STATE OF DELAWARE

DELAWARE GEOLOGICAL SURVEY

BULLETIN NO. 3

AND

THIRD ANNUAL REPORT

# MARINE UPPER CRETACEOUS FORMATIONS

## of the

# CHESAPEAKE AND DELAWARE CANAL

*By*

JOHAN J. GROOT

*State Geologist of Delaware*

DONNA M. ORGANIST

*Geologist, Delaware Geological Survey*

and

HORACE G. RICHARDS

*Associate Curator of Geology and Paleontology*
*Academy of Natural Sciences of Philadelphia*
*Lecturer, University of Pennsylvania*

NEWARK, DELAWARE

November 1954

STATE OF DELAWARE

DELAWARE GEOLOGICAL SURVEY

BULLETIN NO. 3

AND

THIRD ANNUAL REPORT

# MARINE UPPER CRETACEOUS FORMATIONS

## of the

# CHESAPEAKE AND DELAWARE CANAL

By


JOHAN J. GROOT

*State Geologist of Delaware*

DONNA M. ORGANIST

*Geologist, Delaware Geological Survey*

and

HORACE G. RICHARDS

*Associate Curator of Geology and Paleontology*
*Academy of Natural Sciences of Philadelphia*
*Lecturer, University of Pennsylvania*



NEWARK, DELAWARE

NOVEMBER 1954

STATE OF DELAWARE
DELAWARE GEOLOGICAL SURVEY
UNIVERSITY OF DELAWARE
NEWARK, DELAWARE

GEOLOGICAL COMMISSION

TEL. NEWARK 511, EXT. 342

JOHN R. HITCHENS, GEORGETOWN
CLAYTON M. HOFF, WILMINGTON
CLAYTON M. LIDDELL, NEW CASTLE
JOHN A. PERKINS, NEWARK
JOHAN J. GROOT, STATE GEOLOGIST

October 14, 1954

The Honorable J. Caleb Boggs
Governor of Delaware
State House
Dover, Delaware

Dear Sir:

I have the honor to submit to you Bulletin No. 3 of the Delaware Geological Survey, titled *The Marine Upper Cretaceous Formations of the Chesapeake and Delaware Canal.*

Although this report may seem highly technical, a detailed knowledge of geological formations and their age is essential for the purpose of correctly correlating sedimentary beds from one locality to another, and therefore has economic utility as well as scientific interest.

For reasons of economy the *Third Annual Report of the Delaware Geological Survey* has been included in this publication.

Respectfully yours,

John A. Perkins, Chairman
Geological Commission

## DELAWARE GEOLOGICAL SURVEY

**University of Delaware**

**Newark, Delaware**

## CONTENTS



## ILLUSTRATIONS



## TABLES



# Marine Upper Cretaceous Formations of the Chesapeake and Delaware Canal

By J. J. Groot, D. M. Organist, and H. G. Richards

## ABSTRACT

In the Coastal Plain of Delaware, the non-marine Cretaceous sands and clays are separated from the Tertiary formations by a series of marine formations of Upper Cretaceous age. The sedimentary and hydrologic characteristics of these formations deserve detailed study because some of them are water-bearing beds, whereas others act as confining beds. A clear understanding of their relative age, and the presence or absence of unconformities is needed for proper correlation with formations found in wells throughout the State, as well as in Maryland and New Jersey.

The marine Upper Cretaceous formations of the Chesapeake and Delaware Canal were investigated in view of the lack of agreement concerning their age assignment and correlation with the formations of New Jersey. On the basis of fossils and sedimentary characteristics, the formations found in the Canal are: the Merchantville and Wenonah formations of the Matawan group which are present below the *Exogyra cancellata* zone, and the Mount Laurel-Navesink and Red Bank formations of the Monmouth group. They are shown, in order of geologic time, in the following table.

| | | Carter (1937) | | Spangler & Peterson (1950) | | Groot, Organist, & Richards (1954) |
|---|---|---|---|---|---|---|
| Upper Cretaceous | Mon-mouth | Mount Laurel | Eo-cene | Vincentown<br>—unconformity— | Moumouth | Red Bank |
| | | —unconformity— | Monmouth | Navesink | | Navesink-Mount Laurel |
| | Matawan | Marshalltown | Matawan | Mount Laurel | | |
| | | —unconformity— | | | | |
| | | Englishtown | | Wenonah | | Wenonah |
| | | Crosswicks | | Marshalltown<br>Woodbury<br>Merchantville<br>undifferentiated | Matawan | Merchantville |

This table also shows previous interpretations by William C. Carter, and Walter B. Spangler and Jahn J. Peterson who studied the marine Upper Cretaceous formations in 1937 and 1950, respectively.

# INTRODUCTION

## Purpose and Scope

The development of Delaware's most valuable natural resource—ground water—has taken place to a great extent without the aid of geologic information. However, with the growth of population and industry and the corresponding increase in ground-water consumption, a sound knowledge of the geology of the State has become imperative. In order to properly correlate water-bearing strata from one locality to another, to determine their thickness and extent, and to predict their depth, a detailed study of the geologic formations of the Coastal Plain is necessary. This report is the result of an investigation of some of these formations, namely, the marine Upper Cretaceous deposits of northern Delaware.

In addition to the practical application of geology mentioned above, scientific interest demands an explanation of the differences in interpretation between the marine Upper Cretaceous deposits of Maryland and those of New Jersey. In Maryland, two marine formations of Upper Cretaceous age have been recognized: the Matawan and Monmouth. In New Jersey these formations have been raised to group rank; the Matawan has been divided into the Merchantville, Woodbury, Englishtown, Marshalltown, and Wenonah formations, while the Monmouth group has been divided into the Mount Laurel, Navesink, Red Bank, and Tinton formations. Delaware, located between these two states, should be a transition zone where the changes in formation can be properly studied. Therefore, the purposes of this investigation are: (1) to determine what marine Cretaceous formations are present in northern Delaware on the basis of their lithology and fossil content and (2) to study their stratigraphic relationships.

The geology of the Canal area is of particular significance because some aquifers intersected by it could be recharged by brackish water under conditions of heavy pumping. Therefore, the geologic information contained in this report should be helpful in understanding problems of ground-water conservation in the area.

The Chesapeake and Delaware Canal offers an excellent and nearly continuous outcrop, about 16 miles long, of the Cretaceous formations present in Delaware, and for this reason it was selected as the best site for this investigation. (For location see pl. 1, p. 9).

This Canal, which connects Chesapeake Bay with the Delaware River, was originally built between the years 1824 and 1829. At first it was privately owned, and was operated with a system of locks. In 1922, the United States Government took over ownership and deepened it to 12 feet at mean low tide and widened it to 90 feet at the bottom, making the Canal a sea-level waterway. The Canal was enlarged again in 1937 by deepening it to 27 feet at mean low tide and widening it to 150 feet at the bottom.

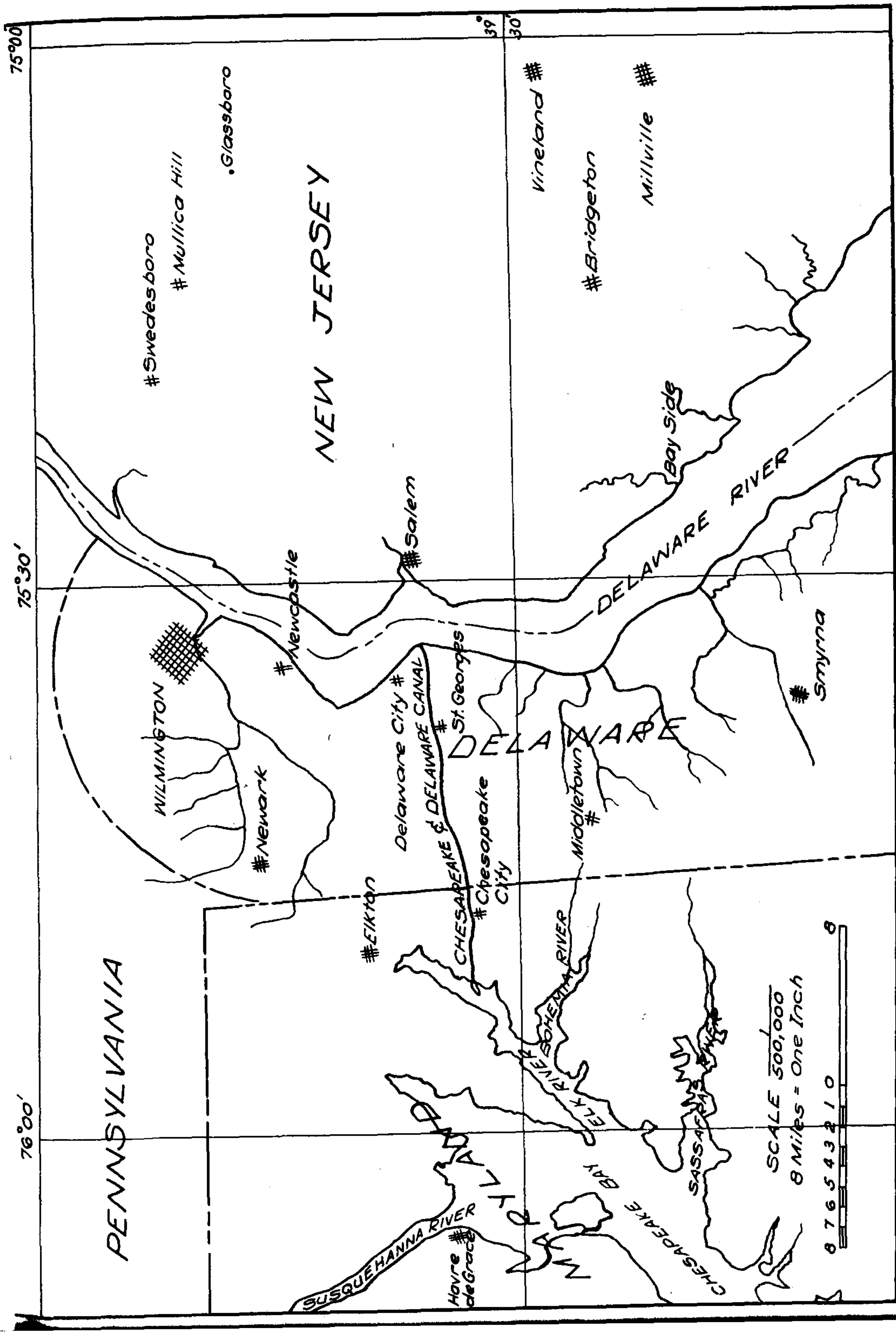
The Corps of Engineers, U. S. Army, reports its present depth to be 27 feet and its width as 250 feet. An average of 18 ships use this Canal each day. A proposal for again deepening and widening the Chesapeake and Delaware Canal is under consideration by the United States Government at present (September, 1954).

The topography of the area cut by the Canal is essentially flat. The highest altitude of approximately 80 feet above sea level occurs near the Maryland-Delaware state line. This area marks the divide between streams flowing westward into Chesapeake Bay and eastward into the Delaware River. In the vicinity of St. Georges the surface descends to about 30 feet above sea level and further gently slopes to an elevation of about 10 feet near the eastern entrance.

The field work for this investigation was begun in October, 1952, in conjunction with a study of the heavy mineral suites of the Cretaceous formations of northern New Castle County. An intensive search for fossils during the spring of 1954 resulted in the collection of numerous species.



**Plate 1.—Map showing location of Chesapeake and Delaware Canal.**



## Acknowledgments

Clarence Brown, Superintendent, Chesapeake City office, Corps of Engineers, U. S. Army, extended many courtesies to the writers, and made available a motor launch when it was necessary to visit locations along the Canal which were otherwise difficult to reach. Eugene L. Cronin, Director of the Marine Biological Laboratory in Lewes, Delaware, provided a boat for use during the winter months of the investigation.

The writers are indebted to Joseph T. Singewald, Jr., Director of the Maryland Department of Geology, Mines, and Water Resources, and to H. E. Vokes, Professor of Paleontology of the Johns Hopkins University, for making available for study a collection of Cretaceous fossils from the Chesapeake and Delaware Canal.

They are also indebted to John B. Reeside and L. W. Stephenson of the United States Geological Survey in Washington, D.C., for making available Charles W. Carter's collection of fossils obtained during the deepening operations of 1935-1937.

J. A. Jeletzky of the Geological Survey of Canada offered advice on the identification and correlation of the specimens of *Belemnitella*.

Valuable advice was obtained during the course of several field conferences. Among those whose suggestions were most helpful are Meredith E. Johnson, State Geologist of New Jersey, and I. Wendell Marine of the U. S. Geological Survey, Newark Office, Delaware.

James L. Ruhle was field assistant during certain phases of the work and also aided in the study of the fossils at the Academy of Natural Sciences of Philadelphia.



## HISTORICAL REVIEW

Although relatively few papers have been published on the marine Upper Cretaceous formations in Delaware, a fairly large number of publications concerning these formations in New Jersey and Maryland have appeared in the past. Because of their importance to an understanding of the geology of Delaware, they are discussed in this report.

An important contribution which led to the correct interpretation of the Cretaceous as opposed to Tertiary age of some of the Atlantic Coastal Plain sediments was made by Vanuxem (1829).* He referred to these sediments as the "Secondary Formation" and correlated them with the Green Sand and Chalk of Europe. As evidence for his correlation he listed the pelagian fossils *Terebratula*, *Gryphaea*, *Exogyra*, *Ammonites*, *Baculites*, and *Belemnites*, which he described as belonging to the Secondary and not Tertiary class.

