cretaceous age were penetrated in the drilling of the well. The report on the foraminifera has, therefore, been divided into three parts; and the charts accompanying the report give the detailed distribution of the various species within the three age divisions so far as they could be determined. A very few species cross over the dividing lines between the age divisions and these are noted in both divisions of the report in which they occur. A considerable number of species are represented by too few or broken specimens to make a specific determination certain. Most of the *Globigerina* group have been left out, as their classification is in too chaotic a state for them to be of value in stratigraphic work.

A few species appear to be new, and they are described and figured. In order to save duplication, references are made to available papers with figures and descriptions. Brief notes under the various species give the data pertinent to the particular problem of determining the age of the various parts of the subsurface beds penetrated in the drilling. Species with known restricted ranges should be given the greatest value in correlation and this has been taken into account in the age determinations.

There is some evidence of contamination, either in the drilling or in the preparation of the samples. Therefore the first occurrence or top record on the charts should be given the greatest significance. On the other hand, there is a possibility that the upper part of the Eocene beds may have been reworked during the deposition of the earliest Miocene beds. One example of this is *Bolivinopsis curta* (Cushman), known elsewhere only from the Cooper marl of Jackson Eocene age. This is abundant in the 1150–1160-foot sample assigned to the Eocene and also in the 1130–1140-foot sample assigned to the Miocene. Another example is the occurrence of *Gyroidina marylandica* Cushman, n. sp., in the uppermost strata assigned to the Eocene and also in the basal strata assigned to the Miocene. These two species would appear to indicate that the line between the Eocene and the Miocene should be placed higher than indicated on the distribution charts. Many more first appearances of Eocene species, however, are in the 1140–1150-foot sample. With ten-foot intervals in the core it is difficult to be more exact in the line of separation.

MIOCENE

From the known ranges of Miocene species, the Calvert and Choptank formations are represented, with a possibility that the upper portion of the well section may belong in the St. Marys formation. The portion below 1000 feet was core-drilled and should give more accurate information than the cuttings above 1000 feet. From the known ranges of various species it would appear that the section from 1000 to 1090 feet, and perhaps to 1140 feet, belongs to the Calvert formation. In the section above 900 feet a number of species occur which are recorded only from the Choptank formation and it would seem, therefore, that this part of the well section should be referred to that formation.

References are given to the report by Cushman and Cahill (U. S. Geol. Survey Prof. Paper 175-A, 1933, pp. 1–50, pls. 1–13), where many of the Maryland species are figured, and to the report in this volume by Ann Dorsey, prepared from a study of carefully collected outcrop material of the Maryland Miocene. The distribution of the Miocene forms is shown in figure 25.

SYSTEMATIC PALEONTOLOGY

Family TEXTULARIIDAE

Genus SPIROPLECTAMMINA Cushman, 1927

Spiroplectammina mississippiensis (Cushman)

(For references and figures, see Dorsey, p. 275, pl. XXVII, figs. 3, 4.)

This species is known from the Eocene, Oligocene, and lower members of the Miocene. It is common in the Miocene portion of the well samples as well as in the Eocene.

Spiroplectammina exilis Dorsey

Spiroplectammina gracilis Cushman and Cahill (not von Münster), U. S. Geol. Survey Prof. Paper 175-A, 1933, p. 6, pl. 1, figs. 6, 7.
Spiroplectammina exilis Dorsey, p. 275, pl. XXVII, figs. 1, 2.

This species occurs in the Choptank and St. Marys formations of the Miocene. In the well samples it occurs in the upper part of the Miocene section.

Genus TEXTULARIA Defrance, 1824

Textularia gramen d'Orbigny

(For references and figures, see Dorsey, p. 278, pl. XXVIII, fig. 3.)

This species apparently has a wide range. It occurs throughout the Miocene, but in Maryland outcrops is most common in the Choptank formation. It occurs in many samples in the well.

Textularia consecta d'Orbigny

(For references and figures, see Dorsey, p. 277, pl. XXVIII, fig. 1.)

The outcrop records for this species are from the Choptank formation. A few specimens in the lower part of the Miocene section in the well seem identical.

Textularia cf. T. foliacea Heron-Allen and Earland

(For references and figures, see Dorsey, p. 278, pl. XXVIII, fig. 2.)

Specimens referred to this species in outcrop samples are best developed in the Calvert formation. Only a few scattered specimens occur in the well samples.

Textularia obliqua Dorsey

Textularia obliqua Dorsey, p. 279, pl XXVIII, figs. 6, 7.

A single specimen in the 920′–930′ sample is referred to this species, described from the St. Marys formation.

Family MILIOLIDAE

Genus SIGMOILINA Schlumberger, 1887

Sigmoilina tenuis (Czjzek)

(For references and figures, see U. S. Geol. Survey Prof. Paper 175-A, 1933, p. 11, pl. 3, fig. 1.)

This species is widely distributed in the Miocene and has been recorded from the Choptank formation of Maryland.

Family LAGENIDAE

Genus ROBULUS Montfort, 1808

Robulus americanus (Cushman)

(For references and figures, see Dorsey, p. 282, pl. XXX, fig. 3.)

This species is one of the most common in the Miocene section of the well samples, found in nearly all the samples from 650 feet to 1130 feet.

Robulus americanus (Cushman), var. spinosus (Cushman)

(For references and figures, see Dorsey, p. 283, pl. XXX, fig. 4.)

The variety is less common than the typical form of the species but occurs in many of the well samples.

Genus PLANULARIA Defrance, 1824

Planularia sp. A

(Plate XV, figs. 2, 3)

Rare specimens, two of which are figured, occur in the lower part of the Miocene section. It is unlike any of the species previously recorded from the American Miocene.

Planularia sp. B

(Plate XV, fig. 1)

Single specimens of this species were found in the samples between 1090 feet and 1110 feet.

Genus MARGINULINA d'Orbigny, 1826

Marginulina dubia Neugeboren

(For references and figures, see U. S. Geol. Survey Prof. Paper 175–A, 1933, p. 13, pl. 4, fig. 7.)

Specimens referable to this species occur at numerous stations from 700 feet to 920 feet.

Marginulina sp. D Dorsey

Marginulina sp. D Dorsey, p. 285, pl. XXX, figs. 12, 13.

This species was recorded by Dorsey from the Calvert formation. Similar forms appear in the lower part of the Miocene section of the well.

Genus DENTALINA d'Orbigny, 1826

Dentalina cf. D. communis d'Orbigny

(For references and figures, see. U. S. Geol. Survey Prof. Paper 175-A, 1933, p. 14, pl. 5, fig. 2.)

Two specimens only, from the samples at 680′–690′ and 740′–750′, are referable to this species.

Genus PSEUDOGLANDULINA Cushman, 1929

Pseudoglandulina sp.

Single specimens from 1070 feet to 1090 feet do not seem identical with any of the recorded Miocene species.

Genus SARACENARIA Defrance, 1824

Saracenaria acutauricularis (Fichtel and Moll)

(For references and figures, see U. S. Geol. Survey Prof. Paper 175-A, 1933, p. 13, pl. 5, fig. 1.)

Numerous records for this species apparently give it a wide range. It was found in the 1070 feet to 1090 feet samples only.

Genus VAGINULINA d'Orbigny, 1826

Vaginulina sp.

(Plate XV, fig. 4)

The single specimen here figured is from the 1110′–1120′ sample. It is unlike any species recorded from the American Miocene.

Genus LAGENA Walker and Jacob, 1798

Lagena clavata (d'Orbigny)

(For references and figures, see Dorsey, p. 287, pl. XXXI, fig. 4.)

A few specimens in scattered samples are the only ones found in the well section.

Lagena costata (Williamson), var. amphora Reuss

(For references and figures, see U. S. Geol. Survey Prof. Paper 175-A, 1933, p. 16, pl. 5, fig. 14.)

This variety has previously been recorded from the Calvert formation of Maryland. It occurs in a few well samples from the lower part of the Miocene section.

Lagena substriata Williamson

(For references and figures, see U. S. Geol. Survey Prof. Paper 175-A, 1933, p. 16, pl. 5, fig. 11.)

A few specimens occur in the lower part of the Miocene section of the well. It has previously been recorded from the St. Marys and Calvert formations of Maryland.

Lagena cf. L. striato-punctata Parker and Jones

(For figures, see U. S. Geol. Survey Prof. Paper 175-A, 1933, p. 16, pl. 5, fig. 13.)

This form has not previously been recorded from the Maryland Miocene but occurs in the Miocene of Florida. The occurrences in the well samples are all from the lower part of the Miocene section.

Lagena sulcata (Walker and Jacob)

(For references and figures, see U. S. Geol. Survey Prof. Paper 175-A, 1933, p. 16, pl. 5, fig. 10.)

A single specimen from the 1070′–1080′ sample seems to be this species, recorded from the Miocene of Florida.

Lagena tenuis (Bornemann)

(For references and figures, see Dorsey, p. 289, pl. XXXI, figs. 5, 6.)

This species occurs in the well samples very rarely toward the base of the Miocene section.

Lagena sp. A Dorsey

Lagena sp. A Dorsey, p. 290, pl. XXXI, figs. 7, 8.

A single specimen from the 680′–690′ sample is similar to that figured from the Calvert formation.

Lagena sp. C Dorsey

Lagena sp. C Dorsey, p. 291, pl. XXXI, figs. 17, 18.

The only occurrence of this species is in the 730′–740′ sample. It was figured from the Calvert formation.

Family POLYMORPHINIDAE

Genus GLOBULINA d'Orbigny, 1839

Globulina rotundata (Bornemann)

(For references and figures, see Dorsey, p. 295, pl. XXXII, fig. 6.)

A single specimen from the 810′–820′ sample resembles this species, recorded from the Calvert formation of Maryland.

Globulina inaequalis Reuss

(For references and figures, see Dorsey, p. 294, pl. XXXII, fig. 10.)

A single specimen of this species was found in the 1020′–1030′ sample. It is recorded from the Calvert and Choptank formations of the Maryland Miocene.

Genus PSEUDOPOLYMORPHINA Cushman and Ozawa, 1928

Pseudopolymorphina striata (Bagg)

(For references and figures, see Dorsey, p. 297, pl. XXXIII, figs. 4, 5.)

Single specimens, somewhat poorly preserved, from a few samples are similar to this species known only from the Choptank formation of Maryland.

Pseudopolymorphina calvertensis Cushman, n. sp.

(Plate XV, figs. 5–7)

Test elongate, slightly compressed; chambers of the early portion generally triserial, in the adult biserial, the last two or three making up more than half the test, increasing rapidly in size as added; sutures distinct but only slightly depressed; wall smooth; aperture radiate, terminal. Maximum length 1.15 mm.; breadth 0.35 mm.

Holotype (Cushman Coll. No. 45673) from Miocene material from the 1100′–1110′ sample. The species is apparently restricted to the Calvert formation of the Miocene, occurring in abundance in the samples between 1100 feet and 1130 feet and with a few specimens slightly higher in the well.

The species differs from *Pseudopolymorphina decora* (Reuss) in the more inflated early portion and more pointed apertural end.

Genus SIGMOMORPHINA Cushman and Ozawa, 1928

Sigmomorphina nevifera Dorsey

Pyrulina albatrossi Cushman and Cahill (not Cushman and Ozawa), U. S. Geol. Survey Prof. Paper 175-A, 1933, p. 18, pl. 6, fig. 5.
Sigmomorphina nevifera Dorsey, p. 298, pl. XXXIV figs. 6, 7a-b.

This species was described from the Choptank formation of Maryland. It was found only in the 680′–690′ sample.

Sigmomorphina marylandica Cushman, n. sp.

(Plate XV, fig. 8)

Test strongly compressed, nearly as broad as long, initial end with a distinct basal spine, periphery rounded, adult irregularly rhomboid; chambers distinct, slightly inflated, in the adult gradually removed from the base; sutures distinct, slightly depressed; wall smooth; aperture radiate, terminal. Maximum length 0.70 mm.; breadth 0.55 mm.

Holotype (Cushman Coll. No. 45676) from Miocene material from the 1080′–1090′ sample. It occurs in several samples from the lower part of the Miocene section of the well.

This species resembles *Sigmomorphina bornemanni* Cushman and Ozawa, from the middle Oligocene of Germany, but differs in the smaller size, more inflated chambers, and more prominent basal spine.

Genus SIGMOIDELLA Cushman and Ozawa, 1928

Sigmoidella cf. S. kagaensis Cushman and Ozawa

(For references and figures, see Dorsey, p. 298, pl. XXXIV, fig. 5.)

This species has been recorded from the Calvert formation of Maryland. Specimens occur rarely in the 1010′–1020′ and 1070′–1080′ samples, a part of the section evidently Calvert in age. The specimens are not entirely typical but are evidently not fully developed.

Genus POLYMORPHINELLA Cushman and Hanzawa, 1936

Polymorphinella sp.

A single specimen of this genus from the 1040′–1050′ sample is unlike any described species and is here noted for the record until more specimens are available for description.

Family NONIONIDAE

Genus NONION Montfort, 1808

Nonion advenum (Cushman)

(For references and figures, see Dorsey, p. 299, pl. XXXV, fig. 1.)

A few rather poorly preserved specimens seem to belong here.

Nonion incisum (Cushman)

(For references and figures, see U. S. Geol. Survey Prof. Paper 191, 1939, p. 15, pl. 4, fig. 6.)

A single specimen was found in the 500′–510′ sample.

Nonion cf. N. pizarrense W. Berry

(For references and figures, see Dorsey, p. 300, pl. XXXV, fig. 6.)

Specimens referred to this species occur in a number of samples in the lower part of the Miocene section. They are not entirely typical.

Nonion cf. N. grateloupi (d'Orbigny)

(For references and figures, see Dorsey, p. 300, pl. XXXV, fig. 5.)

This species occurs in all samples from 680 feet to 1140 feet and in a few scattered samples above. Specimens show much variation, and some of them tend toward *Nonionella*.

Genus NONIONELLA Cushman, 1926

Nonionella auris (d'Orbigny)

(For references and figures, see Dorsey, p. 301, pl. XXXV, fig. 3.)

The only appearance of this species is in the 650′–660′ sample.

Family HETEROHELICIDAE

Genus BOLIVINOPSIS Yakovlev, 1891

Bolivinopsis curta (Cushman)

Abundant specimens from the 1130′–1140′ sample seem identical with this species of the Eocene, Cooper marl, of South Carolina. The species is common also in the 1150′–1160′ sample in the Eocene section. Single specimens occur in the 1030′–1040′ and 1090′–1100′ samples, perhaps owing to contamination or reworking. This species may indicate that the line between the Miocene and Eocene occurs at the 1130′-depth or above rather than at the 1140′-depth.

Genus AMPHIMORPHINA Neugeboren, 1850

Amphimorphina miocenica Cushman, n. sp.

(Plate XV, figs. 16–18)

Amphimorphina sp. Cushman and Ponton, Bull. 9, Florida State Geol. Survey, 1932, p. 75, pl. 11, figs. 4–6.

Test much compressed in the earlier stages, very elongate, narrow, very gradually tapering, sides in the adult portion nearly parallel, with a distinct keel; chambers distinct, uniserial, except the very earliest in the microspheric form, inflated in the later portion, increasing rather rapidly in height as added; sutures distinct, nearly at right angles to the elongate axis; wall ornamented with several longitudinal costae; aperture in the early stages elliptical, later circular, terminal. Maximum length 2.20 mm.; diameter 0.25–0.30 mm.

Holotype (Cushman Coll. No. 45684) from Miocene material from the 1090′–1100′ sample. It is limited to the samples between 1070 feet and 1110 feet where it is common, and should make an excellent index fossil. Broken specimens, evidently the same, are recorded from the Miocene of Florida.

This species differs from *Amphimorphina haueriana* Neugeboren in the more costate early portion and more tapering test in the early megalospheric specimens.

Family BULIMINIDAE

Genus BULIMINELLA Cushman, 1911

Buliminella elegantissima (d'Orbigny)

(For references and figures, see Dorsey, p. 302, pl. XXXVI, fig. 2.)

This common species was found in many of the samples in the Miocene part of the section, most frequently in the lower portion.

Genus BULIMINA d'Orbigny, 1826

Bulimina elongata d'Orbigny

(For references and figures, see Dorsey, p. 303, pl. XXXVI, figs. 5, 6.)

This is one of the commonest species in the Miocene part of the well section, occurring in all but two samples from 710 feet to 1140 feet.

Bulimina inflata Seguenza

(For references and figures, see U. S. Geol. Survey Prof. Paper 175-A, 1933, p. 24, pl. 8, fig. 1.)

Rare specimens occur in the 1090′–1100′ and 1110′–1120′ samples.

Genus ENTOSOLENIA Ehrenberg, 1848

Entosolenia lucida Williamson

(For references and figures, see Dorsey, p. 304, pl. XXXVI, fig. 8.)

Single specimens from three samples, 920′–930′, 980′–990′, and 1020′–1030′, are the only representatives of this species.

Genus VIRGULINA d'Orbigny, 1826

Virgulina punctata d'Orbigny

(For references and figures, see U. S. Geol. Survey Prof. Paper 175-A, 1933, p. 25, pl. 8, fig. 8.)

This species is rare and widely scattered in the Miocene part of the well section.

Virgulina schreibersiana Czjzek

(For references and figures, see Special Publ. 9, Cushman Lab. Foram. Res., 1937, p. 13, pl. 2, figs. 11–20.)

This species occurs in the lower part of the Miocene section, from 1040 feet to 1120 feet. It has a wide distribution in the Miocene of Europe and northern Africa.

Virgulina fusiformis Cushman

(For references and figures, see Dorsey, p. 306, pl. XXXVI, fig. 11.)

A single specimen from the 600′–610′ sample is the only occurrence of this species. It is recorded from the Miocene Choctawhatchee marl of Florida and in the Choptank formation of Maryland.

Genus BOLIVINA d'Orbigny, 1839

Bolivina paula Cushman and Cahill

(For references and figures, see Dorsey, p. 307, pl. XXXVI, fig. 20.)

This small but distinctive species is well distributed through most of the Miocene section of the well. The gaps in distribution are probably due to insufficient material rather than to absence of the species.

Bolivina floridana Cushman

(For references and figures, see Dorsey, p. 306, pl. XXXVI, fig. 15.)

A single specimen was found in the 780′–790′ sample.

Bolivina marginata Cushman, var. multicostata Cushman

(For references and figures, see Special Publ. 9, Cushman Lab. Foram. Res., 1937, p. 87, pl. 10, figs. 7–10.)

This variety occurs commonly in the middle part of the Miocene section of the well. It is widely distributed in the American Miocene.

Bolivina calvertensis Dorsey

Bolivina calvertensis Dorsey, p. 306, pl. XXXVI, fig. 17.

This is a very common species in the well samples, particularly in the lower portion of the Miocene section, which is probably of Calvert age.

Genus UVIGERINA d'Orbigny, 1826

Uvigerina auberiana d'Orbigny

(For references and figures, see Dorsey, p. 307, pl. XXXVI, fig. 23.)

This species, described from Recent material from the West Indies, is known from the Miocene Choctawhatchee formation of Florida, and the Calvert formation of Maryland. It occurs in numerous samples in the lower part of the Miocene section of the well.

Uvigerina calvertensis Cushman, n. sp.

(Plate XV, figs. 9–11)

Test elongate, slender, fusiform, initial end pointed, tending to become biserial in the later portion, periphery lobulate; chambers large, distinct, inflated in the later portion; sutures distinct, deeply incised; wall thin, ornamented by numerous high, thin costae, about 12 to 15 on each chamber in the later portion, the costae usually appearing serrate, occasionally irregular in pattern and branching, those of each chamber independent, the greatest development of the costae on the initial part of the test, usually diminishing in strength on the last one or several chambers, often breaking down into aligned spines, occasional specimens being very finely hispid over the later half of the test; aperture terminal, at the end of a short, cylindrical neck, surrounded by a narrow phialine lip. Length 0.45–0.70 mm.; diameter 0.17–0.23 mm.

Holotype (Cushman Coll. No. 45677) from Miocene material from the 1040′–1050′ sample. The species occurs commonly to abundantly in the lower part of the Miocene section in the well. It exhibits considerable variation in ornamentation as noted in the description.

This species differs from *Uvigerina juncea* Cushman and Todd, from the Pliocene of California, in the more pointed initial end and in the more numerous costae. The appearance of spinose ornamentation in some specimens recalls *U. auberiana* d'Orbigny, which occurs with it in much fewer numbers. Forms which may be considered transitional between the two species are present.

The forms referred to *Uvigerina kernensis* Barbat and von Estorff by Dorsey (p. 308, pl. XXXVI, fig. 24) appear to belong in this species. Although they are much smaller and shorter, they have the characteristic ornamentation of *U. calvertensis.*

Uvigerina cf. U. lirettensis Cushman and Ellisor

Uvigerina lirettensis Cushman and Ellisor, Contr. Cushman Lab. Foram. Res., vol. 15, 1939, p. 7, pl. 1, fig. 13.

A very few specimens appear close to this species described from Miocene well material from Louisiana.

Uvigerina cf. U. subperegrina Cushman and Kleinpell

(For references and figures, see Dorsey, p. 308, pl. XXXVI, fig. 22.)

This species, described from the Miocene of California, is known from the Choctawhatchee formation of Florida, the Yorktown formation of Virginia, and the Calvert formation of Maryland.

Genus SIPHOGENERINA Schlumberger, 1883

Siphogenerina lamellata Cushman

(For references and figures, see Dorsey, p. 309, pl. XXXVI, fig. 13.)

This species is fairly common in the lower part of the Miocene section of the well.

Siphogenerina cf. S. spinosa (Bagg)

(For references and figures, see Dorsey, p. 309, pl. XXXVI, fig. 14.)

Single specimens, not very well preserved, may be referred to this species, described from the Choptank formation of Maryland. They occur much higher in the well samples than *S. lamellata* Cushman.

Family ELLIPSOIDINIDAE

Genus ELLIPSONODOSARIA A. Silvestri, 1900

Ellipsonodosaria calvertensis Cushman, n. sp.

(Plate XV, figs. 14, 15)

Test elongate, slender, tapering, circular in transverse section; chambers distinct, rectilinear, except in the earliest stage in the microspheric form where there may be a tendency to be slightly biserial, increasing rather evenly in height and diameter as added; sutures distinct, depressed; wall of the early portion smooth, in the adult with a very few scattered spines near the base of the chambers, later nearly covering the entire chamber; aperture terminal, circular, with a distinct tooth at one side. Length up to 2.50 mm. in complete specimens; diameter up to 0.20 mm.

Holotype (Cushman Coll. No. 45682) from Miocene material from the 1100′–1110′ sample. It is found mostly in the lower part of the Miocene section, that assigned to the Calvert formation.

This species differs from *Ellipsonodosaria curvatura* Cushman in the more gradually tapering test, much longer chambers, and the smoother early portion.

Genus ELLIPSOLAGENA A. Silvestri, 1923

Ellipsolagena bidens Cushman

(For references and figures, see Dorsey, p. 309, pl. XXXVI, fig. 7.)

Rare in the lower part of the Miocene section. The species occurs in the Miocene of Florida and has been recorded from the Calvert and Choptank formations of Maryland.

Family ROTALIIDAE

Genus DISCORBIS Lamarck, 1804

Discorbis cavernata Dorsey

Discorbis cavernata Dorsey, p. 311, pl. XXXVII, fig. 2.

This species is described from the Calvert formation of Maryland. The only specimen found in the well material is from the 1070′–1080′ sample.

Genus VALVULINERIA Cushman, 1926

Valvulineria floridana Cushman

(For references and figures, see Dorsey, p. 311, p. XXXVII, fig. 6.)

This species is rare in samples from the upper portion of the Miocene section of the well. From the records it is widely distributed in outcrop samples in Maryland from the St. Marys, Choptank, and Calvert formations.

Genus GYROIDINA d'Orbigny, 1826

Gyroidina marylandica Cushman, n. sp.

(Plate XV, figs. 19, 20)

Test small, rotaliform, dorsal side flattened or very slightly convex, ventral side strongly convex, deeply umbilicate, periphery subacute; chambers numerous, distinct, not inflated, 12 to 15 in the adult whorl; sutures distinct, not depressed, nearly radial; wall smooth; aperture a narrow opening on the ventral side of the last-formed chamber. Maximum diameter 0.50 mm.; thickness 0.25 mm.

Holotype (Cushman Coll. No. 45687) from Miocene(?) material from the 1090′–1100′ sample. It is common in samples from 1090 feet to 1120 feet in the section assigned to the Miocene, and also in samples from 1150 feet to 1170 feet in the section assigned to the Eocene. Owing to contamination or reworking of sediments, the type material may not be in place, and the age of the species is therefore questionable.

This species differs from *Gyroidina soldanii* d'Orbigny, var. *multilocula* Coryell and Mossman in the slightly larger size and more compressed test.

Genus EPONIDES Montfort, 1808

Eponides mansfieldi Cushman

(For references and figures, see Dorsey, p. 311, pl. XXXVII, fig. 7.)

The species has been recorded from the St. Marys and Choptank formations of Maryland. The only specimen found was from the 500′–510′ sample.

Genus CANCRIS Montfort, 1808

Cancris sagra (d'Orbigny), var. communis Cushman and Todd

(For references and figures, see Dorsey, p. 312, pl. XXXVII, fig. 10.)

This variety, known from the Miocene of Florida and recorded from the Choptank formation of Maryland, is represented by a single specimen from the 800′–810′ sample.

Family CASSIDULINIDAE

Genus CASSIDULINA d'Orbigny, 1826

Cassidulina crassa d'Orbigny

(For references and figures, see Dorsey, p. 312, pl. XXXVIII, fig. 2.)

This widely distributed species has been recorded from the Calvert formation of Maryland. It occurs in a number of the well samples, all from that portion of the Miocene section assigned to the Calvert.

Cassidulina cf. C. oblonga Reuss

Numerous specimens from the lower part of the Miocene section in the well seem closer to this species than to any other. There is a slight tendency toward *Cassidulinoides*. It was found in all samples from 1020 feet to 1140 feet.

Family GLOBOROTALIIDAE

Genus GLOBOROTALIA Cushman, 1927

Globorotalia cf. G. canariensis (d'Orbigny)

A few specimens, apparently of this species, were found in a few scattered well samples. The species has been widely recorded from Eocene to Recent.

Family ANOMALINIDAE

Genus CIBICIDES Montfort, 1808

Cibicides americanus (Cushman)

(For references and figures, see Dorsey, p. 314, pl. XXXIX, fig. 4.)

Specimens, apparently of this species, occur in a larger number of samples. It is possible that some of these may be the young stages of *Cibicides concentricus* (Cushman).

Cibicides concentricus (Cushman)

(For references and figures, see Dorsey, p. 315, pl. XXXIX, figs. 1, 2.)

The only well developed specimen of this widely distributed species was found in the 630′–640′ sample.

Cibicides lobatulus (Walker and Jacob)

(For references and figures, see Dorsey, p. 315, pl. XXXIX, fig. 5.)

This species is fairly common in the upper part of the Miocene portion of the well. A few specimens tend toward var. *ornatus* Cushman.

EOCENE

The samples from 1140 feet to 1350 feet seem, from the foraminifera, to be definitely of Eocene age. Those from 1140 feet to 1170 feet contain numerous species that are known elsewhere only from beds of Jackson age and are especially limited in their occurrence to the Cooper marl. Other species of known Jackson age occur in samples down to about 1250 feet. With these and extending somewhat below 1250 feet are species found also in the recently described Chickahominy formation of the upper Eocene (subsurface) of Virginia, probably of Jackson age. In the section from 1280 feet to 1320 feet a very few species occur that are known elsewhere only from beds of Claiborne age. The samples from 1320 feet to 1350 feet contain numerous species limited elsewhere, so far as known, to beds of Paleocene age. A few species known elsewhere only from the Paleocene occur as high as 1260 feet, indicating that the interval from 1260 feet to 1320 feet must remain somewhat in doubt as to its exact position in the Eocene section.

The Eocene outcrop extending from Virginia northeasterly across Maryland 50 to 60 miles northwest of the Hammond well had been correlated, by means of its macrofossils, with the Wilcox and Claiborne groups, and no beds of Paleocene and Jackson ages had been recognized (18). In the Hammond well no beds can be assigned definitely to Wilcox and Claiborne ages on the basis of the foraminifera, but beds of Paleocene and Jackson ages seem clearly indicated. This meant that the outcrop had not been adequately searched for faunas of Paleocene and Jackson ages or that the subsurface Eocene is different from that of the outcrop. The latter explanation has been confirmed by Elaine Shifflett.[1]

References are given to the paper on the upper Eocene foraminifera of the southeastern United States (U. S. Geol. Survey Prof. Paper 181, pp. 1–88, pls. 1–23, 1935) and to the paper by Cushman and Cederstrom (Virginia Geol. Survey Bull. 67, pls. 1–6, In press) describing the Chickahominy foraminiferal fauna. Distribution of the Eocene forms is shown in Figure 26.

SYSTEMATIC PALEONTOLOGY

Family TEXTULARIIDAE

Genus SPIROPLECTAMMINA Cushman, 1927

Spiroplectammina mississipiensis (Cushman)

(Plate XVI, fig. 1)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 7, pl. 1, fig. 3.)

This species is known from the Eocene and Oligocene of the Gulf Coastal region of the United States. Typical specimens occur in a number of the samples as shown on the chart.

Spiroplectammina plummerae Cushman, new name

(Plate XVI, fig. 2)

Textularia carinata d'Orbigny, var. *expansa* Plummer, Univ. Texas Bull. 2644, 1926 (1927), p. 67, pl. 3, fig. 1.

As the name *Spiroplectammina expansa* has already been used by LeRoy, a new name should be given this species, first figured by Mrs. Plummer from the upper part of the Midway (Paleocene) of Texas. Specimens occur in the samples from 1280 feet to 1330 feet.

[1] Elaine Shifflett, Eocene stratigraphy and foraminifera of the Aquia Formation. Maryland, Dept. Geol., Mines and Water Resources, Bulletin 3, 1948.

Genus TEXTULARIA Defrance, 1824

Textularia cf. T. subhauerii Cushman

(Plate XVI, fig. 3)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 8, pl. 1, fig. 10.)

A single immature specimen from the sample at 1250′–1260′ may possibly be the early stage of this species, known from the Eocene and Oligocene of the southern United States and Mexico.

Family VERNEUILINIDAE

Genus GAUDRYINA d'Orbigny, 1839

Gaudryina cf. G. (Pseudogaudryina) alazanensis Cushman

(Plate XVI, fig. 4)

Numerous specimens very similar to those from the lower Oligocene of Mexico occur in the sample from 1270′–1280′. Similar specimens occur in the upper Eocene of Virginia.

Genus PSEUDOCLAVULINA Cushman, 1936

Pseudoclavulina cf. P. cocoaensis Cushman

(Plate XVI, fig. 5)

A single specimen from the sample at 1320′–1330′ may belong to this species, but more specimens are needed to confirm the identification.

Family MILIOLIDAE

Genus QUINQUELOCULINA d'Orbigny, 1826

Quinqueloculina cf. Q. longirostra d'Orbigny

(Plate XVI, fig. 6)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 12, pl. 2, fig. 16.)

A few specimens from 1220′–1230 and 1250′–1270′ may belong to this species, recorded from the Eocene, Jackson formation, of Mississippi.

Genus MASSILINA Schlumberger, 1893

Massilina decorata Cushman

(Plate XVI, fig. 7)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 13, pl. 3, figs. 14–16.)

Specimens from 1200′–1230′ and 1240′–1250′ are very similar to this species, known from the upper Eocene and Oligocene of the United States.

Family LAGENIDAE

Genus ROBULUS Montfort, 1808

Robulus alato-limbatus (Gümbel)

(Plate XVI, fig. 8)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 15, pl. 6, fig. 2.)

This species was originally described from the upper Eocene of Europe and is recorded from the Eocene, Jackson formation, of South Carolina, Alabama, Mississippi, and Texas. It occurs in most of the samples from 1140 feet to 1240 feet.

Robulus virginianus Cushman and Cederstrom

(Plate XVI, fig. 9)

Robulus virginianus Cushman and Cederstrom, Bull. 67, Virginia Geol. Survey, p. 10, pl. 1, fig. 3, (In press).

This species described from the Eocene, Chickahominy formation, of Virginia occurs in a number of samples from 1160 feet to 1250 feet.

Genus MARGINULINA d'Orbigny, 1826

Marginulina subrecta Franke

(Plate XVI, fig. 10)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 18, pl. 7, fig. 3.)

This species has been recorded from the Eocene, Jackson formation, of South Carolina and Chickahominy formation of Virginia. Specimens assigned to it occur between 1150 feet and 1270 feet.

Marginulina cooperensis Cushman

(Plate XVI, fig. 13)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 19, pl. 7, figs. 11, 12.)

Very typical specimens of this species occur in the 1160′–1170′ sample. It is known from the Eocene, Cooper marl, of South Carolina.

Marginulina subbullata Hantken

(Plate XVI, fig. 14)

(For references and figures, see Bull. 67, Virginia Geol. Survey, p. 12, pl. 2, fig. 5, In press).

Rare specimens, very similar to those found in the Eocene of a submarine core off the east coast of the United States and in the Eocene, Chickahominy formation, of Virginia, occur in the 1290′–1300′ sample.

Marginulina karreriana Cushman

(Plate XVI, fig. 11)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 18, pl. 7, figs. 1, 2.)

A single specimen from the 1140′–1150′ sample seems the same as this species which occurs at several stations in the Eocene, Cooper marl, of South Carolina.

Marginulina cf. M. subaculeata (Cushman), var. tuberculata (Plummer)

(Plate XVI, fig. 12)

Cristellaria subaculeata Cushman, var. *tuberculata* Plummer, Univ. Texas Bull. 2644, 1926 (1927), p. 101, pl. 7, fig. 2; pl. 14, fig. 1.

The types of this variety are from the Paleocene, upper beds of the Midway, of Texas. Several specimens, apparently identical, were found in the 1340′–1350′ sample.

Genus DENTALINA d'Orbigny, 1826

Dentalina cooperensis Cushman

(Plate XVII, fig. 2)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 20, pl. 8, figs. 3, 4.)

Specimens from scattered samples seem related to this species, widely distributed in the upper Eocene of Jackson age.

Dentalina capitata (Boll)

(Plate XVII, fig. 3)

(For references and figures, see Bull. 67, Virginia Geol. Survey, p. 13, pl. 2, figs. 6–10, In press.)

The records for this species are largely from the upper Eocene of Europe, but it is also recorded from the upper Eocene of Virginia and California. A few specimens were found in the samples from 1160 feet to 1180 feet.

Dentalina cf. D. soluta Reuss

(Plate XVII, fig. 4)

(For references and figures, see Bull. 67, Virginia Geol. Survey, p. 14, pl. 2, figs. 13, 14, In press.)

This is a widely distributed species recorded from the Upper Cretaceous to the Oligocene. A few broken specimens seem to belong here.

Dentalina bevani Cushman and Cederstrom

(Plate XVII, figs. 5, 6)

Dentalina bevani Cushman and Cederstrom, Bull. 67, Virginia Geol. Survey, p. 15, pl. 2, figs. 15–18, (In press).

This distinctive species, described from the Eocene, Chickahominy formation, of Virginia occurs in a number of the well samples and should make a good index fossil for this part of the Eocene.

Genus PSEUDOGLANDULINA Cushman, 1929

Pseudoglandulina laevigata (d'Orbigny)

(Plate XVII, fig. 1)

(For references and figures, see Bull. 67, Virginia Geol. Survey, p. 15, pl. 3, fig. 1, In press.)

This species is recorded from the Eocene of a core off the east coast of the United States and from the upper Eocene of Virginia. It was found as rare specimens in two of the well samples.

Pseudoglandulina conica (Neugeboren)

(Plate XVII, fig. 7)

(For references and figures, see Bull. 67, Virginia Geol. Survey, p. 16, pl. 3, fig. 2, In press.)

There are records for this species from both the Eocene and Oligocene. A very few specimens occur in the well samples. It occurs in the upper Eocene, Chickahominy formation, of Virginia.

Genus SARACENARIA Defrance, 1824

Saracenaria arcuata (d'Orbigny), var. hantkeni Cushman

(Plate XVII, fig. 8)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 17, pl. 5, figs. 6, 7.)

This species is recorded from the upper Eocene of Virginia, South Carolina, Alabama, and Mississippi. It was found only in the 1240′–1250′ sample.

Genus VAGINULINA d'Orbigny, 1826

Vaginulina cf. V. midwayana Fox and Ross

A single specimen from the 1260′–1270′ sample resembles this species which was described from the Paleocene, Midway, of Texas and has been recorded from a number of other localities in the Paleocene in Arkansas, Alabama, Florida, Illinois, and Trinidad.

Vaginulina longiforma (Plummer)

(Plate XVII, fig. 9)

Cristellaria longiforma Plummer, Univ. Texas Bull. 2644, 1926 (1927), p. 102, pl. 13, fig. 4.
Vaginulina longiforma Cushman, Contr. Cushman Lab. Foram. Res., vol. 20, 1944, p. 38, pl. 6, figs. 11–13.

Rare specimens from the 1170′–1180′ and 1240′–1250′ samples are very similar to this species, described from the Paleocene, Midway, of Texas and found also in the Paleocene, Naheola formation, of Alabama.

Genus LAGENA Walker and Jacob, 1798

Lagena acuticosta Reuss

(Plate XVII, fig. 10)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 23, pl. 9, figs. 5, 6.)

A single specimen from the 1210′–1220′ sample may be placed under this name.

Lagena costata (Williamson)

(Plate XVII, fig. 11)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 23, pl. 9, figs. 7, 8.)

This species is recorded from the upper Eocene, Ocala limestone of Georgia, Cooper marl of South Carolina, and the Chickahominy formation of Virginia. Specimens referable to the species occur in several of the well samples.

Family POLYMORPHINIDAE

Genus GUTTULINA d'Orbigny, 1839

Guttulina problema d'Orbigny

(Plate XVII, fig. 12)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 23, pl. 9, fig. 12.)

This, from the records, is a widely ranging species. Specimens were found in only a few of the samples.

Guttulina irregularis (d'Orbigny)

(Plate XVII, fig. 14)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 24, pl. 9, figs. 13–16.)

This widely ranging species was found in nearly all the Eocene well samples except those probably to be referred to the Paleocene.

Guttulina spicaeformis (Roemer)

(Plate XVII, fig. 13)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 24, pl. 9, fig. 17; pl. 10, figs. 9, 10.)

Specimens in most of the samples from 1140 feet to 1270 feet may be referred to this species although some of them tend toward *G. hantkeni* Cushman and Ozawa. The latter usually occurs in slightly older beds, however.

Genus GLOBULINA d'Orbigny, 1839

Globulina gibba d'Orbigny

(Plate XVII, fig. 16)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 25, pl. 9, fig. 18.)

This very widely ranging species is fairly common in some of the well samples.

Globulina gibba d'Orbigny, var. punctata d'Orbigny

(Plate XVII, fig. 17)

(For references and figures, see Bull. 67, Virginia Geol. Survey, p. 20, pl. 3, fig. 12, In press.)

Rare specimens with a peculiar spinose surface may be referred to this variety. The only other American record is that from the Eocene, Chickahominy formation, of Virginia.

Globulina rotundata (Bornemann)

(Plate XVII, fig. 15)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 27, pl. 9, fig. 24.)

Specimens were found in only three of the well samples in the Eocene portion. The American Eocene records are from the Cooper marl of South Carolina.

Globulina münsteri (Reuss)

(Plate XVII, fig. 18)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 27, pl. 9, fig. 25.)

The only specimen of this species is from the 1250′–1260′ sample. The species is recorded from the Jackson Eocene, Ocala limestone of Georgia and Alabama, and the Chickahominy formation of Virginia.

Genus SIGMOMORPHINA Cushman and Ozawa, 1928

Sigmomorphina jacksonensis (Cushman)

(Plate XVII, fig. 19)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 28, pl. 10, figs. 1–4.)

A few specimens, apparently of this typical Jackson Eocene species, occur in a few samples.

Genus SIGMOIDELLA Cushman and Ozawa, 1928

Sigmoidella plummerae Cushman and Ozawa

(Plate XVII, fig. 20)

(For references and figures, see Bull. 67, Virginia Geol. Survey, p. 22, pl. 4, figs. 1, 2, In press.)

This is more common than the preceding species. The young stages of the two are often difficult to separate. It is common in the Jackson Eocene but also occurs in the Claiborne, Cook Mountain formation.

Genus RAMULINA Rupert Jones, 1875

Ramulina cf. R. aculeata (d'Orbigny)

(Plate XVII, fig. 21)

Single specimens from two of the well samples may belong to this species which, from the records, is widely distributed in the lower Eocene and the Cretaceous.

Family NONIONIDAE

Genus NONION Montfort, 1808

Nonion planatum Cushman and Thomas

(Plate XVIII, fig. 1)

(For references and figures, see Bull. 67, Virginia Geol. Survey, p. 23, pl. 4, fig. 4, In press.)

This species occurs in the American Eocene in beds of Jackson, Claiborne, and Wilcox age. It is common in many of the well samples of Eocene age.

Nonion micrum Cole

(Plate XVIII, fig. 2)

(For references and figures, see U. S. Geol. Survey Prof. Paper 191, 1939, p. 5, pl. 1, figs. 20–22.)

This species was described from the Eocene, Guayabal formation, of Mexico. It is also recorded from the Chapapote formation of Mexico and from the Yegua formation and the Jackson Eocene of Texas. It also occurs in the Eocene of a core taken off the east coast of the United States.

Genus NONIONELLA Cushman, 1926

Nonionella hantkeni (Cushman and Applin), var. spissa Cushman

(Plate XVIII, fig. 3)

(For references and figures, see Bull. 67, Virginia Geol. Survey, p. 24, pl. 4, fig. 6, In press.)

This variety is common in the upper Eocene of Virginia, South Carolina, Florida, Alabama, Mississippi, and Texas, and the Oligocene of Alabama. It occurs in the upper well samples of the Eocene portion.

Family HETEROHELICIDAE

Genus BOLIVINOPSIS Yakovlev, 1891

Bolivinopsis curta (Cushman)

(Plate XVIII, fig. 4)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 33, pl. 12, fig. 7.)

The only previous records for this species are from the Eocene, Cooper marl, of South Carolina. It is common in the 1150′–1160′ sample, and also in the lower part of the section assigned to the Miocene.

Genus GÜMBELINA Egger, 1899

Gümbelina cubensis Palmer, var. heterostoma Bermúdez

(Plate XVIII, fig. 5)

Gümbelina cubensis Palmer, var. *heterostoma* Bermúdez, Mem. Soc. Cubana Hist. Nat., vol. 11, 1937, p. 143, pl. 17, figs. 5–7.

Numerous specimens from the sample at 1240′–1250′ are very similar to this variety, described from the Eocene of Cuba and recorded from the Eocene, Chickahominy formation, of Virginia.

Gümbelina mauriciana Howe and Roberts

(Plate XVIII, fig. 6)

Gümbelina mauriciana Howe and Roberts, in Howe, Geol. Bull. 14, Louisiana Geol. Survey, 1939, p. 62, pl. 8, figs. 9–11.—Cushman and Todd, Contr. Cushman Lab. Foram. Res. vol. 21, 1945, p. 16, pl. 4, fig. 2.

Rare specimens from 1280 feet to 1330 feet seem to be identical with this species, known from the Claiborne Eocene, Cook Mountain formation of Louisiana, and Lisbon formation of Alabama.

Gümbelina cf. G. trinitatensis Cushman and Renz

(Plate XVIII, fig. 7)

Gümbelina trinitatensis Cushman and Renz, Contr. Cushman Lab. Foram. Res., vol. 18, 1942, p. 8, pl. 2, fig. 8.

A few specimens from the sample at 1340′–1350′ are very similar to this species described from the Paleocene, Midway, of Trinidad.

Genus PLECTOFRONDICULARIA Liebus, 1903

Plectofrondicularia cookei Cushman

(Plate XVIII, fig. 8)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 34, pl. 12, figs. 11, 12.)

This is a characteristic species of the Cooper marl of the Jackson Eocene. It was found only in the samples from 1140 feet to 1160 feet, giving a good indication of the age of the beds penetrated at this depth.

Plectofrondicularia virginiana Cushman and Cederstrom

(Plate XVIII, fig. 9)

Plectofrondicularia virginiana Cushman and Cederstrom, Bull. 67, Virginia Geol. Survey, p. 26, pl. 4, fig. 8, In press.

This species, described from the Eocene Chickahominy formation of Virginia, occurs in a number of the well samples below the occurrence of the preceding species.

Genus PSEUDOUVIGERINA Cushman, 1927

Pseudouvigerina cf. P. naheolensis Cushman and Todd

(Plate XVIII, fig. 10)

Pseudouvigerina naheolensis Cushman and Todd, Contr. Cushman Lab. Foram. Res., vol. 18, 1942, p. 36, pl. 6, figs. 18, 19.—Cushman, Amer. Journ. Sci., vol. 242, 1944, p. 11, pl. 1, figs. 15, 16.

A few specimens from samples indicated on the chart are very close to this species described from the Paleocene, Naheola formation, of Alabama and recorded from the Wilcox Eocene, Bashi formation, of Alabama.

Genus SIPHOGENERINOIDES Cushman, 1927

Siphogenerinoides eleganta (Plummer)

(Plate XVIII, fig. 11)

Siphogenerina eleganta Plummer, Univ. Texas Bull. 2644, 1926 (1927), p. 126, pl. 8, fig. 1.
Siphogenerinoides eleganta Cushman, Contr. Cushman Lab. Foram. Res., vol. 16, 1940, p. 66, pl. 11, fig. 17.—Cushman and Renz, l. c., vol. 18, 1942, p. 8.—Cushman, l. c., vol. 20, 1944, p. 42, pl. 7, fig. 8.—Cooper, Journ. Pal., vol. 18, 1944, p. 351, pl. 54, fig. 14.

This is apparently an index fossil for the Paleocene, being recorded from the Midway of Texas and Trinidad, the Naheola formation of Alabama, and the Porters Creek formation of Illinois.

A single specimen in the 1340′–1350′ sample is typical and should help to fix the Paleocene age of this part of the section.

Family BULIMINIDAE

Genus BULIMINELLA Cushman, 1911

Buliminella basistriata Cushman and Jarvis, var. nuda Howe and Wallace

(Plate XVIII, fig. 12)

Buliminella basistriata Cushman and Jarvis, var. *nuda* Howe and Wallace, Louisiana Geol. Bull. 2, 1932, p. 60, pl. 11, fig. 4.

The types of this variety are from the Eocene, Jackson formation, of Louisiana, and it also occurs in the Jackson formation of Texas.

Genus BULIMINA d'Orbigny, 1826

Bulimina jacksonensis Cushman

(Plate XVIII, fig. 17)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 35, pl. 13, figs. 7–9.)

Rather typical specimens of this characteristic Jackson Eocene species occur abundantly in a few samples from the upper part of the Eocene section.

Bulimina ovata d'Orbigny

(Plate XVIII, fig. 13)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 35, pl. 13, figs. 15, 16.)

Specimens of this common species occur in a number of samples in the upper part of the Eocene section.

Bulimina cacumenata Cushman and Parker

(Plate XVIII, fig. 16)

Bulimina cacumenata Cushman and Parker, Contr. Cushman Lab. Foram. Res., vol. 12, 1936, p. 40, pl. 7, fig. 3.—Cushman, l. c., vol. 16, 1940, p. 67, pl. 11, fig. 20.—Cushman and Todd, l. c., vol. 18, 1942, p. 37.

From the records this species is known only from the Paleocene, Midway, of Texas and Alabama. Typical specimens occur in the samples from 1280 feet to 1340 feet.

Bulimina arkadelphiana Cushman and Parker, var. midwayensis Cushman and Parker

(Plate XVIII, fig. 14)

Bulimina arkadelphiana Cushman and Parker, var. *midwayensis* Cushman and Parker, Contr. Cushman Lab. Foram. Res., vol. 12, 1936, p. 42, pl. 7, figs. 9, 10.—Cole, Florida Dept. Conservation, Geol. Bull. 16, 1938, p. 32 (list), pl. 1, fig. 14.

This species was described from the Paleocene, Midway, of Texas and recorded from the Paleocene of Florida wells. Specimens apparently identical occur in the 1320′–1330′ and 1340′–1350′ samples.

Bulimina cf. B. cooperensis Cushman

(Plate XVIII, fig. 15)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 35, pl. 13, figs. 12–14.)

A few specimens that seem close to this Jackson Eocene species occur in a few samples. It has been recorded from the Jackson, Cooper marl of South Carolina and Chickahominy formation of Virginia.

Genus VIRGULINA d'Orbigny, 1826

Virgulina danvillensis Howe and Wallace

(Plate XVIII, fig. 18)

Virgulina danvillensis Howe and Wallace, Louisiana Geol. Bull. 2, 1932, p. 65, pl. 11, fig. 2.—Cushman, Special Publ. 9, Cushman Lab. Foram. Res., 1937, p. 9, pl. 1, figs. 28, 29.

Specimens of this typical Jackson species occur in the samples from 1140 feet to 1170 feet.

Genus BOLIVINA d'Orbigny, 1839

Bolivina gardnerae Cushman

(Plate XVIII, fig. 19)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 37, pl. 14, figs. 6, 7.)

This species occurs in the Jackson Eocene, Ocala limestone, in Georgia and Alabama and also is recorded from the Oligocene. It is fairly common in the 1140′–1150′ and 1180′–1190′ samples.

Bolivina jacksonensis Cushman and Applin

(Plate XVIII, fig. 20)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 37, pl. 14, figs. 11–13.)

Rare specimens of the typical form of the species were found in the 1150′–1160′ sample.

Bolivina jacksonensis Cushman and Applin, var. striatella Cushman and Applin

(Plate XVIII, fig. 21)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 37, pl. 14, figs. 14–18.)

This widely distributed species in the Jackson Eocene occurs in a number of samples in the upper part of the Eocene section.

Bolivina virginiana Cushman and Cederstrom, var.

(Plate XVIII, fig. 23)

A few specimens are evidently related to this species of the Eocene, Chickahominy formation, of Virginia. The peripheral costae are less developed than in the typical form.

Bolivina spiralis Cushman

(Plate XVIII, fig. 22)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 37, pl. 15, figs. 1, 2.)

This species has been recorded previously only from the Cooper marl in South Carolina. It is very common in the 1150 feet to 1170 feet samples.

Genus LOXOSTOMUM Ehrenberg, 1854

Loxostomum cf. L. claibornense Cushman

(Plate XIX, fig. 1)

Specimens from the 1220′–1230′ sample seem much like this Claiborne Eocene species, and some from the 1270′–1280′ sample are less typical and seem intermediate between this species and *Bolivina spiralis* Cushman.

Loxostomum longiforme Cushman and Cederstrom

(Plate XIX, fig. 2)

Loxostomum longiforme Cushman and Cederstrom, Bull. 67, Virginia Geol. Survey, p. 28 pl. 4, fig. 13, (In press).

Specimens from the 1280′–1290′ and 1310′–1320′ samples are identical with this species, described from the Jackson Eocene, Chickahominy formation, of Virginia.

Genus UVIGERINA d'Orbigny, 1826

Uvigerina jacksonensis Cushman

(Plate XIX, fig. 3)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 40, pl. 16, figs. 1–3.)

This common Jackson species occurs in considerable numbers in the upper part of the Eocene section in the well samples.

Uvigerina exilis Cushman, n. sp.

(Plate XV, fig. 12)

Test small, slender; chambers distinctly inflated, except earlier ones which are compact, later chambers becoming loosely arranged with the inner face of each chamber concave; sutures depressed; wall thin, perforate, finely hispid and ornamented with a few weakly developed longitudinal costae, usually absent on the central part of each chamber, not continuous across the sutures; aperture circular, at the end of a very short neck, surrounded by a narrow lip. Length 0.40–0.50 mm.; diameter 0.15–0.20 mm.

Holotype (Cushman Coll. No. 45680) from Eocene material from the 1150′–1160′ sample. It is common in this sample, but only a single specimen was found in the sample above.

This species differs from *Uvigerina russelli* Howe in its ornamentation, larger size, more inflated chambers, and lack of a distinct neck. It appears to be close to *Angulogerina oligocaenica* (Andreae) from the Oligocene of Europe, but is generally less ornamented and is not distinctly angled in transverse section.

Uvigerina dumblei Cushman and Applin

(Plate XIX, fig. 4)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 39, pl. 15, fig. 17.)

A few specimens of this Jackson species occur in two samples.

Uvigerina cookei Cushman

Uvigerina cookei Cushman, U. S. Geol. Survey Prof. Paper 181, 1935, p. 39, pl. 15, figs. 14–16.—Cushman and Edwards, Contr. Cushman Lab. Foram. Res., vol. 13, 1937, p. 76, pl. 11, figs. 10, 11.

This Jackson species occurs abundantly.

Uvigerina cocoaensis Cushman

(Plate XIX, fig. 5)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 39, pl. 15, figs. 11–13.)

A few specimens of this Jackson species were found in the 1240′–1250′ sample.

Uvigerina elongata Cole

(Plate XIX, fig. 6)

(For references and figures, see Bull. 67, Virginia Geol. Survey, p. 31, pl. 4, fig. 15, In press.)

A few specimens of this Claiborne species occur in the lower part of the Eocene section. It was described from the Guayabal formation of Mexico and has been recorded from the Cook Mountain formation of Louisiana and the Eocene of cores taken off the east coast of the United States, as well as the Oligocene of Cuba and upper Oligocene to lower Miocene of Porto Rico.

Uvigerina russelli Howe

(Plate XIX, fig. 7)

Uvigerina russelli Howe, Geol. Bull. 14, Louisiana Geol. Survey, 1939, p. 71, pl. 8, figs. 21, 22.

This small species, described from the Cook Mountain formation of Louisiana, occurs in considerable numbers in the lowermost part of the Eocene section.

Genus ANGULOGERINA Cushman, 1927

Angulogerina cooperensis Cushman

(Plate XIX, fig. 8)

Angulogerina cooperensis Cushman, U. S. Geol. Survey Prof. Paper 181, 1935, p. 42, pl. 16, fig. 9.—Bermúdez, Mem. Soc. Cubana Hist. Nat., vol. 11, 1937, p. 338.

A single typical specimen of this Jackson species was found in the 1150′–1160′ sample near the top of the Eocene portion.

Angulogerina exigua Cushman, n. sp.

(Plate XV, fig. 13)

Test small, fusiform, greatest breadth at or below the middle, triangular in transverse section; chambers indistinct, compact in the earlier portion; rapidly increasing in size and height as added, becoming more loosely arranged toward the apertural end, the inner face of the last chamber characteristically concave; sutures depressed; wall ornamented with numerous, rather high costae, tending to be serrate, and generally ending in spines at the initial end, the costae not continuous across the sutures, the last chamber or two sometimes hispid instead of costate; aperture circular at the end of a long, slender neck, surrounded by a phialine lip. Length 0.35–0.40 mm.; diameter 0.15–0.18 mm.

Holotype (Cushman Coll. No. 45681) from Eocene material from the 1160′–1170′ sample. It also occurs in the underlying samples to 1250 feet.

This species differs from *Angulogerina danvillensis* Howe and Wallace, from the Jackson Eocene of Louisiana, in the stouter form and the more compact early chambers and more attenuated later chambers.

Family ELLIPSOIDINIDAE

Genus ELLIPSONODOSARIA A. Silvestri, 1900

Ellipsonodosaria alexanderi Cushman

(Plate XIX, fig. 10)

Ellipsonodosaria alexanderi Cushman, Contr. Cushman Lab. Foram. Res., vol. 12, 1936, p. 52, pl. 9, figs. 6–9; vol. 16, 1940, p. 69, pl. 11, figs. 27–29.

This species, known from the Paleocene and Cretaceous of Alabama and Texas, occurs in the sample from 1340′–1350′ as well as in the Cretaceous part of the well section.

Ellipsonodosaria atlantisae Cushman, var. hispidula Cushman

(Plate XIX, fig. 9)

Ellipsonodosaria atlantisae Cushman, var. *hispidula* Cushman, Contr. Cushman Lab. Foram. Res., vol. 15, 1939, p. 70, pl. 12, fig. 5.

Specimens from several samples seem to be very similar to this form, described from the Eocene of cores in the Atlantic and occurring also in the Eocene, Chickahominy formation, of Virginia.

Ellipsonodosaria cf. E. longiscata (d'Orbigny)

(Plate XIX, figs. 12, 13)

Broken specimens from a number of samples may be referred with some question to this widely recorded species.

Ellipsonodosaria sp.

(Plate XIX, fig. 11)

A number of specimens, none of which is complete, do not seem to be identical with any described species.

Family ROTALIIDAE

Genus DISCORBIS Lamarck, 1804

Discorbis assulata Cushman

(Plate XIX, fig. 14)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 44, pl. 17, figs. 1, 2.)

Rare specimens from 1220′–1230′ and 1280′–1290′ are very similar to this species known from the Eocene, Jackson formation, of Georgia and Alabama.

Genus VALVULINERIA Cushman, 1926

Valvulineria jacksonensis Cushman

(Plate XIX, fig. 15)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 44, pl. 18, fig. 2.)

This is a characteristic species of the Jackson Eocene, occurring in the Ocala limestone of Georgia and Alabama. There is a single specimen from the 1220′–1230′ sample.

Genus GYROIDINA d'Orbigny, 1826

Gyroidina orbicularis d'Orbigny, var. planata Cushman

(Plate XIX, fig. 16)

Gyroidina orbicularis d'Orbigny, var. *planata* Cushman, U. S. Geol. Survey Prof. Paper 181, 1935, p. 45, pl. 18, fig. 3.

This species was described from the Cooper marl of the Jackson Eocene in South Carolina. It is common in the well samples.

Gyroidina soldanii d'Orbigny, var. octocamerata Cushman and G. D. Hanna

(Plate XIX, fig. 17)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 45, pl. 18, fig. 4.)

This variety seems to have a rather wide range in the upper Eocene. In the well samples its range seems to be lower than that of the preceding species.

Gyroidina aequilateralis (Plummer)

(Plate XIX, fig. 18)

Rotalia aequilateralis Plummer, Univ. Texas Bull. 2644, 1926 (1927), p. 155, pl. 12, fig. 3.
Gyroidina aequilateralis Cushman, Contr. Cushman Lab. Foram. Res., vol. 20, 1944, p. 45, pl. 7, fig. 24.
Gyroidina subangulata Cushman and Todd (not Plummer), l. c., vol. 18, 1942, p. 40, pl. 7, figs. 11, 12.

A few specimens from the sample at 1340′–1350′ seem typical of this species, described from the Paleocene of Texas and recorded from the Paleocene, Naheola formation, of Alabama.

Gyroidina marylandica Cushman, n. sp.

(Plate XV, figs. 19, 20)

(For description, see Miocene portion of report.)

This species is described from the lower part of the well section assigned to the Miocene, but, owing to possible reworking of sediments or other contamination, the material is questionable as to its Miocene or Eocene age. The species is common in the samples from 1150 feet to 1170 feet.

Genus EPONIDES Montfort, 1808

Eponides umbonatus (Reuss)

(Plate XIX, fig. 19)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 48, pl. 19, fig. 10.)

A few specimens in the well samples seem typical of this very widely distributed species.

Eponides cf. E. exigua (H. B. Brady)

(Plate XIX, fig. 20)

A single specimen from the sample at 1340′–1350′ is very similar to the specimen figured by Mrs. Plummer from the Paleocene of Texas (Univ. Texas Bull. 2644, 1926 (1927), pl. 11, fig. 3).

Eponides cocoaensis Cushman

(Plate XIX, fig. 21)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 47, pl. 19, figs. 1, 2.)

This is a common species of the Jackson Eocene of Alabama, Mississippi, and South Carolina.

Genus SIPHONINA Reuss, 1850

Siphonina tenuicarinata Cushman

(Plate XIX, fig. 22)

(For references, see Bull. 67, Virginia Geol. Survey, p. 35, In press.)

This species seems to range from the upper Eocene to the Miocene. There is some variation in the specimens from the well samples but all are probably to be included under this species.

Family CASSIDULINIDAE

Genus CERATOBULIMINA Toula, 1915

Ceratobulimina cf. C. rotundata Cushman and Cederstrom

A single specimen may be an immature stage of this species from the Eocene, Chickahominy formation, of Virginia.

Genus ALABAMINA Toulmin, 1941

Alabamina wilcoxensis Toulmin

(Plate XX, fig. 1)

Alabamina wilcoxensis Toulmin, Journ. Pal., vol. 15, 1941, p. 603, pl. 81, figs. 10–14, text figs. 4A–C.—Cushman, Contr. Cushman Lab. Foram. Res., vol. 24, 1948, p. 14, pl. 2, figs. 18–20.
Pulvinulina exigua H. B. Brady, var. *obtusa* Plummer (not Burrows and Holland), Univ. Texas Bull. 2644, 1926 (1927), p. 151, pl. 11, fig. 2.
Pulvinulinella exigua (H. B. Brady), var. *obtusa* Cushman and Ponton (not Burrows and Holland), Contr. Cushman Lab. Foram. Res., vol. 8, 1932, p. 71, pl. 9, fig. 9.—Jennings, Bull. Amer. Pal., vol. 23, no. 78, 1936, p. 34, pl. 4, fig. 4.—Howe, Louisiana Geol. Sur., Geol. Bull. 14, 1939, ,p. 81, pl. 11, figs. 4–6.
Pulvinulinella obtusa (Burrows and Holland) Cushman and Garrett, Contr. Cushman Lab. Foram. Res., vol. 15, 1939, p. 87, pl. 15, figs. 12, 13.—Cushman and Renz, 1. c., vol. 18, 1942, p. 11, pl. 2, fig. 16.—Cushman and Todd, 1. c., vol. 18, 1942, p. 42, pl. 7, figs. 19, 20.—Cushman, 1. c., vol. 20, 1944, p. 27, pl. 4, fig. 32; p. 46, pl. 7, fig. 29; Amer. Journ. Sci., vol. 242, 1944, p. 14, pl. 2, figs. 7, 8.—Applin and Jordan, Journ. Pal., vol. 19, 1945, p. 132 (list).—Cushman and Todd, Contr. Cushman Lab. Foram. Res., vol. 21, 1945, p. 101, pl. 16, figs. 7, 8; vol. 22, 1946, p. 63, pl. 11, figs. 9, 10.

This species is common in the middle and lower portions of the Eocene. In the Paleocene, Midway, it occurs in material from Texas and Trinidad, and the Naheola formation of Alabama. In the Wilcox Eocene, it is recorded from the Bashi formation of Alabama and the Aquia formation of Virginia.

Genus CASSIDULINA d'Orbigny, 1826

Cassidulina globosa Hantken

(Plate XX, fig. 2)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 49, pl. 20, fig. 12.)

Rare specimens probably of this common species occur in only a few samples.

Genus CASSIDULINOIDES Cushman, 1927

Cassidulinoides howei Cushman

(Plate XV, fig. 21; Plate XX, fig. 3)

Cassidulinoides howei Cushman, Cushman Lab. Foram. Res., Special Pub. 16, 1946 p. 36 pl. 7, figs. 9, 10.
Cassidulinoides braziliensis Howe and Wallace (not *Cassidulina braziliensis* Cushman), Louisiana Geol. Bull. 2, 1932, p. 72, pl. 10, fig. 6.

Specimens common in the samples between 1140 feet and 1160 feet are similar to this species described from the Jackson Eocene, Cocoa sand of Alabama and recorded from the Jackson Eocene of Louisiana.

Family CHILOSTOMELLIDAE

Genus PULLENIA Parker and Jones, 1862

Pullenia eocenica Cushman and Siegfus

(Plate XX, fig. 5)

Pullenia eocenica Cushman and Siegfus, Contr. Cushman Lab. Foram. Res., vol. 15, 1939, p. 31, pl. 7, fig. 1; Trans. San Diego Soc. Nat. Hist., vol. 9, 1942, p. 420, pl. 18, fig. 2.—Cushman and Todd, Contr. Cushman Lab. Foram. Res., vol. 19, 1943, p. 10, pl. 2, fig. 2.

This species was described from the Eocene, Kreyenhagen shale, of California. A few specimens from the 1160′–1170′ sample are very similar.

Pullenia quinqueloba (Reuss), var. angusta Cushman and Todd

(Plate XX, fig. 4)

Pullenia quinqueloba (Reuss), var. *angusta* Cushman and Todd, Contr. Cushman Lab. Foram. Res., vol. 19, 1943, p. 10, pl. 2, figs. 3, 4.

This variety apparently has a wide range in the lower Eocene but also occurs in material of Jackson age.

Family GLOBIGERINIDAE

Genus GLOBIGERINA d'Orbigny, 1826

Globigerina compressa Plummer

(Plate XX, fig. 6)

Globigerina compressa Plummer, Univ. Texas Bull. 2644, 1926 (1927), p. 135, pl. 8, fig. 11.

A few specimens from the sample at 1330′–1340′ seem to be identical with this species, described from the Paleocene, Midway, of Texas and recorded from a number of localities in the lower Eocene.

Family HANTKENINIDAE

Genus HANTKENINA Cushman, 1924

Hantkenina longispina Cushman

(Plate XX, fig. 7)

Hantkenina longispina Cushman, Proc. U. S. Nat. Mus., vol. 66, Art. 30, 1924, p. 2, pl. 2, fig. 4; Bull. Amer. Assoc. Petr. Geol., vol. 9, 1925, p. 299, pl. 7, fig. 3.—Cole, Bull. Amer. Pal., vol. 14, no. 51, 1927, p. 24, pl. 4, fig. 7.—Cushman, Journ. Pal., vol. 1, 1927, p. 160, pl. 26, fig. 2.—Nuttall, 1. c., vol. 4, 1930, pp. 274, 284.—Howe, Geol. Bull. 14, Louisiana Geol. Survey, 1939, p. 85, pl. 12, fig. 23.—Thalmann, Stanford Univ. Publ., Univ. Ser., Geol. Sci., vol. 3, no. 1, 1942, p. 6 (table).—Cushman and Herrick, Contr. Cushman Lab. Foram. Res., vol. 21, 1945, p. 70, pl. 11, figs. 11, 12.

This species is recorded almost entirely from Eocene beds of Claiborne age. Typical specimens occur rarely between 1280 feet and 1330 feet, indicating a Claiborne age for this part of the section.

Family GLOBOROTALIIDAE

Genus GLOBOROTALIA Cushman, 1927

Globorotalia crassata (Cushman), var. densa (Cushman)

(For references and figures, see Bull. 67, Virginia Geol. Survey, p. 39, pl. 5, fig. 13, In press.)

A few specimens seem to belong to this widely recorded variety from the Eocene.

Globorotalia crassata (Cushman), var. aequa Cushman and Renz

(Plate XX, fig. 8)

Globorotalia crassata (Cushman), var. *aequa* Cushman and Renz, Contr. Cushman Lab. Foram. Res., vol. 18, 1942, p. 12, pl. 3, fig. 3.—Cushman and Todd, 1. c., p. 44, pl. 8, figs. 7–9.

This variety was described from the Paleocene, Midway, of Trinidad and also occurs in the Naheola formation of Alabama. A few specimens from the sample at 1340′–1350′ seem typical.

Family ANOMALINIDAE

Genus ANOMALINA d'Orbigny, 1826

Anomalina cf. A. midwayensis (Plummer)

(Plate XX, fig. 11)

A very few specimens from the sample at 1330′–1340′ seem close to this species described from the Paleocene, Midway, of Texas.

Genus CIBICIDES Montfort, 1808

Cibicides westi Howe

(Plate XX, fig. 9)

Cibicides westi Howe, Geol. Bull. 14, Louisiana Geol. Survey, 1939, p. 88, pl. 13, figs. 20–22.

A few specimens from 1280′–1290′ seem identical with this species described from the Claiborne Eocene, Cook Mountain formation, of Louisiana. Rare specimens from 1300 feet to 1320 feet may be the same, although they tend toward *C. blanpiedi* Toulmin, known from the Wilcox Eocene and the Paleocene.

Cibicides ocalanus Cushman

(Plate XX, fig. 10)

(For references and figures, see Bull. 67, Virginia Geol. Survey, p. 40, pl. 6, fig. 2, In press.)

Rare specimens in samples from 1160 feet to 1190 feet and in the 1230′–1240′ sample resemble this species recorded from the Eocene of Jackson age from Virginia, South Carolina, Georgia, Florida, and Alabama.

Cibicides ouachitaensis Howe and Wallace

(Plate XX, fig. 12)

Cibicides ouachitaensis Howe and Wallace, Louisiana Geol. Bull. 2, 1932, p. 78, pl. 14, fig. 6.

Specimens apparently identical with this species, known from the Eocene, Jackson formation, of Louisiana, occur in a few samples.

Cibicides cf. C. lobatulus (Walker and Jacob)

(Plate XX, fig. 14)

Numerous specimens which may be assigned to this species with some question occur in the 1220′–1230′ sample and in samples between 1250 feet and 1270 feet.

Cibicides cf. C. pseudoungerianus (Cushman)

(Plate XX, fig. 15)

(For references and figures, see U. S. Geol. Survey Prof. Paper 181, 1935, p. 52, pl. 23, fig. 1.)

Specimens referred to this species, but not entirely identical, occur in a number of samples. They show a considerable amount of variation.

Cibicides speciosus Cushman and Cederstrom

(Plate XX, fig. 13)

Cibicides speciosus Cushman and Cederstrom, Bull. 67, Virginia Geol. Survey, p. 41, pl. 6, figs. 3, 4, In press.)

Specimens from samples at 1220′–1230′ and 1250′–1270′ seem to be identical with this rather highly ornate species of the Eocene, Chickahominy formation, of Virginia.

CRETACEOUS

The Cretaceous section, from 1360 feet to 1480 feet, is very rich in foraminifera and more definite in its correlation than those of the Miocene and Eocene. The sample from 1350 feet to 1360 feet was not plotted on the distribution chart. It appears to have a mixture of Paleocene and Cretaceous species. The section from 1360 feet to 1390 feet has a number of species which are known from beds of Navarro age but not from beds of Taylor age:

Vaginulina cretacea Plummer
Guttulina adhaerens (Olszewski)
Gümbelina glabrans Cushman
Gümbelitria cretacea Cushman
Bolivinita costifera Cushman
Pseudouvigerina seligi (Cushman)
Buliminella cushmani Sandidge
Bolivina decurrens (Ehrenberg)
Loxostomum plaitum (Carsey), var. *limbosum* (Cushman)
Siphonina prima Plummer

The section from 1390 feet to 1480 feet likewise contains a number of species which are index fossils for beds of Taylor age. Some of these species, occurring from 1390 feet to 1420 feet, are known only from upper beds of Taylor age:

Dorothia conula (Reuss)
Marginulina armata Reuss

Marginulina munda Cushman
Nodosaria aspera Reuss
Nodosaria proboscidea Reuss
Gümbelina planata Cushman
Nodosarella primitiva Cushman
Globotruncana calcarata Cushman
Cibicides beaumontianus (d'Orbigny)

A few species, occurring from 1440 feet to 1470 feet, are recorded in lower beds of Taylor age:

Nodosaria fusula Reuss
Nodosaria gracilitatis Cushman
Gümbelina carinata Cushman
Neobulimina irregularis Cushman and Parker

The above species would therefore seem to fix rather definitely the age of these parts of the section.

References are given to the report on the Upper Cretaceous foraminifera of the Gulf Coastal region (U. S. Geol. Survey Prof. Paper 206, 1945, pp. 1–160, pls. 1–66) for descriptions and figures of the Cretaceous species. Distribution of the Cretaceous forms is contained in Figure 27.

SYSTEMATIC PALEONTOLOGY

Family AMMODISCIDAE

Genus AMMODISCUS Reuss, 1861

Ammodiscus cretaceus (Reuss)

(Plate XXI, fig. 1)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 17–18, pl. 1, fig. 35.)

This species has a wide range in the American Upper Cretaceous.

Family TEXTULARIIDAE

Genus SPIROPLECTAMMINA Cushman, 1927

Spiroplectammina laevis (Roemer), var. cretosa Cushman

(Plate XXI, fig. 2)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 27–28, pl. 6, figs. 1–3.)

Though found in beds of both Taylor and Austin age, this variety is more characteristic of the upper part of the Taylor.

Genus TEXTULARIA Defrance, 1824

Textularia ripleyensis W. Berry

(Plate XXI, fig. 3)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 29–30, pl. 6, figs. 17–20.)

Though this species occurs widely in beds of Taylor age and in the lower beds of Navarro age, it is most characteristic of the upper Taylor.

Textularia subconica Franke

(Plate XXI, fig. 4)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 30, pl. 6, figs. 21, 22.)

This species occurs rarely in various parts of the Taylor marl with a single record from the Austin chalk.

Family VERNEUILINIDAE

Genus VERNEUILINA d'Orbigny, 1840

Verneuilina cretosa Cushman ?

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 31, pl. 7, fig. 7.)

The types of this species are from the upper part of the Taylor marl, but it occurs also in the upper part of the Austin chalk.

Genus GAUDRYINA d'Orbigny, 1839

Gaudryina rudita Sandidge ?

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 34–35, pl. 7, figs. 23, 24; pl. 8, fig. 1.)

This species has a wide range in the American Cretaceous but is most common in the upper beds of Navarro age.

Gaudryina (Siphogaudryina) stephensoni Cushman

(Plate XXI, fig. 5)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 35, pl. 8, figs. 8–11.)

Although there are a few American records for this species from beds of Navarro and Austin age, it is most characteristic of the upper beds of Taylor age.

Genus PSEUDOCLAVULINA Cushman, 1936

Pseudoclavulina clavata (Cushman)

(Plate XXI, fig. 7)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 36–37, pl. 8, figs. 22–31; pl. 9, figs. 1, 2.)

This species has a very wide range in the American Upper Cretaceous but seems to be most common in beds of Taylor age.

Genus CLAVULINOIDES Cushman, 1936

Clavulinoides trilatera (Cushman), var. concava (Cushman)

(Plate XXI, fig. 6)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 38, pl. 9, figs. 17–22.)

This variety ranges widely in the American upper Cretaceous but is most common in the upper beds of Taylor age.

Genus PSEUDOGAUDRYINELLA Cushman, 1936

Pseudogaudryinella capitosa (Cushman)

(Plate XXI, fig. 8)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 40, pl. 10, figs. 15–19.)

This species ranges throughout the Taylor with rare occurrences in the upper part of the Austin.

Genus HETEROSTOMELLA Reuss, 1865

Heterostomella austinana Cushman

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 41, pl. 11, figs. 2–7.)

Although there are a few records from the lower part of the Taylor marl, this is a characteristic species of beds of Austin age.

Heterostomella americana Cushman

(Plate XXI, fig. 9)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 41–42, pl. 11' figs. 10, 12–21.)

The records show this species to be characteristic of beds of lower Taylor age and those of upper Austin age.

Family VALVULINIDAE

Genus ARENOBULIMINA Cushman, 1927

Arenobulimina americana Cushman

(Plate XXI, fig. 14)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 42–43, pl. 12, fig. 1.)

This species has a very wide range in the American Upper Cretaceous, from the uppermost Austin chalk to beds of upper Navarro age.

Genus EGGERELLA Cushman, 1933

Eggerella? trochoides (Reuss)

(Plate XXI, fig. 10)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 43, pl. 12, fig. 2.)

The American records for this species are almost all from the upper beds of Taylor age.

Genus MARSSONELLA Cushman, 1933

Marssonella oxycona (Reuss)

(Plate XXI, fig. 11)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 43–44, pl. 12, figs. 3–5.)

The species ranges from beds of Austin age through the Taylor and into those of Navarro age.

Genus DOROTHIA Plummer, 1931

Dorothia conula (Reuss)

(Plate XXI, fig. 12)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 44–45, pl. 12, figs. 12–14.)

The only American record for this species is from the Annona chalk of Taylor age, and it should be a good index fossil for this part of the Upper Cretaceous.

Dorothia bulletta (Carsey)

(Plate XXI, fig. 13)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 46, pl. 12, figs. 21–26.)

This species ranges from the upper Austin to the top of the Navarro.

Family LAGENIDAE

Genus ROBULUS Montfort, 1808

Robulus pondi Cushman

(Plate XXI, fig. 15)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 52, pl. 16, figs. 1–5.)

Although occurring in the Navarro, this species is more characteristic of beds of upper Taylor age.

Robulus münsteri (Roemer)

(Plate XXI, fig. 16)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 53, pl. 17, figs. 3–9.)

This variable species apparently ranges from the upper Austin through the Taylor into the Navarro.

Robulus pseudosecans Cushman

(Plate XXI, fig. 17)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 53–54, pl. 17, figs. 11–13.)

The types of this species are from Selma chalk, of Taylor age, and it also occurs in the basal part of the Navarro.

Robulus macrodiscus (Reuss)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 54, pl. 17, fig. 14.)

There are very few records for this species from the American Upper Cretaceous. It has been recorded from Trinidad and Mexico and from the Cretaceous of Georges Bank.

Robulus stephensoni Cushman

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 55, pl. 18, figs. 12, 13.)

The records for this species are from upper beds of Taylor age and lower beds of Navarro age.

Genus LENTICULINA Lamarck, 1804

Lenticulina rotulata Lamarck

(Plate XXI, fig. 18)

(For figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 56–57, pl. 18, fig. 19; pl. 19, figs. 1–7.)

This species as recorded seems to have a wide range both in Europe and America.

Genus MARGINULINA d'Orbigny, 1826

Marginulina armata Reuss

(Plate XXI, fig. 20)

(For reference and figure, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 60, pl. 21, fig. 1.)

The only other American Upper Cretaceous record for this species is from the upper part of the Taylor marl.

Marginulina munda Cushman

(Plate XXI, fig. 19)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 60, pl. 21, figs. 2, 3.)

This is a characteristic species of the upper beds of Taylor age and should determine definitely the age of the section of the well samples in which it occurs.

Marginulina cf. M. recta (d'Orbigny)

(Plate XXI, fig. 21)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 60, pl. 21, figs. 4, 5.)

The only other American Cretaceous records for this species are from beds of upper Taylor age.

Marginulina cretacea Cushman

(Plate XXI, fig. 22)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 61, pl. 21, figs. 16–20, 39.)

The records for this species include most of the Taylor and the lower part of the Navarro. It is most common in the upper beds of Taylor age.

Marginulina cf. M. tripleura (Reuss)

(Plate XXII, fig. 2)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 61–62, pl. 21, figs. 30, 31.)

The American Cretaceous records for this species are mostly from upper beds of Taylor age with a few from the Neylandville marl of Navarro age.

Marginulina bullata Reuss

(Plate XXII, fig. 1)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 62, pl. 21, figs. 32–37.)

In the American Cretaceous this species is most common in the upper beds of Taylor age. It is also recorded from the basal beds of Navarro age.

Genus DENTALINA d'Orbigny, 1826

Dentalina alternata (Jones)

(Plate XXII, fig. 3)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 64–65, pl. 22, figs. 29–33.)

The range in the American Cretaceous is from upper beds of Austin age, through those of Taylor age into lower beds of Navarro age. It occurs in several of the well samples.

Dentalina legumen Reuss

(Plate XXII, fig. 6)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 65, pl. 23, figs. 1, 2.)

This species has a wide range in the American Cretaceous and occurs in most of these well samples of Taylor age.

Dentalina gracilis d'Orbigny

(Plate XXII, fig. 5)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 65–66, pl. 23, figs. 3–6.)

This species has a wide range from the Austin to the upper beds of Navarro age, but is most common in beds of Taylor age.

Dentalina lorneiana d'Orbigny

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 66, pl. 23, figs. 7–11.)

This species ranges from the Austin through the Taylor and into the lower part of the Navarro.

Dentalina basitorta Cushman

(Plate XXII, fig. 4)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 66–67, pl. 23, figs. 18–20.)

From the American records this seems to be an index fossil for the Taylor marl.

Dentalina aculeata d'Orbigny

(Plate XXII, fig. 8)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 66, pl. 26, figs. 17, 18.)

The only other American Cretaceous records are from beds of Taylor age.

Dentalina multicostata d'Orbigny

(Plate XXII, fig. 9)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 67, pl. 23, figs. 21–23.)

From the known American records this species seems to be a good index fossil for beds of Taylor age.

Dentalina megalopolitana Reuss

(Plate XXII, fig. 10)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 67, pl. 23, figs. 24–26.)

Although recorded rarely from the lower beds of Navarro age, this species seems most characteristic of the beds of Taylor age.

Dentalina catenula Reuss

(Plate XXII, fig. 11)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 67–68, 70, pl. 23, figs. 27–32.)

American Cretaceous records show that this species is most common in the upper and middle beds of Taylor age.

Dentalina basiplanata Cushman

(Plate XXII, fig. 12)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 68, pl. 24, figs. 9–12.)

This species has a wide range throughout the Taylor and Navarro.

Dentalina solvata Cushman

(Plate XXII, fig. 7)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 69, pl. 24, figs. 13–17, 22.)

The American Cretaceous records give this species a range from upper beds of Austin age to lower beds of Navarro age, but it is most common in upper beds of Taylor age.

Dentalina pertinens Cushman

(Plate XXII, fig. 13)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 70, pl. 24, figs. 18–21.)

The few records for this species are from upper beds of Taylor age and lower beds of Navarro age.

Dentalina cf. D. consobrina d'Orbigny

(Plate XXII, figs. 14, 15)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 69–70, pl. 24, figs. 23–27.

The few records for this species in the American Cretaceous are from beds of Navarro age and upper beds of Taylor age.

Genus NODOSARIA Lamarck, 1812

Nodosaria affinis Reuss

(Plate XXII, fig. 23)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 64, 70–71, pl. 25, figs. 8–23.)

This common species apparently ranges from lower Austin to upper Navarro.

Nodosaria fusula Reuss

(Plate XXII, fig. 20)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 71–72, pl. 26, fig. 5.)

The American records for this species indicate a range from lower beds of Taylor age through those of Austin age.

Nodosaria aspera Reuss

(Plate XXII, fig. 19)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 72, pl. 26, fig. 6.)

The American records for this species are from beds of Taylor age, mostly from the upper part.

Nodosaria gracilitatis Cushman

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 72, pl. 26, figs. 7-10.)

The only other records for this species are from lower beds of Taylor age, and it should indicate the age of the samples in which it occurs.

Nodosaria proboscidea Reuss

(Plate XXII, fig. 21)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 72, pl. 26, figs. 12, 13.)

From the American Cretaceous records this seems to be a characteristic species of the upper beds of Taylor age.

Nodosaria obscura Reuss

(Plate XXII, fig. 22)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 73, pl. 26, figs. 15, 16.)

The range of this species in America is largely limited to lower beds of Navarro age and upper beds of Taylor age.

Genus PSEUDOGLANDULINA Cushman, 1929

Pseudoglandulina manifesta (Reuss)

(Plate XXII, fig. 18)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 76, pl. 27, figs. 20-26.)

This species has a wide range through the Austin, Taylor, and Navarro.

Pseudoglandulina lagenoides (Olszewski)

(Plate XXII, fig. 17)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 76, pl. 27, fig. 29.)

From the American records this species occurs mainly in beds of Navarro age and the upper beds of Taylor age.

Genus SARACENARIA Defrance, 1824

Saracenaria triangularis (d'Orbigny)

(Plate XXII, fig. 16)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 58, pl. 28, figs. 1-3.)

From the records this species has a wide range in the Upper Cretaceous. In the well samples it occurs both in samples referred to the Navarro and to the Taylor.

Genus VAGINULINA d'Orbigny, 1826

Vaginulina wadei Kelley

(Plate XXII, fig. 24)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 79, pl. 29, figs. 1-6.)

From the American records this species ranges from beds of Austin age, through those of Taylor age, and into the lower beds of Navarro age.

Vaginulina multicostata Cushman

(Plate XXIII, fig. 5)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 79–80, pl. 29, figs. 9–16.)

Most of the American Cretaceous records are from beds of Navarro and Taylor age.

Vaginulina cretacea Plummer

(Plate XXIII, fig. 6)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 80, pl. 30, figs. 11–14.)

This is a characteristic species of the Navarro and should help to fix the age of the sample in which it occurs.

Vaginulina suturalis Cushman

(Plate XXIII, fig. 3)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 81, pl. 30, figs. 1–3.)

From the records this species seems to range throughout the Navarro and Taylor.

Vaginulina taylorana Cushman

(Plate XXIII, fig. 1)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 81–82, pl. 28, figs. 28, 29.)

This is an index fossil for beds of Taylor age.

Genus PALMULA Lea, 1833

Palmula rugosa (d'Orbigny)

(Plate XXIII, fig. 2)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 83–84, pl. 31, figs. 9–17.)

There are rare occurrences of this species in beds of Navarro and Austin ages, and it is very common in those of Taylor age.