One of the first publications which specifically referred to the Deep Cut in the Chesapeake and Delaware Canal was written by Morton (1829), and appeared in the Journal of the Academy of Natural Sciences of Philadelphia. Morton described six genera of fossils, *Terebratula*, *Gryphaea*, *Exogyra*, *Ammonites*, *Baculites*, and *Belemnites* which characterize the "Atlantic Secondary Formation" of New Jersey and Delaware. In another publication of the same year (1829), Morton listed all the fossils which had been found in the "Marls" of New Jersey and Delaware and stated that he was able to trace, with some interruptions, the Cretaceous formations resting on the "Ferruginous" sand or marl from Salem to Vincentown, New Jersey.

A paper was written by Durand in 1832 in which the green color of the Canal water near Chesapeake City was discussed; however, this paper does not contain any geological information.

In 1837 the first State Geological Survey of Delaware under the direction of James C. Booth was organized. The results of his work were published as a Memoir in 1841.

Booth recognized the existence of a lower stratum of green sand outcropping in the Chesapeake and Delaware Canal. He called this sand "Cretaceous or cretoidal green sand" and recognized that it could be further subdivided into formations, although he did not attempt to name them.

On the south bank of the Canal, 2 miles west of St. Georges he found a variety of fossils and mentioned the following:

*Exogyra costata*
*Gryphaea convexa* and *vomer*
*Ostraea falcata*
*Turritella*
A few belemnites

Booth found fossil remains more numerous 1½ miles west of St. Georges, on the south bank of the Canal, and added to the previous list:

*Anomia tellinoides*
*Trigonia*
*Belemnites americana*
*Pecten quinquecostata*
*Ammonites* (*placenta* or *delawarensis*)
*Cucullaea vulgaris*
*Rostellaria*
*Natica*

Booth also described the mineral resources of the State and gave a general soil analysis.

Lyell (1845) made several references to the Cretaceous formations in New Jersey and adjacent areas and correlated these formations with the divisions between the Gault and Maestrichtian of Europe. He also stated that he believed that Morton's uppermost division of the Cretaceous should be placed in the Eocene.

---

* See references at the end of the text, p. 55.

Several fossils from the Chesapeake and Delaware Canal were described by Gabb (1858, 1860) in the Journal of the Academy of Natural Sciences of Philadelphia.

Chester (1884) pointed out that the Cretaceous, as developed in Delaware, was a continuation of the same formation found in New Jersey. He divided the formation into Lower, Middle, and Upper Cretaceous, recognizing his lower marl bed as Upper Cretaceous in age.

Chester described a "Red Sand" (Red Bank), as being well exposed at the Railroad bridge and at St. Georges.

Above the "Red Sand" Chester recognized an "Indurated Marl and a Middle Marl bed" which are now considered to be of Eocene age.

The July 17, 1829, volume of the Proceedings of the American Philosophical Society (p. 594) records that Dexter and Livermore presented to the society a collection of fossil earths and minerals from the Deep Cut of the Canal, with a memoir and profile of the geological strata.

Although Clark (1892, 1893) did not refer to the Upper Cretaceous sediments in Delaware, his publications are considered noteworthy because he described the Upper Cretaceous formations in their type localities. In these reports Clark proposed geographic names for these formations, corresponding to their type localities rather than to the lithologic or economic equivalents which had previously been ascribed to them. They are as follows (p. 334):

| Age | Formation | Economic Equivalents |
|---|---|---|
| Pleistocene | Columbia | |
| Neocene | Lafayette | |
| | Chesapeake | |
| Eocene | Shark River | Upper Marl Bed. |
| | Manasquan | |
| Cretaceous | Rancocas | Middle Marl Bed |
| | Redbank | Red Sand |
| | Navesink | Lower Marl Bed |
| | Matawan | Clay Marls |
| | Raritan | Plastic Clay |

Clark (1895) was able to trace the Upper Cretaceous formations from New Jersey to Delaware and into Maryland. In the Chesapeake and Delaware Canal he found the same dark, micaceous, sandy clays and fauna which were characteristic of the Matawan in New Jersey. The Navesink formation was followed from Raritan Bay across the state of New Jersey and found to be exposed in the banks of the Canal. Although he mentioned no outcrops of the Red Bank in Delaware, he noted several good exposures in nearby Maryland. At Bohemia Mills, just south of the Canal and across the Delaware state line, Clark studied an exposure of Red Bank and stated that it retained most of its northern New Jersey characteristics.

During this same year (1895) Roberts completed a study of the deposits and fossils exposed in the Chesapeake and Delaware Canal and the head waters and tributaries of the Bohemia and Sassafras Rivers. He stated (p. 16):

> Sufficient data and material were collected to clearly establish the identity of the Cretaceous formations on the Eastern Shore, and upon a comparison with the characteristic fossils of New Jersey, the correlation with the Matawan, Navesink, Redbank, and Rancocas Formations.

Roberts listed exposures and fossils from the Matawan, Navesink, and Red Bank formations in the Chesapeake and Delaware Canal.

Clark, Bagg, and Shattuck (1897) studied the sediments of Upper Cretaceous age in New Jersey, Delaware, and Maryland, and divided them into the Matawan and Monmouth formations, mentioning representative fossils for each.

The name Matawan was proposed to include the Crosswicks clays and Hazlet sands (Wenonah) because they felt that while the former subdivisions were easily recognizable in northern New Jersey, farther south the division became obscured.

The name Monmouth was proposed to include the previously recognized Navesink and Red Bank formations and the newly recognized Mount Laurel sands, which were described as conformably overlying the Matawan formation. Again, Monmouth was used because the authors wished a name which would be applicable to the entire northern Atlantic Coastal Plain.



The authors stated that in Delaware and the eastern counties of Maryland the Mount Laurel sand is between 30 and 40 feet thick. They found the Navesink to be highly fossiliferous in Delaware, but less glauconitic and more argillaceous than the same formation in New Jersey. They concluded that the Red Bank sands did not occur throughout southern New Jersey but reappeared in Delaware and the eastern counties of Maryland; they recorded a thickness of 60 feet for the formation in the Sassafras River basin.

Clark et al. (1897) at this time believed the Rancocas, Manasquan and Shark River formations to be of Upper Cretaceous age.

It is significant to note Shattuck's (1902) statement regarding these formations in Cecil County, Maryland. He did not subdivide the Matawan formation but recognized its presence. Shattuck divided the Monmouth formation into the Navesink marls and the Red Bank sands. He cited the occurrence of 20 feet of Navesink at Grove Point on the Sassafras River and 25 feet at Ordinary Point. At the base of a 40 foot exposure at Bohemia Mills (near the Maryland-Delaware state line) he found 12 feet of Navesink, and 2 miles south of Pivot bridge, on a branch of Back Creek, at the base of a 55 foot section he recorded a thickness of 20 feet. Shattuck found the Red Bank to be continuously exposed along the Sassafras River; he also found extensive exposures in Scotchman Creek, Little and Great Bohemia Creeks and tributaries. At the aforementioned Bohemia Mills he noted a 28 foot exposure. Shattuck further stated (p. 163):

> Without going into details . . . . it is sufficient to say that their distribution indicates a great development of Red Bank in this region. Although fossils are occasionally discovered, they are not well preserved and are not numerous. They consist almost entirely of marine mollusca.

Clark (1904) discussed the Matawan formation of Maryland, Delaware, and New Jersey, and its relation to overlying and underlying formations and expressed his belief that the Upper Cretaceous deposits were practically conformable throughout their entire thickness. He did not subdivide the Matawan or Monmouth formations in Maryland although he stated that it is possible to subdivide these units in New Jersey. Clark placed the division between the two formations at the base of the Mount Laurel, thus including the Wenonah in the Matawan.

Weller's report on the Cretaceous paleontology of New Jersey was published in 1907 and his interpretation has since been followed with the exception of the Hornerstown, Vincentown, and Manasquan formations being assigned to the Eocene rather than to the Cretaceous by Cooke and Stephenson (1928).

The following table shows Weller's interpretation of the stratigraphy of the Cretaceous formations in New Jersey (1907, p. 25):

| | |
|---|---|
| Manasquan | |
| Vincentown including "yellow sand" | |
| Hornerstown | |
| Tinton | |
| Red Bank | |
| Navesink | Mt. Laurel |
| Wenonah | |
| Marshalltown | |
| Woodbury | |
| Merchantville | |
| Magothy (including Cliffwood Clay) | |
| Raritan | |

Weller was able to divide the Crosswicks clay into the Merchantville clay-marl and the Woodbury clay, which exhibit a general lack of glauconite. He traced the Englishtown sand from the Atlantic Highlands to Swedesboro in Salem County, and stated that it is devoid of fossils. The Marshalltown clay-marl was mapped from Monmouth to Salem Counties. The Wenonah sand was easily differentiated from the overlying Mount Laurel in Monmouth County but farther south Weller believed the two formations to become more similar lithologically. With regard to the presence of *Halymenites major* in the Wenonah he mentioned in an outcrop description (1907, p. 92) the presence of:

> Variegated red and yellow sand with many cylindrical bodies, lying in all directions, probably plant remains or burrows.

Weller found it impossible to differentiate the Mount Laurel sand and the Navesink marl on the basis of paleontological evidence. He made the following observation on their lithology (p. 103):

> In the southwestern extension of the Mount Laurel and Navesink formations the lower sand formation apparently increases at the expense of the upper greensand marl formation, until it is probable that the entire interval occupied in eastern Monmouth County by the two formations is occupied by the Mount Laurel sand alone.

Weller found a gradual transition from the Navesink marl into the Red Bank sand. He was unable to trace it completely across New Jersey and in this connection he wrote (p. 137):

> The disappearance of the Red Bank sand to the southwest, therefore, does not represent any lack of continuity of sedimentation, nor an overlap unconformity, but simply a change in the nature and thickness of the sediments in passing along the strike of the beds.

Weller recognized that the glauconitic formations (Merchantville, Marshalltown, Navesink, and Tinton) and the clays and sandy clays (Magothy, Woodbury, Wenonah and Red Bank) are represented by faunas from two distinct environmental facies. Offshore or deeper-water fauna are more characteristic of the former, while the near-shore or shallow-water fauna are characteristic of the latter.

Clark (1907) listed the divisions of the Cretaceous for the Middle Atlantic Coastal Plain which had been adopted by the Committee on Geologic Names of the U. S. Geological Survey. He recognized the presence of the Rancocas, Monmouth, and Matawan formations in Delaware.

In 1916 the Maryland Geological Survey published a comprehensive volume on the Upper Cretaceous sediments of Maryland, their petrography and genesis, and the Upper Cretaceous floras of the world (Clark et al.). The stratigraphy and general correlations were written by Clark, the paleontology by Gardner, Berry and others.

In considering the stratigraphic and paleontologic characteristics of the Upper Cretaceous deposits of Maryland, Clark divided the sediments into the Matawan and Monmouth formations.

In discussing the Matawan formation Clark noted that it is more argillaceous than the Monmouth, is generally darker or black in color, and contains less glauconite. In the Chesapeake and Delaware Canal at Summit Bridge and Post 105 (1/5 mile west of Summit Bridge) he found a fauna analogous to that of the Merchantville and Woodbury of New Jersey, with the Merchantville types being the dominant forms. At Post 236, in the vicinity of Camp Fox, he recorded the presence of *Exogyra ponderosa* fossils at the base of the *Exogyra cancellata* zone and an abundance of *Gryphaea vesicularis*. At this location he believed the fauna to be similar to the Marshalltown of New Jersey.

Clark felt that the Matawan was unconformably overlain by the Monmouth formation although he did not observe marked irregularities of surface in the region. He described the Monmouth formation as being composed of reddish and pinkish sands, generally containing glauconite, often to a considerable degree, making the beds dark green in color.

Clark believed that the fauna and glauconitic nature of the Monmouth sediments indicates a slightly deeper environment than that of the Matawan. Gardner (Clark et al., 1916) recorded numerous lists of mollusks from the Chesapeake and Delaware Canal.



In his study of the stratigraphy in that portion of the Coastal Plain included in the Elkton-Wilmington folio of the U. S. Geological Survey, Miller (Bascom and Miller, 1920) found excellent outcrops of the Matawan and Monmouth formations in the Chesapeake and Delaware Canal. His description of the Matawan, in outcrop near the Pennsylvania Railroad bridge, is similar to Weller's description of the New Jersey Merchantville, although Miller did not use the name Merchantville or Crosswicks. He recognized an unconformity between the Magothy and Matawan formations.

Miller did not subdivide the Monmouth formation although he recognized a change within the formation from reddish-brown to dark green or nearly black. He also believed it to be an extension of the same formation which is exposed across the state of New Jersey to Raritan Bay. Stratigraphically, Miller believed the Monmouth to conformably overlie the Matawan, and conformably underlie the Tertiary formations.

The Matawan and Monmouth formations, as exposed in Kent County, Maryland, were discussed by Miller in 1926.

Although Miller wrote that the Matawan formation is poorly exposed at the surface, he described the formation as consisting of micaceous, glauconitic sand and black clay, with the uppermost layers often consisting of white to dark greenish-black sands, in some places firmly indurated by iron oxide.

Shattuck (1902) had recognized an unconformity between the Matawan and Monmouth in Cecil County, Maryland, but Miller (1926) writes (p. 68):

> . . . . the Matawan is conformably overlain by the Monmouth. The separation between the Matawan and Monmouth is made chiefly on the basis of change in lithologic character, but in part on fossil content. Although some organic forms range through both the Matawan and Monmouth, yet each formation has a few characteristic ones, the assemblages in each being on the whole quite distinctive.

Miller noted the transitional character of the formation, grading from a very glauconitic lower phase to an upper portion consisting of red to reddish-brown coarse sand which is frequently indurated.

A guidebook was prepared for the Chesapeake Bay region for the Sixteenth International Geological Congress by Stephenson, Cooke, and Mansfield (1932).

The marine Upper Cretaceous sediments exposed in the Canal were divided into the Matawan and Monmouth formations. The Matawan was recorded as occurring in the area from Summit Bridge to the Pennsylvania Railroad bridge and farther east, overlain by the Monmouth formation. A list of fossils collected in the area is given.

The Monmouth formation was found outcropping "from place to place" along the Canal from the Pennsylvania Railroad bridge to St. Georges. A list of fossils is also given for this formation.

The fossil pelecypod *Exogyra cancellata* has proven a valuable index fossil for the Monmouth sediments; in particular for the Mount Laurel formation and its equivalents in other parts of the Coastal Plain. Stephenson (1933), traced this zone for twenty-five hundred miles from the Navesink Highlands in New Jersey to Cardenas in the state of San Luis Potosi, Mexico.

Stephenson recorded the presence of *Exogyra cancellata* from the Mount Laurel formation in New Jersey which he considered to be in unconformable contact with the Wenonah below and the Navesink marl above.

Regarding the presence of this index fossil in the Chesapeake and Delaware Canal and its vicinity, Stephenson wrote (1933, pp. 1353-54):

> In Delaware and Maryland the zone forms the lower part of the undivided Monmouth formation, and *Exogyra cancellata* and *Anomia tellinoides* are both present in the zone; the zone is unconformably underlain by the Matawan formation. The former species has been recorded by Julia Gardner from 6 localities on and near the Chesapeake and Delaware Canal in Delaware, between Summit Bridge, 3 miles east of the state line, and Delaware City. Although 5 of these localities are correlated by Gardner with the Matawan formation, subsequent investigations by the present writer indicate that they

should have been referred to the Monmouth formation. The matrix in which the shells occur here is very much like the Mount Laurel sand. The species is also listed from the head of Bohemia Creek in New Castle County, Delaware, and from Bohemia Mills in Cecil County, Maryland.

The author also presented a list of other mollusks from the *Exogyra cancellata* zone that range from New Jersey to the Gulf region, and discussed the environmental conditions under which this fauna must have existed.

During the years 1935 to 1937 when the Chesapeake and Delaware Canal was widened and deepened an excellent opportunity was presented for studying the formations traversed by the Canal. Carter took advantage of this opportunity and published the results of his findings in 1937.

Carter recognized the presence of the following marine Upper Cretaceous formations in the Canal (p. 245):

Upper Cretaceous series
- Monmouth group
  - Navesink marl (presence inferred in area south of the Canal)
  - Mount Laurel sand
- Matawan group
  - Marshalltown formation
  - Englishtown sand
  - Crosswicks clay—in New Jersey {Woodbury clay, Merchantville clay}

Carter did not subdivide the Crosswicks clay into the New Jersey equivalent of the Merchantville and Woodbury clays for the Canal section; however, he considered both clays to be present. He recorded a thickness of 50 feet for the formation.

The author recognized (p. 256)

> . . . a soft, yellow to buff, micaceous, fluffy, fine-grained quartz sand containing very thin ferruginous clay laminae . . .

conformably overlying the Crosswicks clay, with a thickness ranging from 6 to 16 feet and containing *Halymenites major* Lesquereux. He called this sand Englishtown, and considered it an extension of the New Jersey Englishtown which Knapp, Weller, and others thought had lost its identity southwest of Swedesboro, New Jersey.

The Marshalltown formation was found by Carter unconformably overlying the Englishtown sand. He traced it in outcrop from 2100 feet west of Summit Bridge to one-fourth mile east of St. Georges Bridge.

Carter stated that the Mount Laurel sand is exposed eastward in the Canal where the banks are high, beginning 2 or 3 miles eastward from the Pennsylvania Railroad bridge. Its fauna included *Belemnitella americana*, *Exogyra cancellata*, *E. costata* and *Anomia tellinoides*. He recognized an unconformable contact with the Marshalltown lying below it.

According to Carter, the Navesink marl is not exposed in the Canal; however, he believed it to be present south of the Canal under the cover of Pleistocene deposits.

Kummel (1940) in a general summary of the geology of New Jersey discussed the various subdivisions of the Cretaceous.

Stephenson, King, Monroe, and Imlay (1942) presented a correlation of the outcropping Cretaceous formations of the Atlantic and Gulf Coastal Plain and Trans-Pecos Texas in which they found the Mount Laurel sand to be of lower Navarro age on the basis of the presence of *Exogyra cancellata* and its micro-fossil fauna.

In 1950 an article was published by Spangler and Peterson on the geology of the Atlantic Coastal Plain in New Jersey, Delaware, Maryland and Virginia. The authors state their disagreement with Carter's interpretation of the stratigraphy of the Upper Cretaceous formations exposed in the Chesapeake and Delaware Canal.

Spangler and Peterson stated that the Merchantville, Woodbury and Marshalltown formations cannot be differentiated in the Canal. Conformably overlying this unit



the authors recognize the existence of a sand which they correlate with the Wenonah of New Jersey on the basis of lithology and the presence of *Halymenites major*. Carter had called this sand Englishtown.

Above the Wenonah sand and below the *Exogyra cancellata* zone, Spangler and Peterson believed the Mount Laurel sand to be present, thus disagreeing with Carter's interpretation of Englishtown for the same unit. They considered the dark green, marly clay containing *Exogyra cancellata* and contemporary forms as Navesink, and stated that they (p. 47):

> believe that Carter has identified the Navesink beds as being Mount Laurel-Marshalltown in several of his sections in the canal. This misinterpretation by Carter is believed to be the result of the presence of *Exogyra cancellata* which closely resemble *Exogyra ponderosa* in some of the sections he described as Marshalltown which the writers call Navesink because of the presence of *Exogyra costata*, *E. cancellata*, *Terebratella plicata*, *Ostrea mesenterica*, and others.

According to these authors the Vincentown formation is also present in the Canal with a lithology similar to that of the Vincentown of New Jersey, although they do not mention the exact location where they believe this formation to be exposed.

Spangler and Peterson found unconformities at the base of the undifferentiated Merchantville-Woodbury-Marshalltown, between the Navesink and Vincentown, and below the Pleistocene formations.

Johnson and Richards (1952) published a critical review of the New Jersey sections of Spangler and Peterson's paper and also presented some new information.

## TABLE 1

### Nomenclature of the Marine Upper Cretaceous Formations, 1884-1954

| | Chester, 1884 (Delaware) | | | Clark, 1892-93 (New Jersey) | | | Clark, 1895 (Delaware) | | Roberts, 1895 (C. & D. Canal) |
|---|---|---|---|---|---|---|---|---|---|
| Upper Cretaceous (Chalk) | Middle Marl Bed | Yellow Sand<br>Shell Layer<br>Pure Green Sand | Eocene | Shark River | Upper Marl Bed | Cretaceous | Manasquan (in New Jersey, if in Delaware under cover of Tertiary) | Cretaceous | Rancocas (Sassafras River) |
| | | | Cretaceous | Manasquan | | | Rancocas (Sassafras River) | | |
| | Indur-ated Marl Bed | Indurated Marl | | Rancocas | Middle Marl Bed | | Red Bank (Bohemia Mills) | | Red Bank |
| | | | | Red Bank | Red Sand | | | | |
| | | Red Sand | | Navesink | Lower Marl Bed | | Navesink | | Navesink |
| | Lower Marl Bed | Black Argilo-micaceous Marl<br>Shell Marl<br>Cretoidal Marl | | Matawan | Clay Marls | | Matawan | | Matawan |
| Middle Cretaceous (Gault) | Sand Marl | Sand and Clay Marls | | | | | | | |



## TABLE 1 (continued)

| | Clark, Bagg, & Shattuck, 1897 (New Jersey, Delaware & Maryland) | | | Shattuck, 1902 (Cecil Co., Md.) | | | Clark, 1907 (Delaware) | | Weller, 1907 (New Jersey) |
|---|---|---|---|---|---|---|---|---|---|
| Upper Cretaceous | | Manasquan | Upper Cretaceous | Monmouth | Red Bank Sand | Upper Cretaceous | Rancocas | Upper Cretaceous | Manasquan |
| | | Rancocas | | | | | | | Vincentown |
| | | ——Unconformity?—— | | | | | Monmouth | | Hornerstown |
| | Monmouth | Red Bank | | | | | | | Tinton |
| | | | | | | | | | Red Bank |
| | | Navesink | | | Navesink Marls | | | | Navesink Marl |
| | | Mount Laurel Sand | | | | | | | Mount Laurel Sand |
| | | | | | | | Matawan | | Wenonah |
| | Matawan | Hazlet Sand | | | | | | | Marshalltown |
| | | Crosswicks Clay | | Matawan | Matawan | | | | Englishtown |
| | | | | | | | | | Woodbury |
| | | | | | | | | | Merchantville |

**TABLE 1 (continued)**

| Clark et al., 1916 (Maryland) | | Bascom & Miller, 1920 (Delaware & Maryland) | | Miller, 1926 (Kent Co., Md.) | | Stephenson, Cooke, & Mansfield, 1932 (C. & D. Canal) | | Stephenson, 1933 (C. & D. Canal) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Upper Cretaceous | Monmouth (Fauna analogous to Navesink of New Jersey) | Upper Cretaceous | Monmouth | Upper Cretaceous | Monmouth | Upper Cretaceous | Monmouth | Upper Cretaceous | Lower Monmouth | *Exogyra costata* zone<br>Mount Laurel |
| | —Unconformity— | | | | | | | | | —Unconformity— |
| | Matawan (Fossils analogous to Woodbury and Merchantville of New Jersey) | | Matawan | | Matawan | | Matawan | | | |



**TABLE 1 (continued)**

| | Carter, 1937 C. & D. Canal | | Stephenson, King, Monroe, & Imlay, 1942 (Delaware and New Jersey) | | Spangler & Peterson, 1950 (C. & D. Canal) | | | Groot, Organist, & Richards, 1954 (C. & D. Canal) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Upper Cretaceous | Monmouth | —Unconformity— | Upper Cretaceous | | Eocene | Aquia | —Unconformity— | Upper Cretaceous | Monmouth | Red Bank |
| | | Mount Laurel | | | | | Vincentown | | | |
| | | —Unconformity— | | | | | —Unconformity— | | | |
| | Matawan | Marshalltown | | *Exogyra costata* zone<br>Mount Laurel | Upper Cretaceous | Monmouth | Navesink | | | Navesink-<br>Mount Laurel |
| | | —Unconformity— | | | | | | | | |
| | | Englishtown | | | | Matawan | Mount Laurel | | Matawan | Wenonah |
| | | | | | | | Wenonah | | | |
| | | Crosswicks | | | | | Marshalltown<br>Woodbury<br>Merchantville<br>undifferentiated | | | Merchantville |

TABLE 1

## MARINE UPPER CRETACEOUS FORMATIONS

### General Geology

Cretaceous formations of both non-marine and marine origin have been found in New Castle County, Delaware. Their stratigraphy is, according to Miller (Bascom and Miller, 1920), as follows:

**Cretaceous Formations of New Castle County, Delaware**

| System | Series | Formation |
|---|---|---|
| Cretaceous | Upper Cretaceous | Monmouth |
| | | Matawan |
| | | ——unconformity—— |
| | | Magothy |
| | | ——unconformity—— |
| | | Raritan |
| | | ——unconformity—— |
| | Lower Cretaceous (Potomac Group) | Patapsco |
| | | ——unconformity—— |
| | | Patuxent |

These formations are unconformably overlain throughout the area by Pleistocene sands, gravels, and clays.

The non-marine Upper Cretaceous sediments in the Chesapeake and Delaware Canal have been divided into the Patapsco, Raritan, and Magothy formations in the past. The Patapsco and Raritan consist mainly of buff, red, and white sands and red, white, light gray, yellow, pink, and purple variegated clays. They exhibit rapid changes in texture and color within relatively short distances. Although these formations may exhibit marine phases down dip, or in the case of the Magothy and Raritan in some outcrops in New Jersey, they are non-marine in northern Delaware.

The youngest non-marine deposit, the Magothy, exhibits more the characteristics of a sheet sand and consists predominantly of white to buff, micaceous, "sugary" sands, with lenses of black plastic clay containing a large amount of lignitized tree trunks and plant material. These non-marine Cretaceous formations are best exposed between Summit Bridge and the western entrance of the Chesapeake and Delaware Canal.

The marine Upper Cretaceous formations have been divided into the Matawan and Monmouth groups with the *Exogyra cancellata* zone marking the separation. Both group and formation names are used in this report so that a clearer understanding may be had of the relationships between the New Jersey, Delaware, and Maryland classifications, and to facilitate correlation with beds to the south. The authors believe that the term formation rather than member is justified since the divisions are mappable geologic units of considerable extent.



The following marine Upper Cretaceous formations have been differentiated in the Canal area:

TABLE 2

**Marine Upper Cretaceous Formations of the Chesapeake and Delaware Canal**

| Sequence | System | Series | Group | Formation |
|---|---|---|---|---|
| Mesozoic | Cretaceous | Upper Cretaceous | Monmouth | Red Bank |
| | | | | Navesink-Mount Laurel |
| | | | Matawan | Wenonah |
| | | | | Merchantville |

Sands, gravels, and clays of Pleistocene age can be seen in the Canal unconformably overlying most of the Cretaceous sediments. Sand-filled river channels which at times cut deep into the underlying formations are visible in the Canal, as well as a number of peat bogs consisting of black clays and sandy clays containing tree trunks and plant remains.