Palmula suturalis (Cushman)

(Plate XXIII, fig. 4)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 82–83, pl. 32, figs. 3–14.)

The records for this species are mostly from beds of Austin and Taylor age with a few from the lower beds of Navarro age.

Genus FRONDICULARIA Defrance, 1826

Frondicularia cf. F. extensa Morrow

(For reference and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 86, pl. 34, figs. 3, 4.)

Rare specimens which resemble this species occur in a single sample.

Frondicularia goldfussi Reuss

(Plate XXIII, fig. 7)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 87–88, pl. 34, figs. 18–20; pl. 35, figs. 1, 2.)

From the American records this species is limited to beds of Austin and Taylor age.

Frondicularia cuspidata Cushman

(Plate XXIII, fig. 8)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 89, pl. 36, figs. 3–7.)

The records for this species are mostly from upper beds of Taylor age.

Frondicularia striatula (Reuss)

(Plate XXIII, fig. 9)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 90–91, pl. 37, figs. 1–4.)

The American occurrences of this species are mostly in the upper beds of Taylor age with a very few in those of Austin age.

Frondicularia archiaciana d'Orbigny

(Plate XXIII, fig. 10)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 91–92, pl. 37, figs. 8–20.)

Except for a very few records, the range of this species in the American Cretaceous is almost entirely in beds of Taylor age.

Genus KYPHOPYXA Cushman, 1929

Kyphopyxa christneri (Carsey)

(Plate XXIII, fig. 11)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 92–93, pl. 38, figs. 12–17; pl. 39, figs. 1–12.)

This species is found in beds of Austin and Taylor age, and its occurrence in the well samples seems to be consistent.

Genus LAGENA Walker and Jacob, 1798

Lagena acuticosta Reuss

(Plate XXIII, fig. 12)

(For figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 94, pl. 39, figs. 14, 15.)

This is a very widely ranging species, both in the Cretaceous and later.

Lagena apiculata Reuss

(Plate XXIII, fig. 13)

(For figure, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 94, pl. 39, fig. 23.)

The few American records for this species are mostly from the upper beds of Taylor age with a single record from the Neylandville marl of the lower part of the Navarro.

Lagena sulcata (Walker and Jacob), var. semiinterrupta W. Berry

(Plate XXIII, fig. 14)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 94, pl. 39, figs. 18–21.)

This variety is found in beds of Navarro and Taylor age.

Lagena cf. L. globosa Montagu

(Plate XXIII, fig. 15)

(For figure, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 95, pl. 39, fig. 26.)

This widely ranging species occurs rarely in the well samples.

Family POLYMORPHINIDAE

Genus GUTTULINA d'Orbigny, 1839

Guttulina trigonula (Reuss)

(Plate XXIII, fig. 16)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 95–96, pl. 40, figs. 6, 7.)

The previous American Cretaceous records for this species are from beds of Navarro and Taylor age. This agrees with its occurrence in the well samples.

Guttulina adhaerens (Olszewski)

(Plate XXIII, fig. 17)

For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 96, pl. 40, figs. 8–10.)

The American Cretaceous records are almost entirely from beds of Navarro age with a single record from the Taylor.

Genus GLOBULINA d'Orbigny, 1839

Globulina lacrima Reuss, var. subsphaerica (Berthelin)

(Plate XXIII, figs. 18, 19)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 96–97, pl. 40, figs. 11, 12.)

This widely distributed form ranges through beds of Taylor and Navarro age.

Genus PYRULINA d'Orbigny, 1839

Pyrulina cylindroides (Roemer)

(Plate XXIII, fig. 20)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 97, pl. 40, figs. 18, 19.)

This species has a wide range through beds of Navarro and Taylor age.

Genus SIGMOMORPHINA Cushman and Ozawa, 1928

Sigmomorphina semitecta (Reuss), var. terquemiana (Fornasini)

(Plate XXIII, fig. 21)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 98, pl. 41, fig. 13.)

This variety seems to be mostly found in beds of Navarro age with a single record from the Taylor.

Genus RAMULINA Rupert Jones, 1875

Ramulina cf. R. aculeata (d'Orbigny)

(Plate XXIII, figs. 22, 23)

(For figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 100, pl. 43, figs. 11–16.)

The Cretaceous records seem to be mostly from beds of Taylor age with a few from the Austin.

Family HETEROHELICIDAE

Genus BOLIVINOPSIS Yakovlev, 1891

Bolivinopsis rosula (Ehrenberg)

(Plate XXIV, figs. 5, 6)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 101–102, pl. 44, figs. 4–8.)

This species occurs in beds of Navarro, Taylor, and Austin age.

Bolivinopsis papillata (Cushman)

(Plate XXIV, fig. 1)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 102, pl. 44, fig. 9.)

The few records for this species are from beds of Taylor age and from the Ripley formation of Navarro age.

Genus GÜMBELINA Egger, 1899

Gümbelina plummerae Loetterle

(Plate XXIV, fig. 2)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 104, pl. 45, figs. 1–3.)

This species is recorded from beds of Navarro, Taylor, and Austin age.

Gümbelina striata (Ehrenberg)

(Plate XXIV, fig. 3)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 104–105, pl. 45, figs. 4, 5.)

This species has a long range in beds of Navarro, Taylor, and Austin age.

Gümbelina planata Cushman

(Plate XXIV, fig. 7)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 105, pl. 45, figs. 6, 7.)

This is a characteristic species of upper beds of Taylor age.

Gümbelina carinata Cushman

(Plate XXIV, fig. 8)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 105, pl. 45, fig. 8.)

This species is characteristic of the lower part of the Taylor marl but has been recorded also from one locality in upper beds of Austin age.

Gümbelina globulosa (Ehrenberg)

(Plate XXIV, fig. 9)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 103, 105–106, pl. 45, figs. 9–15.)

This species ranges throughout the beds of Navarro and Taylor age and is present in all the samples between 1360 feet and 1480 feet.

Gümbelina pseudotessera Cushman

(Plate XXIV, fig. 10)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 106–107, pl. 45, figs. 16–20.)

This species ranges through most of the Austin and Taylor but seems to be absent from the Navarro.

Gümbelina costulata Cushman

(Plate XXIV, fig. 4)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 108, pl. 46, figs. 10–12.)

From the records this species ranges throughout the Navarro and Taylor.

Gümbelina glabrans Cushman

(Plate XXIV, fig. 11)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 109, pl. 46, figs. 17, 18.)

This is apparently an index fossil for beds of Navarro age.

Genus GÜMBELITRIA Cushman, 1933

Gümbelitria cretacea Cushman

(Plate XXIV, fig. 12)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 103, pl. 44, fig. 14.)

Numerous records for this species are all from beds of Navarro age, and it should be a good index fossil.

Genus VENTILABRELLA Cushman, 1928

Ventilabrella eggeri Cushman

(Plate XXIV, fig. 13)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 111, pl. 47, figs. 17–19.)

The range of this species includes the lower part of the Taylor marl, where it is most common, and the upper part of the Austin chalk.

Genus BOLIVINOIDES Cushman, 1927

Bolivinoides decorata (Jones)

(Plate XXIV, fig. 14)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 113, pl. 48, figs. 8, 9.)

The American records for this species are mostly from upper beds of Taylor age, a few from the Navarro, and a single record from the Austin chalk.

Bolivinoides decorata (Jones), var. delicatula Cushman

(Plate XXIV, fig. 15)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 113, pl. 48, figs. 10–14.)

Nearly all the records for this variety are from beds of Taylor age with a very few from the Navarro.

Genus BOLIVINITA Cushman, 1927

Bolivinita eleyi Cushman

(Plate XXIV, fig. 16)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 114, pl. 48, figs. 18–20.)

This species is widely distributed in beds of Taylor age with a few records from beds of Austin age.

Bolivinita costifera Cushman

(Plate XXIV, fig. 17)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 115, pl. 49, fig. 3.)

The only records for this species are from upper beds of Navarro age.

Genus EOUVIGERINA Cushman, 1926

Eouvigerina americana Cushman

(Plate XXIV, fig. 18)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 115, pl. 49, figs. 4, 5.)

Most of the records for this species are from beds of Taylor age with rare occurrences in the Navarro and Austin.

Eouvigerina americana Cushman, var.

A few specimens, occurring just below those referred to here as typical, have the ornamentation slightly greater with the ridges more raised and a tendency to spinosity on the angles.

Eouvigerina gracilis Cushman

(Plate XXIV, fig. 19)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 115, pl. 49, fig. 6.)

From the records this should be a good index fossil for beds of Taylor age.

Eouvigerina hispida Cushman

(Plate XXIV, fig. 20)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 115–116, pl. 49, figs. 7, 8.)

The very few records of this species include beds of Navarro age and the upper part of the Taylor marl with a somewhat questionable record from a bed apparently of upper Austin age.

Genus PSEUDOUVIGERINA Cushman, 1927

Pseudouvigerina plummerae Cushman

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 116–117, pl. 49, figs. 14–16.)

The records for this species include a very few from upper beds of Austin age, numerous records from beds of Taylor age, and some from lower beds of Navarro age.

Pseudouvigerina seligi (Cushman)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 117, pl. 49, figs. 21–24.)

This species is an index fossil for the upper beds of Navarro age.

Family BULIMINIDAE

Genus BULIMINELLA Cushman, 1911

Buliminella cushmani Sandidge

(Plate XXIV, fig. 21)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 119, pl. 50, fig. 15.)

Most of the records for this species are from beds of Navarro age, but there are a few records from the Marlbrook marl of Taylor age and a single one from the Austin chalk.

Buliminella carseyae Plummer

(Plate XXIV, fig. 22)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 119–120, pl. 50, figs. 17–20.)

The records for this species include lower beds of Navarro age and beds of Taylor and Austin age.

Genus BULIMINA d'Orbigny, 1826

Bulimina prolixa Cushman and Parker

(Plate XXIV, fig. 23)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 122, pl. 51, figs. 19–22.)

This species is recorded from beds of Navarro age and upper beds of Taylor age.

Bulimina triangularis Cushman and Parker

(Plate XXIV, fig. 24)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 122, pl. 51, fig. 23.)

Except for single records from the Navarro and Austin, this species is found only in beds of Taylor age.

Bulimina taylorensis Cushman and Parker

(Plate XXIV, fig. 25)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 123–124, pl. 52, figs. 1, 2.)

This species is apparently an index fossil for beds of Taylor age.

Genus NEOBULIMINA Cushman and Wickenden, 1928

Neobulimina irregularis Cushman and Parker

(Plate XXV, fig. 1)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 125–126, pl. 52, fig. 13.)

This species is recorded from the lower beds of Taylor age, from the Austin chalk, and from the Eagle Ford shale.

Genus VIRGULINA d'Orbigny, 1826

Virgulina tegulata Reuss

(Plate XXV, fig. 2)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 126, pl. 53, figs. 1–4.)

This species ranges from lower beds of Navarro age, through the Taylor and Austin, into the upper part of the Eagle Ford shale.

Genus BOLIVINA d'Orbigny, 1839

Bolivina incrassata Reuss

(Plate XXV, fig. 3)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 127, pl. 53, figs. 8–11.)

The American records for this species are from the lower beds of Navarro age and throughout beds of Taylor age, but the species is especially common in the upper part of the Taylor.

Bolivina decurrens (Ehrenberg)

(Plate XXV, fig. 4)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 127, pl. 53, figs. 12, 13.)

This is an index fossil for beds of Navarro age, especially those of the upper portion. It confirms the Navarro age of the well samples as indicated on the distribution chart.

Bolivina cretosa Cushman

(Plate XXV, fig. 5)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 128, pl. 53, figs. 14–17.)

This species is most common in the upper beds of Taylor age, but there are a few records also in the Navarro.

Genus LOXOSTOMUM Ehrenberg, 1854

Loxostomum plaitum (Carsey)

(Plate XXV, fig. 6)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 130–131, pl. 54, figs. 10–14.)

This species ranges throughout the Navarro and Taylor, and there is a single record from the upper part of the Austin.

Loxostomum plaitum (Carsey), var. limbosum (Cushman)

(Plate XXV, fig. 7)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 130–131, pl. 54, fig. 15.)

This variety seems to be an index fossil for beds of Navarro age.

Family ELLIPSOIDINIDAE

Genus PLEUROSTOMELLA Reuss, 1860

Pleurostomella subnodosa Reuss

(Plate XXV, fig. 8)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 132, pl. 55, figs. 1–9.)

From the American records this seems to be an index fossil for beds of Taylor age.

Genus NODOSARELLA Rzehak, 1895

Nodosarella primitiva Cushman

(Plate XXV, fig. 9)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 134, pl. 55, fig. 17.)

This species is an index fossil for upper beds of Taylor age and should definitely determine the age of the well samples in which it occurs.

Genus ELLIPSONODOSARIA A. Silvestri, 1900

Ellipsonodosaria stephensoni Cushman

(Plate XXV, fig. 11)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 134–135, pl. 56, figs. 2–7.)

Most of the records for this species are from beds of Taylor age, but it also occurs in beds of Navarro age, and there is a single record from the upper part of the Austin.

Ellipsonodosaria alexanderi Cushman

(Plate XXV, fig. 10)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 135, pl. 56, figs. 12–15.)

This species has been recorded from the Taylor and Navarro groups and the Paleocene. It occurs in the lowermost part of the well section assigned to the Eocene as well as in the Cretaceous part.

Family ROTALIIDAE

Genus VALVULINERIA Cushman, 1926

Valvulineria allomorphinoides (Reuss)

(Plate XXV, fig. 12)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 138, pl. 57, figs. 6, 7.)

Specimens of this species are recorded from beds of Navarro, Taylor, and Austin age.

Valvulineria cretacea (Carsey)

(Plate XXV, fig. 13)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 138–139, pl. 57, fig. 8.)

The records for this species show that it is apparently limited to beds of Navarro and Taylor age. This conforms well with its occurrence in the well samples.

Valvulineria cf. V. umbilicatula (d'Orbigny)

(Plate XXV, fig. 14)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 139, pl. 57, figs. 9–12.)

Nearly all the American records for this species are from beds of Navarro age with a very few from upper beds of Taylor age.

Genus GYROIDINA d'Orbigny, 1826

Gyroidina depressa (Alth)

(Plate XXV, fig. 18)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 139–140, pl. 58, figs. 1–4.)

This species has a wide range throughout the Upper Cretaceous.

Gyroidina globosa (Hagenow)

(Plate XXV, figs. 15, 16)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 140, pl. 58, figs. 6–8.)

This species is particularly common in beds of Taylor age with a few records from the Navarro and Austin.

Gyroidina girardana (Reuss)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 140–141, pl. 58, fig. 9.)

In the American Upper Cretaceous this species is recorded from beds of Navarro, Taylor, and Austin age.

Genus STENSIÖINA Brotzen, 1936

Stensiöina americana (Cushman)

(Plate XXV, fig. 17)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 141–142, pl. 65, fig. 14.)

This species is particularly characteristic of upper beds of Taylor age, although it occurs in beds of Navarro age more rarely.

Genus EPONIDES Montfort, 1808

Eponides haidingeri (d'Orbigny)

(Plate XXV, fig. 20)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 141, 142, pl. 57, figs. 13, 14.)

The very few American records for this species are from the Selma chalk of Tennessee.

Genus SIPHONINA Reuss, 1850

Siphonina prima Plummer

(Plate XXV, fig. 19)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 143, pl. 59, figs. 3–5.)

The Cretaceous records for this species are all from beds of Navarro age, and it should help to determine the age of the well samples in which it occurs.

Family CHILOSTOMELLIDAE

Genus PULLENIA Parker and Jones, 1862

Pullenia americana Cushman

(Plate XXV, fig. 21)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 146, pl. 60, figs. 13, 14.)

This species is recorded from the lower beds of Navarro age and the upper beds of Taylor age.

Family GLOBOROTALIIDAE

Genus GLOBOTRUNCANA Cushman, 1927

Globotruncana canaliculata (Reuss)

(Plate XXV, fig. 22)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 149, 150, pl. 61, figs. 17, 18.)

In the American Cretaceous this species has a wide range in beds of Navarro, Taylor, and Austin age.

Globotruncana fornicata Plummer

(Plate XXVI, fig. 1)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 149, pl. 61, fig. 19.)

This species is most common in the upper beds of Taylor age, although it occurs also in beds of Navarro age.

Globotruncana marginata (Reuss)

(Plate XXVI, fig. 2)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 150, pl. 62, figs. 1, 2.)

This species is most abundant in lower beds of Taylor age but is also found in those of Austin and Eagle Ford age as well as rarely in lower beds of Navarro age.

Globotruncana calcarata Cushman

(Plate XXVI, fig. 3)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, pp. 151–152, pl. 62, fig. 8.)

This species is characteristic of upper beds of Taylor age, although there is a single record from the Neylandville marl of the lower part of the Navarro group.

Genus GLOBOROTALIA Cushman, 1927

Globorotalia micheliniana (d'Orbigny)

(Plate XXVI, fig. 4)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 152, pl. 63, figs. 2, 3.)

Although recorded from beds of Austin age, this species is most abundant in beds of Taylor age, especially the upper portion.

Family ANOMALINIDAE

Genus ANOMALINA d'Orbigny, 1826

Anomalina cf. A. nelsoni W. Berry

(Plate XXVI, fig. 6)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 154, pl. 63, figs. 8, 9.)

This common Cretaceous species occurs in beds of Navarro and Taylor age.

Anomalina ammonoides (Reuss)

(Plate XXVI, fig. 7)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 154, pl. 63, figs. 10, 11.)

From the American Cretaceous records this species is most common in lower beds of Taylor age and beds of Austin age.

Anomalina clementiana (d'Orbigny)

(Plate XXVI, fig. 5)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 155, pl. 63, figs. 12, 13.)

In the American Cretaceous this species occurs in beds of Navarro age and upper beds of Taylor age.

Genus PLANULINA d'Orbigny, 1826

Planulina texana Cushman

(Plate XXVI, fig. 9)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 157, pl. 64, fig. 11.)

This species is characteristic of beds of Austin age and lower beds of Taylor age.

Planulina taylorensis (Carsey)

(Plate XXVI, fig. 8)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 158, pl. 64, figs. 14, 15.)

This species is characteristic of beds of Taylor age with a few records from beds of Navarro age and a single one from the Austin.

Genus CIBICIDES Montfort, 1808

Cibicides stephensoni Cushman

(Plate XXVI, fig. 10)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 159, pl. 65, fig. 4.)

This species is particularly common in upper beds of Taylor age, although there are also records from the lower beds of Navarro age.

Cibicides beaumontianus (d'Orbigny)

(Plate XXVI, fig. 11)

(For references and figures, see U. S. Geol. Survey Prof. Paper 206, 1945, p. 160, pl. 65, fig. 12.)

This species in the American Cretaceous is found largely in the upper beds of Taylor age with a few records from the Saratoga chalk of Navarro age.

FORAMINIFERA FROM THE BETHARDS WELL

BY

JOSEPH A. CUSHMAN

The following is a list of Foraminifera from core sample at 1709 feet to 1728 feet in the Bethards well:

Textularia subconica Franke
Gaudryina (Siphogaudryina) stephensoni Cushman
Robulus macrodiscus (Reuss)
Dentalina gracilis d'Orbigny
Gümbelitria cretacea Cushman
Gümbelina costulata (Ehrenberg)
Gümbelina striata (Ehrenberg)
Gümbelina plummerae (Loetterle)
Gümbelina globulosa (Ehrenberg)
Bolivinita costifera Cushman
Pseudouvigerina seligi (Cushman)
Buliminella cushmani (Sandidge)

Bulimina prolixa Cushman and Parker
Bolivina incrassata Reuss
Pleurostomella subnodosa Reuss
Valvulineria allomorphinoides (Reuss)
Gyroidina depressa (Alth)
Siphonina prima Plummer
Pullenia americana Cushman
Globotruncana fornicata Plummer
Globotruncana canaliculata (Reuss)
Globotruncana marginata (Reuss)

All these species of foraminifera are also found in the Hammond well, and, with the exception of one species (*Pleurostomella subnodosa*) are found in the Navarro. That species has not been recorded above the Taylor. But a number of the other species are, so far as known, limited to the Navarro, and it would seem as though this particular sample would correlate with the uppermost Cretaceous of the Hammond well.

MIOCENE FORAMINIFERA FROM THE CHESAPEAKE GROUP OF SOUTHERN MARYLAND

BY

ANN DORSEY (MRS. ARTHUR W. CLAPP)

INTRODUCTION

This paper presents the results of a study of the numerical analysis, stratigraphic distribution, and the systematic description of the foraminiferal fauna of the Miocene strata of Maryland. One hundred forty-five samples of Miocene sediments were collected from exposures in the cliffs along the western shore of the Chesapeake Bay. Most of these samples were collected in Calvert County from Chesapeake Beach south to Drum Point, and from St. Marys County at Langley's Bluff between Cedar Point and Point No Point. Others were collected from exposures along the St. Marys River in St. Marys County, Charles County, and northern Calvert County. The field work was done in the fall and spring of the year 1938–39. The foraminifera were studied at Bryn Mawr College and at the Cushman Laboratory, Sharon, Massachusetts, during the years 1938–41.

Gratitude is expressed to the Geology Department at Bryn Mawr College for financial assistance and to members of the Department for their help. Dr. Lincoln Dryden proposed the study, discussed the problems, assisted in the field, and criticized the manuscript. Dr. E. H. Watson aided through his encouraging interest and in the photomicrography of the illustrations. Miss

Dorothy King Benedict aided in the work, and Miss Lois Schoonover contributed samples and suggested collecting localities. Especial gratitude is expressed to Dr. Joseph A. Cushman for the full use of the facilities of the Cushman Laboratory for Foraminiferal Research, Sharon, Massachusetts, and for checking the identifications. Dr. C. G. Lalicker of the University of Oklahoma aided in and checked the identifications of the family Textulariidae. Gratitude is also expressed for the aid and interest of Arthur W. Clapp.

Previous Work.—Bagg (1898) published the first paper on Miocene foraminifera from Maryland. In 1904 he contributed the section on foraminifera to the Miocene volume of the Maryland Geological Survey. In this volume about thirty-five species were figured and systematically described.

Cushman (1918) described and figured the Miocene foraminifera of the Atlantic Coastal Plain and considered about thirty-five species from ten localities in Maryland. This paper, however, contributed more to the study of the Miocene foraminifera of Virginia, North and South Carolina, and Florida than to that of Maryland. Later, Cushman and Cahill (1933) published a revised and enlarged treatment of the Atlantic Coastal Plain material. In this paper fifty-three species and varieties were considered from Maryland.

The type collections of Cushman and Cahill (1933) and of Bagg (1904) were at the Cushman Laboratory so that most of the species in this paper have been placed in their position by comparison with actual specimens.

Deposition of Specimens.—The holotypes and figured specimens are deposited in the Cushman Laboratory at Sharon, Massachusetts. The numbers assigned the figured specimens in this paper are those from the catalogue of the Cushman Collections.

NUMERICAL ANALYSIS

The usual check list in paleontological papers records a species as being *rare* (R), *common* (C), or *abundant* (A). These adjectives convey different meanings to different workers. In order to arrive more accurately at the relative abundance of foraminifera in the Maryland Miocene, a method used by the Burmah Oil Company has been followed (30). Table 20 shows the percentages with corresponding frequency numbers and proportions used by this company.

A suite of 20 samples representing about 250 feet of Maryland Miocene sediments was selected and the species counts converted into percentages and frequency numbers. The unwashed samples were uniform in bulk—the contents of a 5 inch by 8½ inch cloth collecting bag.

The species-range chart represents the counts from these 20 samples (Fig. 28). The vertical scale is 1 mm. = 1 frequency unit. This gives a logarithmic scale except for the lowest numbers, where the scale is slightly artificial.

The advantages of this method of plotting the occurrence of relative abundance of foraminifera are that (1) the smaller percentages are weighed and the difference, for example, between 2 percent and 12 percent shows up more than does the difference between 72 percent and 82 percent; (2) there is a zero reading; and, (3) one gets a picture of the relative abundance without laboriously figuring out the meaning of a series of initial letters such as A, C, and R.

STRATIGRAPHIC DISTRIBUTION

GENERAL STRATIGRAPHY

The Miocene deposits of the middle Atlantic slope have been named the Chesapeake Group. In the cliffs on the western shore of Chesapeake Bay, Maryland, there is an almost unbroken exposure of these beds for some 35

TABLE 20

Method of Showing Relative Abundance of Heavy Minerals by Percentage, Frequency Number and Proportion

Percentage	Frequency Number	Proportion
80%	8	Very abundant
40%	7	Abundant
20%	6	Fairly abundant
10%	5	Very common
5%	4	Common
2-3%	3	Fairly common
1-2%	2	Scarce
½-1%	1	Rare
0-½%	1	One grain per slide
0%	0	Absent

miles. They have been divided in ascending order into the Calvert, the Choptank, and St. Marys formations. The Calvert formation is further divided into two members, the basal Fairhaven Diatomaceous Earth and the overlying Plum Point Marls. The Fairhaven Diatomaceous Earth is composed chiefly of diatoms. The rest of the Miocene section consists of a series of bluish-green to buff sandy clays and marls, and yellow sands, 300 feet thick.

Shattuck (91) divided the three formations into 24 "zones," chiefly on the basis of lithology. These zone numbers are retained in this paper in order that a sample might be located stratigraphically in the section at any locality. Some of the zones are difficult to recognize, but there are certain very distinctive ones such as zone 4, zone 10, zone 17, and zone 19 which serve as stratigraphic markers. For the intervening zones, samples were taken approximately every 3 feet and placed into zones according to Shattuck's measured sections.

DISCUSSION OF FAUNAS

Most of the genera and species of foraminifera in the Maryland Miocene have short ranges so that they have definite stratigraphic value. The most valuable family in this respect is that of the *Textulariidae*, as is clearly shown in Figure 29 of the ranges of genera and species of this family. No other family is treated, as such, from the viewpoint of species ranges; however, all species have been arranged in the species range chart, Figure 28, according to stratigraphic sequence rather than families.

Calvert Fauna.—Foraminifera seem to be absent from the lower part of the Calvert formation. No specimens were found below the upper three feet of zone 3. The faunas of the top of zone 3, and of zones 4 and 5 are impoverished. In zones 6 to 9, species of the genus *Polymorphina* and of the family *Textulariidae* become conspicuous. In zones 10 to 15 very diagnostic groups occur. The genera *Globulina*, *Guttulina*, *Siphogenerina*, *Marginulina*, *Planularia*, *Robulus* and others make their first appearance in this section of the Calvert, then disappear within it, or gradually diminish in numbers in the Choptank formation. The bulk of the fauna of these zones, 10 to 15, is made up of species of *Cibicides*, *Rotalia*, and *Nonion*.

Choptank Fauna.—There is no abrupt faunal change at the base of the Choptank formation. However, certain forms die out at the top of the Calvert, and new ones come in with the Choptank, so that there is a recognizable difference in the faunas of the two formations.

In general there are fewer species but a greater number of individuals per species than in the Calvert fauna. The families *Textulariidae* and *Polymorphinidae* are most conspicuous in the Choptank formation, together with the family *Miliolidae*, which makes its appearance in the lower part of the formation.

St. Marys Fauna.—At the base of the St. Marys formation is definite faunal change. The number of species is greatly reduced, and those present are characteristic of brackish water conditions. The fauna is composed almost entirely of the genera *Quinqueloculina*, *Eponides*, *Nonion*, *Elphidium* and *Textularia*.

The foraminiferal faunas of the Miocene of Maryland are most like those of the Miocene of Florida. Most of the Maryland species are colder water forms with no families characteristic of warm water occurring. There are a few species common to the Miocene of Maryland and California, but in general the faunas are quite distinct.

A close correlation with the Miocene of France is indicated by several species of the families *Textulariidae* and *Polymorphinidae* which seem to be common to both.

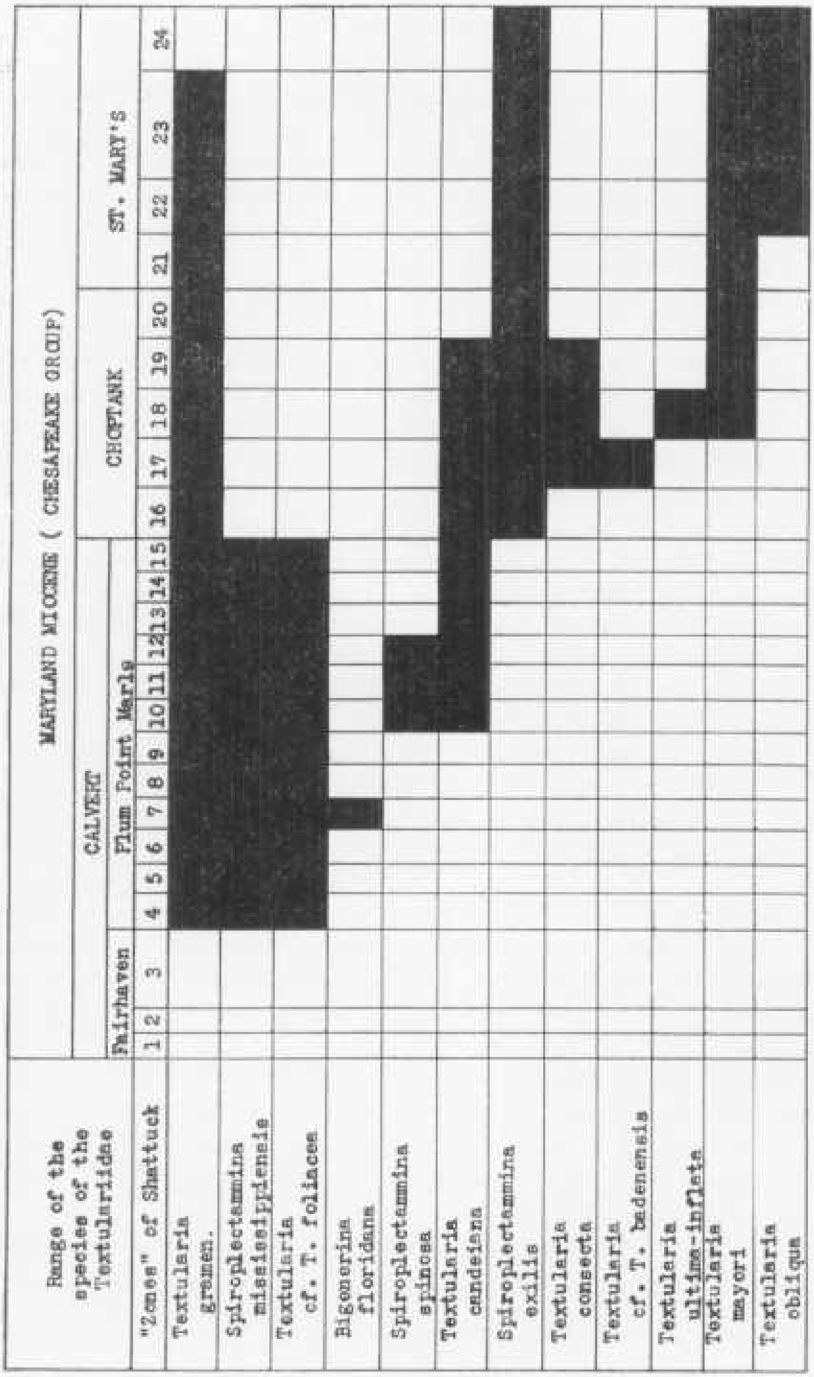

FIGURE 29. Range of the Species of the Textulariidae, Maryland Miocene, Chesapeake Group

LIST OF LOCALITIES

Descriptions of localities are given in the list on page 274. The zone numbers are those zones sampled, and do not necessarily include all zones exposed at

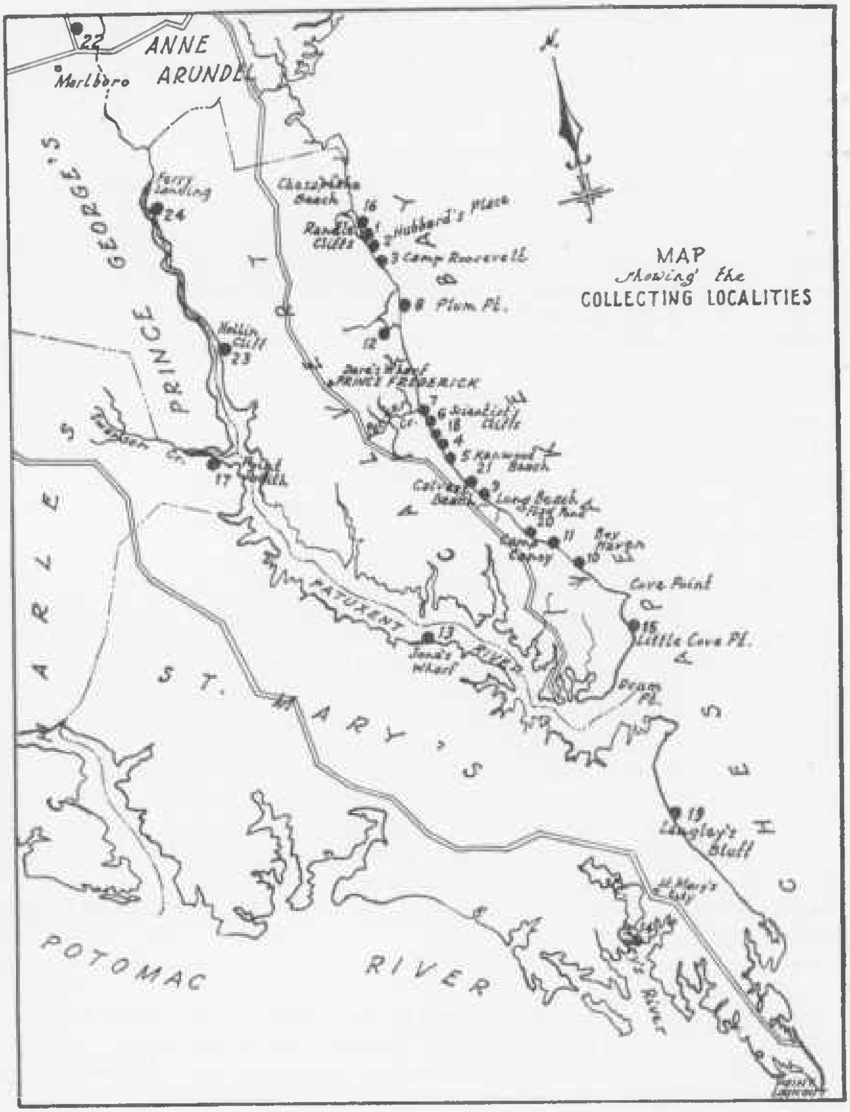

FIGURE 30. Map Showing the Collecting Localities of the Chesapeake Group, Maryland

the locality. Only those samples used in constructing the species-range chart are numbered, in this list. Fig. 30 shows the collecting localities.

Locality 1.—¼ mile south of Randle Cliffs, Calvert County. *Calvert formation, zones 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13.* Chart sample numbers *38, 39, 40, 42, 44, 46.*

Locality 2.—¼ mile north of Captain Collie Hubbard's place; ¾ mile south of Randle Cliffs, Calvert County. *Calvert formation, zones 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13.* Chart sample number *55.*

Locality 3.—South of the first stream on the south side of Camp Roosevelt, Calvert County. *Calvert formation, zones 3, 4, 5, 6, 7, 8, 9, 10.*

Locality 4.—1 mile north of Kenwood Beach (Governor Run), Calvert County. *Calvert formation, zones 14, 15, Choptank formation, zones 16(?), 17, 18.* Chart sample numbers *25, 29.*

Locality 5.—¼ mile north of Kenwood Beach (Governor Run), Calvert County. *Calvert formation, zone 13.* Chart sample numbers *82, 83.*

Locality 6.—½ mile north of Scientists Cliffs, Calvert County. *Choptank formation, zones 17, 18, 19.* Chart sample number *32.*

Locality 7.—South of the mouth of Parker Creek, 1 mile north of Scientists Cliffs, Calvert County. *Calvert formation, zones 11, 12, 13.* Chart sample numbers *61, 62.*

Locality 8.—1¼ miles south of Old Plum Point Wharf, Calvert County. *Calvert formation, zones 10, 11, 12.* Chart sample number *80.*

Locality 9.—Immediately south of Calvert Beach, Calvert County. *Choptank formation, zone 17.*

Locality 10.—North of Camp Boy Haven, 3 miles north of Cove Point, Calvert County. *Choptank formation, zones 18, 19, 20, 21(?).*

Locality 11.—North of Camp Conoy, 2½ miles south of Flag Pond, Calvert County. *Choptank formation, zones 18, 19, 20.* Chart sample number *70.*

Locality 12.—In road cut between Plum Point and Dares Beach, Calvert County. *Choptank formation, zone 17.*

Locality 13.—Second bluff southeast of Old Jones Wharf, on the southwest side of the Patuxent River, St. Marys County. *Choptank formation, zone 17.*

Locality 14.—Cliffs immediately north to ¾ mile north of Rosecroft (opposite Windmill Point), south of Chancellor Point on the east side of the St. Marys River, south of St. Marys City, St. Marys County. *St. Marys formation, zone 24.* Chart sample number *73.*

Locality 15.—Little Cove Point, 1¼ miles south of Cove Point, Calvert County. *St. Marys formation, zones 22, 23.* Chart sample number *75.*

Locality 16.—North of Randle Cliffs, Calvert County. *Calvert formation, zone 10.*

Locality 17.—"Old Walls Place," from headwaters of a tributary to Swanson Creek, 2½ miles east of Patuxent; 2 miles west of Benedict, Charles County. *Calvert formation, zone 10.*

Locality 18.—South of Scientists Cliffs, Calvert County. *Choptank formation, zone 17.*

Locality 19.—1 mile above Langley house, Langley's Bluff, 3½–4 miles south of Cedar Point, St. Marys County. *St. Marys formation, zone 24.*

Locality 20.—1 mile north of Camp Conoy; 1¼ miles south of Flag Pond, Calvert County. *Choptank formation, zones 18, 19, 20.*

Locality 21.—North of Calvert Beach, Calvert County. *Choptank formation, zones 16, 17, 18.* Chart sample number *67.*

(Localities 22, 23, 24 are of the diatomaceous Fairhaven member of the Calvert formation. Beside diatoms, the samples yield radiolarians in abundance, but no foraminifera.)

Locality 22.—Road cut 1½ miles north of highway intersection, east of Marlboro, Prince Georges County. *Calvert formation, zone 3* (?).

Locality 23.—Hollin Cliff on the east side of the Patuxent River, Calvert County. *Calvert formation, zone 3.*

Locality 24.—Diatomite pit, Ferry Landing, on the east side of the Patuxent River, Calvert County. *Calvert-Eocene contact, Calvert formation, zones 1(?), 2.*

SYSTEMATIC DESCRIPTIONS

Phylum PROTOZOA

Class SARCODINA Butschli 1882

Order FORAMINIFERA d'Orbigny 1826

Family TEXTULARIIDAE

Subfamily SPIROPLECTAMMININAE

Genus SPIROPLECTAMMINA Cushman, 1927

SPIROPLECTAMMINA EXILIS Dorsey, n. sp.

(Plate XXVII, figs. 1a–c, 2a–b)

Spiroplectammina gracilis Cushman and Cahill (not Von Muenster), 1933, U. S. Geol. Survey Prof. Paper 175-A, p. 6, pl. 1, figs. 6, 7. (Miocene).

Test elongate, three to three and one-half times as long as broad, compressed, tapering from midportion to initial end, later portion with nearly parallel sides, peripheral margin subacute; chambers planispirally coiled in the early portion, consisting of five or six chambers, the later biserial portion with eleven or twelve pairs of slightly inflated chambers increasing gradually in size as added; sutures distinct, very slightly depressed, strongly curved obliquely downward toward peripheral margin, composed of clear shell material; wall finely arenaceous with much cement and very smooth finish; aperture a low slit at the base of the inner margin of the last-formed chamber. Length 0.74–1.20 mm.; breadth 0.31–0.33 mm.; thickness 0.13 mm.

Holotype (Cushman coll. no. 37701) from zone 17 of the Choptank formation immediately north of Calvert Beach.

This species differs from *Spiroplectammina gracilis* (Von Muenster) in its smaller breadth to length ratio, nearly parallel sides, wider and more curved sutures, more inflated last chambers, and rounded apertural end. Cushman and Cahill figured this species from the Choptank formation and identified it as *S. gracilis*. Their plesiotype specimen and topotype specimens of *S. gracilis* from the upper Oligocene of Germany have been examined and compared by the writer. *S. exilis* occurs in the Choptank and St. Marys formations.

SPIROPLECTAMMINA MISSISSIPPIENSIS (Cushman)

(Plate XXVII, figs. 3a–c, 4a–b)

Textularia mississippiensis Cushman, 1922, U. S. Geol. Survey Prof. Paper 129, pp. 90, 123, pl. 14, fig. 4. (Oligocene); ——, 1923, ibid., Prof. Paper 133, p. 17. (Oligocene); Cole and Ponton, 1930, Florida State Geol. Survey, Bull. 5, p. 27, pl. 10, fig. 3. (Oligocene).
Textularia articulata Bagg (not d'Orbigny), 1904, Maryland Geol. Survey, Miocene, p. 471, pl. 132, figs. 6, 7. (Miocene); Cushman and Ponton, 1932, Florida Geol. Survey, Bull. 9, p. 40, pl. 1, figs. 1a–b. (Miocene); Cushman and Cahill, 1933, U. S. Geol. Survey Prof. Paper 175-A, p. 8, pl. 1, figs. 12a–b. (Miocene).
Textularia carinata Bagg (not d'Orbigny), 1904, Maryland Geol. Survey, Miocene, p. 471, pl. 132, fig. 10. (Miocene).
Textularia sagittula Bagg (not Defrance), l.c. p. 472, pl. 132, figs. 11, 12. (Miocene).

Test wedge-shaped, one to one and one-half times as long as broad, evenly tapering with greatest breadth at apertural end, peripheral margin acute with narrow, notched or irregular keel, greatest thickness in longitudinal midportion giving compressed diamond-shaped cross-section; chambers planispirally coiled in the early portion, consisting of five or six chambers, the later biserial portion in the adult consisting of eight to nine pairs of chambers increasing gradually in size as added; sutures distinct, slightly depressed, very slightly curved downward toward periphery, composed of clear shell material meeting in the center and at the periphery; wall finely arenaceous with much cement and smooth finish; aperture a low slit at the base of the inner margin of the last formed chamber. Length 0.54–0.95 mm.; breadth 0.34–0.52 mm.; thickness 0.20–0.28 mm.

Plesiotypes (Cushman coll. no. 37702) from zone 11 of the Calvert formation at high tide line, south of the mouth of Parker Creek, 1 mile north of Scientists Cliffs.

This species was originally described by Cushman from the Byram Marl (Oligocene) of Mississippi. It has also been recorded from the Oligocene of Florida. The plesiotype specimens of *Textularia articulata*, *T. carinata*, and *T. sagittula* recorded by Bagg from the Miocene of Maryland and *T. articulata* recorded by Cushman and Cahill from Maryland were examined. *T. mississippiensis* is variable in character and these specimens all seem to fall within the limits of variation of the species.

This form is easily distinguished from *Spiroplectammina exilis* by its wedge shape, diamond-shaped cross section, and keeled peripheral margin. In the Maryland material it is confined to the Calvert formation and is best developed in zones 11 and 12.

SPIROPLECTAMMINA SPINOSA Dorsey, n. sp.

(Plate XXVII, figs. 5a–c, 6a–b)

Test compressed, one and one-half times as long as broad, sides strongly divergent, greatest breadth at apertural end, initial end pointed in microspheric form, rounded in megalospheric form, apertural end truncate, peripheral margin spinose; chambers planispirally coiled in early portion, the later biserial portion in the adult consisting of eight or nine pairs of chambers increasing gradually in size as added, each ending in a spinose projection at the peripheral margin; sutures distinct, slightly depressed, straight, directed downward in early portion, almost horizontal in later portion; wall finely arenaceous with smooth finish; aperture a low slit at the inner margin of the last formed chamber. Length 0.60–0.76 mm; breath 0.42–0.56 mm; thickness 0.22 mm.

Holotype (Cushman coll. no. 37703) from zone 11 of the Calvert formation at high tide line, south of Parker Creek valley, 1 mile north of Scientists Cliffs.

Spiroplectammina spinosa most closely resembles *S. mississippiensis* (Cushman) but is to be distinguished from it by its straight, horizontal sutures and spinose projections at the peripheral margin. This species may be confused with *Vulvulina gramen* (d'Orbigny) and its synonyms, *Textularia floridana* Cushman and *T. transversaria* Flint (not H. B. Brady), a form living in the West Indies and Florida waters. *V. gramen* has planispiral and biserial stages which are almost identical with those of *S. spinosa*, but in addition it has a later uniserial stage. *S. spinosa* is probably its ancestral form.

This species occurs only in the Calvert formation in zones 10, 11, and 12 and is an excellent stratigraphic marker for that part of the Maryland Miocene.

Subfamily TEXTULARIINAE

Genus TEXTULARIA Defrance, 1824

TEXTULARIA cf. T. BADENENSIS Lalicker

(Plate XXVII, figs. 8a–c)

Textularia badenensis Lalicker, 1935, Cushman Lab. Foram. Research Contr., vol. 11, pt. 2, p. 44, pl. 7, fig. 1. (Miocene).

This species is represented by only one specimen from zone 17 of the Choptank formation. It was compared with the holotype specimen of *Textularia badenensis* from the Miocene of the Vienna Basin, Austria, and seems to fit its characters closely. It cannot be placed with certainty, however, until more material is available.

Pleisotype (Cushman coll. no. 37704) from zone 17 of the Choptank formation immediately north of Calvert Beach. Length 0.80 mm; breadth 0.35 mm; width 0.25 mm.

TEXTULARIA CANDEIANA d'Orbigny

(Plate XXVII, figs. 7a–c)

Textularia candeiana d'Orbigny, 1839, in de la Sagra, Hist. Physique Pol. Nat. Cuba, Foram., p. 143, pl. 1, figs. 25–27. (Recent); Fornasini, 1903, Accad. Sci. Ist. Bologna Mem., ser. 5, vol. 10, p. 303, pl. 0, fig. 8. (Recent); Cushman, 1911, U. S. Nat. Mus., Bull. 71, pt. 2, p. 12, text figs. 14, 17. (Recent); Heron-Allen and Earland, 1915, Trans. Zool. Soc. London, vol. 20, pt. 2, p. 627, pl. 47, figs. 10–16. (Recent); ——, 1916, ibid., vol. 11, ser. 2, p. 230, pl. 41, figs. 1, 2. (Recent); Cushman, 1921, U. S. Nat. Mus. Proc., vol. 59, p. 50, pl. 11, figs. 7, 8. (Recent); ——, 1922, Carnegie Inst. Washington, Pub. 311, p. 32, pl. 2, fig. 2. (Recent); ——, 1922, U. S. Nat. Mus., Bull. 104, pt. 3, p. 8, pl. 1, figs. 1–3. (Recent); ——, 1932, U. S. Nat. Mus., Bull. 161, pt. 1, p. 9, pl. 2, figs. 4a–b. (Recent); Cushman and Ponton, 1932, Florida Geol. Survey, Bull. 9, p. 41, pl. 8, fig. 4a–b. (Miocene); Yabe and Asano, 1937, Tohoku Imp. Univ. Sci. Rept., ser. 2 (Geol.), vol. 19, no. 1, p. 112 (26), pl. 17 (1), figs. 18a–b. (Pliocene); Galloway and Heminway, 1941, New York Acad. Sci., Sci. Surv. Porto Rico and Virgin Ils. vol. 3, pt. 4, p. 329, pl. 8, figs. 5a–c. (Oligocene, Miocene).

Test elongate, twice as long as broad, compressed in the early portion, gradually tapering to the pointed initial end, the later chambers increasing rapidly in size, much inflated, apertural end circular in cross section; chambers numerous, about ten pairs making up the adult test; sutures gently curved downward, slightly depressed; wall rather coarsely arenaceous; aperture a long, arched, slightly lipped slit in the base of the inner margin of the last formed chamber. Length 1.12 mm; breadth 0.50 mm; thickness 0.50 mm.

Plesiotype (Cushman coll. no. 37705) from zone 17 of the Choptank formation immediately north of Calvert Beach.

The specimens from the Maryland material agree quite closely with d'Orbigny's figures from the Recent of Cuba. It has been recorded from the Recent of the North Pacific, Kerimba Archipelago, West of Scotland, Jamaica, Philippines, Tortugas, Atlantic, Lord Howe Islands, tropical Pacific, Pliocene of Japan, and Miocene of Florida. In the Maryland Miocene it occurs in the Calvert and Choptank formations.

TEXTULARIA CONSECTA d'Orbigny

(Plate XXVIII, figs. 1a–c)

Textularia consecta d'Orbigny, 1826, Annales Sci. Nat. Paris, vol. 7, p. 262. (Miocene); Fornasini, 1901, Riv. ital. Pal., vol. 7, p. 104, pl. 3, fig. 1.

Test elongate, two and one-half to three times as long as broad, compressed, sides almost parallel, peripheral margin rounded; chambers distinct, increasing gradually in height as added, last chamber slightly produced, nine to ten pairs making up the test; sutures distinct, depressed, straight, inclined slightly downward; wall finely arenaceous, smoothly finished; aperture a low, arched slit in a slight reentrant of the inner margin of the last formed chamber. Length 1.08 mm.; breadth 0.40 mm.; thickness 0.25 mm.

Plesiotype (Cushman coll. no. 37706) from zone 17 of the Choptank formation about eight feet above high tide line immediately north of Calvert Beach.

Textularia consecta was described by d'Orbigny from the Miocene of France. The specimens from the Miocene of Maryland compare quite closely with Fornasini's figures taken from d'Orbigny's unpublished plates. This species is somewhat similar to the Eocene species *T.*

recta Cushman, *T. midwayana* Lalicker, and *T. plummerae* Lalicker but differs from them in a more compressed test, more inflated chambers, and inclined sutures.

It is confined to the Choptank formation and was found only in zones 17 and 19.

TEXTULARIA cf. T. FOLIACEA Heron-Allen and Earland

(Plate XXVIII, figs. 2a–c)

Textularia sp. Cushman and Ponton, 1932, Florida Geol. Survey, Bull. 9, p. 42, pl. I, figs. 7a–b. (Miocene).

Textularia foliacea is a recent species which is widely distributed in the tropical Pacific and the Indo-Pacific. It may be that this species also occurs in the Maryland Miocene. Specimens referable to it occur throughout the Calvert formation and are best developed in zone 10.

Plesiotype (Cushman coll. no. 37707) from zone 10 of the Calvert formation, $1\frac{1}{4}$ miles south of Old Plum Point Wharf. Length 1.22 mm.; breadth 0.55 mm.; thickness 0.38 mm.

TEXTULARIA GRAMEN d'Orbigny

(Plate XXVIII, figs. 3a–c)

Textularia gramen d'Orbigny, 1846, Foram. Foss. Bassin Tertiaire, Vienne, p. 248, pl. 15, figs. 4–6. (Miocene); Bagg, 1901, Maryland Geol. Survey, Eocene, p. 233, pl. 62, fig. I. (Eocene); ——, 1904, ibid., Miocene, p. 471, pl. 132, figs. 8, 9. (Miocene); Cushman, 1918, U. S. Geol. Survey, Bull. 676, pp. 8, 45, pl. 9, fig. 5 (not figs. 2, 3, 4). (Miocene); ——, 1930, Florida Geol. Survey, Bull. 4, p. 17, pl. 1, figs. 5a–b. (Miocene); Cushman and Ponton, 1932, ibid., Bull. 9, p. 39. (Miocene); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 7, pl. 1, figs. 9a–b. (Miocene); Cushman and Hobson, 1935, Cushman Lab. Foram. Research Contr., vol. 11, p. 56, pl. 8, figs. 5a–b. (Tertiary); Galloway and Heminway, 1941, New York Acad. Sci., Sci. Surv. Porto Rico and Virgin Ils. vol. 3, pt. 4, p. 330, pl. 8, figs. 4a–c. (Oligocene).

Test elongate, twice as long as broad, compressed, peripheral margin subacute; chambers distinct, five to seven pairs making up the test; sutures distinct, slightly depressed, straight, inclined toward the periphery making an angle of about 20° with horizontal; wall finely arenaceous, smoothly finished; aperture an arched slit in a slight groove at the base of the inner margin of the last formed chamber. Length 0.73–0.80 mm.; breadth 0.32–0.35 mm.; thickness 0.22–0.25 mm.

Plesiotype (Cushman coll. no. 37708) from zone 17 of the Choptank formation about eight feet above high tide line immediately north of Calvert Beach.

This species was described from the Miocene of the Vienna Basin, Austria. It has been further recorded from the Eocene and Miocene of the Atlantic Coastal Plain. In the Maryland Miocene it occurs throughout the section but is most abundant in the Choptank formation.

TEXTULARIA MAYORI Cushman

(Plate XXVIII, figs. 5a–c)

Textularia mayori Cushman, 1922, Carnegie Inst. Washington, Pub. 311, p. 23, pl. 2, fig. 3. (Recent); ——, 1922, U. S. Nat. Mus., Bull. 104, pt. 3, p. 7. (Recent); ——, 1930, Florida Geol. Survey, Bull. 4, p. 17, pl. 1, figs. 6, 8. (Miocene); Cushman and Ponton, 1932, Florida Geol. Survey, Bull. 9, p. 40., pl. 1, figs. 2, 3. (Miocene).

Textularia gramen (in part) Cushman (not d'Orbigny), 1918, U. S. Geol. Survey, Bull. 676, p. 45, pl. 9, figs. 4, 5 (not figs. 2, 3). (Miocene).

Test elongate, compressed, sides strongly divergent, periphery rounded; chambers numerous, seven to eight pairs making up the test, periphery of each chamber strongly overlapping the periphery of the preceding chamber; sutures slightly depressed, strongly arched; wall finely arenaceous with smooth finish; aperture a low, elongate opening in a definite reentrant of the inner margin of the last formed chamber. Length 0.60–0.84 mm.; breadth 0.41–0.50 mm.; thickness 0.20–0.23 mm.

Plesiotype (Cushman coll. no. 37709) from zone 18 of the Choptank formation, ½ mile south of the mouth of Parker Creek, or ½ mile north of Scientists Cliffs.

The spinose projections from the base of the chambers, which are typically developed in this species in the Miocene of Virginia and Florida, are absent in the specimens from Maryland. However, the general characters of shape, compression, and overlap of the peripheral margins of the chambers, especially in the early chambers, are the same.

Textularia mayori has been recorded from the Recent of the Atlantic and the Miocene of Florida and Virginia. In the Maryland Miocene it occurs in the Choptank and St. Marys formations.

TEXTULARIA OBLIQUA Dorsey, n. sp.

(Plate XXVIII, figs. 6a–c, 7a–c)

Test of medium size, biserial throughout, tapering from an obliquely truncated apertural end to a bluntly pointed initial end, thickest through medial line, periphery rounded; chambers comparatively few, longer than high, strongly overlapping, about eight pairs making up the test; sutures indistinct, slightly depressed, straight, oblique, forming an angle of 25° to 30° with horizontal; wall coarsely arenaceous, smoothly finished; aperture an arched slit in a deep reentrant of the inner margin of the last formed chamber. Length 0.92–1.35 mm.; breadth 0.71–0.78 mm.; thickness 0.53–0.62 mm.

Holotype (Cushman coll. no. 37710) from zones 22–23 of the St. Marys formation, 1¼ miles south of the pier at Cove Point.

This species is perhaps most closely related to *Textularia schivelyi* Kleinpell, but it is much smaller, is wider in relation to length, has a rounded periphery, and fewer chambers. It occurs in zones 22, 23, and 24 of the St. Marys formation.

TEXTULARIA ULTIMA-INFLATA Dorsey, n. sp.

(Plate XXVIII, figs. 8a–c)

Test almost as broad as long, strongly compressed in early portion, only slightly compressed in later portion, triangular in front view, broadly oval in end view, peripheral margin subacute in early portion, broadly rounded in later portion; chambers increasing rapidly but uniformly in size as added, about eight pairs making up the test; sutures indistinct, not depressed, gently curved downward toward the peripheral margin; wall finely arenaceous with a roughening of coarse sand grains on the surface, a conspicuous portion of the sand grains made up of black material; aperture a long, low slit in a slight reentrant of the inner margin of the last formed chamber. Length 0.85 mm.; breadth 0.76 mm.; thickness 0.55 mm.

Holotype (Cushman coll. no. 37711) from zone 18 of the Choptank formation, ½ mile south south of the mouth of Parker Creek.

This species may be compared with *Textularia conica* but differs from it in its more inflated apertural face, compressed peripheral margin, and greater length in relation to breadth.

It occurs in zone 18 of the Choptank formation.

Genus BIGENERINA d'Orbigny, 1826

BIGENERINA FLORIDANA Cushman and Ponton

(Plate XXVIII, figs. 4a–b)

Bigenerina floridana Cushman and Ponton, 1932, Florida Geol. Survey, Bull. 9, p. 42, pl. 1, figs. 9–12. (Miocene); Ellisor, 1940, Bull. Amer. Assoc. Petr. Geol., vol. 24, no. 3, pl. 4, figs. 15–18. (Miocene); Palmer, 1940, Mem. Soc. Cubana Hist. Nat., vol. 14, no. 2, p. 117, pl. 18, fig. 6. (Oligocene).

This species is represented by a single specimen which has only one chamber in the uniserial portion. The aperture is an oval opening in the inner margin of the last chamber. This specimen shows the transition stage between the biserial portion with marginal aperture and the uniserial portion with terminal aperture.

Plesiotype (Cushman coll. no. 37712) from zone 7 of the Calvert formation, ¼ mile south of Randle Cliffs. Length 1.14 mm.; breadth 0.47 mm.; thickness 0.32 mm.

Family MILIOLIDAE

Genus QUINQUELOCULINA d'Orbigny, 1826

QUINQUELOCULINA CONTORTA d'Orbigny var. STRIATA Asano

(Plate XXIX, figs. 1a–c)

Quinqueloculina contorta d'Orbigny var. *striata* Asano, 1936, Jour. Geol. Soc. Japan, vol. 43, no. 519, p. 943, pl. 51, figs. 2a–c. (Neogene).
Quinqueloculina contorta Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A p. 9, pl. 2, figs. 3a–c. (Miocene).

Test almost twice as long as broad, periphery flattened, sides slightly concave; chambers angled in cross-section; wall ornamented with fine, closely spaced discontinuous striations; aperture long and narrow, slightly lipped with a long thin tooth bifid at the tip. Length 1.02 mm.; breadth 0.59 mm.; thickness 0.32 mm.

Plesiotype (Cushman coll. no. 37713) from zone 17 of the Choptank formation, immediately north of Calvert Beach.

This variety is rare and was found only in zone 17.

QUINQUELOCULINA SEMINULA (Linnaeus)

(Plate XXIX, fig. 2a–c)

Serpula seminulum Linnaeus, 1767, Systema naturae, 12th ed., p. 1264. (Recent).
Quinqueloculina seminulum d'Orbigny, 1826, Annales Sci. Nat. Paris, vol. 7, p. 303; Cushman, 1917, U. S. Nat. Mus., Bull. 71, pt. 6, p. 44, pl. 11, fig. 2. (Recent); ——, 1918, ibid., Bull. 103, p. 78, pl. 27, figs. 4a–b; pl. 29, figs. 1a–c. (Tertiary); ——, 1918, U. S. Geol. Survey, Bull. 676, p. 22, pl. 1, fig. 8; p. 70, pl. 28, figs. 2, 4, 5, (Pliocene, Miocene); ——, 1929, U. S. Nat. Mus., Bull. 104, pt. 6, p. 24, pl. 2, figs. 1, 2. (Recent); Phleger, 1939, Bull. Geol. Soc. Amer., vol. 50, pl. 2, fig. 15, p. 1421. (Pleistocene); Galloway and Heminway, 1941, New York Acad. Sci., Sci. Surv. Porto Rico and Virgin Ils. vol. 3, pt. 4, p. 305, pl. 2, figs. 8a–c. (Oligocene); Le Roy, 1944, Colorado School of Mines Quart., vol. 39, no. 3, pt. 2, p. 77, pl. 7, figs. 11–13. (Miocene); Cushman, 1945, Special Publ. no. 13, Cushman Lab. Foram. Res., p. 17, pl. 2, fig. 16. (Pliocene).
Quinqueloculina seminula Cushman, 1929, Cushman Lab. Foram. Research Contr., vol. 5, pt. 3, p. 59, pl. 9, figs. 16–18. (Recent); Cushman and Cole, 1930, ibid., vol. 6, pt. 4, p. 95, pl. 13, figs. 1a–c. (Pleistocene); Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 19, pl. 2, figs. 1, 2. (Miocene); Kornfeld, 1931, Stanford Univ., Dept. Geol. Contr., vol. 1, no. 3, p. 83, pl. 14, figs. 4a–c. (Recent); Dolgopolskaja and Pauli, 1931, Travaux Sta. Biol. Karadagh, vol. 4, p. 27, pl. 1, figs. 2a–c. (Recent); Hada, 1931, Tohoku Imp. Univ. Sci. Rept., Ser. 4, Biol., vol. 6, p. 76, fig. 28. (Recent); Howe and Wallace, 1932, Louisiana Geol. Bull. 2, p. 22, pl. 2, fig. 3. (Eocene); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 9, pl. 2, figs. 2a–c. (Miocene); Cushman, 1933, Cushman Lab. Foram. Research, Spec. Pub., no. 5, pl. 14, figs. 3, 4. (Recent); Asano, 1937, Saito Ho-on Kai Research Bull. 13, p. 113, pl. 15, figs. 2a–c. (Recent); Tolmachoff, 1934, Annals Carnegie Museum, vol. 23, p. 292, pl. 40, figs. 8–10. (Miocene).
Miliolina seminulum Williamson, 1858, Recent Foram. Great Britain, p. 85, pl. 7, figs. 183–185. (Recent); H. B. Brady, 1884, Challenger Rept., Zool., vol. 9, p. 157, pl. 5, fig. 6. (Recent).

Test longer than wide, broadly oval in outline, periphery rounded; chambers distinct; sutures distinct, slightly depressed; wall smooth, polished; aperture a broadly oval, slightly lipped opening with a short, simple tooth. Length 0.90 mm.; breadth 0.68 mm.; thickness 0.38 mm.

Plesiotype (Cushman coll. no. 37714) from zone 24 of the St. Marys formation, between Rosecroft (opposite Windmill Point) and Chancellor Point on the east side of the St. Marys River south of St. Marys City.

This species is widely distributed in the present oceans. It has been recorded from the Atlantic Ocean, Pacific Ocean, Gulf of Mexico, Black Sea, and Mutsu Bay (Japan). As a fossil it has been reported from the Eocene, Miocene, and Pleistocene of the Atlantic Coastal region. Many references have been made to this rather definite form which are not typical of the species. Only those with figured specimens which seem typical are listed in the above synonymy.

In Maryland this species occurs abundantly throughout the Choptank and St. Marys formations.

Genus MASSILINA Schlumberger, 1893

MASSILINA GLUTINOSA Cushman and Cahill

(Plate XXIX, figs. 6a–c)

Massilina glutinosa Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 10, pl. 2, figs. 10a–c. (Miocene).

The following is the description from Cushman and Cahill:

"Test much compressed, broad, periphery rounded, the apertural end somewhat projecting; chambers numerous, somewhat indistinct, nearly circular in transverse section; sutures indistinct; wall arenaceous, of fine angular fragments with much cement, the surface smoothly finished; aperture circular, projecting, with a slight lip and tooth. Length 0.60 mm.; breadth 0.42–0.45 mm.; thickness 0.10 mm."

Plesiotype (Cushman coll. no. 37715) from zone 17 of the Choptank formation, immediately north of Calvert Beach. Length 0.50 mm.; breadth 0.34 mm.; thickness 0.10 mm.

This species was described from zone 17 of the Choptank formation. It is a rare yet distinctive form and occurs in zones 16, 17, and 18.

MASSILINA MANSFIELDI Cushman and Cahill

(Plate XXIX, figs. 4a–c, 5a–c)

Massilina mansfieldi Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 11, pl. 2, figs. 11a–c. (Miocene).

The following is the description from Cushman and Cahill:

"Test about twice as long as broad, much compressed, periphery broadly rounded; chambers distinct, nearly circular in transverse section; sutures distinct but very slightly depressed; wall smooth and polished; aperture large with a very slight rounded border. Length 1.00–1.10 mm.; breadth, 0.60–0.65 mm.; thickness, 0.18–0.20 mm."

Plesiotypes (Cushman coll. nos. 37716, 37723) from zone 24 of the St. Marys formation, between Rosecroft (opposite Windmill Point) and Chancellor Point on the east side of the St. Marys River, south of St. Marys City. Length 0.75 mm.; breadth 0.62 mm.; thickness 0.15 mm.

This species was described from the Yorktown formation (Miocene) of Virginia. In the Maryland Miocene it occurs only in zone 24 of the St. Marys formation.

MASSILINA QUADRANS Cushman and Ponton

(Plate XXIX, figs. 3a–c)

Massilina quadrans Cushman and Ponton, 1932, Florida Geol. Survey, Bull. 4, p. 47, pl. 3, figs. 7, 8. (Miocene).

Test large, compressed, longer than broad, periphery truncate with slight keels, sides deeply concave in center; chambers indistinct, numerous, quadrate in cross-section; sutures slightly depressed; wall smooth; aperture an oblong opening with a long tooth and a very distinct lip. Length 1.14 mm.; breadth 0.88 mm.; thickness 0.30 mm.

Plesiotype (Cushman coll. no. 37717) from zone 17 of the Choptank formation, immediately north of Calvert Beach.

This species has been described from the Chipola formation (Miocene) of Florida and has not been recorded elsewhere. It is rare in the Maryland Miocene, having been found only in zone 17.

Genus TRILOCULINA d'Orbigny, 1826

TRILOCULINA cf. T. TRIGONULA (Lamarck)

(Plate XXX, figs. 1a-c)

A single specimen which may be referred to this species was found.

Plesiotype (Cushman coll. no. 37718) from zone 17 of the Choptank formation, immediately north of Calvert Beach. Length 0.42 mm.; breadth 0.38 mm.; thickness 0.31 mm.

Genus PYRGO Defrance, 1924

PYRGO SUBSPHAERICA (d'Orbigny)

(Plate XXIX, figs. 7a-c)

Biloculina subsphaerica d'Orbigny, 1839, in de la Sagra, Hist. Physique Pol. Nat. Cuba, Foram., p. 162, pl. 3, figs. 25-27. (Recent).

Pyrgo subsphaerica Cushman, 1929, U. S. Nat. Mus., Bull. 104, pt. 6, p. 68, pl. 18, figs. 1, 2. (Recent); ——, 1930, Florida Geol. Survey, Bull. 4, p. 23, pl. 3, figs. 5a-c. (Miocene); Cushman and Parker, 1931, U. S. Nat. Mus. Proc., vol. 80, art. 3, p. 5, pl. 1, figs. 13a-b. (Recent); Cushman and Ponton, 1932, Florida Geol. Survey, Bull. 4, p. 56. (Miocene); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 11, pl. 3, figs. 4a-c. (Miocene); Cushman, 1944, Special Publ. No. 12, Cushman Lab. Foram. Res., p. 17, pl. 2, fig. 27. (Recent).

The following description by Cushman and Cahill fits the Maryland specimens:

"Test small, rotund, slightly longer than broad, somewhat broader than thick; chambers rounded, periphery rounded; sutures distinct, depressed, in side view showing a sinuous line concave toward the preceding chamber at the opposite end; wall smooth and polished; aperture broadly oval, with a somewhat flattened tooth with short lateral extensions at the tip only partly filling the aperture. Length, 0.58 mm.; breadth, 0.40 mm.; thickness, 0.35 mm."

Plesiotype (Cushman coll. no. 37719) from zone 24 of the St. Marys formation, between Rosecroft (opposite Windmill Point) and Chancellor Point, on the east side of the St. Marys River, south of St. Marys City. Length 0.55 mm.; breadth 0.50 mm.; thickness 0.46 mm.

This species is very rare and was found only in zone 24.

Family LAGENIDAE

Subfamily NODOSARIINAE

Genus ROBULUS Montfort, 1808

ROBULUS AMERICANUS (Cushman)

(Plate XXX, figs. 3a-b)

Cristellaria americana Cushman, 1918, U. S. Geol. Survey, Bull. 676, p. 50, pl. 10, figs. 5, 6. (Miocene).

Robulus americanus Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 24, pl. 3, figs. 7a–b. (Miocene); Cushman and Ponton, 1932, ibid., Bull. 9, p. 58. (Miocene); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 12, pl. 3, figs. 6a–b. (Miocene); Bandy, 1944, Journ. Pal., vol. 18, no. 4, p. 368, pl. 60, fig. 4. (Eocene).

Test large, closely coiled, biconvex, periphery acute, keeled; chambers increasing gradually in size as added, seven or eight making up the last formed whorl; sutures distinct, raised, gently curved, ending in the center in a prominent umbo and at the periphery in the keel; wall smooth and polished; aperture radiate with a well-developed ventral slit extending into the apertural face. Diameter 1.00 mm.; thickness 0.50 mm.

Plesiotype (Cushman coll. no. 37720) from zone 11 of the Calvert formation, south of the mouth of Parker Creek, ½ mile north of Scientists Cliffs.

This species was originally described from the Duplin marl (Miocene) of South Carolina. It also occurs in the Miocene of Florida. In Maryland this species occurs in samples from zone 11 of the Calvert formation through zone 17 of the Choptank formation. It is abundant, however, only in zones 11, 12, and 13 of the Calvert formation.

ROBULUS AMERICANUS (Cushman) var. SPINOSUS (Cushman)

(Plate XXX, figs. 4a–b)

Cristellaria americana Cushman var. *spinosa* Cushman, 1918, U. S. Geol. Survey, Bull. 676, p. 51, pl. 10, fig. 7. (Miocene).

Robulus americanus var. *spinosus* Cushman, Stewart and Stewart, 1930, San Diego Soc. Nat. Hist., Trans., vol. 6, p. 53, pl. 8, fig. 2. (Miocene); Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 24. pl. 3, figs. 8a–b. (Miocene); Cushman and Ponton, 1932, ibid., Bull. 9, p. 58, (Miocene); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 12, pl. 3, figs. 7a–b. (Miocene); Ellisor, 1940, Bull. Am. Assoc. Petrol. Geologists, vol. 24, no. 3, p. 438 (list), pl. 4, figs. 20a–b. (Miocene).

This variety differs from the typical form by the spinose projections of the periphery developed opposite the sutures, the sutures are not distinct and raised, and the umbo is not prominent.

Plesiotype (Cushman coll. no. 37721) from zone 11 of the Calvert formation, south of the mouth of Parker Creek, ½ mile north of Scientists Cliffs. Diameter 0.90 mm.; thickness 0.50 mm.

This form occurs rarely in zones 11, 12 and 13 of the Calvert formation.

ROBULUS BRANNERI Cushman and Kleinpell

(Plate XXX, figs. 2a–b)

Robulus branneri Cushman and Kleinpell, 1934, Cushman Lab. Foram. Research Contr., vol. 10, pt. 1, p. 2, pl. 1, figs. 4a–b. (Miocene); Kleinpell, 1938, Miocene Stratigraphy of California, pp. 43, 148, 197. (Miocene).

Test small, closely coiled, biconvex, periphery acute with a narrow keel; chambers increasing gradually in size as added, seven or eight making up the last formed whorl; sutures distinct, flush with the surface, slightly curved; wall smooth, highly polished, translucent except at the suture lines where it is opaque; aperture radiate, at the peripheral angle of the test with a prominent, crenulate, ventral slit extending into the apertural face. Diameter 0.55 mm.; thickness 0.21 mm.

Plesiotype (Cushman coll. no. 37722) from zone 12 of the Calvert formation, south of the mouth of Parker Creek, ½ mile north of Scientists Cliffs.

Robulus branneri has been previously recorded only from the Miocene of California. The Maryland specimens are almost identical with the holotype specimen. It occurs in zones 11, 12 and 13 of the Calvert formation.

Genus PLANULARIA Defrance, 1824

PLANULARIA VAUGHANI (Cushman)

(Plate XXX, figs. 6a–b)

Cristellaria vaughani Cushman, 1918, U. S. Nat. Mus., Bull. 103, p. 61, pl. 22, fig. 3. (Oligocene).
Robulus cf. *vaughani* Cushman, 1927, Jour. Paleontology, vol. 1, p. 151, pl. 23, fig. 10. (Alazan, Mexico).
Robulus vaughani Cushman and Ponton, 1932, Florida Geol. Survey, Bull. 9, p. 59, pl. 8, figs. 5–10. (Miocene); Ellisor, 1940, Bull. Am. Assoc. Petrol. Geologists, vol. 24, no. 3, pp. 438 (list), 440 (list), 441 (list), pl. 5, figs. 1–6. (Miocene).
Planularia cf. *vaughani* Ellisor, l.c. p. 440 (list), pl. 3, figs. 8a–b. (Miocene).
Cristellaria wetherellii Bagg (not Jones), 1904, Maryland Geol. Survey, Miocene, p. 475, pl. 32, fig. 16. (Miocene).
Cristellaria catenulata Cushman, 1918, U. S. Geol. Survey, Bull. 676, p. 51, pl. 11, fig. 2. (Miocene).
Robulus catenulatus Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 25, pl. 4, figs. 3a–b. (Miocene); Cushman and Ponton, 1932, ibid., Bull. 9, p. 58, (Miocene); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 13, pl. 4, figs. 3a–b. (Miocene).
Cristellaria vicksburgensis Cushman, 1922, U. S. Geol. Survey, Prof. Paper 129-A, p. 130, pl. 31, figs. 6, 7. (Oligocene).
? *Robulus vicksburgensis* Ellisor, 1933, Bull. Am. Petrol. Geologists, vol. 17, no. 11, pl. 2, fig. 2. (Oligocene).

Test strongly compressed, closely coiled with a tendency to uncoil in the last formed chambers, periphery acute with a narrow keel; chambers numerous, about ten in the last formed whorl, increasing gradually in size as added; sutures distinct, raised, usually marked by rows of raised bosses; wall smooth, except for the bossed sutures, highly polished; aperture located at the peripheral angle of the test, radiate, with a slight neck; apertural face truncate, with slightly keeled, subparallel sides. Length 0.78 mm.; breadth 0.58 mm.; thickness 0.20 mm.

Plesiotype (Cushman coll. no. 37724) from zone 13 of the Calvert formation, ¼ mile north of Governor Run or Kenwood Beach.

This form is hard to place in a genus. It cannot be placed in the genus *Robulus* because that is restricted to those forms which have a slit from the aperture extending into the apertural face. The last chambers are not circular in cross section, but are triangular, so it cannot fall within the limits of the genus *Marginulina*. It seems best to place it in the genus *Planularia*.

This species differs from *Planularia fragaria* var. *texasensis* in the lack of ornamentation between the sutures. It consistently seems to have the bosses or beads in rows on the sutures and not on the chamber areas.

This species occurs in zones 11, 12, and 13 of the Calvert formation.

PLANULARIA SP.

(Plate XXX, figs. 7a–b)

The specimen figured is from the zone 12 of the Calvert formation, south of the mouth of Parker Creek, 1 mile north of Scientists Cliffs. No other specimens have been found.

Plesiotype (Cushman coll. no. 37725). Length 0.46 mm.; breadth 0.30 mm.; thickness 0.10 mm.

Genus MARGINULINA d'Orbigny, 1826

Numerous specimens seem to fit the characters of the genus *Marginulina*. Because of the great variation in specific characters it has seemed best to make no specific identifications, but to figure the specimens for completeness of fauna.

MARGINULINA SP. A

(Plate XXX, figs. 9a–b)

Plesiotype (Cushman coll. no. 37726) from zone 13 of the Calvert formation, ¼ mile north of Governor Run or Kenwood Beach. Length 0.65 mm.; breadth 0.42 mm.; thickness 0.20 mm.

MARGINULINA SP. B

(Plate XXX, figs. 10a–b)

Plesiotype (Cushman coll. no. 37727) from zone 11 of the Calvert formation, south of the mouth of Parker Creek, 1 mile north of Scientists Cliffs. Length 0.82 mm.; breadth 0.33 mm.; thickness 0.25 mm.

MARGINULINA SP. C

(Plate XXX, figs. 11a–b)

Plesiotype (Cushman coll. no. 37728) from zone 13 of the Calvert formation, ¼ mile north of Governor Run or Kenwood Beach. Length 1.08 mm.; breadth 0.33 mm.; thickness 0.28 mm.

MARGINULINA SP. D

(Plate XXX, figs. 12a–b, 13a–b)

Plesiotypes (Cushman coll. nos. 37729, 37730) from zone 13 of the Calvert formation, ¼ mile north of Governor Run or Kenwood Beach. Length 1.07–1.57 mm.; breadth 0.33–0.36 mm.; thickness 0.30–0.32 mm.

Genus DENTALINA d'Orbigny, 1826

DENTALINA cf. D. COMMUNIS d'Orbigny

(Plate XXXI, fig. 1)

The specimen figured is the only one found.

Plesiotype (Cushman coll. no. 37731) from zone 17 of the Choptank formation, immediately north of Calvert Beach. Length 1.10 mm.; diameter 0.17 mm.

DENTALINA SP.

(Plate XXXI, fig. 2)

This figured fragment showing rather coarse costae seems to be the same as fragments of *Dentalina* sp. figured by Cushman and Ponton from the Miocene of Florida. (1932, Florida Geol. Survey, Bull. 9, p. 61, pl. 9, figs. 1–4).

Plesiotype (Cushman coll. no. 37732) from zone 17 of the Choptank formation, immediately north of Calvert Beach. Diameter 0.13 mm.

Genus NODOSARIA Lamarck, 1812

NODOSARIA PYRULA d'Orbigny

(Plate XXXI, fig. 3)

Nodosaria pyrula d'Orbigny, 1826, Annales Sci. Nat. Paris, vol. 7, p. 253, no. 13. (Tertiary); Williamson, 1858, Recent British Foram., p. 17, fig. 39. (Recent); Schwager, 1866, Novara-Reise, geol. Theil, vol. 2, p. 217, pl. 5, fig. 38. (Tertiary); H. B. Brady, 1884, Challenger Rept., Zool., vol. 9, p. 497, pl. 62, figs. 10–12. (Recent); Balkwill and Wright, 1885, Trans. Roy. Irish Acad., vol. 28, Sci., p. 343, pl. 12, fig. 28. (Recent); Fornasini, 1890, Accad. sci. Ist. Bologna Mem., ser. 4, vol. 10, p. 8, pl., fig. 11. (Pliocene); Silvestri, 1896, Pont. accad. Nuovi Lincei Mem., vol. 12, p. 134, pl. 3, figs. 21a–b. (Pliocene); Flint, 1897, U. S. Nat. Mus. Rept., p. 309, pl. 55, fig. 4. (Recent); Mills, 1900, Trans. Hull Sci. and Field Nat. Club, vol. 1, p. 148, pl. 11, fig. 30. (Recent); Cushman, 1913, U. S. Nat. Mus., Bull. 71, pt. 3, p. 49, pl. 26, figs. 1–3. (Recent); ——, 1921, ibid., Bull. 100, p. 187, pl. 33, figs. 1–3. (Recent); ——, 1923, ibid., Bull. 104, pt. 4, p. 67, pl. 16, figs. 1–4. (Recent); Cushman and Schenck, 1928, Univ. California Pub., Bull. Dept. Geol. Sci., vol. 17, p. 308, pl. 43, figs. 1, 2. (Tertiary); Galloway and Morrey, 1929, Bull. Am. Paleontology, vol. 15, p. 16, pl. 1, fig. 16. (Eocene); Macfadyen, 1930 (1931), Geol. Survey Egypt, p. 68, pl. 2, fig. 16. (Miocene); Hofker, 1932, Pubbl. Staz. Zool. Napoli, vol. 12, pt. 1, p. 108, fig. 24 (in text). (Recent); Palmer and Bermudez, 1936, Soc. Cubana Hist. Nat. Mem., vol. 10, no. 4, p. 265, pl. 14, fig. 2. (Oligocene); Howe, 1939, Louisiana Geol. Survey, Bull. 14, p. 48, pl. 5, fig. 16. (Eocene).

This species was described by d'Orbigny from the Eocene of France and is widely distributed in Tertiary sediments and present oceans. Only those references are given in the synonymy which figure typical specimens.

Plesiotype (Cushman coll. no. 37733) from zone 12 of the Calvert formation, south of the mouth of Parker Creek, 1 mile north of Scientists Cliffs. Length (fragmental) 0.64 mm.; diameter 0.13 mm.

This species is extremely rare and was found only in zone 12 of the Calvert formation.

Genus SARACENARIA Defrance, 1824

SARACENARIA SP.

(Plate XXX, figs. 5a–b)

The figured specimen is probably that of a young megalospheric form. This species occurs very rarely in the Calvert and Choptank formations.

Plesiotype (Cushman coll. no. 37734) from zone 11 of the Calvert formation, south of the mouth of Parker Creek, 1 mile north of Scientists Cliffs. Length 0.32 mm.; breadth 0.21 mm.; thickness 0.15 mm.

Genus VAGINULINA d'Orbigny, 1826

VAGINULINA SP.

(Plate XXX, figs. 8a–b)

The figured specimen is the only one of this species found. Its general characters seem to correspond to those of the genus *Vaginulina*. The test is compressed, with one margin subacute, the other convex, coiled in the early portion, uncoiled in the later portion with long, narrow chambers; aperture is radiate and located at the peripheral angle.

Plesiotype (Cushman coll. no. 37735) from zone 18 of the Choptank formation, ½ mile north of Scientists Cliffs. Length 0.40 mm.; breadth 0.20 mm.; thickness 0.11 mm.

Subfamily LAGENINAE

Genus LAGENA Walker and Jacob, 1798

LAGENA ACUTICOSTA Reuss

(Plate XXXI, figs. 11, 12)

Lagena acuticosta Reuss, 1870, Akad. Wiss. Wien., Sitzungsber., p. 476; v. Schlicht, 1870, Foram. Septarien-Thones Pietzpuhl, pl. 3, figs. 17, 23. (Oligocene); Egger, 1893, Abhandl. k. bay. Akad. Wiss., München, Cl. 2, vol. 18, p. 329, pl. X, figs. 47, 48, 80–84.

(Recent); Mills, 1900, Trans. Hull Sci. and Field Nat. Club, vol. 1, p. 148, pl. 10, fig. 20. (Recent); Sidebottom, 1912, Jour. Quekett Micr. Club, vol. 11, p. 388, pl. 15, fig. 22 (not fig. 23). (Recent); Cushman, 1913, U. S. Nat. Mus., Bull. 71, pt. 3, p. 23, pl. 8, figs. 9, 10; pl. 23, fig. 2. (Recent); ——, 1923, ibid., Bull. 104, pt. 4, p. 5, pl. 1, figs. 1–3. (Recent); Wiesner, 1929, Süd-Polar-Exped., vol. 20, Zool., p. 117, pl. 18, figs. 208–210. (Recent); Cushman and Ponton, 1932, Cushman Lab. Foram. Research Contr., vol. 8, pt. 3, p. 59, pl. 7, figs. 20a–b. (Eocene); Cushman, 1933, U. S. Nat. Mus., Bull. 161, pt. 2, p. 34, pl. 8, figs. 9, 10, 12. (Recent); Earland, 1933, Discovery Repts., vol. 7, p. 108, pl. 3, fig. 52. (Recent); Cushman, 1935, U. S. Geol. Survey, Prof. Paper 181, p. 23, pl. 9, figs. 5, 6. (Eocene); Kleinpell, 1938, Bull. Amer. Assoc. Petr. Geol., p. 224, pl. 7, fig. 13. (Miocene); Cushman and Garrett, 1939, Contr. Cushman Lab. Foram. Res., vol. 15, p. 80, pl. 14, fig. 6. (Eocene); Cushman, 1939, Cushman Lab. Foram. Res. Contr., vol. 15, p. 59, pl. 10, figs. 32–34. (Eocene); Toulmin, 1941, Journ. Pal., vol. 15, no. 6, p. 593, pl. 80, fig. 6. (Eocene); Cushman and Siegfus, 1942, Trans. San Diego Soc. Nat. Hist., vol. 9, no. 34, p. 409, pl. 16, fig. 24. (Eocene); Cushman, 1944, Spec. Publ. no. 12, Cushman Lab. Foram. Res., p. 20, pl. 3, fig. 5. (Recent); LeRoy, 1944, Colorado School Mines Quart., vol. 39, no. 3, pt. 1, p. 22, pl. 1, fig. 11. (Miocene); ——, 1944, ibid., pt. 2, p. 83, pl. 7, fig. 23. (Miocene).

Lagena sulcata H. B. Brady (not Walker and Jacob), 1884, Challenger Rept., Zool., vol. 9, p. 463, pl. 57, fig. 34 (not figs., 23, 26, 33). (Recent); Chapman, 1900, California Acad. Sci. Proc., ser. 3 (Geol.), vol. 1, no. 8, p. 246, pl. 29, fig. 9. (Miocene); Bagg, 1905 U. S. Geol. Survey, Bull. 268, p. 28, pl. 4, fig. 6. (Miocene); Cushman, 1923, U. S. Geol. Survey, Prof. Paper 133, p. 25, pl. 3, fig. 8 (Oligocene); Cushman and Parker, 1931, Cushman Lab. Foram. Research Contr., vol. 7, p. 6, pl. 1, fig. 20. (Miocene); Macfadyen, 1932, Geol. Mag., vol. 69, pl. 34, fig. 7. (Pleistocene-Pliocene).

Lagena costata Heron-Allen and Earland (not Williamson), 1932, Discovery Rept., vol. 4, p. 369, figs. 19–22, 24 (not fig. 23). (Recent).

Test subglobular, slightly longer than broad; wall with about fifteen rather coarse, longitudinal costae, half of which fuse in alternate pairs to form a smooth collar at the apertural end, the other half extend only to the collar, neck smooth, short; aperture terminal without lip. Length 0.35 mm.; diameter 0.25 mm.

Plesiotypes (Cushman coll. no. 37736) from zone 13 of the Calvert formation, ¼ mile north of Governor Run or Kenwood Beach, Calvert County, Maryland.

This form has often been erroneously recorded in literature as *Lagena sulcata* (Walker and Jacob) or *L. costata* (Williamson), both of which were described from the Recent. The original figure of *L. sulcata* (Walker and Jacob, 1798, in Adam's Essays on the Microscope, Ed. 2, pl. 14, fig. 5.) shows a subglobular test which tapers gradually to a smooth neck. The test is ornamented with at least 20 costae, eleven of which show on the side view figure. The figure of the type specimen of *L. costata* (Williamson, 1858, Recent British Foram., p. 9, pl. 1, fig. 18.) shows a globular test with no neck, which is ornamented by about fourteen costae, seven of which show on the side view figure. In this species the costae extend to the aperture. Reuss designated the species *L. acuticosta* from the Oligocene of Germany, and the figure shows a specimen with a subglobular test with a smooth collar and short neck. The test is ornamented with thirteen costae. Thus it is evident that *L. acuticosta* has definite characters, a collar and a short neck, which distinguish it from *L. sulcata* and *L. costata*.

This species was found in the Calvert formation from zone 3 through zone 13. It does not occur in abundance at any of the localities.

LAGENA CLAVATA (d'Orbigny)

(Plate XXXI, fig. 4)

Oolina clavata d'Orbigny, 1846, Foram. Foss. Bassin Tertiaire, Vienne, p. 24, pl. 1, fig. 2. (Miocene).

Lagena clavata Reuss, 1862, Akad. Wiss. Wien. Math. Naturwiss Kl., Sitzungsber., vol. 46, pt. 1, p. 320, pl. 1, figs. 13, 14. (Recent); Terquem, 1882, Mem. Soc. Geol. France, ser. 3, vol. 2, Mem. 3, p. 25, pl. 1, fig. 2. (Eocene); Egger, 1893, Abhandl. kön. bay. Akad. Wiss., München. Cl. 2, vol. 18, p. 324, pl. X, fig. 68. (Recent); Goës, 1894, Kongl.

Svensk. Vet. Akad. Handl., vol. 25, no. 9, p. 75, pl. 13, figs. 725–727. (Recent); Jones, 1895, Pal. Soc. Mon., pt. 2, p. 182, pl. 7, fig. 5. (Pliocene); Morton, 1897, Portland Soc. Nat. Hist. Proc., vol. 2, p. 116, pl. 1, fig. 2. (Recent); Reade, 1900, Geol. Mag., vol. 7, pl. 5, fig. 13. (Post Glacial); Cushman, 1923, U. S. Nat. Mus., Bull. 104, pt. 4, p. 10, pl. 1, fig. 15. (Recent); Franke, 1925, Abhandl. Ber. Mus. Natur. und Heimatkunde und Nat. Ver., vol. 4, p. 164, pl. 5, fig. 19. (Oligocene); Cushman, 1929, Cushman Lab. Foram. Research Contr., vol. 5, p. 68, pl. 11, fig. 3. (Pliocene); ——, 1930, Florida Geol. Survey, Bull. 4, p. 29, pl. 5, figs. 6a–b. (Miocene); Hada, 1931, Tohoku Imp. Univ. Sci. Rept., ser. 4 (Biol.), vol. 6, p. 103, fig. 57 (in text). (Recent); Cushman and Ponton, 1932, Florida Geol. Survey, Bull. 9, p. 62. (Miocene); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 15, pl. 5, figs. 7a–b. (Miocene); Asano, 1938, Tohoku Imp. Univ. Sci. Rept., ser 2, (Geol.), vol. 19, no. 2, p. 216(38), pl. 27(4), figs. 57, 61; pl. 30(7), fig. 26. (Tertiary); Cushman and LeRoy, 1938, Journ. Pal., vol. 12, no. 2, p. 125, pl. 22, fig. 14. (Miocene); Cushman, 1944, Contr. Cushman Lab. Foram. Res., vol. 20, pt. 1, p. 23, pl. 4, fig. 12. (Eocene); Cushman, 1944, Spec. Publ. No. 12, Cushman Lab. Foram. Res., p. 21, pl. 3, fig. 6. (Recent).

Lagena vulgaris Williamson var. *clavata* Williamson (not d'Orbigny), 1858, Recent British Foram., p. 5, pl. 1, fig. 6. (Recent).

Lagena gracillima Mills (not Seguenza), 1900, Hull Sci. and Field Nat. Club, vol. 1, p. 147, pl. 10, fig. 19. (Recent).

Amphorina elongata Costa (not Seguenza), 1864, Atti. Accad. Pont., vol. 8, pt. 2, p. 122, pl. XI, fig. 12. (Pliocene).

Test elongate, fusiform, tapering gradually to a long, thin neck at the oral end, but rounding to a blunt, spinose projection on the basal end, circular in cross-section; wall smooth, highly polished, transparent; aperture without a phialine lip. Length 0.68 mm.; diameter 0.26 mm.

Plesiotype (Cushman coll. no. 37737) from zone 8 of the Calvert formation, ½ mile south of Randle Cliff Beach.

Lagena clavata was described from the Vienna Basin (Miocene) of Austria. It occurs as fossils throughout the Tertiary and is living today in the North Pacific and Atlantic. In the Maryland Miocene it is a very common species and occurs in all three formations. It is particularly abundant from zone 4 to zone 10 of the Calvert formation.

LAGENA HISPIDA Reuss

(Plate XXXI, figs. 15, 16)

Lagena hispida Reuss, 1862, Akad. Wiss. Wien., Sitzungsber., vol. 46, pt. 1, p. 335, pl. 6, figs. 77–79. (Oligocene); ——, 1870, ibid., vol. 62, pt. 1, p. 468; v. Schlicht, 1870, Foram. Septarien-Thones Pietzpuhl, pl. 3, figs. 26, 27. (Oligocene); Terquem, 1882, Soc. Géol. France, Mém., ser. 3, vol. 2, p. 28, pl. 1(9), fig. 13. (Eocene); H. B. Brady, 1884, Challenger Rept., Zool., vol. 9, p. 459, pl. 57, figs. 1, 2 (not figs. 3, 4). (Recent); Gös, 1894, Kongl. Svensk. Vet.-Akad. Handl., vol. 25, no. 9, p. 74, pl. 13, fig. 723. (Recent); Sidebottom, 1912, Jour. Quekett Micr. Club, vol. 11, p. 385, pl. 15, fig. 2. (Recent); Cushman, 1913, U. S. Nat. Mus., Bull. 71, pt. 3, p. 13, pl. 4, figs. 4, 5; pl. 5, fig. 1. (Recent); ——, 1923, ibid., Bull. 104, pt. 4, p. 26, pl. 4, fig. 7 (not fig. 8). (Recent); Chapman and Parr, 1926, Jour. Linn. Soc. Zool., vol. 36, p. 375, pl. 17, fig. 9. (Tertiary); Cushman, 1929, Cushman Lab. Foram. Research Contr., vol. 5, pt. 3, p. 71, pl. 11, fig. 13. (Pliocene); Cushman and Moyer, 1930, ibid., vol. 6, pt. 3, p. 53, pl. 7, fig. 13. (Recent); Heron-Allen and Earland, 1932, Discovery Repts., vol. 4, p. 364, pl. 10, figs. 7, 8. (Recent); Howe and Wallace, 1932, Louisiana Geol. Bull. 2, p. 28, pl. 6, fig. 13. (Eocene). Jennings, 1936, Bull. Amer. Pal., vol. 23, no. 78, p. 23, pl. 2, fig. 22. (Eocene); Asano, 1938, Science Rep. Tohoku Imp. Univ., ser. 2 (Geol.), vol. 19, no. 2, p. 216 (38), pl. 27(4), fig. 53. (Tertiary); Matthes, 1939, Palaeontographica, vol. 90, pt. A, p. 60, pl. 3, figs. 19, 20.

Test globular with a slender, cylindrical neck at the oral end, basal end rounded, circular in cross-section; wall of globular chamber and neck covered with mediumly coarse, short spines, arranged in rows when viewed from the oral end; aperture small, without a lip. Length 0.57 mm.; diameter 0.38 mm.

Plesiotypes (Cushman coll. no. 37738) from zone 11 of the Calvert formation, south of the mouth of Parker Creek, 1 mile north of Scientists Cliffs.

This species is not abundant and occurs from zone 11 of the Calvert formation through zone 19 of the Choptank formation.

LAGENA LAEVIS (Montagu)

(Plate XXXI, figs. 9, 10)

"*Serpula* (*Lagena*) *laevis ovalis*" Walker and Boys, 1784, Test. Min., p. 3, pl. 1, fig. 9. (Recent).

Vermiculum laeve Montagu, 1803, Test. Britain, p. 524. (Recent).

Lagena laevis Williamson, 1848, Annal. Mag. Nat. Hist., ser. 3, vol. 1, p. 12, pl. 1, figs. 1, 2. (Recent); H. B. Brady, 1884, Challenger Rept., Zool., vol. 9, p. 455, pl. 56, figs. 7–14, ?30. (Recent); Fornasini, 1890, Accad. Sci. Istit. Bologna Mem., ser. 4, vol. 10, p. 6, pl., fig. 1. (Pliocene); Terrigi, 1893, Atti R. Accad. Lincei, ser. 4, Mem. vol. 6, p. 112, pl. 5, fig. 12. (Tertiary); Gös, 1894, Kongl. Svensk. Vet.-Akad. Handl., vol. 25, no. 9, p. 74, pl. 13, figs. 719–722. (Recent); Jones, 1895, Foram. Crag, pt. 2, p. 181, pl. 1, fig. 28. (Pliocene); Flint, 1897, U. S. Nat. Mus. Rept., p. 306, pl. 53, fig. 6. (Recent); Mills, 1900, Trans. Hull Sci. and Field Nat. Club, vol. 1, p. 147, pl. 11, fig. 28. (Recent); Reade, 1900, Geol. Mag., vol. 7, pl. 5, fig. 12 ("Post Glacial"); Bagg, 1912, U. S. Geol. Suvey, Bull. 513, p. 48, pl. 13, figs. 5–8, 10, 11; pl. 14, figs. 23, 24. (Pleistocene-Pliocene); Cushman, 1913, U. S. Nat. Mus., Bull. 71, pt. 3, p. 5, pl. 1, fig. 3; pl. 38, fig. 5 (Recent); Chapman and Parr, 1926, Jour. Linn. Soc. Zool., vol. 36, p. 373, pl. 17, fig. 1. (Miocene); Hada, 1931, Tohoku Imp. Univ. Sci. Rept., ser. 4 (Biol.), vol. 6, p. 102, fig. 56 (in text). (Recent); Cushman, 1933, U. S. Nat. Mus., Bull. 161, pt. 2, p. 19, pl. 4, fig. 5 (Recent); ——, 1935, U. S. Geol. Survey, Prof. Paper 181, p. 22, pl. 9, figs. 3, 4. (Eocene); Howe, 1939, Louisiana Geol. Survey, Bull. no. 14, p. 50, pl. 6, fig. 12. (Eocene); Toulmin, 1941, Journ. Pal., vol. 15, no. 6, p. 593, pl. 80, fig. 7. (Eocene); Cooper, 1944, ibid., vol. 18, no. 4, p. 348, pl. 54, figs. 6, 7. (Paleocene).

Lagena clavata Cole (not d'Orbigny), 1931, Florida Geol. Survey, Bull. 6, p. 28, pl. 6, fig. 6 (Pleistocene-Pliocene).

Lagena perlucida Cushman and McGlamery (not Montagu), 1938, U. S. Geol. Survey, Prof. Paper 189-D, p. 105, pl. 24, fig. 11. (Oligocene).

Test elongate, subpyriform, circular in cross-section, tapering gradually toward the oral end into a slender, cylindrical neck, broadly rounded toward the basal end; wall unornamented, highly polished; aperture without a lip. Length 0.44 mm.; diameter 0.17 mm.

Plesiotypes (Cushman coll. no. 37739) from zone 7 of the Calvert formation, ½ mile south of Randle Cliff Beach.

This species is entirely smooth. Specimens with the same shape but with fine costae on the basal portion have been erroneously referred to it. Such specimens fall in the species *Lagena tenuis* (Bornemann).

Lagena laevis is rare in the Maryland Miocene. However, it occurs sparingly from zone 3 of the Calvert formation to zone 19 of the Choptank formation.

LAGENA TENUIS (Bornemann)

(Plate XXXI, figs. 5, 6)

Ovulina tenuis Bornemann, 1855 (1856), Zeitschr. deutsch. geol. Ges., vol. 7, p. 13, pl. 1, figs. 3a–b, 3*a–b. (Oligocene).

Lagena tenuis Reuss, 1863, Acad. Roy. Sci. Belgium Bull., ser. 2, vol. 15, p. 141, pl. 1, figs. 7, 8, 9 (not 6). (Pliocene); ——, 1870, Akad. Wiss. Wien., Sitzungsber., vol. 62, pt. 1, p. 466; v. Schlicht, 1870, Foram. Septarien-Thones Pietzpuhl, pl. 2, figs. 12–18 (not 21–23); (not pl. 3, figs. 6, 12). (Oligocene); Terquem, 1882, Soc. Géol. France Mém., ser. 2. vol. 2, p. 22, pl. 1(9), fig. 8. (Eocene).

Lagena vulgaris Williamson var. *perlucida* Montagu, Williamson, 1858, Recent British Foram., p. 5, pl. 1, fig. 7 (not 8). (Recent).

Lagena perlucida Schlumberger, 1881, Feuille Jeunes Nat., vol. 12, pl. 1, fig. 2. (Recent); Cushman, 1923, U. S. Nat. Mus., Bull. 104, pt. 4, p. 46, pl. 8, fig. 12 (not fig. 13). (Recent); Cushman and Parker, 1931, U. S. Nat. Mus. Proc., vol. 80, art. 3, p. 8, pl. 3, fig. 6. (Recent); Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 29, pl. 5, fig. 5. (Miocene); ——, 1931, Cushman Lab. Foram. Research Contr., vol. 7, p. 6, pl. 1, fig. 22. (Miocene); ——, 1933, U. S. Nat. Mus., Bull. 161, pt. 2, p. 20, pl. 4, figs. 6–8. (Recent); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 15, pl. 5, figs. 6a–b. (Miocene).

"*Lagena vulgaris* Walk. var. *semistriata* R." Hantken, 1875 (1881), Ungar. Geol. Anst. Jahrb., vol. 4, p. 22, pl. 12, fig. 6. (Eocene).

Lagena semistriata Cushman, 1923, U. S. Geol. Survey, Prof. Paper 133, p. 25, pl. 3, fig. 11. (Oligocene).

Lagena sp. (C) Howe and Wallace, 1932, Louisiana Geol. Bull. 2, p. 31, pl. 6, fig. 6. (Eocene).

The following is a translation of Bornemann's description of *Lagena tenuis* from the Oligocene of Germany:

"Elongate-oval or almost cylindrical, slightly drawn out or abruptly truncate below, contracted into a long pointed neck above. On the base are 5–7 costae placed so as to form a star, part of which continue straight over the sides, while others end at the sides. The remaining part of the test including the neck, is smooth. In many specimens the costae are thicker and longer, in others very short or almost entirely absent. Length: 0.36 to 0.45 mm."

Plesiotypes (Cushman coll. no. 37740) from zone 6 of the Calvert formation, ¼ mile south of Randle Cliff Beach. Length 0.36 mm.; diameter 0.14 mm.

Many records of this species have been referred to *Lagena perlucida* (Montagu). The figure of the type specimen of *Vermiculum perlucidum* (Montagu, 1803, Testacea Britannica, p. 525, pl. 14, fig. 3) or the reproduction by Cushman (1927, Cushman Lab. Foram. Research Contr., vol. 3, pt. 2, p. 123, pl. 24) shows no basal costae. Some authors credit Williamson with the species *L. perlucida*, but this is a mistake since Williamson's reference is *L. vulgaris* Williamson, var. *perlucida* Montagu (1858, Recent British Foram., p. 5, pl. 1, figs. 7, 8.).

This species occurs frequently from zone 3 of the Calvert formation to zone 19 of the Choptank formation.

LAGENA SP. A

(Plate XXXI, figs. 7, 8)

Finely striate specimens of this genus occur frequently in the Maryland material. They show a variation in size and shape of test, size of costae and ornamentation of the neck. It has seemed best to figure them and to make no specific designations.

The specimens referred to *Lagena* sp. *A* have comparatively few costae. Alternating costae continue straight on to the neck, the others extend only to the neck.

Plesiotypes (Cushman coll. no. 37741) from zone 9 of the Calvert formation, ½ mile south of Randle Cliff Beach. Length, 0.37 mm.; diameter 0.14 mm.

LAGENA SP. B.

(Plate XXXI, figs. 13, 14)

There are only two specimens of this form. The test is subglobular, ornamented with coarse costae; the neck is long and slender with a square cross-section, ornamented by closely spaced annular costae.

Plesiotypes (Cushman coll. no. 37742) from zone 11 of the Calvert formation, south of the mouth of Parker Creek, 1 mile north of Scientists Cliffs. Length 0.60 mm.; diameter 0.30 mm.

LAGENA SP. C

(Plate XXXI, figs. 17, 18)

The specimens referred to *Lagena* sp. *C* have a small, globular or subglobular test ornamented with straight costae which continue on the neck as spiral costae.

Plesiotypes (Cushman coll. no. 37743) from zone 13 of the Calvert formation, ¼ mile north of Governor Run or Kenwood Beach. Length 0.32–0.40 mm.; diameter 0.13–0.17 mm.

LAGENA SP. D

(Plate XXXI, figs. 19–23)

This is a very common form in the Maryland material. The test is large and globular, ornamented with numerous, fine striations; the neck is ornamented with narrow costae which wrap about it in the form of closely spaced corkscrew ornamentation. Figures 19–21 are of typical specimens, and figures 22 and 23 of freak specimens with striations forming a labyrinthian pattern on the test.

Plesiotypes (Cushman coll. no. 37744) from zone 8 of the Calvert formation, ¼ mile south of Randle Cliffs. Length 0.42–0.48 mm.; diameter 0.25–0.27 mm.

Plesiotypes (Cushman coll. no. 37745) figures 22 and 23 from zone 14 of the Calvert formation, south of the mouth of Parker Creek, 1 mile north of Scientists Cliffs. Length 0.50 mm.; diameter 0.30 mm.

LAGENA SP. E

(Plate XXXI, fig. 24)

Only one specimen of *Lagena* sp. E was found. It is figured here. The test is large, globular and unornamented.

Plesiotype (Cushman coll. no. 37746) from zone 18 of the Choptank formation, ½ mile south of the mouth of Parker Creek, ½ mile north of Scientists Cliffs. Length 0.50 mm.; diameter 0.28 mm.

Family POLYMORPHINIDAE

Subfamily POLYMORPHININAE

Genus GUTTULINA d'Orbigny 1826

GUTTULINA AUSTRIACA d'Orbigny

(Plate XXXI, figs. 25a–b, 26)

Guttulina austriaca d'Orbigny, 1846, Foram. Foss. Bassin Tertiaire, Vienne, p. 223, pl. 12, figs. 23–25. (Miocene); Terquem, 1882, Soc. Géol. France Mém., ser. 3, vol. 2, p. 133, pl. 13(21), fig. 36. (Eocene); Cushman and Ozawa, 1930, U. S. Nat. Mus. Proc., vol. 77, art. 6, p. 29, pl. 4, figs. 3–5. (Miocene); Howe and Wallace, 1932, Louisiana Geol. Bull. no. 2, p. 47, pl. 8, fig. 3. (Eocene); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 17, pl. 6, figs. 3, 4. (Miocene); Asano, 1938, Japanese Jour. Geol. Geog., vol. 15, nos. 1–2, p. 94, pl. 11, fig. 3. (Pliocene); Howe, 1939, Louisiana Geol. Survey, Bull. no. 14, p. 52, pl. 6, figs. 21, 22. (Eocene); Ellisor, 1940, Bull. Am. Assoc. Petr. Geol., vol. 24, no. 3, pl. 5, fig. 7, 8. (Miocene).

Guttulina lactea Cushman and Ponton, 1932, Florida Geol. Survey, Bull. 9, p. 65, pl. 9, figs. 15a–b. (Miocene).

Pyrulina albatrossi Cushman (not Cushman and Ozawa), 1930, Florida Geol. Survey, Bull. 4, p. 34, pl. 5, figs. 17, 18. (Miocene).

The following description is from Cushman and Ozawa:

"Test fusiform to oblong, more or less rounded at the base, rather acute at the apertural end, often botryoidal, greatest breadth usually above the middle; chambers oval to clavate, slightly embracing; arranged in a clockwise, quinqueloculine series, each succeeding chamber removed much farther from the base; sutures depressed and very distinct; wall smooth, translucent; aperture produced, radiate. Length 0.60–1.15 mm.; breadth 0.40–0.55 mm.; thickness 0.35–0.50 mm."

Plesiotypes (Cushman coll. nos. 37747, 37748) from zone 13 of the Calvert formation, ¼ mile north of Governor Run or Kenwood Beach. Length 0.82–0.90 mm.; breadth 0.40 mm.; thickness 0.30–0.32 mm.

The specimens of this species compare very closely with d'Orbigny's original figure and with the topotype specimens figured by Cushman and Ozawa. This species occurs abundantly in the Calvert formation from zones 9 to 14.

GUTTULINA ELEGANS Dorsey, n. sp.

(Plate XXXII, figs. 4a–b, 5a–b)

Guttulina austriaca Cushman and Ponton (not d'Orbigny), 1932, Florida Geol. Survey, Bull. 9, p. 65, pl. 9, figs. 13, 14. (Miocene); Ellisor, 1940, Bull. Am. Assoc. Petrol. Geologists, vol. 24, no. 3, pl. 5, figs. 7, 8. (Miocene).

Test elongate, greatest breadth below the middle, acute at apertural end, acute at the initial end with a short spine, subcircular to oval in cross-section; chambers clavate, strongly inflated, not embracing, increasing rapidly in size as added, each succeeding chamber added farther from the base; sutures depressed, distinct; wall smooth, highly polished, thick; aperture radiate. Length 0.62–0.80 mm.; breadth 0.35–0.45 mm.; thickness 0.30–0.40 mm.

Holotype (Cushman coll. no. 37751) and paratype (Cushman coll. no. 37752) from zone 11 of the Calvert formation, south of the mouth of Parker Creek, 1 mile north of Scientists Cliffs.

This species is similar to *Guttulina frankei* Cushman and Ozawa but is subcircular rather than subtriangular in cross-section and has its greatest breadth below the middle rather than at the middle or above. It differs from *G. hantkeni* Cushman and Ozawa in its initial spine and greatest breadth below the middle.

This is a distinctive species in the Calvert formation and occurs frequently in zones 9 to 14.

GUTTULINA PROBLEMA d'Orbigny

(Plate XXXI, figs. 27a–b)

Guttulina problema d'Orbigny, 1826, Annales Sci. Nat. Paris, vol. 7, p. 266, no. 14. (Pliocene); ——, 1846, Foram. Foss. Bassin Tertiarie, Vienne, p. 224, pl. 12, figs. 26–28. (Miocene); Cushman and Schenck, 1928, Univ. California Pub., Bull. Dept. Geol. Sci., vol. 17, p. 310, pl. 43, figs. 9–11. (Tertiary); Cushman and Ozawa, 1930, U. S. Nat. Mus. Proc., vol. 77, art. 6, p. 19, pl. 2, figs. 1–6; pl. 3, figs. 1a–c. (Cretaceous, Tertiary); Cushman and Ponton, 1932, Cushman Lab. Foram. Research Contr., vol. 8, pt. 3, p. 61, pl. 8, figs. 3, 4. (Eocene); Cushman, 1935, U. S. Geol. Survey, Prof. Paper 181, p. 23, pl. 9, fig. 12. (Eocene); Cushman and McGlamery, 1938, ibid., 189–D, p. 105, pl. 24, fig. 15. (Oligocene); Cushman, 1940, FORAMINIFERA, *3rd* Ed., pl. 18, fig. 5; Key, pl. 22, fig. 5. (Miocene); Toulmin, 1941, Journ. Pal., vol. 15, no. 6, p. 594, pl. 80, fig. 8. (Eocene); Colom, 1942, Instit. Español Oceanografía, Notas y Resúmenes, ser. 2, no. 108, p. 31, pl. 10, figs. 197, 201. (Recent); Cushman, 1942, Reports of Great Barrier Reef Committee, vol. 5, p. 114, pl. 11, (Recent); Beck, 1943, Journ. Pal. vol. 17, no. 6, p. 602, pl. 106, figs. 11, 17, 20. (Eocene); ——, 1944, Contr. Cushman Lab. Foram. Res., vol. 20, pt. 2, p. 39, pl. 6, figs. 15–17. (Paleocene); LeRoy, 1944, Colorado School Mines Quart., vol. 39, no. 3, pt. 2, p. 83, pl. 2, figs. 21–23. (Miocene); Cushman, 1945, Special Publ. No. 13, Cushman Lab. Foram. Res., p. 14, pl. 2, figs. 3, 4. (Pliocene).

Test about one and one-half times as long as broad, fusiform, greatest breadth near the middle, rounded at the initial end, pointed at the apertural end; chambers elongate, inflated, few, usually four making up the test, arranged in a quinqueloculine series, each succeeding chamber slightly removed from the base; sutures distinct, depressed; wall opaque, smooth; aperture radiate. Length 0.52 mm.; breadth 0.33 mm.; thickness 0.27 mm.

Plesiotype (Cushman coll. no. 37749) from zone 14 of the Calvert formation, south of the mouth of Parker Creek, 1 mile north of Scientists Cliffs.

This species occurs in the Calvert and Choptank formations. It is most abundant in zones 9, 10, and 11 of the Calvert formation.

GUTTULINA PULCHELLA d'Orbigny

(Plate XXXII, figs. 3a–b)

Guttulina pulchella d'Orbigny, 1839, in de la Sagra, Hist. Physique Pol. Nat. Cuba, Foram., p. 129, pl. 2, figs. 4–6. (Recent); Cushman and Ozawa, 1930, U. S. Nat. Mus. Proc., vol. 77, art. 6, p. 33, pl. 5, figs. 7a–c. (Recent); Cole, 1931, Florida Geol. Survey, Bull. 6, p. 29, pl. 4, fig. 12. (Pliocene).

Polymorphina pulchella, H. B. Brady, Parker and Jones, 1870, Trans. Linn. Soc., vol. 27, p. 239, pl. 41, figs. 28a–b. (Recent); Cushman, 1922, Carnegie Inst. Washington, Pub. 311, p. 33, pl. 4, figs. 7, 8. (Recent); ——, 1923, U. S. Nat. Mus., Bull. 104, pt. 4, p. 157, pl. 40, fig. 6. (Recent).

Test elongate, fusiform, pointed at both initial end and apertural end; chambers elongate, mediumly inflated, only slightly overlapping, arranged in a contraclockwise quinqueloculine series, each chamber farther removed from the base; sutures distinct, depressed; wall ornamented with fine, closely spaced, longitudinal costae; aperture radiate. Length 0.87 mm.; breadth 0.32 mm.; thickness 0.25 mm.

Plesiotype (Cushman coll. no. 37750) from zone 10 of the Calvert formation, 1¼ miles south of Old Plum Point Wharf.

This species occurs rarely and was found only in zone 10 of the Calvert formation.

GUTTULINA RECTIORNATA Dorsey, n. sp.

(Plate XXXII, figs. 1a–b, 2a–b)

Guttulina costatula Cushman (not Galloway and Wissler), 1930, Florida Geol. Survey, Bull. 4, p. 33, pl. 5, fig. 15. (Miocene); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 17, pl. 6, fig. 1a–b. (Miocene).

Test comparatively small, slightly compressed, acute at both ends; chambers inflated, circular in cross-section, not much embracing, arranged in a contraclockwise quinqueloculine series, each succeeding chamber removed farther from the base; sutures depressed, distinct; wall ornamented with longitudinal costae which are not continuous from one chamber to another; aperture radiate. Length 0.67–0.72 mm.; breadth 0.28–0.37 mm.; thickness 0.20–0.26 mm.

Holotype (Cushman coll. no. 37753) and paratype (Cushman coll. no. 37754) from zone 9 of the Calvert formation, ¼ mile south of Randle Cliff Beach.

This species differs from *Guttulina costatula* in its fusiform shape and absence of the five strong costae on the initial end; from *G. regina* var. *crassicostata* in finer costae; from *G. spicaeformis* var. *australis* in less inflated chambers and finer costae; from *G. costulata* in shorter chambers, finer costae, and absence of initial spine; from *G. regina* in fewer coarser costae and longer, less inflated chambers.

In Maryland this species occurs in the Calvert formation and is common in zone 9.

Genus GLOBULINA d'Orbigny, 1839

GLOBULINA FIMBRIATA Cushman and McGlamery

(Plate XXXII, figs. 8a–c)

Globulina fimbriata, Cushman and McGlamery, 1938, U. S. Geol. Survey, Prof. Paper 189-D, p. 105, pl. 24, fig. 20. (Oligocene).

Test small, slightly longer than broad, planoconvex; chambers indistinct, four visible on the dorsal side, two on the ventral; sutures indistinct, flush with the surface; wall smooth, perforate; aperture obscure. Length 0.45 mm.; breadth 0.35 mm.; thickness 0.23 mm.

Plesiotype (Cushman coll. no. 37755) from zone 17 of the Choptank formation, immediately north of Calvert Beach.

This species is extremely rare and was found only in zone 17 at one locality, yet it is quite distinctive. The specimens are almost identical with the holotype specimen of *Globulina fimbriata* from the Oligocene of Choctaw Bluff, Alabama.

GLOBULINA INAEQUALIS Reuss

(Plate XXXII, figs. 10a–b)

Globulina inaequalis Reuss, 1850, Akad. Wiss. Wien Math.-Naturwiss. Kl., Denkschr., vol. 1, p. 377, pl. 48, fig. 9. (Miocene); Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 35, pl. 5, fig. 22. (Miocene); Cushman and Ozawa, 1930, U. S. Nat. Mus. Proc., vol. 77, art. 6, p. 73, pl. 18, figs. 2–4. (Tertiary); Cushman and Ponton, 1932, Florida Geol. Survey, Bull. 9, p. 66, pl. 10, figs. 1a–c. (Miocene); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 18, pl. 6, figs. 7, 8. (Miocene); Cushman, 1935, ibid., 181, p. 26, pl. 9, fig. 22. (Eocene); Cushman, 1939, Cushman Lab. Foram. Research Contr., vol. 15, p. 60, pl. 10, fig. 36. (Eocene). Cushman and McGlamery, 1942, U. S. Geol. Survey, Prof. Paper 197-B, p. 68, pl. 4, fig. 33. (Oligocene); Cushman, 1945, Cushman Lab. Foram. Res. Contr., vol. 21, pt. 1, p. 4, pl. 1, fig. 10. (Eocene).

Test broadly ovate, slightly compressed, pointed at the apertural end, broadly rounded at the initial end; chambers few, elongate, strongly overlapping, arranged in an almost triserial series; sutures slightly depressed; wall smooth; aperture radiate. Length 0.47 mm.; breadth 0.42 mm.; thickness 0.30 mm.

Plesiotype (Cushman coll. no. 37756) from zone 17 of the Choptank formation, immediately north of Calvert Beach.

This species was described from the Miocene of Austria. It has been recorded from the Eocene of France, Oligocene of Germany, and the Eocene and Miocene of the Atlantic Coastal Plain. In Maryland it occurs in the Calvert and Choptank formations.

GLOBULINA INAEQUALIS Reuss var. CARIBAEA d'Orbigny

(Plate XXXII, figs. 9a–b)

Globulina caribaea d'Orbigny, 1839, in de la Sagra, Hist. Physique Pol. Nat. Cuba, Foram., p. 130, pl. 2, figs. 7, 8. (Recent); Cole, 1931, Florida Geol. Survey, Bull. 6, p. 30, pl. 7, fig. 12. (Pleistocene, Pliocene); Cushman and Ponton, 1932, Florida Geol. Survey, Bull. 9, p. 66, pl. 10, fig. 2. (Miocene); Cushman, 1944, Special Publ. No. 12, Cushman Lab. Foram Res., p. 22, pl. 3, fig. 20. (Recent).

This variety differs from the typical species by having short, fine spines over the entire test.

Plesiotype (Cushman coll. no. 37757) from zone 10 of the Calvert formation, $1\frac{1}{4}$ miles south of Old Plum Point Wharf. Length 0.34 mm.; breadth 0.30 mm.; thickness 0.22 mm.

It was found only in zones 9 and 10 of the Calvert formation, and there it occurs sparingly.

GLOBULINA MINUTA (Roemer)

(Plate XXXII, figs. 7a–b)

Polymorphina minuta Roemer, 1838, Neues Jahrb. für. Min., etc., p. 386, pl. 3, fig. 35. (Tertiary); Reuss, 1870, Akad. Wiss. Wien., Sitzungsber., vol. 62, pt. 1, p. 486; v. Schlicht, 1870, Foram. Septarien-Thones Pietzpuhl, pl. 27, figs. 13–15; pl. 25, figs. 51–56. (Oligocene); Bornemann, 1855, Deutsch. geol. Gesell, Zeitschr., vol. 7, p. 344, pl. 17, fig. 3. (Oligocene); Reuss, 1850, Akad. Wiss. Wien. Math.-Naturwiss. Kl., Denkschr., vol. 1, p. 377, pl. 48, fig. 8. (Miocene).

Globulina minuta Cushman and Ozawa, 1930, U. S. Nat. Mus. Proc., vol. 77, art. 6, p. 83, pl. 20, figs. 3, 4. (Oligocene); Cushman, 1935, U. S. Geol. Survey, Prof. Paper 181, p. 27, pl. 9, fig. 23. (Eocene); Howe, 1939, Louisiana Geol. Survey, Bull. 14, p. 54, pl. 7, figs. 15, 16. (Eocene).

Test small, fusiform, pointed at both ends, elliptical in cross-section; chambers few, elongate; sutures distinct, slightly depressed; wall smooth; aperture radiate. Length 0.41 mm.; breadth 0.25 mm.; thickness 0.21 mm.

Plesiotype (Cushman coll. no. 37758) from zone 17 of the Choptank formation, immediately north of Calvert Beach.

The specimens of this species are quite small but occur commonly in zone 17 of the Choptank formation.

GLOBULINA ROTUNDATA (Bornemann)

(Plate XXXII, figs. 6a-b)

Guttulina rotundata Bornemann, 1855, Deutsch. geol. Gesell. Zeitschr., vol. 7, p. 346, pl. 18, fig. 3. (Oligocene).
Globulina rotundata Cushman and Ozawa, 1930, U. S. Nat. Mus. Proc., vol. 77, art. 6, p. 86, pl. 21, figs. 3, 4. (Oligocene); Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 35, pl. 5, fig. 16. (Miocene); Howe and Wallace, 1932, Louisiana Geol. Survey, Bull. 2, p. 47, pl. 15, fig. 4. (Eocene); Cushman and Cahill, 1933, U. S.Geol. Survey, Prof. Paper 175-A, p. 18, pl. 6, fig. 9. (Miocene); Cushman, 1935, ibid., 181, p. 27, pl. 9, figs. 24a–c. (Eocene); ?Parr, 1937, Jour. Roy. Soc. W. Australia, vol. 24, p. 80, pl. 2, figs. 2a–b. (Eocene), Cushman, 1944, Contr. Cushman Lab. Foram. Res., vol. 20, pt. 2, p. 40, pl. 6, figs. 20–22. (Paleocene).

Test broadly ovate in side view, rounded at the base, pointed at the apertural end, circular in cross-section; chambers strongly overlapping, increasing rapidly in size as added, circular in cross-section; sutures distinct, flush with surface; wall smooth; aperture radiate. Length 0.46 mm.; diameter 0.30 mm.

Plesiotype (Cushman coll. no. 37759) from zone 12 of the Calvert formation, south of the mouth of Parker Creek, 1 mile north of Scientists Cliffs.

This species occurs quite rarely in the Maryland Miocene and was found only in zone 12 of the Calvert formation.

Genus PYRULINA d'Orbigny, 1839

PYRULINA FUSIFORMIS (Roemer)

(Plate XXXIII, figs. 1a-b)

Polymorphina fusiformis Roemer, 1838, Neues Jahrb. für Min., etc., p. 386, pl. 3, fig. 37. (Tertiary).
Pyrulina fusiformis Cushman and Ozawa, 1930, U. S. Nat. Mus. Proc., vol. 77, art. 6, p. 54, pl., 13 figs. 3–8. (Cretaceous, Tertiary); Parr and Collins, 1937, Roy. Soc. Victoria Proc., vol. 50 (n. ser.), pt. 1, p. 197, pl. 13, figs. 2, 3; pl. 14, figs. 5a–c. (Miocene).

Test fusiform, broadly rounded at the initial end, subacute at the apertural end, subcircular in cross-section; chambers few, comparatively short, arranged in triserial series in the initial end, later becoming uniserial; sutures distinct, slightly depressed in later portion, flush with the surface in early portion; wall smooth, aperture radiate. Length 1.00 mm.; breadth 0.48 mm.; thickness 0.38 mm.

Plesiotype (Cushman coll. no. 37760) from zone 13 of the Calvert formation, ¼ mile north of Governor Run or Kenwood Beach.

The figured specimen is identical with the specimen figured by Cushman and Ozawa (1930) from the Miocene of Austria.

This species is quite uncommon in the Maryland material and was found only in zone 13 of the Calvert formation.

Genus PSEUDOPOLYMORPHINA Cushman and Ozawa, 1928

PSEUDOPOLYMORPHINA DECORA (Reuss)

(Plate XXXIII, figs. 3a–b)

Polymorphina decora Reuss, 1863, Acad. Roy. Sci. Belgique Bull., ser. 2, vol. 15, p. 152, pl. 3, fig. 41. (Pliocene).
Pseudopolymorphina decora Cushman and Ozawa, 1930, U. S. Nat. Mus. Proc., vol. 77, art. 6, p. 96, pl. 24, figs. 6–8. (Miocene); Cushman, 1935, U. S. Geol. Survey, Prof. Paper 181, p. 29, pl. 10, figs. 11, 12. (Eocene); Toulmin, 1941, Journ. Pal., vol. 15, no. 6, p. 595, pl. 80, fig. 14. (Eocene).
Polymorphina texana Cushman and Applin, 1926, Bull. Am. Assoc. Petrol. Geologists, vol. 10, p. 173, pl. 9, figs. 1, 2. (Eocene).

Test elongate, compressed, periphery rounded, sides of adult nearly parallel; chambers elongate, embracing, arranged biserially in later portion; sutures flush with the surface, distinct; wall smooth; aperture radiate. Length 1.12–1.42 mm.; breadth 0.50–0.59 mm.; thickness 0.25–0.30 mm.

Plesiotypes (Cushman coll. no. 37761) from zone 13 of the Calvert formation, ¼ mile north of Governor Run or Kenwood Beach.

This species occurs quite sparingly in zone 13 of the Calvert formation.

PSEUDOPOLYMORPHINA DUMBLEI (Cushman and Applin)

(Plate XXXIII, figs. 2a–b)

Polymorphina compressa d'Orbigny var. *dumblei* Cushman and Applin, 1926, Bull. Am. Assoc. Petrol. Geologists, vol. 10, p. 173, pl. 9, figs. 4, 5. (Eocene).
Pseudopolymorphina dumblei Cushman and Ozawa, 1930, U. S. Nat. Mus. Proc., vol. 77, art. 6, p. 97, pl. 25, figs. 1a–b. (Eocene); Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 35, pl. 6, fig. 5. (Miocene); Cushman and Ponton, 1932, Florida Geol. Survey, Bull. 9, p. 67. (Miocene); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 19, pl. 6, figs. 10a–b. (Miocene); Ellisor, 1933, Bull. Am. Assoc. Petrol. Geologists, vol. 17, no. 11, pl. 7, fig. 2. (Eocene); Cushman, 1935, U. S. Geol. Survey, Prof. Paper 181, p. 29, pl. 10, figs. 14, 15. (Eocene).

Test elongate, compressed, rounded at the initial end, acute at the apertural end; chambers longer than wide, embracing, triserial in arrangement at first, later becoming biserial; sutures slightly depressed, distinct; wall smooth; aperture radiate. Length 0.57 mm.; breadth 0.30 mm.; thickness 0.20 mm.

Plesiotype (Cushman coll. no. 37762) from zone 17 of the Choptank formation, immediately north of Calvert Beach.

In Maryland this species occurs in the Choptank formation.

PSEUDOPOLYMORPHINA JONESI Cushman and Ozawa

(Plate XXXIV, fig. 2)

Pseudopolymorphina jonesi Cushman and Ozawa, 1930, U. S. Nat. Mus. Proc., vol. 77, art. 6, p. 107, pl. 28, figs. 1a–c. (Miocene).
Polymorphina nodosaria Jones, 1896, Foram. Crag, pt. 3, p. 262, pl. 1, figs. 55–58. (Pliocene).
Polymorphina thouini Jones (not d'Orbigny), 1896, Foram. Crag, pt. 3, p. 261, pl. 1, fig. 59. (Pliocene).

Test quite elongate, slightly compressed; chambers numerous, about ten making up the test, slightly longer than wide, arranged triserially at initial end, later becoming uniserial;

sutures distinct, but little depressed; wall smooth; aperture radiate. Length 2.00 mm.; breadth 0.40 mm.; thickness 0.25 mm.

Plesiotype (Cushman coll. no. 37763) from zone 19 of the Choptank formation, 1 mile north of Camp Conoy.

This species was described from the Miocene, Burdigalien, near Bordeaux, France. Only one specimen was found in the Maryland material.

PSEUDOPOLYMORPHINA RUTILA (Cushman)

(Plate XXXIII, figs. 6a–b, 7a–b, 8a–b)
(Plate XXXIV, fig. 1a–b)

Polymorphina regina H. B. Brady, Parker and Jones, var. *rutila* Cushman, 1923, U. S. Geol. Survey, Prof. Paper 133, p. 34, pl. 5, figs. 7, 8. (Oligocene).

Pseudopolymorphina rutila Cushman and Ozawa, 1930, U. S. Nat. Mus. Proc., vol. 77, art. 6, p. 100, pl. 26, figs. 3a–b. (Oligocene); Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 36, pl. 5, fig. 20. (Miocene); Cole, 1931, ibid., Bull. 6, p. 30, pl. 4, fig. 13. (Pliocene); Cushman and Ponton, 1932, ibid., Bull. 9, p. 67. (Miocene); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 19, pl. 6, fig. 11. (Miocene).

Pseudopolymorphina striata Cushman, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 19 (part), pl. 6, figs. 12, 13. (Miocene).

Test elongate, compressed, initial end rounded in megalospheric specimens, acute and occasionally bluntly spined in microspheric specimens; chambers elongate, not much embracing, arranged at first in a quinquloculine series, later becoming biserial; sutures distinct, depressed; wall ornamented with mediumly strong, longitudinal costae; aperture radiate. Length 1.05–1.50 mm.; breadth 0.40–0.60 mm.; thickness 0.20–0.25 mm.

Plesiotypes (Cushman coll. no. 37764) from zone 9 of the Calvert formation, ¼ mile south of Randle Cliffs.

The specimens of this species in the Maryland Miocene vary from the microspheric specimens, which are narrow and almost acutely pointed at the initial end, to the broad, rounded megalospheric specimens. A series of this variation has been figured. This species may be distinguished from *Pseudopolymorphina striata* by stronger costae and usually by a greater breadth in relation to length.

This form occurs only in the Calvert formation but is abundant there from zone 4 to zone 15. It is thus an excellent index fossil for the Calvert formation.

PSEUDOPOLYMORPHINA STRIATA (Bagg)

(Plate XXXIII, figs. 4a–b, 5a–b)

Polymorphina compressa var. *striata* Bagg, 1904, Maryland Geol. Survey, Miocene, p. 476, pl. 133, fig. 2. (Miocene).

Pseudopolymorphina striata Cushman and Ozawa, 1930, U. S. Nat. Mus. Proc., vol. 77, art. 6, p. 92, pl. 23, figs. 5a–c. (Miocene); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 19, pl. 6, figs. 12, 13. (Miocene).

Test elongate, compressed, initial end rounded, apertural end acute; chambers elongate, not much embracing; arranged at first in a quinqueloculine series, later becoming biserial; sutures distinct, slightly depressed; wall ornamented with fine, closely spaced, longitudinal costae which may be absent in last chambers of senile specimens; aperture radiate. Length 1.02–1.85 mm.; breadth 0.40–0.50 mm.; thickness 0.20–0.23 mm.

Plesiotypes (Cushman coll. no. 37765) from zone 17 of the Choptank formation, immediately north of Calvert Beach.

This species was designated by Bagg. His figured specimen was from the Choptank formation, Jones Wharf, Maryland. I find this species throughout the Choptank formation but absent in the Calvert formation below, and the St. Marys formation above. It is easily distinguished from *Pseudopolymorphina rutila* by its finer, more closely spaced costae which are often absent in the last formed chambers.

Genus SIGMOMORPHINA Cushman and Ozawa, 1928

SIGMOMORPHINA NEVIFERA Dorsey, n. sp.

(Plate XXXIV, figs. 6, 7a–b)

Pyrulina albatrossi Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 18, pl. 6, figs. 5a–b. (Mioeene).

Test elongate, compressed, greatest breadth at the middle, apertural end acute, initial end subacute to rounded; chambers elongate, compressed, not much embraeing, arranged in a sigmoid series, each succeeding chamber removed farther from the base; wall rather thick, ornamented with very fine granules giving a frosted appearanee; sutures indistinct, slightly depressed; aperture radiate. Length 0.80–2.00 mm.; breadth 0.40–0.55 mm.; thickness 0.25–0.30 mm.

Holotype (Cushman coll. no. 37766) and paratype (Cushman coll. no. 37767) from zone 17 of the Choptank formation, immediately north of Calvert Beach.

This species is similar to *Sigmomorphina nysti* but is broadest at the middle or below, is rounded at the initial end except in microspherie specimens, and the wall is covered with extremely fine granules giving a frosted appearance.

It occurs only in the Choptank formation and is particularly abundant in zone 17. It is most distinctive because of its granular surface.

Genus SIGMOIDELLA Cushman and Ozawa, 1928

SIGMOIDELLA KAGAENSIS Cushman and Ozawa

(Plate XXXIV, figs. 5a–b)

Sigmoidella kagaensis Cushman and Ozawa, 1928, Cushman Lab. Foram. Research Contr., vol. 4, p. 19, pl. 2, fig. 14. (Pliocene); ——, 1929, Japanese Jour. Geol. and Geog., vol. 6, p. 76, pl. 13, fig. 15; pl. 16, fig. 9; pl. 17, fig. 18. (Pliocene); ——, 1930, U. S. Nat. Mus. Proc., vol. 77, art. 6, p. 141, pl. 39, figs. 2, 5. (Recent); Hada, 1931, Tohoku Imp. Univ. Sei. Rept., ser. 4, Biol., vol. 6, p. 116, fig. 75 (in text). (Recent); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 19, pl. 6, figs. 15a–b. (Miocene); Asano, 1937, Saito Ho-on Kai Mus. Researeh, Bull. 13, p. 115, pl. 16, fig. 1. (Reeent); Parr and Collins, 1937, Roy. Soc. Victoria Proc., vol. 50, (n. ser.), pt. 1, p. 207, pl. 14, fig. 10. (Tertiary, Recent).

The Maryland specimens of this species may be described by the following description from Cushman and Ozawa (1930):

"Test broadly ovate, base very broadly rounded, apertural end somewhat tapering, sides nearly parallel for more than half the length, compressed, periphery subacute; chambers elongate, narrow, five or six times as long as broad, arranged in an open, clockwise sigmoid form, resulting in a test in which, when viewed from either side, one elongate chamber appears at the left and all other visible chambers are in a series of gradually increasing length on its right, and involute; sutures very distinct, eurved, not depressed, exeept on the growing edge, which is depressed; wall smooth, translucent; aperture terminal, radiate."

Plesiotype (Cushman eoll. no. 37768) from zone 10 of the Calvert formation, 1¼ miles south of Old Plum Point Wharf.

This speeies is very rare in the Maryland material and was found only at the above locality in zone 10 of the Calvert formation.

SIGMOIDELLA SP.

(Plate XXXIV, figs. 3a–b, 4a–b)

Polymorphina elegantissima Bagg (not Parker and Jones), 1904, Maryland Geol. Survey, Miocene, p. 476, pl. 133, fig. 3, (Miocene).

There are only a few specimens of this form which may be *Sigmoidella margaretae* described by Cushman and Ozawa (1930) from the Recent off Terao Miura, Japan. More material is necessary before it can be placed in a species. It does not seem likely that the specimens are the young of *S. kagaensis* since the chambers are more inflated and the periphery broadly rounded.

Plesiotypes (Cushman coll. no. 37769) from zone 11 of the Calvert formation, south of the mouth of Parker Creek, 1 mile north of Scientists Cliffs. Length 0.60–0.98 mm.; breadth 0.31–0.50 mm.; thickness 0.20 mm.

Genus POLYMORPHINA d'Orbigny, 1826

POLYMORPHINA ADVENA Cushman var. NUDA Howe and Roberts

(Plate XXXIV, figs. 8a–b)

Polymorphina advena var. *nuda* Howe and Roberts, 1939, Louisiana Geol. Survey, Bull. 14, p. 56, pl. 7, fig. 4. (Eocene).

Only one specimen of this variety was found. It is very small, entirely smooth, and transparent.

Plesiotype (Cushman coll. no. 37770) from zone 11 of the Calvert formation, south of the mouth of Parker Creek, 1 mile north of Scientists Cliffs. Length 0.50 mm.; breadth 0.23 mm.; thickness 0.05 mm.

POLYMORPHINA SCHLUMBERGERI Cushman and Ozawa

(Plate XXXIV, figs. 9a–b)

Polymorphina schlumbergeri Cushman and Ozawa, 1930, U. S. Nat. Mus. Proc., vol. 77, art. 6, p. 121, pl. 31, figs. 8a–b. (Miocene).

Test large, compressed, fusiform, rounded at both ends; chambers few, elongate, biserial in the greater part of the test; wall smooth, polished; sutures slightly depressed, distinct; aperture radiate.

Plesiotype (Cushman coll. no. 37771) from zone 6 of the Calvert formation, $\frac{1}{4}$ mile south of Randle Cliff Beach. Length 1.28 mm.; breadth 0.75 mm.; thickness 0.30 mm.

This species was described from the Miocene, Aquitanian superieur, St. Avit, near Mont de Marsan, France. The specimens in the Maryland material are almost identical with the holotype specimen. It is rare in the Maryland Miocene and was found only in zone 6 of the Calvert formation.

Family NONIONIDAE

Genus NONION Montfort, 1808

NONION ADVENUM (Cushman)

(Plate XXXV, figs. 1a–c)

Nonionina advena Cushman, 1922, U. S. Geol. Survey, Prof. Paper 129 F, p. 139, pl. 32, fig. 8. (Oligocene); ——, 1923, ibid., Prof. Paper 133, p. 50. (Oligocene); Cushman and Applin, 1926, Bull. Am. Assoc. Petrol. Geol., vol. 10, p. 181, pl. 10, figs. 16, 17. (Oligocene).

Nonion advena Howe, 1928, Journ. Pal., vol. 2, p. 175 (list). (Oligocene).
Nonion advenus Cole and Gillespie, 1930, Bull. Am. Pal., vol. 15, no. 57b, p. 132, pl. 2, fig. 15. (Oligocene).
Nonion advenum Cushman, 1935, U. S. Geol. Survey, Prof. Paper 181, p. 30, pl. 11, figs. 1–4. (Eocene); ——, 1939, ibid., Prof. Paper 191, p. 9, pl. 20, figs. 3, 4. (Eocene, Oligocene).

Plesiotype (Cushman coll. no. 37772) from zone 3 of the Calvert formation, ¼ mile north of Captain Collie Hubbard's place, ¾ mile south of Randle Cliffs. Length 0.30 mm.

This species occurs in the lower part of the Calvert formation from zone 3 through zone 8.

NONION GRATELOUPI (d'Orbigny)

(Plate XXXV, figs. 5a–c)

Nonionina grateloupi d'Orbigny, 1826, Annales Sci. Nat. Paris, vol. 7, p. 294, no. 19. (Miocene); ——, 1839, in de la Sagra, Hist. Physique Pol. Nat. Cuba, Foram., p. 46, pl. 6, figs. 6, 7. (Recent); Fornasini, 1904, Accad. sci. Ist. Bologna Mem., ser. 6, vol. 1, p. 12, pl. 3, fig. 5. (Recent); Cushman, 1921, U. S. Nat. Mus. Proc., vol. 59, p. 61, pl. 14, figs. 9–11. (Recent); ——, 1922, Carnegie Inst., Washington, Pub. 311, p. 55, pl. 9, figs. 7, 8. (Recent).
Nonion grateloupi Cushman, 1930, U. S. Nat. Mus., Bull. 104, pt. 7, p. 10, pl. 3, figs. 9–11; pl. 4, figs. 1–4. (Recent); ——, 1930, Florida Geol. Survey, Bull. 4, p. 36, pl. 6, figs. 1–3. (Miocene); Cushman and Valentine, 1930, Stanford Univ., Dept. Geol. Contr., vol. 1, no. 1, p. 20, pl. 5, figs. 9a–b. (Recent); Cushman and Parker, 1931, U. S. Nat. Mus. Proc., vol. 80, art. 3, p. 10, pl. 2, figs. 6a–b. (Recent); Cole, 1931, Florida Geol. Survey, Bull. 6, p. 32, pl. 7, figs. 7, 8. (Pleistocene, Pliocene); Cushman and Ponton, 1932, ibid., Bull. 9, p. 68. (Miocene); Heron-Allen and Earland, 1932, Discovery Repts., vol. 4, p. 437, pl. 16, figs. 9, 10. (Recent); Cushman, 1933, U. S. Nat. Mus., Bull. 161, pt. 2, p. 43, pl. 10, figs. 8a–c. (Recent); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 20, pl. 7, figs. 1a–b. (Miocene); Cushman, 1939, ibid., Prof. Paper 191, p. 21, pl. 6, figs. 1–7. (Miocene, Recent); Cushman and McCulloch, 1940, Allan Hancock Pacific Exped., vol. 6, no. 3, p. 153, pl. 17, fig. 2. (Recent).
Nonionina punctulata d'Orbigny, 1839, Voyage Am. Mérid., vol. 5, p. 28, pl. 5, figs. 21, 22. (Recent).

Plesiotype (Cushman coll. no. 37773) from zone 9 of the Calvert formation, ¼ mile south of Randle Cliffs. Length 0.56 mm.

This species occurs abundantly in the lower part of the Calvert formation.

NONION MEDIO-COSTATUM (Cushman)

(Plate XXXV, figs. 4a–c)

Nonionina medio-costata Cushman, 1926, Cushman Lab. Foram. Research Contr., vol. 1, pt. 4, p. 89, pl. 13, figs. 1a–c; ibid., vol. 2, pt. 3, p. 65.
Nonion medio-costatum Kleinpell, 1938, Bull. Am. Assoc. Petrol. Geol., p. 233, pl. 9, fig. 11. (Miocene); Cushman, 1939, U. S. Geol. Survey, Prof. Paper 191, p. 15, pl. 4, figs. 7, 8. (Miocene); Ellisor, 1940, Bull. Am. Assoc. Petrol. Geol., vol. 24, no. 3, pl. 4, figs. 3a, b. (Miocene); Renz, 1942, Proc. 8th Amer. Sci. Congress, p. 553. (Miocene).

Plesiotype (Cushman coll. no. 37774) from zone 16 of the Choptank formation, north of Calvert Beach. Length 0.60 mm.

This species appears in the upper part of the Calvert formation and occurs throughout the Choptank and St. Marys formations.

NONION PIZARRENSE W. Berry

(Plate XXXV, figs. 6a–c)

Nonion pizarrensis W. Berry, 1928, Jour. Paleontology, vol. 1, p. 269, text fig. I, figs. 1–3. (Recent); Cushman and Kellett, 1929, U. S. Nat. Mus. Proc., vol. 75, art. 25, p. 4, pl. 1,

figs. 10a–b. (Recent); Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 37, pl. 6, figs. 7, 8. (Miocene); Cushman and Ponton, 1932, ibid., Bull. 9, p. 69. (Miocene).
Nonion pizarrense Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 20, pl. 7, figs. 3a–b. (Miocene); Cushman and Kleinpell, 1934, Cushman Lab. Foram. Research Contr., vol. 10, p. 4, pl. 1, figs. 9a–b. (Miocene); Cushman, 1939, U. S. Geol. Survey, Prof. Paper 191, p. 24, pl. 6, fig. 27. (Miocene, Recent).
Nonionina depressula Cushman (not Walker and Jacob), 1918, U. S. Nat. Mus., Bull. 103, p. 72, pl. 25, figs. 5a–b. (Miocene).
Nonionina boueana Cushman (not d'Orbigny), 1918, U. S. Geol. Survey, Bull. 676, p. 68, pl 25, fig. 3. (Miocene).

Plesiotype (Cushman coll. no. 37775) from zone 7 of the Calvert formation, ¼ mile south of Randle Cliffs. Length 0.80 mm.

This is a very common species and occurs in all three formations, Calvert, Choptank and St. Marys. It is particularly abundant in the Calvert formation.

NONION MARYLANDICUM Dorsey, n. sp.

(Plate XXXV, figs. 2a–c)

Test small, closely coiled, planispiral, bilaterally symmetrical, nearly involute, slightly depressed, umbilical area filled with small beads, periphery rounded, sides nearly parallel; chambers few, 7 or 8 making up the adult coil; sutures depressed, distinct, curved; wall smooth except for umbilical area, very finely perforate; aperture a narrow opening at the base of the apertural face. Length 0.38 mm.; thickness 0.20 mm.; breadth 0.33 mm.

Holotype (Cushman coll. no. 37776) from zone 19 of the Choptank formation, north of Camp Conoy.

This species differs from *Nonion granosum* in its depressed sutures, fewer chambers, and finer beading in the umbilical area.

Nonion marylandicum is confined to the Choptank and St. Marys formations in Maryland and can be used as an index species for these formations.

Genus NONIONELLA Cushman, 1926

NONIONELLA AURIS (d'Orbigny)

(Plate XXXV, figs. 3a–c)

Valvulina auris d'Orbigny, 1839, Voyage Am. Mérid., vol. 5, pt. 5, p. 47, pl. 2, figs. 15–17. (Recent).
Nonionina auris Cushman, 1925, Cushman Lab. Foram. Research Contr., vol. 1, pt. 2, p. 44, pl. 7, figs. 3a–c. (Recent).
Nonionella auris Cushman and Kellett, 1929, U. S. Nat. Mus. Proc., vol. 75, art. 25, p. 5, pl. 1, figs. 9a–c; pl. 2, figs. 2, 3. (Recent); Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 38, pl. 7, figs. 1a–c. (Miocene); Heron-Allen and Earland, 1932, Discovery Repts., vol. 4, p. 438, pl. 16, figs. 17, 18. (Recent); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 21, pl. 7, figs. 6a–b. (Miocene); Cushman, 1933, Cushman Lab. Foram. Research, Spec. Pub. no. 4, pl. 19, figs. 2a–c; ——, 1933, U. S. Nat. Mus., Bull. 161, pt. 2, p. 45, pl. 10, fig. 10 (not fig. 11); pl. 11, figs. 1a–c. (Recent); ——, 1936, Geol. Soc. Am. Bull., vol. 47, pl. 5, figs. 1a–c. (Late Tertiary); ——, 1939, U. S. Geol. Survey, Prof. Paper 191, p. 33, pl. 9, fig. 4. (Recent).

Plesiotypes (Cushman coll. no. 37777) from zone 5 of the Calvert formation, ¼ mile south of Randle Cliffs. Length 0.40 mm.

This species ranges throughout the section of the Maryland Miocene. However, it makes up a major part of the assemblage only in zones 3 and 4 of the Calvert formation.

Genus ELPHIDIUM Montfort, 1808

ELPHIDIUM POEYANUM (d'Orbigny)

(Plate XXXV, figs. 7a–c, 8a–b)

Polystomella poeyana d'Orbigny, 1839, in de la Sagra, Hist. Physique Pol. Nat. Cuba, Foram., p. 55, pl. 6, figs. 25, 26. (Recent); Cushman, 1926, Carnegie Inst. Washington, Pub. 344, p. 79. (Recent).

Elphidium poeyanum Cushman, 1930, U. S. Nat. Mus., Bull. 104, pt. 7, p. 25, pl. 10, figs. 4, 5. (Recent); ——, 1930, Florida Geol. Survey, Bull. 4, p. 39, pl. 7, figs. 3, 4. (Miocene); Cole, 1931, ibid., Bull. 6, p. 36. (Pleistocene, Pliocene); Cushman and Parker, 1931, U. S. Nat. Mus. Proc., vol. 80, art. 3, p. 10. (Recent); Cushman and Ponton, 1932, Florida Geol. Survey, Bull. 9, p. 69. (Miocene); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 21, pl. 7, figs. 7a–b. (Miocene); Cushman, 1939, ibid., Prof. Paper 191, p. 54, pl. 14, figs. 25, 26. (Recent); Galloway and Heminway, 1941, New York Acad. Sci., Sci. Surv. Porto Rico and Virgin Ils. vol. 3, pt. 4, p. 363, pl. 14, figs. 6a–b. (Oligocene, Miocene).

Plesiotype (Cushman coll. no. 37778) from zone 22 of the St. Marys formation, Little Cove Point, $1\frac{1}{4}$ miles south of Cove Point. Length 0.53 mm.

Plesiotype (Cushman coll. no. 37779) from zone 23 of the St. Marys formation, Little Cove Point, $1\frac{1}{4}$ miles south of Cove Point. Length 0.80 mm.

This species occurs only in the St. Marys formation.

Family HETEROHELICIDAE

Subfamily EOUVIGERININAE

Genus NODOGENERINA Cushman, 1927

NODOGENERINA ADVENA Cushman and Laiming

(Plate XXXVI, figs. 1a–b)

Nodogenerina advena Cushman and Laiming, 1931, Jour. Paleontology, vol. 5, p. 106, pl. 11, figs. 19a–b. (Miocene); Cushman and Ponton, 1932, Florida Geol. Survey, Bull. 9, p. 75, pl. 11, fig. 10. (Miocene); Barbat and von Estorff, 1933, Jour. Paleontology, vol. 7, no. 2, p. 171, pl. 23, fig. 2. (Miocene). Cushman, 1933, Special Publ. No. 5, Cushman Lab. Foram. Res., pl. 26, figs. 38 a, b; Kleinpell, 1938, Bull. Amer. Assoc. Petrol. Geol., p. 243, pl. 9, fig. 10. (Miocene).

Plesiotype (Cushman coll. no. 37780) from zone 13 of the Calvert formation, $\frac{1}{4}$ mile north of Kenwood Beach or Governor Run. Length 0.75 mm.

This is a rare species in the Maryland material and recorded only in zone 13 of the Calvert formation.

Family BULIMINIDAE

Subfamily TURRILININAE

Genus BULIMINELLA Cushman, 1911

BULIMINELLA ELEGANTISSIMA (d'Orbigny)

(Plate XXXVI, fig. 2)

Bulimina elegantissima d'Orbigny, 1839 (1843), Voyage Am. Merid., vol. 5, pt. 5, p. 51, pl. 7, figs. 13, 14. (Recent); Williamson, 1858, Recent British Foram., p. 64, pl. 5, figs. 134, 135. (Recent); H. B. Brady, 1884, Challenger Rept., Zool., vol. 9, p. 402, pl. 50, figs. 20–22. (Recent); Sidebottom, 1905, Manchester Lit. Philos. Soc. Mem. and Proc., vol. 49, no. 5, p. 11, pl. 2, fig. 6. (Recent).

Buliminella elegantissima Cushman, 1911, U. S. Nat. Mus., Bull. 71, pt. 2, p. 89. (Recent); ——, 1925, Cushman Lab. Foram. Research Contr., vol. 1, pt. 2, p. 40, pl. 6, figs. 5a–b.

(Recent); Cushman and Kellett, 1929, U. S. Nat. Mus. Proc., vol. 75, art. 25, p. 6, pl. 3, figs. 1–3. (Recent); Cushman and Wickenden, 1929, ibid., art. 9, p. 8, pl. 3, figs. 12a–b. (Recent); Wiesner, 1929, Deutsche Süd-Polar Exped., vol. 20, Zool., p. 124, pl. 19, figs. 235, 236. (Recent); Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 42, pl. 8, figs. 2, 3. (Miocene); Cushman, Stewart and Stewart, 1930, San Diego Soc. Nat. History Trans., vol. 6, no. 2, p. 64, pl. 4, figs. 7a–b. (Pliocene); Cushman and Parker, 1931, U. S. Nat. Mus. Proc., vol. 80, art. 3, p. 13, pl. 3, figs. 12, 13. (Recent); Cole, 1931, Florida Geol. Survey, Bull. 6, p. 39, pl. 2, fig. 8. (Pleistocene and Pliocene); Cushman and Ponton, 1932, Cushman Lab. Foram. Research Contr., vol. 8, pt. 3, p. 67, pl. 8, figs. 20, 21. (Eocene); Howe and Wallace, 1932, Louisiana Geol. Bull. 2, p. 61, pl. 11, fig. 3. (Eocene); Cushman, 1933, Cushman Lab. Foram. Research, Spec. Pub. no. 4, pl. 22, fig. 3. (Recent); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 23, pl. 7, figs. 13, 14. (Miocene); Barbat and Johnson, 1934, Jour. Paleontology, vol. 8, p. 12, pl. 1, figs. 12, 13. (Eocene); Kleinpell, 1938, Bull. Amer. Assoc. Petrol. Geol., p. 249, pl. 16, fig. 10. (Miocene); Cushman and Henbest, 1940, U. S. Geol. Survey, Prof. Paper 196-A, pl. 9, fig. 20. (Recent); Hanna and Hertlein, 1941, State of Calif. Div. of Mines, Bull. 118, pt. 2, p. 178, fig. 67 (plate), figs. 5–7. (Pliocene); Cushman, 1944, Special Publ. No. 12, Cushman Lab. Foram. Res., p. 27, pt. 3, figs. 43, 44. (Recent); ——, 1945, Contr. Cushman Lab. Foram. Res., vol. 21, pt. 1, p. 7, pl. 2, fig. 6. (Eocene).

Plesiotype (Cushman coll. no. 37781) from zone 6 of the Calvert formation, ¼ mile south of Randle Cliffs. Length 0.36 mm.

This form occurs throughout the Miocene of Maryland. It is especially common in the lower part of the Calvert formation.

BULIMINELLA CURTA Cushman

(Plate XXXVI, fig. 3)

Buliminella curta Cushman, 1925, Cushman Lab. Foram. Research Contr., vol. 1, pt. 2, p. 33, pl. 5, fig. 13. (Miocene); Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 43, pl. 8, fig. 4. (Miocene); Cushman and Laiming, 1931, Jour. Paleontology, vol. 5, p. 106, pl. 11, fig. 16 (not fig. 15). (Miocene); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 23, pl. 7, fig. 15. (Miocene); Cushman and LeRoy, 1938, Jour. Paleontology, vol. 12, p. 125, pl. 22, figs. 17a–c. (Miocene); Kleinpell, 1938, Bull. Amer. Assoc. Petrol. Geol., p. 248, pl. 7, fig. 3; pl. 15, fig. 4; pl. 16, fig. 8. (Miocene); Ellisor, 1940, Bull. Amer. Assoc. Petrol. Geol., vol. 24, no. 3, pl. 4, fig. 4, pl. 5, fig. 17. (Miocene).
Bulimina elongata Bagg (not d'Orbigny), 1905, U. S. Geol. Survey, Bull. 268, p. 21, pl. 2, fig. 5. (Miocene).

Plesiotype (Cushman coll. no. 37782) from zone 11 of the Calvert formation, south of the mouth of Parker Creek, 1 mile north of Scientists Cliffs. Length 0.45 mm.

This species occurs in the Calvert formation and the lower part of the Choptank formation in zones 3 to 17. It occurs sparingly except in zones 11 and 12 of the Calvert formation where it is found abundantly.

Subfamily BULIMININAE

Genus BULIMINA d'Orbigny, 1826

BULIMINA ELONGATA d'Orbigny

(Plate XXXVI, figs. 5, 6)

Bulimina elongata d'Orbigny, 1846, Foram. Foss. Bassin Tertiaire, Vienne, p. 187, pl. 11, figs. 19, 20. (Miocene); Fornasini, 1901, Accad. sci. Ist. Bologna Mem., ser. 5, vol. 9, p. 373, fig. 5 (in text); Macfadyen, 1930 (1931), Geol. Survey Egypt, p. 54, pl. 1, fig. 17. (Miocene); Cushman and Parker, 1937, Cushman Lab. Foram. Research Contr., vol. 13, p. 49, pl. 7, figs. 1–3. (Miocene); Cushman and Parker, 1938, Cushman Lab. Foram. Research Contr., vol. 14, p. 93, pl. 16, fig. 12. (Recent).
Bulimina inconstans Egger, 1857, Neues Jahrb. für. Min., p. 283, pl. 12, figs. 1–3, 8, 9. (Miocene).

Bulimina scabriuscula Reuss, 1860 (1861), Sitz. k. Akad. Wiss. Wien, Math.-Naturwiss. Kl., vol. 42, p. 360, pl. 2, figs. 13a–b. (Tertiary).
Bulimina gracilis Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 43, pl. 8, figs. 5a–b. (Miocene); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 24, pl. 7, figs. 16a–b. (Miocene); Cushman, 1936, Geol. Soc. America Bull., vol. 47, no. 3, p. 431, pl. 5, figs. 8a–b. (Tertiary).

Plesiotypes (Cushman coll. no. 37783) from zone 13 of the Calvert formation, ¼ mile north of Kenwood Beach or Governor Run. Length 0.70 mm.

Bulimina elongata occurs in all three formations of the Miocene of Maryland. It is found abundantly in zones 3 to 18 of the Calvert and Choptank formations and sparingly in the St. Marys formation.

BULIMINA SP.

(Plate XXXVI, fig. 4)

The Maryland material contains a single specimen that seems to be the same as specimens from the Miocene of Florida referred to *Bulimina inflata* Seguenza and *B. marginata* d'Orbigny. The specific identification of the Maryland specimen is uncertain until more material is available.

Plesiotype (Cushman coll. no. 37784) from zone 13 of the Calvert formation, ¼ mile north of Kenwood Beach or Governor Run. Length 0.45 mm.

Genus ENTOSOLENIA Ehrenberg, 1848

ENTOSOLENIA ORBIGNYANA (Seguenza)

(Plate XXXVI, fig. 10)

Fissurina orbignyana Seguenza, 1862, Descrizione dei Foraminiferi Monotalamici delle Marne Mioceniche del Distretto di Messina, p. 66, pl. 2, figs. 24, 26. (Miocene).
Lagena arbignyana H. B. Brady, 1884, Challenger Rept., Zool. vol. 9, p. 484, pl. 59, figs. 1, 18, 24, 26. (Recent); Jones, 1895, Pal. Soc., Mon., pt. 2, p. 204, pl. 7, figs. 13a–b. (Tertiary); Flint, 1897 (1899), U. S. Nat. Mus. Rept., p. 308, pl. 54, fig. 4. (Recent); Mills, 1900, Trans. Hull Sci. Field Nat. Club, vol. 1, p. 148, pl. 11, fig. 29. (Recent); Chapman, 1909, Subantarctic Ils. New Zealand, art. 15, p. 337, pl. 15, fig. 10. (Recent); Sidebottom, 1913, Jour. Queckett Micr. Club, vol. 12, p. 194, pl. 17, figs. 9–11. (Recent); Chapman, 1926, New Zealand Geol. Survey, Pal. Bull. no. 11, p. 45, pl. X, fig. 8. (Eocene, Miocene); Cushman, 1933, Cushman Lab. Foram. Research Spec. Publ. no. 5, pl. 21, figs. 19a–b. (Cretaceous); Chapman and Parr, 1926, Jour. Linn. Soc. Zool., vol. 36, p. 377, pl. 17, fig. 17. (Tertiary); Cushman, 1934, Bernice P. Bishop Mus., Bull. 119, p. 119, pl. 13, figs. 18, 19. (Pliocene); Earland, 1936, Discovery Repts., vol. 13, p. 49, pl. I, figs. 54, 55, 60, 61. (Recent).
Entosolenia orbignyana Cushman, 1933, Cushman Lab. Foram. Research, Spec. Publ. no. 5, pl. 27, fig. 20. (Recent).

Plesiotype (Cushman coll. no. 37785) from zone 11 of the Calvert formation, 1¼ miles south of Old Plum Point Wharf. Length 0.24 mm.

This species is very rare in the Maryland Miocene. It was found only in zone 11 of the Calvert formation.

ENTOSOLENIA LUCIDA Williamson

(Plate XXXVI, figs. 8a–b)

Entosolenia marginata Montagu var. *lucida* Williamson, 1848, Ann. Mag. Nat. Hist., ser. 2, vol. 2, p. 17, pl. 2, fig. 17. (Recent); ——, 1858, Recent British Foram., p. 10, pl. I, figs. 22, 23. (Recent).
Entosolenia lucida Cushman and Cole, 1930, Cushman Lab. Foram. Research Contr., vol. 6, p. 98, pl. 13, figs. 11, 12, (Pleistocene); Cole, 1931, Florida Geol. Survey, Bull. 6, p. 40, pl. 7, figs. 5, 6. (Pleistocene-Pliocene).

Lagena lucida Balkwill and Millett, 1884, Jour. Micr., vol. 3, p. 12, pl. 2, fig. 7. (Recent); Sidebottom, 1906, Manchester Lit. Philos. Soc. Mem. Proc., no. 5, vol. 50, p. 6, pl. 1, figs. 9–12. (Recent); Chapman, 1910, Jour. Linn. Soc. Zool., vol. 30, p. 409, pl. 54, fig. 8. (Recent); Heron-Allen and Earland, 1911, Jour. Roy. Micr. Soc., p. 318, pl. 10, fig. 16. (Recent); Sidebottom, 1912, Jour. Queckett Micr. Club, vol. 11, p. 401, pl. 17, figs. 12, 13 (not 14). (Recent); ——, 1913, ibid., vol. 12, p. 183, pl. 16, fig. 9. (Recent); Cushman, 1923, U. S. Nat. Mus., Bull. 104, pt. 4, p. 33, pl. 6, figs. 1, 2. (Recent).

Plesiotype (Cushman coll. no. 37786) from zone 17 of the Choptank formation, north of Calvert Beach. Length 0.25 mm.

This species occurs in the Calvert and Choptank formations from zones 3 to 17.

ENTOSOLENIA QUADRATA Williamson

(Plate XXXVI, fig. 9)

Entosolenia marginata Montagu var. *quadrata* Williamson, 1858, Recent British Foram., p. 11, pl. 1, figs. 27, 28. (Recent).
Entosolenia quadrata Moebius, 1880, Foram. von Mauritius, p. 90, pl. 8, fig. 9. (Recent).
Lagena quadrata H. B. Brady, 1884, Challenger Rept., Zool., vol. 9, p. 475, pl. 59, figs. 3, 16; pl. 60, fig. 5. (Recent); Balkwill and Millett, 1884, Jour. Micr., vol. 3, p. 13, pl. 2, fig. 8. (Recent); Egger, 1893, Abhandl. kön. bay. Akad. Wiss., München, Kl. 2, vol. 18, p. 331, pl. X, figs. 78, 79. (Recent); Jones, 1895, Pal. Soc., Mon., pt. 2, p. 198, pl. 7, fig. 9. (Tertiary); Sidebottom, 1906, Manchester Lit. Philos. Soc. Mem. Proc., no. 5, vol. 5, p. 8, pl. 1, figs. 21, 22; pl. 2, figs. 1–3. (Recent); Millett, 1908, Recent Foram. of Galway, p. 6, pl. 2, fig. 8. (Recent); Bagg, 1912, U. S. Geol. Survey, Bull. 513, p. 50, pl. 15, figs. 19a–b, 20. (Pliocene, Pleistocene); Cushman, 1913, U. S. Nat. Mus., Bull. 71, pt. 3, p. 35, pl. 14, fig. 9. (Recent); ——, 1923, ibid., Bull. 104, pt. 4, p. 47, pl. 9, figs. 5, 6. (Recent); Chapman and Parr, 1926, Jour. Linn. Soc. Zool., vol. 36, p. 377, pl. 17, fig. 16. (Miocene); Cushman and Ponton, 1932, Florida Geol. Survey, Bull. 9, p. 64, pl. 12, figs. 17, 18. (Miocene).

Plesiotype (Cushman coll. no. 37787) from zone 11 of the Calvert formation, south of the mouth of Parker Creek, 1 mile north of Scientists Cliffs. Length 0.20 mm.

This species occurs in the Calvert formation and was found only in zones 11 to 14.

Subfamily VIRGULININAE

Genus VIRGULINA d'Orbigny, 1826

VIRGULINA (VIRGULINELLA) MIOCENICA Cushman and Ponton

(Plate XXXVI, fig. 12)

Virgulina miocenica Cushman and Ponton, 1931, Cushman Lab. Foram. Research Contr., vol. 7, pt. 2, p. 32, pl. 4, figs. 14–16. (Miocene).
Virgulina (*Virgulinella*) *miocenica* Cushman, 1932, Cushman Lab. Foram. Research Contr., vol. 8, p. 23, pl. 3, fig. 19. (Miocene); Cushman and Ponton, 1932, Florida Geol. Survey, Bull. 9, p. 81, pl. 12, fig. 9. (Miocene); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 24, pl. 8, figs. 3–6. (Miocene); Cushman, 1933, Cushman Lab. Foram. Research, Spec. Pub. no. 5, pl. 27, fig. 24. (Miocene); Cushman, 1937, Cushman Lab. Foram. Research, Spec. Pub. no. 9, p. 35, pl. 5, figs. 15, 16. (Miocene); Ellisor, 1940, Bull. Amer. Assoc. Petrol. Geologists, vol. 24, no. 3, pl. 5, fig. 15. (Miocene).

Plesiotype (Cushman coll. no. 37788) from zone 4 of the Calvert formation, ¼ mile south of Randle Cliffs. Length 0.98 mm.

This species is quite common throughout the Maryland Miocene, but is most abundant in the Calvert formation. It is an index form for the Miocene since it has been reported only from that period.

VIRGULINA FUSIFORMIS Cushman

(Plate XXXVI, fig. 11)

Virgulina fusiformis Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 45, pl. 8, figs. 8a–b. (Miocene); Cushman and Ponton, 1932, ibid., Bull. 9, p. 79. (Miocene); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 25, pl. 8, figs. 7a–b. (Miocene); Cushman, 1936, Bull. Geol. Soc. Amer., vol. 47, p. 429, pl. 5, figs. 6, 7. (Miocene); Cushman, 1937, Cushman Lab. Foram. Research, Spec. Pub. no. 9, p. 18, pl. 2, fig. 29. (Miocene).

Plesiotype (Cushman coll. no. 37789) from zone 18 of the Choptank formation, ½ mile north of Scientists Cliffs. Length 0.56 mm.

Virgulina fusiformis occurs in zones 10 to 19 of the Calvert and Choptank formations. It is fairly abundant in the upper part of the Calvert formation but is quite inconspicuous in the Choptank.

Genus BOLIVINA d'Orbigny, 1839

BOLIVINA cf. B. MARGINATA Cushman

(Plate XXXVI, figs. 16a-b)

Only one specimen was found. It is marginate with an indication of spines. The latter may be due to broken margins. More material is necessary before a more positive identification can be made.

Plesiotype (Cushman coll. 37790) from zone 14 of the Calvert formation, 1 mile north of Kenwood Beach or Governor Run. Length 0.43 mm.

BOLIVINA CALVERTENSIS Dorsey, n. sp.

(Plate XXXVI, figs. 17a-c)

Test compressed in the early portion, inflated in the later portion, of small size for the genus, periphery rounded; sutures slightly depressed; chambers slightly inflated in later portion, indistinct in early portion; wall mediumly punctate, decorated with closely spaced, longitudinal costae of varying length which cover the test; aperture elongate. Length 0.31 mm.; breadth 0.16 mm.; thickness 0.10 mm.

Holotype (Cushman coll. no. 37791) from zone 13 of the Calvert formation, ¼ mile north of Kenwood Beach or Governor Run.

This species differs from *Bolivina marginata* var. *multicostata* in the absence of peripheral keel, in its smaller size, and more inflated test. The costae cover the chamber outlines and sutures.

Bolivina calvertensis occurs only in the Calvert formation ranging from zone 6 to zone 14. It occurs abundantly only in zone 13.

BOLIVINA FLORIDANA Cushman

(Plate XXXVI, figs. 15a-b)

Bolivina floridana Cushman, 1918, U. S. Geol. Survey, Bull. 676, p. 47, pl. 10, fig. 4. (Miocene); Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 46, pl. 8, figs. 15a–b. (Miocene); Cushman and Parker, 1931, Cushman Lab. Foram. Research Contr., vol. 7, p. 9, pl. 2, fig. 2. (Miocene); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 26, pl. 11, figs. 11a–b. (Miocene); Cushman, 1937, Cushman Lab. Foram. Research, Spec. Pub. no. 9, p. 85, pl. 10, figs. 2, 3. (Miocene); Kleinpell, 1938, Bull. Amer. Assoc. Petrol. Geologists, p. 271, pl. 12, fig. 1. (Miocene); Ellisor, 1940, Bull. Amer. Assoc. Petrol. Geologists, vol. 24, no. 3, pl. 5, fig. 20. (Miocene); Palmer, 1940, Mem. Soc. Cubana Hist. Nat., vol. 14, no. 4, p. 299, pl. 51, figs. 1, 2. (Oligocene); ——, 1941, ibid., vol. 15, no. 3, p. 299, pl. 51, figs. 1, 2; p. 303, pl. 31, fig. 4. (Oligocene).

Bolivina decussata Cushman (not H. B. Brady), 1925, Cushman Lab. Foram. Research Contr., vol. 1, p. 31, pl. 5, figs. 6a–b. (Miocene).

Plesiotype (Cushman coll. no. 37792) from zone 18 of the Choptank formation, ½ mile north of Scientiffs Cliffs. Length 0.51 mm.

This species occurs in the Calvert and Choptank formations but is not a common form.

BOLIVINA PLICATELLA Cushman

(Plate XXXVI, fig. 18)

Bolivina plicatella Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 46, pl. 8, figs, 10a–b. (Miocene); Cushman and Parker, 1931, U. S. Nat. Mus. Proc., vol. 80, art. 3, p. 15, pl. 3, fig. 19. (Recent); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 26, pl. 8, figs. 12a–b (Miocene); Cushman, 1937, Cushman Lab. Foram. Research, Spec. Pub. no. 9, p. 89, pl. 11, figs. 3, 4. (Miocene, Recent).

Plesiotype (Cushman coll. no. 37793) from zone 14 of the Calvert formation, 1 mile north of Kenwood Beach or Governor Run. Length 0.46 mm.

This species occurs from zone 3 of the Calvert formation to zone 18 of the Choptank formation.