### Matawan Group

Matawan was first suggested as a name for the glauconitic sands and clays exposed along Matawan Creek in New Jersey by Wm. Bullock Clark (1894). This unit had previously been known as the "clay marl series."

The Matawan is classed as a formation in Maryland and was at first so considered in New Jersey, with the subdivisions regarded as members. Subsequently, it was found that the members could be traced for considerable distances in outcrop and in the subsurface; therefore, the members were given the rank of formations and the Matawan was raised to a group. However, the 1950 edition of the New Jersey geologic map does not use the group names.

#### *Merchantville*

George N. Knapp (Salisbury, 1899, p. 35) proposed that the name Merchantville be given to the marine Upper Cretaceous sediments exposed near Merchantville, Camden County, New Jersey.

The Merchantville formation in the Chesapeake and Delaware Canal grades from a dark blue to black, very coarse to coarse, poorly sorted, micaceous, glauconitic silt, to a dark greenish-brown, very fine, subangular, poorly to well sorted, micaceous, glauconitic, quartz sand with considerable silt and clay. The uppermost layer, grading into the Wenonah sand, is a gray, very fine, well sorted, subangular quartz sand with some mica and glauconite.

The Merchantville of New Jersey was described by Weller (1907, p. 43) as consisting of:

> a black, glauconitic, micaceous clay, often somewhat sandy, the basal and upper portions of the bed commonly being more glauconitic than the middle portion.

An orange layer may be seen comprising the upper two feet of the Merchantville formation in the Canal from navigation light 39 to about 2900 feet west of Summit Bridge (see pl. 2, facing p. 24). Carter mentioned the phenomenon as being due to weathering. He stated (1937, p. 251):

The "cinnamon brown" of the Merchantville clay of New Jersey has been observed along the canal, but this is a feature that may result from the weathering of any part of the unit.

Although Carter does not mention it, it is significant to note that the "cinnamon brown" is formed only in that part of the Canal where the top of the Merchantville is an erosional surface upon which the Pleistocene sediments were deposited.

Weller (1907, p. 43) and Spangler and Peterson (1950, p. 24) also note the "cinnamon brown" weathered zone as being typical of the Merchantville of New Jersey.

The writers do not use the term "Crosswicks" as Carter did for this unit (1937, p. 251) but have employed the term Merchantville, basing their decision on the fact that the lithology of the sediments is similar to that of the Merchantville of New Jersey, and on the predominance of Merchantville fossils.

The Woodbury (New Jersey), a slightly micaceous, generally non-glauconitic clay which weathers to a light chocolate color, and breaks into blocks which often show conchoidal fracture, is not present in the Canal.

Among the most characteristic Merchantville fossils the following may be mentioned: *Liopistha alternata, Protocardium jerseyensis, Gastrochena linguiformis, Cerithium pilsbryi, Turritella merchantvillensis, Endoptygma umbilicata, Volutomorpha delawarensis, Scaphites hippocrepis, Menabites ("Mortoniceras") delawarensis*, and *Hoploparia gabbi*. Among those more characteristic of the Woodbury of New Jersey are *Breviarca haddonfieldensis, Legumen concentricum, Anchura johnsoni*, and *Cadulus obnotus*. Many other species are known from both the Merchantville and Woodbury, or have a wide range in New Jersey. By far the most extensive fauna has come from the spoil bank (station 1A) about 2500 feet east of Summit Bridge. Admittedly, a fauna from a spoil bank is subject to mixing and is not too valuable for correlation purposes. However, some of these same species were found "in place" by Carter or by the present writers. Claws of the Crustacean *Callianassa mortoni* were especially abundant in the Merchantville formation near the Railroad bridge.

Weller (1907, p. 81) described the Marshalltown as being variable in its lithologic characteristics; however, he wrote that in Salem County, New Jersey, the formation is a nearly pure greensand marl, and was once extensively used for fertilizer.

A careful examination of all undisturbed exposures in the Chesapeake and Delaware Canal has provided no evidence that Marshalltown sediments with a lithology similar to the Marshalltown of New Jersey outcrop in the banks of the Canal.

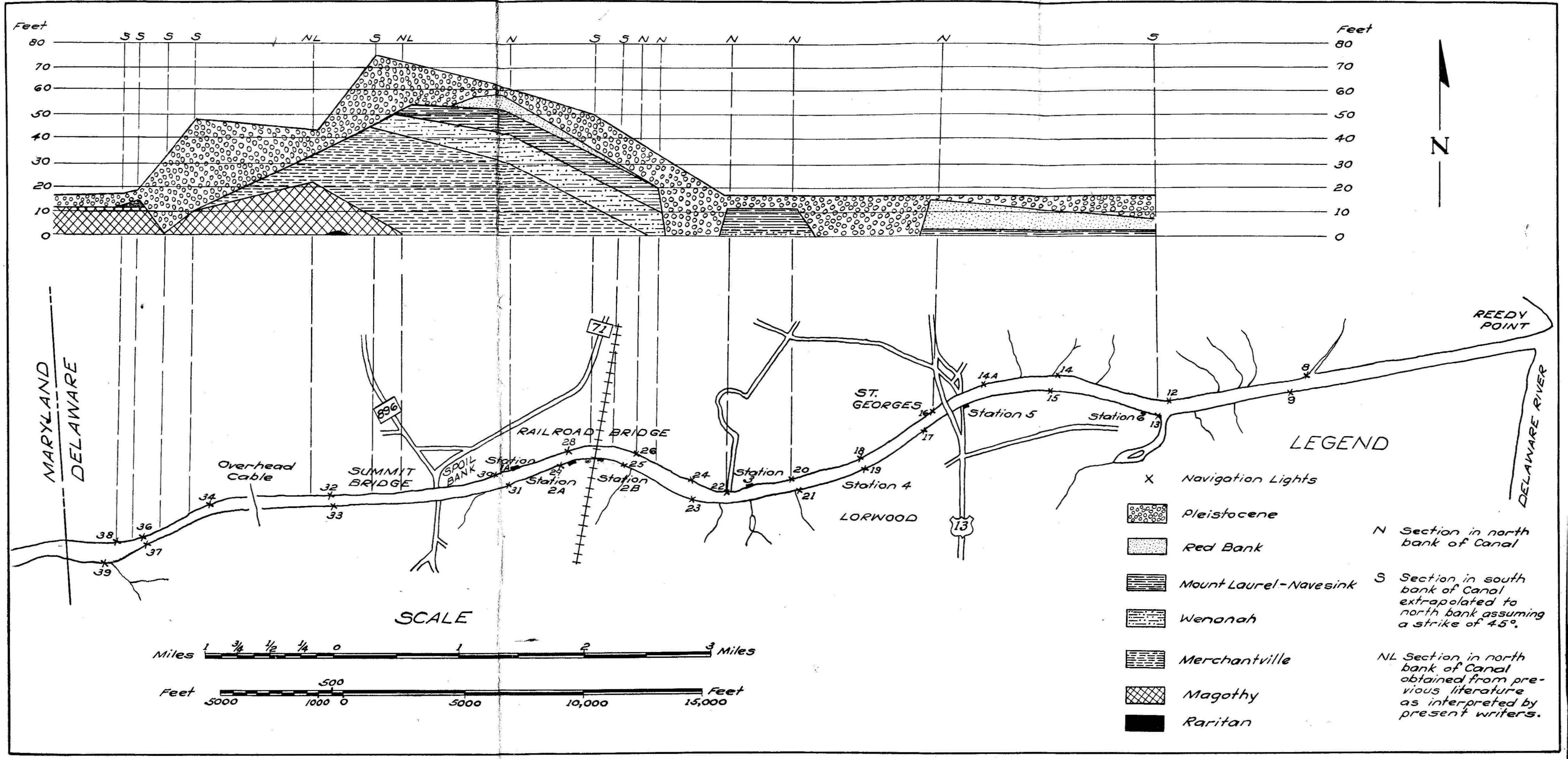
If present, the Marshalltown should lie between the Wenonah and the Merchantville formations. A detailed study was made of those areas in which the Wenonah sand, containing *Halymenites major*, and the Merchantville clay, with its typical fossils, could be seen together in the same outcrop. Although lithologically the Woodbury and Marshalltown are absent, an unconformity is not assumed because deposition may have continued during this interval of time but of a different facies from that of the New Jersey sediments of this age. This would also account for the presence of fossils which have previously been reported only from the Woodbury and Marshalltown sediments of New Jersey.

In New Jersey the Marshalltown formation contains the index fossil *Exogyra ponderosa*. Numerous specimens of this pelecypod were found in spoil banks and along the north shore of the Canal between the Railroad bridge and station 3. Presumably these were dredged from below sea level. Similar specimens of *E. ponderosa* were also found along the south bank of the Canal between Lorwood Grove and St. Georges. Furthermore, Gardner (1916, p. 570) reported this species from a marl pit east of post 236 which lies approximately 1.5 miles east of the Railroad bridge, on the north bank of the Canal.

An examination of the specimens of *E. ponderosa* collected by Carter shows them also to be limited to the region between the Railroad bridge and St. Georges; the majority of these came from disposal areas.

Judging by the distribution of *E. ponderosa* it may also be possible to assume the presence of the Marshalltown in the subsurface roughly between the Railroad bridge and St. Georges as a separate formation, rather than as existing undifferentiated from the Merchantville. A careful and thorough subsurface investigation would probably establish or disprove the existence of the Marshalltown as a separate unit in Delaware; however, such a study is beyond the scope of this report.

Plate 2.—Index map showing location of stations along the Chesapeake and Delaware Canal with a cross section of the marine Upper Cretaceous formations.



Several of the characteristic Marshalltown fossils cited by Carter also occur in the Mount Laurel-Navesink and thus can not be taken as definite proof of the presence of the Marshalltown above sea level. Some of the other species definitely restricted to the Marshalltown, such as *Turritella marshalltownensis*, may have a wider range than previously known, or may have been misidentified because of their poor preservation. Furthermore, Carter's list of Marshalltown fossils is a composite list of some found in disposal areas where a mixture with the Mount Laurel might have taken place (as indicated on Carter's labels in the U. S. National Museum) plus some found in place in what the present authors are calling Mount Laurel-Navesink. At any rate, the stratigraphic and lithologic evidence, particularly the presence of numerous *E. cancellata*, is in favor of associating these fossils with the Mount Laurel-Navesink rather than with the Marshalltown.

In the Chesapeake and Delaware Canal the Merchantville unconformably overlies the Magothy formation. From navigation light 39 eastward to about 2900 feet west of Summit Bridge the Merchantville is unconformably overlain by Pleistocene sediments.

From about 2900 feet west of Summit Bridge to 1800 feet east of the Pennsylvania Railroad bridge where the formation dips below sea level, it is conformably overlain by the Wenonah.

The Merchantville may first be seen in the Canal 2400 feet east of Bethel, Maryland, at navigation light 39 (see pl. 2) and it can be traced over a distance of 4.2 miles to 1800 feet east of the Pennsylvania Railroad bridge where it passes below sealevel. About 4500 feet east of Bethel, in the vicinity of navigation light 37, a large Pleistocene river channel has cut into the Magothy formation, thus removing the Merchantville for a distance of about 1800 feet.

The thickest section of Merchantville exposed in the Canal may be seen in the vicinity of the overhead cable, about 1.5 miles west of Summit Bridge. Here the formation is about 40 feet thick.

### *Wenonah*

The Wenonah sand was first named by Knapp in 1899 (Salisbury, 1899, pp. 35-36). In New Jersey it occurs in a belt extending approximately from Sharptown, Salem County, to Atlantic Highlands, Monmouth County.

The Wenonah is composed of rust-brown and gray, well stratified, fine, subangular, well sorted, micaceous quartz sand, with some glauconite and numerous cylindrical tubes which have been called *Halymenites major* Lesquereux. At station 3 (pl. 2), there is six inches of light chocolate-brown, plastic clay with a few very thin sand laminae at the top of the formation.

This formation was described by Johnson and Richards (1952, p. 2158) at a large borrow pit at Runnemede, Camden County, New Jersey, as follows:

| Formation | Description | Thickness (feet) |
|---|---|---|
| Wenonah | Very light gray, fine to medium-grained cross-bedded, glauconitic sand with *Halymenites* and thin, ferruginous sandstone crusts | 26.8 |
| Wenonah | Greenish yellow, fine-grained micaceous, slightly glauconitic sand | 28.6 |

They add that in many other localities the Wenonah contains thin clay laminae interbedded with the sand.

Carter (1937) considered this unit to be correlative with the Englishtown of New Jersey. His description of the lithology and the presence of *Halymenites major*, however, agree with that of the New Jersey Wenonah. *Halymenites major* has not been recorded from the Englishtown of New Jersey.

Spangler and Peterson (1950) disagreed with Carter's correlation and stated (p. 29):

> The writers examined the sections in the Chesapeake and Delaware Canal and believe that Carter's interpretation of the stratigraphy in the canal is in error. There is no Englishtown present in the canal and the beds referred to the Englishtown by Carter are in reality the Wenonah.

*Halymenites major*, while not an index fossil, is conspicuous in the Wenonah formation of New Jersey. The exact nature of these tubes is unknown. They have been identified as worm tubes, mollusk borings and remains of plant origin. They are widespread in some Cretaceous and Tertiary formations.

Carter reported no fossils, other than *Halymenites major* from his "Englishtown" (Wenonah). The fossils found during the present survey, while not typical of the Wenonah, are compatible with that correlation. These include: *Anomia argentaria*, *Inoceramus proximus*, *Martesia cretacea*, *Meretrix* sp., *Turritella encrinoides*, *Diploconcha cretacea* and *Faujasia geometricus*.

The Wenonah sand, where visible in the Canal, conformably overlies the Merchantville and is gradational into it.

There has been considerable disagreement in the past as to whether or not an unconformity exists between the units here considered Wenonah and the overlying Mount Laurel-Navesink. Unfortunately, previous investigators did not present the detailed evidence which served as a basis for their conclusions. The present writers believe that no recognizable major unconformity exists.

The sudden change (as shown in the outcrop description p. 33) from a medium sand in the Wenonah to the coarse silt of the younger layer may be considered as evidence of a local unconformity or perhaps a facies change, because 1100 feet east of this site, there is a gradual change from one formation to the other. At station 1, (outcrop description p. 31) a gradational change from the Wenonah to the Mount Laurel-Navesink may also be seen. At station 3 (outcrop description p. 35) the pinkish-brown clay layer which separates the two formations may also be indicative of a facies change or local unconformity.

Sufficient evidence cannot be obtained from exposures in the Canal to indicate that there was a period of uplift and subaerial erosion followed by a period of subsidence and deposition. It is possible that a regional study of the subsurface geology of New Castle County will present a sound basis for establishing the presence or absence of an unconformity.

The first good exposure of the Wenonah may be seen 2100 feet east of Summit Bridge in the south bank where its thickness is 12 feet. Undoubtedly, the place at which the Canal first intersects the formation lies to the west of Summit Bridge, but slumping of the banks in that area obscures it.

The Wenonah may be traced in outcrop, eastward, to navigation light 20 (pl. 2), where the top of the formation rises about 2 feet above the water at mean tide., From here on the Pleistocene deposits occur at water level and continue to navigation light 16 near St. Georges, thus obscuring the point at which the unit passes below sea level.

## Monmouth Group

The Monmouth formation was named by Wm. Bullock Clark (Clark et al., 1897) from Monmouth County, New Jersey, where the Mount Laurel, Navesink, Red Bank and Tinton are typically developed. Later, the members were raised to the rank of formation and the Monmouth was raised to the rank of group. The Wenonah-Mount Laurel sand is treated as one unit on the 1950 edition of the New Jersey geologic map; however, the younger formations are mapped separately.

In Maryland the Monmouth was originally subdivided into the Navesink and Red Bank (Clark, 1895; Roberts, 1895; Clark, et al., 1897; and Shattuck, 1902). At present, however, the Monmouth is treated as a single formation.

### *Mount Laurel-Navesink*

The name Mount Laurel was established by Wm. Bullock Clark in 1897 (Clark et al., 1897) for the sand which was exposed at Mount Laurel, about 7 miles southwest of Mount Holly, Burlington County, New Jersey. The Navesink was also named by Clark in 1894 (pp. 336-337), the type locality being at the Navesink Highlands in Monmouth County, New Jersey.

There is a gradual change downward within the Mount Laurel-Navesink formation from a dark greenish-brown with numerous rust brown spots, very fine to fine, poorly sorted, subangular, glauconitic quartz sand with some silt and clay and little mica,



to a dark green to black, coarse silt with abundant glauconite. Where the unit contains an abundance of clay the surface weathers to greenish-white.

In New Jersey, the Navesink formation (Kummel, 1940, p. 118)

> . . . . consists of greensand (glauconite) marl mixed with varying amounts of quartz sand and fine earth, the latter of which contains much calcium carbonate in a powdery state. When purest the marl has a dark-green to bluish-black color. The upper part of the bed contains progressively less greensand and is more clayey.

Weller (1907) described the typical Mount Laurel as a quartz sand with some glauconite, and the Navesink as being composed of a nearly pure greensand. Although in many places he distinguished the formations on the basis of lithology, he stated (p. 103):

> The faunas of the Mount Laurel sand and the Navesink marl constitute a single unit and in any discussion of them they must be considered together.

Stephenson (1923) believed that the pelecypod *Exogyra cancellata* was found only in the Mount Laurel and not in the Navesink formation. Recent collecting in New Jersey has shown this species to be present in both Mount Laurel and Navesink formations near New Egypt, N. J. Therefore, the value of this species as an index fossil of the Mount Laurel is open to question.

Although the Mount Laurel and Navesink are treated as separate formations in New Jersey no basis can be found for separating them in Delaware either lithologically or faunally. Therefore, they are treated here as one unit.

In considering the glauconitic, clayey sand overlying the *Halymenites major* unit to be Mount Laurel-Navesink, the authors confirm the correlations presented by Spangler and Peterson and previous workers in the Canal area (Stephenson, 1933; Clark, Bagg and Shattuck, 1897; Roberts, 1895; and Clark, 1895) as shown in table 1 on page 18.

Carter's consideration of this section as belonging to the Marshalltown-Mount Laurel was probably due to his misidentification of a very worn adult form of *Exogyra cancellata* as *E. ponderosa*.

Although this unit is less fossiliferous than the corresponding formations in New Jersey, the faunas are analogous and the lithologic similarities are too great to be ignored.

The relationship between the Wenonah and Mount Laurel-Navesink formations have been discussed on page 26. The Mount Laurel-Navesink is conformable with, and grades into the overlying Red Bank formation.

The Mount Laurel-Navesink is first encountered in the Canal 1000 feet east of Summit Bridge in the South bank. It continues, although interrupted by excavating work carried on in the Canal and by Pleistocene or pre-Pleistocene erosion, for a distance of 4.7 miles to 1.5 miles east of St. Georges where the top of the formation is 2 feet above sea level. At station 3 (pl. 2) the Mount Laurel-Navesink has a thickness of 11 feet.

Although distinct faunal zones within the Mount Laurel-Navesink could not be established with certainty, it is likely that there are three different assemblages. One, probably the oldest, occurs near the Railroad bridge and contains poorly preserved specimens of *Exogyra* sp., *Cucullea neglecta*, *Cardium tenuistriatum*, *Ostrea mesenterica*, *Cypremeria excavata*, *Trigonia mortoni*, *Anchura abrupta*, and *Cliona cretacica*. Farther east, at station 3, the fauna suggests an oyster reef and consists of quantities of specimens of *Exogyra cancellata*, *Gryphaea mutabilis* together with a few specimens of *E. costata*, *Neithea quinquecostata*, *Cardium tenuistriatum*, *Ostrea nasuta*, and others. This same association was formerly seen on the south bank of the Canal just east of Lorwood Grove. A few specimens of *E. cancellata* and *G. mutabilis* can also be seen on the south bank just east of the highway bridge at St. Georges. The third phase, probably the youngest, can be seen at the Biggs Farm (station 6) about 1 mile east of St. Georges on the south bank. Here, there are numerous specimens of *Belemnitella americana*, *E. cancellata*, *E. costata*, *Gryphaea mutabilis*, *Anomia tellinoides*, *Baculites ovatus*, and many other species. In fact, the most extensive Mount Laurel-Navesink fauna has been collected at this station.

The specimens of *Belemnitella americana* found at the Biggs Farm, in the Mount Laurel-Navesink and the overlying Red Bank formation consist of both the normal form (pl. 7, fig. 1) and a more slender variety (pl. 7, fig. 2). According to J. A. Jeletzky of the Geological Survey of Canada who is studying the Cretaceous belemnites of the Atlantic Coastal Plain, the thin specimens

> . . . . appear to be rather distinct morphologically from the forms of the Navesink-Mount Laurel rocks with which I have compared them . . . . The association of the belemnites of the upper zone at this locality is thus distinctly different from what I have on hand from the Navesink-Mount Laurel rocks of New Jersey and resembles more closely that of the more southerly formations.*

Since the belemnites appear to be similarly distributed in both lower (Mount Laurel-Navesink) and upper (Red Bank) formations, the outcrop at the Biggs Farm (station 6) may represent a younger phase of the Navesink than any occurring in New Jersey. Further work by Jeletzky on this matter may shed light on the correlation.

## *Red Bank*

The Red Bank sand was named by Wm. Bullock Clark in 1892 for the ferruginous red sands typically developed at Red Bank, Monmouth County, New Jersey.

The Red Bank is a reddish-yellow to reddish-brown with some rust brown spots, fine to medium, well sorted, subrounded, slightly "dirty", quartz sand with some glauconite and black minerals, and a little mica and feldspar. Most of the quartz grains are stained with iron hydroxide. The unit is gradational into the Mount Laurel-Navesink, and it becomes slightly more clayey and glauconitic toward the base of the formation. Varying degrees of induration may be seen in the Red Bank as exposed in the banks of the Canal, probably due to the oxidation of the glauconite.

The lithologic similarity of the Red Bank in the Canal to the Red Bank of New Jersey is clearly shown in a description of this formation as it is seen in New Jersey by Spangler and Peterson (1950, p. 49).

> The Red Bank is marine in origin and the greater percentage of it, particularly in its weathered phase in which it is most commonly seen, is a ferruginous, red to yellow fairly coarse sand. Its lower part which is gradational into the Navesink consists of dark-colored, sparingly glauconitic, sandy clay to a clayey sand. Locally beds of white, micaceous sand and dark clays occur. Where weathered, the beds are commonly indurated and stained with iron.

With the exception of the material which Carter considered reworked Pleistocene at the Pennsylvania Railroad bridge, he identified the exposures of the Red Bank along with the uppermost section of the Mount Laurel-Navesink (see station 6, p. 37) as belonging to the Mount Laurel formation.

The Vincentown of Eocene age was believed by Spangler and Peterson to be present in the Canal. They do not give outcrop descriptions or the exact locations where they consider this formation to be exposed. In a comparison of their interpretation of the Canal section with that of Carter's (1950, p. 47), however, they show their Vincentown to be analogous to the upper part of Carter's Mount Laurel. Therefore, it can be assumed that the bed which they referred to the Vincentown is that which is here established as Red Bank. These sediments cannot be Eocene in age since typical Upper Cretaceous fossils have been found in the formation.

In New Jersey the Red Bank has not been recognized south of Sykesville, Monmouth County. However, the formation had previously been found in the Canal area by Clark, Bagg, and Shattuck (1897), Roberts (1895), and as the Red Sand by Chester (1884). It has been recorded in nearby Cecil County, Maryland, by Shattuck (1902) and Clark (1895).

The Red Bank first makes its appearance in the Canal 2600 feet east of Summit Bridge on the south bank. It may be traced along both the north and south banks with relatively few interruptions to the Pennsylvania Railroad bridge. East of this location erosion has removed the Red Bank and cut down into the Mount Laurel-Navesink formation. The Red Bank appears again, 1.5 miles east of St. Georges, in the south bank where it conformably overlies the Mount Laurel-Navesink.

---

* Letter from J. A. Jeletzky to Horace G. Richards of August 25, 1954.



The Red Bank formation in Delaware contains very few fossils. The thin form of *Belemnitella americana* (see p. 28) is present at the Biggs Farm as is *A. tellinoides* and a few other fragmentary fossils. Tubes resembling *Halymenites major*, but generally thinner and more fragile, were found in the Red Bank at one place near the Railroad bridge, while some slightly larger less corrugated tubes have been found at several places in the formation (pl. 7, fig. 8). These latter tubes resembles those found in the Red Bank and Tinton formations in Monmouth County, N. J. No other fossils have been recognized in the Red Bank of Delaware.

On the other hand a small fauna was reported from the Red Bank near Bohemia Mills, just west of the Maryland-Delaware state line (Roberts, 1895). This fauna contains some typical Navesink species such as *Belemnitella americana, Natica abyssina, Exogyra costata, "Terebratella" plicata, Cucullaea vulgaris,* and *Volutomorpha conradi,* and is lacking in typical species of the Red Bank formation of New Jersey. It is therefore possible that the Red Bank of Delaware and Maryland is not quite as young as the Red Bank formation of New Jersey but is a time equivalent of the upper part of the Navesink.

The marine Upper Cretaceous formations of Delaware and their correlation with the neighboring states are shown in table 3.

**TABLE 3**

**Correlation of the Marine Upper Cretaceous Formations of New Jersey, Delaware, and Maryland**

| | New Jersey | | | Delaware | | | Maryland | |
|---|---|---|---|---|---|---|---|---|
| | | Formation | Physical Character[1] | | Formation | Physical Character | Formation | Physical Character[2] |
| Upper Cretaceous | Monmouth Group | Red Bank and Tinton Sands | Coarse rusty sand, consolidated in places by iron oxide. In Monmouth Co. overlain by consolidated beds of green clayey glauconitic sand (Tinton) | Monmouth Group | Red Bank | Reddish-yellow to reddish-brown with some rust brown spots, fine to medium, well sorted, subrounded, slightly "dirty", quartz sand with some glauconite. | Monmouth Formation | Reddish and pinkish sands generally glauconitic, the beds in places forming a dark greensand. |
| | | Navesink Marl | Dark greenish-gray, clayey greensand with occasional shell beds. | | Navesink-Mount Laurel | Dark greenish-brown with numerous rust brown spots, very fine to fine, poorly sorted, subangular, glauconitic, quartz sand with some silt and clay, grading to a dark green to black coarse silt with abundant glauconite. | | |
| | | Mount Laurel Sand | Coarse glauconitic sand. | | | | | |
| | Matawan Group | Wenonah Sand | Fine micaceous sand. | Matawan Group | Wenonah | Rust brown and gray, well stratified, fine, subangular, well sorted, micaceous, quartz sand with some glauconite. | Matawan Formation | Dark-colored micaceous sandy clays, often glauconitic. At times the deposits become very sandy and lighter-colored, while at other times they form a black clay. The upper part of the formation is generally predominantly arenaceous, the sands varying in color from almost white to a dark greenish-black. |
| | | Marshalltown Formation | Black sandy clay to clayey glauconitic marl. | | Merchantville | Dark greenish-brown, very fine, subangular, poorly to well sorted, micaceous, glauconitic, quartz sand with considerable silt and clay, grading into a very coarse to coarse, poorly sorted, micaceous, glauconitic silt. | | |
| | | Englishtown Sand | White and yellow sand with little mica and glauconite and thin layers of clay. | | | | | |
| | | Woodbury Clay | Black to dove-colored clay, usually non-glauconitic. | | | | | |
| | | Merchantville Clay | Black sandy clay, usually glauconitic | | | | | |

1. Geologic map of New Jersey, revised 1950: New Jersey Dept. of Conservation and Economic Development, and comments by Meredith E. Johnson, State Geologist.
2. Clark, Wm. Bullock, 1916, The Upper Cretaceous deposits of Maryland: Maryland Geological Survey Upper Cretaceous, pp. 66, 70.