BOLIVINA PAULA Cushman and Cahill

(Plate XXXVI, figs. 20a–b)

Bolivina paula Cushman and Cahill, 1932, M. S. in Cushman and Ponton, Florida Geol. Survey, Bull. 9, p. 84, pl. 12, figs. 6a–b. (Miocene); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 26, pl. 8, figs. 14a–b. (Miocene); Cushman, 1937, Cushman Lab. Foram Research, Spec. Pub. no. 9, p. 91, pl. 11, fig. 9. (Miocene); Cushman and McGlamery, 1938, U. S. Geol. Survey, Prof. Paper 189-D, p. 107, pl. 25, figs. 14, 18, 19. (Oligocene).

Plesiotype (Cushman coll. no. 37794) from zone 16 of the Choptank formation, 1 mile north of Kenwood Beach or Governor Run. Length 0.39 mm.

This form occurs in the Calvert, Choptank and St. Marys formations. It is common only in the upper part of the Calvert formation and the middle part of the Choptank formation.

BOLIVINA OBLIQUA Barbat and Johnson

(Plate XXXVI, figs. 19a–b)

Bolivina obliqua Barbat and Johnson, 1934, Jour. Paleontology, vol. 8, p. 15, pl. 1, fig. 20. (Miocene); Cushman, 1937, Cushman Lab. Foram. Res., Special Publ. No. 9, p. 103, pl. 11, fig. 16. (Miocene); Hanna and Hertlein, 1941, State of Calif. Div. of Mines, Bull. 118, pt. 2, p. 180, fig. 67 (plate), figs. 20, 21. (Miocene).

Plesiotype (Cushman coll. no. 37795) from zone 13 of the Calvert formation, ¼ mile north of Kenwood Beach or Governor Run. Length 0.32 mm.

This species occurs rarely in the Calvert and Choptank formations from zone 13 to zone 18.

Subfamily UVIGERININAE

Genus UVIGERINA d'Orbigny, 1826

UVIGERINA AUBERIANA d'Orbigny

(Plate XXXVI, fig. 23)

Uvigerina auberiana d'Orbigny, 1839, in de la Sagra, Hist. Physique Pol. Nat. Cuba, Foram., p. 106, pl. 2, figs. 23, 24. (Recent); Gös, 1894, Kongl. svensk. vet.-akad. Handl., vol. 25, no. 9, p. 52, pl. 9, figs. 494, 495. (Recent); Cushman, 1923, U. S. Nat. Mus., Bull. 104, pt. 4, p. 163, pl. 42, figs. 3, 4. (Recent); Galloway and Wissler, 1927, Journ.

Paleontology, vol. 1, p. 75, pl. 11, fig. 22. (Pliocene); Nuttall, 1928, Quart. Journ. Geol. Soc., vol. 84, p. 94, pl. 6, fig. 16. (Tertiary); Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 49, pl. 9, fig. 7. (Miocene); Cushman and Ponton, 1932, Florida Geol. Survey, Bull. 9, p. 86. (Miocene); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 27, pl. 9, fig. 3. (Miocene); Cushman, 1936, Geol. Soc. Am. Bull., vol. 47, p. 423, pl. 2, figs. 18a, b. (Tertiary); Cushman and Edwards, 1938, Cushman Lab. Foram. Res. Contr., vol. 14, p. 89, pl. 14, fig. 13. (Oligocene); Kleinpell, 1938, Bull. Amer. Assoc. Petrol. Geologists, p. 293, pl. 5, fig. 11. (Miocene); Cushman and Todd, 1941, Cushman Lab. Foram. Res. Contr., vol. 17, p. 44, pl. 13, figs. 4, 5. (Miocene).

Plesiotype (Cushman coll. no. 37796) from zone 5 of the Calvert formation, ¼ mile south of Randle Cliffs. Length 0.40 mm.

This species occurs in the Calvert and Choptank formations.

UVIGERINA CARMELOENSIS Cushman and Kleinpell

(Plate XXXVI, fig. 25)

Uvigerina carmeloensis Cushman and Kleinpell, 1934, Cushman Lab. Foram. Res. Contr., vol. 10, p. 11, pl. 2, figs. 7a, b. (Miocene); Kleinpell, 1938, Bull. Amer. Assoc. Petrol. Geologists, p. 294. (Miocene); Cushman and Todd, 1941, Cushman Lab. Foram. Res. Contr., vol. 17, p. 44, pl. 13, fig. 10. (Miocene).

Plesiotype (Cushman coll. no. 37797) from zone 16 of the Choptank formation, 1 mile north of Kenwood Beach or Governor Run. Length 0.62 mm.

This species was found only in zone 16 of the Choptank formation.

UVIGERINA KERNENSIS Barbat and von Estorff

(Plate XXXVI, fig. 24)

Uvigerina kernensis Barbat and von Estorff, 1933, Journ. Paleontology, vol. 7, p. 172, pl. 23, figs. 13a–c. (Miocene); Kleinpell, 1938, Bull. Amer. Assoc. Petrol. Geologists, p. 296. (Miocene); Cushman and Todd, 1941, Contr. Cushman Lab. Foram. Res., vol. 17, pt. 2, p. 49, pl. 12, figs. 6, 7. (Miocene).

Plesiotype (Cushman coll. no. 37798) from zone 3 of the Calvert formation, ¼ mile north of Captain Collie Hubbard's place, ¾ mile south of Randle Cliffs. Length 0.32 mm.

This species is common in zone 3 of the Calvert formation. It occurs from zone 3 to zone 8.

UVIGERINA SUBPEREGRINA Cushman and Kleinpell

(Plate XXXVI, fig. 22)

Uvigerina subperegrina Cushman and Kleinpell, 1934, Cushman Lab. Foram. Res. Contr., vol. 10, pt. 1, p. 12, pl. 2, figs. 9–11. (Miocene); Kleinpell, 1938, Bull. Am. Assoc. Petrol. Geologists, p. 298. (Miocene); Cushman and Todd, 1941, Cushman Lab. Foram. Res. Contr., vol. 17, pt. 2, p. 52, pl. 14, figs. 19–23. (Miocene).

Plesiotype (Cushman coll. no. 37799) from zone 13 of the Calvert formation, ¼ mile north of Kenwood Beach or Governor Run. Length 0.50 mm.

This species occurs in the upper part of the Calvert formation and the lower part of the Choptank formation. It is abundant only in zone 14 of the Calvert formation.

UVIGERINA DIRECTA Dorsey, n. sp.

(Plate XXXVI, figs. 21a–b)

Uvigerina cf. *pigmea* Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 49, pl. 9, fig. 5. (Miocene).

Test elongate, fusiform, periphery lobulate; chambers inflated; sutures depressed, distinct; wall ornamented with mediumly fine costae which are sometimes absent in the last chamber; apertural end tapering with a completely terminal, elongate, cylindrical neck without lip. Length 0.56 mm., diameter 0.24 mm.

Holotype (Cushman coll. no. 37800) from zone 17 of the Choptank formation, immediately north of Calvert Beach.

This species is similar to *Uvigerina segundoensis* but has a terminal neck and aperture, chambers are more inflated, test fusiform and ornamentation less constant toward the apertural end.

This species occurs in the Choptank and St. Marys formations.

Genus SIPHOGENERINA Schlumberger, 1883

SIPHOGENERINA LAMELLATA Cushman

(Plate XXXVI, figs. 13a-b)

Siphogenerina lamellata Cushman, 1918, U. S. Geol. Survey, Bull. 676, p. 55, pl. 12, fig. 3. (Miocene); ——, 1926, U. S. Nat. Mus. Proc., vol. 67, art. 25, p. 10, pl. 1, fig. 13. (Miocene); ——, 1930, Florida Geol. Survey, Bull. 4, p. 49, pl. 9, fig. 10. (Miocene); Cushman and Ponton, 1932, Florida Geol. Survey, Bull. 9, p. 86, (Miocene); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 23, pl. 9, fig. 4. (Miocene); Cole, 1938, Florida Dept. Conservation, Geol. Bull. no. 16, p. 181 list), pl. 1, fig. 1. (Miocene); Ellisor, 1940, Bull. Am. Assoc. Petrol. Geologists, vol. 24, no. 3, pl. 4, fig. 6. (Miocene).

Plesiotype (Cushman coll. no. 37801) from zone 13 of the Calvert formation, ¼ mile north of Kenwood Beach or Governor Run. Length 1.40 mm.

This species was found only in the Calvert formation.

SIPHOGENERINA SPINOSA (Bagg)

(Plate XXXVI, figs. 14a-b)

Sagrina spinosa Bagg, 1904, Maryland Geol. Survey, Miocene, p. 480, pl. 133, fig. 11. (Miocene).

Siphogenerina spinosa Cushman, 1926, U. S. Nat. Mus. Proc., vol. 67, art. 25, p. 10, pl. 1, fig. 14. (Miocene); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 28, pl. 9, figs. 5, 6. (Miocene).

Plesiotype (Cushman coll. no. 37802) from zone 11 of the Calvert formation, ½ mile north of Scientists Cliffs. Length 1.17 mm.

This species occurs from zone 9 to zone 13 of the Calvert formation.

Family ELLIPSOIDINIDAE

Genus ELLIPSOLAGENA A. Silvestri, 1923

ELLIPSOLAGENA BIDENS Cushman

(Plate XXXVI, figs. 7a-b)

Ellipsolagena bidens Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 50, pl. 9, figs. 11a-b. (Miocene); Cushman and Ponton, 1932, ibid., Bull. 9, p. 87. (Miocene); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 28, pl. 9, figs. 9a-b. (Miocene); Cushman, 1931, Contr. Cushman Lab. Foram. Res., vol. 7, pt. 2, p. 32, pl. 4, fig. 6. (Pliocene).

Plesiotype (Cushman coll. no. 37803) from zone 17 of the Choptank formation, north of Calvert Beach. Length 0.42 mm.

This species occurs throughout the Miocene of Maryland but is most common in the Calvert formation.

Family ROTALIIDAE

Subfamily DISCORBINAE

Genus DISCORBIS Lamarck, 1804

DISCORBIS CANDEIANA (d'Orbigny)

(Plate XXXVII, figs. 4a–c)

Rosalina candeiana d'Orbigny, 1839, in de la Sagra, Hist. Physique Pol. Nat. Cuba, Foram., p. 97, pl. 4, figs. 2–4. (Recent).
Discorbis candeiana Cushman, 1931, U. S. Nat. Mus., Bull. 104, pt. 8, p. 19, pl. 7, figs. 4a–c. (Recent); Cushman and Ponton, 1932, Florida Geol. Survey, Bull. 9, p. 88, pl. 13, figs. 4a–c. (Miocene); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 29, pl. 10, figs. 3a–c. (Miocene).

Plesiotype (Cushman coll. no. 37804) from zone 16 of the Choptank formation, north of Calvert Beach. Length 0.80 mm.

This species occurs in the Choptank and St. Marys formations.

DISCORBIS VALVULATA (d'Orbigny)

(Plate XXXVII, figs. 1a–c)

Rosalina valvulata d'Orbigny, 1826, Annales Sci. Nat. Paris, vol. 7, p. 271, no. 4. (Pliocene); ——, 1839, in Barker, Webb and Berthelot, Hist. Nat. Iles Canaries, vol. 2, Foram., p. 136, pl. 2, figs. 19–21. (Recent); ——, 1839, in de la Sagra, Hist. Physique Pol. Nat. Cuba, Foram., p. 96, pl. 3, figs. 21–23. (Recent).
Discorbis valvulata Cushman, 1921, U. S. Nat. Mus. Proc., vol. 59, pl. 14, figs. 4, 5. (Recent); Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 53, pl. 10, figs. 5a–c. (Miocene); Cushman and Ponton, 1932, ibid., Bull. 9, p. 90. (Miocene); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 30, pl. 10, figs. 2–5. (Miocene).

Plesiotype (Cushman coll. no. 37805) from zone 7 of the Calvert formation, ¼ mile south of Randle Cliffs. Length 0.36 mm.

Discorbis valvulata is quite rare and recorded only from zone 7 of the Calvert formation.

DISCORBIS WARRENI Dorsey, n. sp.

(Plate XXXVII, figs. 5a–c)

? *Discorbis floridana* Cushman (not Cushman 1922), 1932, Florida Geol. Survey, Bull. 9, p. 88, pl. 13, figs. 2a–c. (Miocene); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 29, pl. 9, figs. 12a–c. (Miocene).

Test biconvex, somewhat involute on the dorsal side, almost completely so on the ventral side, periphery acute, keeled, chambers inflated; sutures distinct, depressed, curved; wall with a finely granulate surface giving a frosted appearance; aperture below the plate-like extension of the umbilical end of the chamber. Length 0.75 mm.; breadth 0.60 mm.; thickness 0.22 mm.

Holotype (Cushman coll. no. 37806) from zone 17 of the Choptank formation, immediately north of Calvert Beach.

This species is similar to *Discorbis floridana* but is much larger, is keeled at the periphery, and has a granular, frosted ornamentation.

This is a very distinctive species in the Choptank formation and occurs abundantly in zones 16 and 17.

DISCORBIS CAVERNATA Dorsey, n. sp.

(Plate XXXVII, figs. 2a–c)

Test planoconvex, involute on dorsal side, irregularly excavated on ventral side giving a cavernate appearance, circular in outline, periphery subacute; chambers distinct on ventral side, increasing rapidly in size; sutures distinct, slightly depressed; wall punctate with a chitinous inner shell lending brownish color; aperture below the plate-like extension of the umbilical end of the chamber. Length 0.45 mm.; breadth 0.40 mm.; thickness 0.20 mm.

Holotype (Cushman coll. no. 37807) from zone 7 of the Calvert formation, $\frac{1}{4}$ mile south of Randle Cliffs.

This species resembles *Discorbis alveata* but differs in its rounded dorsal outline and more irregular umbilical cavity. It differs from *D. choctawensis* in finer punctae, depressed sutures, and deeper umbilical cavity.

Discorbis cavernata occurs abundantly in the Calvert formation of the Maryland Miocene.

DISCORBIS SP.

(Plate XXXVII, figs. 3a–c)

Plesiotype (Cushman coll. no. 37809) from zone 24 of the St. Marys formation, south of Chancellor Point on the east side of the St. Marys River. Length 0.48 mm.

Genus VALVULINERIA Cushman, 1926

VALVULINERIA FLORIDANA Cushman

(Plate XXXVII, figs. 6a–c)

Valvulineria floridana Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 54, pl. 10, figs. 6a–c. (Miocene); Cushman and Ponton, 1932, ibid., Bull. 9, p. 91. (Miocene); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 30, pl. 10, figs. 7a–c. (Miocene).

Plesiotype (Cushman coll. no. 37810) from zone 18 of the Choptank formation, $\frac{1}{2}$ mile north of Scientists Cliffs. Length 0.68 mm.

This species occurs abundantly throughout the Calvert formation and is entirely missing in the Choptank and St. Marys formations.

Subfamily ROTALIINAE

Genus EPONIDES Montfort, 1808

EPONIDES MANSFIELDI Cushman

(Plate XXXVII, figs. 7a–c)

Eponides mansfieldi Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 54, pl. 11, figs. 1a–c. (Miocene); Cushman and Parker, 1931, Cushman Lab. Foram. Research Contr., vol. 7, p. 12, pl. 2, figs. 10a–c. (Miocene); Cushman and Ponton, 1932, Florida Geol. Survey, Bull. 9, p. 92. (Miocene); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 31, pl. 10, figs. 8a–c. (Miocene).

Plesiotype (Cushman coll. no. 37811) from zone 23 of the St. Marys formation, from Little Cove Point, $1\frac{1}{4}$ miles south of Cove Point. Length 0.62 mm.

This species is absent in the Calvert formation but appears in zone 16, the first zone of the Choptank formation. It can be used as an index species for the Choptank and St. Marys formations as it is a common species in both.

Genus ROTALIA Lamarck, 1804

ROTALIA BASSLERI Cushman and Cahill

(Plate XXXVII, figs. 8a–c)

Rotalia bassleri Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 30, pl. 10, figs. 7a–c. (Miocene).

Plesiotype (Cushman coll. no. 37812) from zone 8 of the Calvert formation, ¼ mile south of Randle Cliffs. Length 0.45 mm.

Rotalia bassleri does not occur abundantly in any zone. It is present in all three formations from zone 5 to zone 23.

ROTALIA BECCARII Linnaeus var. TEPIDA Cushman

(Plate XXXVII, figs. 9a–c)

Rotalia beccarii Linnaeus var. *tepida* Cushman, 1926, Carnegie Instit. Washington, Publ. 344, p. 79. (Recent); Kornfield, 1931, Contr. Dept. Geol. Stanford Univ., vol. 1, no. 3, p. 91, pl. 13, figs. 3a–c (Recent); Cushman, 1931, U. S. Nat. Mus., Bull. 104, pt. 8, p. 61, pl. 13, figs. 3a–c. (Recent); Cole, 1931, Florida State Geol. Survey, Bull. 6, p. 50, pl. 3, figs. 3, 4. (Pleistocene, Pliocene); Stephenson, 1935, Dept. Conservation, Louisiana Geol. Survey, Bull. 6, p. 189, pl. 5, figs. 20–22 (Miocene); Hadley, 1936, Jour. Elisha Mitchell Sci. Soc., vol. 52, no. 1, p. 36. (Recent); Le Roy, 1939, Nat. Tijdschr. Nederl.-Indie, vol. 99, pt. 6, p. 256, pl. 2, figs. 1–3. (Miocene); Hanna and Hertlein, 1941, State of California, Div. of Mines, Bull. 118, pt. 2, p. 180, fig. 67 (plate), figs. 11–13. (Pliocene); Le Roy, 1941, Colorado School of Mines Quart., vol. 36, no. 1, pt. 3, p. 117, pl. 2, figs. 25–27. (Pliocene); Palmer, 1945, Bull. Amer. Pal., vol. 29, no. 115, p. 60. (Miocene).

Plesiotype (Cushman coll. no. 37813) from zone 11 of the Calvert formation, south of the mouth of Parker Creek, 1 mile north of Scientists Cliffs. Length 0.47 mm.

This variety occurs rarely from zone 11 of the Calvert formation to zone 24 of the St. Marys formation.

Subfamily BAGGININAE

Genus CANCRIS Montfort, 1808

CANCRIS SAGRA (d'Orbigny) var. COMMUNIS Cushman and Todd

(Plate XXXVII, figs. 10a–c)

Cancris sagra (d'Orbigny) var. *communis* Cushman and Todd, 1942, Cushman Lab. Foram. Res. Contr., vol. 18, pt. 4, p. 79, pl. 19, figs. 8–11; pl. 20, fig. 1. (Miocene, Recent); LeRoy, 1944, Colorado School Mines Quart., vol. 39, no. 3, pt. 1, p. 36, pl. 3, figs. 10–12. (Miocene).

Plesiotype (Cushman coll. no. 37814) from zone 17 of the Choptank formation, ¼ mile north of Kenwood Beach or Governor Run. Length 0.80 mm.

This variety occurs rarely in zones 9 to 13 of the Calvert formation.

Family CASSIDULINIDAE

Subfamily CASSIDULININAE

Genus CASSIDULINA d'Orbigny, 1826

CASSIDULINA CRASSA d'Orbigny

(Plate XXXVIII, figs. 2a–c)

Cassidulina crassa d'Orbigny, 1839 (1843), Voyage Am. Merid., vol. 5, pt. 5, p. 56, pl. 7, figs. 18–20. (Recent); ——, 1846, Foram. Foss. Bassin Tertiaire, Vienne, p. 213, pl. 21, figs. 42, 43. (Miocene); H. B. Brady, 1884, Challenger Rept., Zool., vol. 9, p. 429, pl. 54, figs. 4, 5. (Recent); Egger, 1893, Abhandl. k. bay. Akad. Wiss. Munchen, Kl. II, vol. 18, p. 303, pl. 7, figs. 35, 36. (Recent); Silvestri, 1896, Pont. Accad. Nuovi Lincei Mem., vol. 12, p. 104, pl. 2, figs. 11, 12. (Pliocene); Morton, 1897, Portland Soc. Nat. Hist. Proc., vol. 2, p. 116, pl. 1, fig. 12. (Pleistocene); Flint, 1897 (1899), U. S. Nat. Mus. Rept., p. 292, pl. 38, fig. 3. (Recent); Cushman, 1911, U. S. Nat. Mus., Bull. 71, pt. 2, p. 97, fig. 151. (Recent); Bagg, 1912, U. S. Geol. Survey, Bull. 513, p. 43, pl. 12, figs. 6a–c. (Pliocene, Pleistocene); Cushman, 1922, U. S. Nat. Mus., Bull. 104, pt. 3, p. 124, pl. 26, fig. 7. (Recent); Cushman, 1926, Cushman Lab. Foram. Research Contr., vol. 2, pt. 3, p. 56, pl. 7, figs. 4a–b. (Miocene); ——, 1929, ibid., vol. 5, pt. 4, p. 100, pl. 14, figs. 10a–b. (Miocene); Cushman and Wickenden, 1929, U. S. Nat. Mus. Proc., vol. 75, art. 9, p. 12, pl. 5, figs. 5a–c. (Recent); Wiesner, 1929, Deutsche Süd-Polar Exped., vol. 20, Zool., p. 131, pl. 21, fig. 259. (Recent); Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 58, pl. 11, figs. 6a–b. (Miocene); Cushman and Parker, 1931, U. S. Nat. Mus. Proc., vol. 80, art. 3, p. 21, pl. 4, figs. 6a–b. (Recent); Cole, 1931, Florida Geol. Survey, Bull. 6, p. 54, pl. 7, fig. 2. (Pleistocene, Pliocene); Macfadyen, 1932, Geol. Mag., vol. 69, pl. 34, figs. 6a–b. (Pleistocene, Pliocene); Heron-Allen and Earland, 1932, Discovery Repts., vol. 4, p. 357, pl. 9, figs. 26–33. (Recent); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 33, pl. 12, figs. 2a–c. (Miocene); Cushman, 1936, Geol. Soc. Am. Bull., vol. 47, p. 434, pl. 5, figs. 12a–b. (Late Tertiary); Cushman and McGlamery, 1938, U. S. Geol. Survey, Prof. Paper 189-D, p. 111, pl. 28, figs. 4a–c. (Oligocene); Kleinpell, 1938, Miocene Stratigraphy of California, p. 331, pl. 12, figs. 8a, b. (Miocene); Cushman, 1941, Cushman Lab. Foram. Research Contr., vol. 17, p. 37, pl. 9, figs. 23, 24. (Pleistocene, Pliocene).

Plesiotype (Cushman coll. no. 37815) from zone 11 of the Calvert formation, south of the mouth of Parker Creek, 1 mile north of Scientists Cliffs. Length 0.23 mm.

This species occurs in zones 11 to 13 of the Calvert formation.

CASSIDULINA LAEVIGATA d'Orbigny var.

(Plate XXXVIII, figs. 1a–c)

Plesiotype (Cushman coll. no. 37816) from zone 13 of the Calvert formation, ¼ mile north of Kenwood Beach or Governor Run. Length 0.42 mm.

A single specimen which is probably a variety of *Cassidulina laevigata* was found in zone 24 of the St. Marys formation.

Family GLOBIGERINIDAE

Subfamily GLOBIGERININAE

Genus GLOBIGERINA d'Orbigny, 1826

GLOBIGERINA ALTISPIRA Cushman and Jarvis

(Plate XXXVIII, figs. 3a–c)

Globigerina altispira Cushman and Jarvis, 1936, Cushman Lab. Foram. Research Contr., vol. 12, p. 5, pl. 1, figs. 13, 14. (Miocene); Coryell and Rivero, 1940, Jour. Paleontology, vol. 14, p. 339, pl. 42, fig. 31. (Miocene).

Plesiotype (Cushman coll. no. 37817) from zone 11 of the Calvert formation, 1¼ miles south of Old Plum Point Wharf. Length 0.43 mm.

This species occurs in the Calvert and Choptank formations from zone 10 to zone 16.

GLOBIGERINA SP.

(Plate XXXVIII, figs. 4a–b)

Plesiotype (Cushman coll. no. 37818) from zone 11 of the Calvert formation, 1¼ miles north of old Plum Point Wharf. Length 0.80 mm.

This species of *Globigerina* occurs throughout the Maryland Miocene.

Genus GLOBIGERINOIDES Cushman, 1927

GLOBIGERINOIDES SP. A

(Plate XXXVIII, figs. 5, 6, 7)

Plesiotypes (Cushman coll. no. 37820) from zone 11 of the Calvert formation, 1¼ miles south of Old Plum Point Wharf. Length 0.38 mm.

This species occurs from zone 6 to zone 24 in the Calvert, Choptank and St. Marys formations.

GLOBIGERINOIDES SP. B

(Plate XXXVIII, figs. 8, 9)

Plesiotypes (Cushman coll. no. 46855) from zone 11 of the Calvert formation, 1¼ miles south of Old Plum Point Wharf. Length 0.35 mm.

This is a rare species recorded only in zones 10 and 11 of the Calvert formation.

Subfamily CANDEININAE

Genus CANDORBULINA Jedlitschka, 1933

CANDORBULINA UNIVERSA Jedlitschka

(Plate XXXVIII, fig. 10)

Candorbulina universa Jedlitschka, 1934, (1933) Verhandl. Nat. Ver. Brunn, 65, p. 21, text figs. 1–7, 19, 21–23. (Miocene); ——, 1934 (1935), ibid., p. 8. (Miocene); Cushman and Dorsey, 1940, Cushman Lab. Foram. Research Contr., vol. 16, pt. 2, p. 41, pl. 8, figs. 1–7. (Miocene).

Plesiotype (Cushman coll. no. 46856) from zone 17 of the Choptank formation, north of Calvert Beach. Diameter 0.45 mm.

This is a very rare species in the Maryland Miocene. Single specimens were found in zones 11, 12 and 17 in the Calvert and Choptank formations.

Family ANOMALINIDAE

Subfamily CIBICIDINAE

Genus CIBICIDES Montfort, 1808

CIBICIDES AMERICANUS (Cushman)

(Plate XXXIX, figs. 4a–c)

Truncatulina americana Cushman, 1918, U. S. Geol. Survey, Bull. 676, p. 63, pl. 20, figs. 2, 3; pl. 21, fig. 1. (Miocene); ——, 1918, U. S. Nat. Mus., Bull. 103, p. 68, pl. 23, figs. 2a–c. (Oligocene); ——, 1920, U. S. Geol. Survey, Prof. Paper 128-B, p. 70, pl. 11, figs. 10, 11. (Miocene); ——, 1922, ibid., Prof. Paper 129-E, p. 97, pl. 20, figs. 7, 8. (Oligocene).
Cibicides americana Cushman, 1930, Florida Geol. Survey, Bull. 4, p. 61, pl. 12, figs. 5a–c. (Miocene); Nuttall, 1932, Jour. Paleontology, vol. 6, p. 32, pl. 7, figs. 10, 11. (Oligocene).
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Geol. Survey, Prof. Paper 197-B, p. 75, pl. 7, figs. 8–10 (Oligocene); Franklin, 1944, Journ. Pal., vol. 18, no. 14, p. 319, pl. 48, fig. 13. (Oligocene).

Plesiotype (Cushman coll. no. 46857) from zone 7 of the Calvert formation, ¼ mile south of Randle Cliffs. Length 0.35 mm.

This is not a common species and is recorded only from zones 5 to 10 of the Calvert formation.

CIBICIDES CONCENTRICUS (Cushman)

(Plate XXXIX, figs. 1a–c, 2a–c)

Truncatulina concentrica Cushman, 1918, U. S. Geol. Survey, Bull. 676, p. 64, pl. 21, fig. 3. (Miocene).
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Plesiotypes (Cushman coll. no. 46858, 46859) from zone 11 of the Calvert formation, ½ mile north of Scientists Cliffs. Length 0.54 mm.

This species is quite common in the Calvert formation and also occurs rarely in the Choptank and St. Marys formations.

CIBICIDES LOBATULUS (Walker and Jacob)

(Plate XXXIX, figs. 5a–c)

Nautilus lobatulus Walker and Jacob, 1798, Adam's Essays, Kanmacher's ed., p. 642, pl. 14, fig. 36. (Recent).
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Plesiotype (Cushman coll. no. 46860) from zone 17 of the Choptank formation, north of Calvert Beach. Length 0.60 mm.

This species is very common in the Calvert, Choptank and St. Marys formations from zone 5 to zone 23.

CIBICIDES SP.

(Plate XXXIX, figs. 3a–c)

Plesiotype (Cushman coll. no. 46861) from zone 13 of the Calvert formation, ¼ mile north of Kenwood Beach or Governor Run. Length 0.60 mm.

Genus DYOCIBICIDES Cushman and Valentine, 1930

DYOCIBICIDES BISERIALIS Cushman and Valentine

(Plate XXXIX, figs. 6a–b, 7a–b)

Dyocibicides biserialis Cushman and Valentine, 1930, Stanford Univ., Dept. Geol. Contr., vol. 1, p. 31, pl. 10, figs. 1, 2. (Recent); Cushman, 1930, Cushman Lab. Foram. Research Contr., vol. 6, pt. 4, pl. 12, fig. 12. (Recent); ——, 1930, ibid., Spec. Publ. no. 2, pl. 3, fig. 12. (Recent); ——, 1930, Florida Geol. Survey, Bull. 4, p. 62, pl. 12, figs. 6a–b. (Miocene); ——, 1931, U. S. Nat. Mus., Bull. 104, p. 126, pl. 24, fig. 2. (Recent); Cushman and Parker, 1931, U. S. Nat. Mus. Proc., vol. 80, art. 3, p. 22, pl. 4, fig. 8. (Recent); Cole, 1931, Florida Geol. Survey, Bull. 6, p. 57, pl. 5, figs. 11, 12. (Pliocene); Cushman, 1933, Cushman Lab. Foram. Research, Spec. Pub. no. 4, pl. 28, fig. 7. (Recent); ——, 1933, ibid., Spec. Pub. no. 5, pl. 36, fig. 12. (Recent); Cushman and Cahill, 1933, U. S. Geol. Survey, Prof. Paper 175-A, p. 35, pl. 13, figs. 5a–c. (Miocene); Chapman, Parr and Collins, 1934, Linn. Soc. Jour. Zool., vol. 38, no. 262, p. 572, pl. 11, figs. 43a–c. (Miocene).

Plesiotype (Cushman coll. no. 46862) from zones 22 and 23 of the St. Marys formation, at Little Cove Point, 1¼ miles south of Cove Point. Length 0.85 mm.

Plesiotype (Cushman coll. no. 46863) from zone 19 of the Choptank formation, north of Camp Conoy, 2½ miles south of Flag Pond. Length 1.00 mm.

This species is common in the Choptank and St. Marys formations.

Genus CIBICIDELLA Cushman, 1927

CIBICIDELLA VARIABILIS (d'Orbigny)

(Plate XXXIX, figs. 8a–b)

Truncatulina variabilis d'Orbigny, 1839, in Barker, Webb and Berthelot, Hist. Nat. Iles Canaries, vol. 2, pt. 2, Foram., p. 135, pl. 2, fig. 29. (Recent); Cushman, 1931, U. S. Nat. Mus., Bull. 104, pt. 8, p. 127, pl. 24, fig. 3. (Recent).

Cibicidella variabilis Cushman and Ponton, 1932, Florida Geol. Survey, Bull. 9, p. 102, pl. 15, figs. 5–7. (Miocene); Galloway and Heminway, 1941, New York Acad. Sci., Sci. Surv. Porto Rico and Virgin Ils., vol. 3, pt. 4, p. 401, pl. 24, figs. 1a–c. (Oligocene); Cushman and McGlamery, 1938, U. S. Geol. Survey, Prof. Paper 189-D, p. 112, pl. 28, fig. 7, (Oligocene).

Plesiotype (Cushman coll. no. 37819) from zone 19 of the Choptank formation, north of Camp Conoy, 2½ miles south of Flag Pond. Length 1.00 mm.

This species occurs in the Choptank formation.

CONCLUSIONS

The results of this study are: first, an increase in knowledge of Miocene foraminifera from Maryland. Of the one hundred and fifteen species treated, fifty are recorded from Maryland for the first time, and twelve of the species are new.

Second, the occurrence chart shows a new method of representing frequencies and stratigraphic range of foraminifera (Fig. 28). The numerical method, as described earlier in the paper, makes it possible to read from the chart the percentage of individuals of a particular species in any given zone. This information should prove of value to future workers studying foraminifera numerically. Another feature of the chart is the arrangement of species in stratigraphic sequence, so that earlier species appear at the top of the chart, and successively later ones toward the bottom. This enables one to see at a glance the relative times of appearance of the different species.

Third, the synonymies accompanying the descriptions of the species are as complete as possible up to the date of writing. They contain references to both domestic and foreign literature, as catalogued in the Cushman Laboratory. Each reference was examined, and only those containing figures are listed. The synonymies collectively make a complete bibliography of all pertinent and useful works treating of the one hundred and fifteen species considered.

Fourth, the bibliography that follows is a compilation and summary of all literature on Miocene foraminifera, whatever their geographic occurrence.

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DESCRIPTION OF PLATES

PLATE I

Miocene fossils, figures 1–27

Figure

1. *Nucula sinaria* Dall; depth 330–340 feet. Exterior of left valve, × 5.
2, 3. *Mactra clathrodon* Lea; depth 370–380 feet.
2. Exterior of right valve, × 6.
3. Interior of right valve shown in figure 2, × 6.
4. *Nucula sinaria* Dall. Interior of left valve shown in figure 1, × 5.
5. *Nuculana concentrica* (Say)?; depth 390–400 feet. Exterior of right valve, × 4.
6. *Chlamys* (*Lyropecten*) sp. cf. *C.* (*L.*) *madisonia* (Say); depth 590–600 feet. Fragment of ribs, × 4.
7. *Chlamys* (*Lyropecten*) sp. cf. *C.* (*L.*) *madisonia* (Say); depth 710–720 feet. Fragment of rib, × 3.
8. *Chlamys* (*Lyropecten*) *madisonia* (Say)?; depth 590–600 feet. Incomplete juvenile right valve, × 4.
9. *Anomia aculeata* Gmelin?; depth 590–600 feet. Incomplete left valve, × 6.
10. *Nuculana concentrica* (Say)?; depth 390–400 feet. Dorsal view of double valves of which the right is pictured in figure 5, × 4.
11. *Dentalium caduloide* Dall; depth 390–400 feet. Longitudinal view, × 4.
12. *Chlamys* (*Lyropecten*) *madisonia* (Say)?; depth 710–720 feet. Fragment of rib, × 3.
13. *Cymatosyrinx limatula* (Conrad); depth 410–420 feet. Apertural view, × 3.
14. *Anomia aculeata* Gmelin?; depth 590–600 feet. Exterior of left valve, × 6.
15. *Parvilucina prunus* Dall?; depth 650–660 feet. Exterior of right valve, × 8.
16. *Terebra simplex* Conrad; depth 420–430 feet. Apertural view, × 2.
17. *Bulliopsis quadrata* (Conrad); depth 430–440 feet. Side view, × 2.
18, 19. *Turbonilla* (*Pyrgiscus*) sp.; depth 420–430 feet.
18. Apertural view, × 6.
19. Rear view, × 6.
20, 21. *Acteon* sp. cf. *A. pusillus* Forbes; depth 500–510 feet.
20. Rear view, × 2.
21. Apertural view, × 2.
22. *Turritella* sp. cf. *T. variabilis* Conrad; depth 420–430 feet. Rear view of incomplete specimen, × 3.
23, 24. *Terebra curvilirata* Conrad; depth 420–430 feet.
23. Apertural view, × 3.
24. Rear view, × 3.
25, 26. *Ucita peralta* (Conrad); depth 330–340 feet.
25. Apertural view, × 2.
26. Rear view, × 2.
27. *Bulliopsis quadrata* (Conrad); depth 410–420 feet. Apertural view, × 2.

Cretaceous fossils (*Navesink marl*), *figures 28–35*

28. *Pecten venustus* Morton; depth 1362 feet. Exterior of right valve, × 2.
29, 30. *Paranomia scabra* Morton; depth 1380 feet. Interior and exterior views of an incomplete right valve, × 1.

31. *Pecten* sp.; depth 1382 feet. Exterior view, × 1.
32–34. *Choristothyris plicata* (Say), × 1; depth 1362 feet. 32, Exterior of ventral valve; 33, exterior of dorsal valve; 34, edge view of the united valves.
35. *Choristothyris* sp.; depth 1362 feet. Exterior of an incomplete ventral valve, × 1.

PLATE II

Cretaceous fossils (Matawan formation), figures 1–5

1, 2. *Exogyra ponderosa* Roemer?; depth 1476 feet. Exterior side and rear views of a young left valve, × 2.
3–5. *Exogyra ponderosa* Roemer?; depth 1476 feet. Exterior side, front, and rear views of a young left valve, × 2.

Cretaceous fossils (Roritan formotion), figures 6–21

6, 7. *Breviarca?* sp.; depth 1588–1603 feet. Interior and exterior views of a left valve, × 2.
8, 9. *Breviarca?* sp.; depth 1588–1603 feet. Interior and exterior views of a left valve, × 2.
10. *Fulpia wicomicoensis* (Richards)?; depth 1588–1603 feet. Hinge of a small right valve, × 3.
11. *Fulpia wicomicoensis* (Richards)?; depth 1588–1603 feet. Hinge of a small left valve, × 6.
12. *Fulpia wicomicoensis* (Richards)?; depth 1588–1603 feet. Incomplete hinge of a left valve, × 2.
13, 14. *Fulpia wicomicoensis* (Richards)?; depth 1588–1603 feet. Exterior and hinge views of an incomplete right valve, × 2.
15. *Fulpia* sp.; depth 2250–2257 feet. Incomplete hinge of a left valve, × 4.
16, 17. "*Corbula*" aff. *C. manleyi* Weller; depth 1588–1603 feet. Exterior and interior views of a right valve, × 2.
18. "*Corbula*" aff. *C. manleyi* Weller; depth 1588–1603 feet. Exterior view of a right valve, × 2.
19. "*Corbula*" aff. *C. monleyi* Weller; depth 1588–1603 feet. Exterior view of a large left valve, × 2.
20. "*Corbula*" aff. *C. manleyi* Weller; depth 1588–1603 feet. Interior view of an incomplete left valve, × 2.
21. "*Cerithium*" sp. *a;* depth 1588–1603 feet. Side view of an incomplete example, × 6.

PLATE III

1–4. *Ursirivus oceanus*, new species. 1. Holotype left valve, U.S.N.M. 104432, × 1; 2. Latex cast of natural mold of holotype, × 1; 3. Posterior end of imperfect left valve, Paratype, U.S.N.M. 104406 × 1; Dorsal view of holotype showing hinge structure, × 1.
5–7. *Ursirivus atlanticus*, new species. 5. Immature right valve paratype, U.S.N.M. 104429; 6. Dorsal view of hinge of left valve Paratype, U.S.N.M. 104420; 7. Holotype right valve, × 1, U.S.N.M. 104422.
8. Arcid indeterminate, U.S.N.M. 104419.
9–11. *Barbatia assawomanensis*, new species. 9. Holotype, right valve, U.S.N.M. 104416a; 10. Left valve, paratype, U.S.N.M. 104416b; 11. Latex cast of imperfect mold of left hinge, greatly enlarged, paratype, U.S.N.M. 104423.
12. *Inoceramus* (?) species, U.S.N.M. 104425.
13–14. *Nemocardium marinum*, new species. 13. Holotype left valve, U.S.N.M. 104401; 14. Hinge of holotype, greatly enlarged.
15. Corbulidae, indeterminate, A left valve, U.S.N.M. 104417.

16. Pelecypoda, indeterminate. U.S.N.M. 104411.
17–19. *Brachidontes stephensoni*, new species. 17. Fragments of shell from Holotype. 18. Holotype left valve, U.S.N.M. 104403; 19. Latex cast of natural mold of right valve, Paratype, U.S.N.M. 104396.
20. *Parmicorbula* species. Right valve, U.S.N.M. 104394.
21. Corbulidae indeterminate, B right valve of form somewhat similar to "*Corbula*" *manleyi* Weller. U.S.N.M. 104393.
22. "*Corbula*" *tethys* Stephenson. Hypotype right valve, U.S.N.M. 104412.
23. Pelecypoda, indeterminate. U.S.N.M. 104388..
24–25. *Anomia urbismarina*, new species. 24. Holotype left valve, and inflated individual, U.S.N.M. 104413; 25. Relatively flat left valve showing ornamentation, Paratype U.S.N.M. 104415.
26. Corbulidae, indeterminate, C right valve, U.S.N.M. 104414.
27–30. *Eomiodon maretesta*, new species. 27. Interior and hinge of left valve, Paratype, U.S.N.M. 104410c (natural size is shown on fig. 30). 28. Fragmentary exterior of right valve, Paratype, U.S.N.M. 104410b; 29. Interior and hinge of left valve, holotype, U.S.N.M., 104410a (natural size is shown on fig. 30); 30. Part of surface of core section showing local abundance of this species. × 1.
31–33. *Ostrea* species indeterminate. 31. Exterior of left valve, U.S.N.M. 104399; 32. Interior of same specimen. 33. Exterior of left valve, U.S.N.M. 104424; (magnification of figs. 32, 33, same as fig. 31).

PLATE IV

1–8. *Cassiope marylandensis*, new species. 1, 2. Dorsal and apertural views, Paratype, U.S.N.M. 104392; 3. Crushed fragment of apical portion showing variation from normal sculptural pattern, Paratype, U.S.N.M. 104387; 4. Apical area, showing usual sculptural pattern, Paratype, U.S.N.M. 104421; 5. Specimen with ornamentation suppressed on later whorls, Paratype, U.S.N.M. 104391; 6. Holotype, showing development of nodes on primary spirals, U.S.N.M. 104408; 7. Fragment possessing nuclear whorls, Paratype, U.S.N.M. 104397; 8. Crushed fragment showing adult ornamentation, × I, Paratype, U.S.N.M. 104418.
9–12. *Anteglosia essoensis*, new genus, new species. 9. Apertural view of Holotype, U.S.N.M. 104404a; 10. Nuclear whorls, greatly enlarged, Paratype, U.S.N.M. 104407; 11. Apertural view of small crushed specimen, Paratype, U.S.N.M. 104404b; 12. Dorsal view Paratype, U.S.N.M. 104404c.
13. Gastropod, genus and species indeterminate, U.S.N.M. 104398.
14–20. *Plesiopotamides marinus*, new genus, new species. 14. Apertural view of crushed adult specimen, Paratype, U.S.N.M. 104400e; 15. Paratype, U.S.N.M. 104400c; 16. Dorsal view of uncrushed specimen, showing true apical angle, Paratype, U.S.N.M. 104400d; 17. Dorsal view of uncrushed holotype, U.S.N.M. 104400a; 18. Largest specimen in core, somewhat crushed, Paratype, U.S.N.M. 104400b; 19. Small fragment showing relatively complete aperture, Paratype, U.S.N.M. 104428; 20. Crushed fragment, possessing nuclear whorls, greatly enlarged. U.S.N.M. 104400f.
21–23. *Metacerithium oceanum*, new species. 21. Dorsal view of Holotype, U.S.N.M. 104395; 22. Apertural view of crushed Paratype, U.S.N.M. 104405a; 23. Well preserved fragment showing sculptural details, Paratype, U.S.N.M. 104405b.
24. Surface of a portion of core section showing abundance of gastropoda. × 1.
25–26. *Euspira parvissima*, new species. 25. Dorsal view of holotype, U.S.N.M. 104430, 26. Apertural view of crushed paratype, U.S.N.M. 104431.

PLATE V

1–3. *Melosira complexa* Lohman, n.sp. Paratype. U.S.G.S. diatom catalog no. 2368-62, locality 3081. Diameter, 42μ. × 1000.

4, 5. *Melosira complexa* Lohman, n.sp. Holotype. U.S.G.S. diatom catalog no. 2363-37, locality 3076. Diameter, 67μ. × 600.

6, 7. *Melosira complexa* Lohman, n.sp. Paratype. U.S.G.S. diatom catalog no. 2377-8, locality 3080. Diameter, 65μ × 600.

PLATE VI

1. *Coscinodiscus arcus* Lohman, n.sp. Holotype. U.S.G.S. diatom catalog no. 2376-14, locality 3079. Diameter, 80μ. × 600.
2. *Coscinodiscus apiculatus* Ehrenberg. U.S.G.S. diatom catalog no. 2373-38, locality 3076. Diameter, 77μ. × 600.
3. *Stephanopyxis lineata* (Ehrenberg) Forti. U.S.G.S. diatom catalog no. 2368-57, locality 3081. Diameter, 61μ. × 600.
4. *Endictya robusta* (Greville) Hanna and Grant. U.S.G.S. diatom catalog no. 2362-32, locality 3075. Diameter, 68μ. × 600.
5. *Coscinodiscus crassipunctatus* Forti. U.S.G.S. diatom catalog no. 2372-3, locality 3075. Length, 63μ. × 1000.
6. *Coscinodiscus lewisianus* var. *similis* Rattray. U.S.G.S. diatom catalog no. 2378-12, locality 3081. Length, 68μ. × 1000.
7. *Coscinodiscus lewisianus* Greville. U.S.G.S. diatom catalog no. 2366-21, locality 3079. Length, 62μ. × 1000.

PLATE VII

1. *Coscinodiscus asteroides* Truan and Witt. U.S.G.S. diatom catalog no. 2372-1, locality 3075. Diameter, 181μ. × 300.
2. *Coscinodiscus lineatus* Ehrenberg. U.S.G.S. diatom catalog no. 2377-43, locality 3080. Diameter, 88μ. × 600.
3. *Coscinodiscus obscurus* Schmidt. U.S.G.S. diatom catalog no. 2369-1, locality 3074. Diameter, 102μ. × 500.
4. *Coscinodiscus marginatus* Ehrenberg. U.S.G.S. diatom catalog no. 2369-23, locality 3074. Diameter, 55μ. × 500.
5. *Coscinodiscus salisburyanus* Lohman, n.sp. Holotype. U.S.G.S. diatom catalog no. 2370-16, locality 3074. Diameter, 43μ × 1000.
6. *Coscinodiscus monicae* Grunow. U.S.G.S. diatom catalog no. 2377-44, locality 3080. Diameter, 154μ. × 400.

PLATE VIII

1–2. *Cestodiscus marylandicus* Lohman, n.sp. Holotype. U.S.G.S. diatom catalog no. 2368-54, locality 3081. Diameter, 46μ. × 1000.

3. *Coscinodiscus perforatus* Ehrenberg var. *cellulosa* Grunow. U.S.G.S. diatom catalog no. 2372-27, locality 3075. Diameter, 79μ. × 600.
4. *Liradiscus minimus* Lohman, n.sp. Holotype. U.S.G.S. diatom catalog no. 2368-6, locality 3081. Diameter, 17μ. × 1000.
5. *Liradiscus bipolaris* Lohman, n.sp. Holotype. U.S.G.S. diatom catalog no. 2366-29, locality 3079. Length, 49μ. × 1000.
6. *Craspedodiscus coscinodiscus* Ehrenberg. U.S.G.S. diatom catalog no. 2377-22, locality 3080. Diameter, 114μ. × 400.

7. *Craspedodiscus elegans* Ehrenberg. U.S.G.S. diatom catalog no. 2378-23, locality 3081. Diameter, 224μ. × 200.
8. *Actinocyclus octonarius* Ehrenberg. U.S.G.S. diatom catalog no. 2378-21, locality 3081. Diameter, 130μ. × 400.

PLATE IX

1. *Actinocyclus partitus* Grunow. U.S.G.S. diatom catalog no. 2374-8, locality 3077. Diameter, 62μ. × 1000.
2. *Stictodiscus kittonianus* Greville. U.S.G.S. diatom catalog no. 2372-68, locality 3075. Diameter, 37μ. × 600.
3. *Actinoptychus heliopelta* Grunow. U.S.G.S. diatom catalog no. 2373-25, locality 3076. Diameter, 110μ. × 500.
4. *Cladogramma ellipticum* Lohman, n.sp. Holotype. U.S.G.S. diatom catalog no. 2368-20, locality 3081. Length, 41μ. × 1000.
5. *Cladogramma dubium* Lohman, n.sp. Holotype. U.S.G.S. diatom catalog no. 2377-2, locality 3080. Diameter, 34μ. × 1000.
6. *Actinoptychus kymatodes* Pantocsek. U.S.G.S. diatom catalog no. 2371-30, locality 3075. Diameter, 110μ. × 500.
7. *Cymatogonia amblyoceras* (Ehrenberg) Hanna. U.S.G.S. diatom catalog no. 2378-11, locality 3081. Diameter, 90μ. × 600.
8. *Aulacodiscus sollitianus* Norman. U.S.G.S. diatom catalog no. 2376-13, locality 3079. Diameter, 177μ. × 300.

PLATE X

1. *Pseudauliscus spinosus* (Christian) Rattray. U.S.G.S. diatom catalog no. 2376-16, locality 3079. Diameter, 86μ. × 600.
2. *Triceratium interpunctatum* Grunow. U.S.G.S. diatom catalog no. 2372-35, locality 3075. Altitude, 74μ. × 600.
3. *Triceratium tessellatum* Greville. U.S.G.S. diatom catalog no. 2368-21, locality 3081. Length of one side, 46μ. × 1000.
4. *Triceratium kainii* Schultze. U.S.G.S. diatom catalog no. 2368-50, locality 3081. Length of one side, 57μ. × 600.
5. *Triceratium kainii* Schultze. U.S.G.S. diatom catalog no. 2377-9, locality 3080. Length of one side, 69μ. × 600.
6. *Biddulphia decipiens* Grunow. U.S.G.S. diatom catalog no. 2368-43, locality 3081. Length of one side, 46μ. × 600.
7. *Hemiaulus bipons* (Ehrenberg) Grunow. U.S.G.S. diatom catalog no. 2368-61, locality 3081. Length, 37μ. × 600.
8. *Mastogonia crux* Ehrenberg. U.S.G.S. diatom catalog no. 2377-20, locality 3080. Diameter, 77μ × 400.

PLATE XI

1. *Rhaphoneis gemmifera* Ehrenberg. U.S.G.S. diatom catalog no. 2377-19, locality 3080. Length 93μ. × 600.
2. *Rhaphoneis elegans* Pantocsek and Grunow. U.S.G.S. diatom catalog no. 2372-70, locality 3075. Length, 82μ. × 600.
3. *Rhaphoneis scalaris* Ehrenberg. U.S.G.S. diatom catalog no. 2374-10, locality 3077. Length, 78μ. × 600.
4. *Dimerogramma novae-caesareae* Kain and Schultze. U.S.G.S. diatom catalog no. 2363-9, locality 3076. Length, 52μ. × 1000.

5. *Dimerogramma novae-caesareae* Kain and Schultze. U.S.G.S. diatom catalog no. 2363-28, locality 3076. Length, 71μ. × 1000.
6. *Rhaphoneis immunis* Lohman, n.sp. Holotype. U.S.G.S. diatom catalog no. 2371-20, locality 3075. Length, 71μ. × 1000.
7. *Sceptroneis caducea* Ehrenberg. U.S.G.S. diatom catalog no. 2177-1, locality 2385, near Nottingham, Md., Calvert formation, zone 3, middle Miocene. Length, 126μ. × 500.
8. *Diploneis prisca* (Schmidt) Cleve. U.S.G.S. diatom catalog no. 2368-49, locality 3081. Length, 64μ. × 1000.
9. *Rhaphoneis wicomicoensis* Lohman, n.sp. Holotype. U.S.G.S. diatom catalog no. 2375-44, locality 3078. Length, 43μ. × 1000.
10. *Rhaphoneis parilis* Hanna. U.S.G.S. diatom catalog no. 2363-7, locality 3076. Length, 39μ. × 1000.
11. *Rhaphoneis angustata* Pantocsek. U.S.G.S. diatom catalog no. 2368-28, locality 3081. Length, 32μ. × 1000.
12. *Cocconeis costata* Gregory. U.S.G.S. diatom catalog no. 2368-53, locality 3081. Length, 46μ. × 1000.
13. *Raphidodiscus marylandicus* Christian. U.S.G.S. diatom catalog no. 2377-18, locality 3080. Length, 52μ. × 1000.

PLATE XII

All figures approximately × 47

1. *Bythocypris? wicomicoensis* Swain, n.sp. View of right side of holotype.

2, 3. *Bythocypris subaequata* Ulrich. Right side and dorsal views of a complete shell having a recrystallized surface.

4. *Cytherella* cf. *C. submarginata* Ulrich. View of left side of a complete shell that is somewhat crushed dorsally.

5. *Cytherelloidea howei* Swain, n.sp. View of right side of holotype, a complete but slightly imperfect shell.

6. *Paracypris* aff. *P. augusta* Alexander. Right valve view of a complete specimen.

7. *Argilloecia alexanderi* Swain, n.sp. View of left side of holotype, a complete shell.

8, 9. *Eucythere* sp. Right valve views of two specimens here referred to this genus.

10. *Bairdia postextensa* Swain, n.sp. View of right side of holotype, a complete shell.

11. *Bairdia* cf. *B. rotunda* Alexander. View of right side of a complete shell.

12. *Loxoconcha? postdecliva* Swain, n.sp. View of right side of holotype, a complete shell.

13. *Loxoconcha* cf. *L. creolensis* Howe and Chambers. View of right side of a complete shell.

14, 15. *Cythereis exanthemata* (Ulrich and Bassler). 14, Right valve view of a complete shell, thought to represent a female example. 15, Left valve view of a complete shell thought to represent a male example.

16, 17. *Cythereis martini* (Ulrich and Bassler). 16, Exterior of a separated right valve. 17, Left valve view of a complete shell.

18. *Cythereis martini* var. *punctopustula* Swain, n. var. Right valve view of holotype, a complete shell.

19. *Cythereis evax* (Ulrich and Bassler). View of left side of a complete shell.

20. *Cythereis evax* var. *oblongula* (Ulrich and Bassler). View of left side of a complete shell.

PLATE XIII

All figures approximately × 47

1. *Cytherideis ashermani* Ulrich and Bassler. View of right side of a complete shell on which surface pitting somewhat obscured by recrystallization.

2. *Cytherideis longula* Ulrich and Bassler. View of left side of a complete shell.
3, 4. *Cytheretta plebia* (Ulrich and Bassler). 3, View of right side of a complete shell. 4, Interior of a right valve showing hinge structure and an antero-ventrally sinuate inner margin.
5. *Cytheretta inaequivalvis* (Ulrich and Bassler). Exterior view of a separated left valve.
6. *Leguminocythereis clarkana* (Ulrich and Bassler). View of right side of a complete shell which bears a discoloration dorsomedially.
7. *Cythereis bassleri* Ulrich. View of right side of a complete shell.
8. *Cythereis dorsopleura* Swain, n.sp. View of right side of holotype, a complete shell.
9. *Cythereis paraustinensis* Swain, n.sp. View of right side of holotype, a complete shell.
10. *Cythereis* cf. *C. hysonensis* Howe and Chambers. View of right side of a complete shell.
11. *Leguminocythereis? pustulosa* Swain, n.sp. Left valve view of holotype, distorted posteriorly, giving false impression of right valve overlap in that area.
12. *Cythereis marginoreticulata* Swain, n.sp. View of left side of holotype, a complete shell, showing reticulation of anterior marginal rim.
13, 14. *Cythereis reticulodacyi* Swain, n.sp. Views of exterior and interior of the holotype, a left valve.
15, 16. *Cythereis* cf. *C. bicornis* Israelsky. Left side and ventral views of a complete shell.
17, 18. *Cythereis parawinniana* Swain, n.sp. Right side and ventral views of holotype, a complete shell.
19, 20. *Cythereis goochi* Swain, n.sp. Left side and dorsal views of holotype, a complete shell.

PLATE XIV

All figures approximately × 42

1, 2. *Cythereis pellucinoda* Swain, n.sp. 1, View of right side of holotype, a complete shell. 2, View of left side of a paratype specimen.
3. *Cythereis reesidei* Swain, n.sp. View of right side of holotype, a complete shell.
4. *Cythereis* (*Pterygocythereis*) *cornuta* var. *americana* Ulrich and Bassler. View of right side of a complete example.
5–7. *Cythereis* (*Pterygocythereis*) cf. *C.* (*P.*) *communis* Israelsky. Right side and ventral view of holotype, a specimen that is imperfect postdorsally. 7, Right valve view of a paratype specimen.
8. *Cythereis* cf. *spiniferrima* Jones and Sherborn. View of left side of a complete shell.
9, 10. *Cythereis ventroconvexa* Swain, n.sp. Dorsal and right side views of holotype, a complete shell.
11. *Cythereis* cf. *splendens* Sutton and Williams. View of right side of a complete shell.
12, 13. *Brachycythere betzi* Jennings. Left side and ventral views of a complete shell.
14. *Cytheridea* (*Haplocytheridea*) cf. *monmouthensis* Berry. View of right side of a complete shell having the characteristic postventral winglike expansion poorly exhibited.
15. *Cytheridea* (*Haplocytheridea*) *obovata* Swain, n.sp. View of right side of holotype, a complete shell.
16. *Cytheridea?* sp. aff. *C. perforata* (Roemer). View of left side of a complete shell.
17. *Cytheridea* (*Haplocytheridea*) *parvasulcata* Swain, n.sp. View of right side of holotype, a complete shell.
18. *Cytheridea* (*Haplocytheridea*) *israelskyi* Stephenson. View of interior of a left valve.
19. *Cytheridea* (*Clithrocytheridea?*) *aquia* Swain, n.sp. View of right side of holotype, a complete shell.

PLATE XV

1. *Planularia* sp. B. × 39. Miocene, 1100′–1110′ sample.
2, 3. *Planularia* sp. A. × 39. Miocene. 2, 1100′–1110′ sample. 3, 1110′–1120′ sample.

4. *Vaginulina* sp. × 39. Miocene, 1110′–1120′ sample.
5–7. *Pseudopolymorphina calvertensis* Cushman, n.sp. × 39. Miocene, 1100′–1110′ sample. 5, Holotype. 6, 7, Paratypes.
8. *Sigmomorphina marylandica* Cushman, n.sp. × 39. Miocene, 1080′–1090′ sample.
9–11. *Uvigerina calvertensis* Cushman, n.sp. × 39. Miocene. 9, Paratype, 1080′–1090′ sample. 10, Holotype, 1040′–1050′ sample. 11, Paratype, 1110′–1120′ sample.
12. *Uvigerina exilis* Cushman, n.sp. × 61. Eocene, 1150′–1160′ sample.
13. *Angulogerina exigua* Cushman, n.sp. × 61. Eocene, 1160′–1170′ sample.
14, 15. *Ellipsonodosaria calvertensis* Cushman, n.sp. × 39. Miocene. 14, Holotype, early chambers, 1100′–1110′ sample. 15, Paratype, adult chambers, 1110′–1120′ sample.
16–18. *Amphimorphina miocenica* Cushman, n.sp. × 39. Miocene, 1090′–1100′ sample. 16, 17, Paratype, megalospheric. 18, Holotype, microspheric.
19, 20. *Gyroidina marylandica* Cushman, n.sp. × 39. Miocene(?), 1090′–1100′ sample. 19. Holotype, dorsal side. 20, Paratype, ventral side.
21. *Cassidulinoides howei* Cushman. × 39. Eocene, 1140′–1150′ sample.

PLATE XVI

1. *Spiroplectammina mississippiensis* (Cushman). × 33.
2. *Spiroplectammina plummerae* Cushman, new name. × 33.
3. *Textularia* cf. *T. subhauerii* Cushman. × 33.
4. *Gaudryina* cf. *G.* (*Pseudogaudryina*) *alazanensis* Cushman. × 22.
5. *Pseudoclavulina* cf. *P. cocoaensis* Cushman. × 33.
6. *Quinqueloculina* cf. *Q. longirostra* d'Orbigny. × 33.
7. *Massilina decorata* Cushman. × 33.
8. *Robulus alato-limbatus* (Gümbel). × 33.
9. *Robulus virginianus* Cushman and Cederstrom. × 22.
10. *Marginulina subrecta* Franke. × 33.
11. *Marginulina karreriana* Cushman. × 33.
12. *Marginulina* cf. *M. subaculeata* (Cushman), var. *tuberculata* (Plummer). × 33.
13. *Marginulina cooperensis* Cushman. × 33.
14. *Marginulina subbullata* Hantken. × 33.

PLATE XVII

1. *Pseudoglandulina laevigata* (d'Orbigny). × 33.
2. *Dentalina cooperensis* Cushman. × 33.
3. *Dentalina capitata* (Boll). × 22.
4. *Dentalina* cf. *D. soluta* Reuss. × 22.
5, 6. *Dentalina bevani* Cushman and Cederstrom. × 22. Fig. 5, microspheric form; fig. 6, megalospheric form.
7. *Pseudoglandulina conica* (Neugeboren). × 33.
8. *Saracenaria arcuata* (d'Orbigny), var. *hantkeni* Cushman. × 33.
9. *Vaginulina longiforma* (Plummer). × 22.
10. *Lagena acuticosta* Reuss. × 33.
11. *Lagena costata* (Williamson). × 33.
12. *Guttulina problema* d'Orbigny. × 33.
13. *Guttulina spicaeformis* (Roemer). × 33.
14. *Guttulina irregularis* (d'Orbigny). × 33.
15. *Globulina rotundata* (Bornemann). × 33.
16. *Globulina gibba* d'Orbigny. × 33.
17. *Globulina gibba* d'Orbigny, var. *punctata* d'Orbigny. × 33.
18. *Globulina münsteri* (Reuss). × 33.

19. *Sigmomorphina jacksonensis* (Cushman). × 33.
20. *Sigmoidella plummerae* Cushman and Ozawa. × 33.
21. *Ramulina* cf. *R. aculeata* (d'Orbigny). × 33.

PLATE XVIII

1. *Nonion planatum* Cushman and Thomas. × 33.
2. *Nonion micrum* Cole. × 33.
3. *Nonionella hantkeni* (Cushman and Applin), var. *spissa* Cushman. × 33.
4. *Bolivinopsis curta* (Cushman). × 55.
5. *Gümbelina cubensis* Palmer, var. *heterostoma* Bermúdez. × 55.
6. *Gümbelina mauriciana* Howe and Roberts. × 55.
7. *Gümbelina* cf. *G. trinitatensis* Cushman and Renz. × 55.
8. *Plectofrondicularia cookei* Cushman. × 55.
9. *Plectofrondicularia virginiana* Cushman and Cederstrom. × 33.
10. *Pseudouvigerina* cf. *P. naheolensis* Cushman and Todd. × 55.
11. *Siphogenerinoides eleganta* (Plummer). × 55.
12. *Buliminella basistriata* Cushman and Jarvis, var. *nuda* Howe and Wallace. × 55.
13. *Bulimina ovata* d'Orbigny. × 33.
14. *Bulimina arkadelphiana* Cushman and Parker, var. *midwayensis* Cushman and Parker. × 55.
15. *Bulimina* cf. *B. cooperensis* Cushman. × 33.
16. *Bulimina cacumenata* Cushman and Parker. × 55.
17. *Bulimina jacksonensis* Cushman. × 33.
18. *Virgulina danvillensis* Howe and Wallace. × 33.
19. *Bolivina gardnerae* Cushman. × 55.
20. *Bolivina jacksonensis* Cushman and Applin. × 55.
21. *Bolivina jacksonensis* Cushman and Applin, var. *striatella* Cushman and Applin. × 55.
22. *Bolivina spiralis* Cushman. × 55.
23. *Bolivina virginiana* Cushman and Cederstrom, var. × 55.

PLATE XIX

(*a*, dorsal view; *b*, ventral view)

1. *Loxostomum* cf. *L. claibornense* Cushman. × 55.
2. *Loxostomum longiforme* Cushman and Cederstrom. × 55.
3. *Uvigerina jacksonensis* Cushman. × 33.
4. *Uvigerina dumblei* Cushman and Applin. × 33.
5. *Uvigerina cocoaensis* Cushman. × 33.
6. *Uvigerina elongata* Cole. × 33.
7. *Uvigerina russelli* Howe. × 55.
8. *Angulogerina cooperensis* Cushman. × 55.
9. *Ellipsonodosaria atlantisae* Cushman, var. *hispidula* Cushman. × 55.
10. *Ellipsonodosaria alexanderi* Cushman. × 33.
11. *Ellipsonodosaria* sp. × 55.

12, 13. *Ellipsonodosaria* cf. *E. longiscata* (d'Orbigny). × 33.

14. *Discorbis assulata* Cushman. × 55.
15. *Valvulineria jacksonensis* Cushman. × 55.
16. *Gyroidina orbicularis* d'Orbigny, var. *planata* Cushman. × 33.
17. *Gyroidina soldanii* d'Orbigny, var. *octocamerata* Cushman and G. D. Hanna. × 33
18. *Gyroidina aequilateralis* (Plummer). × 33.

19. *Eponides umbonatus* (Reuss). × 55.
20. *Eponides* cf. *E. exigua* (H. B. Brady). × 32.
21. *Eponides cocoaensis* Cushman. × 32.
22. *Siphonina tenuicarinata* Cushman. × 32.

PLATE XX

(*a*, dorsal view; *b*, ventral view)

1. *Alabamina wilcoxensis* Toulmin. × 33.
2. *Cassidulina globosa* Hantken. × 55.
3. *Cassidulinoides howei* Cushman. × 55. Paratype.
4. *Pullenia quinqueloba* (Reuss), var. *angusta* Cushman and Todd. × 33.
5. *Pullenia eocenica* Cushman and Siegfus. × 55.
6. *Globigerina compressa* Plummer. × 33.
7. *Hantkenina longispina* Cushman. × 33.
8. *Globorotalia crassata* (Cushman), var. *aequa* Cushman and Renz. × 33.
9. *Cibicides westi* Howe. × 33.
10. *Cibicides ocalanus* Cushman. × 33.
11. *Anomalina* cf. *A. midwayensis* (Plummer). × 33.
12. *Cibicides ouachitaensis* Howe and Wallace. × 33.
13. *Cibicides speciosus* Cushman and Cederstrom. × 33.
14. *Cibicides* cf. *C. lobatulus* (Walker and Jacob). × 33.
15. *Cibicides* cf. *C. pseudoungerianus* (Cushman). × 33.

PLATE XXI

1. *Ammodiscus cretaceus* (Reuss). × 45.
2. *Spiroplectammina laevis* (Roemer), var. *cretosa* Cushman. × 45.
3. *Textularia ripleyensis* W. Berry. × 45.
4. *Textularia subconica* Franke. × 45.
5. *Gaudryina* (*Siphogaudryina*) *stephensoni* Cushman. × 45.
6. *Clavulinoides trilatera* (Cushman), var. *concava* (Cushman). × 22.
7. *Pseudoclavulina clavata* (Cushman). × 22.
8. *Pseudogaudryinella capitosa* (Cushman). × 22.
9. *Heterostomella americana* Cushman. × 22.
10. *Eggerella? trochoides* (Reuss). × 45.
11. *Marssonella oxycona* (Reuss). × 45.
12. *Dorothia conula* (Reuss). × 22.
13. *Dorothia bulletta* (Carsey). × 22.
14. *Arenobulimina americana* Cushman. × 45.
15. *Robulus pondi* Cushman. × 22.
16. *Robulus münsteri* (Roemer). × 22.
17. *Robulus pseudosecans* Cushman. × 22.
18. *Lenticulina rotulata* Lamarck. × 45.
19. *Marginulina munda* Cushman. × 45.
20. *Marginulina armata* Reuss. × 45.
21. *Marginulina* cf. *M. recta* (d'Orbigny). × 45.
22. *Marginulina cretacea* Cushman. × 45.

PLATE XXII

1. *Marginulina bullata* Reuss. × 45.
2. *Marginulina* cf. *M. tripleura* (Reuss). × 45.

3. *Dentalina alternata* (Jones). × 22.
4. *Dentalina basitorta* Cushman. × 45.
5. *Dentalina gracilis* d'Orbigny. × 22.
6. *Dentalina legumen* Reuss. × 45.
7. *Dentalina solvata* Cushman. × 22.
8. *Dentalina aculeata* d'Orbigny. × 22.
9. *Dentalina multicostata* d'Orbigny. × 22.
10. *Dentalina megalopolitana* Reuss. × 22.
11. *Dentalina catenula* Reuss. × 45.
12. *Dentalina basiplanata* Cushman. × 22.
13. *Dentalina pertinens* Cushman. × 45.
14, 15. *Dentalina* cf. *D. consobrina* d'Orbigny. × 22.
16. *Saracenaria triangularis* (d'Orbigny). × 45.
17. *Pseudoglandulina lagenoides* (Olszewski). × 45.
18. *Pseudoglandulina manifesta* (Reuss). × 45.
19. *Nodosaria aspera* Reuss. × 22.
20. *Nodosaria fusula* Reuss. × 45.
21. *Nodosaria proboscidea* Reuss. × 45.
22. *Nodosaria obscura* Reuss. × 22.
23. *Nodosaria affinis* Reuss. × 22.
24. *Vaginulina wadei* Kelley. × 45.

PLATE XXIII

1. *Vaginulina taylorana* Cushman. × 22.
2. *Palmula rugosa* (d'Orbigny). × 45.
3. *Vaginulina suturalis* Cushman. × 22.
4. *Palmula suturalis* (Cushman). × 45.
5. *Vaginulina multicostata* Cushman. × 45.
6. *Vaginulina cretacea* Plummer. × 45.
7. *Frondicularia goldfussi* Reuss. × 45.
8. *Frondicularia cuspidata* Cushman. × 45.
9. *Frondicularia striatula* (Reuss). × 22.
10. *Frondicularia archiaciana* d'Orbigny. × 22.
11. *Kyphopyxa christneri* (Carsey). × 45.
12. *Lagena acuticosta* Reuss. × 45.
13. *Lagena apiculata* Reuss. × 45.
14. *Lagena sulcata* (Walker and Jacob), var. *semiinterrupta* W. Berry. × 45.
15. *Lagena* cf. *L. globosa* Montagu. × 45.
16. *Guttulina trigonula* (Reuss). × 45.
17. *Guttulina adhaerens* (Olszewski). × 45.
18, 19. *Globulina lacrima* Reuss, var. *subsphaerica* (Berthelin). 18, × 45. 19, × 90.
20. *Pyrulina cylindroides* (Roemer). × 22.
21. *Sigmomorphina semitecta* (Reuss). var. *terquemiana* (Fornasini). × 90.
22, 23. *Ramulina* cf. *R. aculeata* (d'Orbigny). × 22.

PLATE XXIV

1. *Bolivinopsis papillata* (Cushman). × 45.
2. *Gümbelina plummerae* Loetterle. × 45.
3. *Gümbelina striata* (Ehrenberg). × 45.
4. *Gümbelina costulata* Cushman. × 90.

5, 6. *Bolivinopsis rosula* (Ehrenberg). × 45.
7. *Gümbelina planata* Cushman. × 90.
8. *Gümbelina carinata* Cushman. × 90.
9. *Gümbelina globulosa* (Ehrenberg). × 45.
10. *Gümbelina pseudotessera* Cushman. × 90.
11. *Gümbelina glabrans* Cushman. × 90.
12. *Gümbelitria cretacea* Cushman. × 90.
13. *Ventilabrella eggeri* Cushman. × 45.
14. *Bolivinoides decorata* (Jones). × 45.
15. *Bolivinoides decorata* (Jones), var. *delicatula* Cushman. × 45.
16. *Bolivinita eleyi* Cushman. × 45.
17. *Bolivinita costifera* Cushman. × 45.
18. *Eouvigerina americana* Cushman. × 45.
19. *Eouvigerina gracilis* Cushman. × 45.
20. *Eouvigerina hispida* Cushman. × 45.
21. *Buliminella cushmani* Sandidge. × 45.
22. *Buliminella carseyae* Plummer. × 90.
23. *Bulimina prolixa* Cushman and Parker. × 45.
24. *Bulimina triangularis* Cushman and Parker. × 90.
25. *Bulimina taylorensis* Cushman and Parker. × 45.

PLATE XXV

(Unless otherwise noted, *a*, dorsal view; *b*, ventral view)

1. *Neobulimina irregularis* Cushman and Parker. × 45.
2. *Virgulina tegulata* Reuss. × 45.
3. *Bolivina incrassata* Reuss. × 22.
4. *Bolivina decurrens* (Ehrenberg). × 45.
5. *Bolivina cretosa* Cushman. × 45.
6. *Loxostomum plaitum* (Carsey). × 45.
7. *Loxostomum plaitum* (Carsey), var. *limbosum* (Cushman). × 45.
8. *Pleurostomella subnodosa* Reuss. × 45.
9. *Nodosarella primitiva* Cushman. × 45.
10. *Ellipsonodosaria alexanderi* Cushman. × 45.
11. *Ellipsonodosaria stephensoni* Cushman. × 45.
12. *Valvulineria allomorphinoides* (Reuss). × 45.
13. *Valvulineria cretacea* (Carsey). × 45.
14. *Valvulineria* cf. *V. umbilicatula* (d'Orbigny). × 45.
15, 16. *Gyroidina globosa* (Hagenow). × 45.
17. *Stensiöina americana* (Cushman). × 45.
18. *Gyroidina depressa* (Alth). × 45.
19. *Siphonina prima* Plummer. × 45.
20. *Eponides haidingeri* (d'Orbigny). × 45.
21. *Pullenia americana* Cushman. × 45. *a*, side view; *b*, apertural view.
22. *Globotruncana canaliculata* (Reuss). × 45.

PLATE XXVI

(*a*, dorsal view; *b*, ventral view)

1. *Globotruncana fornicata* Plummer. × 45.
2. *Globotruncana marginata* (Reuss). × 22.

3. *Globotruncana calcarata* Cushman. × 22.
4. *Globorotalia micheliniana* (d'Orbigny). × 22.
5. *Anomalina clementiana* (d'Orbigny). × 45.
6. *Anomalina* cf. *A. nelsoni* W. Berry. × 22.
7. *Anomalina ammonoides* (Reuss). × 45.
8. *Planulina taylorensis* (Carsey). × 22.
9. *Planulina texana* Cushman. × 45.
10. *Cibicides stephensoni* Cushman. × 45.
11. *Cibicides beaumontianus* (d'Orbigny). × 45.

PLATE XXVII

1a–c, 2a–b. *Spiroplectammina exilis* Dorsey n.sp., × 40.
3a–c, 4a–b. *Spiroplectammina mississippiensis* (Cushman), × 40.
5a–c, 6a–b. *Spiroplectammina spinosa* Dorsey n.sp., × 40.
7a–c. *Textularia candeiana* d'Orbigny, × 40.
8a–c. *Textularia* cf. *T. badenensis* Lalicker, × 40.

PLATE XXVIII

1a–c. *Textularia consecta* d'Orbigny, × 40.
2a–c. *Textularia* cf. *T. foliacea* Heron-Allen and Earland, × 40.
3a–c. *Textularia gramen* d'Orbigny, × 40.
4a–b. *Bigenerina floridana* Cushman and Ponton, × 40.
5a–c. *Textularia mayori* Cushman, × 40.
6a–c, 7a–c. *Textularia obliqua* Dorsey n.sp., × 40.
8a–c. *Textularia ultima-inflata* Dorsey n.sp., × 40.

PLATE XXIX

1a–c. *Quinqueloculina contorta* d'Orbigny var. *striata* Asano, × 30.
2a–c. *Quinqueloculina seminula* (Linnaeus), × 30.
3a–c. *Massilina quadrans* Cushman and Ponton, × 30.
4a–c, 5a–c. *Massilina mansfieldi* Cushman and Cahill, × 30.
6a–c. *Massilina glutinosa* Cushman and Cahill, × 30.
7a–c. *Pyrgo subsphaerica* (d'Orbigny), × 30.

PLATE XXX

1a–c. *Triloculina* cf. *T. trigonula* (Lamarck), × 30.
2a–b. *Robulus branneri* Cushman and Kleinpell, × 30.
3a–b. *Robulus americanus* (Cushman), × 30.
4a–b. *Robulus americanus* (Cushman) var. *spinosus* (Cushman), × 30.
5a–b. *Saracenaria* sp., × 30.
6a–b. *Planularia vaughani* (Cushman), × 30.
7a–b. *Planularia* sp., × 30.
8a–b. *Vaginulina* sp., × 30.
9a–b. *Marginulina* sp. A, × 30.
10a–b. *Marginulina* sp. B, × 30.
11a–b. *Marginulina* sp. C, × 30.
12a–b, 13a–b. *Marginulina* sp. D, × 30.

PLATE XXXI

1. *Dentalina* cf. *D. communis* d'Orbigny, × 30.
2. *Dentalina* sp., × 30.
3. *Nodosaria pyrula* d'Orbigny, × 30.
4. *Lagena clavata* (d'Orbigny), × 50.

5–6. *Lagena tenuis* (Bornemann), × 50.
7–8. *Lagena* sp. A, × 50.
9–10. *Lagena laevis* (Montagu), × 50.
11–12. *Lagena acuticosta* Reuss, × 50.
13–14. *Lagena* sp. B, × 50.
15–16. *Lagena hispida* Reuss, × 50.
17–18. *Lagena* sp. C, × 50.
19–23. *Lagena* sp. D, × 50.
24. *Lagena* sp. E, × 50.
25a–b, 26. *Guttulina austriaca* d'Orbigny, × 40.
27a–b. *Guttulina problema* d'Orbigny, × 40.

PLATE XXXII

1a–b, 2a–b. *Guttulina rectiornata* Dorsey n.sp., × 40.
3a–b. *Guttulina pulchella* d'Orbigny, × 40.
4a–b, 5a–b. *Guttulina elegans* Dorsey n.sp., × 40.
6a–b. *Globulina rotundata* (Bornemann), × 60.
7a–b. *Globulina minuta* (Roemer), × 60.
8a–c. *Globulina fimbriata* Cushman and McGlamery, × 60.
9a–b. *Globulina inaequalis* Reuss var. *caribaea* d'Orbigny, × 60.
10a–b. *Globulina inaequalis* Reuss, × 60.

PLATE XXXIII

1a–b. *Pyrulina fusiformis* (Roemer), × 40.
2a–b. *Pseudopolymorphina dumblei* (Cushman and Applin), × 30.
3a–b. *Pseudopolymorphina decora* (Reuss), × 30.
4a–b, 5a–b. *Pseudopolymorphina striata* (Bagg), × 30.
6a–b, 7a–b, 8a–b. *Pseudopolymorphina rutila* (Cushman), × 30.

PLATE XXXIV

1a–b. *Pseudopolymorphina rutila* (Cushman), × 30.
2. *Pseudopolymorphina jonesi* Cushman and Ozawa, × 40.
3a–b, 4a–b. *Sigmoidella* sp., × 30.
5a–b. *Sigmoidella kagaensis* Cushman and Ozawa, × 40.
6, 7a–b. *Sigmomorphina nevifera* Dorsey, n.sp., × 40.
8a–b. *Polymorphina advena* Cushman var. *nuda* Howe and Roberts, × 30.
9a–b. *Polymorphina schlumbergeri* Cushman and Ozawa, × 30.

PLATE XXXV

1a–c. *Nonion advenum* (Cushman), × 40.
2a–c. *Nonion marylandicum* Dorsey, n.sp., × 40.
3a–c. *Nonionella auris* (d'Orbigny), × 40.

4a–c. *Nonion medio-costatum* (Cushman), × 40.
5a–c. *Nonion grateloupi* (d'Orbigny), × 50.
6a–c. *Nonion pizarrense* W. Berry, × 40.
7a–c, 8a–b. *Elphidium poeyanum* (d'Orbigny), × 40.

PLATE XXXVI

1a–b. *Nodogenerina advena* Cushman and Laiming, × 50.
2. *Buliminella elegantissima* (d'Orbigny), × 50.
3. *Buliminella curta* Cushman, × 50.
4. *Bulimina* sp., × 50.
5–6. *Bulimina elongata* d'Orbigny, × 50.
7a–b. *Ellipsolagena bidens* Cushman, × 50.
8a–b. *Entosolenia lucida* Williamson, × 50.
9. *Entosolenia quadrata* Williamson, × 50.
10. *Entosolenia orbignyana* (Seguenza), × 50.
11. *Virgulina fusiformis* Cushman, × 50.
12. *Virgulina* (*Virgulinella*) *miocenica* Cushman and Ponton, × 50.
13a–b. *Siphogenerina lamellata* Cushman, × 50.
14a–b. *Siphogenerina spinosa* (Bagg), × 50.
15a–b. *Bolivina floridana* Cushman, × 50.
16a–b. *Bolivina* cf. *B. marginata* Cushman, × 50.
17a–c. *Bolivina calvertensis* Dorsey, n.sp., × 50.
18. *Bolivina plicatella* Cushman, × 50.
19a–b. *Bolivina obliqua* Barbat and Johnson, × 50.
20a–b. *Bolivina paula* Cushman and Cahill, × 50.
21a–b. *Uvigerina directa* Dorsey, n.sp., × 50.
22. *Uvigerina subperegrina* Cushman and Kleinpell, × 50.
23. *Uvigerina auberiana* d'Orbigny, × 50.
24. *Uvigerina kernensis* Barbat and von Estorff, × 50.
25. *Uvigerina carmeloensis* Cushman and Kleinpell, × 50.

PLATE XXXVII

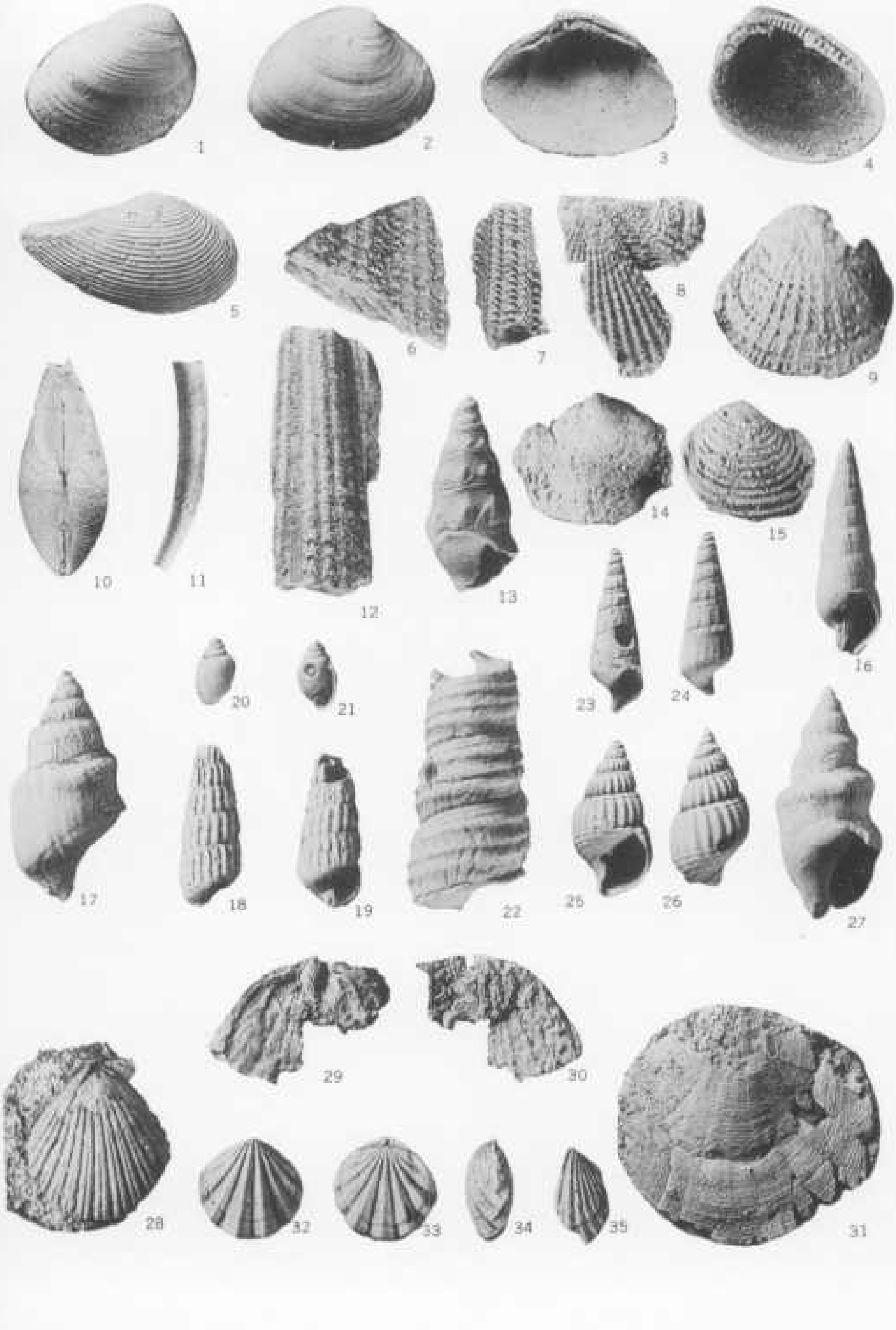
1a–c. *Discorbis valvulata* (d'Orbigny), × 30.
2a–c. *Discorbis cavernata* Dorsey, n.sp., × 30.
3a–c. *Discorbis* sp., × 30.
4a–c. *Discorbis candeiana* (d'Orbigny), × 30.
5a–c. *Discorbis warreni* Dorsey, n.sp., × 30.
6a–c. *Valvulineria floridana* Cushman, × 30.
7a–c. *Eponides mansfieldi* Cushman, × 30.
8a–c. *Rotalia bassleri* Cushman and Cahill, × 30.
9a–c. *Rotalia beccarii* Linnaeus var. *tepida* Cushman, × 30.
10a–c. *Cancris sagra* (d'Orbigny) var. *communis* Cushman and Todd, × 30.