## Selected Outcrop Descriptions

**Station 1**

**Location:** North bank, 2600 feet east of Summit Bridge

**Height of Outcrop:** 60 feet

| | Feet |
|---|---|
| **Pleistocene series** | |
| Buff, very fine to coarse, poorly sorted, "dirty" sand and gravel, with a layer of ironstone at the base. | 0–2 |
| **Unconformity** | |
| **Upper Cretaceous series** | |
| Monmouth group | |
| Red Bank formation | |
| Reddish-brown, fine to medium, well sorted, subrounded to rounded, "dirty", quartz sand; little glauconite and black minerals. Most quartz grains are stained with iron hydroxide. This layer is slightly indurated. | 2–6 |
| Greenish-brown with rust brown spots, fine to medium, normally sorted, subrounded to rounded, "dirty", quartz sand; some glauconite and mica. Streaks of iron stone up to one foot in length may be seen within the section. This layer is gradational into the Mount Laurel- Navesink formation. | 6–7 |
| Mount Laurel-Navesink formation | |
| Greenish-gray with rust brown spots, fine, normally sorted, subangular, quartz sand; considerable glauconite; some silt and mica. | 7–9 |
| Dark green with rust brown spots, fine to very fine, normally sorted, subangular, very glauconitic, quartz sand; considerable silt and clay; some mica. A few small limonite concretions may be found within the layer. It weathers to a greenish-white hard silt. | 9–12 |
| Light green with rust brown spots, fine to very fine, normally sorted, subangular, glauconitic, quartz sand; considerable silt and clay; some mica. | 12–14 |
| Grayish-green with rust brown spots, fine to very fine, normally sorted, subangular, glauconitic, quartz sand; some silt, clay and mica. There are numerous small gray sand pockets within the unit. | 14–16 |
| Slightly greenish-brown, fine to very fine, normally sorted, subangular, quartz sand; some glauconite and mica. Small pockets of greenish-gray sand occur throughout the layer. | 16–18 |
| Matawan group | |
| Wenonah formation | |
| Rust brown with a few green spots, fine, well sorted, subangular quartz sand; some glauconite and mica. | 18–20 |
| Gray, fine, well sorted, subangular, micaceous quartz sand; little glauconite. This layer contains abundant *Halymenites major*. | 20–22 |
| Alternating layers of rust brown and gray, well stratified, fine, well sorted, subangular, micaceous, quartz sand; litte glauconite. Numerous *Halymenites major*. | 22–24 |
| Predominantly rust-brown with some gray streaks, fine, well sorted, subangular, quartz sand; some mica; little glauconite. | 24–26 |

| | Feet |
|---|---|
| Rust brown and gray, fine, well sorted, subangular, quartz sand; considerable mica; little glauconite. | 26–28 |
| Rust brown, fine, well sorted, subangular, quartz sand; considerable glauconite; some mica. | 28–30 |

Merchantville formation

| | |
|---|---|
| Greenish-gray, fine, well sorted, angular, quartz sand; some glauconite and mica. | 30–31 |
| Greenish-brown with some rust-brown and gray spots, fine, normally sorted, subangular, quartz sand; some silt, clay, mica, and glauconite. | 31–31½ |
| A few spots of macerated organic material. | 31½ |
| Dark greenish-brown with some rust brown spots, very fine, poorly sorted, subangular, quartz sand; considerable silt and clay; some glauconite and mica. | 31½–35 |
| Dark blue, poorly sorted, heavily micaceous, very fine, quartz sand; grading into a very coarse silt. | 35–60 |

Station 1A

Location: Spoil bank north side of Canal about 2500 feet east of Summit Bridge.

Abundant fossils, primarily Merchantville species—but a few characteristic of the Woodbury.

Characteristic fossils

Annelida

*Hamulus falcatus* Conrad
*Longitubus lineatus* Weller

Pelecypoda

*Cucullaea vulgaris* Morton
*C. neglecta* Gabb
*Pinna laqueata* Conrad
*Cardium tenuistriatum* Whitfield
*Pholadomya occidentalis* Morton
*Glycymeris mortoni* Morton
*Panopea decisa* Conrad

Gastropoda

*Turritella encrinoides* Morton
*Volutomorpha conradi* Gabb
*Anchura rostrata* Gabb
*Endoptygma umbilicata* Tuomey
*Gyrodes crenata*

Cephalopoda

*Baculites ovatus* Say
*Menabites ("Mortoniceras") delawarensis* Morton
*Placenticeras placenta* DeKay

Station 2A

Location: South bank, 1000 feet west of the Pennsylvania Railroad bridge.

Height of outcrop: 50 feet

Pleistocene series

| | Feet |
|---|---|
| Buff and tan, medium to coarse, subrounded to rounded, well sorted, "dirty", quartz sand; little feldspar and black minerals; some silt, pebbles and cobbles. | 0–5 |



| | Feet |
|---|---|
| Buff and rust brown, coarse to very coarse, subrounded to rounded, quartz sand; some grit but no pebbles or cobbles. Cross-bedding is a prominent feature of this layer. | 5–6 |
| Buff and tan, medium to coarse, subrounded to rounded, poorly sorted, "dirty" quartz sand. Pebbles or cobbles up to 12 inches in diameter are scattered throughout this layer but are more heavily concentrated near the bottom. Boulders are found scattered on the beach and on land surface. | 6–10 |

Unconformity

Upper Cretaceous series
Monmouth group
Red Bank formation

| | |
|---|---|
| Predominantly gray, some thin bands of rust brown, fine to medium, well sorted, subangular, "dirty" quartz sand; little glauconite and mica. This layer contains numerous fragile sand casts, smaller than yet similar to *Halymenites major*. | 10–12 |
| Predominantly rust brown, some streaks of gray, fine, subangular, well sorted, "dirty" quartz sand; little glauconite and mica. Numerous sand casts as in previous layer. | 12–15 |
| Slightly greenish-brown, fine, subangular, well sorted, "dirty", quartz sand; little feldspar, glauconite and mica; very little silt. A mottled appearance is caused by the spotty weathering of the glauconite to a rust-brown color. | 15–17 |
| Greenish-brown, some rust brown spots, very fine to fine, well sorted, subangular, quartz sand; some feldspar, mica, glauconite and silt; very little clay. The sand casts become less numerous and the sand more argillaceous toward the base of the formation, thus grading into the Mount Laurel-Navesink formation. | 17–20 |

Mount Laurel-Navesink formation

| | |
|---|---|
| Dark greenish-brown with numerous rust brown spots, very fine to fine, poorly sorted, subangular, glauconitic, quartz sand; some silt and clay; little mica. | 20–21 |
| Dark green, with brick-red spots, very fine, poorly sorted, subangular, very glauconitic, quartz sand; considerable silt and clay; little mica. | 21-25 |
| Greenish-black with rust brown and brick-red spots, very fine, poorly sorted, very glauconitic, clayey, quartz sand; grades into a very coarse to coarse silt with abundant glauconite. The surface of this layer weathers to a greenish-white hard silt. | 25–30 |

Matawan group
Wenonah formation

| | |
|---|---|
| Light gray to greenish-white with some rust brown spots, medium, well sorted, "sugary", quartz sand; some mica; little glauconite. | 30–32 |
| Predominantly gray with thin bands of rust brown, fine, well sorted, subangular, quartz sand; some mica; little glauconite. This layer contains some tubes of *Halymenites major*. | 32–34 |

| | Feet |
|---|---|
| Predominantly rust brown with some gray streaks, fine, well sorted, subangular, quartz sand; some mica; little glauconite. This layer has a stratified appearance from a distance. Abundant *Halymenites major*. | 34–39 |
| **Merchantville formation** | |
| Gray with very little rust brown, fine to very fine, well sorted, subangular, quartz sand; some mica and glauconite. This layer represents a gradational change from the Wenonah above to the Merchantville below. | 39–40 |
| Dark greenish-brown with some rust brown spots, very fine, poorly sorted, subangular, quartz sand; considerable silt and clay; some glauconite. | 40–43 |
| Dark blue, poorly sorted, heavily micaceous, very fine, quartz sand; grades into a very coarse silt. | 43–50 |

Station 2B

Location: South bank, 100 feet west of the Pennsylvania Railroad bridge.

Height of Outcrop: 28 feet

| Upper Cretaceous series | |
|---|---|
| Monmouth group | |
| Mount Laurel-Navesink formation | Feet |
| Dark green with reddish-brown spots, fine, poorly sorted, subangular to angular, glauconitic, quartz sand; some mica and silt. Very fossiliferous. | 0–5 |
| Dark green with reddish-brown spots, fine, poorly sorted, subangular to angular, glauconitic, quartz sand; considerable silt and clay; some mica. | 5–8 |
| Slightly greenish-brown, fine to very fine, normally sorted, subangular, quartz sand; some glauconite and mica. This layer grades into the Wenonah below. | 8–9 |
| Matawan group | |
| Wenonah formation | |
| Rust brown with a few green spots, fine, well sorted, subangular, quartz sand; some glauconite and mica. | 9–11 |
| Gray, fine, well sorted, subangular, micaceous, quartz sand; little glauconite. Aboundant *Halymenites major*. | 11–13 |
| Alternating layers of rust brown and gray, well stratified, fine, well sorted, subangular, micaceous, quartz sand; little glauconite. Numerous *Halymenites major*. | 13–16 |
| Rust brown and gray, fine, well sorted, subangular, quartz sand; considerable mica; little glauconite. | 16–18 |
| Rust brown, fine, well sorted, subangular, quartz sand; considerable glauconite; some mica. | 18–19 |
| Merchantville formation | |
| Gray with very little rust brown, fine to very fine, well sorted, subangular, quartz sand; some mica and glauconite. This layer represents a gradational change from the Wenonah above to the Merchantville below. | 19–20 |
| Dark greenish-brown with some rust brown spots, very fine, poorly sorted, subangular, quartz sand; considerable silt and clay; some glauconite. | 20–23 |
| Dark blue, poorly sorted, heavily micaceous, very fine, quartz sand; grades into a very coarse silt. | 23–28 |



Characteristic fossils from Stations 2A and 2B

Mount Laurel-Navesink formation

Pelecypoda

*Cucullaea neglecta* Gabb
*Cypremeria excavata* Morton
*Trigonia* sp.
*Cardium tenuistriatum* Whitfield
*Exogyra* sp.
*Ostrea mesenterica* Morton

Gastropoda

*Anchura abrupta* Conrad

Merchantville formation

Annelida

*Hamulus falcatus* Conrad

Pelecypoda

*Cardium tenuistriatum* Whitfield

Gastropoda

*Volutomorpha delawarensis* Gabb

Crustacea

*Callianassa mortoni* Pilsbry

**Station 3**

**Location:** North bank, 900 feet east of light 22

**Height of outcrop:** 18 feet

| **Pleistocene series** | Feet |
|---|---|
| Buff, fine, poorly to normally sorted, subangular to subrounded, "dirty", quartz sand; some silt, mica, and black minerals. Toward the bottom of the formation the sand becomes cleaner, contains more black minerals and some glauconite. Stratification and cross-bedding are prominent. | 0–6 |
| **Unconformity** | |
| **Upper Cretaceous series** | |
| Monmouth group | |
| Mount Laurel-Navesink formation | |
| Greenish-brown with rust brown spots, fine to very fine, poorly sorted, subangular, quartz sand; considerable silt and clay; a lot of glauconite; some black minerals; little mica. | 6–10 |
| Dark green with rust brown spots, very coarse silt with abundant glauconite. The surface of this layer weathers to a greenish-white hard silt. | 10–15 |
| Matawan group | |
| Wenonah formation | |
| Light gray to pink, plastic clay with a few very thin sand streaks. | 15–15½ |
| Rust brown, fine, well sorted, subangular, quartz sand; many grains stained with iron hydroxide; little mica, black minerals, and glauconite; abundant *Halymenites major*. This layer is strongly indurated. | 15½–18 |

Characteristic fossils

Mount Laurel-Navesink formation

Pelecypoda

*Exogyra cancellata* Stephenson
*E. costata* Say
*Gryphaea mutabilis* Say
*Cardium tenuistriatum* Whitfield
*Ostrea mesenterica* Morton
*O. nasuta* Morton

Gastropoda

*Turritella* sp.
*Gyrodes crenatus* Conrad

Wenonah formation

Pelecypoda

*Martesia cretacea* Gabb
*Anomia* sp.
*Meretrix* sp.
*Inoceramus proximus* Tuomey

Gastropoda

*Turritella encrinoides* Morton

Annelida

*Diploconcha cretacea* Conrad

Echinodermata

*Faujasia geometricus* Morton

*Halymenites major* Lesquereux

Station 4

Location: South bank, about 0.5 miles east of Lorwood Grove

The bank at this point has been completely sodded and no exposure is now visible. However, about 1942 the Mount Laurel-Navesink was exposed near the water level and numerous fossils were obtained. The beach of the Canal at this point was also covered with fossils, most of them being of Mount Laurel-Navesink age, although a few specimens of *Exogyra ponderosa* suggested that there might have been a Marshalltown equivalent in the subsurface. Among the fossils obtained from this locality were the following:

Pelecypoda

*Gryphaea convexa* Say
*Exogyra cancellata* Stephenson
*E. ponderosa* Roemer
*Cardium tenuistriatum* Whitfield
*Anomia argentaria* Morton
*Paranomia scabra* Morton

Gastropoda

*Anchura solitaria* Whitfield
*Turritella encrinoides* Morton

Station 5

Location: South bank, 500 feet east of St. Georges bridge

Height of outcrop: 17 feet

| Pleistocene series | Feet |
| --- | --- |
| Tan, fine to medium, poorly sorted, subangular, "dirty", quartz sand; some gravel and cobbles up to one foot in length. Ironstone is found at the base of this formation. | 0–2 |

Unconformity

Upper Cretaceous series
Monmouth group
Red Bank formation

| | |
| --- | --- |
| Reddish-brown with some rust brown spots, fine, well sorted, subrounded, quartz sand; many grains stained with iron hydroxide; some glauconite and black minerals; little feldspar and mica. The upper two feet of this layer are reddish-yellow in color and the quartz grains are "dirty". | 2–13 |

Mount Laurel-Navesink formation

| | |
| --- | --- |
| Greenish-brown with rust brown spots, very fine, poorly sorted, subangular, glauconitic, quartz sand; considerable silt; some black minerals; very little feldspar and mica. | 13–17 |

Fossils at locality 5 are generally poorly preserved and limited to *Exogyra cancellata* Say and *Gryphaea mutabulis* Say.

Station 6

Location: South bank, 900 feet west of light 13

Height of outcrop: 8 feet

Upper Cretaceous series
Monmouth group

| Red Bank formation | Feet |
| --- | --- |
| Reddish-brown with some rust brown spots, medium, well sorted, subrounded, slightly "dirty", quartz sand; most grains stained with iron hydroxide; some glauconite and black minerals, little mica and feldspar. | 0–6 |

Mount Laurel-Navesink formation

| | |
| --- | --- |
| Rust brown with green and red spots, medium, well sorted, subrounded, quartz sand; most grains stained with iron hydroxide; some glauconite; few black minerals; some brick red and gray clay balls. A highly fossiliferous zone is found at sea-level. | 6–8 |

## Characteristic fossils

### Red Bank formation

#### Pelecypoda

*Anomia tellinoides* Morton

#### Cephalopoda

*Belemnitella americana* Morton

### Mount Laurel-Navesink formation

#### Pelecypoda

*Exogyra cancellata* Stephenson
*E. costata* Say
*Anomia tellinoides* Morton
*Gryphaea mutabilis* Say
*Ostrea falcata* Morton
*O. mesenterica* Morton
*O. monmouthensis* Weller

#### Gastropoda

*Lunatia halli* Gabb
*Napulus octoliratus* Conrad

#### Cephalopoda

*Baculites ovatus* Say
*Belemnitella americana* Morton

# SYSTEMATIC PALEONTOLOGY

No attempt has been made to make this list complete. The majority of the species listed have been collected during the present survey or are part of the collections of the Academy of Natural Sciences of Philadelphia. Specimens have also been studied in the collections of the Department of Geology at Johns Hopkins University and the United States National Museum in Washington. Many of the species cited by Charles W. Carter and Julia Gardner are listed in this report, but no attempt has been made to discuss those species which Carter refers merely to genus or which he indicates as new. This would require a more detailed study of Carter's orginal material than was possible during the present survey.

Also, no attempt has been made to give a complete bibliography or synonymy. Such information is available in various reports, notably those of Weller (1907), Gardner (1916) and Stephenson (1923). The present report merely cites the original description, gives a reference to Weller or Gardner where further information is available, and records the localities or formations in Delaware and New Jersey where the species has been found.

Abbreviations of formations:

| | | | |
|---|---|---|---|
| RAR | Raritan | WEN | Wenonah |
| MAG | Magothy | MtL-NAV | Mount Laurel-Navesink |
| MCH | Merchantville | RB | Red Bank |
| WBY | Woodbury | TIN | Tinton |
| MARSH | Marshalltown | | |

Since the faunas of the Mount Laurel and Navesink formations of New Jersey are treated as a single unit by Weller (1907), their distribution records are combined under the symbol MtL-NAV in the following systematic discussion.

## PORIFERA

### CLIONA CRETACICA Fenton and Fenton — Pl. 3, Fig. 1

*C. cretacica* F. & F., 1932, Am. Midland Naturalist, vol. 12, p. 55, pl. 7, figs. 8, 9.

Borings of this sponge are common on shells of *Exogyra* and other species, and rarely on *Belemnitella* at stations 2, 3, 4 and 6.

Del.: MtL-NAV — N.J.: MtL-NAV

## COELENTERATA

### MICRABACIA Sp.

One small coral from the Biggs Farm (station 6) is close to *M. rotalis* according to Dr. John W. Wells who kindly examined the specimen.

Del.: MtL-NAV

## ANNELIDA

### HAMULUS FALCATUS Conrad

*Dentalium falcatum* Conrad, 1869, Am. Jour. Conch., vol. 5, p. 44, pl. 1, figs. 11, 12.

This worm boring has been found in the Merchantville and Mount Laurel-Navesink formations along the Canal.

Del.: MCH; MtL-NAV — N.J.: MARSH; MtL-NAV

### LONGITUBUS LINEATUS Weller

*Hamulus lineatus* Weller, 1907, New Jersey Geol. Survey Paleontology, vol. 4, p. 310, pl. 19, fig. 7.

Fairly common at the spoil bank (station 1-A).

Del.: MCH — N.J.: MCH; MtL-NAV

### DIPLOCONCHA CRETACEA Conrad

*D. cretacea* Conrad, 1875, in Kerr, Geol. Survey North Carolina, App. A., pl. 12, fig. 20. [Weller (*Serpula whitfieldi*), p. 308, pl. 19, fig. 2; Gardner, 1916, p. 746.]

A few tubes at station 3.

Del.: WEN; MtL-NAV N.J.: MCH; MtL-NAV

## ECHINODERMATA

### FAUJASIA GEOMETRICUS Morton Pl.3, Fig. 2

*Clypeaster geometricus* Morton, 1833, Am. Jour. Sci., 1st ser., vol 24, p. 131, pl. 10, fig. 9.

Originally described from the Chesapeake and Delaware Canal. Several specimens have recently been found in the Wenonah formation at station 3.

Other echinoids reported by Cooke (1953) from the Chesapeake and Delaware Canal include: *Hardouria florealis* (Morton), *Hemiaster ungula* (Morton) and *H. delawarensis* (Clark).

## BRACHIOPODA

### TEREBRATULINA ATLANTICA Morton

*T. atlantica* Morton, 1842, Acad. Nat. Sci. Philadelphia Jour., 1st ser., vol. 8, p. 214.

One specimen from the Biggs Farm (station 6). This species is characteristic of the Navesink, but has been confused with *T. manasquani* Stenzel which is Eocene.

Del.: MtL-NAV N.J.: MtL-NAV

### CHORISTOTHYRIS PLICATA Say

*Terebratula plicata* Say, 1820, Am. Jour. Sci., 1st ser., vol. 2, p. 43. [Weller (*Terebratella*), p. 364, pl. 27, figs. 1-11.]

This characteristic fossil of the Navesink of New Jersey has not been reported from the Chesapeake and Delaware Canal, although Roberts (1895) listed it from the Red Bank sand at Bohemia Mills, Md.

## PELECYPODA

### NUCULA SLACKIANA Gabb

*Leda slackiana* Gabb, 1860, Acad. Nat. Sci. Philadelphia Jour., 2nd ser., vol. 4, p. 397, pl. 69, fig. 36. [Gardner, p. 511, pl. 19, figs. 1-4.]

Not found during the recent survey. Gardner and Carter report it from the Merchantville and Mount Laurel-Navesink.

Del.: MCH; MtL-NAV N.J.: WBY

### NUCULANA PROTEXTA Gabb

*Leda protexta* Gabb, 1860, Acad. Nat. Sci. Philadelphia Jour., 2nd ser., vol. 4, p. 303, pl. 48, fig. 23. [Weller, (*L. gabbana*), p. 375, pl. 29, fig. 26.]

Rare at Biggs Farm (station 6).

Del.: MtL-NAV N.J.: WBY

### YOLDIA GABBANA Whitfield

*Nuculana gabbana* Whitfield, 1886, New Jersey Geol. Survey Paleontology, vol. 1, figs. 11-13. [Weller, p. 378, pl. 29, figs. 28-30; Gardner, p. 520.]

Rare at Biggs Farm (station 6).

Del.: MtL-NAV N.J.: NAV



### NUCULANA LONGIFRONS Conrad

*Leda longifrons* Conrad, 1860, Acad. Nat. Sci. Philadelphia Jour., 2nd ser., vol. 4, p. 281, pl. 46, fig. 18. [Weller, (*Yoldia*), p. 381, pl. 30, fig. 5; Gardner, (*Yoldia*), p. 518, pl. 19, fig. 13.]

Gardner reports this from Post 105.

Del.: MCH (?) N.J.: WBY

### CUCULLAEA ANTROSA Morton

*C. antrosa* Morton, 1834, Synop. Org. Rem. Cret. Gr. U. S., p. 65, pl. 13, fig. 6. [Weller, p. 391, pl. 32, figs. 7-9; Gardner, p. 534.]

Reported by Carter.

Del.: MtL-NAV N.J.: MCH;MtL-NAV; TIN

### CUCULLAEA NEGLECTA Gabb Pl. 3, Figs. 4, 5

*C. neglecta* Gabb, 1861, Acad. Nat. Sci. Philadelphia Proc., p. 326. [Weller, p. 396, pl. 31, figs. 1-4.]

Spoil bank (station 1A) and near Railroad bridge (station 2).

Del.: MCH; MtL-NAV N.J.: MCH; MtL-NAV

### CUCULLAEA VULGARIS Morton Pl. 3, Fig. 6

*C. vulgaris* Morton, 1830, Am. Jour. Sci., 1st ser., vol. 17, p. 285, pl. 3, fig. 21. [Weller, p. 394, 397, pl. 31-32, figs. 5-10 and 5-6; Gardner, p. 529, pl. 20, figs. 8-9, pl. 21, figs. 1-2.]

Spoil bank; also Camp Fox (Gardner).

Del.: MCH N.J.: MCH; MARSH; TIN; EOCENE

### BREVIARCA HADDONFIELDENSIS Stephenson

*B. haddonfieldensis*, 1935, Washington Acad. Sci. Jour., vol. 25, p. 362.

Carter reports this species from the Crosswicks (Merchantville).

Del.: MCH N.J.: WBY

### GLYCYMERIS MORTONI Conrad Pl. 3, Fig. 7

*Axinea mortoni* Conrad, 1869, Am. Jour. Conch., vol. 5, p. 44, pl. 1, fig. 14. [Weller, p. 414, pl. 35, figs. 1-8, (*A. subaustralis*) Gardner, p. 540.]

Spoil bank (station 1A).

Del.: MCH N.J.: MCH; MtL-NAV; TIN

### PINNA LAQUEATA Conrad

*P. laqueata* Conrad, 1858, Acad. Nat. Sci. Philadelphia Jour., 2nd ser., vol. 3, p. 328. [Weller, p. 419, pl. 36, fig. 1, pl. 37, fig. 1; Gardner, p. 545, pl. 21, fig. 12.]

Fragments are fairly common at the spoil bank (station 1A).

Del.: MCH N.J.: MCH; WBY; MtL-NAV

### PULVINITES ARGENTEUS Conrad (?) Pl. 3, Fig. 11

*P. argenteus* Conrad, 1858, Acad. Nat. Sci. Philadelphia Jour., 2nd ser., vol. 3, p. 330, pl. 34, fig. 5.

Carter reported *Pulvinites* sp. from the Crosswicks in the spoil bank east of Summit Bridge. A comparison of Carter's specimen with specimens of *P. argenteus* from [illegible]h County, Mississippi, in the Academy of Natural Sciences, suggests that the Delaware specimen be tentatively referred to this species. *P. argenteus* has been reported previously from the Ripley formation of Coon Creek, Tennessee, and the Chattahoochee River, Georgia-Alabama, the Providence sand of the Chattahoochee River, the Owl Creek formation of Mississippi, the Nacotah sand of Arkansas and the Corsicana marl (Navarro) of Texas. If the Delaware specimen be cospecific with the southern forms, it is stratigraphically lower than previously reported. No other species of *Pulvinites* has been reported from the Atlantic Coastal Plain.

Del: MCH — N.J.:

### GERVILLIPOSIS ENSIFORMIS Conrad — Pl. 3, Fig. 3

*Gervillia ensiformis* Conrad, 1858, Acad. Nat. Sci. Philadelphia Jour., 2nd ser., vol. 3, p. 328, pl. 34, fig. 10. [Weller, p. 421, pl. 37, figs. 4-5; pl. 38, figs. 1-3.]

A few specimens have been collected near the Railroad bridge (station 2).

Del.: MCH; MtL-NAV — N.J.: MCH; WBY; MARSH; WEN; MtL-NAV; RB

### INOCERAMUS PROXIMUS Tuomey — Pl. 3, Fig. 8

*I. proximus* Tuomey, 1854, Acad. Nat. Sci. Philadelphia Proc., vol. 7, p. 171, [Weller p. 424, pl. 40, figs. 1-6; pl. 41, fig. 1.]

One specimen, probably this species, was obtained from the lower layer at station 3.