PLATE XXXVIII

1a–c. *Cassidulina laevigata* d'Orbigny var., × 30.
2a–c. *Cassidulina crassa* d'Orbigny, × 30.
3a–c. *Globigerina altispira* Cushman and Jarvis, × 30.
4a–b. *Globigerina* sp., × 30.
5, 6, 7. *Globigerinoides* sp. A, × 30.
8, 9. *Globigerinoides* sp. B, × 30.
10. *Candorbulina universa* Jedlitschka, × 30.

PLATE XXXIX

1a–c, 2a–c. *Cibicides concentricus* (Cushman), × 30.
3a–c. *Cibicides* sp., × 30.
4a–c. *Cibicides americanus* (Cushman), × 30.
5a–c. *Cibicides lobatulus* (Walker and Jacob), × 30.
6a–b, 7a–b. *Dyocibicides biserialis* Cushman and Valentine, × 30.
8a–b. *Cibicidella variabilis* (d'Orbigny), × 30.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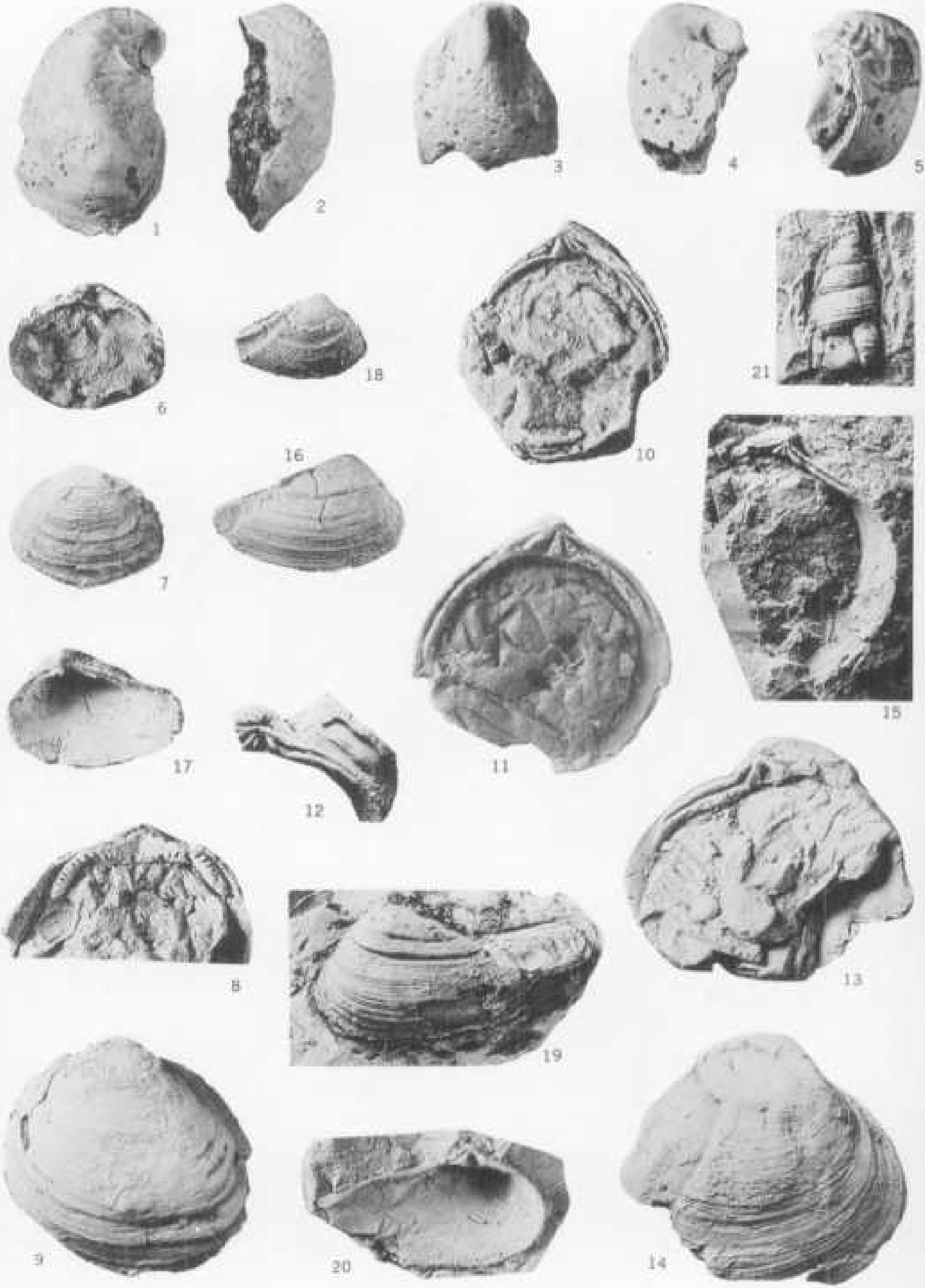
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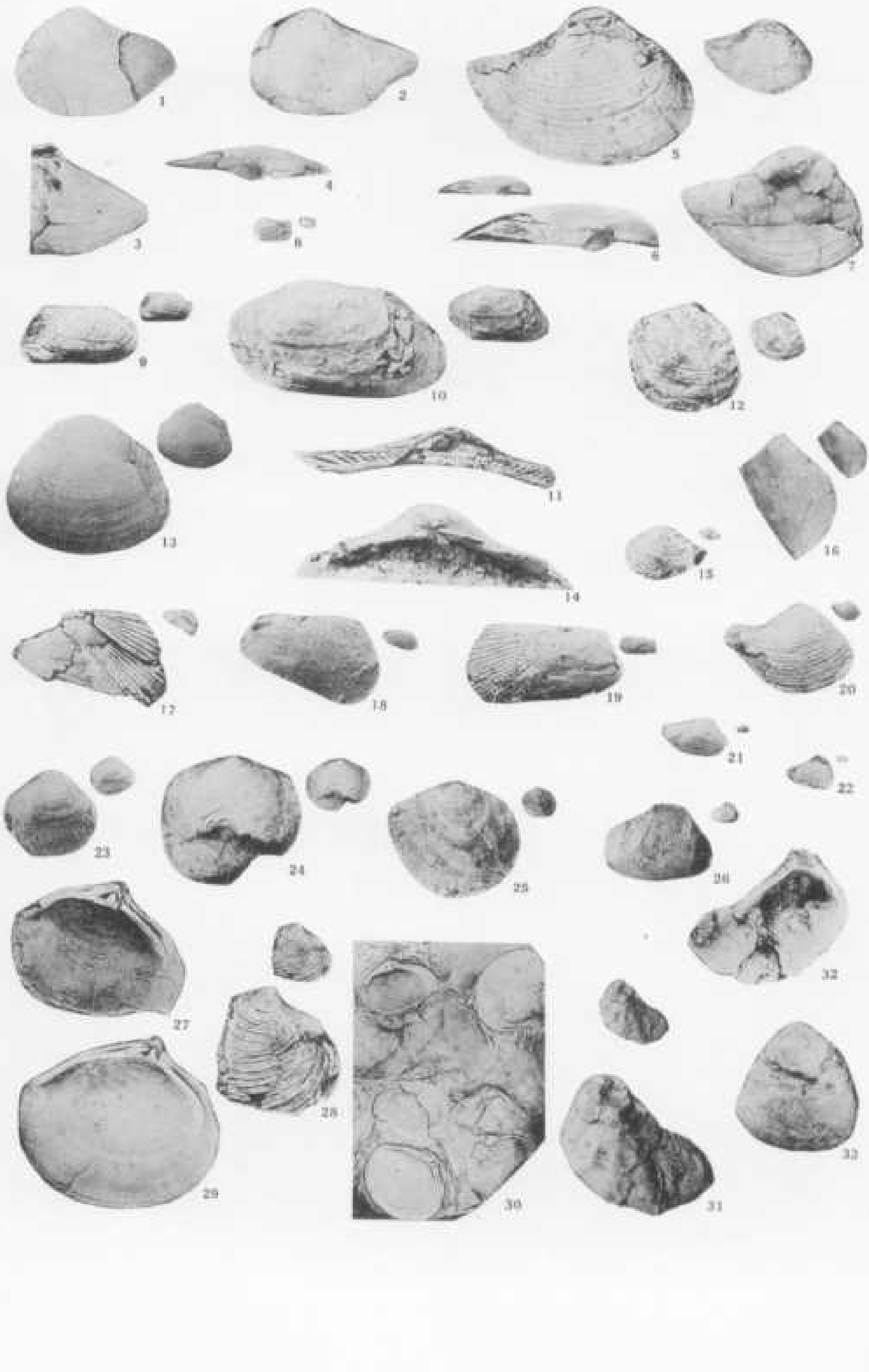
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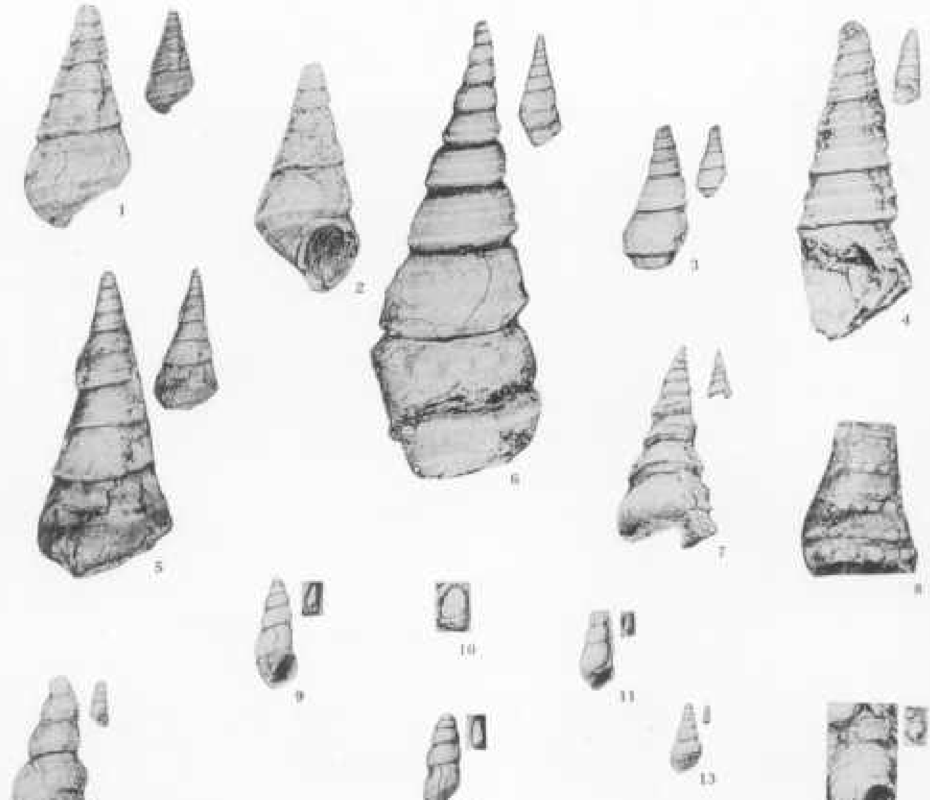
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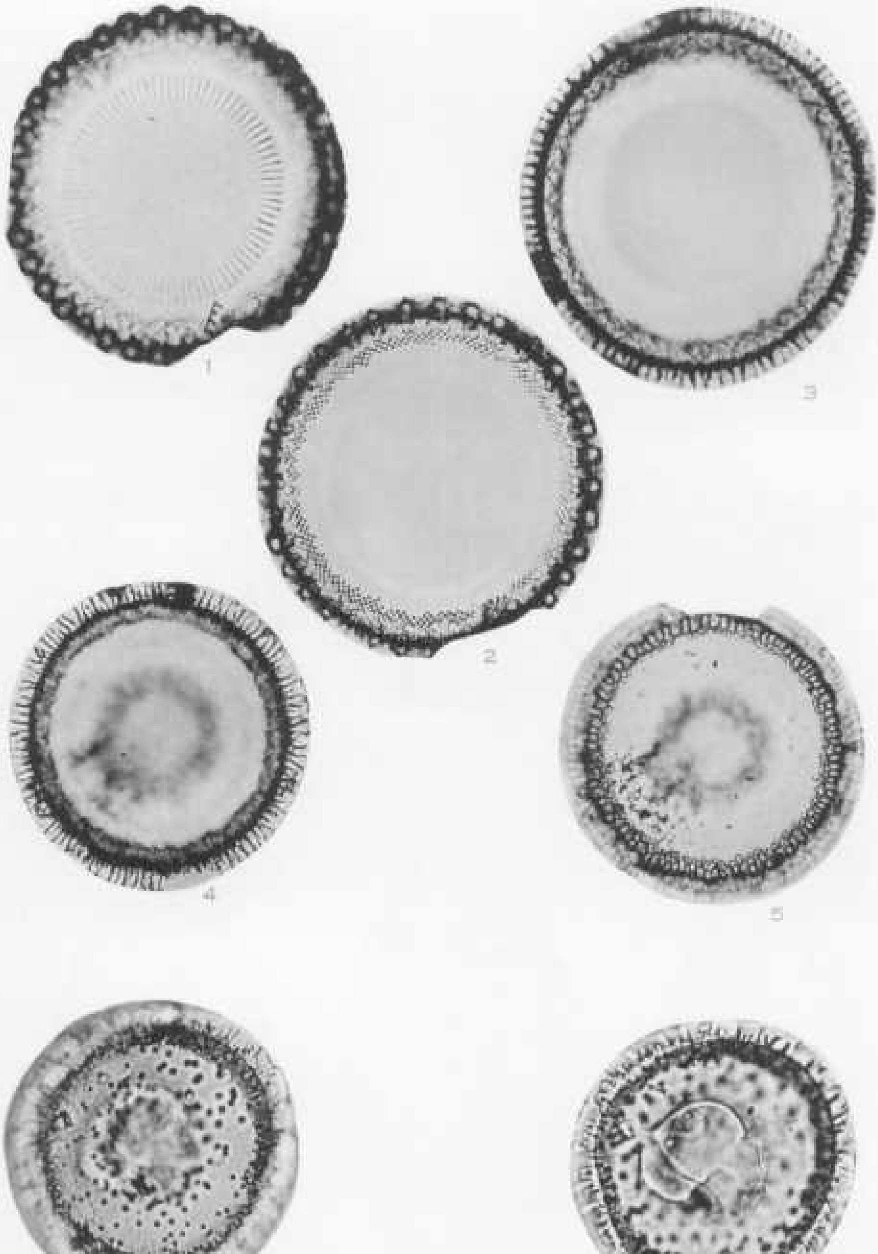
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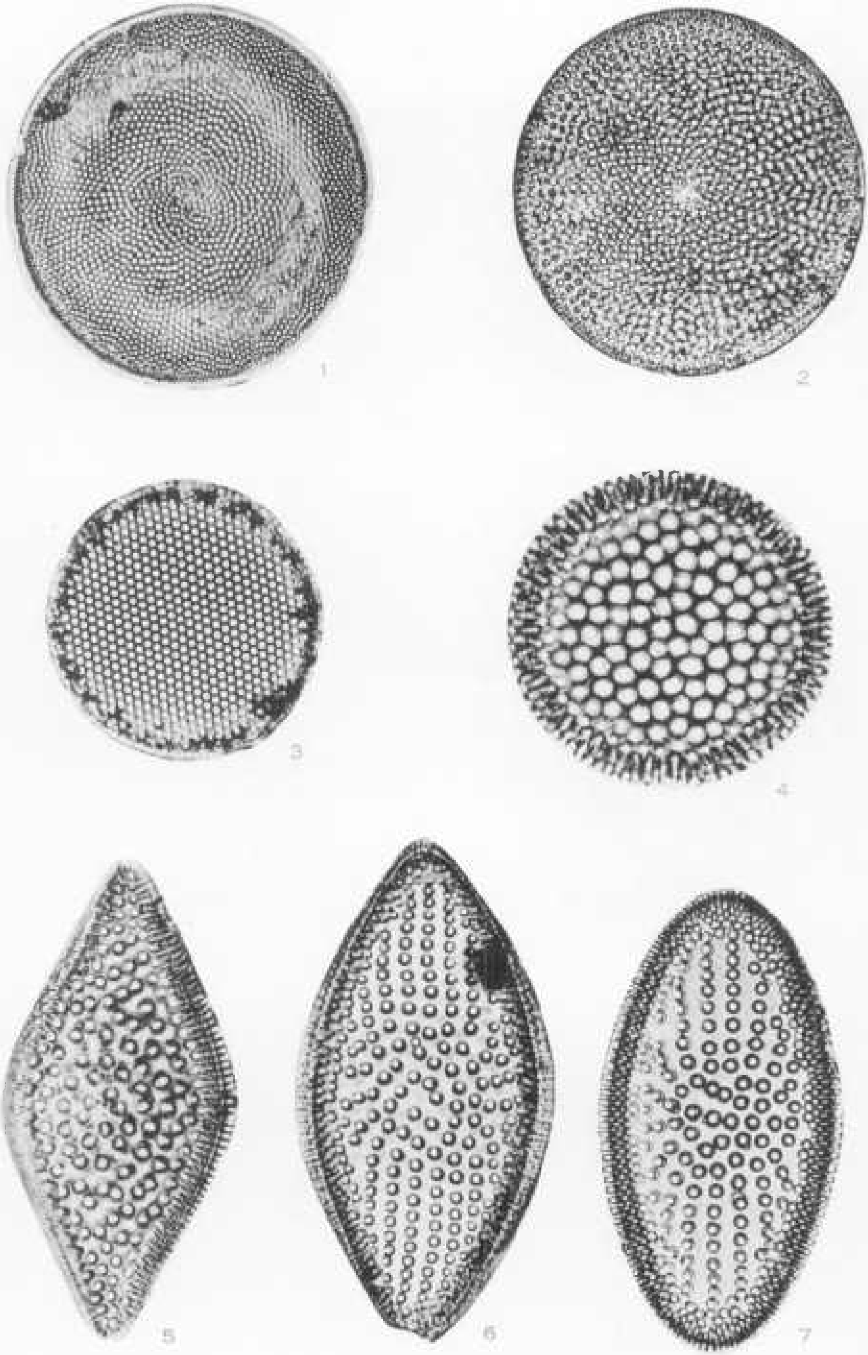
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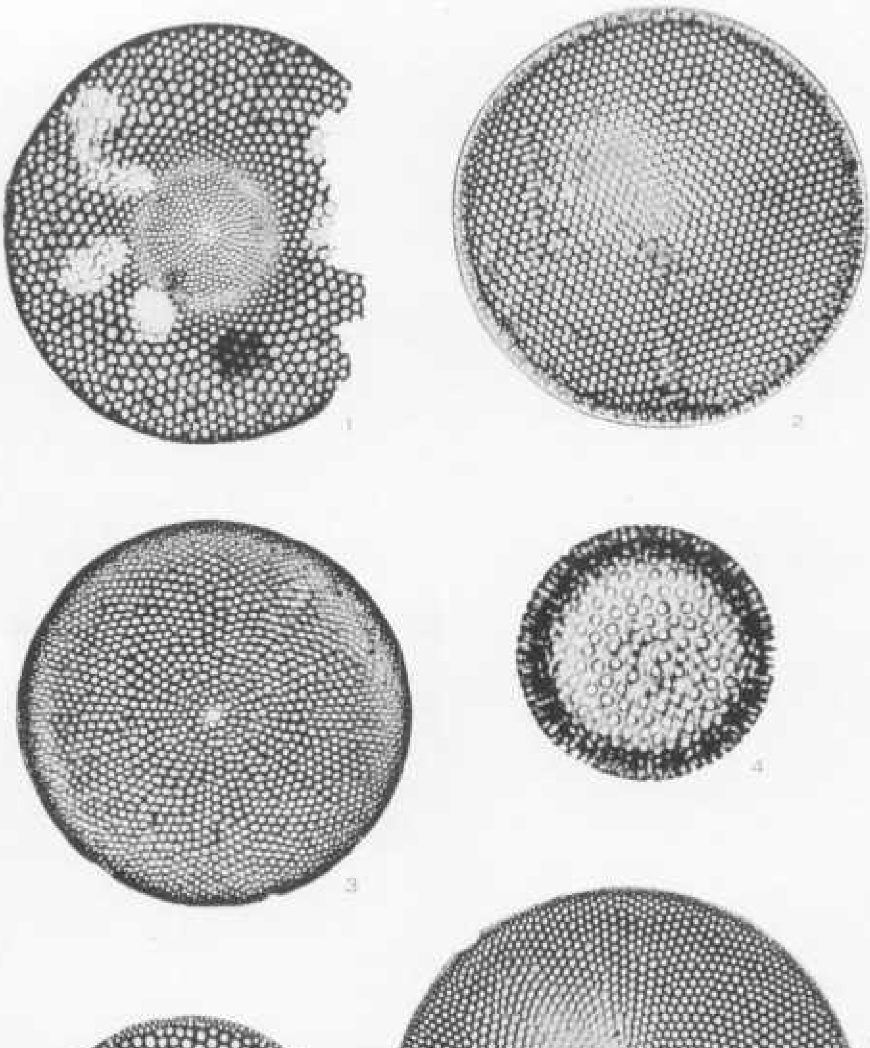

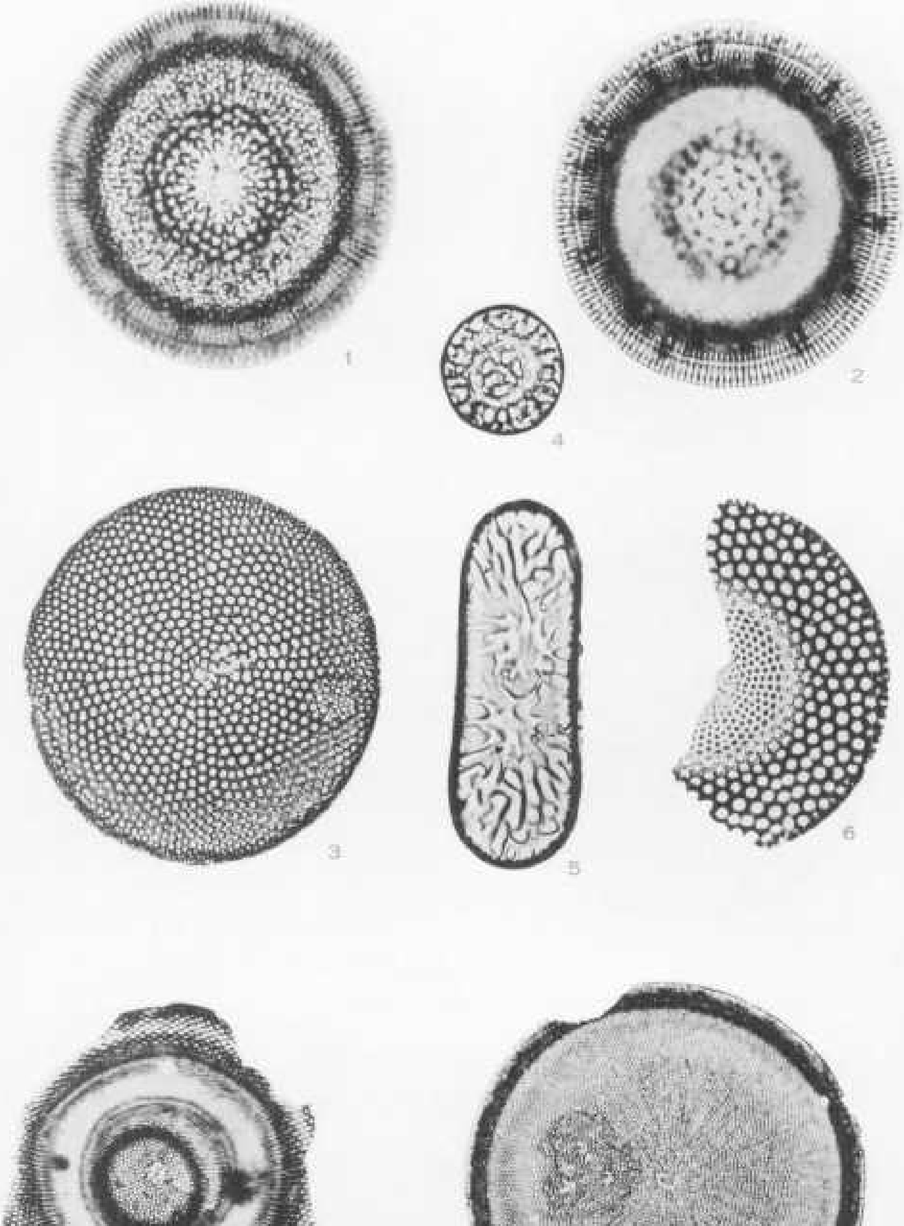
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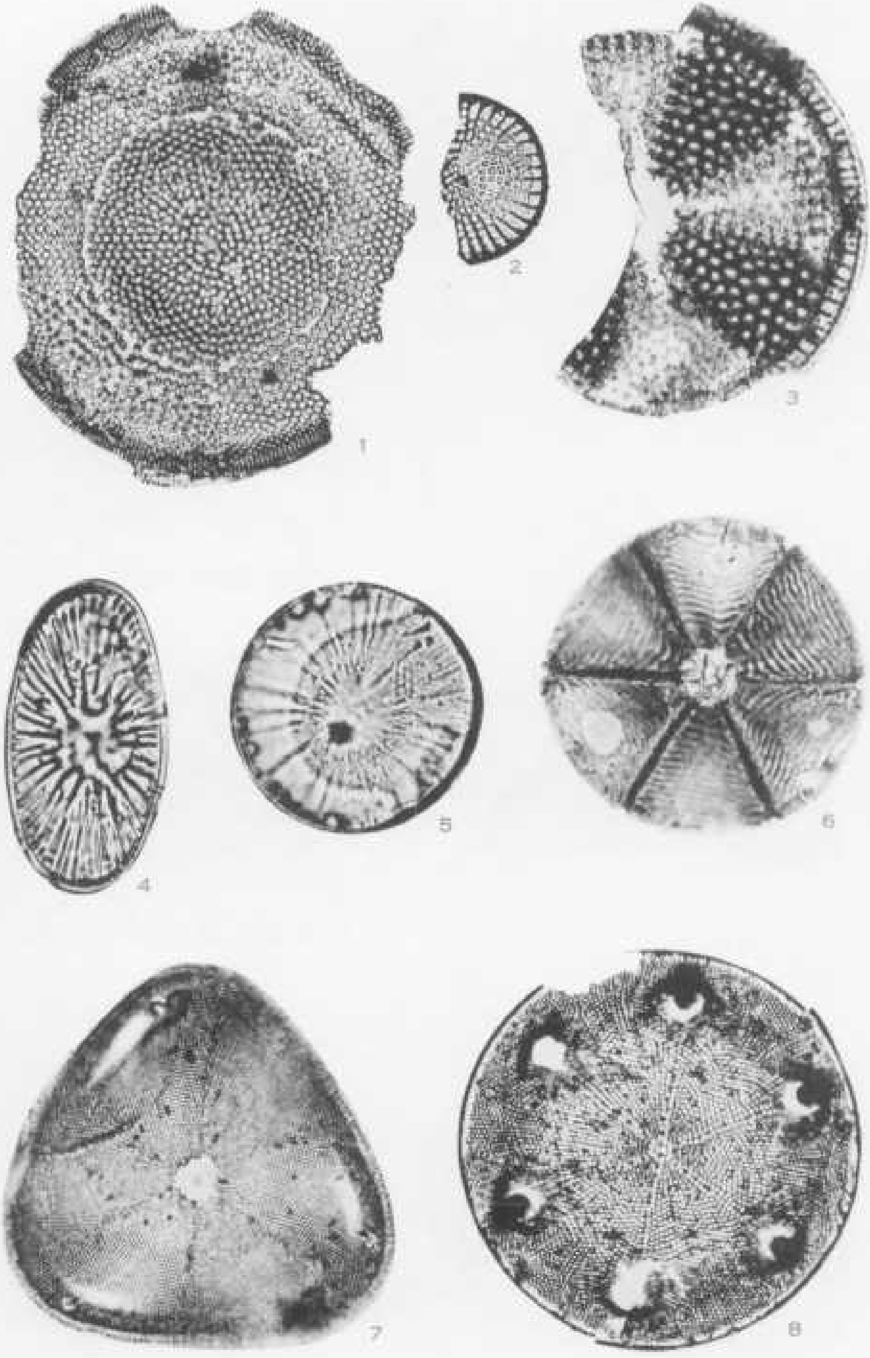
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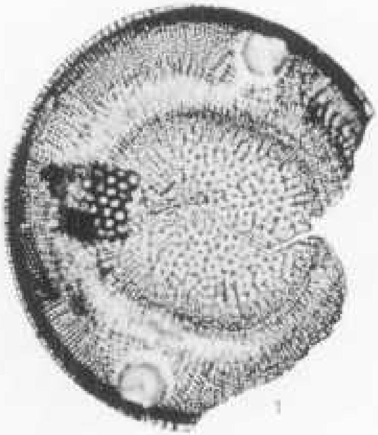
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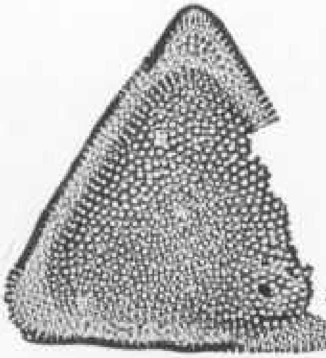
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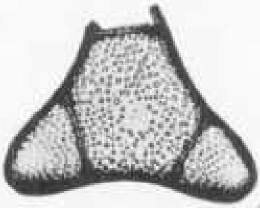
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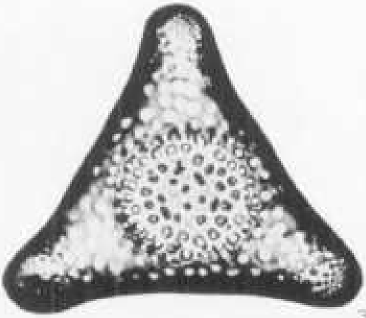
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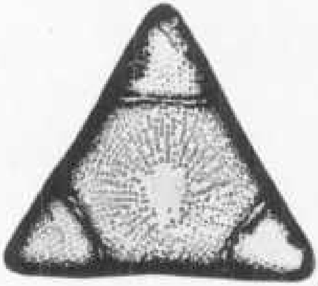
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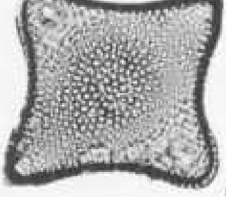
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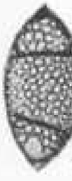
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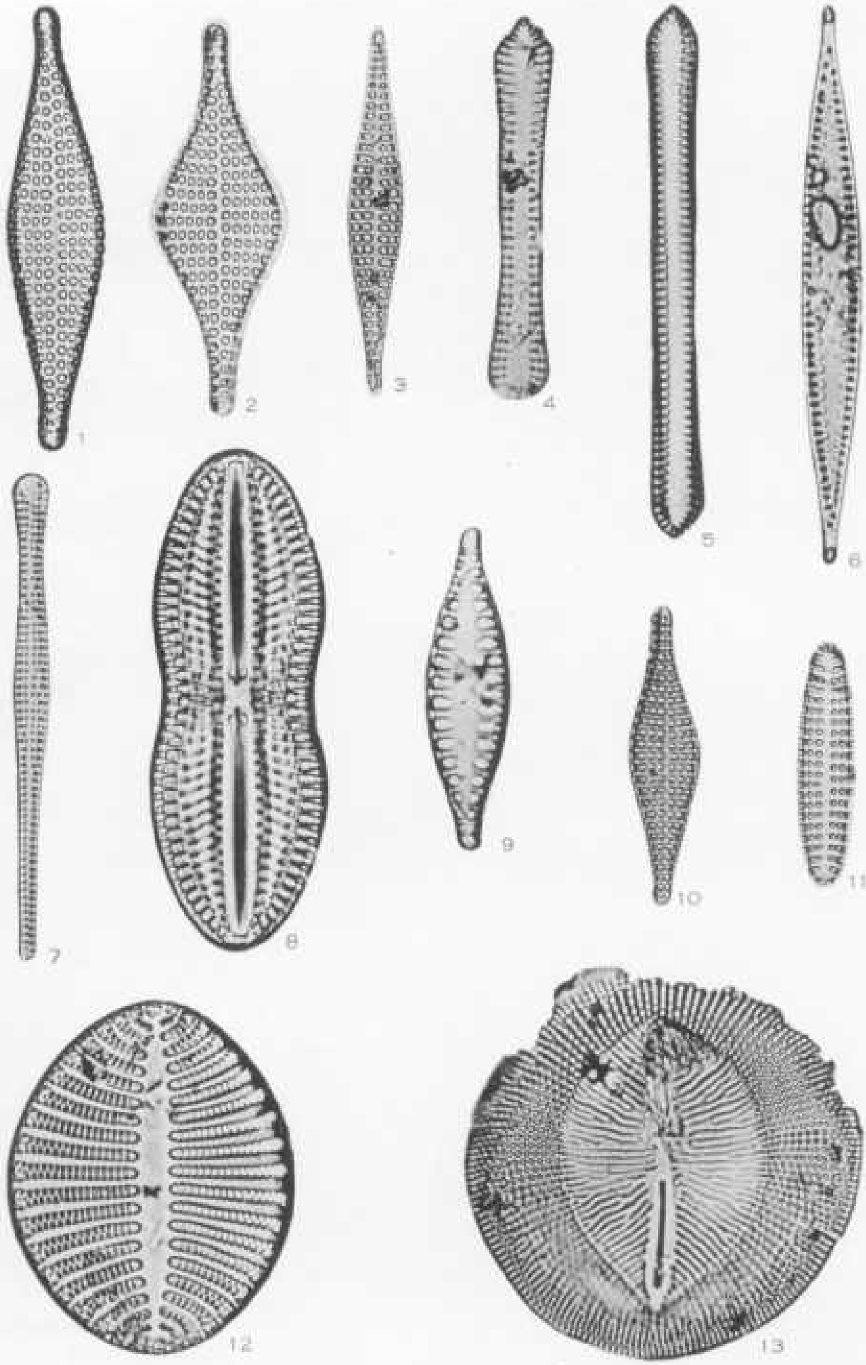
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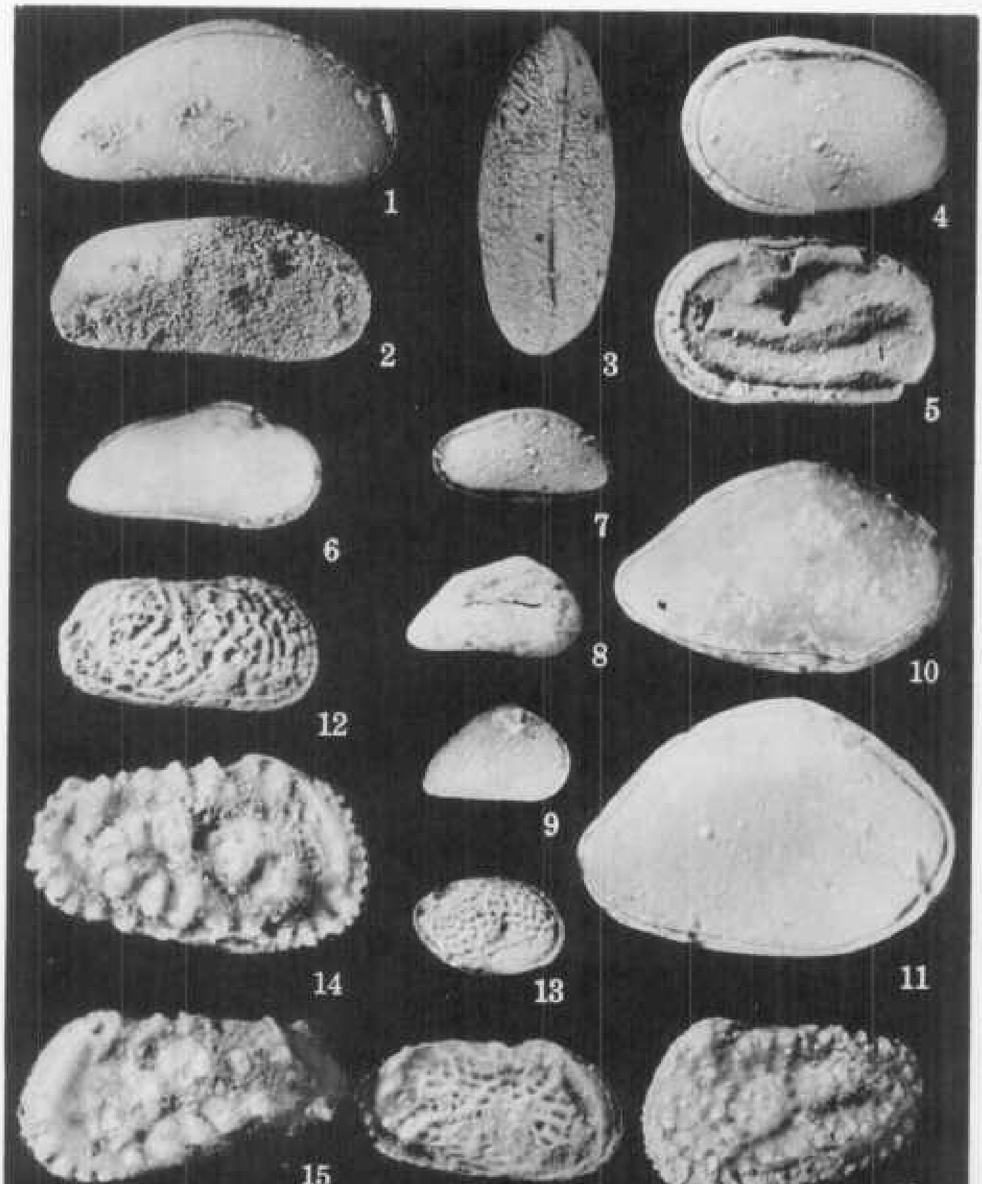
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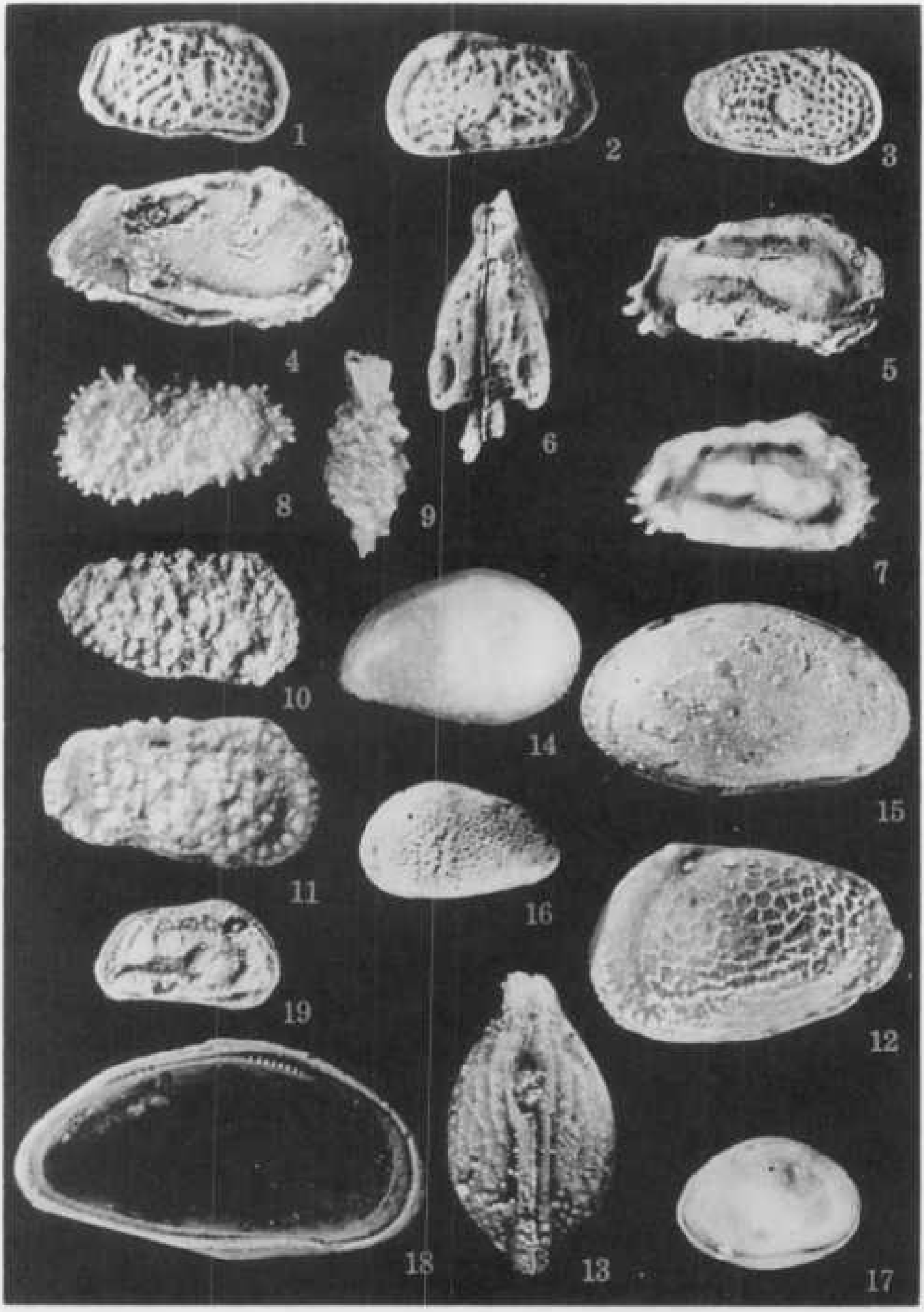
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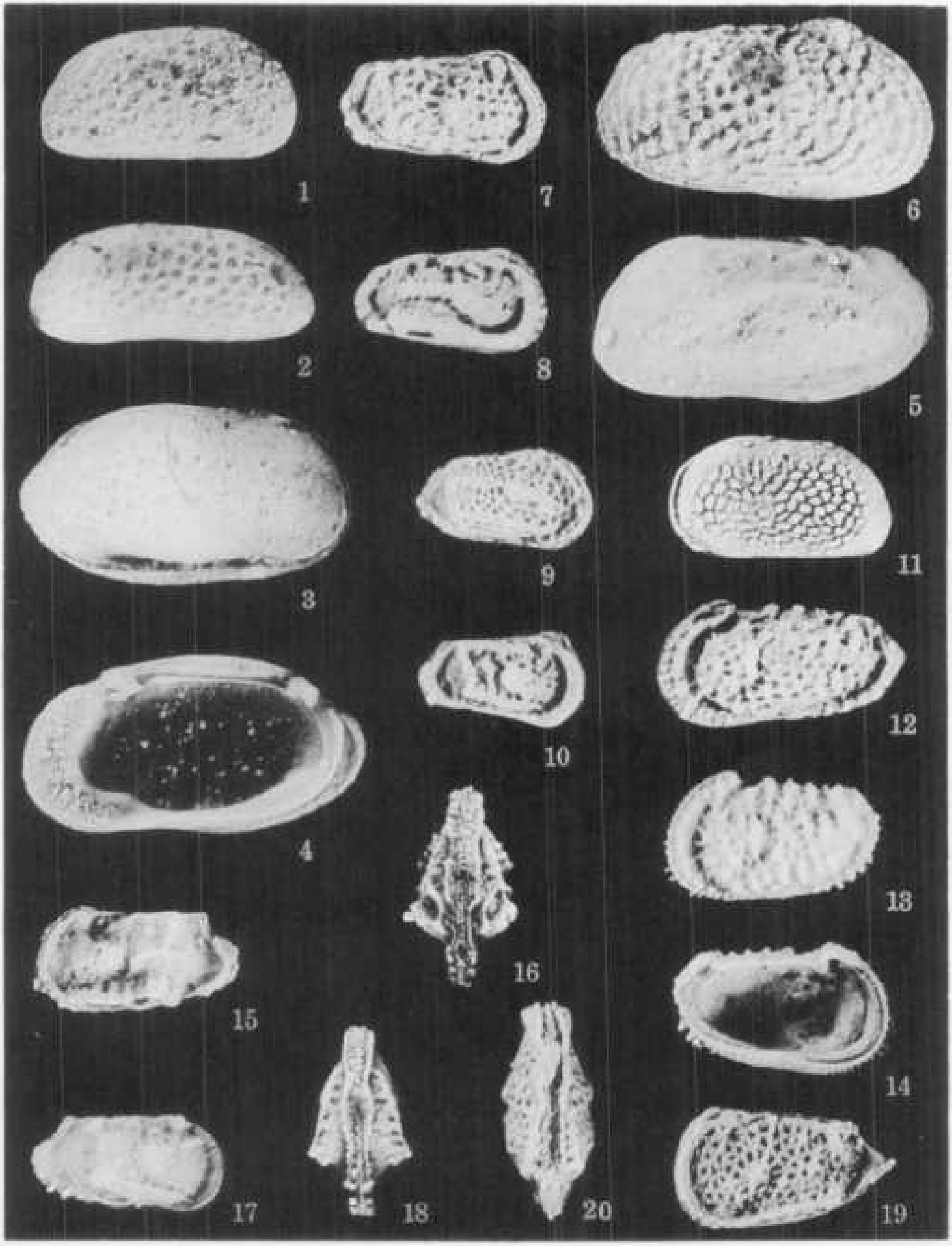
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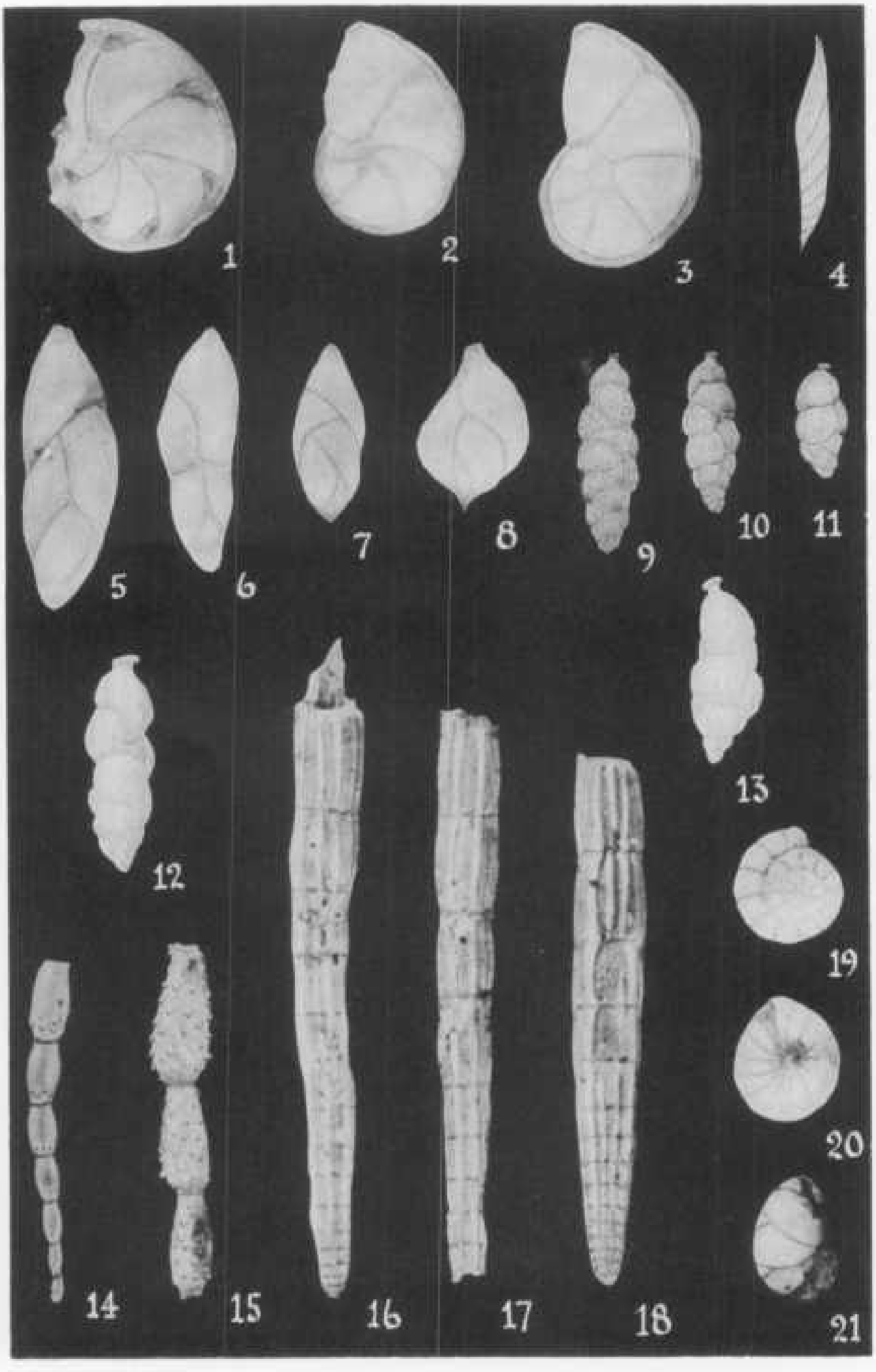
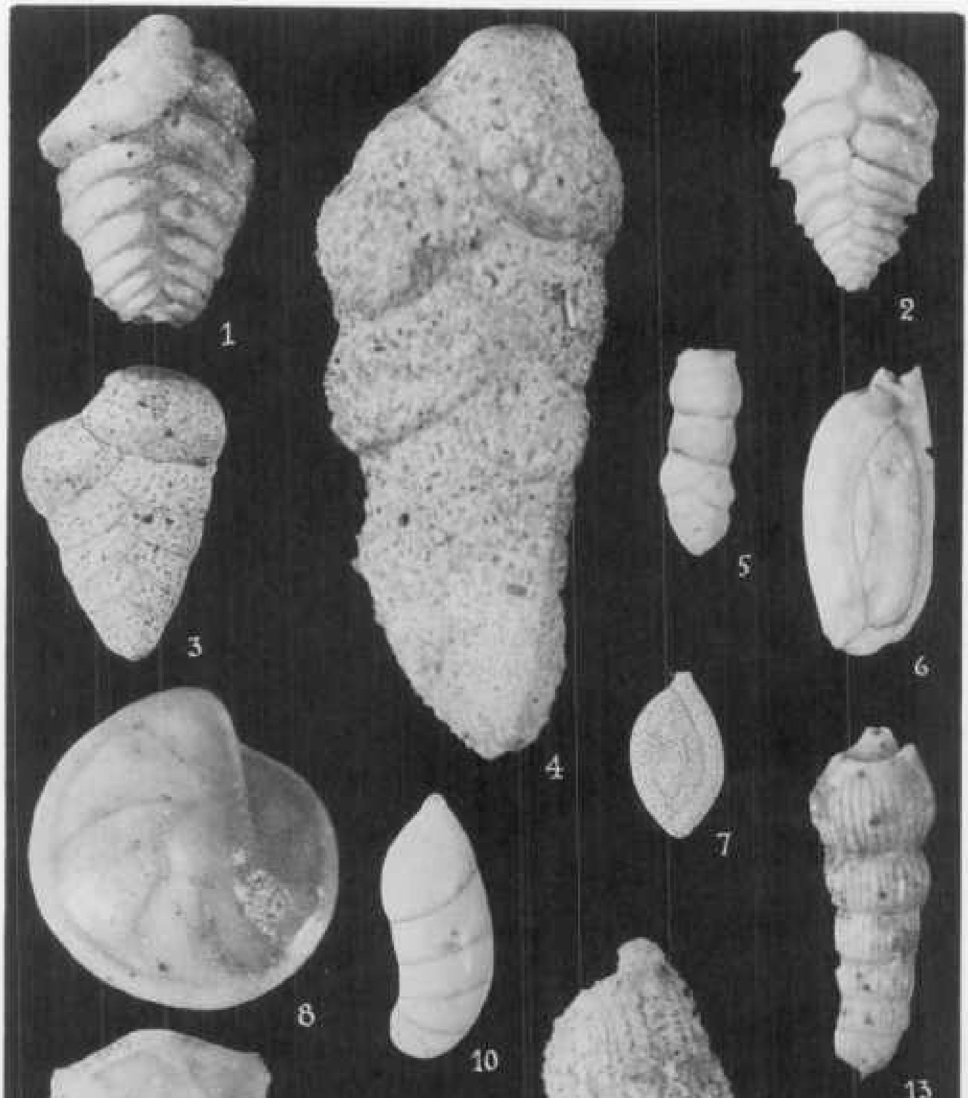
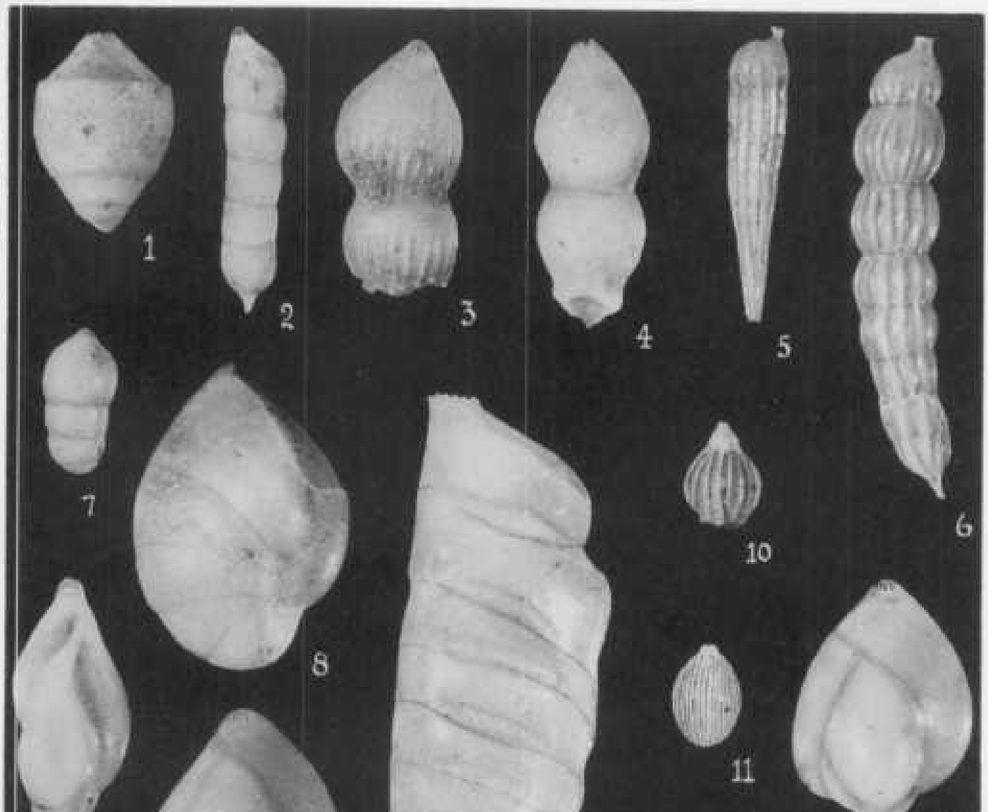
 PLATE XV



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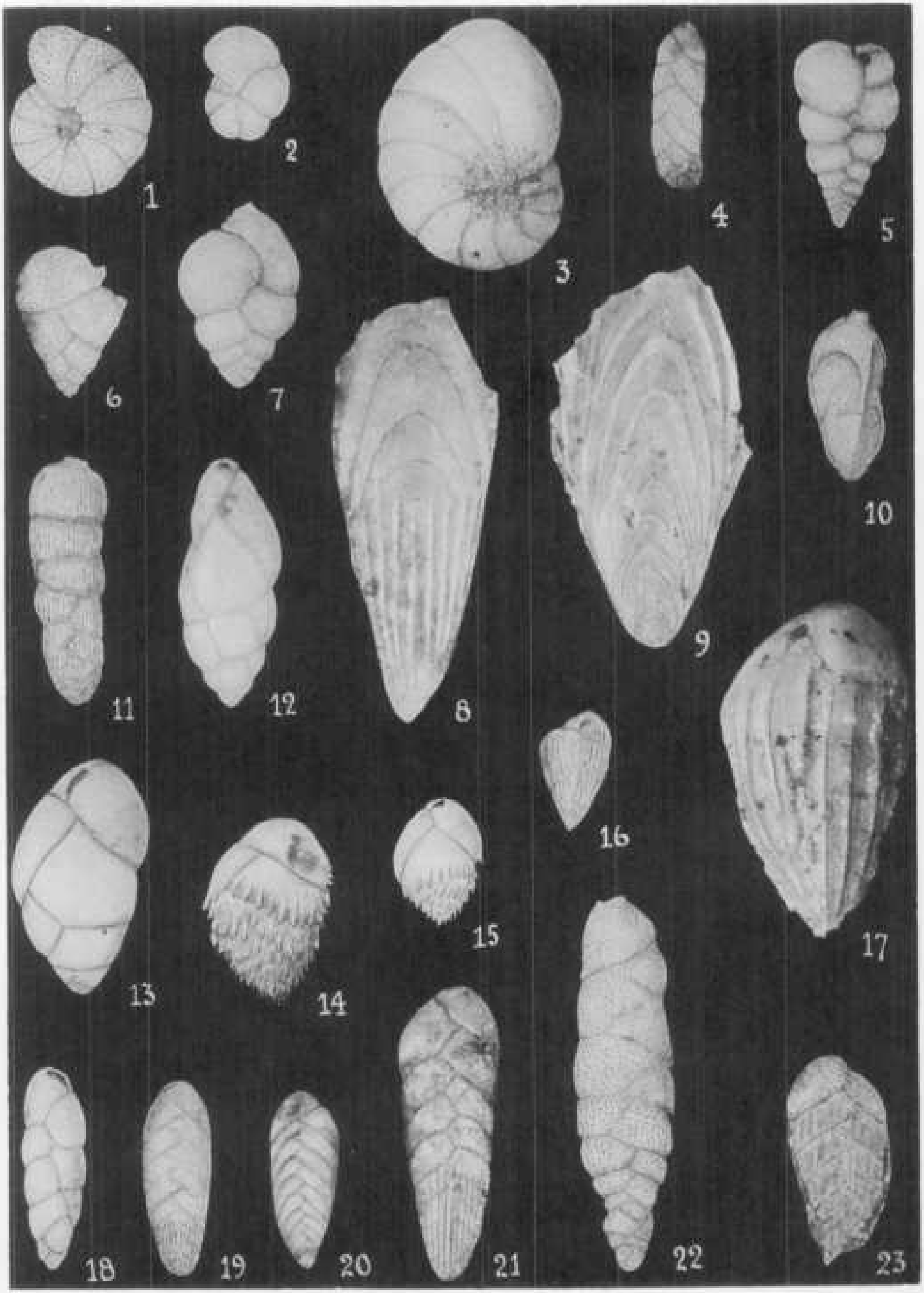
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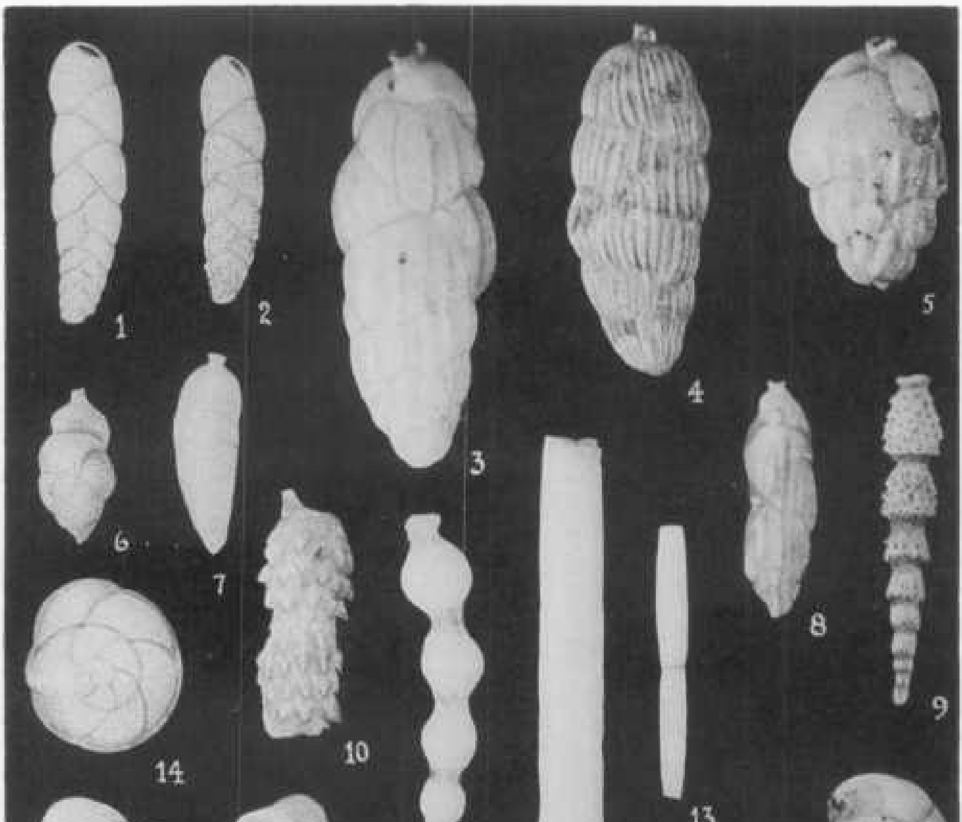
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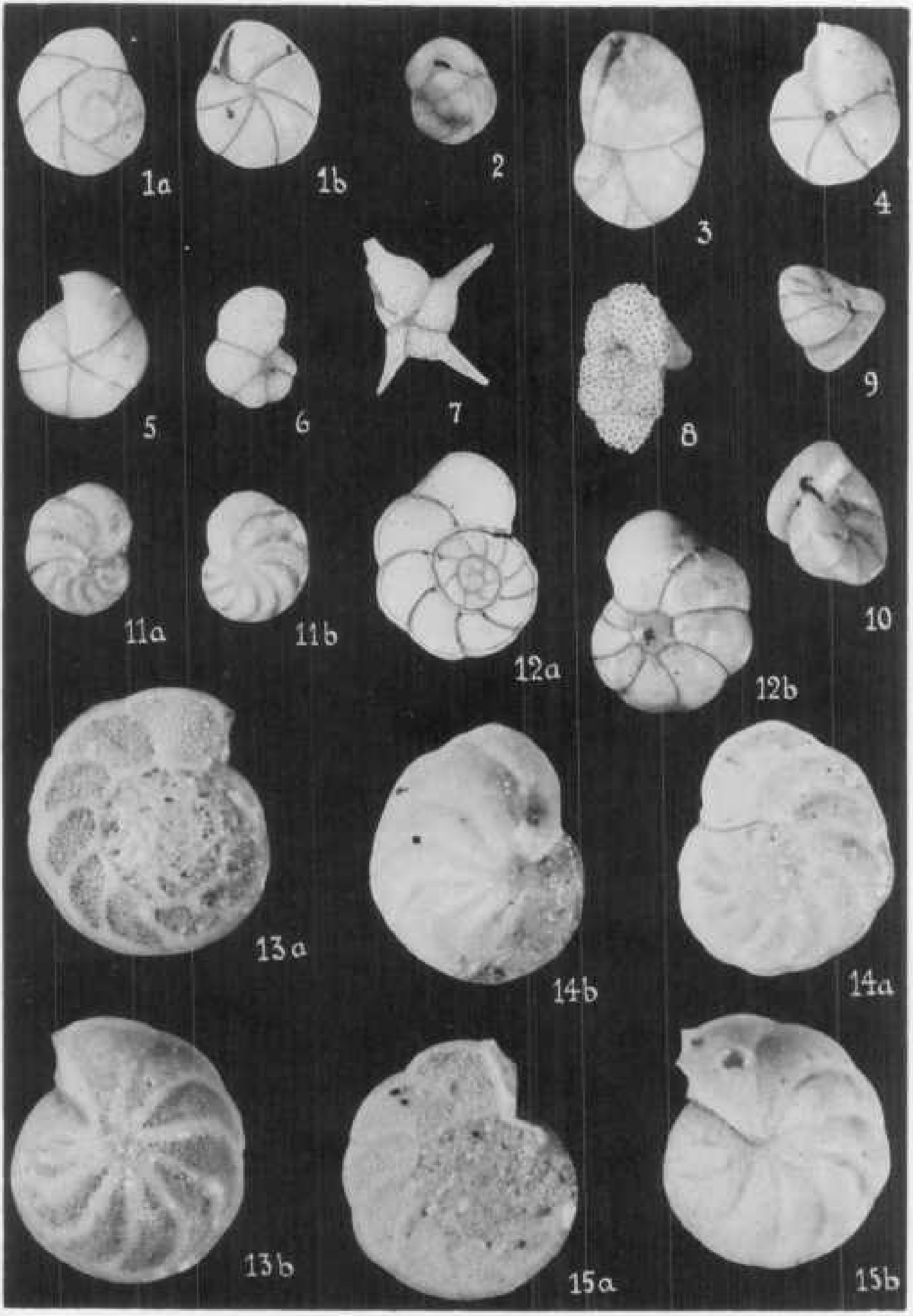
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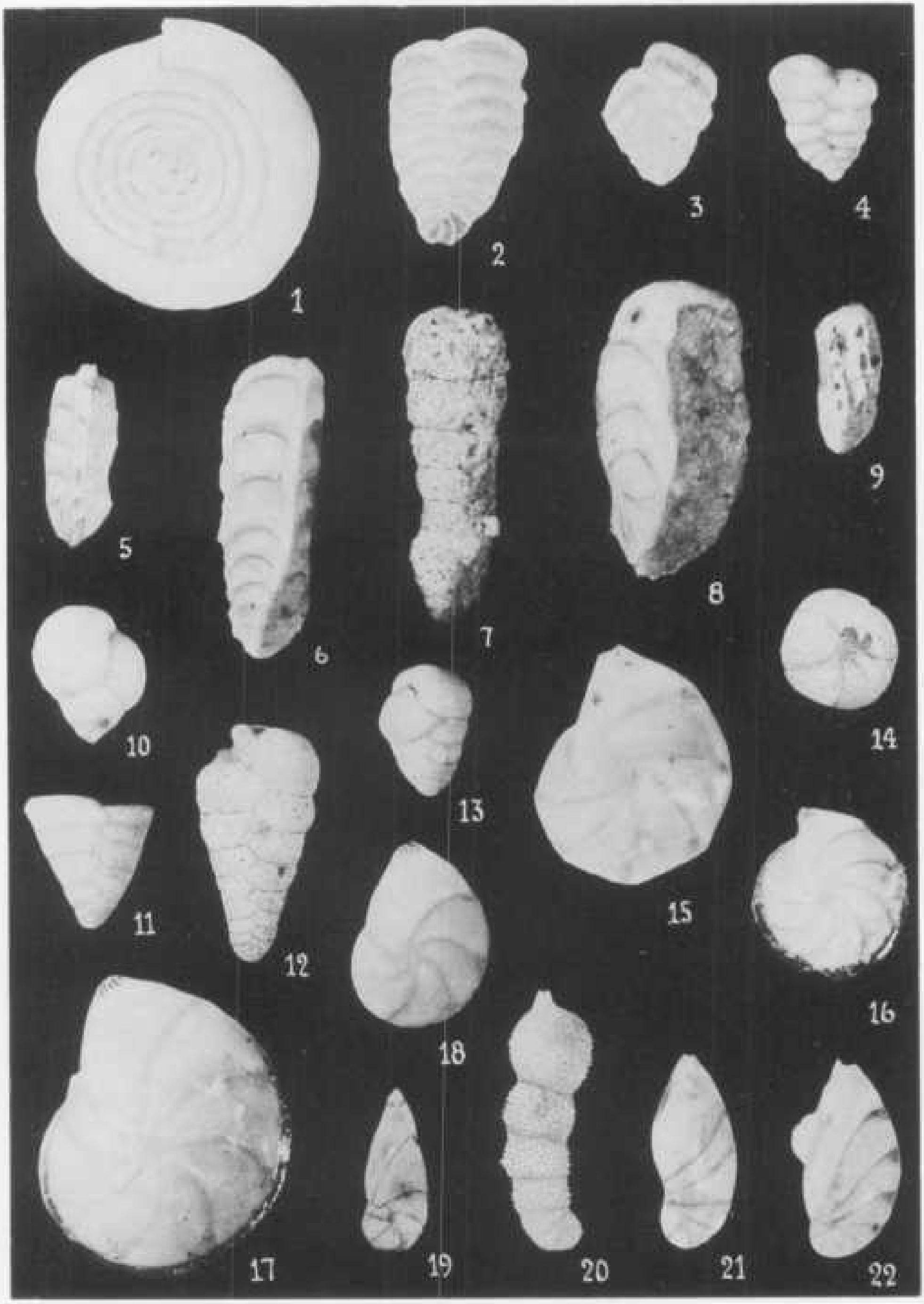
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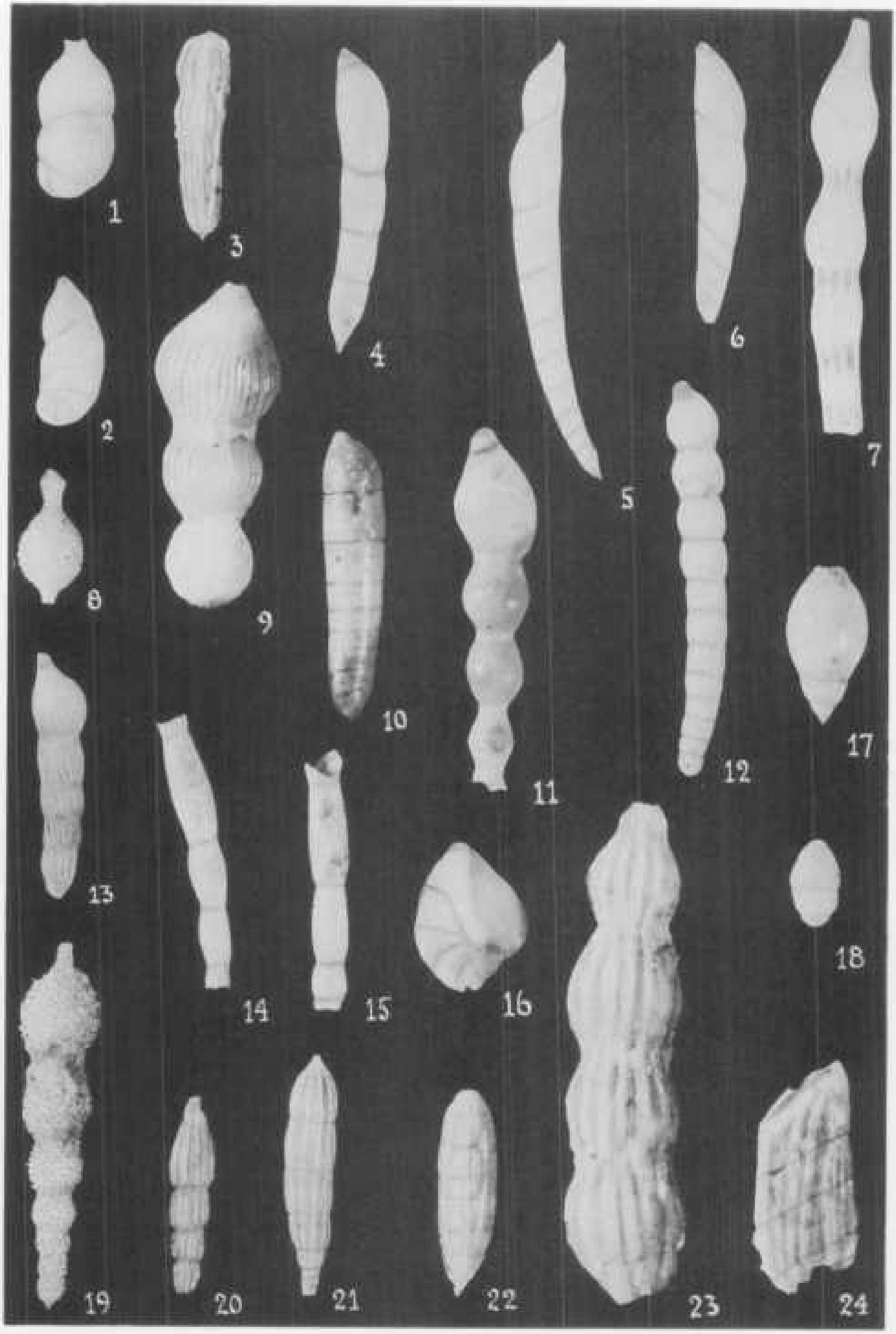
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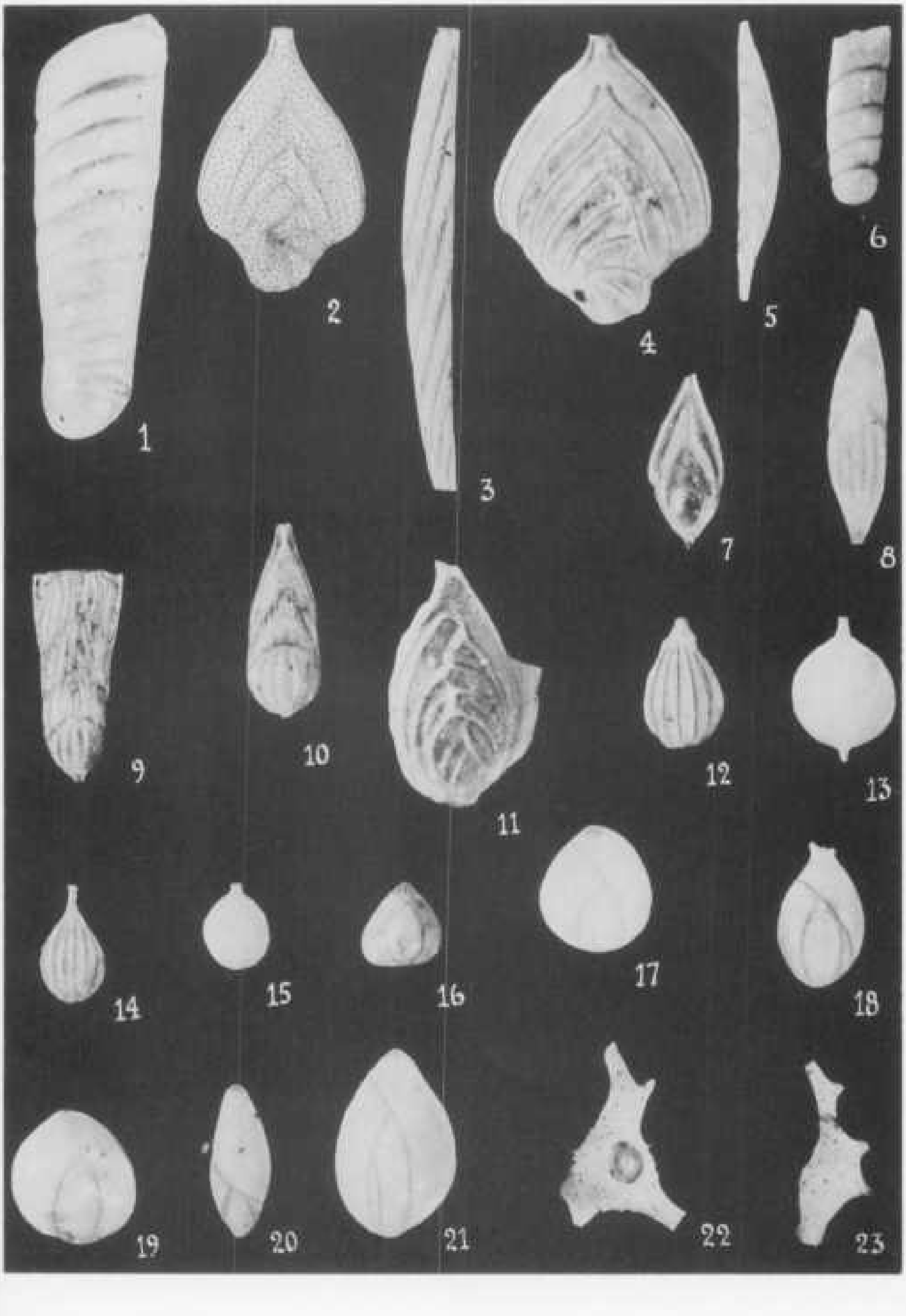
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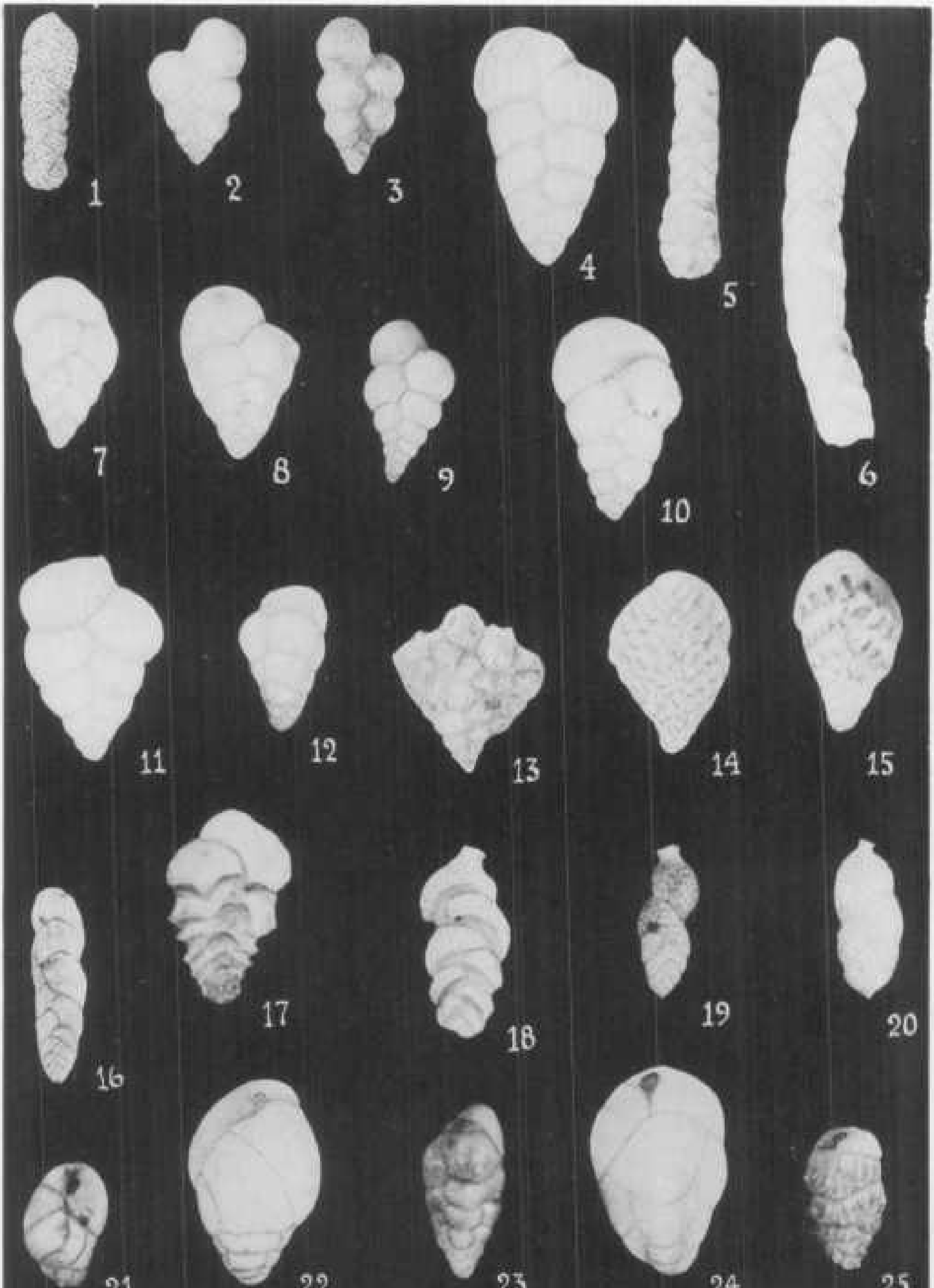

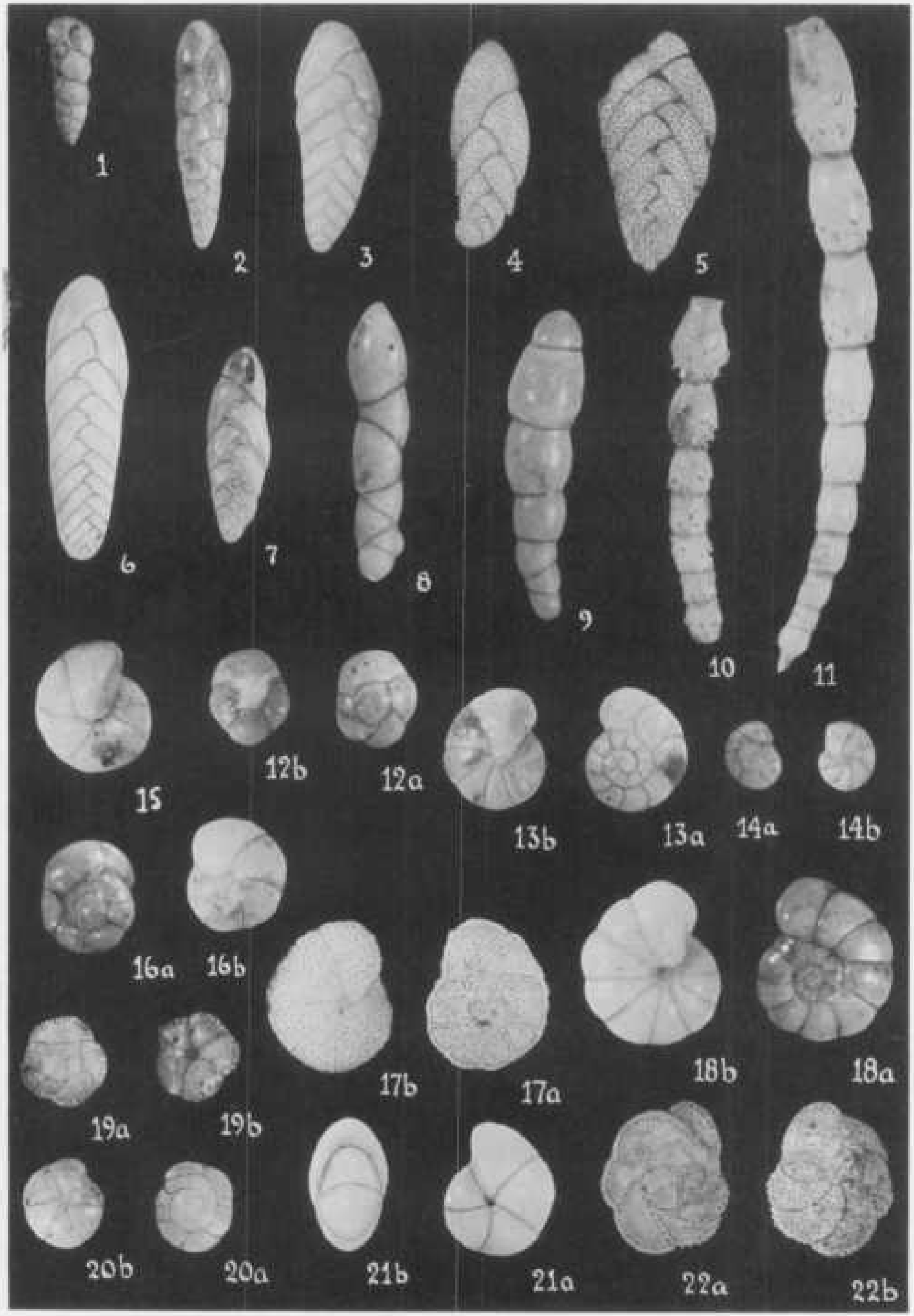
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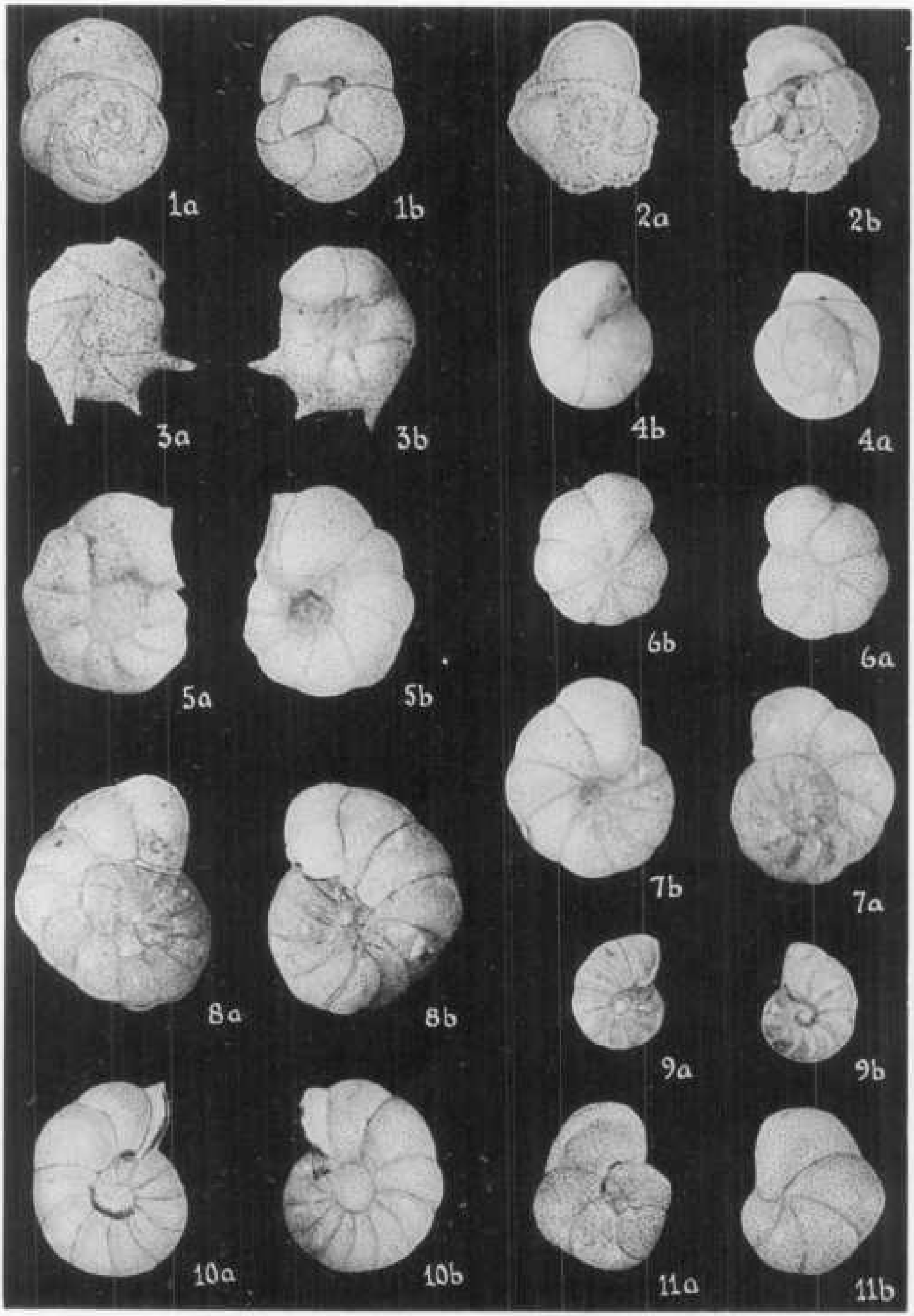
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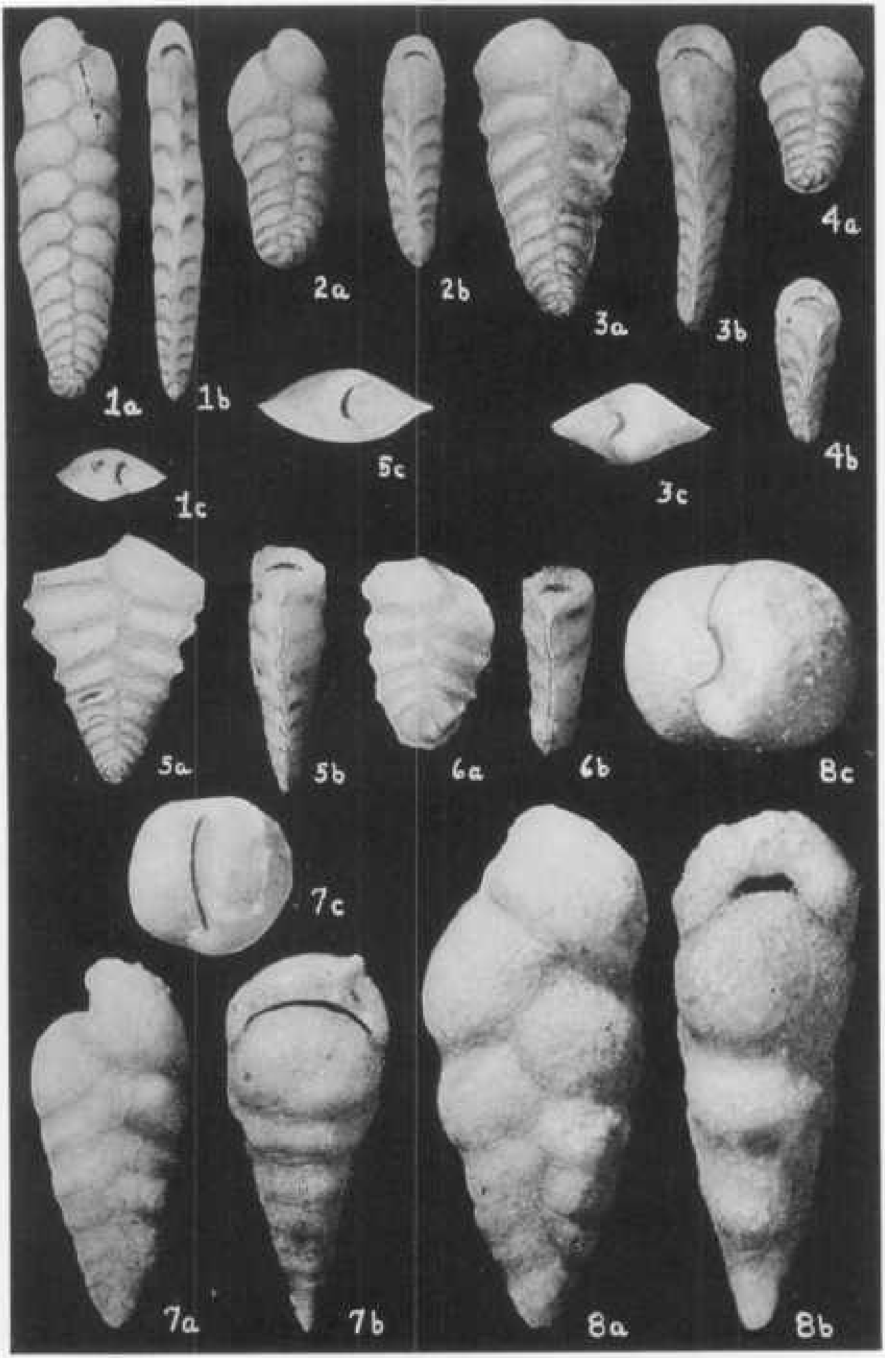
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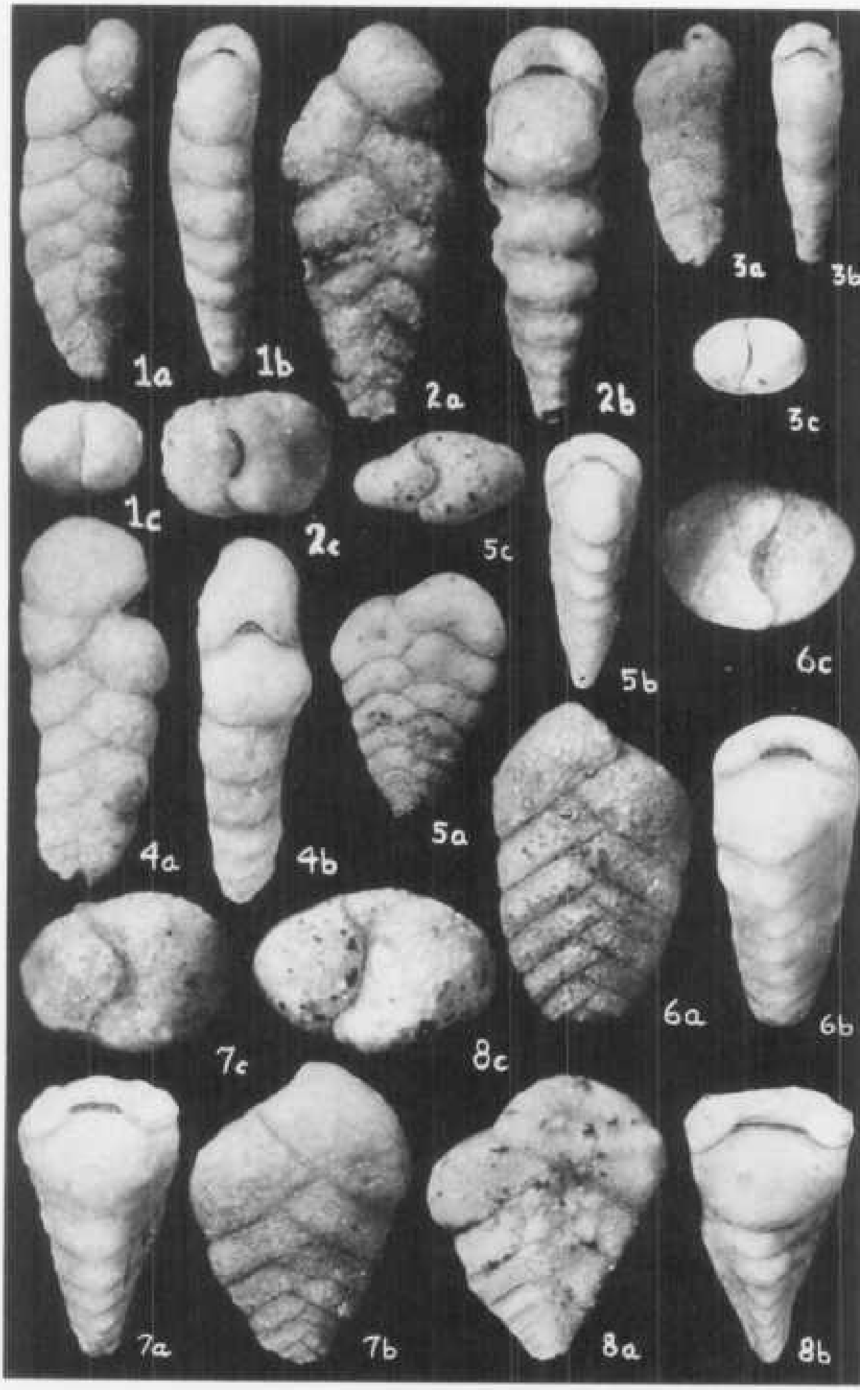
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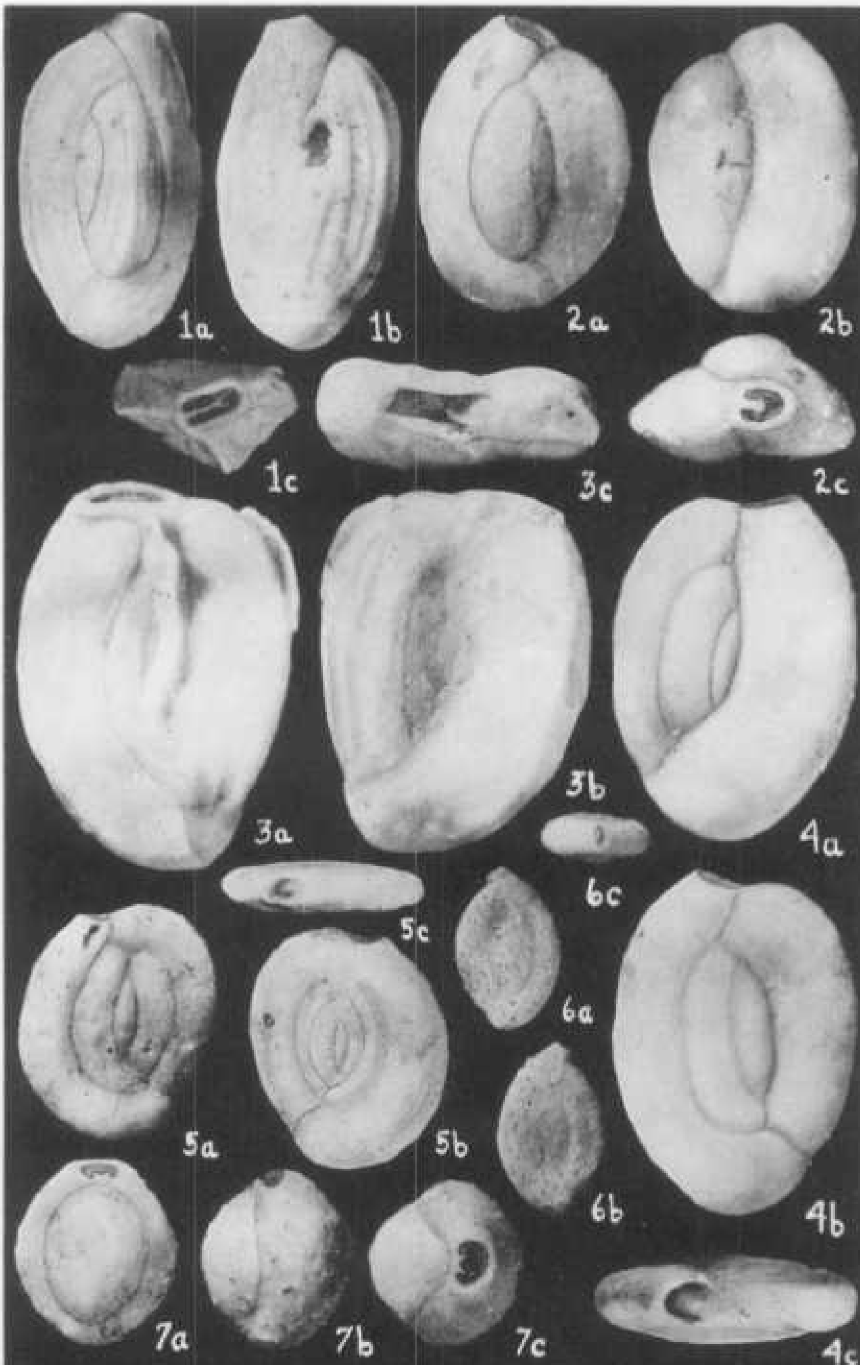
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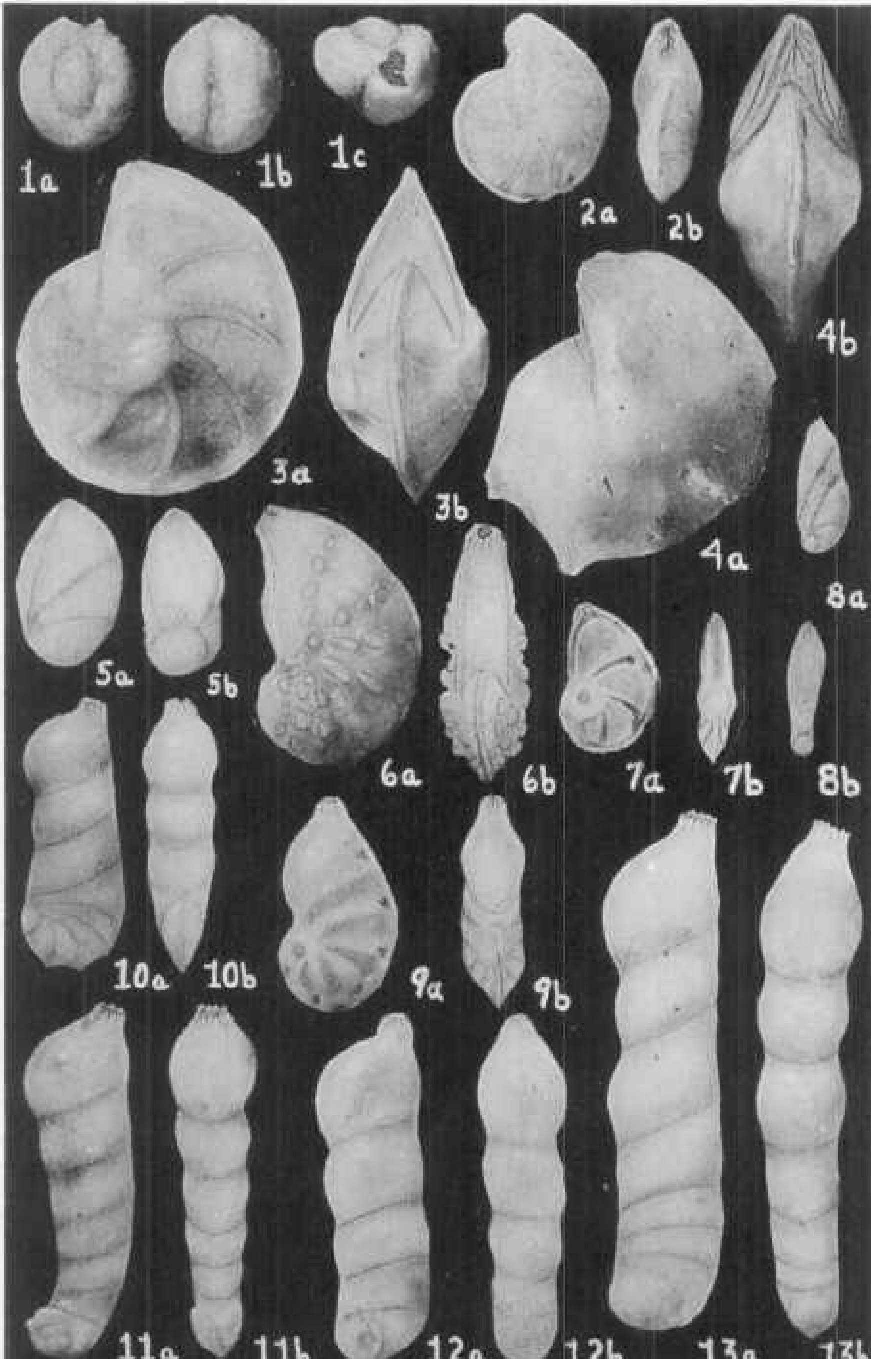
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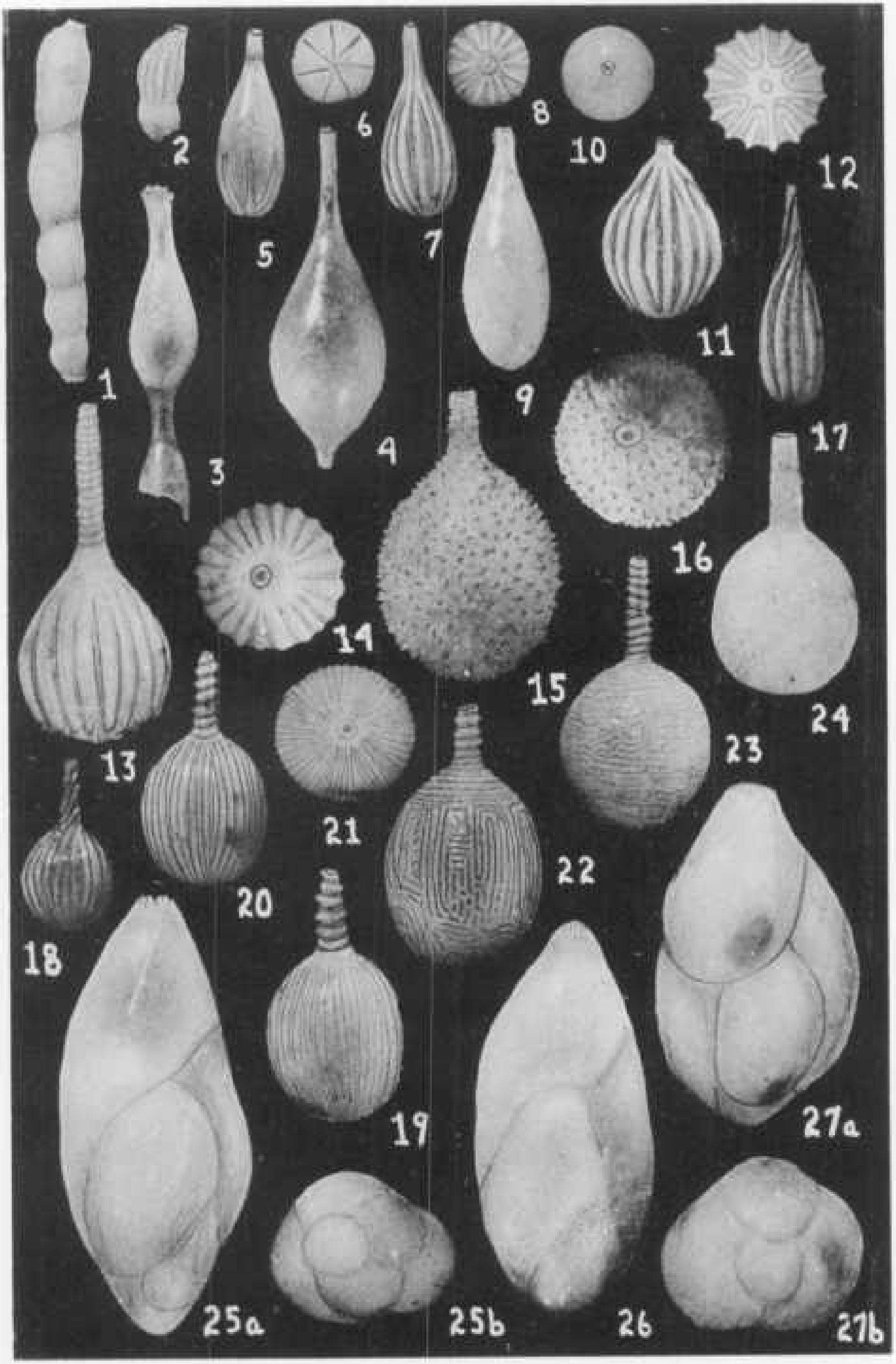
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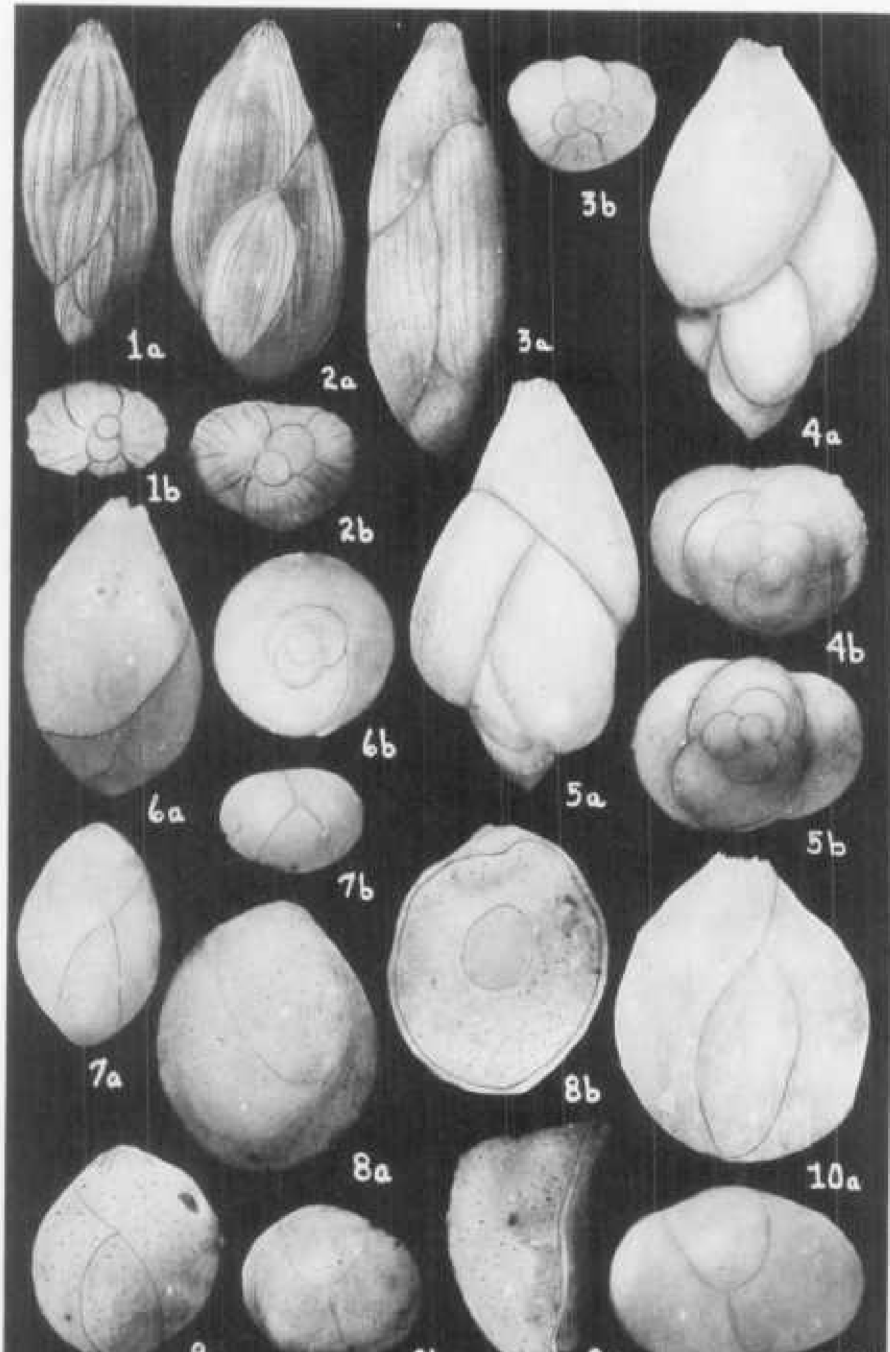
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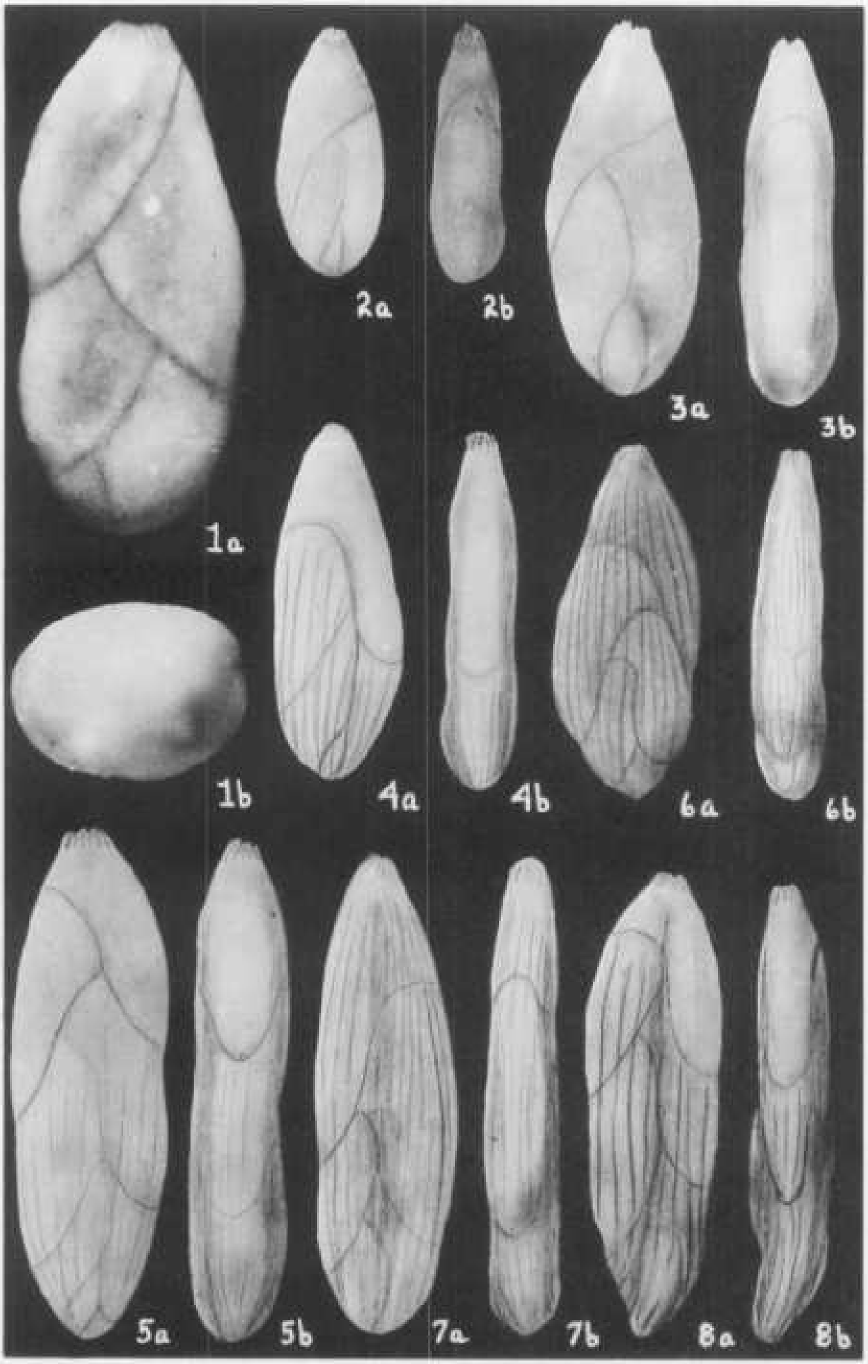
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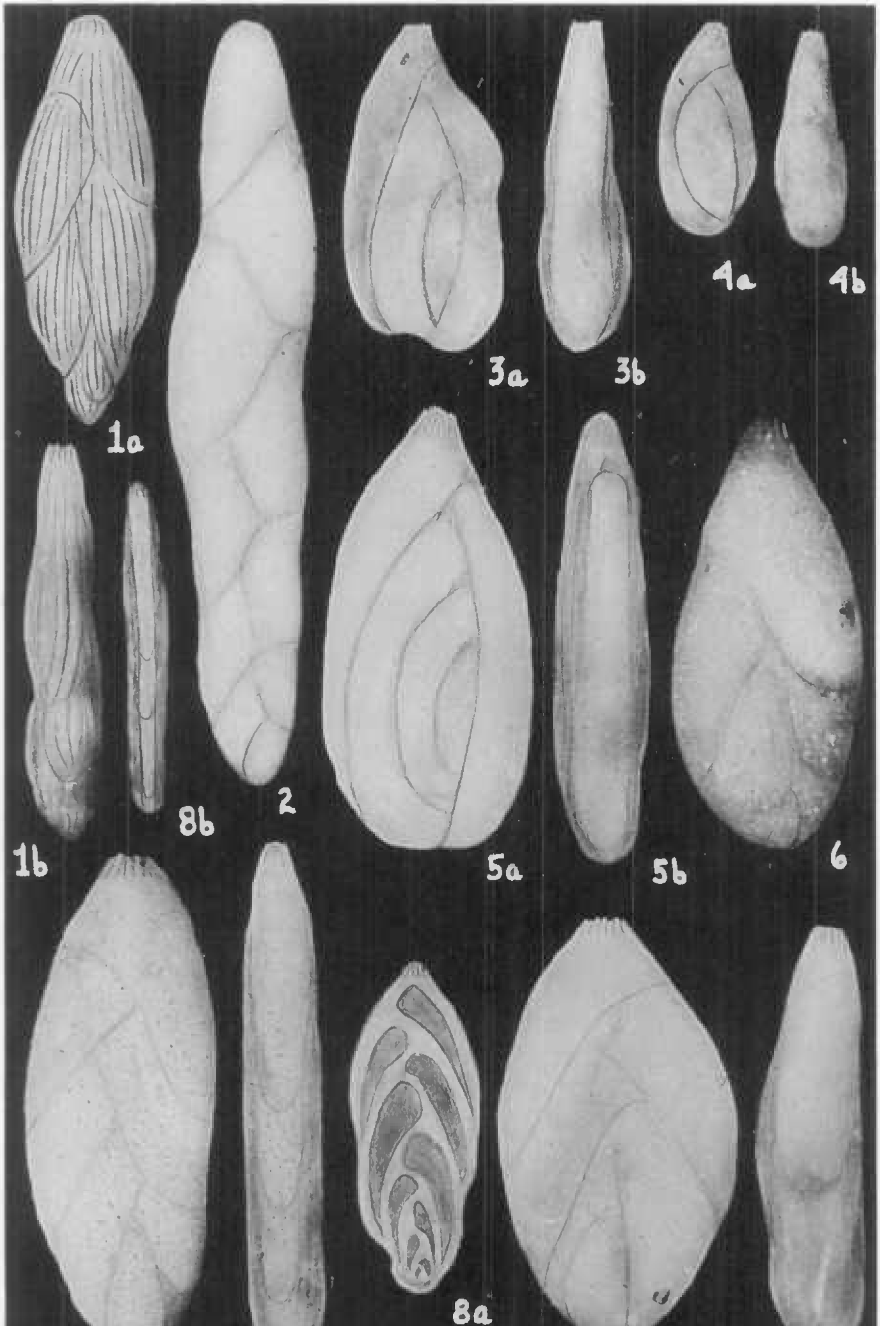
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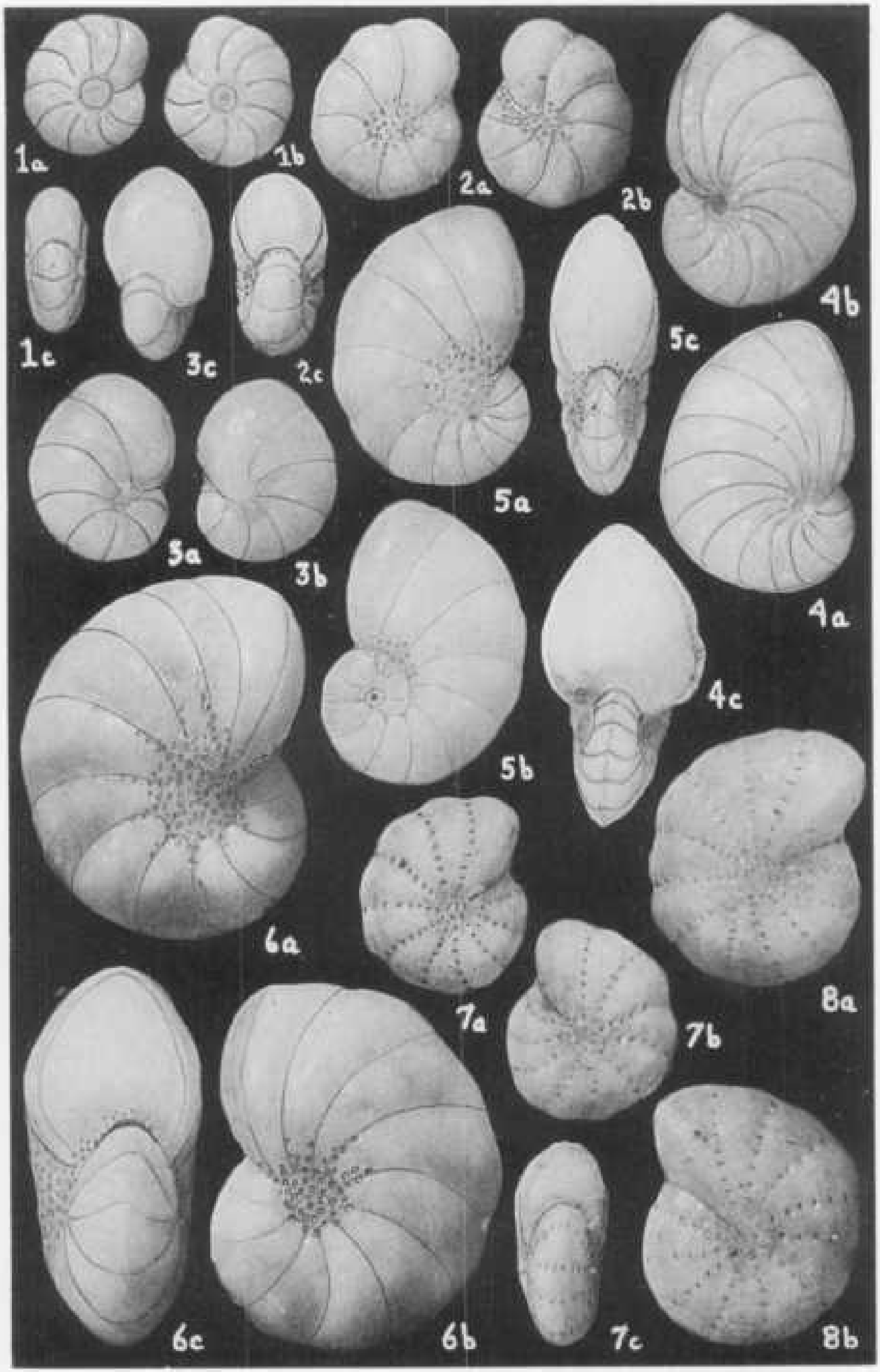
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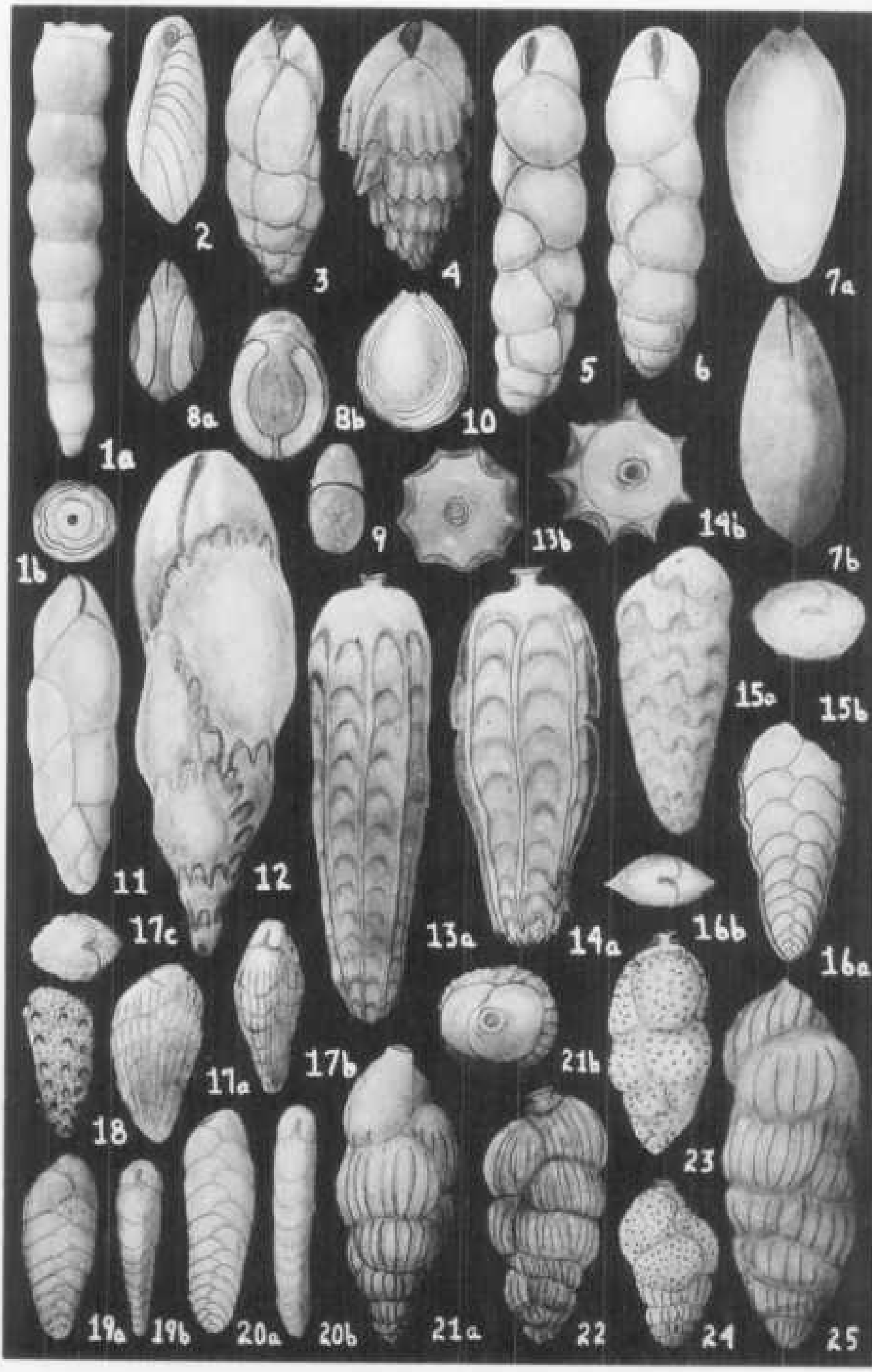
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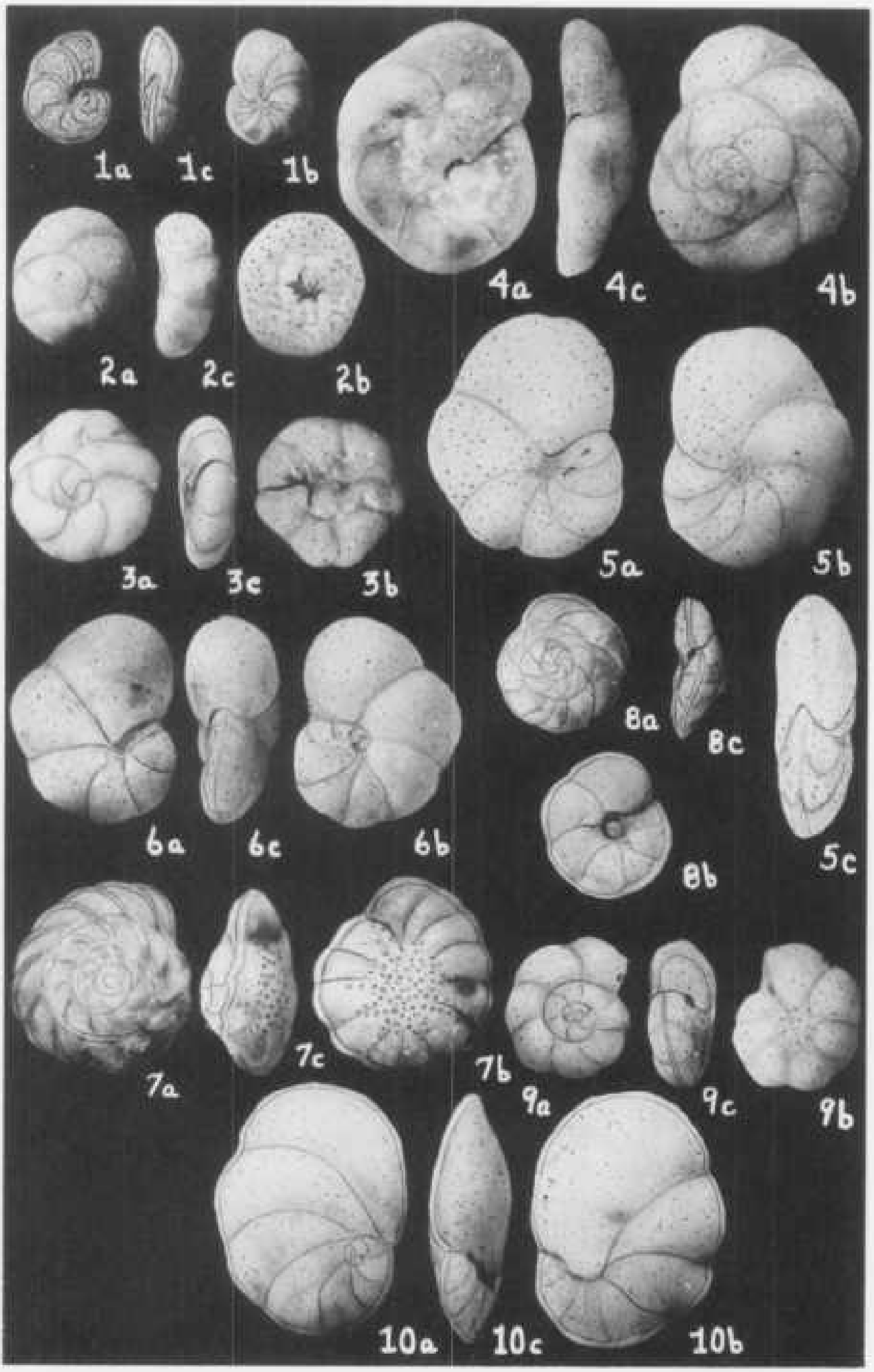
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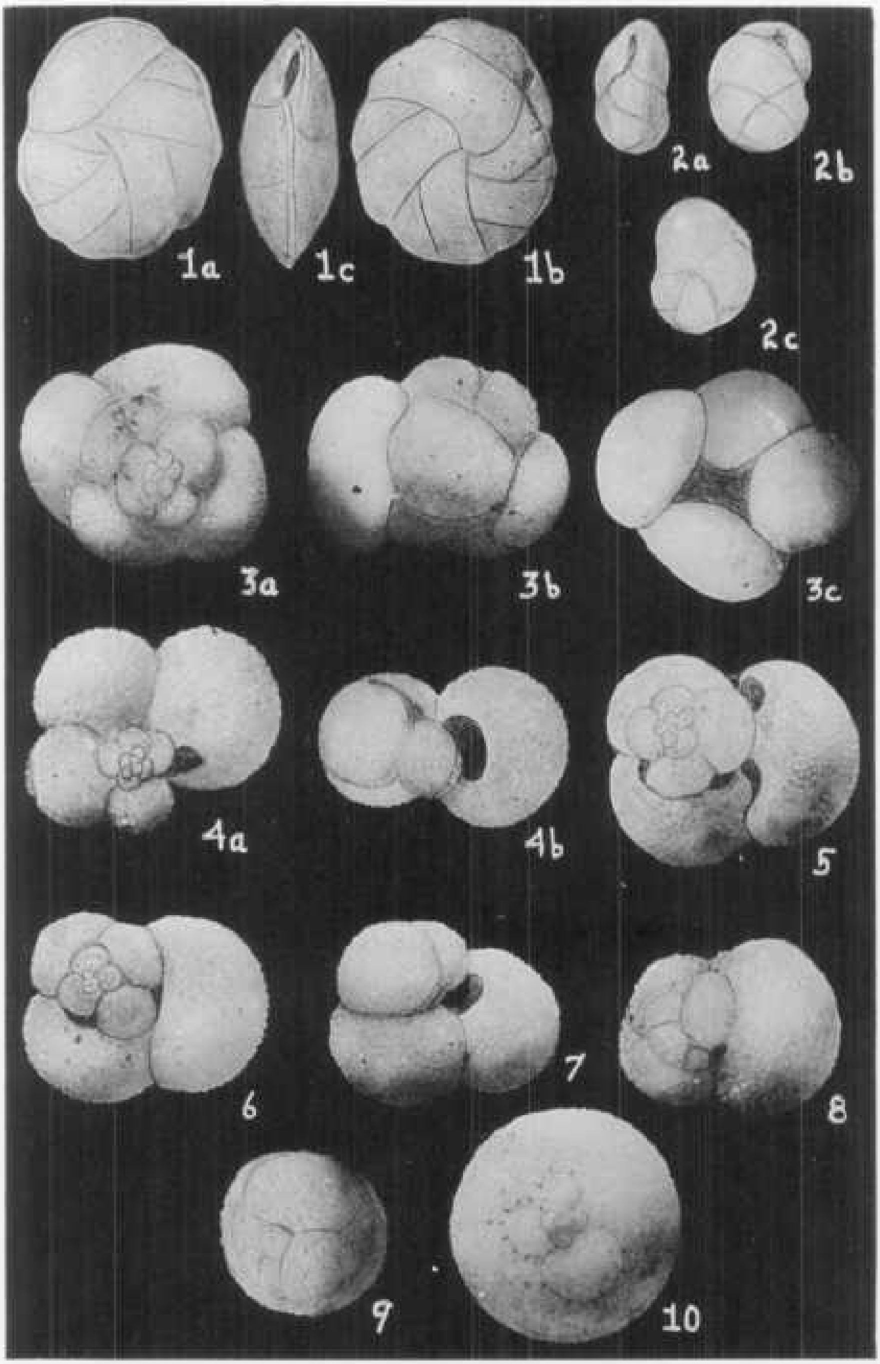
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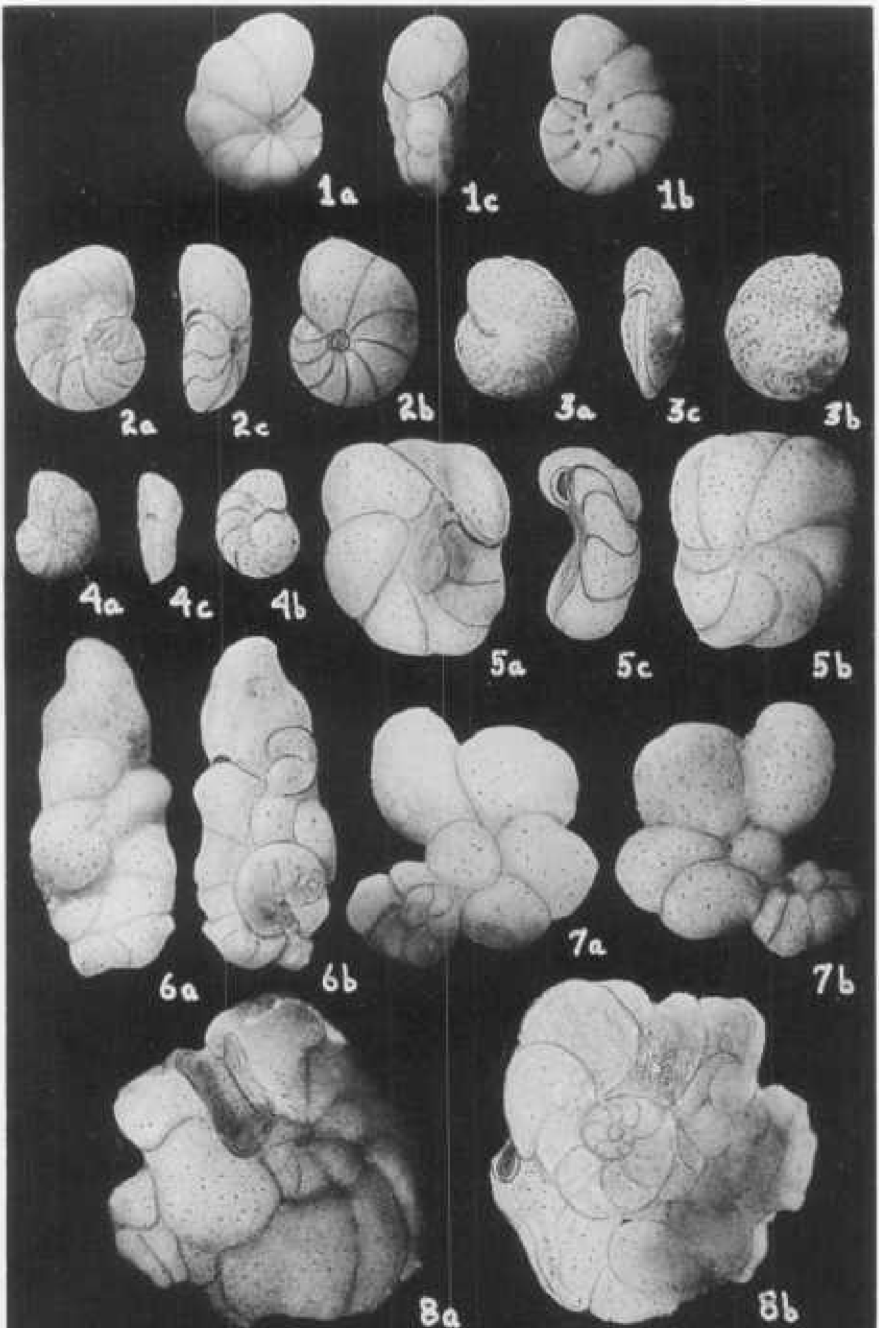
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APPENDIX

DESCRIPTION OF WELL SAMPLES

LARRY G. HAMMOND NO. 1 WELL, OHIO OIL COMPANY, SALISBURY, MARYLAND

BY

JUDSON L. ANDERSON

DITCH SAMPLES, 0–1000 FEET

Depth in Feet	
10–20	Sand and granule gravel. Sand predominates, very coarse, occasional black chert pebbles.
20–30	Sand and granule gravel. Sand predominates, very coarse, occasional black chert pebbles, quartz pebbles.
30–40	Sand and granule gravel. Sand predominates, very coarse, occasional black chert pebbles.
40–50	Sand and granule gravel. Sand predominates, very coarse, occasional black chert pebbles, possibly some bone fragments.
50–60	Sand and granule gravel. Sand predominates, very coarse, occasional black chert pebbles.
60–70	Sand and granule gravel. Sand predominates, very coarse, occasional black chert pebbles.
70–80	Sand and granule gravel. Sand predominates, very coarse, occasional black chert pebbles, color brown.
80–90	Sand and granule gravel. Sand predominates, very coarse, occasional black chert pebbles, color white.
90–100	Sand and granule gravel. Sand predominates, very coarse, occasional black chert pebbles, color brown.
100–110	Sand and granule gravel. Sand predominates, very coarse, occasional black chert pebbles, color white and yellow.
110–120	Sand and granule gravel. Sand predominates, very coarse, occasional black chert pebbles, color brown, fish vertebrae.
120–130	Sand and granule gravel. Sand predominates, very coarse, occasional black chert pebbles, color brown.
130–140	Sand and granule gravel. Sand predominates, very coarse, occasional black chert pebbles, color yellow-white.
140–150	Sand and granule gravel. Sand predominates, very coarse, occasional black chert pebbles, color yellow-white.
150–160	Sand and granule gravel. Sand predominates, very coarse, occasional black chert pebbles, much gravel.
160–170	Sand and granule gravel. Sand predominates, very coarse, occasional black chert pebbles.

Depth in Feet	
170–180	Sand and granule gravel. Sand predominates, very coarse, occasional black chert pebbles, yellow-white.
180–190	Sand and granule gravel. Sand predominates, very coarse, occasional black chert pebbles, yellow-white, much black and gray quartz.
190–200	Sand and granule gravel. Sand predominates, very coarse, occasional black chert pebbles, much black and gray quartz.
200–210	Sand and granule gravel. Sand predominates, very coarse, occasional black chert pebbles, yellow-white.
210–220	Sand and granule gravel. Sand predominates, very coarse, occasional black chert pebbles.
220–230	Sand and granule gravel. Sand predominates, very coarse, occasional black chert pebbles, yellow.
230–240	Sand and granule gravel. Sand predominates, very coarse, occasional black chert pebbles.
240–250	Sand and granule gravel. Sand predominates, very coarse, occasional black chert pebbles, yellow.
250–260	Granule gravel and mixed sand. Very coarse to fine.
260–280	Granule gravel and mixed sand. Very coarse to fine.
280–290	Granule gravel and mixed sand. Very coarse to fine.
290–300	Granule gravel and mixed sand. Very coarse to fine.
300–310	Granule gravel and mixed sand. Very coarse to fine.
310–320	Granule gravel and mixed sand. Very coarse to fine.
320–330	Granule gravel and mixed sand. Very coarse to fine.
330–340	Granule gravel and mixed sand. Very coarse to fine. Shell fragments of gastropods and pelecypods.
340–350	Granule gravel and mixed sand. Very coarse to fine. Shell fragments of gastropods and pelecypods.
350–360	Granule gravel and mixed sand. Very coarse to fine. Shell fragments of gastropods and pelecypods, teeth.
360–370	Coarse sand and little gravel and shell fragments.
370–380	Coarse sand and little gravel and shell fragments.
380–390	Coarse sand and little gravel and shell fragments.
390–400	Coarse sand and little gravel and shell fragments.
400–410	Coarse sand and little gravel and shell fragments.
410–420	Coarse sand and little gravel and shell fragments.
420–430	Coarse sand and little gravel and shell fragments.
430–440	Coarse sand and little gravel and shell fragments.
440–450	Coarse sand and little gravel and shell fragments. Very small glauconite.
450–460	Coarse sand and little gravel and shell fragments. Definite increase small amount of glauconite.
460–470	Coarse sand and little gravel and shell fragments. Small amount of glauconite.
470–480	Coarse sand and little gravel and shell fragments. Small amount of glauconite.
480–490	Coarse sand and little gravel and shell fragments. More glauconite.
490–500	Coarse sand and little gravel and shell fragments. Increasing glauconite.

Casing set at 500 feet.

500–510	Fine to coarse sand with some gravel. Fossils and glauconite.
510–515	Fine to coarse sand with some gravel. Fossils and glauconite.

Depth in Feet	
540–550	Fossiliferous, sandy (limy), pearl-gray to white marl and medium grained sand, trace of glauconite.
550–560	Fossiliferous, sandy (limy), pearl-gray to white marl and medium grained sand.
560–570	Fossiliferous, sandy (limy), pearl-gray to white marl and medium grained sand; less sand.
570–580	Fossiliferous, sandy (limy), pearl-gray to white marl and medium grained sand.
580–590	Fossiliferous, sandy (limy), pearl-gray to white marl and medium grained sand, rich fossils.
590–600	Fossiliferous, sandy (limy), pearl-gray to white marl and medium grained sand, rich fossils.
600–610	Fossiliferous, sandy (limy), pearl-gray to white marl and medium grained sand, white marl with green streaks, glauconite.
610–620	Fossiliferous, sandy (limy), pearl-gray to white marl and medium grained sand. Fine sand with green color and small amount of glauconite.
620–630	Fossiliferous, sandy (limy), pearl-gray to white marl and medium grained sand.
630–640	Fossiliferous, sandy (limy), pearl-gray to white marl and medium grained sand.
640–650	Very fine, dull gray loamy sand with fossil fragments.
650–660	Very fine, dull gray loamy sand with fossil fragments, trace of glauconite.
660–670	Very fine, dull gray loamy sand with fossil fragments, trace of glauconite.
670–680	Very fine, dull gray loamy sand with fossil fragments, trace of glauconite.
680–690	Very fine, dull gray loamy sand with fossil fragments, trace of glauconite.
690–700	Very fine, dull gray loamy sand with fossil fragments, trace of glauconite.
700–710	Dull pale-gray silty clay, fossils.
710–720	Dull plae-gray silty clay, fossils.
720–730	Dull pale-gray silty clay, fossils.
730–740	Dull pale-gray silty clay, very few fossils.
740–750	Dull pale-gray silty clay, very few fossils.
750–760	Dull pale-gray silty clay, very few fossils.
760–770	Dull pale-gray silty clay, very few fossils.
770–780	Dull pale-gray silty clay, very few fossils.
780–790	Dull pale-gray silty clay, very few fossils, some glauconite.
790–800	Dull pale-gray silty clay, fossils, some glauconite.
800–810	Fine-grained loamy sand. Some fossils and some glauconite.
810–820	Fine-grained loamy sand. Some fossils, glauconite increasing.
820–830	Pale dull-gray silty clay. Few fossils and little glauconite.
830–840	Pale dull-gray silty clay. Few fossils and little glauconite.
840–850	Pale dull-gray silty clay. Few fossils and little glauconite.
850–860	Pale dull-gray silty clay. Some coarse sand. Fossils and some glauconite.
860–870	Pale dull-gray silty clay. Few fossils and little glauconite.
870–880	Pale dull-gray silty clay. Few fossils and little glauconite. Sand increase.
880–890	Pale dull-gray silty clay. Few fossils and little glauconite. Decrease in sand, few fossils.
890–900	Pale dull-gray silty clay. Few fossils and little glauconite.
900–910	Pale dull-gray silty clay. Few fossils and little glauconite.
910–920	Pale dull-gray silty clay. Few fossils and little glauconite.
920–930	Pale dull-gray silty clay. Few fossils and little glauconite.
930–940	Pale gray, silty clay, few fossils. Trace of glauconite.
940–950	Pale gray, silty clay, few fossils. Trace of glauconite.
950–960	Pale gray, silty clay, few fossils. Trace of glauconite.

Depth in Feet	
960–970	Pale gray, silty clay, few fossils. Trace of glauconite.
970–980	Pale gray, silty clay, few fossils. Trace of glauconite.
980–990	Pale gray, silty clay, few fossils. Trace of glauconite.
990–1000	Pale gray, silty clay, few fossils. Trace of glauconite.

End of Ditch Samples.

CORE SAMPLES

Depth in Feet Recovery	
1000–1010, Rec. 6′	Very pale brownish-gray clay shale becoming silty toward bottom of core. Micro-fossil remains.
1010–1020, Rec. 7′	Very pale brownish-gray, micaceous, very silty shale. Poorly preserved shell fragments. Fish scales.
1020–1030, Rec. 8′	Very pale brownish-gray, micaceous, very silty shale. Poorly preserved shell fragments. Fish scales.
1030–1040, Rec. 9′	Very pale brownish-gray, micaceous, very silty shale. Poorly preserved shell fragments. Several fragments of poorly preserved pelecypods.
1040–1050, Rec. 9′	Very pale brownish-gray, micaceous, very silty shale. Poorly preserved shell fragments. Several fragments of poorly preserved pelecypods.
1050–1060, Rec. 1′ 8″	Very pale brownish-gray, micaceous, very silty shale. Poorly preserved shell fragments. Several fragments of poorly preserved pelecypods.
1060–1070, Rec. 10′	Very pale brownish-gray, micaceous, very silty shale. Several fragments of poorly preserved pelecypods. Slight trace of glauconite associated with very poor fossil fragments about 2 feet from bottom of core.
1070–1080, Rec. 10′	Very pale brownish-gray, micaceous, very silty shale. Few poor fossils and fish scales.
1080–1090, Rec. 3′ 3″	Very pale brownish-gray, micaceous, very silty shale. Few poor fossils and fish scales.
1090–1100, Rec. 3′	Very pale brownish-gray, micaceous, very silty shale. Few poor fossils and fish scales.
1100–1110, Rec. 10′	Very pale brownish-gray, micaceous, very silty shale. Few poor fossils and fish scales.
1110–1120, Rec. 9′	Very pale brownish-gray, micaceous, very silty shale. Few poor fossils and fish scales.
1120–1130, Rec. 5′ 6″	Very pale brownish-gray, micaceous, very silty shale. Poorly preserved shell fragments.
1130–1140, Rec. 9′	1′ Pale gray-brown clay shale. ½′ Dull brown-black clay shale and fine grained deep-green glauconite sand. 6½′ Same as first. Brown clay shale.
1140–1150, Rec. 2′	Very poor mashed core. Same as above.
1150–1160, Rec. 8½′	2′ Very fine-grained glauconitic sand. 6½′ Dull waxy-brown foraminiferal clay.
1160–1170, Rec. 6′	Very fine grained, at times silty, highly glauconitic sand.
1170–1180, Rec. 1½′	Dull earthy-brown clay. Appears to contain forams.
1180–1190, Rec. 8′	Badly crushed and partly contaminated dull-brown foraminiferal clay.
1190–1200, Rec. 8′	Laminated cinnamon-brown foraminiferal clay.

Depth in Feet Recovery	
1200–1210, Rec. $8\frac{1}{2}'$	Laminated cinnamon-brown foraminiferal clay.
1210–1220, Rec. $9'$	Dull-brown clay shale. Forams and silty in top 3 feet. At bottom (1213 feet) containing little very fine glauconitic sand in waxy, dull-brown shale. Shale becomes lighter in color and silty, at about 1215 feet contains forams. Dull waxy-brown clay with pelecypods at about 1218–1220 feet.
1220–1230, Rec. $8\frac{1}{2}'$	$\frac{1}{2}'$ Pale cinnamon-brown foraminiferal silty clay.
	$2\frac{1}{2}'$ Very fine grain, micaceous sand with trace of glauconite and with few carbonaceous partings.
	$\frac{1}{2}'$ Highly glauconitic, very fine to coarse, micaceous sand with large ($\frac{1}{2}$ inch to $\frac{1}{16}$ inch) clay pebbles. Looks like a clay pebble conglomerate.
	$4\frac{1}{2}'$ Medium and fine-grained highly glauconitic sand (green).
	$\frac{1}{2}'$ Pale brownish-white, silty, hygroscopic clay. Forams.
1230–1240, Rec. $5'$	$1'$ Dull cinnamon-brown clay. Forams.
	$4'$ Dull-brown, waxy clay.
1240–1250, Rec. $5'$	$1'$ Dull cinnamon-brown clay. Forams.
	$4'$ Dull-brown waxy clay.
1250–1260, Rec. $10'$	$9'$ Fine grained highly glauconitic green sand with some dull brown glauconitic clay near top ($6''$).
	$1'$ Brown-black glauconitic clay.
1260–1270, Rec. $6'$	$\frac{1}{2}'$ Pale-brown foraminiferal clay.
	$3'$ Very fine grain, dark-green glauconitic sand.
1270–1280, Rec. $8\frac{1}{2}'$	Pale brownish-white silty clay. Trace of glauconite. Apparently rich in forams.
1280–1290, Rec. $10'$	Pale brownish-white hygroscopic chalky clay.
1290–1300, Rec. $9'$	Pale brownish-white hygroscopic chalky clay. Hard white.
1300–1310, Rec. $4'$	$\frac{1}{2}'$ Pale brownish-white, hygroscopic chalky clay.
	$3\frac{1}{2}'$ Pale brownish-green clay, fish scales.
1310–1320, Rec. $10'$	Pale gray-white, hard, silty foraminiferal clay shale. Some fish remains.
1320–1330, Rec. $10'$	Same as above but becoming progressively more glauconitic from top to bottom. Glauconite is dark green and coarse. Fish remains.
1330–1340, Rec. $9'$	$9'$ highly glauconitic, pale buff-colored silty clay shale, hard. Glauconitic, fine to very coarse.
1340–1350, Rec. $3'$	Lead-gray to black, highly glauconitic clay shale.
1350–1360, Rec. $8'$	Medium-grained, argillaceous, glauconitic sand. Matrix is lead-gray clay. Glauconite is dark green.
1360–1370, Rec. $7'$	Medium-grained argillaceous, glauconitic sand. Matrix is lead-gray clay. Glauconite is dark green. Fossil pelecypods.
1370–1380, Rec. $5'$	Medium-grained, argillaceous, glauconitic sand. Matrix is lead-gray clay. Glauconite is dark green.
1380–1390, Rec. $8'\ 4''$	Medium-grained, argillaceous, glauconitic sand. Matrix is lead-gray clay. Glauconite is dark green. Fossil pelecypods.
1390–1400, Rec. $9'$	$3'$ Same as above.
	$6'$ Very hard, white silty chalk. Glauconitic at top of interval and dying out toward base. Few fish remains.

Depth in Feet Recovery	
1400–1410, Rec. 9′	Very hard, white silty chalk. One pyritized stem. Very few macro-fossils.
1410–1420, Rec. 10′	Very hard, white silty chalk. Very few badly mashed fossil fragments. Fish spines and scales.
1420–1423, Rec. 3′	Very hard, white silty chalk. Glauconitic at top of interval and dying out toward base. Glauconite increasing but still not abundant. One fish spine. No large fossils seen in core (fossils reported by Ohio Oil Company).
1423–1433, Rec. 3′	Lead-gray, glauconitic clay shale, glauconite more abundant than in preceding core. Badly mashed fossil fragments.
1433–1440, Rec. 6′	Lead-gray, glauconitic clay shale, glauconite more abundant than in preceding core, fairly abundant. No large fossils. Fish spine.
1440–1450, Rec. 5′	Lead-gray, glauconitic clay shale.
1450–1460, Rec. 6′	Lead-gray, glauconitic clay shale. One mashed fossil fragment.
1460–1470, Rec. 9′	Lead-gray, glauconitic clay shale. Fossil fragments. Many badly mashed. Trace of very fine sand coming in at base of core.
1470–1480, Rec. 10′	Lead-gray, argillaceous, micaceous, somewhat glauconitic conglomeratic sand with occasional clay lenses. Some fossils which appear to be reworked. Pebbles up to ¼ inch.
1480–1490, Rec. 10′	6′ Lead-gray and olive-green mixture of fine sand and clay, micaceous, conglomeratic and glauconitic. Some fossils.
	1′ Hard, argillaceous, very fine grained sandstone, lead-gray.
	2′ Lead-gray and olive-green mixture of fine sand and clay, micaceous, conglomeratic and glauconitic. Some fossils.
	1′ Very fine, soft micaceous sandstone.
1490–1498, Rec. 8′	Very fine grained somewhat argillaceous micaceous sand and occasional interlaminated lead-gray clay shale. Zone of reworked fossil fragments, from 1494–1498 feet.
1498–1508, Rec. 6′	Soft, micaceous fine sand with occasional partings of lead-gray clay. Carbonaceous matter rare on top becoming abundant below 1502 feet. Remains of stems and one seed (?).
1508–1518, Rec. 7′ 10″	Lead-gray shale with some carbonaceous matter and interlaminated fine-grained micaceous sand. Sand (1 foot) at base is soft.
1518–1528, Rec. 10′	1′ Pale lead-gray slightly carbonaceous shale with lens of blue shale at base.
	3′ Olive-green glauconite shale with minor amount of glauconitic sand. Shale lumps present.
	½′ Pale blue-gray clay shale.
	5½′ Cinnamon-brown clay shale with paper thin, very fine brown sand partings. Shale becomes darker cinnamon-brown toward base.
1528–1538, Rec. 8½′	1′ Earthy, gray-brown, slightly carbonaceous argillaceous sand.
	3½′ Lead-gray interlaminated slightly carbonaceous shale and very fine sand.
	4′ Hard, dark brownish-black shale with 6 inches of very hard, indurated shale at top.

Depth in Feet Recovery	
1538–1548, Rec. 7′	2′ Hard brown shale as above.
	5′ Very hard, cinnamon-brown siltstone with occasional lens of hard shale of same color.
1548–1558, Rec. 2½′	Brownish-black shale with siderite spherules.
1558–1568, Rec. 8′	Hard, dark cinnamon-brown shale. Occasionally showing mottling in yellow and red-brown tones. Lens of very fine (3 inches) sand at base.
1568–1578, Rec. 10′	4′ Pale gray clay shale with paper thin partings of very fine sand and lenses up to 6 inches of very fine soft sand. Carbonaceous matter, wood remains.
	6′ Hard, pale brown-gray somewhat gritty shale.
1578–1588, Rec. 10′	3′ Very fine, argillaceous, carbonaceous sand with some shale partings.
	3′ Hard, pale brownish-gray shale.
	4′ Hard, dark brownish-black carbonaceous shale.
1588–1598, Rec. 10′	Lead-gray richly fossiliferous shale. Pelecypods, gastropods and fossil amber.
1598–1608, Rec. 8′	4′ Thinly laminated, lead-gray fossiliferous shale.
	2′ Silty lead-gray shale without fossils.
	2′ Very fine grained argillaceous sand. Highly carbonaceous in first foot of interval.
1608–1618, Rec. 7′	Very fine grained, argillaceous, buff-colored sandstone and occasional buff silty shale partings. Sand is occasionally carbonaceous.
1618–1628, Rec. 10′	2′ Very fine grained buff-colored sandstone.
	8′ Hard, silty, dark cinnamon-brown shale with frequent carbonaceous matter.
1628–1638, Rec. 9′	Hard, pale cinnamon-brown, occasionally gritty shale.
1638–1648, Rec. 9′	3′ Hard, pale cinnamon-brown gritty shale.
	2′ Pale cinnamon-brown very fine sandstone.
	2′ Dark gray sandy shale with abundant lignite.
	2′ Hard, pale cinnamon-brown waxy shale.
1648–1658, Rec. 7½′	Hard, pale cinnamon-brown gritty shale with occasional very fine pale brown sandstone lenses.
1658–1667, Rec. 9′	1′ Fine-grained micaceous soft sand with a black 2 inch lignitic sand lens at top.
	2′ Dark brownish-black highly carbonaceous mixture of shale and very fine sand.
	3′ Hard cinnamon-brown shale.
	2′ Very fine, micaceous, soft, occasionally carbonaceous, sand.
	½′ Black lignitic shale and buff fine sand.
	½′ Cinnamon-brown shale.
1667–1677, Rec. 9′	3′ Pale cinnamon-brown gritty shale.
	6′ Dark brownish-black carbonaceous shale.
1677–1687, Rec. 10′	4′ Pale grayish to brownish-white gritty shale.
	6′ Dull, earthy, brown sandy shale with common lignite.
1687–1697, Rec. 8½′	6′ Fine-grained, soft, occasionally carbonaceous, white sandstone.
	2½′ Brownish-gray occasionally carbonaceous sandy shale.

Depth in Feet Recovery	
1697–1707, Rec. 10′	10′ Very fine grained micaceous sand with an occasional shale parting. Highly lignitic.
1707–1717, Rec. 10′	Pale greenish-gray shale becoming sandy shale toward base. Lower half silty.
1717–1727, Rec. 7.9′	3′ Very fine grained, pale greenish-gray, micaceous sandstone.
	4′ Mottled cinnamon-brownish gray and dark brown clay shale.
1727–1737, Rec. 8′	Mottled olive-green shale. Brown and yellow, becoming sandy in bottom foot of core.
1737–1747, Rec. 4.7′	3′ Mottled shale as above.
	1.7′ Very fine silty sand. Pale green and chloritic.
1747–1757, Rec. 3.9′	Very fine, micaceous soft sandstone with some lignite.
1757–1767, Rec. 3.35′	3′ Very fine-grained, silty, micaceous thinly laminated, pale gray sand.
1767–1777, Rec. 3.75′	Very soft, friable, medium-grained sand. Pale gray-white with possibly some calcareous matrix in places.
1777–1787, Rec. 3.75′	1½′ Soft sand as above.
	½′ Very fine, carbonaceous sand.
	1.75′ Dark cinnamon-brown, silty clay shale.
1787–1797, Rec. 7¼′	5′ Highly mottled cinnamon-brown shale.
	¼′ Grass-green glauconitic silty shale.
	2′ Cinnamon-brown very fine grained sand.
1797–1807, Rec. 6½′	Pale olive-green shale with occasional mixture of very fine silty, cinnamon-brown sand.
1807–1817, Rec. 6½′	3′ Pale olive-green shale with occasional mixture of very fine silty, cinnamon-brown sand.
	3½′ Very fine grained, micaceous, thinly laminated gray sand and lead-gray occasionally lignitic shale. At base sand is soft and gray-white.
1817–1824, Rec. 4½′	Soft, fine grained, gray-white, friable, sparingly micaceous, porous, slightly argillaceous sand. Occasional lignite streak.
1824–1834, Rec. 10′	3′ Pale cinnamon-brown silty shale.
	7′ Pale olive-green to grass-green shale with silt increasing at base.
1834–1844, Rec. 10′	3′ Very fine grained, slightly micaceous, grass-green sand.
	7′ Grass-green with occasional rusty-brown shale and occasional lenses of very fine grass-green sand. Sand looks glauconitic. No pellets seen.
1844–1854, Rec. 8′	5′ Very fine grained, soft, friable, white and occasionally rusty-brown sand.
	3′ Highly mottled rusty-brown, gray-green and red-brown shale.
1854–1864, Rec. 10′	Highly mottled red, yellow and greenish-gray shale.
1864–1874, Rec. 9′	Mottled shale. Color olive-green with rusty-brown mottling. Last 1½′ is pale brownish-white shale.
1874–1884, Rec. 4′	Bottle-green, waxy-looking shale with a small amount of sand grains in shale. Becomes an argillaceous greensand at base.
1884–1894, Rec. 6.15′	Mottled grass-green to pale-gray, very argillaceous, very fine grained sand.
1894–1904, Rec. 5½′	2′ Bottle-green argillaceous sand as above with some green shale at base.

Depth in Feet Recovery	
	1′ Fine-grained, dull, gray sand, friable.
	1′ Lead-gray, silty, and micaceous shale.
	1′(−) Soft, fine, micaceous white sand.
1904–1914, Rec. 3′	Soft, friable, fine-grained, porous white sand.
1914–1924, Rec. 6.65′	Grass-green and pale cinnamon-brown sandy shale with silt increasing toward base.
1924–1934, Rec. 10′	2′ Very fine grained, pale gray-white, highly argillaceous sand becoming progressively softer and medium-grained toward base.
	7′ Mottled pale-gray shale. Color red-brown mottled.
	1′ Very fine grained white sandy shale.
1934–1944, Rec. 6.3′	Pearly-gray, mottled in rusty-brown and red colors, shale with a lens of very fine grained, micaceous, lignitic sand at base.
1944–1954, Rec. 9.4′	Fine-grained, rather soft, micaceous, dull gray, occasionally lignitic, sand with occasionally lead-gray carbonaceous shale parting.
1954–1964, Rec. 1.7′	Sand and shale as above. Sand medium-coarse at times.
1964–1974, Rec. 5.6′	Pale lead-gray sandy shale with occasional lignite and becoming an argillaceous sandstone in bottom 2′.
1974–1984, Rec. 5′	Dull pearly-gray, very highly mottled shale in reddish-brown colors.
1984–1994, Rec. 8′	6′ Hard very fine, cinnamon-brown sandy shale.
	1′ Soft, mixture of very fine, dark brownish-gray micaceous sand and dull gray, highly lignitic shale.
	1′ Dull brownish-gray very fine grained sandstone.
1994–2004′, Rec. 8½′	3′ Pale yellowish-gray siltstone, some micaceous.
	4½′ Laminated, lignitic, dull yellowish-gray shale with paper thin partings of yellow-brown silty sand.
	1′ Very fine grained, micaceous, soft sand.
2004–2014, Rec. 6½′	Soft, friable, porous, sparingly micaceous, lignitic, pale gray-white sand.
2014–2024, Rec. 9½′	1′ Soft sand as above.
	8½′ Hard, pale brownish-gray sandy shale and mixture of very fine sand and shale. Bottom 6″ is very fine, pale gray sand.
2024–2034, Rec. 8½′	Gray shale with yellow tone, silty. Bottom 1′ is chocolate-brown shale.
2034–2044, Rec. 3′	2′ Pale lead-gray, highly mottled red-brown shale.
	1′ Very fine grained, micaceous, pale gray sandstone.
2044–2054, Rec. 7′	3′ Fine-grained, micaceous, light gray, soft sandstone.
	4′ Hard, dull yellowish lead-gray silty, micaceous shale.
2054–2064, Rec. 6′	Pale lead-gray, highly mottled red-brown, shale.
2064–2074, Rec. 5′	Pale lead-gray, highly mottled red-brown, shale. At base is a fine brownish-gray sand that has a small amount of glauconite in pellets.
2074–2084, Rec. 3′8″	Pale lead-gray, highly mottled red-brown, shale. No glauconite sand. Shale is dark lead-gray with some mottling at base.
2084–2094, Rec. 6′ 4″	Lead-gray mottled shale becoming lighter in color to a brownish-white siltstone at base.
2094–2099, Rec. 5′	Mottled shale as above.

Depth in Feet Recovery	
2099–2109, Rec. 1.35′	Mottled shale as above.
2109–2119, Rec. 5½′	Mottled shale as above.
2119–2129, Rec. 4′	Pale gray slightly mottled shale with color becoming pale olive-green toward base with some silt sand.
2129–2137,	8 feet of core missing.
2137–2147, Rec. 10′	Olive-green silty shale. Color lighter at top.
2147–2157, Rec. 3′	2′ Shale as above.
	1′ medium-grained gray white sand.
2157–2167, Rec. 2′ 8″	Fine grained, pale brownish-white, soft sandstone.
2167–2177, Rec. 7½′	3′ Very fine grained lignitic cross-bedded sand and occasionally thin lead-gray shale partings.
	3′ Thinly laminated, lead-gray, somewhat silty, micaceous shale with thin sand partings. Sand is occasionally glauconitic in minor amounts. Fossil fragments appear to be reworked and not too abundant.
	1′ Hard, dark lead-gray, silty, micaceous shale.
2177–2187, Rec. 10′	8′ Very fine grained, micaceous, pale olive-gray sandstone and occasionally pale olive shale.
	2′ Very fine grained, micaceous, lead-gray, very carbonaceous sandstone with some earthy brown clay pellets.
2187–2197, Rec. 9′	2′ Lead-gray, micaceous, highly carbonaceous and lignitic, argillaceous, very fine grained, laminated sandstone.
	7′ Silty olive-green shale.
2197–2207, Rec. 2′ 8″	Fine to medium grained, soft, white, somewhat micaceous, friable porous sand with dark lead-gray (2 inches) shale at top.
2207–2217, Rec. 9′	3′ Pale olive-gray silty shale.
	6′ Lead-gray silty shale with occasional partings of paper thin silt and carbonaceous matter.
2217–2227, Rec. 10′	1′ Olive-green silty shale.
	1′ Very fine grained olive-green sandstone.
	8′ Thinly laminated, very fine grained, cinnamon-brown silt and lead-gray silty shale. Micaceous and carbonaceous.
2227–2237, Rec. 8¾′	5¾′ Lead-gray, very thinly laminated, silty shale with some carbonaceous matter and rare silty sand.
	3′ Pale olive-gray, very fine grained, micaceous sandstone with very thin lead-gray shale partings.
2237–2247, Rec. 8.9′	6′ Pale lead-gray shale with paper thin silty sand.
	2.9′ Black, thinly laminated, carbonaceous shale with rare shell fragments (possibly forams?).
2247–2257, Rec. 10′	4′ Very fine grained micaceous, lignitic, brown-gray sandstone with few broken fossil fragments at base.
	6′ Lead-gray, hard, highly fossiliferous shale. Core badly mashed and fossils badly grounded up. Pelecypods and gastropods noted.
2257–2267, Rec. 3.9′	3′ Hard lead-gray silty shale with trace of green-brown glauconite pellets. At base shale becomes a very fine micaceous gray sandstone.
	1′ Fine to medium, gray-white, soft, micaceous sand.
2267–2277, Rec. 3.4′	Soft sand as above.

Depth in Feet Recovery	
2277–2287, Rec. 4.8′	Soft sand as above.
2287–2297, Rec. 3.3′	Soft sand as above.
2297–2307, Rec. 4.75′	Soft sand as above with 2 inches of hard, lead-gray, silty, micaceous shale at base.
2307–2313, Rec. 3.35′	Hard, dark gray-black, micaceous shale with 3 inches of olive-green sandy shale at base.
2313–2323, Rec. 8½′	5′ Olive-green shale and sandy shale with what appear to be cinnamon-brown siderite spherules.
	1′ Hard, lead-gray, micaceous shale with paper thin very fine sand.
	2′ White mixture of sand and shale.
2323–2333, Rec. 5′	4′ Olive-green, highly argillaceous, very fine sand.
	½′ Hard, olive-green shale and very fine sand.
	½′ Hard lead-gray shale.
2333–2343, Rec. 4½′	2′ Hard, gray carbonaceous shale as above.
	2½′ Pale buff hard sandy shale.
2343–2353, Rec. 10′	10′ Hard black shale.
2353–2363, Rec. 7′	Hard, very fine sandy shale. Color pale olive-green to buff to dark brownish-gray at base.
2363–2373, Rec. 7½′	Hard, brownish gray carbonaceous sandy shale. Below 2368 feet lignite is abundant.
2373–2383, Rec. 10′	Very fine, pale olive-green sandy shale. At 2378–2379 feet glauconitic, argillaceous, deep olive-green sand. Then back to sandy shale.
2383–2393, Rec. 5½′	4½′ Pale buff very fine sandy shale and shale.
	1′ Hard, lead-gray, somewhat mottled red, shale.
2393–2403, Rec. 4½′	4½′ Hard, pale lead-gray shale.
2403–2413, Rec. 7½′	3′ Hard, laminated, dull brown-gray shale with very small specks of carbonaceous matter.
	4½′ Pale lead-gray, highly mottled red-brown, shale.
2413–2423, Rec. 10′	Pale lead-gray mottled shale as above.
2423–2433, Rec. 3′	Pale lead-gray mottled shale as above.
2433–2443, Rec. 2′ 8″	Pale lead-gray mottled shale as above.
2443–2448, Rec. 2′	Pale lead-gray mottled shale as above.
2448–2453, Rec. 3′	2½′ Hard white shale with pink mottling.
	½′ Hard, fine grained, argillaceous, white to pink-white sand.
2453–2460, Rec. 7′	Highly mottled shale. Color varies from pink-white to deep red-brown.
2460–2465, Rec. 5′	Highly mottled shale. Color varies from pink-white to deep red-brown
2465–2473, Rec. 2′ 5″	Hard, rusty-yellow shale.
2473–2478, Rec. 3′	Pale gray, highly mottled red-brown, shale.
2478–2483, Rec. 1′ 7″	Pale gray, highly mottled red-brown, shale.
2483–2488, Rec. 1′	Pale gray, highly mottled red-brown, shale.
2488–2493, Rec. 8″	No core in box. Shale from electric log.
2493–2498, Rec. 6″	Mottled shale.
2498–2508, Rec. 9½′	Mottled shale as above. In middle of core there is some very fine argillaceous sand.
2508–2513, Rec. 5′	Highly mottled shale.
2513–2517, Rec. 2½′	Highly mottled shale.

Depth in Feet Recovery	
2517–2521, Rec. 1.3′	No core in box. Electric log indicates shale.
2521–2523, Rec. 1′	No core in box. Electric log indicates shale.
2523–2525, Rec. 2′	Highly mottled shale.
2525–2527, Rec. 1.5′	No core in box. Possibly shale?
2527–2530, Rec. 3′	Mottled, pale lead-gray shale, red-brown.
2530–2535, Rec. 4′	Mottled, pale lead-gray shale, red-brown.
2535–2540, Rec. 4½′	Mottled, pale lead-gray shale, red-brown.
2540–2550, Rec. 8′ 8″	3′ Pale gray-white shale mottled pink and rusty-brown.
	3′ Pale lead-gray sandy shale, trace lignite.
	2′ 8″ Very fine, pale gray, argillaceous sand with some lignite.
2550–2555, Rec. 5′	Pale brownish-gray, highly lignitic, gritty, and sparingly micaceous shale.
2555–2565, Rec. 5½′	Pale brownish-gray, highly lignitic, gritty, and sparingly micaceous shale. (Electric log shows good sand in bottom of interval. Doubtless lost, as only 2 inches of fine lignitic sand recovered.)
2565–2575, Rec. 2′	Soft, friable, porous, medium-grained, gray-white sand.
2575–2585, Rec. 6.6′	Soft, friable, medium-grained, white, porous, micaceous sand.
2585–2595, Rec. 5′	Soft, friable, medium-grained, white, porous, micaceous sand.
2595–2605, Rec. 4′ 10″	Soft, micaceous sand as above.
2605–2615, Rec. 8′	Soft, fine-grained, somewhat micaceous, friable, white sand. White, micaceous, lead-gray sandy shale break at 2612 feet.
2615–2625, Rec. 8.7′	3′ Hard, pale lead-gray, laminated lignitic shale with thin very fine, micaceous, lignitic sand partings.
	2′ Medium fine, soft, micaceous sand.
	1′ Hard shale and sand as above.
	2.7′ Medium fine sand as above.
2625–2635, Rec. 2′	½′ Hard, pale lead-gray, sparingly lignitic shale and very fine sand partings.
	1½′ Soft, medium-grained white sand.
2635–2645, Rec. 3′	Pale olive-green shale and sandy shale. At base there are 2 inches of what appears to be a shale conglomerate with small ⅛ inch shale pellets.
2645–2650, Rec. 3′	Pale olive-gray slightly gritty shale.
2650–2653, Rec. 3′	Highly mottled, pale gray, red-brown and yellow-brown shale.
2653–2655, Rec. 2′	Highly mottled, pale gray, red-brown and yellow-brown shale. At top is 3 inches of very fine grained, chloritic, pale-green sandstone.
2655–2659, Rec. 2′ 10″	Deep red-brown shale.
2659–2664, Rec. 4′ 8″	Highly mottled shale.
2664–2669, Rec. 3′	Highly mottled shale.
2669–2674, Rec. 1′	Highly mottled shale.
2674–2679, Rec. 4′ 3″	3′ 9″ Mottled brown, gray shale.
	6″ Pale green, very fine grain, chloritic sand and shale mixture.
2679–2689, Rec. 7′	4′ Pale olive-green, very fine, chloritic sand and shale mixture tending toward sandy shale at base.
	2′ Very fine, greenish-white, micaceous, argillaceous sand.
	1′ Fine-grained, soft, micaceous, lignitic sand.
2689–2699, Rec. 5′	Fine grained, somewhat micaceous, pale green, soft sand becoming white at base.

Depth in Feet Recovery	
2699–2709, Rec. 5′	Fine to medium soft, white, friable sand, lignitic at base.
2709–2719, Rec. 7.4′	3′ Sand as above. Color pale green-white.
	4.4′ Very fine, micaceous, green-gray sand becoming shaly toward base.
2719–2729, Rec. 5.5′	1′ Very fine grained, highly chloritic, pale olive-green soft sand.
	4½′ Medium-grained soft white sand.
2729–2739, Rec. 4.4′	½′ Very fine grained, argillaceous, deep olive-green, micaceous sand and sandy shale.
	3′ 11″ Soft, white, fine-grained micaceous sand.
2739–2749, Rec. 5.6′	2′ Fine-grained, soft, white sand. Lignite at base.
	2′ Pale greenish-gray sandy shale and shale with some paper thin very fine silty sand.
	1.6′ Fine-grained, soft gray-white sand.
2749–2759, Rec. 4′ 10″	1′ Medium-grained, soft, gray-white sand.
	2′ Hard, pale gray shale.
	1′ Very fine grained, gray-white sand.
2759–2769, Rec. 2′ 5″	Soft, fine grained, micaceous, gray-white sand.
2769–2774, Rec. 5′	2′ Olive-green sandy shale and shale.
	3′ Very fine to fine-grained, green-gray micaceous sand.
2774–2784, Rec. 2′ 5″	1′ Pale olive-green silty sand and shale.
	1′ 5″ Very fine grained, micaceous, pale olive-green sand.
2784–2789, Rec. 4′	1′ Soft, fine-grained, micaceous gray-white sand.
	2′ Hard, pale lead-gray shale.
	1′ Soft, fine-grained, micaceous and sparingly lignitic, gray-white sand.
2789–2794, Rec. 2′ 5″	Soft, fine-grained, micaceous, gray-white sand.
2794–2801, Rec. 5′	Soft, white, highly micaceous, fine-grained sand. (Epidote noted.)
2801–2806, Rec. 3′ 8″	Soft, medium-grained, gray-white sand.
2806–2811, Rec. 5′	2′ Soft sand as above. Lignite at base.
	3′ Olive-green, silty shale and shale.
2811–2821, Rec. 4′ 3″	Olive-green sandy shale becoming mottled and rusty-brown at base.
2821–2826, Rec. 5′	4′ Olive-green, micaceous, extremely fine grained sandy shale.
	1′ Fine grained, pale olive-green sand.
2826–2832, Rec. 2′	Very poor recovery.
	Very fine grained micaceous, olive-green sand.
2832–2837, Rec. 5′	Soft, fine-grained, olive-green sand. In center 1 foot of white sand.
2837–2842, Rec. 3′	Olive-green, slightly mottled rusty brown, shale with occasionally sandy shale. At base, fine-grained green sand.
2842–2847, Rec. 1′	Mottled brown, olive-green shale.
2847–2852, Rec. 3′	Mottled shale as above.
2852–2857, Rec. 3′	Mottled shale as above.
2857–2862, Rec. 5′	Olive-green shale and very fine sandy shale in center.
Missing 2862–2867	
2867–2872, Rec. 4′ 5″	Hard, olive green, sandy shale and shale with 1 foot of very fine, micaceous, olive-green sand at about 2868 feet.
2873–2877, Rec. 4′ 5″	1′ Very fine grained, pale olive-green micaceous sand with lignite.
	3′ 5″ Hard, olive-green sandy shale and shale.

Depth in Feet Recovery	
2877–2887, Rec. 5′	3′ Hard, olive green mixture of sandy shale and shale (6 inches) followed by 3 inches of olive-green conglomerate consisting of shale pellets (⅛ inch) and coarse sand with $\frac{1}{16}$ inch layer of lignite with a C.D. of 13°. Remainder of interval is very fine, highly lignitic, olive-green sand.
	2′ Soft, white, very fine to fine-grained sand.
2887–2897, Rec. 7½′	3′ Soft, white, fine grained sand.
	4′ Hard, olive-green, micaceous sandy shale, with some shale and becoming sandier at base.
2897–2907, Rec. 5½′	Very fine grained, micaceous, soft, argillaceous olive-green sand.
2907–2917, Rec. 6′ 6″	5½′ Fine-grained, soft, micaceous, pale olive-green sand with about 6 inches of white sand in middle.
	1′ Hard, pale lead-gray silty, micaceous shale.
2917–2923, Rec. 3′	Hard shale as above with occasional partings of very fine silty sand.
2923–2932, Rec. 5½′	Hard, lead-gray, micaceous sandy shale and laminated shale with 4 inches of white fine sand 6 inches from base.
2932–2938, Rec. 3′	6″ Soft, white, fine-grained sand.
	2½′ Hard olive-green shale.
2938–2943, Rec. 4′ 3″	2′ Pale green, hard sandy shale and very fine sand.
	1′ Very fine grained hard argillaceous sandstone.
2943–2948, Rec. 1′ 4″	Hard, pale green sandy shale.
2948–2953, Rec. 1′	Mottled brown and green shale.
2953–2958, Rec. 3′ 7″	Highly mottled, red-brown, yellow shale.
2958–2963, Rec. 4′ 8″	Highly mottled, olive-green, red-brown and yellow shale.
2963–2970	No core recovery reported.
2970–2975	No core recovery reported.
2975–2980	No core recovery—trouble.
2980–2985, Rec. 6″	None in box. Few fragments indicate very fine green-gray sand.
2985–2990, Rec. 4″	Few fragments indicate a medium-grained sand.
2990–2995,	No core recovered.
2995–3005, Rec. 8″	Only few fragments in box. Fine-grained green-gray sand.
3005–3010, Rec. 1′ 4″	(Very little left in box.) Pale olive-green shale and thin sand partings followed by fine-grained green-gray sand.
3010–3015, Rec. 3′	Mixture of fine-grained olive-green sand and some colored sandy shale.
3015–3020, Rec. 2′ 6″	Poor core.
3020–3030, Rec. 4′ 6″	Poor core. Fine to medium-grained, white soft, friable sand.
3030–3040, Rec. 7′	1½′ Sand as above.
	5½′ Lead-gray micaceous sandy shale and silty sand.
3040–3046, Rec. 4′	4′ Very fine grained, micaceous, argillaceous, gray-white sand with thin lead-gray shale at base.
3046–3051, Rec. 5′	Hard mixture of mottled brown and olive-green sandy shale and some very fine sand.
3051–3061, Rec. 9′	3′ Hard, pale olive-green micaceous sandy shale.
	6′ Mottled brown and green sandy shale and shale.
3061–3071, Rec. 9′	Deep reddish chocolate-brown and some olive shale.
3071–3076, Rec. 5′	Hard, pale green sandy shale and shale mixture.
3076–3086, Rec. 3′ 4″	Hard, pale green sandy shale and shale mixture, becoming sandier.

Depth in Feet Recovery	
3086–3091, Rec. 3′ 2″	Very fine grained, olive-green argillaceous sand.
3091–3096, Rec. 4′ 6″	Hard, olive-green micaceous sandy shale with 4 inches lead-gray, micaceous, lignitic sandy shale at base.
3096–3101, Rec. 3′	Hard, gray-black, carbonaceous and lignitic, micaceous, laminated sandy shale and shale, with very fine lignitic sand at base.
3101–3107, Rec. 5′ 3″	6″ Hard, olive-green micaceous sandy shale.
	4′ 9″ Fine-grained, white, lignitic and carbonaceous, soft sand.
3107–3117, Rec. 3′	Sand as above. (Epidote—pink garnet.)
3117–3122, Rec. 4′ 5″	Soft, white, fine-grained, micaceous sand.
3122–3127, Rec. 4′	Sand as above.
3127–3132, Rec. 4′ 4″	Sand as above with 2 inches of gray sandy shale at base.
3132–3137, Rec. 4′ 3″	1′ Pale lead-gray, lignitic, micaceous sandy shale.
	3′ 3″ Pale olive-green sandy shale and shale.
3137–3142, Rec. 3′ 7″	(Only 6 inches of poor core in box.) Pale lead-gray, micaceous, lignitic sandy shale.
3142–3147, Rec. 3′ 8″	Pale olive-gray sandy shale and shale. Lower foot becomes very fine argillaceous sand. Lignitic.
3147–3157, Rec. 7′ 10″	5′ 10″ Pale olive-gray mixture of sandy shale and shale.
	2′ Very fine, olive-gray, argillaceous sand. 2 inches at base is mixture of a little coarse sand and green shale pellets, also lignite.
3157–3162, Rec. 3′ 3″	6″ Coarse and fine sand and mud pellets followed by very fine white sand.
	2′ 9″ Deep olive-green shale with sandy shale at top half of interval.
3162–3168, Rec. 5′ 7″	Deep olive-green shale with traces of silty sand. About 2 feet below top color changes for about 1 foot to brown-gray (sandy shale).
3168–3178, Rec. 4′ 4″	2′ Hard, buff-colored sandy shale.
	1′ Hard, lignitic, drab gray, very sandy shale.
	2′ 4″ Olive-green, very fine sand and sandy shale with 2 inches of very fine, lignitic, pale lead-gray silty sand.
3178–3183, Rec. 4′ 2″	Hard, pale lead-gray silty shale occasionally lignitic.
3183–3193, Rec. 9′	Soft, fine-grained, gray-white, very lignitic sand. Some lignite seams are $\frac{1}{16}$ inch thick.
3193–3198, Rec. 3′ 8″	Olive-green and buff clay shale.
3198–3208, Rec. 6′ 2″	Bottle-green shale with occasionally chocolate-brown shale. Very fine green-white sand (2 inches) about 1 foot from top.
3208–3213, Rec. 3′	Shale as above.
3213–3218, Rec. 2′	Highly mottled red-brown and bottle-green shale.
3218–3223, Rec. 5′	Chocolate-brown shale, followed by buff shale and black, slightly mottled brown, shale at base.
3223–3227, Rec. 4′	Highly mottled, red-brown, pearl-gray and pale green shale.
3227–3232, Rec. 4′ 6″	2′ Shale as above.
	$\frac{1}{2}$′ Same shale with shale pebbles up to $\frac{1}{4}$ inch.
	1′ Buff to very pale green shale.
	1′ Fine-grained white sand, rusty-brown at base.
3232–3237, Rec. 4′ 3″	1′ 3″ Pearl-gray silty shale.
	3′ Highly mottled rusty-brown red-brown, and pale green shale.

Depth in Feet Recovery	
3237–3242, Rec. 5′	(Poor core.) Mottled shale as above.
	3 inches of fine-grained, pale greenish-white sand at base.
3242–3250, Rec. 4′	½′ Drab shale.
	3¼′ Hard, brittle, green to pale-green, argillaceous, very fine, highly micaceous sand.
	¼″ Bottle-green slightly mottled shale.
3250–3259, Rec. 4′ 7″	1′ Shale as above.
	3′ 7″ Bottle-green, very fine, micaceous sandy shale with very fine, white (1 inch) sand at base.
3259–3269, Rec. 4′ 7″	Soft, medium-grained, white sand with kaolinized feldspars.
3269–3274, Rec. 5′	Sand as above. Toward base some coarse sand.
3274–3281, Rec. 4′ 8″	Sand as above. Sand does not appear clean.
3280–3285, Rec. 5′	1′ Very fine grained, micaceous, pale gray clean sand.
	1′ Medium fine-grained, white sand.
	3′ Drab shale with dark green-black glauconite pellets.
3285–3290, Rec. 3′ 7″	Fine to medium-grained, white, soft micaceous sand. At base sand has a few coarse grains and bottle-green shale pellets up to ⅛ inch.
3290–3300, Rec. 10′	9′ Sand as above. Coarse grains and green shale pellets.
	1′ Drab, gray-black shale with trace of olive-green mottling.
3300–3310, Rec. 5′	6″ Very fine grained, pale gray, micaceous, sparingly lignitic sand.
	4½′ Highly mottled, purplish red, and olive-green silty shale.
3310–3315, Rec. 2′	(Poor) Fragments of shale as above. Medium-grained soft sand.
3315–3325, Rec. 4′	Medium-grained, soft, gray white, sand with shale pebbles (bottle-green) some up to ½ inch. Kaolinized feldspars. At base is mottled, brittle, green shale.
3325–3335, Rec. 7′	Sand as above with pale gray, sparingly lignitic, shale at base.
3335–3345, Rec. 7′	6′ Very fine grained, micaceous, pale lead-gray sand.
	1′ Pale olive-green with trace of brown mottled shale and very fine silty sand.
3345–3355, Rec. 5′ 8″	4′ 8″ Highly mottled, pale bottle-green and red-brown sandy shale.
	1′ Very fine grained, micaceous, pale green chloritic sand.
3355–3360, Rec. 4′ 6″	Very fine grained, pale greenish-gray clean sand. Epidote seen.
3360–3370, Rec. 8′ 6″	Very fine grained, pale greenish-gray clean sand.
3370–3376, Rec. 2′	Very fine grained, pale greenish-gray clean sand.
3376–3386, Rec. 10′	Very fine grained, pale greenish gray clean sand. At 3385 feet is 2 inches of abundant lignite in silty sand.
3386–3396, Rec. 3½′	Same sand with what appears to be kaolized feldspars.
3396–3401, Rec. 5′	Very fine grained, pale greenish-gray clean sand.
3401–3407, Rec. 5′	Very fine grained, pale greenish-gray clean sand.
3407–3417, Rec. 10′	Very fine grained, pale greenish-gray clean sand.
3417–3427, Rec. 6′ 5″	3′ Very fine grained, pale greenish-gray clean sand.
	½′ Coarse white sand.
	½′ Pale bottle-green sandy shale with lead-gray shale at base.
3427–3437, Rec. 10′	Pale greenish-gray silty shale with occasionally streaks of red-brown shale.

Depth in Feet Recovery	
3437–3447, Rec. 10	8′ Pale greenish-gray sandy shale and interlaminated silty sand. Occasionally mottled brown and pale green shale.
	2′ Very fine grained, pale greenish-white soft sand.
3447–3457, Rec. 9′ 8″	4′ Laminated, pale gray, silty shale.
	5′ 8″ Very fine grained, soft, pale gray-white sand.
3457–3467, Rec. 5′	Fine-grained soft white sand.
3467–3472	No recovery. Electric log shows sand with a small shale break.
3472–3477, Rec. 4′ 6″	1′ Mottled brown and green silty shale.
	3½′ Fine-grained, white, soft sand. Some green shale lumps.
3477–3487, Rec. 9′ 8″	Soft, medium to coarse, white sand.
3487–3497, Rec. 10′	2′ Medium-grained soft white sand.
	2′ Bottle-green shale and occasionally lead-gray lignitic shale.
	½′ Mixture of coarse sand and green shale with some shale pellets.
	2′ Bottle-green and drab lignitic shale.
	3½′ Soft, white, medium-grained sand.
3497–3507, Rec. 4½′	1′ Medium-grained sand as above.
	3½′ Highly mottled, pale green and red-brown shale.
3507–3512, Rec. 5′	4′ Highly mottled, brown and bottle-green shale.
	1′ Pale green sandy shale.
3512–3521, Rec. 9′	1′ Pale greenish-gray, silty, micaceous shale.
	2′ Very fine grained, white, soft, clean sand.
	1′ Hard, lead-gray, laminated shale with paper thin silty sand.
	1′ Very fine sand as above.
	3′ Hard, laminated, lead-gray shale and paper thin silty sand.
	1′ Very fine sand as above.
3521–3529, Rec. 7′ 5″	Very fine grained, white, soft sand with 6 inch lens of lead-gray sandy shale and paper thin sand at 3525 feet.
3529–3539, Rec. 10′	Soft, white, fine to medium-grained, sparingly lignitic sand becoming somewhat coarse toward base. (Pyrite noted).
3539–3549, Rec. 10′	4′ Coarse, white, soft sand with milky, smoky and amethystine quartz. Very lignitic at base.
	4′ Pale olive-green very fine sand and sandy shale.
	2′ Very fine grained, white soft sand.
3549–3555, Rec. 6′	5′ Fine to medium-grained soft white sand.
	1′ Hard, indurated, very fine, white sandstone. Lime cement.
3555–3560, Rec. 5′	Soft, white, fine-grained sand becoming more micaceous toward base.
3560–3570, Rec. 1′	Soft sand as above.
3570–3575, Rec. 5′	Medium-grained, soft, white sand, some micaceous.
3575–3583, Rec. 8′	5′ Soft, medium fine grained, white sand, lignitic at base.
	3′ Olive-green shale with occasionally paper thin silty sand.
3583–3590, Rec. 5′ 4″	Pale greenish-gray silty shale becoming mottled with cinnamon-brown at base. Rare paper thin silty sand partings.
3590–3593, Rec. 8″	Only chips of shale as above in box.
3593–3598, Rec. 3′	Highly mottled, pale greenish-gray and red-brown shale.
3598–3608, Rec. 6′	Highly mottled, purple, pale green, red-brown, and rusty-brown shale.

Depth in Feet Recovery	
3608–3613, Rec. 4′	4′ Shale varying in color from greenish pearl-gray to purple at base.
3613–3621, Rec. 6′	1′ Very fine grained white argillaceous sand.
	5′ Chocolate-brown silty shale (1 foot), then pale greenish-gray silty shale.
3621–3631, Rec. 6′	3′ Pale greenish-gray mottled sandy shale.
	3′ Very fine grained silty sand, pale greenish-white with 3 inches of rusty-brown mottled sandy shale at base.
3631–3641, Rec. 9′ 10″	1′ Very fine, silty, pale greenish-white sandstone.
	4′ Highly mottled, pale green, chocolate, red-brown, rusty-brown shale.
	1′ Pearl-gray silty shale and finely laminated silty sand.
	3′ 10″ Mottled shale as above.
3641–3646, Rec. 2′ 8″	Mottled, lead-gray, rusty-brown, shale.
3646–3651, Rec. 2′ 8″	Drab lead-gray mottled shale as above.
3651–3657, Rec. 1′	Drab lead-gray mottled shale as above.
3657–3662, Rec. 2′ 8″	Shale varying from pale grayish-brown to brownish-black.
3662–3672, Rec. 6′	3′ Dark chocolate-brown shale.
	3′ Highly mottled, pale green and purple shale.
3672–3682, Rec. 6″	Drab chocolate-brown shale.
3682–3692, Rec. 3′(?)	2½′ Pale lead-gray slightly mottled shale.
	½′ White, thinly laminated sandy shale.
3692–3697, Rec. 5′	5′ Drab, brownish-black shale.
3697–3702, Rec. 2′ 4″	Pale olive-gray shale, occasionally silty.
3702–3707, Rec. 2′	Shale as above changing to drab chocolate-brown and mottled rusty-brown at base.
3707–3712, Rec. 1′	Pale olive-gray shale, occasionally silty, changing to drab chocolate-brown and mottled rusty-brown at base.
3712–3717, Rec. 5′	Very fine grained, white, argillaceous sand. Some micaceous.
3717–3722, Rec. 5′	Very fine grained, white, argillaceous sand. Some micaceous.
3722–3727, Rec. 2′ 6″	Laminated, lead-gray, lignitic shale and very fine grained white micaceous sand.
3727–3732, Rec. 4′ 4″	3′ 4″ Dark lead-gray to black shale.
	1′ Olive-green shale.
3732–3737, Rec. 4½′	Pale olive-green sandy shale.
3737–3743, Rec. 5′ 10″	2½′ Very fine grained, pale greenish-white soft sand with occasional thin sandy shale.
	½′ Drab greenish-gray shale.
	2′ 10″ Very fine grained, laminated white sand as above.
3743–3748, Rec. 3′ 6″	3′ Dark lead-gray shale with trace of lignite. At top is thin, micaceous, very fine sand.
	½′ Pale lead-gray sandy shale.
3748–3753, Rec. 5′	Dark gray to gray-black shale.
3753–3758, Rec. 5′	Pale lead-gray shale changing to a pale olive-gray silty shale at base.
3758–3763, Rec. 4′ 10″	Pale lead-gray sandy shale and interlaminated silty white sand. Some lignite noted.
3763–3768, Rec. 1′	Fragments of pale buff-gray shale.
3768–3773, Rec. 5′	Pale greenish-gray, highly mottled purple and rusty-brown shale.

Depth in Feet Recovery	
3773–3778, Rec. 5′ 8″	8″ Pale olive-green shale.
	3′ Pale olive-green sandy micaceous shale.
	2′ Very fine grained micaceous green sand.
3778–3783, Rec. 5′	Fine-grained, greenish-white, micaceous sand. C.D. 13° on micaceous layers good in 3 pieces of core.
3783–3788, Rec. 5′	Sand as above.
3788–3793, Rec. 10″	(Nothing in box). Sand on electric log.
3793–3798, Rec. 2′	Fine-grained, greenish-white, micaceous sand.
3798–3804, Rec. 5′	Fine-grained, greenish-white, micaceous sand. (4 inch streak in middle is very micaceous).
3804–3810, Rec. 6′	6″ Very hard, micaceous, sandy, limy, pale green shale. (HCl reaction).
	5½′ Very fine grained, micaceous, soft white sand.
3810–3815, Rec. 5′	Very fine grained white soft sand.
3815–3820, Rec. 5′	3½′ Soft, white, fine-grained sand.
	1′ Olive-green shale.
	½′ Hard, pale lead-gray limestone with lumps of olive-green shale.
3820–3830, Rec. 10′	1½′ Pale olive-green, micaceous sandy shale to very fine grained olive-green sand.
	8½′ Very fine grained, white, soft, micaceous sand.
3830–3835, Rec. 4′ 10″	Dull bottle-green sandy shale and shale.
3835–3840, Rec.	No box. Electric log indicates sandy shale to fine sand.
3840–3850, Rec. 5′ 5″	Soft, fine grained, micaceous, pale olive-white sand.
3850–3855, Rec. 4′ 9″	Heterogeneous mixture of fine to very coarse to gravelly sand. Soft, white, micaceous.
3855–3865, Rec. 5′ 8″	4′ Coarse-grained, white, soft sand.
	1′ Very fine grained, thinly laminated, white micaceous sand, and lead-gray sandy shale. Lignite.
	8″ Coarse sand as above.
3865–3875, Rec. 7′	Soft, white, medium to very coarse sand.
3875–3880, Rec. 5′	½′ Coarse, white, soft sand.
	4½′ Medium to fine-grained, white, soft sand.
3880–3885, Rec. 5′	Fine-grained, soft, white sand.
3885–3895, Rec. 8′ 10″	6′ Sand as above. Very fine, micaceous, pale green sandstone.
	2′ 10″ Pale olive-green sandy shale and shale.
3895–3900, Rec. 5′	3′ Pale greenish-gray shale.
	2′ Highly mottled, chocolate-brown and pale green, silty shale.
3900–3905, Rec. 1′ 8″	Mottled sandy shale.
3905–3910, Rec. 3′	Mottled chocolate-brown shale with dark lead-gray shale in center and sandy shale at base.
3910–3915, Rec. 1′ 4″	Pale lead-gray, mottled brown, shale.
3915–3920, Rec. 2′ 6″	Pale lead-gray, mottled brown, shale.
3920–3925, Rec. 2′ 10″	Pale greenish-gray, mottled red-brown, sandy shale.
3925–3930, Rec. 5′	Very fine grained, pale greenish-gray, micaceous, argillaceous sand.
3930–3940, Rec. 10′	Very fine grained, gray-white, thinly laminated micaceous sand.
3940–3950, Rec. 10′	Fine grained, soft, white, clean sand.
3950–3955, Rec. 3′	1′ Fine sand as above.
	6″ Pale green-gray, slightly mottled brown, shale.

Depth in Feet Recovery	
3955–3960, Rec. 4′	Drab lead-gray, mottled chocolate-brown, shale.
3960–3965, Rec. 3′ 7″	Pale greenish-gray shale, mottled red-brown.
3965–3970, Rec. 5′	Very fine grain, pale greenish-white argillaceous sand.
3970–3980, Rec. 10′	Very fine to fine-grained, micaceous soft white sand.
3980–3985, Rec. 5′	Very fine grained, pale greenish-white sand.
3985–3990, Rec. 5′	1′ Very fine sand as above.
	2½′ Thinly laminated, micaceous, lead-gray sandy shale and silty sand.
	1½′ Very white sand as above.
3990–4000, Rec. 10′	1½′ Very fine grained, pale green-white, micaceous, soft sand.
	1½′ Lead-gray, thinly laminated, silty micaceous sand and sandy shale, cross-bedded.
	7′ Fine-grained, white, micaceous, soft sand.
4000–4010, Rec. 10′	10′ Fine-grained, white, soft, micaceous sand with seams of lignite scattered throughout.
4010–4015, Rec. 5′	4½′ Fine, white, lignitic sand as above.
	½′ Lead-gray, thinly laminated, micaceous sandy shale and silty sand.
4015–4020, Rec. 4′ 8″	Lead-gray, thinly laminated, sandy shale, shale and silty sand. Lignite plentiful.
4020–4025, Rec. 5′	2′ Lignitic sandy shale, as above.
	3′ Fine-grained, soft, white sand.
4025–4035, Rec. 10′	4½′ Medium-grained, soft, white, friable sand.
	½′ Thinly laminated, lead-gray shale and silty sand.
	5′ Fine-grained, soft, friable white sand.
4035–4045, Rec. 10′	Fine-grained, soft, white, friable sand with thin lead-gray shale at 4040 feet.
4045–4051, Rec. 6′	Fine-grained, white, friable sand.
4051–4053, Rec. ½′	Fine-grained, white, friable sand.
4053–4058, Rec. 5′	1′ Very hard, fine-grained, white micaceous calcareous sandstone.
	½′ Pale olive-green micaceous silty shale.
	3½′ Medium to fine-grained, white sand with coarse and granule gravel at top.
4058–4068, Rec. 10′	3′ Fine to medium-grained, soft white sand.
	1′ Medium to very coarse white sand and rounded green shale pebbles.
	6′ Medium to fine, white, at times micaceous, soft sand.
4068–4076, Rec. 9′ 3″	Medium to coarse-grained soft white sand.
4076–4086, Rec. 9′ 6″	8′ Medium and coarse-grained, soft, white sand with very coarse sand and some shale pebbles in lenses in center.
	1′ Lead-gray, micaceous shale. Hard and laminated.
4086–4091, Rec. 5′	Thinly laminated, lead-gray shale and thin partings up to $\frac{1}{16}$ inch of buff silty sand. Good C.D. = 6°.
4091–4101, Rec. 10′	3′ Lead-gray highly lignitic sandy shale and very fine sand.
	7′ Pale olive-gray very fine argillaceous soft sand.
4101–4107, Rec. 5½′	2′ Pale greenish-gray, highly argillaceous, fine to coarse sand.
	3′ Pale greenish-gray, highly argillaceous, fine-grained sand.
4107–4117, Rec. 10′	Fine to medium-grained, pale greenish-gray soft sand.

Depth in Feet Recovery	
4117–4127, Rec. 10′	4′ Pale olive-green, fine to medium-grained, soft sand becoming very coarse at base.
	1′ Mixture of very coarse sand and medium-grained sandstone and dark lead-gray carbonaceous shale.
	5′ White, soft, fine to very fine grained sand.
4127–4137, Rec. 10′	6′ Pale greenish-white, soft, fine-grained sand.
	2′ Mixture of pale bottle-green shale and very coarse sand.
	2′ Fine-grained, white, soft sand as above.
4137–4147, Rec. 10′	Medium to coarse-grained soft white sand, becoming micaceous at base.
4147–4157, Rec. 1′	(Very poor core). Fragments of greenish-gray shale and coarse sand. (Doubtless lost sand core).
4157–4162, Rec. 1′	½′ Coarse white soft sand.
4162–4168, Rec. 6′	Coarse-grained, soft white sand with very coarse streak at top and medium-grained at base.
4168–4178, Rec. 10′	1′ Medium-grained, soft, white sand, abundant pink and brown garnets.
	9′ Coarse, medium and fine-grained soft, white sand.
4178–4183, Rec. 8″	Fragments of olive-green shale.
4183–4188, Rec. 4′	Highly mottled, drab greenish-gray and chocolate-brown shale.
4188–4193, Rec. 3′ 3″	Highly mottled, drab greenish-gray and chocolate-brown shale.
4193–4199, Rec. 6′	3′ Mottled shale as above. In bottom 1 foot of shale is olive-green without mottling.
	1′ Very fine, micaceous, olive-green, argillaceous sand.
	2′ Very fine grained white soft sand.
4199–4209, Rec. 10′	5′ Very fine grained olive-green argillaceous sand (2 feet) to fine-grained, white soft sand.
	1′ Dark lead-gray laminated shale.
	4′ Fine-grained white sand.
4209–4219, Rec. 10′	Medium-grained, white, soft sand with a little very coarse sand in lower 3 feet.
4219–4229, Rec. 8′ 5″	Medium-grained, soft, white sand, pink garnets plentiful.
4229–4237, Rec. 8″	Poor core. Fragments of coarse sand and green shale.
4237–4242, Rec. 4′ 2″	½′ Coarse, soft white sand.
	1′ Hard, dark lead-gray to black, silty lignitic shale.
	1′ Pale olive-green silty shale.
	1′ Very fine grained, pale olive-green, micaceous sand.
4242–4247, Rec. 2′	Very fine grained, pale green-gray, micaceous sand.
4247–4252, Rec. 3′	1′ Thinly laminated, gray sandy shale and very fine gray sand.
	2′ Mottled brown and olive-green shale.
4252–4260, Rec. 6′ 10″	Chocolate-brown and mottled olive-green shale.
4260–4265, Rec. 5′	Chocolate-brown and mottled olive-green shale.
4265–4275, Rec. ?	No core. Electric log indicates shale.
4275–4280, Rec. 4½′	1′ Pale green and rusty-brown mottled sandy shale.
	2′ Pale bottle-green sandy shale.
	1½′ Laminated, lead-gray shale and very fine silty white sand.
4280–4290, Rec. 4′ 9″	3′ Lead-gray silty shale and very thin, white silty sand. (No more core in box. Should be some sand by electric log.)
4290–4297	Core missing. Should be sand from electric log.
4297–4302, Rec. 3′ 2″	Medium-grained, soft, white sand with a little coarse sand.

Depth in Feet Recovery	
4302–4312	Core missing. Sand and shale from electric log.
4312–4317, Rec. 1′	Only 6 inches in box. Hard, pale green-gray sandy shale.
4317–4322, Rec. 4½′	Medium-grained white soft sand.
4322–4327	Core missing.
4327–4332, Rec. 5′	Medium coarse, soft, white sand.
4332–4337, Rec. 2′	Only about 6 inches in box. Very soft coarse white sand.
4337–4342, Rec. 4′ 8″	About 2 feet in box. Loose and very soft coarse white sand
4342–4347, Rec. 1′ 4″	Loose and very soft coarse white sand.
4347–4351, Rec. 1′ 4″	Sand as above plus fragments of buff cinnamon-brown shale with forams. (Contamination).
4351–4356, Rec. 3′	1′ Hard, deep bottle-green sandy shale.
	2′ Very fine grained, pale greenish-gray sand.
4356–4361, Rec. 5½′	Fine-grained, gray-green very argillaceous sand.
4361–4366, Rec. 3′	Fine-grained soft white sand.
4366–4375, Rec. 4″	Fine-grained soft white sand. Some lignite.
4375–4380, Rec. 3′ 2″	2″ Hard, dark lead-gray shale.
	1′ Soft, heterogeneous, medium to very coarse sand and occasional granule gravel.
4380–4384, Rec. 2½′	1½′ Medium to very coarse soft white sand.
	½′ Dark lead-gray silty shale.
4384–4387, Rec. 2′	1′ Dark shale as above with very fine argillaceous sand (2 inches) at base.
4387–4391, Rec. 1½′	1″ Laminated, drab gray shale. Rest poor core of disintegrated sand with variable grain sizes up to ½ inch pebbles.
4391–4396, Rec. 1′ 3″	2″ of core left. Dark gray-black shale.
4396–4401, Rec. 4′ 6″	Medium to coarse soft white sand with one pebble noted ¾ inch x ½ inch.
4401–4406, Rec.	No core received. Electric log indicates sand.
4406–4414, Rec. 6′ 2″	1½′ Deep bottle-green, medium-grained sandstone with a glauconitic matrix.
	1½′ Medium-grained, pale greenish-white argillaceous and limy sandstone; HCl reaction.
4414–4424, Rec. 10′	9′ Soft, pale greenish-white sand varying from fine to coarse-grained mixture?
	1′ Deep bottle-green glauconitic shale with a minor amount of fine sand and shale pebbles.
4424–4434, Rec. 9½′	1′ Fine-grained, apparently glauconitic, argillaceous sand.
	2′ Medium-grained soft white sand.
	6½′ Mixture of fine to granule gravelly sand, argillaceous.
4434–4444, Rec. 6′ 8″	6′ Sand fine to granule sand as above.
	8″ Fine-grained, argillaceous, soft white sand.
4444–4454, Rec. 10′	2′ Bottle-green, highly micaceous, laminated sandy shale.
	8′ Mixture of all grain sizes of sand up to granule gravel. Soft, white, argillaceous sand containing shale pebbles and lumps up to ¾ inch.
4454–4464, Rec. 5′ 10″	Sand mixture as above. Pebbles up to 1 inch x ¾ inch.
4464–4469, Rec. 4′ 6″	Sand as above.
4469–4480	No cores received. Electric log indicates sand.
4480–4486, Rec. 2′ 10″	About 1 foot of core in box. 1 inch hard, pale gray shale. Rest, coarse sand mixture as above.

Depth in Feet Recovery	
4486–4493	No core received.
4493–4500, Rec. 1½′	Coarse sand mixture as above.
4500–4506, Rec. 4′ 9″	Coarse sand mixture as above.
4506–4516, Rec. 8′ 5″	2′ Coarse to fine mixture soft, argillaceous sand. Upper 1 foot is white, lower 1 foot is pale green. 6′ 5″ Fine-grained, argillaceous, pale green, soft sand becoming coarse toward base (lower 1 foot).
4516–4521, Rec. 3′ 5″	Fine-grained, soft, highly argillaceous, pale green sand with few green shale lenses.
4521–4526, Rec. 6′	Fine-grained, argillaceous, white soft sand.
4526–4531, Rec. 1′ 5″	Same sand as above but coarse at base.
4531–4536, Rec. 1′ 3″	Mixture of fine to coarse, white, argillaceous soft sand.
4536–4546, Rec. 8′	Sand as above with some granule gravel.
4546–4551, Rec. 1′ 6″	Very fine grained, micaceous, lignitic, argillaceous sand.
4551–4556, Rec. 1′ 7″	About 6 inches in box of very poor core. Fragments of gray shale and coarse sand.
4556–4561, Rec. 4′ 10″	Coarse to fine-grained, soft, white argillaceous sand.
4561–4566, Rec. 4′ 11″	Coarse to fine-grained, soft, white argillaceous sand.
4566–4576, Rec. 5′ 9″	Coarse to fine-grained, soft, white argillaceous sand, with granule gravel.
4576–4582, Rec. 5′	1′ Coarse sand as above. 1′ Dull green-gray shale. 1′ Very fine grained argillaceous sandstone.
4582–4592, Rec. 3′ 6″	Soft, arkosic, white, coarse-grained sand.
4592–4600, Rec. 2′ 10″	Coarse to very coarse grained, soft, white sand with granule gravel.
4600–4601	No core.
4601–4605, Rec. 2½′	Only about 2 inches of fragments in box. Pale green shale.
4605–4610, Rec. 3′ 6″	Pale bottle-green shale with some rusty-brown mottling.
4610–4615, Rec. 2′ 10″	Shale as above with red-brown mottling.
4615–4620, Rec. 3′ 4″	Shale as above.
4620–4626, Rec. 3′	Hard, lead gray sandy shale with some red-brown mottling with chocolate-brown sandy followed by white sandy shale.
4626–4632, Rec. 2′ 6″	Hard, white sandy shale with red-brown mottling at base.
4632–4637, Rec. 3½′	Hard, white sandy shale with red-brown mottling at base.
4637–4642, Rec. 2′	Highly mottled gray and red-brown shale.
4642–4645, Rec. 2″	Fragments of gray shale.
4645–4650, Rec. 4′ 7″	Red-brown, micaceous sandy shale (2 feet), then laminated silty shale.
4650–4656, Rec. 6′	Pale gray-white sandy shale, slightly mottled at base, then pale green laminated silty shale (1 foot), followed by 2 feet of mottled gray and brown shale.
4656–4659, Rec. 3′	2′ Very fine grained, micaceous, white, argillaceous sandstone with 6 inches of fine to medium-grained sand at base.
4659–4664, Rec. 4′ 3″	(Only about 1 foot of core in box). Medium to coarse white sand, followed by gray-black shale, then thinly laminated, dark gray silty shale and thin silty white sand, some lignite.
4664–4674, Rec. 1′ 2″	Fine to very coarse, arkosic, soft white sand.
4674–4677, Rec. 2′ 5″	Brittle, pale olive-green shale.
4677–4679, Rec. 2′	Pale olive-green silty shale.

Depth in Feet Recovery	
4679–4684, Rec. 3′ 10″	Few fragments of medium-grained white sand. Few fragments of black shale. 3′ Pale gray sandy shale with streaks of fine-grained white sand. Mica and lignite.
4684–4689, Rec. 3′	6″ Laminated gray-black silty shale. 2½′ Fine-grained, white, soft, micaceous sand.
4689–4695, Rec. 2′ 10″	Brittle pale greenish gray shale.
4695–4699, Rec. 3′ 5″	Dull gray, mottled red-brown, shale followed by 1 foot of bottle-green sandy shale.
4699–4704, Rec. 2′ 2″	Hard, pale green, slightly mottled, very fine sandy shale.
4704–4707, Rec. 2′ 6″	Pale green-gray, mottled rusty-brown, shale.
4707–4712, Rec. 3′ 8″	Shale as above with some sandy shale.
4712–4717, Rec. 4′ 3″	Very hard, compact, white sandstone, slightly mottled rusty-brown and purple.
4717–4722, Rec. 6″	Nothing in box.
4722–4727, Rec. 5′ 10″	Drab gray and greenish-gray, hard, silty shale with 4 inches of white sandy shale near top.
4727–4737, Rec. 3′	(About 1 foot in box). Pale lead-gray, with cinnamon-brown tone, waxy shale.
4737–4742, Rec. 3′	Pale green, mottled brown, shale.
4742–4747, Rec. 5′	Pale lead-gray, sandy, micaceous shale.
4747–4751, Rec. 3′ 5″	Laminated, pale gray, sandy, micaceous shale and lenses of very fine grained white sand.
4751–4756, Rec. 5′	Fine-grained, white, soft, arkosic sand.
4756–4766, Rec. 2′ 10″	Fine-grained, white, soft, arkosic sand.
4766–4771, Rec. 1′ 9″	Fine-grained, white, soft, arkosic sand and drab gray shale.
4771–4778, Rec. 6′ 10″	Pale lead-gray shale and some sandy shale.
4778–4788, Rec. 5′ 9″	1′ Very fine grained, arkosic, white sand. 1′ Lead-gray, silty shale and sandy shale. 2′ Sand as above with shale as above at base.
4788–4798, Rec. 6″	Nothing in box. Electric log indicates shale.
4798–4803, Rec. 3′ 6″	Mixture of fine to coarse white soft sand with some granule gravel.
4803–4805, Rec. 1′ 3″	Hard, white, fine-grained sandstone. Trace of lignite.
4805–4806, Rec. 1′ 4″	Hard, limy, micaceous, fine-grained white sand with few lignite seams.
4806–4809, Rec. 1′ 10″	Soft, white, fine-grained, slightly micaceous sand.
4809–4813, Rec. 3′ 8″	Soft, white, sand, coarse at top passing into fine-grained sand. Trace of lignite.
4813–4818, Rec. 5′	Sand as above. At base lead-gray laminated shale and very fine micaceous sand.
4818–4823, Rec. 6″	Nothing in box.
4823–4828, Rec. 1′	Medium-grained sand.
4828–4834,	No recovery. Electric log indicates sand.
4834–4839, Rec. 3″	Coarse sand and granule gravel.
4839–4844, Rec. 2′	Hard, pale greenish-gray sandy shale.
4844–4849, Rec. 5′	1′ Brownish-gray hard shale. 1′ Hard, pale bottle-green shale passing into micaceous sandy shale. 1′ Hard, lead-gray silty, slightly lignitic shale. 2′ Hard, very fine grained, argillaceous sandstone.

Depth in Feet Recovery	
4849–4854, Rec. 1′ 9″	Pale lead-gray silty micaceous shale.
4854–4857, Rec. 3′ 9″	Hard, pale lead-gray micaceous shale.
4857–4862, Rec. 3′ 4″	Hard, very fine grained, micaceous, argillaceous white sandstone.
4862–4872, Rec. 1½′	Fine to medium-grained, soft, white sand.
4872–4877, Rec. 2′	Fine-grained, white, soft sand with some lignite.
4877–4882, Rec. 8″	Nothing in box.
4882–4892, Rec. 1′	Sandstone, white and hard lead-gray, lignitic silty shale.
4892–4897, Rec. 1′ 6″	Fine-grained white sand.
4897–4902, Rec. 3′	Coarse-grained, soft, white sand.
4902–4907, Rec. 5′	Mixture of medium to very coarse sand and gravel.
4907–4912, Rec. 5′	Sand as above, not as coarse grained.
4912–4917, Rec. 1′	Sand as above.
4917–4922, Rec. 1′ 9.6″	Fine-grained to coarse-grained soft white sand.
4922–4927, Rec. 4½′	Soft, white, very coarse sand and granule gravel.
4927–4933, Rec. 2′	Dark gray-black slightly silty shale.
4933–4938, Rec. 6″	Nothing in box.
4938–4948, Rec. 6″	Shale as above (determination by Ohio Oil Co.). Electric log indicates sand.
4948–4953, Rec. 1′	Only small fragments in box. Coarse lignitic sand (Ohio Oil Co.).
4953–4958, Rec. 1′ 9.6″	Fine to coarse, soft white sand with small amount of granule gravel.
4958–4963, Rec. 7″	Only few small fragments in box. Fine to coarse, soft white sand with small amount of granule gravel.
4963–4966, Rec. 5″	Fine to coarse, soft white sand with small amount of granule gravel.
4963½–4963½	Very hard quartz sand (determination by Ohio Oil Co.).
4963½–4965½, Rec. 2′	Fine to medium-grained soft, white sand with a little granule gravel.
4965½–4970, Rec. 3′	Sand as above. Trace of lignite. Extremely hard pebble consisting of fine green quartz cemented by iron sulphide.
4970–4975, Rec. 5′	Soft, white, medium-grained sand.
4975–4980, Rec. 3′ 1″	Fine-grained to medium-grained soft white sand with coarse sand in center. Lignitic at base.
4980–4985, Rec. 1′	Some sand and pale brown-gray waxy shale.
4985–4989, Rec. 1′	Hard, deep bottle-green sandy shale. Appears to be glauconitic.
4989–4994, Rec. 2″	Nothing in box. Black shale (determination by Ohio Oil Co). Wet core.
4994–4999, Rec. 3″	Nothing in box. Dark shale (by Ohio Oil Co.). Wet core.
4999–5004, Rec. 1′	Few fragments of black silty, carbonaceous shale. Ditch sample has numerous shell fragments. Contamination.
5004–5007, Rec. 3′ 6″	Soft, white, fine-grained sand. Has distinct salty taste.
5007–5012, Rec. 3′	Soft, fine-grained, white sand. Salty taste.
5012–5017, Rec. 2′	Soft, fine-grained sand at very top, followed by nearly 2 feet of dark gray micaceous sandy shale and interlaminated with very fine silty white sand.
5017–5022, Rec. 1′ 3.6″	Pale greenish-gray shale with cinnamon-brown streaks.
5022–5027, Rec. 2′ 10.8″	Fine-grained, micaceous white sandstone. Hard at top.

Depth in Feet Recovery	
5027–5032, Rec. 4′ 4.8″	1′ Fine-grained, soft white sand.
	1′ Finely laminated, dark gray sandy shale and fine sand. Good C.D. 7°.
	2′ Fine-grained, white, soft lignitic sand.
5032–5037, Rec. 1′	Soft white micaceous sand.
5037–5042, Rec. 5′	Fine-grained, white sand with common carbonaceous streaks. Harder at top.
5042–5047, Rec. 6″	Nothing in box. White sand and drab shale (by Ohio Oil Co.).
5047–5052, Rec. 8″	Nothing in box. Black sandy shale (by Ohio Oil Co.).
5052–5057	No recovery.
5057–5062, Rec. 4″	Nothing in box. Dark shale (by Ohio Oil Co.). Electric log indicates sand also.
5062–5067, Rec. 6″	Nothing in box. Soft to medium hard gray sand to shale (by Ohio Oil Co.).
5067–5069, Rec. 8″	Nothing in box. Soft gray unconsolidated sand (by Ohio Oil Co.).
5069–5074, Rec. 4″	Nothing in box. Coarse gray sand (by Ohio Oil Co.).
5074–5079, Rec. 1′	Nothing in box. Coarse gray sand (by Ohio Oil Co.).
5079–5083	No recovery.
5083–5089, Rec. 1′ 11″	Greenish-gray shale.
5089–5093, Rec. 1′ 7″	Lead-gray, micaceous, carbonaceous sandy shale with streaks of very fine micaceous sand.
5093–5098, Rec. 2″	Nothing in box.
5098–5099, Rec. 1′	Few chips in box. Coarse white sand (by Ohio Oil Co.).
5099–5104, Rec. 1′	Medium-grained, white soft sand.
5104–5112, Rec. 3′ 10″	Fine-grained, white soft sand, highly lignitic in streaks up to $\frac{1}{8}$ inch.
5112–5122, Rec. 6′ 10″	Coarse-grained, soft, white sand.
5122–5127, Rec. 1′	Nothing in box. Same as above (by Ohio Oil Co.).
5127–5130, Rec. 1′ 8″	Coarse, lignitic sand and gray shale.
5130–5135, Rec. 3′ 4″	1′ Coarse white soft sand with hard, fine-grained sand at base.
	1′ Hard lead-gray shale and sandy shale.
	1′ 4″ Very coarse soft white sand.
5135–5140, Rec. 3′ 4.8″	Hard greenish-gray silty shale passing into a lead-gray shale with lead-gray sandy shale at base.
5140–5145	No recovery. Electric log indicates same as above.
5145–5150, Rec. 5′	Dark gray, crossed-bedded, lignitic, hard sandy shale with silty white sand. Very fine hard white limy sandstone at base.
5150–5155, Rec. 8″	Nothing in box. Hard light colored sand, irregular (by Ohio Oil Co.).
5155–5160, Rec. 2′	Hard, fine-grained, limy sandstone with occasional white shale, then thin dark shale, then sand as above.
5160–5165, Rec. 3′ 2.4″	White hard sandy shale passing into fine-grained, micaceous, white soft sand. At base 6 inches of hard lead-gray interlaminated sandy shale and very fine sand.
5165–5168, Rec. 2′	Hard lead-gray silty shale with very hard very fine grained shaly sandstone at base.
5168–5171, Rec. 3′ 6″	Dark micaceous sandy shale to hard sand, brown at bottom (Ohio Oil Co.).

Depth in Feet Recovery	
5171–5173, Rec. 2′	Very hard, cinnamon-brown, sideritic shale. No HCl reaction. Appears to have some oolites.
5173–5175, Rec. 2′	Very hard, cinnamon-brown, sideritic shale. No HCl reaction. Appears to have some oolites.
5175–5178, Rec. 3′	Very hard, cinnamon-brown, sideritic shale. No HCl reaction. Appears to have some oolites.
5178–5183, Rec. 2′	Hard brown shale as above passing into hard, fine-grained, brown-white sand. Trace of lime (very little HCl reaction).
5183–5193, Rec. 2′	Moderately soft, fine-grained, white sand.
5193–5201, Rec. 4′	Soft, fine-grained, white, lignitic sand.
5201–5206, Rec. 1′ 8.4″	Hard, dark gray carbonaceous shale and finely laminated silty sand followed by soft, fine-grained, white sand.
5206–5213, Rec. 5′	Fine-grained, moderately hard, white, slightly lignitic limy sandstone with dark gray-black carbonaceous shale at base.
5213–5217	No recovery.
5217–5222, Rec. 4′ 6″	Dark gray to black, micaceous sandy shale and shale.
5222–5227, Rec. 2′	Hard, lead-gray, argillaceous sandstone grading into lead-gray hard silty shale.
5227–5232, Rec. 5′	Hard, pale buff-gray sandy shale with a streak of dark gray micaceous shale and sand in middle.
5232–5237, Rec. 8″	Nothing in box. Sand as above (by Ohio Oil Co.).
5237–5242, Rec. 1′	Hard, dark gray silty shale.
5242–5247, Rec. 4′ 10.8″	3′ 10.8″ Hard, brownish-gray sandy shale and shale with a 6 inch streak of very fine soft argillaceous sand in middle. Traces of carbonaceous matter. 1′ Moderately hard, white, very fine sandy shale.
5247–5252, Rec. 3′	2″ Hard, medium-grained, lignitic, white limy sandstone, well rounded grains. 2′ 10″ Hard, dark lead-gray, silty shale.
5252–5257, Rec. 4′ 2.4″	Dark gray micaceous silty shale becoming mottled with purple tones at base.
5257–5261	No recovery. Probably same as above by electric log.
5261–5267, Rec. 3′	Hard, dark lead-gray, silty, finely micaceous shale.
5267–5272, Rec. 4′ 10.8″	2½′ Soft, white, fine-grained limy sand. 1′ Hard, lead-gray shale turning to olive mottled gray shale with siderite spherules. 1′+ Fine, gray, moderately hard argillaceous sandstone.
5272–5276, Rec. 2′ 1″	Pale gray-white, hard, highly argillaceous sandstone with moderately soft fine-grained argillaceous sandstone at base.
5276–5279	No recovery. Probably shale from electric log.
5279–5284	No recovery. Probably sandy shale and sand (electric log).
5284–5289 Rec. 1′	Coarse white very gritty sand (by Ohio Oil Co.).
5289–5294 Rec. 8″	White coarse sand (by Ohio Oil Co.).
5294–5297	No recovery.
5297–5302, Rec. 3′ 3.6″	Hard lead-gray shale, mottled yellow and containing spherules about 1 mm. in diameter. Probably siderite.
5302–5307, Rec. 1′ 2″	Very hard coarse sand (by Ohio Oil Co.).
5307–5312, Rec. 1′	Very coarse white sand with some gravel.
5312–5315, Rec. 1′ 6″	Very fine grained, white, soft, micaceous sand.

Depth in Feet Recovery	
5315–5320, Rec. 6″	Hard quartz sand with lime (by Ohio Oil Co.).
5320–5324, Rec. 1′ 6″	Medium hard white sand (by Ohio Oil Co.).
5324–5329, Rec. 6″	Nothing in box. Fine-grained unconsolidated gray sand to gray sandy shale (by Ohio Oil Co.).
5329–5333, Rec. 6″	Fine-grained unconsolidated gray sand (by Ohio Oil Co.).
5333–5338, Rec. 2′	Dark lead-gray shale with some yellow mottling. Spherules of probably siderite.
5338–5343, Rec. 1′ 6″	Hard, lead-gray sandy shale and very fine grained sand mixture.
5343–5348, Rec. 6″	Dark gray to maroon hard shale (by Ohio Oil Co.)
5348–5353, Rec. 6″	Nothing in box. Sandy maroon shale and large gravel (by Ohio Oil Co.).
5353–5359, Rec. 1′ 9.6″	Maroon shale and fine sand (by Ohio Oil Co.).
5359–5361, Rec. 3″	Hard gray shale (by Ohio Oil Co.).
5361–5362, Rec. 1′+	Hard, dark gray sandy shale mottled red-brown.
5362–5372, Rec. 8′ 6″	1′ Hard, green-gray, mottled red-brown, sandy shale.
	3″ Hard arkosic conglomerate with trace of lime cement.
	6′ Sandy shale as above.
	3″ Conglomerate as above.
5372–5380, Rec. 3′ 3.6″	Hard gray conglomerate. Arkosic with some lime cement and gravel up to $\frac{3}{4}$ inch.
5380–5384, Rec. 2′	Hard, bottle-green, silty shale with considerable red-brown mottling.
5384–5390, Rec. 2′	Hard, dark gray, fine-grained sandstone with some lime cement.
5390–5395, Rec. 3′ 6″	Sandstone as above. Slightly mottled red-brown.
5395–5400, Rec. 2′ 8″	Fine-grained, hard, brownish-purple sandstone. Looks like Triassic sandstone.
5400–5403	No recovery.
5403–5408	No recovery.
5408–5409	No recovery.
5409–5411	No recovery.
5411–5416, Rec. 6′ 4.8″	5′ Hard, red hematitic, micaceous sandy shale.
	1′ 4.8″ Red-brown, arkosic, (white areas) moderately hard sandstone.
5416–5421, Rec. 4′ 2″	Mixture of fine to very coarse argillaceous and arkosic red-brown conglomeratic sandstone with some sandy shale lenses near base.
5421–5426, Rec. 2′ 6″	Red-brown sandy shale and very coarse to fine, red-brown conglomeratic sandstone.
5426–5431, Rec. 2′ 8″	Hard red-brown micaceous sandy shale with occasional pale green mottling.
5431–5436, Rec. 7′	6′ Red-brown sandy shale as above with medium to coarse, hard, gray-green sandstone at base, then back into sandy shale.
	1′ Medium-grained pink-white sandstone, arkosic.
5436–5441, Rec. 1′ 5″	Reddish-brown arkosic sandstone as above.
5441–5446, Rec. 1′ 6″	Sandstone as above with some granule gravel. Red-brown shale at base.
5446–5451, Rec. 8″	Nothing in box. Red silty micaceous shale (by Ohio Oil Co.).
5451–5456, Rec. 2′ 7″	$1\frac{1}{2}$′ Hard red-brown, mottled apple-green, argillaceous sandstone.

Depth in Feet Recovery	
	1′ Hard brown shale with granule gravel.
5456–5457	No recovery.
5457–5462, Rec. 1′	Hard, very fine grained, variegated red-brown and pale green, argillaceous sandstone.
5462–5467, Rec. 4′	Medium-coarse, pale gray, arkosic sandstone.
	Hard, red-brown and green, silty shale.
5467–5472, Rec. 5′	4′ Red-brown and pale green gritty shale.
	1′ Mixture of red-brown and green shale with very coarse sand and granule gravel.
5472–5479, Rec. 1′ 8″	Coarse, arkosic, argillaceous, red-brown sandstone and brown shale.
5479–5481	No recovery.
5481–5483, Rec. 1′ 2″	Coarse, arkosic, argillaceous red-brown sandstone.
5483–5488, Rec. 2′ 2″	Soft, arkosic, pale gray conglomerate.
5488–5493, Rec. 3′	Soft conglomeratic sand as above.
5493–5498, Rec. 2′	Medium-grained to very coarse, argillaceous, gray soft sand.
5498–5501, Rec. 5′ 6″	Rotten mica, chlorite schist with small veins of pegmatite.
5501–5506, Rec. 3′ 9″	Only small amount of chips in box. Some rotten schist as above.
5506–5510	No recovery.
5510–5515	No recovery.
5515–5519	No recovery.
5519–5524	No recovery.
5524–5527	Recovered one inch. Igneous in appearance (by Ohio Oil Co.).
5527–5529	No recovery.
5529–5537, Rec. 7′ 4″	Biotitic rich gneiss shot through with coarse pegmatite veins, some of which have rotten orthoclase feldspars and chlorite.
5537–5542, Rec. 6′ 4″	This core appears to be a gneiss with a faint foliation nearly parallel to the length of the core. Biotite rich. Cut by veins of pegmatite containing pink orthoclase and white silicates. These veins cut across the foliation.
5542–5547, Rec. 5′ 8″	The last core. Badly fractured biotite gneiss, intruded by pegmatite containing pink orthoclase, pyrite, chlorite, epidote and garnet.
5547–5568	Gneiss (by Ohio Oil Co.).

J. D. BETHARDS NO. 1 WELL SOCONY-VACUUM OIL COMPANY, BERLIN, MARYLAND

BY

JUDSON L. ANDERSON

CORE SAMPLES

Depth in Feet Recovery	
1709–1728, Rec. 17′	Lead-gray shale, with abundant dark green, rounded glauconite grains.
1894–1914, Rec. 15′	½′ pale lead-gray glauconitic shale.

Depth in Feet Recovery	
	1½′ dark gray, slightly silty, fossiliferous shale. Pelecypods and gastropods.
	13′ silty shale, dark lead-gray, micaceous, irregularly laminated and occasional 3 inch to 6 inch lens of fine-grained, gray micaceous sand.
2110–2125, Rec. 16′	7′ pale greenish-gray brittle shale becoming deeper olive-green in lower 4 feet. Occasional rusty-brown mottling in lower part.
	1′ sand, fine-grained, silty, gray, occasionally micaceous (muscovite) and mottled olive-green and rusty-brown.
	1′ sand as above, but soft and no mottling.
	7′ shale as above. Highly mottled in all but lower 1½ feet of interval.
2325–2340, Rec. 15′	1′ Lead-gray silty micaceous shale.
	3′ very fine grained micaceous, argillaceous sand. Color, pale gray and brown. Traces of lignite and glauconite.
	11′ pale lead-gray brittle shale.
2540–2560, Rec. 20′	3′ interlaminated very fine micaceous gray-brown sand and dark lead-gray shale.
	1½′ fine, pale olive-green, micaceous sand. Chloritic and minor amount of glauconite.
	1′ mixture of very fine grained olive-green, glauconitic sand and shale.
	3′ interlaminated, very fine, micaceous and lignitic gray sand and shale.
	4′ greenish-gray and at times cinnamon-brown very fine silty sand and shale.
	2½′ fine-grained, grayish-brown, micaceous sand slightly glauconitic.
	1′ lead-gray interlaminated shale and very fine sand.
	2′ very fine grained pale olive-green and brown argillaceous and slightly glauconitic and micaceous sand.
	1′ lead-gray shale and sand as above.
	1′ lead-gray, micaceous, fine-grained sand.
2735–2751, Rec. 12′	1′ interlaminated very fine micaceous gray sand and dark gray shale.
	4′ dark gray shale and very fine grained, paper thin sand. Sparingly carbonaceous.
	3′ very fine grained, somewhat argillaceous, light gray sandstone grading into
	4′ dark gray to black silty lignitic shale and gray silty sand. At base shale is pale lead-gray, silty and micaceous.
2950–2966, Rec. 8′	Shale, pale brownish-gray, mottled red-brown, rusty-brown, green. Upper 3′ of core is pearl gray-white.
3155–3171, Rec. 14′	6′ sand, fine to medium-grained, friable, slightly arkosic, white.
	8′ ditto. Clay pebbles up to ½ inch at 3165–66 feet and at 3171 feet.
3375–3391, Rec. 14′	Fine-grained to medium, soft, gray-white sand. Epidote and garnet common. Green shale (2 inches) at base.

Depth in Feet Recovery	
3585–3601, Rec. 4′	Shale, gray with a pale green tone, mottled with purple and rusty-brown.
3795–3801, Rec. 3½′	Shale, pale lead-gray. Slightly mottled, red-brown and rusty-brown. At base shale is slightly carbonaceous.
4010–4025, Rec. 6′	Highly mottled brittle shale. Pale olive-green at top. Mottled red, brown, lavender, pale gray and rusty-brown.
4213–4228, Rec. 9′	Silty shale, pearl-gray, slightly micaceous (muscovite) and carbonaceous. At top and base, pale gray hard siltstone.
4415–4431, Rec. 14′	1′ shale, silty red-brown and chocolate mottled grading into
	5′ fine-grained, argillaceous, mottled red-brown and lavender, hard sandstone.
	2½′ shale, highly mottled, predominately red-brown with some greenish-gray silty, micaceous shale.
	½′ green-gray siltstone, micaceous.
	3½′ shale, mottled as above.
	½′ hard, micaceous (biotite and chlorite) limey, fine-grained sandstone.
	1′ mottled shale as above.
4632–4648, Rec. 11′	8′ Fine to medium-grained sand. Color bottle-green with small amount of glauconite. From 4 to 6 feet the sand is hard, micaceous and limey.
	3′ sand as above. Color, gray-white with 2 inch lead-gray shale lens in center.
4845–4863, Rec. 3′ 6″	3′ shaly sand, fine-grained, greenish-gray.
	½′ sand, soft, friable, medium-grained, white.
5062–5082, Rec. 20′	Sand, white, coarse, very coarse and pebbly with pebbles up to ½ inch. Arkosic. Clay ball and pellets (up to 3 inches) at 5066 feet. Sand has strong salty taste.
5275–5295, Rec. 16′	Shale, gritty, hard, reddish-brown and blue-gray. Streaks of pale green and light gray.
5612–5628, Rec. 7′	Sandy shale, hard, dark lead-gray, cross-bedded, carbonaceous. Streaks of very fine gray-white sand.
5832–5848, Rec. 10′	2′ shale, lead-gray with very fine white sand.
	5′ coarse, very coarse, to granule, white sand. Arkosic and white silt around quartz grains. Some pebbles up to ½ inch.
	3′ sandy shale, hard, lead-gray, micaceous cross-bedded with very fine grained, gray, micaceous, interlaminated sandstone.
6049–6065, Rec. 16′	2′ hard, very fine, micaceous, medium gray sandy shale.
	6′ sandstone, moderately hard, fine-grained, silty. Upper 2 feet has a pale green-white color, middle 2 feet is white and contains large 2 inch pyrite nodule and bottom 2 feet is bottle-green.
	8′ sandstone, medium to fine-grained, white, arkosic, with lignite present in isolated patches. Sand is greenish-gray and chloritic at basal 6 inches.
6265–6281, Rec. 2½′	2′ pearl-gray mottled shale, lavender and rusty-brown.
	½′ fine-grained white sand.
6486–6501, Rec. 4′ 3″	1′ hard, micaceous, greenish-white, argillaceous sandstone slightly calcareous.

Depth in Feet Recovery	
	2′ 3″ chocolate-brown shale.
	1′ medium to coarse-grained, white arkosic sandstone.
6705–6713, Rec. 5′	1′ fine-grained, micaceous, arkosic, white, somewhat cross-bedded sandstone.
	4′ sandy shale, deep chocolate-brown with green-gray sandy shale at sand contact.
6930–6947, Rec. 8′	5′ sandstone, fine-grained, chloritic, mottled red-brown and bottle-green and sandy shale of same color. Grading into
	3′ poorly sorted, arkosic sandstone, white-pink mottled. Pebbles up to ½ inch grading into 6 inches of hard, fine, mottled sandstone as above.
7040–7058, Rec. 15′	1½′ dark lead-gray micaceous, silty shale splotched with red-brown color. Grades into
	13′ poorly sorted, highly arkosic, coarse to pebbly white friable sandstone. Some bottle-green and pink staining. Quartz pebbles, rounded and measuring up to ½ inch.
7111–7120, Rec. 1′	3″ conglomerate, milky quartz, rounded pebbles up to 1½ inches.
	6″ sandstone, fine-grained, micaceous (muscovite and chlorite), mottled red-brown and gray containing rounded pebbles up to ½ inch.
	3″ conglomerate, arkosic, with pebbles of quartzite (3 inches), pegmatite and serpentine.
7157–7168, Rec. 8½′	Gabbro, medium to fine-grained, dark greenish-black. Jointed with joint planes filled with carbonate and dipping at 75 degrees. Near base of core, brecciated zone with pyrite very common. Serpentinized in parts.
7168–7173, Rec. 3′ 6″	Gabbro as above. Jointed but no brecciation and pyrite.
7173–7177½, Rec. 4½′	Gabbro as above.
7177½–7178, Rec. 6″	Gabbro as above.

SCHLUMBERGER SIDE-WALL CORES

Depth in Feet	
1955	Sand, fine-grained, gray, rather well rounded.
1958	Ditto.
1965	Sand, as above, and sticky, dark-gray, fossiliferous clay.
1967	Ditto.
2195	Sand, argillaceous, fine-grained, chloritic.
2205	Sand, fine-grained, minor amount of glauconite, chlorite and muscovite.
2288	Sand, fine-grained, sparingly micaceous (chlorite and muscovite).
2894	Ditto.
2897	Ditto.
2904	Ditto. Also minor amount of glauconite.
2906	Sand, medium-grained, green-gray, some glauconite and dark gray sticky clay.
3232	Sand, fine-grained, sparingly micaceous (chlorite and muscovite). Garnet, chlorite, epidote.
3320	Ditto. Garnet, chlorite, epidote and trace of milky-blue quartz.
3375	Sand, medium to coarse-grained, milky-blue and rose quartz, garnet, epidote, pyrite, trace of mica.
3764	Sand, very fine grained and silty. Mica common. Blue and rose quartz.
3767	Ditto.

Depth in Feet	
3902	Sand, fine-grained, micaceous, moderately hard, slightly calcareous. Gray-white
4890	Sand, fine to medium-grained, gray, with blue and rose quartz.
5152	Sand, medium and fine-grained and silty, gray-white. Slightly calcareous.
5248	Sand, fine to very fine grained, slightly calcareous, micaceous, gray-white.
5488	Ditto.
5735	Clay, silty and sandy, micaceous, greenish-gray.
5808	Sand, fine-grained, silty, gray-white, slightly calcareous with minor amount of mica.
5986	Ditto.
6050	Sand, very fine to medium-grained. Lead-gray and silty.
6416	Sand, white, poorly sorted, fine to coarse-grained, with kaolinized feldspars.
6434	Ditto. Mostly partially decomposed feldspars.

DITCH SAMPLES

Depth in Feet	
40–100	Sand, medium to very coarse. Rounded quartz pebbles about ⅛ inch common. Occasional shell fragments of pecten.
791–794	Pale gray siltstone and medium-grain sand. Shell fragments and lignite.
804–835	Pale gray siltstone. Occasional shell fragments.
833–866	Pale gray siltstone. Few quartz pebbles, ⅛ inch, occasional shell fragments. Shark's tooth.
866–897	Pale gray siltstone. Occasional shell fragments and echinoid spines.
897–927	Very fine grain, gray-white silty sand. Occasional black chert and quartz pebbles (⅛ inch). Shell fragments, echinoid spines, forams, and small amount of glauconite. Some pyrite.
927–935	Ditto.
940–950	Grayish-white silty clay. Few very coarse quartz grains. Shell fragments and small amount of lignite.
950–960	Ditto. Cinnamon-brown fragments may be phosphatic.
960–970	Ditto.
970–980	Ditto.
980–990	Ditto.
990–1000	Ditto. Probably less silty. Spines.
1000–1010	Pearl gray-white clay with very little silt. Numerous shell fragments. Clear medium-coarse sand.
1010–1020	Ditto.
1020–1030	Ditto.
1030–1040	Ditto.
1040–1050	Ditto.
1050–1060	Pearl gray-white silty and very fine sandy clay. Trace of medium coarse sand. Few shells and spines.
1060–1070	Ditto.
1070–1080	Pale gray, very fine, sandy clay and sand. Few medium-grained sand grains. Shell fragments, spines, few white chalk fragments and cinnamon-brown phosphatic fragments.
1080–1090	Ditto.
1090–1100	Ditto. Few black chert grains.
1100–1110	Sand, fine-grained, few medium grains. Occasional shell fragments, forams, spines and glauconite.
1270–1280	Dark earthy-gray clay with forams and occasional glauconite grains.

Depth in Feet	
1500–1510	Dark, slightly greenish, gray somewhat silty clay. Forams, glauconite and a few shell fragments.
1510–1520	Ditto.
1520–1530	Ditto.
1530–1540	Dark earthy-gray clay with forams, glauconite and shell fragments.
1540–1550	Ditto.
1550–1560	Ditto. Small amount of very fine sand.
1560–1570	Ditto.
1570–1580	Ditto.
1580–1590	Ditto.
1590–1600	Ditto.
1600–1610	Ditto.
1610–1620	Ditto.
1620–1630	Ditto.
1630–1640	Ditto. Few soft white limy fragments.
1640–1650	Ditto. " " " " "
1650–1660	Ditto.
1660–1670	Ditto.
1670–1680	Ditto.
1690–1700	Brownish gray, slightly silty shale with common glauconite, some forams and shell fragments. Occasional medium-grained sand.
1700–1710	Ditto. Glauconite increasing.
1710–1720	Ditto. Glauconite very common.
1720–1730	Ditto. Glauconite very common.
1730–1740	Ditto. Glauconite very common. Also very fine sand in clay binder.
1740–1750	Ditto. " " " " " " " " " "
1750–1760	Ditto. Glauconite abundant.
1760–1770	Ditto. " "
1770–1780	Ditto. " "
1780–1790	Ditto. " "
1790–1800	Ditto. " "
1800–1810	White chalky clay with some glauconite and pale gray glauconitic clay. Forams still present.
1810–1820	Ditto. Not as much white as gray clay.
1820–1830	Ditto. " " " " " " " . Shell fragments.
1830–1840	Ditto.
1840–1850	Dull gray, silty, glauconitic clay with increasing number of forams. Few white chalky fragments.
1850–1860	Ditto.
1860–1870	Ditto.
1870–1880	Ditto.
1880–1890	Ditto.
1920–1930	Cinnamon-brown to gray, fossiliferous clay shale. Glauconite, shell fragments, forams, small amount of sand.
1930–1940	Ditto.
1940–1950	Ditto. Trace of lignite and pyrite.
1950–1960	Ditto.
1960–1970	Ditto. Few rusty-brown siltstone fragments.
1970–1980	Ditto. Common pelecypod and gastropod fragments. Rusty-brown siltstone occasionally.

Depth in Feet	
1980–1990	Entire sample consists of fragments of pelecypods and gastropods. Trace of gray glauconitic shale.
1990–2000	Ditto.
2000–2010	Ditto. Forams also noted.
2010–2020	Ditto. " " " . Trace lead-gray shale.
2020–2030	Ditto. " " "
2030–2040	Ditto. " " "
2040–2050	Brownish-gray, silty, glauconitic shale. Pelecypod and gastropod fragments. Forams.
2050–2060	Ditto plus some lignite
2060–2070	Ditto " more "
2070–2080	Ditto " " " also a small amount of pyrite.
2080–2090	Ditto. Very little lignite. Rather common rusty-brown siltstone fragments.
2090–2100	Ditto. Common lignite. Rather common rusty-brown siltstone fragments.
2100–2110	Ditto. Small amount of very fine sand. Rusty-brown siltstone.
2130–2140	Predominant earthy-gray shale with some rusty-brown, red and green shale. Fossil fragments. Much lignite. Pyrite. Small amount of fine sand and glauconite.
2140–2150	Ditto.
2150–2160	Ditto.
2160–2170	Ditto.
2170–2180	Ditto.
2180–2190	Ditto.
2190–2200	Ditto. Not as much mottled shale. Trace of medium-grained sand.
2200–2210	Ditto. Very little mottled shale. Some medium-grained sand.
2210–2220	Ditto.
2220–2230	Shale, greenish-gray with earthy-brown mottling. Some shell fragments and occasional glauconite and medium-grained sand.
2230–2240	Ditto.
2240–2250	Ditto.
2250–2260	Ditto.
2260–2270	Ditto. Some lignite.
2270–2280	Ditto.
2280–2290	Ditto. Some lignite.
2290–2300	Ditto. " "
2300–2310	Ditto. No mottling. Lignite, shell fragments, forams, glauconite.
2310–2320	Ditto. Some mottled shale. Ditto.
2340–2350	Pale gray and gray-brown shale. Forams in shale. Glauconite. Siderite fragments. Shell fragments. Lignite and pyrite.
2350–2360	Ditto.
2360–2370	Ditto.
2370–2380	Ditto.
2380–2390	Ditto.
2390–2400	Ditto.
2400–2410	Ditto.
2410–2420	Ditto.
2420–2430	Ditto.
2430–2440	Ditto.
2440–2450	Ditto.
2450–2460	Ditto.

Depth in Feet	
2460–2470	Ditto.
2470–2480	Ditto.
2480–2490	Ditto.
2490–2500	Ditto.
2500–2510	Ditto. Sand, medium-fine, increasing.
2510–2520	Ditto. “
2520–2530	Ditto. “
2530–2540	Ditto. “ , forams.
2600–2610	Shale, gray and brown with fine-grained sand, some mottled shale, siderite fragments, shell fragments, glauconite. Lignite.
2610–2620	Ditto.
2620–2630	Ditto.
2630–2640	Sand, fine-grained, argillaceous, gray. Shell fragments, glauconite, siderite fragments.
2640–2650	Ditto.
2650–2660	Ditto.
2660–2670	Ditto.
2670–2680	Shale, dark gray and fine sand. Lignite, pyrite, glauconite, siderite, shell fragments. Few red shale fragments.
2680–2690	Ditto. Few forams.
2690–2700	Ditto.
2700–2710	Ditto.
2710–2720	Ditto. Few forams.
2720–2730	Ditto. Few forams.
2750–2760	Ditto.
2760–2770	Ditto. Some tan mottled silty shale
2770–2780	Ditto. “ “ “ “ “ ; very few shell fragments and glauconite.
2780–2790	Ditto. Ditto. Ditto.
2790–2800	Ditto. Ditto. Ditto. Few forams.
2830–2840	Ditto Ditto. Ditto.
2840–2850	Ditto.
2850–2860	Ditto.
2860–2870	Ditto. Considerable mottled red and brown shale.
2870–2880	Ditto. Mottled shale. Much less sand.
2880–2890	Ditto. “ “ “ “ “
2890–2900	Ditto. “ “ . Sand increased.
2900–2910	Ditto. “ “ “ “
2910–2920	Ditto. “ “ “ “
2970–2980	Pale gray shale, mottled brown, red and tan silty shale and fine sand. Few shells and trace of glauconite and lignite. Siderite.
2980–2990	Ditto.
2990–3000	Ditto.
3000–3010	Ditto.
3010–3020	Ditto.
3020–3030	Ditto.
3030–3040	Ditto.
3040–3050	Ditto.
3050–3060	Ditto. No lignite.
3060–3070	Ditto. Trace of lignite.

Depth in Feet	
3080–3090	Shale, pearl-gray, red-brown, tan, and bottle-green and fine-grained sand. No shells. Trace of glauconite.
3090–3100	Shale, pearl-gray, red-brown, tan, and bottle-green and fine-grained sand. Few shells. Trace of glauconite.
3100–3110	Ditto. More sand than shale.
3110–3120	Ditto. Ditto.
3120–3130	Sand, fine-grained, some glauconite. Small amount of shale as above.
3130–3140	Ditto.
3140–3150	Ditto. Trace of lignite.
3170–3180	Shale, gray, red-brown, tan and bottle-green and very fine sand. Trace of carbonaceous matter in shale.
3180–3190	Ditto.
3190–3200	Ditto. Some pelecypod shells.
3200–3210	Sand, fine-grained. Shale fragments, gray and brown. Trace of shell fragments, lignite, and glauconite.
3210–3220	Ditto.
3220–3230	Ditto.
3230–3240	Ditto.
3240–3250	Ditto. More shale (brown) than sand.
3250–3260	Ditto. Sand more abundant.
3260–3270	Ditto. " " "
3270–3280	Ditto. " " "
3280–3290	Ditto. " " "
3290–3300	Shale, brown, pale gray and green. Small amount of fine sand. Trace of shell fragments, lignite and glauconite.
3300–3310	Ditto
3310–3320	Ditto.
3320–3330	Sand, medium-coarse, quartz sand. Small amount of glauconite and trace of shell fragments.
3330–3340	Ditto.
3340–3350	Ditto.
3340–3350	Ditto.
3350–3360	Ditto.
3360–3370	Ditto.
3370–3380	Ditto.
3380–3390	Ditto.
3390–3400	Ditto.
3400–3410	Ditto.
3410–3420	Ditto.
3420–3430	Ditto.
3430–3440	Ditto.
3440–3450	Ditto.
3450–3460	Ditto. About 5% gray, brown, green shale fragments.
3460–3470	Ditto. Some gray shale.
Missing	
3520–3530	Shale, rusty-brown, silty. Small amount of medium-grained sandstone. Trace lignite, shell fragments.
3530–3540	Ditto.
3540–3550	Ditto.
3550–3560	Shale as above and fine sandstone in about equal proportions.

Depth in Feet	
3560–3570	Ditto.
3570–3580	Ditto.
3595–3600	Shale, rusty-brown, pearl-gray, mottled lavender and green. Shell fragments rare. Some lignite and sandstone.
3600–3610	Ditto.
3610–3620	Ditto.
3620–3630	Ditto. Some siderite.
3630–3640	Ditto. Predominant gray, some mottling.
3640–3650	Ditto. Ditto.
3650–3660	Ditto. Ditto.
3660–3670	Ditto. Ditto.
3670–3680	Ditto. Ditto.
3680–3690	Ditto. Ditto. Considerable lignite.
3690–3700	Ditto. Ditto. Ditto.
3700–3710	Ditto. Ditto. Ditto.
3710–3720	Ditto. Ditto. Ditto.
3720–3730	Ditto. Ditto. Trace of lignite.
3730–3740	Ditto. Ditto. Considerable lignite.
3740–3750	Ditto. Ditto.
3750–3760	Sand, fine-grained. Some glauconite and trace of shell fragments.
3760–3770	Ditto.
3770–3780	Shale, pearl, lead-gray, and red-brown. Some lignite and shell fragments.
3780–3790	Ditto.
3800–3810	Ditto.
3810–3820	Ditto.
3820–3830	Ditto.
3830–3840	Ditto. Some green shale.
3840–3850	Ditto. Ditto.
3850–3860	Ditto. Some siderite and milky quartz.
3860–3870	Ditto. About 10% lignite.
3870–3880	Ditto.
3880–3890	Ditto.
3890–3900	Ditto.
3900–3910	Sand, very fine to coarse-grained. Few shale fragments, shells, lignite and glauconite.
3920–3930	Ditto.
3930–3940	Ditto. Possibly a few rotten white feldspars.
3940–3950	Ditto. Some very coarse sand.
3950–3960	Ditto.
3960–3970	Ditto.
3970–3980	Shale, gray, red-brown, and pale green. Trace of lignite.
3980–3990	Ditto.
3990–4000	Ditto.
4010–4020	Shale as above and very little medium-grained sand.
4020–4030	Ditto.
4030–4040	Ditto.
4040–4050	Ditto.
4050–4060	Ditto.
4060–4070	Ditto.
4070–4080	Ditto.

Depth in Feet	
4080–4090	Ditto.
4090–4100	Ditto.
4100–4110	Ditto.
4110–4120	Ditto.
4120–4130	Ditto.
4130–4140	Ditto. 10% lignite.
4140–4150	Ditto. Some lignite.
4150–4160	Ditto.
4160–4170	Ditto.
4170–4180	Ditto. Some lignite.
4180–4190	Ditto.
4190–4200	Ditto.
4230–4240	Shale, bluish-gray, red-brown, pale green, rusty-brown. Some lignite, shell fragments.
4240–4250	Ditto.
4250–4260	Ditto.
4260–4270	Ditto. A little fine sand.
4270–4280	Ditto.
4280–4290	Ditto.
4290–4300	Ditto. About 20% fine sand.
4300–4310	Ditto. About 10% fine sand.
4310–4320	Ditto. About 25% fine sand.
4320–4330	Ditto. About 10% fine sand.
4330–4340	Ditto. Ditto.
4340–4350	Ditto. Ditto.
4350–4360	Ditto.
4360–4370	Ditto. About 10% fine sand.
4370–4380	Ditto.
4380–4390	Ditto.
4390–4400	Ditto. About 10% fine sand.
4400–4410	Sand, fine-grained with a little glauconite.
4430–4440	Shale, lead-gray and rusty-brown and small amount of very fine sand. Trace of lignite.
4440–4450	Ditto.
4450–4460	Ditto.
4460–4470	Ditto.
4470–4480	Ditto.
4480–4490	Ditto.
4490–4500	Ditto.
4500–4510	Ditto.
4510–4520	Sand, fine-grained, small amount of glauconite and siderite and trace of pyrite. Trace of mottled shale.
4520–4530	Ditto.
4530–4540	Ditto.
4540–4550	Ditto.
4550–4560	Shale, lead-gray, red-brown, bottle-green, silty, and small amount of very fine sand. Lignite, small amount.
4560–4570	Ditto.
4570–4580	Ditto. About 10% lignite.
4580–4590	Ditto. About 5% lignite.

Depth in Feet	
4590–4600	Ditto. Very little lignite.
4600–4610	Ditto. Very little lignite and sand.
4610–4620	Ditto. Ditto.
4620–4630	Ditto. About 10% lignite.
4640–4650	Sand, fine-grained, and shale, lead-gray and red-brown, few shell fragments and lignite.
4648–4690	No recovery.
4690–4700	Shale as above. Small amount very fine sand. Few shell fragments and lignite.
4700–4710	Ditto.
4710–4750	No recovery.
4750–4760	Shale as above and sand, very fine to medium-grained.
4760–4770	Ditto.
4770–4780	Ditto.
4780–4790	Sand, very fine grained to medium coarse grained. Very few shale fragments, glauconite, shell fragments and lignite.
4790–4800	Ditto.
4800–4810	Ditto.
4810–4820	Shale, brown, gray, and pale green. Small amount of very fine sand.
4820–4830	Ditto.
4830–4840	Ditto.
4860–4870	Shale as above and about 10% fine to medium-grained sand.
4870–4880	Ditto. Small amount of lignite.
4880–4890	Ditto.
4890–4900	Ditto. Small amount of lignite.
4900–4930	(No recovery.)
4930–4940	Ditto. Very coarse to pebbly (⅜ inch) sand about 10%.
4940–4950	Ditto. Ditto. Fewer large pebbles.
4950–4960	Ditto. Very coarse to pebbly sand.
4960–4970	Sand, very fine, very coarse, and pebbly (¼ inch).
4970–4980	Ditto. Pebbles up to ½ inch.
4980–4990	Ditto. Minor amount of brown and yellow silty shale and chloritic siltstone.
4990–5000	Ditto.
5000–5010	Ditto.
5010–5020	Ditto.
5020–5030	Ditto.
5030–5040	Ditto.
5040–5050	Ditto.
5080–5090	Ditto.
5090–5100	Ditto.
5100–5130	(No Recovery.)
5130–5140	Ditto. Minor amount of vari-colored shale and minor amount of lignite.
5140–5150	Ditto. Ditto.
5150–5180	(No Recovery.)
5180–5190	Ditto. Ditto.
5190–5200	Ditto. Ditto.
5210–5220	Ditto. Ditto.
5220–5275	(No Recovery.)
5300–5310	Sand, very coarse. Minor amount of brown and gray shale and lignite.
5310–5320	Ditto.

Depth in Feet	
5320–5330	Ditto.
5330–5340	Ditto.
5340–5350	Ditto. Shale increasing—about 50%.
5350–5360	Ditto. Small amount of shale.
5360–5370	Shale, gray-green, red rusty-brown. Small amount of fine-grained sand.
5370–5380	Ditto.
5380–5390	Ditto. About ⅔ shale and ⅓ sand.
5390–5400	Ditto. Ditto.
5400–5410	Ditto.
5410–5420	Ditto.
5420–5430	Ditto.
5430–5440	Shale, sandy, greenish-gray, brown, yellow. Minor amount of lignite.
5440–5450	Ditto.
5450–5460	Ditto.
5460–5470	Ditto.
5470–5480	Ditto.
5480–5490	Ditto.
5490–5500	Ditto.
5500–5510	Ditto.
5510–5520	Ditto.
5520–5530	Ditto. Minor amount of fine-grained sand.
5530–5540	Ditto. Ditto.
5540–5550	Ditto. Increasing fine sand.
5550–5560	Ditto. About 10% fine sand.
5560–5570	Sand, coarse-grained to fine-grained, and shale as above.
5570–5580	Shale as above with about 20% fine to coarse-grained sand.
5580–5590	Sand, fine to very coarse grained with minor amount of shale as above.
5590–5600	Sand as above and sandy shale (50%–50%).
5600–5610	Sand, predominantly fine grained with minor amount of sandy shale as above.
5630–5640	Shale, dark gray, brown, green, minor amount of very fine sand and lignite.
5640–5650	Ditto.
5650–5660	Ditto.
5660–5670	Ditto.
5670–5680	Ditto.
5680–5690	Ditto. Few shell fragments.
5690–5700	Ditto.
5700–5710	Sand, fine to medium-grained. Minor amount of green and brown sandy shale and trace of glauconite.
5710–5720	Sandy shale, lead-gray, green and red-brown, with minor amount of fine sand and lignite.
5720–5730	Ditto.
5730–5740	Ditto.
5740–5750	Ditto.
5750–5760	Ditto.
5760–5770	Ditto.
5770–5780	Ditto.
5780–5790	Ditto.
5790–5800	Ditto.
5800–5810	Ditto. Minor amount of coarse sand.
5810–5820	Ditto. Ditto.

Depth in Feet	
5850–5860	Shale, dark gray and minor amount of brown and green shale. Very fine sand, and lignite.
5860–5870	Ditto. Few shell fragments.
5870–5880	Ditto.
5880–5890	Ditto. Few shell fragments.
5890–5900	Ditto.
5900–5910	Ditto.
5910–5920	Ditto. About 20% fine to medium-grained sand.
5920–5930	Ditto. Ditto.
5930–5940	Shale, lead-gray, with red-brown and bottle-green shale. Lignite and fine sand.
5940–5950	Ditto.
5950–5960	Ditto.
5960–5970	Ditto.
5970–5980	Ditto.
5980–5990	Ditto.
5990–6000	Ditto.
6000–6010	Ditto.
6060–6070	Ditto.
6070–6080	Ditto.
6080–6090	Ditto.
6090–6100	Ditto.
6100–6110	Ditto.
6110–6120	Ditto.
6120–6130	Ditto.
6130–6140	Ditto.
6140–6150	Ditto.
6150–6160	Ditto.
6160–6170	Ditto.
6170–6180	Ditto.
6180–6190	Ditto.
6190–6200	Ditto.
6200–6210	Shale, silty, green-gray and red-brown. Minor amount of lignite and fine sand.
6210–6220	Ditto.
6220–6230	Shale as above with about 20% coarse sand. Lignite.
6230–6240	Ditto.
6250–6265	(No recovery.)
6280–6290	Ditto. Shell fragments.
6290–6300	Ditto. Shell fragments.
6300–6310	Ditto.
6310–6320	Ditto.
6320–6330	Ditto.
6330–6340	Ditto.
6340–6350	Ditto.
6350–6360	Ditto.
6360–6370	Ditto.
6370–6380	Coarse sand, and shale (40%) as above.
6380–6390	Ditto.
6390–6400	Ditto. Minor amount of lignite.

Depth in Feet	
6400–6410	Ditto. Shale above 60%.
6410–6420	Ditto. Ditto.
6420–6430	Ditto. Shale about 50%.
6430–6440	Shale as above. Minor amount of coarse sand.
6440–6450	Shale as above. About 20% coarse sand.
6450–6460	" " " " 10% very coarse and coarse sand.
6460–6470	" " " " 5% " " " " "
6470–6480	" " " " 5% " " " " "
6500–6510	Shale, dark gray, with red-brown and purple shale. Minor amount of coarse sand, lignite and shell fragments.
6510–6520	Ditto. Some very coarse sand.
6520–6530	Ditto. Ditto.
6540–6550	Ditto. Ditto.
6550–6560	Ditto. Ditto.
6560–6570	Ditto. About 40% coarse sand.
6570–6580	Ditto. " 20% " "
6580–6590	Ditto. Ditto.
6590–6600	Ditto. About 50% coarse sand.
6600–6610	Ditto. " 60% " "
6610–6620	Ditto. " 40% " " Shale mostly red-brown.
6620–6630	Ditto. Shell fragments. About 20% coarse sand. Much red-brown shale.
6630–6640	Ditto. About 10% coarse sand, much red-brown shale.
6640–6650	Ditto. " 10% " " and 20% fine sand.
6650–6660	Ditto. Ditto.
6660–6670	Ditto. Ditto.
6670–6680	Ditto. Ditto.
6680–6690	Ditto. Mostly red-brown; minor amount coarse sand.
6690–6700	Ditto. " " " " fine sand.
6710–6720	Ditto. Ditto. minor amount coarse sand and shell fragments.
6720–6730	Shale silty and red-brown. Minor amount gray-green shale. Minor amount coarse sand.
6730–6740	Ditto. Some fine sand.
6740–6750	Ditto.
6740–6760	Ditto.
6750–6760	Ditto.
6760–6770	Ditto.
6770–6780	Ditto.
6790–6800	Ditto.
6800–6810	Ditto.
6810–6820	Ditto.
6820–6830	Ditto.
6830–6840	Ditto.
6840–6850	Ditto.
6850–6860	Ditto.
6860–6870	Ditto.
6870–6880	Ditto.
6880–6890	Ditto.
6890–6900	Ditto. About 50% very coarse sand.
6900–6910	Ditto. " 10% " " "

Depth in Feet	
6910–6920	Ditto. Minor amount very coarse sand.
6950–6960	Ditto. Ditto.
6960–6970	Ditto. About 10% very coarse sand.
6980–6990	Ditto. Ditto.
7000–7010	Ditto. " 60% very coarse sand.
7010–7020	Ditto. About 20% coarse sand.
7020–7030	Ditto. Minor amount coarse sand.
7030–7040	Ditto. Ditto.
7060–7070	Ditto. About 20% coarse sand.
7070–7080	Ditto. About 60% coarse sand.
7080–7090	Ditto. About 20% coarse sand.
7090–7100	Ditto. About 70% coarse and very coarse sand.
7100–7110	Sand, coarse and very coarse, red-brown. Minor amount of red shale.
7120–7130	Shale, silty, gray-green with minor amount of red-brown shale and coarse sand.
7130–7140	Ditto.
7140–7150	Red-brown shale and coarse sand. Relatively few fragments of soft, dark green, basic rock fragments.

Note: No samples were received from the following depths:-

6000–6010 feet
6240–6250 "
6265–6280 "
6700–6710 "
6780–6790 "

MARYLAND ESSO NO. 1 WELL, STANDARD OIL COMPANY OF NEW JERSEY, OCEAN CITY, MARYLAND

DESCRIPTION OF DITCH SAMPLES

BY

ROBERT M. OVERBECK

EXPLANATION OF PROCEDURE

Size classification of sand: granule, 2–4 mm.; very coarse, 1–2 mm.; coarse, 0.5–1 mm.; medium, 0.25–0.50 mm.; fine, 0.125–0.250 mm.; very fine, 0.0625–0.125. Sizing was done by hand sieving, through Tyler screens.

The colors are based on the Munsell Color Chart. The color names are from Research Paper 1239, National Bureau of Standards, by Deane B. Judd and Kenneth L. Kelly.

Forams were separated from about 100 samples. Their age was determined by Dr. Joseph A. Cushman. Only the most striking and obvious ones are mentioned in these descriptions. No study was made of the diatoms, but they were helpful in determining the base of the Miocene.

The abundance terms are qualitative rather than quantitative, but an attempt was made to adhere to the scheme used in Ann Dorsey Clapp's section of this report on Miocene foraminifera.

DESCRIPTIONS OF SAMPLES

Depth in Feet	
0–10	Light grey medium gravel (maximum 5–8 mm.), quartz, opaque white and clear, well rounded and flattened; a little clay; a little vivianite. (Vivianite rather common in the Pleistocene deposits of the Baltimore area, but not abundant.)
10–20	Light grey gravel (max. 7–10 mm.) and a little coarse sand; gravel well rounded, disk like; a little vivianite.
20–30	Light brownish-grey sand, coarse to very fine, traces of clay and gravel; a little vivianite; some wood fragments.
30–40	Light brownish-grey sand, medium and fine; traces of clay and gravel.
40–50	Light yellowish-brown coarse sand; traces of clay and gravel.
50–80	Weak yellow, coarse sand; some medium sand; traces of gravel.
80–90	Light yellowish-brown clay; shell fragments and traces of sand and gravel.
90–100	Light yellowish-brown coarse sand; traces of clay and sea shells; echinoid fragments.
100–112	Light olive-gray gravel and sand. Chiefly very coarse sand and gravel (max. 8 mm.); a little coarse and medium sand; echinoid and shell fragments; sand and gravel rounded to sub-rounded, chiefly quartz, but also some dark fine-grained rock.
112–130	Mixed light grey clay and yellowish-grey, very coarse sand and gravel (max. 6 mm.); a little oxidation.
130–150	Chiefly gravel, 2 mm. to 22 mm., white vein quartz in large pieces; medium grey quartz granules; light olive-grey coarse sand, fairly abundant, chiefly sub-angular to sub-rounded quartz.
150–160	Chiefly light olive-grey sand; very coarse and coarse; a little gravel (max. 12 mm.), quartz sub-angular, clear, light olive-grey; little oxidation.
160–170	Weak yellow sand, from coarse to gravel (max. 12 mm.) sand, chiefly angular and sub-angular grey quartz.
170–180	Weak yellow sand, from coarse to gravel (max. 13 mm.). Sand chiefly grey quartz, slight iron oxide color on some grains; angular to sub-angular, grey, vitreous quartz chiefly; a little chert; a few shell fragments.
180–200	Light olive-grey, very coarse sand and gravel (max. 10 mm.); gravel white, vitreous grey, and red iron-stained quartz; very coarse sand, sub-angular to sub-rounded, grey vitreous quartz; a few shell fragments; some feldspar; a little slightly milky quartz.
200–240	Light brownish-grey sand, chiefly medium-grained, a little gravel and very coarse sand, some medium and fine sand, sub-round and rounded; considerable pale milky quartz; a good deal of clear quartz. (Suggestion here that part of the material is from the Miocene. The few pebbles may have come from the overlying Pleistocene.)
240–260	Light olive-grey sand, a little gravel; sand about equally medium to very coarse; sea shell fragments in fair amount; quartz sub-angular to sub-rounded; very little pale milky quartz.
260–290	Coarse sandy marl, chiefly shell fragments; sand, light olive-grey, from medium to very coarse; forams; 3 specimens of small Rotalids.
290–310	Light olive-grey sand, somewhat fewer shell fragments than in 260–290 feet; sand, fine to very coarse, chiefly medium and coarse; quartz having dark inclusions common in fine and medium sizes; a number of dark rounded grains (not determined), but probably in large part bone.

Depth in Feet	
310–330	Yellowish-grey sand, fine to very coarse, chiefly medium and coarse; few shell fragments; coarse sand, sub-angular to rounded quartz; dark constituents in medium and fine sizes.
330–350	Yellowish-grey sand, medium to very coarse; a few pieces of gravel (max. 6 mm.), a few shell fragments; coarse quartz sub-angular to rounded; fair dark constituents, in part bone.
350–420	Light brownish-grey sand, chiefly coarse and very coarse, a little medium grade; a few flakes of muscovite; a little red and yellow iron-oxide stained quartz; quartz, sub-rounded, edges rounded; echinoid spines.
420–430	Yellowish-grey sand, poorly sorted, medium to gravel, chiefly medium and coarse; gravel, max. 7 mm.; large grained, sub-rounded, polished, shiny grey and clear quartz; faintly pink quartz very noticeable in coarse grade; quartz sub-angular, a few ovoid grains of milky quartz; many of the fine grade quartz grains (+0.125 mm.) are well rounded.
430–440	Poorly sorted, yellowish-grey sand, medium to gravel; fair gravel (max. 9 mm.); quartz sub-angular; much less pink quartz than in previous sample.
440–460	Yellowish-grey sand, chiefly coarse, a little gravel.
460–500	Pale olive sand, chiefly coarse and very coarse, a little gravel (max. 12 mm.). One piece of silicified limestone with fossils; quartz sub-rounded, much of it faint smoky-grey, fine grained, rounded, clear.
500–510	Light olive-grey sand, chiefly medium and coarse, some very coarse and some gravel (max. 12 mm.); a few shell fragments; quartz chiefly sub-rounded to sub-angular.
510–570	Yellowish-grey, poorly mixed sand, from very fine to gravel, chiefly coarse; quartz dirty, possibly from sandy clay; quartz sub-rounded; a few large shell fragments.
570–630	Pale brown sand, very fine to very coarse, quartz grains show some clay adhering (probably considerable clay in lower portion); shell fragments common, chiefly gastropods, suggesting St. Marys or younger formation; quartz sub-rounded; forams rare; a large ribbed Rotalid, Nonions, Bulimina, ostracods.
630–640	Light brownish-gray sand, fine to gravel, a little clay; shell fragments common; gastropods and pelecypods; most of sand coarse and very coarse; some bone fragments; quartz, sub-angular to round; a few grains of faint pinkish quartz.
640–650	Pale olive sandy marl; sand chiefly coarse and very coarse; shell fragments very common; probably fair amount of clay with the sand. Forams few, a large Dentalina and undetermined forms.
650–670	Pale olive sand, some clay; sand chiefly coarse; quartz grains sub-rounded chiefly and some round; shell fragments fairly common. Forams scarce; a large Dentalina and several unidentified forms, large Textularia, large Robulus and a Rotalid.
670–700	Light olive-gray sand and clay, sand from very fine to very coarse. Forams, scarce; a large Robulus, 2 large Textularia, a small Uvigerina, small Rotalids.
700–710	Light olive-gray sand and some clay, but less than in previous sample. Sand chiefly medium and coarse. Forams few, very large Cibicides, large Textularia, ostracods.
710–730	Light olive-grey sand, little clay; sand chiefly coarse grained; considerable clear shiny quartz, sub-rounded, polished, rounded edges; shell fragments few; some fine pyrite or marcasite.

Depth in Feet	
730–780	Light olive-grey sand, some clay; sand chiefly coarse, sub-rounded, polished, rounded edges; shell fragments few; somewhat more clay toward bottom. Forams few; large Robulus.
780–820	Light olive-grey hardshell and sand. Hardshell, lime-cemented clay and sand; rounded and sub-rounded; shell fragments fairly common, echinoid spines and plates. Forams rare, large Robulus.
820–830	Chiefly hardshell and shell fragments. Much recrystallization of calcite as in preceding section.
830–850	Pale olive sand, some hardshell and shell fragments; sand chiefly coarse, some grains very coarse, rounded and sub-rounded. Forams, rare; large Robulus.
850–860	Light olive-grey sand; medium to very coarse grained; some fine, rounded to sub-rounded, smooth and etched; a little pale rose quartz; shell fragments fairly common; ostracods. Forams very rare; 1 small Uvigerina.
860–870	Chiefly hardshell and shell fragments; some coarse sand.
870–900	Light olive-grey sand, chiefly medium and coarse; shell fragments fairly common; some bone fragments; quartz sub-angular to sub-rounded; considerable clear shiny quartz.
900–920	Chiefly shell fragments and lime-cemented hardshell; a little sand.
920–930	Light olive-grey sand, some shells; sand mostly coarse; much of the quartz clear.
930–970	Light olive-grey shell fragments and lime-cemented hardshell.
970–990	Yellowish grey sand, chiefly medium, some fine; some shell fragments; considerable clear quartz, sub-angular to rounded; a little pale milky white quartz; fairly dark constituents; ilmenite. Forams rare, Cibicides, 1 large Textularia, some small Rotalids.
990–1010	Shell fragments, hardshell, a little grey sand. Forams rare, Nonions, small Guttulina (?).
1010–1020	Yellowish grey medium sand, a little clay; some shell fragments; quartz sub-angular to rounded, pitted; dark constituents fair; ilmenite (?), a little glauconite. Forams rare. Nonions, small Guttulina.
1020–1080	Light olive-grey sand, medium-grained; some shell fragments and hard shell; numerous dark constituents, mostly glauconite; quartz mostly sub-angular, pitted, clear, shells increase toward bottom. Forams rare, 1 Cibicides, 1 Robulus.
1080–1160	Chiefly shell fragments and hardshell, varying amounts of sand; quartz, generally clear, pitted; small amounts of glauconite.
1160–1230	Yellowish-grey clay, a little sand. (Very different from previous samples.) Diatom fragments; very diatomaceous; few pieces of a weak orange lime-cemented hardshell.
1230–1260	Chiefly shell fragments and hardshell, a few pieces of weak orange-colored hardshell; a little diatomaceous clay.
1260–1290	Mixed yellowish grey clay, light olive sand, and shell fragments. Clay diatomaceous.
1290–1300	Pale olive mixed coarse sand, diatomaceous clay, and shell fragments.
1300–1310	Mixed yellowish-grey clay and coarse sand; some pink hardshell.
1320–1340	Pale olive mixed sand and clay; clay diatomaceous; sand smeared with clay. Forams common; Bolivina (small) most common, Uvigerina common, a large Robulus, a large Miliolinid.
1340–1350	Pale olive mixed sand, clay, and shells. Forams scarce; large Robulus, small Bolivinas chiefly.
1350–1360	Pale olive clay, some sand and shell fragments; clay carries diatoms.

Depth in Feet	
1360–1370	Pale olive clay, diatomaceous.
1370–1430	Pale brown clay, diatomaceous.
1430–1490	Pale brown clay; some sand, fine to coarse; small shell fragments; diatom fragments.
1490–1510	Pale brown mixed clay, sand, and shells; diatom fragments; quartz generally clear, sub-angular to rounded. Forams, common; many Siphogenerina lamellata?; first appearance (in Hammond Well first appearance of Siphogenerina lamellata at 1010 feet); many Buliminids, a few large Robulus, a few small Nonions.
1510–1550	Pale brown clay with some sand and shell fragments; diatom fragments.
1550–1590	Pale brown clay, little sand. Diatom fragments.
1590–1610	Pale brown clay. Forams scarce; Siphogenerina, Robulus, chiefly small Bolivina and Bulimina, large Marginulina.
1610–1650	Pale brown clay, diatomaceous. Probably Miocene, Calvert formation, Fairhaven member.
1650–1670	Pale brown clay, a little sand; some glauconite. Forams, common; Siphogenerina, large Robulus, Marginulina?, 2 large Uvigerina?, many Bolivina, Bulimina. (Cushman places top of Eocene in interval 1650–1670.)
1670–1690	Weak brown clay, a little sand; very few diatom fragments; possibly a little glauconite.
1690–1730	Weak brown sand and clay; fair glauconite; shell fragments, echinoid spines; glauconite from fine to coarse, most in fine fraction, much of the glauconite is light green. Forams are very abundant; large forms chiefly Uvigerina, a few Robulus, and Guttulina, piece of a large Nodosaria (?) or Dentalina, a large number of small forms.
1730–1800	Light olive-grey sand, chiefly fine and medium, little coarse; quartz sub-angular to rounded, mostly clear; glauconite common, much of it light green, generally fine to medium grained. Forams common; characterized by many large Uvigerina, a few Robulus, no Siphogenerina.
1800–1820	Pale brown clay and sand, fine to coarse sand in about equal fractions; sand smeared with clay; very little glauconite; diatom fragments very scarce. Forams few, one large Dentalina (?).
1820–2030	Weak-brown clay, clay in thin flat pellets or flakes, generally 1–3 mm., but up to 15 mm. Diatoms, common, but not the large forms of the Fairhaven; a few shell fragments. Forams few to 1920 feet, then rather abundant to 2030 feet; at 1880–1890 feet large Robulus both smooth and heavy ribbed, keeled, and spinose, large Uvigerina, large Vaginulina, large Guttulina, Nonion, Glandulina (?).
2030–2040	Weak-brown clay, mixed flaky and granular; a little pyrite, some replacing echinoid spines. Forams, few.
2040–2090	Weak-brown clay, large flat pieces up to 18 mm.; a few shell fragments; a very few ringlike diatoms; glauconite little. Forams abundant at places, 2080–2090 feet; large Uvigerina and Robulus. Many small forms, Globigerina, Nodosaria (?) or Dentalina, a few Bolivina and Bulimina.
2090–2140	Mixed weak-brown clay and yellowish-grey material, the yellowish grey material is chiefly calcite; glauconite fair. One large clay piece, 30 mm. Some of the lime cements grains of glauconite. Forams abundant at 2100–2110 feet. Large Uvigerina, ribbed Robulus, Guttulina, small Globigerina.
2140–2160	Light olive-grey clay mixed with flat weak-brown clay pebbles; gray material

Depth in Feet	
	very calcareous; a little glauconite. Forams few at 2150–2160 feet; large Uvigerina, small Globigerina.
2160–2170	Mixture weak-brown clay and shell fragments; shells mostly barnacles.
2170–2180	Chiefly pale brown clay, a little light olive-grey clay; clay in rather large elongated pieces (max. 25 mm.), some very thin, some rounded; a very little sand with glauconite.
2180–2200	Yellowish-grey clay in rather large (18 mm.) irregular pieces, a little weak-brown clay in flakes, a small amount of sand and glauconite. Forams rare.
2200–2220	Mixed clay, grey and brown and green sand; quartz, angular to sub-angular, generally clear; glauconite common, medium grained, dark to light green. Forams scarce.
2220–2230	Yellowish-grey clay, flattened elongated pieces, max. 20 mm. Forams common.
2230–2290	Yellow-grey clay, flattened, elongated pieces; some sand with much glauconite. Forams generally scarce except at 2270–2280 feet. At 2250–2260 feet large Uvigerina, large keeled and ribbed Robulus. At 2270–2280 feet abundant, large variety, large Uvigerina, large keeled and ribbed Robulus, large Vagenulina, Sigmoidella, Clavulina (?).
2290–2400	Mixed yellowish-grey and green clay and clay flakes, small, generally less than 2 mm. but to 11 mm.; glauconite, very dark dull green, sub-angular to rounded. Forams generally scarce but abundant in the clay fragments.
2400–2450	Mixed greensand and yellowish-grey clay. Little flaky clay. Forams scarce.
2450–2470	Mixed greensand and yellowish-grey clay, some large flat flakes of clay (max. 28 mm.), also some pieces of white lime cement. No forams.
2470–2480	As above, but more greensand; fair number of shell fragments.
2480–2510	Chiefly cemented shell fragments; a few pieces of light yellow and yellowish-grey foraminiferal clay; some sand and glauconite. No forams.
2510–2520	Chiefly large flat pieces of pale brown foraminiferal clay (max. 27 mm.). A few cemented shell fragments. No forams.
2520–2530	Mixed dark greensand and flat, pale brown clay fragments. No forams.
2530–2540	Olive-black to olive-grey mixture of glauconite, sand, and shell fragments, little clay; a little pyrite; echinoid spines. Forams, rare.
2540–2580	Mixed yellowish-grey flaky clay (max. 20 mm.), pale brown clay, and greensand. Forams, rare; at 2550–2560 feet, large Robulus, large Uvigerina, Clavulina?
2580–2590	Mixture of sand, greensand, clay, and lignite. First appearance of light yellowish-brown flakes and fragments of hard clay. Forams, rare.
2590–2640	Mixed pale brown flakes of clay, amorphous clay, and some greensand; a few shell fragments; some siderite pellets. Forams, rare to 2620–2630 feet; at 2620–2630 feet, large keeled Robulus, large Uvigerina, Nodosaria (?) or Dentalina; at 2630–2640 feet, large smooth and ribbed Robulus, large Vaginulina, large Uvigerina, large Valvulina.
2640–2700	Chiefly clay, pale brown thin flakes; some amorphous lumps; some greensand. Forams, rare; at 2660–2670 feet large keeled Robulus, large Uvigerina.
2700–2720	Greensand mixed with flaky pale brown clay, a little yellowish-grey clay; a few pebbles (max. 6 mm.); shell fragments; cemented glauconite grains; a little pyrite. No forams.
2720–2780	Mixed flaky pale brown foraminiferal clay and greensand; lumps of cemented glauconite grains (max. 9 mm.); a few pebbles and shell fragments; echinoid spines; siderite pellets; a little pyrite, finely crystallized; a few rounded and smooth grains of faintly milky quartz; some pieces of hard limestone.

Depth in Feet	
	Forams, scarce generally; at 2740–2750 feet, common. Large Robulus, large Uvigerina, smooth Dentalina.
2780–2810	Mixed pale brown foraminiferal clay (max. 30 mm.) and greensand; considerable muscovite in large flakes (1.5 mm.); a few shell fragments; a little pyrite and lignite. Forams, fairly common.
2810–1820	Chiefly greensand, a little clay; a fair amount of hardshell fragments; some very hard, cemented (not calcareous), fine greensand; glauconite chiefly medium; quartz angular and sub-angular, chiefly clear; some large muscovite flakes; echinoid spines. Forams, fairly common.
2820–2850	Chiefly greensand, some clay; fair shell fragments. Forams, fairly common.
2850–2870	Mixed greensand and flaky light brown clay, a little muscovite. Forams, fairly common.
2870–2910	Greensand and amorphous clay. Fair muscovite; few shell fragments. Forams, scarce.
2910–2920	Weak brown mixture greensand and clay, dark color of clay due probably to carbonaceous material; a few flakes of muscovite; shell fragments. Forams scarce.
2920–2930	Mixed pale brown clay and weak-brown greensand, shell fragments. Forams scarce.
2930–2950	Weak-brown greensand, some amorphous clay and a little flaky pale brown clay; considerable quartz sand. Forams rare.
2950–3000	Chiefly mixed amorphous clay and greensand; very little flaky brown clay; fair quartz sand increasing toward bottom. Forams scarce; at 2990–3000 feet, large Uvigerina, Bulimina, Clavulina?
3000–3010	Chiefly fragments of coarse calcite cement. Some sand; glauconite; very little clay. Forams rare.
3010–3040	Mixed calcite, sand, and glauconite, a piece of fresh orthoclase feldspar; some shell fragments; fair muscovite; much angular to sub-rounded quartz, generally clear, some pale milky; some light-colored feldspar. No forams.
3040–3070	Pale olive sand, very little clay; a few slivers of brown clay; sand chiefly coarse, a fair amount of medium grade; quartz sub-angular to sub-rounded, fairly clear, some faintly milky; very little glauconite; shell fragments and lime cement fair; lignite. Forams rare. At 3050–3060 feet, large Robulus and Uvigerina.
3070–3080	Mixed pale brown foraminiferal clay and pale olive sand. No forams.
3080–3130	Chiefly coarse sand and fair medium grade sand; many coarse fragments of lime cement; glauconite is fairly common; quartz clear, angular, rounded edges; some siderite pellets; a little pyrite; coarse muscovite fairly common; pale brown flaky clay scarce. Forams very rare; at 3120–3130 feet fairly common. Large Robulus, large Uvigerina, Clavulina (?), large Vaginulina.
3130–3160	Mixed pale brown clay flakes and greensand; sand chiefly medium and coarse; glauconite common, dark green, dull surface; shell fragments fairly common. Forams fairly common.
3160–3170	Large flat pieces of pale brown clay (max. 27 mm.). Forams rare.
3170–3210	Pale olive mixture hardshell, shell fragments, clay, and greensand; sand fairly common; lignite. Forams generally rare; abundant at 3190–3200 feet, large Uvigerina and Robulus, Vaginulina, Textularia, ribbed Bulimina.
3210–3350	Similar to above section, but more clay (pale brown) and mica. Forams fairly common. At 3230 feet large Uvigerina, large ribbed Robulus, Vaginulina,

Depth in Feet	
	large Guttulina, Dentalina (several varieties), Gyroidina, Globigerina; at 3340 feet, large Uvigerina and Robulus, Vaginulina, Guttulina (different from above).
3350–3370	Light brownish-grey lumpy clay. Forams rare.
3370–3380	Clay, pale brown, flaky, and some sticky clay. No forams.
3380–3420	Light brownish-grey lumpy clay, a little sand and a few shell fragments. Forams rare.
3420–3430	Light olive-grey sand, some pale brown clay; sand coarse and medium; glauconite, fairly common; a little pyrite; mica fairly common. Forams rare.
3430–3530	Mixed pale brown clay and light olive-grey sand, shell fragments fairly common; a number of small pieces of red iron-oxide; many siderite pellets; much of the rounded quartz is etched; a little pyrite; echinoid spines; some of the clay flaky; glauconite, little. Forams generally scarce; abundant at 3430 foot, large Uvigerina and Robulus, Vaginulina, Dentalina, Nonions, ribbed Bulimina, smooth Robulus relatively more abundant.
3530–3550	Much clay. Clay pale brown and sticky; coal; considerable fine-grained, brownish-grey, hard fragments (non calcareous); quartz sand not abundant; some small slivers of medium grey clay (max. length 6 mm.; very narrow, 1 mm.; rounded ends, not noted before). Forams fairly common; at 3540 feet, Vaginulina, large Robulus, few large Uvigerina.
3550–3570	Mixed sand and very pale brown, hard fragments of sandstone (non calcareous cement) and many siderite pellets; quartz angular to sub-rounded; very little glauconite. Forams rare.
3570–3580	Pale brown lumpy clay. A few fragments of weak orange-pink clay. No forams.
3580–3610	Weak yellowish-orange lumpy clay, mixed light olive-grey and weak-brown clay. No forams.
3610–3620	Light olive-grey lumpy clay. No forams.
3620–3630	Pale olive sand, chiefly medium, some coarse and fine; quartz, dirty, angular to sub-angular, generally clear; lignite fragments, a few shell fragments. Forams rare.
3630–3670	Weak-yellow sand, chiefly medium, some fine and some coarse; quartz, clear, angular; a few pieces of faint-pink rose quartz; a little fresh feldspar; some pyrite; large muscovite flakes fairly common; some pyrite and lignite fragments; a few pale brown clay flakes; more clayey toward bottom. Forams very rare.
3670–3760	Mixed weak-brown sand and clay; clay chiefly small, flat, pale brown flakes (max. 8 mm.); shell fragments fairly common; quartz, chiefly medium, clear, dirty, angular; considerable variation in the relative amounts of clay and sand; clay generally in flakes, some pale brown, some yellowish grey. Forams rare; at 3690 feet large Uvigerina, large Robulus, Dentalina (various); at 3740 feet, large Uvigerina, large ribbed Dentalina.
3760–3770	Weak-brown mixture of sand and clay, brown due to staining; some pieces of clay 15 mm.; unstained clay pale olive-grey. Sand grains angular, clear, dirty; glauconite, trace. Forams rare.
3770–3790	Brownish-grey clay chiefly, some sand; clay both flaky and lumpy; sand chiefly medium to coarse; a few shell fragments. Forams rare.
3790–3800	Weak-brown mixture clay and sand. Forams rare.
3800–3840	Weak-brown clay, sticky, chiefly lumps and some slivers; some sand; a number

Depth in Feet	
	of small particles of weak-brown clay (max. 4 mm.), occasionally lime cement. Forams rare.
3840–3910	Mixture of clay, sand, and calcareous cement; clay weak-brown, pale brown, and yellow-grey; some sand. Forams rare.
3910–3960	Mixed sand and clay; some large flat pieces of pale brown (max. 27 mm.) and rounded thick pieces of pale yellow clay; quartz chiefly medium, angular, dirty, clear; glauconite scarce; a little pyrite, a few shell fragments. Forams scarce; at 3940 feet large Uvigerina and Robulus, large Vaginulina, Nonions, Globigerina.
3960–3980	Mixed clay and sand, weak brown. Forams abundant; at 3970 feet, large Uvigerina and Robulus (few), Vaginulina, ribbed Bulimina, Nonions, Globigerina.
3980–4050	Weak-brown clay, little sand; clay, flaky (max. 10 mm.). Forams rare.
4050–4150	Similar to above except somewhat more pale brown clay, and larger pieces of pale brown clay (max. 17 mm.); shell fragments; siderite pellets from 4100 to 4140 feet. Forams generally rare; at 4060–4070 feet large Uvigerina and Robulus, Nonions, ribbed Bulimina, Clavulina; at 4080–4090 feet large Robulus, large Vaginulina.
4150–4180	Dark reddish-grey clay, many shell fragments—an admixture of lighter clays toward the bottom. Forams rare.
4180–4200	Mixture lignite (chiefly) and sand, a little clay; sand medium grade; quartz, clear angular to sub-rounded; echinoid spines; siderite fair. Forams rare.
4200–4250	Mixed pale brown flaky clay and sand, some weak-brown pieces (small) of clay; lignite, scarce; siderite pellets fairly common; a little muscovite; slivers of pale olive clay fairly common. Forams common; at 4220 feet chiefly large Uvigerina, very few large Robulus, much lignite, Nonions, pieces of large Dentalina.
4250–4260	Weak-brown clay fragments cemented with amber-like substance (origin unknown, but does not seem to be indigenous); a little sand; some siderite pellets. No forams.
4260–4300	As in 4200–4260; a few diatom fragments in the grey clay. Forams scarce; at 4280 feet, large Uvigerina and Robulus.
4310–4320	Chiefly light olive-grey calcareous cement, some flakes of pale brown clay. No forams.
4320–4340	Mixed pale brown clay (chiefly clay) and calcareous cement. No forams.
4340–4370	Similar to 4320–4340 feet, but more small pieces of weak-brown clay. Forams rare.
4370–4410	Pale olive sand, minor clay and calcareous cement fragments (variable); sand chiefly medium grade, some coarse and fine; quartz generally angular, clear; some pyrite. Forams rare.
4410–4480	Mixed pale brown clay flakes (max. 15 mm.) and some sand, some small weak-brown clay pieces. Forams scarce; at 4420 feet, large Uvigerina and Robulus, Dentalina (var. not noted before), ribbed Bulimina.
4480–4490	Chiefly clay, mixed grey and brown, a small gastropod. No forams.
4490–4600	As in 4410–4480 feet, chiefly clay, little sand. At 4560–4580 feet, calcareous cement common; at 4580–4590 feet, much lignite. Forams rare; at 4540 feet, large Uvigerina, very few large Robulus, Nonions, Dentalina.
4600–4690	Brownish-grey clay, the larger pieces (max. 11 mm.) flaky, weak-brown pieces generally smaller; a little sand. At 4660–4670 feet, somewhat more sandy;

Depth in Feet	
	at 4670–4680 feet, a number of flakes of weak yellow-green clay; at 4680–4690 feet, much lignite. Forams rare.
4690–4710	Mixed clays, a little pale brown clay in rather large pieces, considerable weak yellow-green clay, much brownish-grey clay in small pieces, a little yellowish-grey clay; a little lignite; some shell fragments; a little sand. Forams rare.
4710–4740	Light olive-grey mixed sand and clay, much of the clay is olive-grey, in small slivers (max. 11 mm.) and irregular pieces; sand mostly coarse and medium; quartz clear, sub-angular to rounded; siderite pellets. Forams fairly common; at 4720 feet, large Uvigerina, large Robulus, large Vaginulina, Dentalina.
4740–4770	Chiefly hardshell (calcareous cement), little sand; clay intermixed toward bottom. Forams rare.
4770–4800	Mixed clays and sand, olive-grey clay in long thin slivers, some weak yellowish-green clay, very little pale brown clay; shell fragments; some calcareous cement; sand, mostly coarse and medium, some fine; quartz, sub-angular to sub-rounded; a little siderite. Forams rare.
4800–4820	As in 4250–4260 feet, rusty, reddish-brown, heavily-stained material. No forams.
4820–4860	Mixed clays, little sand, thin flat pieces of weak yellow-green clay, elongated slivers (12 mm.) of olive-grey clay, a few flat pieces of pale brown clay. Forams rare.
4860–4870	Chiefly pale brown clay in small flat pieces. No forams.
4870–4880	As in 4820–4860 feet (piece of core (middle) 4875–4885); hard, weak yellow-green clay, similar to pieces found in cuttings from 4670 feet. Not calcareous; no diatoms; bottom 1 foot of core, mixed weak yellow-green and weak-yellow sandy clay; top of core olive-grey, thin-bedded, fine-textured clay containing shells. No forams.
4880–4890	Many shell fragments, mixed clay, chiefly pale brown; a little sand. Forams rare.
4890–4970	Clay, chiefly flakes of olive-grey clay, a little pale brown clay; fair shell fragments; some calcareous cement; some weak yellow-green flakes; clay very variable in the interval, one or the other type predominating. Forams rare.
4970–5000	Chiefly fragments of hardshell (calcareous cement) mixed with clay (olive-grey predominates) and sand. Forams rare.
5000–5040	Light olive-grey sand, almost entirely coarse; quartz, clear, angular to sub-angular; a little coarse pyrite; a very little pale milky quartz. Forams rare; at 5030 feet, large Robulus and Uvigerina, Dentalina.
5040–5070	Mixed clay and sand. Forams rare.
5070–5140	Chiefly clay, light olive-grey, weak yellow and olive-grey in long slivers; somewhat more sandy below 5090 feet. Forams rare.
5140–5170	Clay, chiefly olive-grey; a little sand. Forams rare; at 5160 feet, large Uvigerina and Robulus, small Dentalina (several types), Nonions, Gyroidina, Guttulina (different types).
5170–5210	Mixed sand and clay; clay, olive-grey, weak yellow-green (rather abundant), and a little weak-brown; shell fragments; some pale brown foraminiferal clay. Forams rare.
5210–5240	Light olive-grey clean sand, predominantly coarse; quartz clear, chiefly angular, some sub-rounded; a little pale rose quartz. Forams rare.

Depth in Feet	
5240–5250	Mixed clay and sand; clay as in 5170–5210 feet. Forams rare.
5250–5300	Chiefly mixed clay, pale brown; a little sand; a few shell fragments. Forams rare.
5300–5350	Clay, mixed, chiefly weak-brown fragments, but varying with pale brown. Forams rare.
5350–5370	Light olive-grey coarse sand as in 5210–5240 feet. No forams.
5370–5380	Mixed sand and clay. Forams rare.
5380–5450	Clay, weak-brown chiefly; as in 5300–5350 feet, variable admixture of yellow-grey clay which in some samples is in large flat pieces (max. 23 mm.). Forams scarce; at 5400 feet, large Uvigerina and Robulus, very large Vaginulina, Clavulina, Guttulina; at 5410 feet, same.
5450–5460	Mixed coarse sand and clay, chiefly sand. No forams.
5460–5510	Mixed coarse and very coarse sand and mixed clay, chiefly weak-brown clay. Forams rare.
5510–5520	Mixed clay and some sand, much more clay than in preceding interval, generally weak-brown. Forams rare.
5520–5570	Chiefly light olive-grey sand, some clay; sand coarse, as in 5350–5370 feet. Forams rare.
5570–5640	Mixed clay, weak-brown, light yellow-green, pale olive, and pale brown; considerable coarse sand. At 5630–5640 feet some large (max. 11 mm.) pieces pale brown clay, large number doughnut-like organisms seen under high power microscope (found in the diatomaceous clays). Forams scarce; at 5570 feet, large Uvigerina and Robulus, very few; at 5580 feet, large Uvigerina; at 5580 feet, large Uvigerina, Globigerina; at 5640 feet, large Uvigerina, pieces of large Dentalina, 1 Robulus.
5640–5670	Chiefly coarse sand, fair clay; quartz clear, clean, sub-angular, a little pale milky quartz, a little rose quartz; a few grains of medium green, rough glauconite; echinoid spines and foraminifera. Forams rare.
5670–5690	Chiefly clay (mixed), some sand. Forams scarce.
5690–5700	Sand, considerable pale brown clay. Forams rare.
5700–5750	Chiefly coarse sand, as in 5640–5670 feet; a little clay, increasing clay toward bottom. Forams rare; at 5710 feet, large Uvigerina, Guttulina.
5750–5780	Mixed clay and sand, clay, predominantly weak-brown; a few shell fragments. Forams rare.
5780–5790	Chiefly coarse sand, clay chiefly weak-brown, and considerable light yellow-green. Forams rare.
5790–5830	Yellowish-grey sand, chiefly very coarse and coarse, a fair amount granule size, generally angular to sub-angular, clear and somewhat cloudy; a few pieces of gravel up to 8 mm. No forams.
5830–5840	Mixed clay and sand, clay, chiefly weak yellow-green and some pale and weak-brown; quartz, coarse, angular. No forams.
5840–5870	Chiefly weak yellow-green clay, fair weak-brown clay, very little pale brown clay; some sand. Forams, rare.
5870–5910	Chiefly coarse yellowish-grey sand, a little weak and pale yellow green clay; a few pebbles; clear quartz (max. 7 mm.); sand chiefly coarse and very coarse, angular and sub-angular, clear and partly cloudy. Forams rare.
5910–5960	Mixed clay and sand, pieces of a very fine textured pale yellow-green clay, some weak yellow-green somewhat sandy clay (max. 16 mm.), some fine-grained brown clay, containing organisms, a few pieces weak-brown material. Forams rare.

Depth in Feet	
5960–5980	Mixture of weak yellow-green clay and pieces of a friable micaceous yellowish-grey sandstone (pieces max. 15 mm.), medium-grained, rounded to sub-angular; a little rose quartz. Forams, very rare.
5980–6000	Coarse yellowish-grey sand, a little clay; a few pieces of gravel. No forams.
6000–6010	Mixed clay, sand and sandstone; clay, weak yellow-green chiefly, some weak-brown. Forams rare.
6010–6050	Clay, mixed light olive-grey clay, mostly small flat pieces (about 2 mm.), some weak-brown flakes. Forams, abundant at 6020 feet, large Uvigerina, few large Robulus, large Vaginulina.
6050–6070	Mixed large pieces pale brown clay, small flakes light yellow-green clay, and lime-cemented sand; some coarse sand, a little pale brown clay. No forams.
6070–6090	Mixed clay and sand, large pieces of clay as above; many small rounded pieces of hard weak-brown material; some sand. No forams.
6090–6110	Chiefly yellowish-grey coarse sand, considerable clay; some shell fragments and echinoid spines; a little gravel. No forams.
6110–6160	Mixed sand and clay, considerable weak-brown toward bottom of interval. No forams.
6160–6260	Yellowish-grey coarse sand, a little very coarse and medium; variable colored clay, chiefly weak yellow-green in fair amount, much clay at 6190–6200 feet, 6230–6240 feet, and 6250–6260 feet. Forams, a few at 6210 feet, large Uvigerina, large Globigerina.
6260–6280	Mixed coarse sand and light yellow-green clay, much sand. No forams.
6280–6300	Chiefly pale yellow-green and pale brown rounded pellets (max. 11 mm.), some sand, and a few pebbles. No forams.
6300–6320	Chiefly sand, but considerable fine clay pieces. No forams.
6320–6340	Coarse and very coarse yellow-grey sand, a little clay, chiefly light yellow-green; at 6330–6340 feet chiefly gravel (granule size), much very coarse and coarse sand; a little clay. No forams.
6340–6390	Chiefly light yellow-green clay, some sand, some pale brown clay. Forams, very rare.
6390–6420	Clay, chiefly light yellow-green. Forams scarce; at 6420 feet, large Robulus and Uvigerina, large Dentalina.
6420–6430	Yellow-grey coarse sand. Forams rare.
6430–6490	Mixed coarse sand and clay, clay chiefly medium greenish-grey, in small pieces, a little pale brown; a few pieces of calcite cement. Forams very rare.
6490–6500	Coarse yellow-grey sand, a little clay. No forams.
6500–6560	Mixed clay, chiefly medium greenish-gray, some pale brown. Forams scarce; at 6500–6510 feet, large Uvigerina and large Robulus.
6560–6580	Chiefly coarse yellow-grey sand and admixed clay fragments, chiefly medium greenish-grey, some clay at bottom. No forams.
6580–6620	Mixed clay, chiefly small pieces weak-brown clay which dominates the color of the sample; shell fragments and barnacles; at the top a little sand; medium green-grey clay increases toward the bottom. Forams very rare.
6620–6640	Chiefly coarse yellow-grey sand, a little clay. No forams.
6640–6650	Mixed sand and clay, medium green-grey and pale brown. No forams.
6650–6660	Chiefly yellow-grey coarse sand, some clay, mixed. No forams.
6660–6670	Chiefly clay (pale brown), considerable sand. Forams rare.
6670–6710	Clay, mixed pale brown and medium green-grey, most in flat flakes about 6 mm.

Depth in Feet	
	and smaller; a little coal; increase in medium green-grey clay toward bottom. Forams very rare.
6710–6730	Chiefly coarse and very coarse yellow-grey sand, a little clay. No forams.
6730–6740	Clay, chiefly flaky medium green grey. No forams.
6740–6750	Mixed sand and clay, flakes medium green grey clay and bits of weak brown material. No forams.
6750–6860	Clay, mostly in flakes (max. 12 mm.), chiefly medium green-grey, some pale brown, a little fine-grained, light yellow-green; a little sand at places. Forams scarce; at 6770 feet, large Uvigerina, 1 large Robulus, small Globigerina.
6860–6870	Considerable coarse sand, clay. No forams.
6870–6930	Chiefly clay, but some sand. Clay as in 6750–6860 feet, some long pale olive slivers, generally in small and very small flakes. No forams.
6930–6940	Chiefly coarse sand, but a fair amount of clay. Forams rare.
6940–6960	Mixed coarse sand and clay, fair amount of weak-brown clay. Forams scarce; at 6950 feet, large Uvigerina and Robulus, ribbed Bulimina, Clavulina.
6960–7160	Clay, generally brownish-grey, but much flaky and variable in color to medium grey; at 7000–7010 feet somewhat sandy; at 7020–7040 feet and 7080–7090 feet a little sand and more weak-brown clay. Forams rare; at 7150 feet, large Uvigerina, 1 Nodosaria?
7160–7190	Mixed yellow-grey coarse sand and clay, clay chiefly weak-brown, some medium green-grey. No forams.
7190–7200	Mixed weak-brown and medium green-grey clay, little sand. Forams very rare.
7200–7370	Mixed flaky weak-brown and medium grey-green clay; at 7240–7250 feet, much sand; occasional shells; at 7330–7350 feet, considerable sand. Forams, very few at 7360 feet, large Uvigerina and Robulus.
7370–7390	Mixed coarse sand and clay. No forams.
7390–7400	Chiefly, coarse and very coarse sand; quartz partly clear, sub-angular, to sub-rounded. No forams.
7400–7430	Mixed clay and sand, generally olive-grey. Forams, very rare; at 7410 feet, large Uvigerina and Robulus, very few.
7430–7460	Clay, olive-grey, small and very small flakes. No forams.
7460–7470	Coarse yellow-grey sand. No forams.
7470–7480	Clay, mixed olive-grey and weak brown. No forams.
7480–7570	Mixed clay, sand, and gravel (max. 5 mm.), gravel scarce; general color brownish-grey; a few fragments of shells; at 7510–7520 feet, somewhat more sand; at 7540–7560 feet, much yellow-grey coarse sand. Forams scarce; at 7480 feet, a few large Robulus and Uvigerina; at 7500 feet, same, also broken Dentalina.
7570–7590	Mixed pale olive and weak-brown clay, flaky; a little coal; some sand, at 7570–7579 feet, much sand. No forams.
7590–7620	Clay, chiefly brownish-grey. Forams, rare; at 7600 feet, 1 large Robulus, 1 large Vaginulina.
7620–7650	Chiefly coarse sand and some gravel, some clay; gravel, max. 12 mm.; at 7630–7640 feet, largely pale olive clay; some sand. No forams.
7650–7710	Mixed coarse sand, a little gravel and clay; at 7700–7710 feet, chiefly yellow-grey coarse sand and a little gravel (max. 3 mm.); little clay; sand clear and partly cloudy, sub-angular quartz. Forams very rare; 1 large Uvigerina.

DESCRIPTION OF SCHLUMBERGER SIDE-WALL CORES

BY

JUDSON L. ANDERSON

Depth in Feet

1565 No recovery

2492 No recovery

3354 No recovery

3555 Clay, chocolate-brown with small areas of mustard-yellow. Several small areas appear to be glauconitic. Green silty particles scattered through clay. Trace of micaceous and quartz silt.

3598 No recovery

3673 No recovery

4050 Clay, pale lead-gray, mottled rusty-yellow, reddish-brown and occasionally purple.

5007 Sand, soft, very fine grained, white, with epidote, brown mica, chlorite, staurolite, pink garnet, and very fine to silty kaolinized feldspars.

5320 Clay, lead-gray with occasional red-brown mottling. Rarely olive-green mottling.

5930 Sand, very fine grained, white, soft kaolinized feldspars abundant. No epidote. Brown mica, chlorite, brown garnet.

5930 Sand, as above.

6214 Sand, white, fine grained, with a matrix of silty, slightly calcareous kaolinized sand. Muscovite, chlorite, biotite, staurolite. No epidote. Garnets.

6350 Clay, silty, micaceous lead-gray.

6603 Sand, very fine grained, richly chloritic, with garnet and kaolinized feldspar.

6790 Ditto.

7136 Ditto. Brown garnets quite abundant.

7280 Clay, silty, micaceous, with occasionally fine quartz sand, lead-gray.

7702 Sand, fine grained, white, kaolinized, with small amount of pale greenish-white clay matrix. About 10% medium-grained subangular sand. Small amount of muscovite.

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*Page numbers in *italics* indicate detailed descriptions.

FIGURE 1

CORRELATION CHART OF CENOZOIC and MESOZOIC SEDIMENTS.

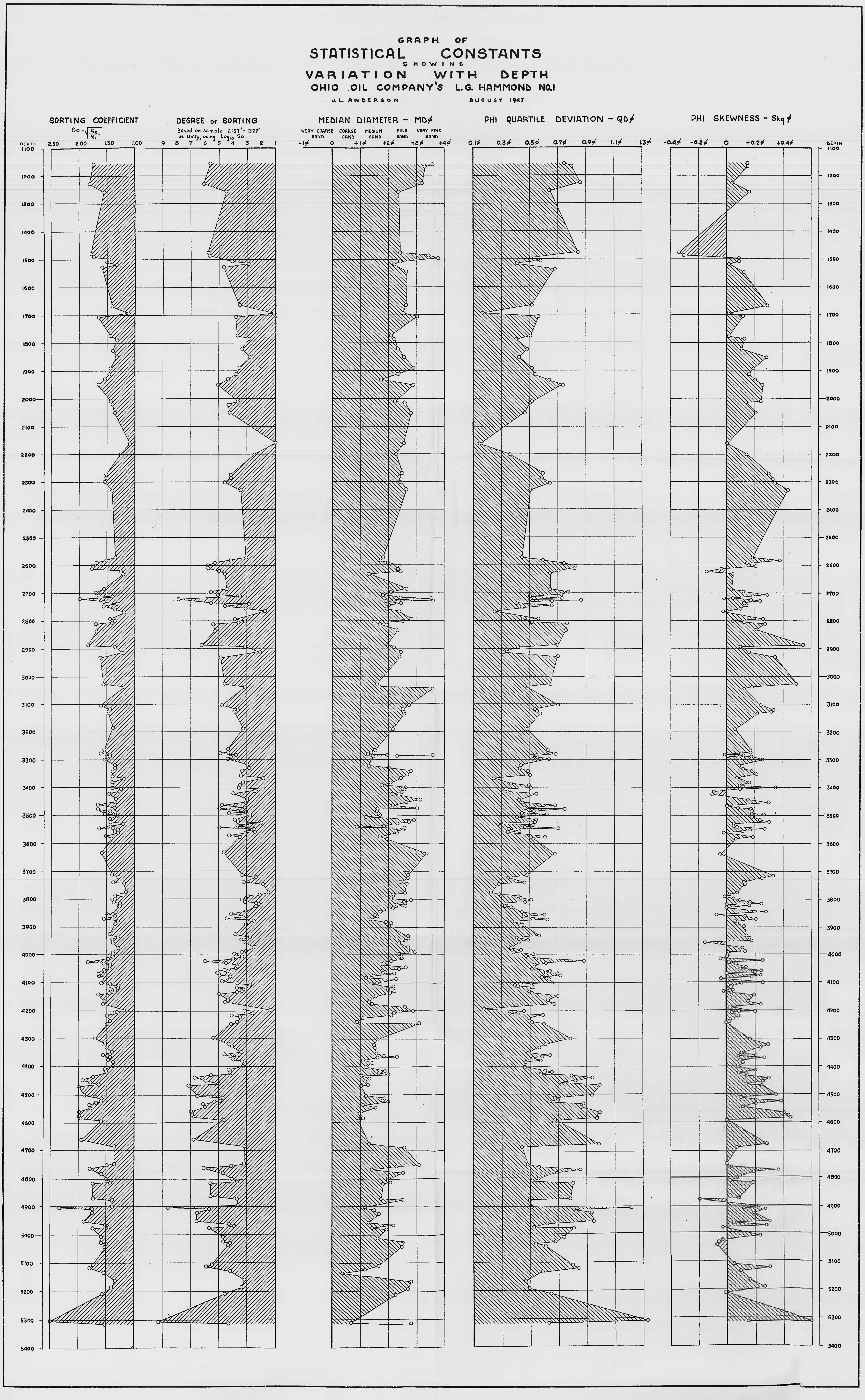
Era	Series	Generalized Standard Section: American Subdivisions	Generalized Standard Section: European Subdivisions	Gulf Coast: Texas	Atlantic Coast: Maryland
CENOZOIC	PLEISTOCENE	Wisconsin	Würm glacial	Undifferentiated	Pamlico fm.
CENOZOIC	PLEISTOCENE	Sangamon	Würm-Riss interglacial	Beaumont clay	Talbot fm. Penholoway fm. Wicomico fm.
CENOZOIC	PLEISTOCENE	Illinoian	Riss glacial		
CENOZOIC	PLEISTOCENE	Yarmouth	Riss-Mindel interglacial	Lissie sand	Sunderland fm. Coharie fm.
CENOZOIC	PLEISTOCENE	Kansan	Mindel glacial		
CENOZOIC	PLEISTOCENE	Aftonian	Mindel-Günz interglacial	Undifferentiated	Brandywine fm.
CENOZOIC	PLEISTOCENE	Nebraskan	Günz glacial		
CENOZOIC	PLIOCENE	UPPER	Astian	Willis sand (Pliocene?)	
CENOZOIC	PLIOCENE	LOWER	Plaisancian	Goliad sand	
CENOZOIC	MIOCENE	UPPER	Sahelian: Pontian	Largato clay (Miocene)	Yorktown fm.
CENOZOIC	MIOCENE	UPPER	Sahelian: Sarmatian	?	
CENOZOIC	MIOCENE	MIDDLE	Tortonian	Oakville sandstone	St. Mary's fm.
CENOZOIC	MIOCENE	MIDDLE	Helvetian	Oakville sandstone	Choptank fm. Calvert fm.
CENOZOIC	MIOCENE	LOWER	Burdigalian		
CENOZOIC	MIOCENE	LOWER	Aquitanian	Catahoula sandstone	
CENOZOIC	OLIGOCENE	UPPER	Chattian	?	
CENOZOIC	OLIGOCENE	MIDDLE	Rupelian	Frio clay	
CENOZOIC	OLIGOCENE	LOWER	Tongrian	?	?
CENOZOIC	EOCENE	JACKSON	Ludian	Jackson fm.	Present in the subsurface only
CENOZOIC	EOCENE	JACKSON	Bartonian	Jackson fm.	?
CENOZOIC	EOCENE	CLAIBORNE	Auversian	Yegua fm. Cook Mt. fm.	
CENOZOIC	EOCENE	CLAIBORNE	Lutetian	Mt. Selman fm. Carrizo sand	Nanjemoy formation
CENOZOIC	EOCENE	WILCOX	Cuisian	Wilcox group	Nanjemoy formation
CENOZOIC	EOCENE	WILCOX	Ypresian	Indio fm.	Aquia fm.
CENOZOIC	PALEOCENE	MIDWAY	Thanetian	Wills Point fm.	Present on outcrop but unnamed
CENOZOIC	PALEOCENE	MIDWAY	Montian	Kincaid fm.	Present in the subsurface
MESOZOIC	CRETACEOUS	UPPER CRETACEOUS	SENONIAN: Maestrichtian	Navarro group: Kemp clay	
MESOZOIC	CRETACEOUS	UPPER CRETACEOUS	SENONIAN: Maestrichtian	Navarro group: Corsicana marl	?
MESOZOIC	CRETACEOUS	UPPER CRETACEOUS	SENONIAN: Maestrichtian	Navarro group: Nacatoch sand	Monmouth formation
MESOZOIC	CRETACEOUS	UPPER CRETACEOUS	SENONIAN: Maestrichtian	Navarro group: Neylandville marl	Monmouth formation
MESOZOIC	CRETACEOUS	UPPER CRETACEOUS	SENONIAN: ?	Taylor marl (upper)	?
MESOZOIC	CRETACEOUS	UPPER CRETACEOUS	SENONIAN: Campanian	Pecan Gap chalk member	Matawan formation
MESOZOIC	CRETACEOUS	UPPER CRETACEOUS	SENONIAN: Campanian	Wolfe City sand member	Matawan formation
MESOZOIC	CRETACEOUS	UPPER CRETACEOUS	SENONIAN: Campanian	Taylor marl (lower)	(Undifferentiated)
MESOZOIC	CRETACEOUS	UPPER CRETACEOUS	SENONIAN: ? Santonian ?		
MESOZOIC	CRETACEOUS	UPPER CRETACEOUS	SENONIAN: Coniacian	Austin chalk	Magothy fm.
MESOZOIC	CRETACEOUS	UPPER CRETACEOUS	Turonian	Eagle Ford shale	?
MESOZOIC	CRETACEOUS	UPPER CRETACEOUS ?	Cenomanian	Woodbine sand	Raritan fm. Patapsco-Arundel fms.
MESOZOIC	CRETACEOUS	LOWER CRETACEOUS	? Albian	Washita group	
MESOZOIC	CRETACEOUS	LOWER CRETACEOUS	Albian	Fredricksburg group	
MESOZOIC	CRETACEOUS	LOWER CRETACEOUS	Albian	Trinity group	
MESOZOIC	CRETACEOUS	LOWER CRETACEOUS	Aptian		
MESOZOIC	CRETACEOUS	LOWER CRETACEOUS	Barremian		
MESOZOIC	CRETACEOUS	LOWER CRETACEOUS	Hauterivian		
MESOZOIC	CRETACEOUS	LOWER CRETACEOUS	Valanginian		Patuxent fm.
MESOZOIC	CRETACEOUS	LOWER CRETACEOUS	Berriasian		
MESOZOIC	JURASSIC			Present in subsurface	Absent
MESOZOIC	TRIASSIC			?	Present in subsurface from Hammond well eastward
					Basement metamorphics

Modified after Correlation of the Cenozoic & the Mesozoic Formations etc. Buils. Geol. Soc. of Amer.

FIGURE 2. Mineral Chart, Ohio Oil Company's L. G. Hammond Well No. 1


MINERAL GRAPH
SHOWING
VARIATION of PRINCIPAL MINERALS
OHIO OIL COMPANY'S L.G. HAMMOND NO.1
J.L. ANDERSON AUGUST 1947
ZIRCON
TOURMALINE
STAUROLITE
GARNET
RUTILE
TITANITE
EPIDOTES
DEPTH
PLEISTOCENE
YORKTOWN
ST. MARYS
CHOPTANK
CALVERT
MIOCENE
EOCENE
MONMOUTH
MATAWAN
MAGOTHY
RARITAN
CRETACEOUS
PATAPSCO
ARUNDEL
UPPER
PATUXENT
LOWER CRETACEOUS
NEWARK
TRIASSIC

FIGURE 10. Columnar Section with Mineral Zones, Fossil Zones, Electric Log, and Color Distribution. L. G. Hammond Well No. 1

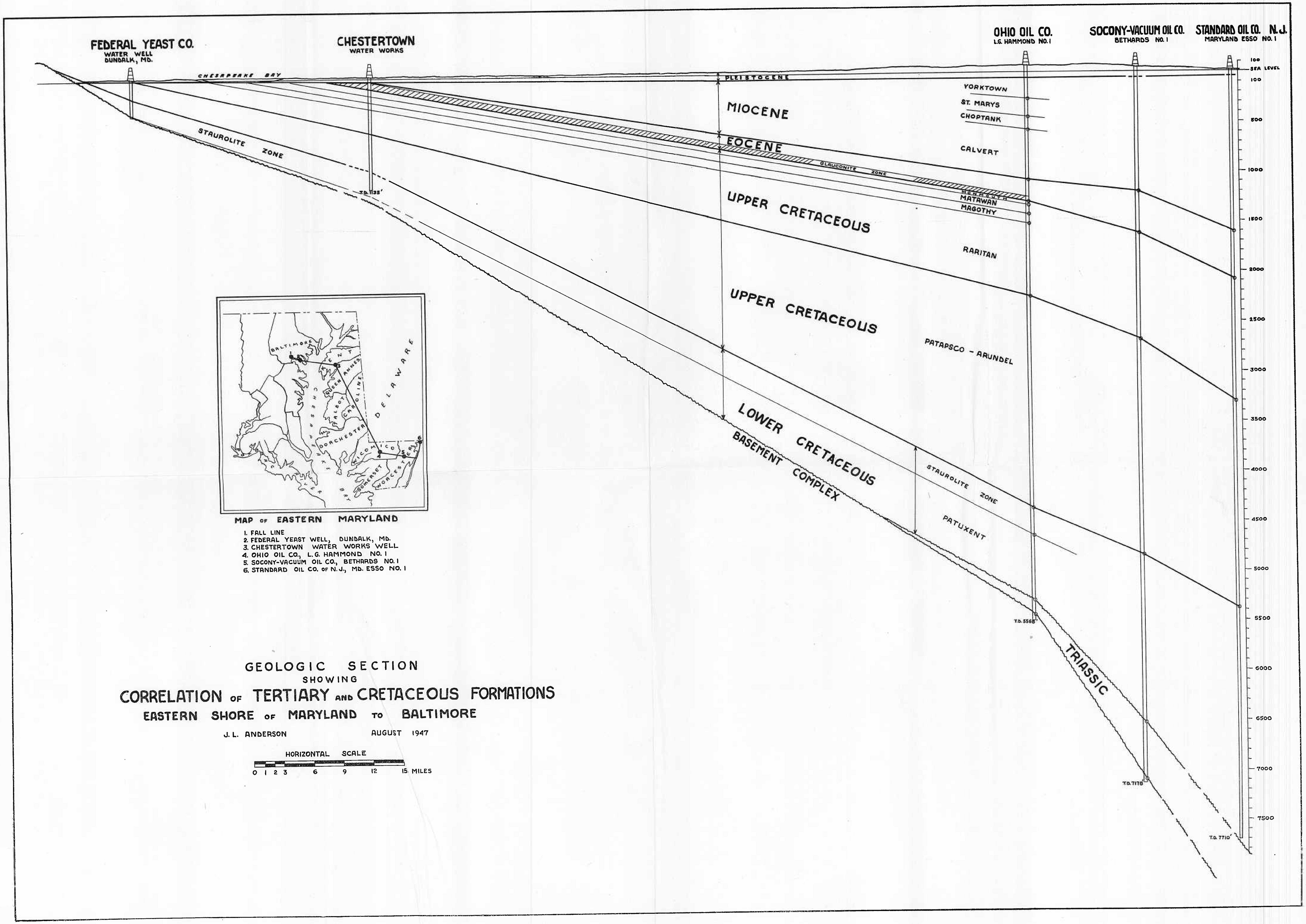

GRAPH OF
STATISTICAL CONSTANTS
SHOWING
VARIATION WITH DEPTH
OHIO OIL COMPANY'S L.G. HAMMOND NO.1
J.L. ANDERSON
AUGUST 1947
SORTING COEFFICIENT
DEGREE of SORTING
Based on sample 2157'-2167' as Unity, using Log10 So
MEDIAN DIAMETER - MDφ
VERY COARSE SAND
COARSE SAND
MEDIUM SAND
FINE SAND
VERY FINE SAND
PHI QUARTILE DEVIATION - QDφ
PHI SKEWNESS - Skqφ
DEPTH

ELECTRIC LOG-MINERAL-FAUNAL CORRELATIONS

DEEP TESTS-EASTERN SHORE of MARYLAND

FIGURE 20

FIGURE 21



FEDERAL YEAST CO.
WATER WELL
DUNDALK, MD.
CHESTERTOWN
WATER WORKS
OHIO OIL CO.
L.G. HAMMOND NO. 1
SOCONY-VACUUM OIL CO.
BETHARDS NO. 1
STANDARD OIL CO. N.J.
MARYLAND ESSO NO. 1
CHESAPEAKE BAY
PLEISTOCENE
MIOCENE
EOCENE
UPPER CRETACEOUS
UPPER CRETACEOUS
LOWER CRETACEOUS
BASEMENT COMPLEX
TRIASSIC
STAUROLITE ZONE
STAUROLITE ZONE
GLAUCONITE ZONE
YORKTOWN
ST. MARYS
CHOPTANK
CALVERT
MONMOUTH
MATAWAN
MAGOTHY
RARITAN
PATAPSCO - ARUNDEL
PATUXENT
T.D. 5568'
T.D. 7178'
T.D. 7710'
100
SEA LEVEL
100
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
BALTIMORE
KENT
QUEEN ANNES
CAROLINE
TALBOT
DORCHESTER
WICOMICO
SOMERSET
WORCESTER
DELAWARE
CHESAPEAKE BAY
MAP OF EASTERN MARYLAND
1. FALL LINE
2. FEDERAL YEAST WELL, DUNDALK, MD.
3. CHESTERTOWN WATER WORKS WELL
4. OHIO OIL CO., L.G. HAMMOND NO. 1
5. SOCONY-VACUUM OIL CO., BETHARDS NO. 1
6. STANDARD OIL CO. OF N.J., MD. ESSO NO. 1
GEOLOGIC SECTION
SHOWING
CORRELATION OF TERTIARY AND CRETACEOUS FORMATIONS
EASTERN SHORE OF MARYLAND TO BALTIMORE
J. L. ANDERSON
AUGUST 1947
HORIZONTAL SCALE
0 1 2 3 6 9 12 15 MILES

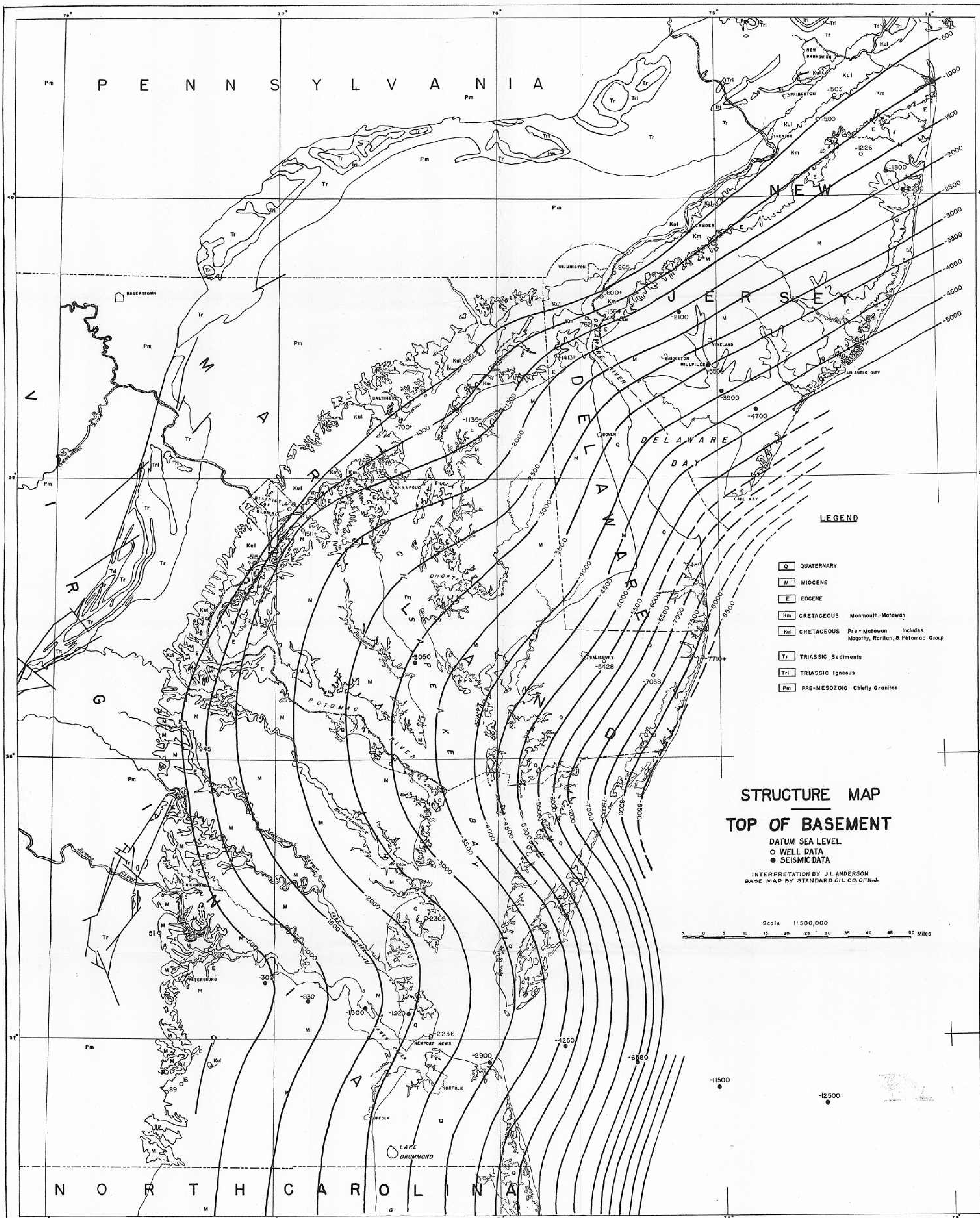


FIGURE 24. Structure Map on Top of Basement Complex, North Atlantic Coastal Plain

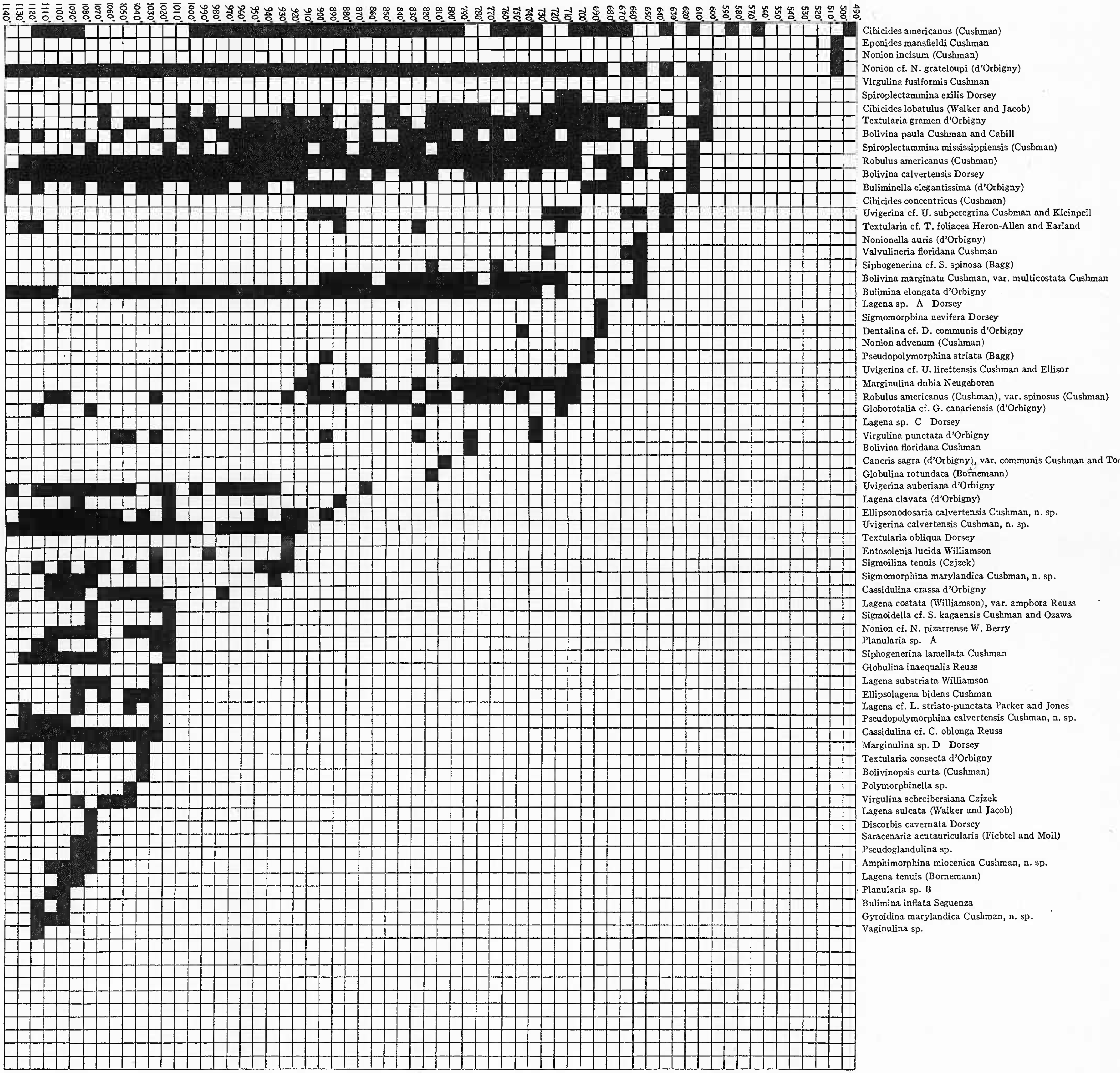


FIGURE 25. Species Range Chart of Miocene Foraminifera. L. G. Hammond Well No. 1

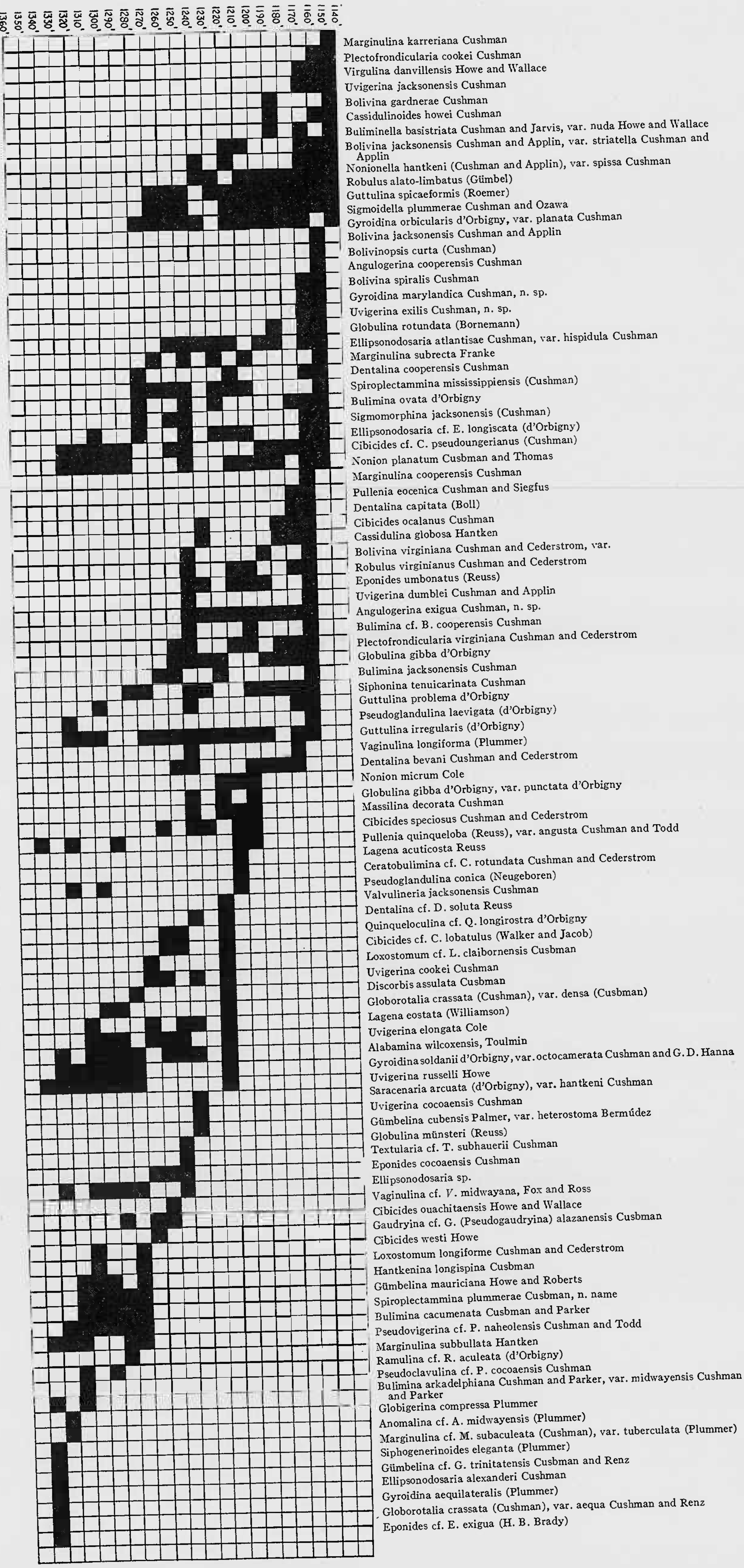


Figure 26. Species Range Chart of Eocene Foraminifera. L. G. Hammond Well No. 1

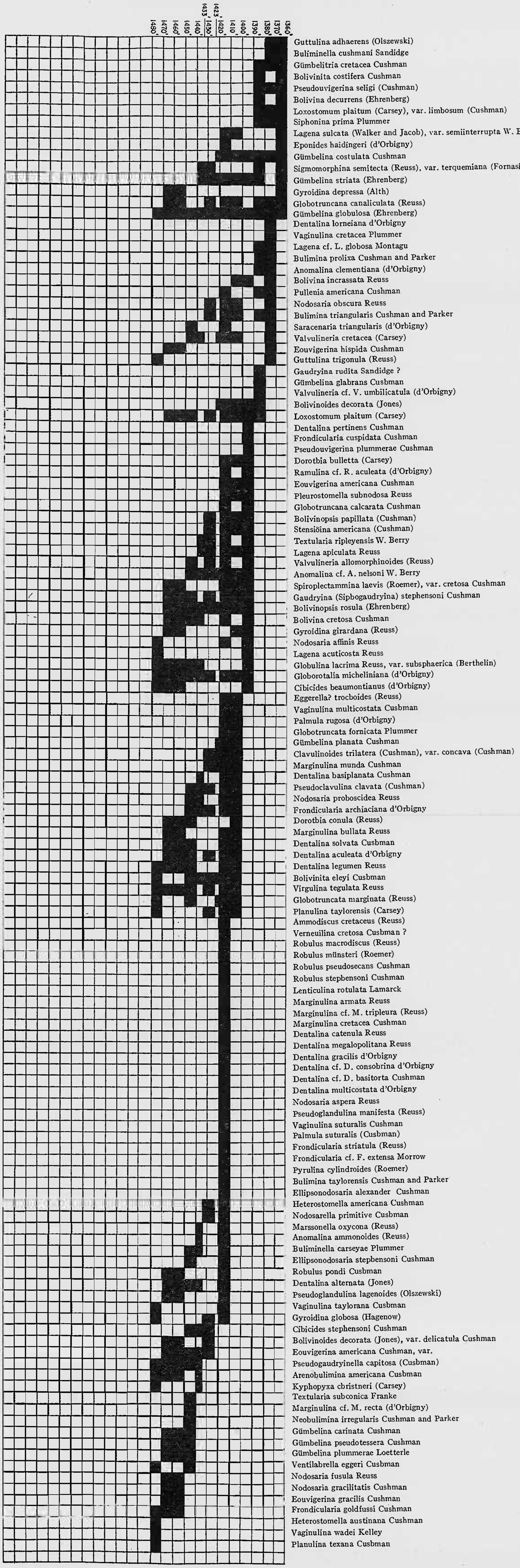


FIGURE 27. Species Range Chart of Cretaceous Foraminifera. L. G. Hammond Well No. 1

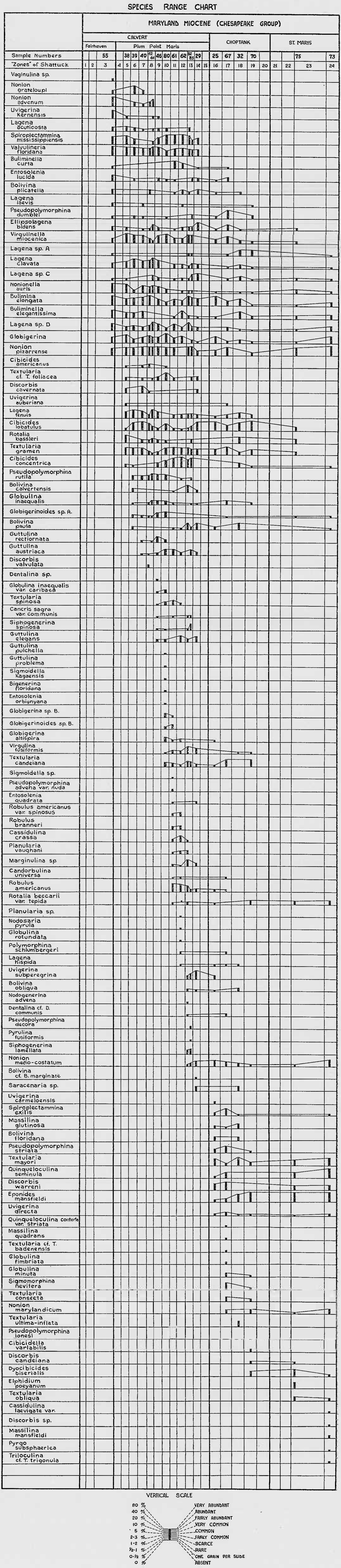


FIGURE 28. Species Range Chart of Foraminifera, Maryland Miocene, Chesapeake Group