Del.: WEN — N.J.: RAR; MAG; MCH; MARSH

### INOCERAMUS PEROVALIS Conrad — Pl. 3, Fig. 9

*I. perovalis* Conrad, 1852, Acad. Nat. Sci. Philadelphia Jour., 2nd ser., vol. 2, p. 299, pl. 27, fig. 7. [Weller, pl. 38, fig. 5.]

A rare species known only from the type specimen described many years ago from the Chesapeake and Delaware Canal. Its exact relationship is uncertain.

### PTERIA LARIPES Morton — Pl. 3, Fig. 10

*Avicula laripes* Morton, 1834, Synop. Org. Rem. Cret. Gr. U. S., p. 63, pl. 17, fig. 5. [Weller, p. 431, pl. 42, fig. 3.]

The label on the type specimen in the Academy of Natural Sciences says both New Jersey and Delaware. It has not been found during recent years.

### OSTREA FALCATA Morton — Pl. 3, Fig. 13

*O. falcata* Morton, 1830, Acad. Nat. Sci. Philadelphia Jour., 1st ser., vol. 6, p. 50, pl. 1, fig. 2. [Weller, p. 444, pl. 43, figs. 3-6; Gardner, p. 553, pl. 22, fig. 4.]

Fairly common at Biggs Farm (station 6) and Lorwood Grove (station 4).

Del.: MtL-NAV — N.J.: MARSH; MtL-NAV

### OSTREA MESENTERICA Morton — Pl. 3, Fig. 14

*O. falcata* var B (*O. mesenterica*) Morton, 1834, Synop. Org. Rem. Cret. Gr. U. S., p. 51, pl. 9, fig. 7. [Weller, p. 446, pl. 43, figs. 9-14; Gardner, p. 555, pl. 22, figs. 6-8; pl. 23, figs. 1-2.]

Biggs Farm (station 6).

Del.: MtL-NAV — N.J.: MtL-NAV; TIN

### OSTREA PANDA Morton

*O. panda* Morton, 1833, Am. Jour. Sci., 1st ser., vol. 23, p. 293. [Weller, p. 437, pl. 42, fig. 10.]

A few poorly preserved specimens near the Railroad bridge.

Del.: MtL-NAV — N.J.: MARSH; EOCENE



### OSTREA MONMOUTHENSIS Weller — Pl. 3, Fig. 12

*O. monmouthensis* Weller, 1907, New Jersey Geol. Survey Paleontology, vol. 4, p. 442, pl. 43, fig. 15.

Described from the Navesink of New Jersey.

Del.: MtL-NAV — N.J.: MtL-NAV

### GRYPHAEOSTREA VOMER Morton

*Gryphaea vomer* Morton, 1834, Synop. Org. Rem. Cret. Gr. U. S., p. 54, pl. 9, fig. 5. [Weller, p. 455, pl. 44, figs. 6-11; Gardner p. 579, pl. 25, figs. 1-4.]

Biggs Farm (station 6); also reported by Gardner and Carter.

Del.: MtL-NAV — N.J.: MARSH; MtL-NAV; RB

### EXOGYRA COSTATA Say — Pl. 4, Fig. 3

*E. costata* Say, 1820, Am. Jour. Sci., 1st ser., vol. 2, p. 43. [Weller, p. 456, pl. 47, fig. 1; Gardner, p. 564.]

A few specimens at stations 3, 4 and 6. Not as common as *E. cancellata.*

Del.: MtL-NAV — N.J.: MtL-NAV;RB; TIN

### EXOGYRA PONDEROSA Roemer — Pl. 4, Fig. 1

*E. ponderosa* Roemer, 1849, Texas, p. 395. [Weller, p. 458, pl. 47, fig. 2; Gardner, p. 569.]

A few large specimens were picked up on the beach of the south bank of the canal between the Railroad bridge and station 3; some were also collected about 1941 on the beach east of Lorwood Grove and Gardner reports the species at a marl pit east of post 236. (It seems probable that these came from the subsurface.)

Del.: MARSH (?) — N.J.: MARSH

### EXOGYRA CANCELLATA Stephenson — Pl. 4, Fig. 2

*E. costata* var. *cancellata* Stephenson, 1914, U. S. Geol. Survey Prof. Paper 81, p. 53, pl. 20, figs. 2-4; pl. 21, figs. 1-2, 1914. [Gardner, p. 566, pl. 27, fig. 3.]

Very abundant at stations 2, 3, 4, 5 and 6. Has apparently been confused with *E. ponderosa* but a careful examination shows these to be rather large specimens of *E. cancellata.* Once thought to be a index fossil of the Mount Laurel formation, but specimens have recently been collected from the Navesink formation near New Egypt, New Jersey. The specimens at station 2, near the Railroad bridge, are poorly preserved and are only tentatively referred to this species.

Del.: MtL-NAV — N.J.: MtL-NAV

### GRYPHAEA MUTABILIS Morton — Pl. 4, Fig. 4

*G. mutabilis* Morton, 1828, Acad. Nat. Sci. Philadelphia Jour., 1st ser., vol. 6, p. 81, pl. 4, fig. 4. [Weller, p. 451-55, pl. 45, 46; Gardner, p. 512, pl. 31-33.]

The common Gryphaea of the Cretaceous of New Jersey and Delaware has been described as *G. mutabilis*, *G. convexa* and *G. dissimilaris.* These are probably all variations of a single species.

Del.: MtL-NAV — N. J.: MARSH; MtL-NAV; HORNERSTOWN (Eocene)

### TRIGONIA MORTONI Whitfield

*T. mortoni* Whitfield, 1886, New Jersey Geol. Survey Paleontology, vol. 1, p. 112, pl. 14, figs. 5-6. [Weller, p. 460, pl. 48, figs. 1-4, *T. thoracica* not of Morton.]

Poorly preserved specimens tentatively referred to this species from stations 2, 3 and 6.

Del.: MtL-NAV — N.J.: MARSH; WEN

## TRIGONIA EUFAULENSIS Gabb

*T. eufaulensis* Gabb, 1860, Acad. Nat. Sci. Philadelphia Jour., 2nd ser., vol. 4, p. 396, pl. 68, fig. 32. [Weller, p. 462, pl. 48, figs. 5-10; Gardner, p. 582, pl. 34, figs. 1-2.]

Reported by Gardner and Carter from 2 miles west of Delaware City.

Del.: MtL-NAV (?) N.J.: WBY; MCH; WEN

## PECTEN BELLISCULPTUS Conrad

*Camptonectes bellisculptus* Conrad, 1869, Am. Jour. Conch., vol. 5, p. 99, pl. 9, fig. 11. [Weller, p. 472, pl. 49, figs. 1-4; Gardner, p. 588, pl. 34, figs. 3-5. *P. argillensis* not of Conrad.]

Reported by Carter; not observed during the present survey.

Del.: MCH; MtL-NAV N.J.: MCH; WBY; MARSH; MtL-NAV

## PECTEN QUINQUENARIUS Conrad

*P. quinquenaria* Conrad, 1853, Acad. Nat. Sci. Philadelphia Jour., 2nd ser., p. 275, pl. 24, fig. 10. [Weller, p. 476, pl. 50, figs. 10-12.]

Poorly preserved specimens near the Railroad bridge (station 2).

Del.: MtL-NAV N.J.: WEN; MtL-NAV

## PECTEN SIMPLICIUS Conrad

*P. simplicius* Conrad, 1860, Acad. Nat. Sci. Philadelphia Jour., 2nd ser., vol. 4, p. 283, pl. 46, fig. 44. [Weller, p. 480, pl. 51, fig. 6; Gardner, p. 595, pl. 34, figs. 8-9.]

Reported by Carter.

Del.: MCH; MtL-NAV N.J.: WBY; RB; TIN

## NEITHEA QUINQUECOSTATA Sowerby

*P. quinquecostata* Sowerby, 1814, Min. Conch., vol. 1, p. 122, pl. 56, figs. 4-8. [Weller, p. 481, pl. 51, figs. 7-12; Gardner, p. 596, fig. 10.]

Of wide range; not uncommon.

Del.: MCH (?); MtL-NAV N.J.: MCH; MARSH; MtL-NAV

## PECTEN WHITFIELDI Weller — Pl. 4, Fig. 5

*P. whitfieldi* Weller, 1907, New Jersey Geol. Survey Paleontology, vol. 4, p. 468, pl. 50, fig. 14.

One specimen probably this species, from Lorwood Grove.

Del.: MtL-NAV N.J.: MtL-NAV

## LIMA SERRATA Gardner

*L. serrata* Gardner, 1916, Maryland Geol. Survey, Upper Cretaceous, p. 602, pl. 34, figs. 14, 15.

Rare at Biggs Farm (station 6); described from Monmouth formation of Maryland.

Del.: MtL-NAV N.J.:

## LIMA RETICULATA Lyell & Forbes

*L. reticulata* Lyell & Forbes, 1845, Quart. Jour. Geol. Soc. London, vol. 1, p. 62; two text figures. [Weller, p. 492, pl. 54, figs. 3-4; Gardner, p. 600, pl. 34, figs. 12-13.]

Spoil bank (station 1A).

Del.: MCH N.J.: MCH; MARSH; WEN; MtL-NAV RB; TIN



## ANOMIA ARGENTARIA Morton

[illegible]*rgentaria* Morton, 1833, Am. Jour. Sci., 1st ser., vol. 23, p. 293, pl. 5, fig. 10. [Weller, [illegible]96, pl. 54, figs. 12-14; Gardner, p. 608, pl. 35, figs. 1-2.]

[illegible]wood Grove; spoil bank (station 1A); not as common as *A. tellinoides*.

[illegible]: MCH; MtL-NAV N.J.: RAR; MAG; MCH; WBY; MARSH; WEN; MtL-NAV

## ANOMIA TELLINOIDES Morton — Pl. 4, Fig. 6

[illegible] *tellinoides* Morton, 1834, Synop. Org. Rem. Cret. Gr. U. S., p. 61, pl. 5, fig. 11. [Weller, p. 496, pl. 54, fig. 15; Gardner, p. 610, pl. 35, figs. 3-4.]

[illegible]ecially common and well preserved at Biggs Farm (station 6). Differs from [illegible] *argentaria* by its weaker radiating lines and by having the muscle scars fused.

Del.: MtL-NAV; RB N.J.: MtL-NAV

## PARANOMIA SCABRA Morton

*Placuna scabra* Morton, 1834, Synop. Org. Rem. Cret. Gr. U. S., p. 62. [Weller, p. 500, pl. 52, figs. 10-13; Gardner, p. 605, pl. 35, figs. 11-12.]

Fairly common.

Del.: MCH; MtL-NAV N.J.: MCH; MARSH; MtL-NAV

## VOLSELLA BURLINGTONENSIS Whitfield

*Modiola burlingtonensis* Whitfield, 1886, New Jersey Geol. Surv. Paleontology Vol. 1, p. 65, pl. 17, figs. 8-9. [Weller, p. 505, pl. 55, figs 18-19; Gardner, p. 615.]

Not found recently. Gardner reports it from Post 192.

Del.: (?) N.J.: MCH

## CRENELLA ELEGANTULA Meek & Hayden

*C. elegantula* Meek & Hayden, 1861, Acad. Nat. Sci. Philadelphia Proc., p. 441. [Weller, p. 511, pl. 56, fig. 6; Gardner, p. 625, pl. 36, fig. 19.]

Biggs Farm (Station 6).

Del.: MtL-NAV N.J.: TIN

## LITHOPHAGA RIPLEYANA Gabb — Pl. 4, Fig. 7

*Lithophagus ripleyanus* Gabb, 1861, Acad. Nat. Sci. Philadelphia Proc., p. 326. [Weller, p. 512, pl. 56, figs. 9-12; Gardner, p. 618, pl. 36, figs. 4-6.]

Spoil bank (station 1A); reported by Gardner from Camp Fox.

Del.: MCH N.J.: MCH; WEN; MtL-NAV

## PHOLADOMYA OCCIDENTALIS Morton — Pl. 5, Fig. 1

[illegible] *occidentalis* Morton, 1833, Am. Jour. Sci., 1st ser., vol. 23, p. 292, pl. 8, fig. 3. [Weller, [illegible]513, pl. 56, figs. 1-3; Gardner, p. 630, pl. 37, figs. 1-3.]

[illegible]y common at spoil bank (station 1A).

[illegible] MCH N.J.: MAG; MCH; WBY

## CORIMYA Sp.

[illegible] Farm (station 6).

### CLAVAGELLA ARMATA Morton

*C. armata* Morton, 1834, Synop. Org. Rem. Cret. Gr. U. S., p. 69, pl. 9, fig. 11. [Weller, p. 525, pl. 58, figs. 1-2.]

Biggs Farm (station 6).

Del.: MtL-NAV N.J.: MCH; MtL-NAV

### LIOPISTHA PROTEXTA Conrad Pl. 5, Fig. 2

*Cardium protextum* Conrad, 1853, Acad. Nat. Sci. Philadelphia Jour., 2nd ser., vol. 2, p. 275, pl. 24, fig. 12. [Weller, p. 526, pl. 58, figs. 4-6; Gardner, p. 636, pl. 36, fig. 15.]

Biggs Farm (station 6).

Del.: MtL-NAV N.J.: WEN; MtL-NAV; RB; TIN

### LIOPISTHA ALTERNATA Weller

*L. alternata* Weller, 1907, New Jersey Geol. Survey Paleontology, vol. 4, p. 527, pl. 58, figs. 7-9. [Gardner, p. 637.]

Near Summit Bridge.

Del.: MCH N.J.: MCH

### CYMELLA BELLA Conrad Var. Pl. 5, Fig. 3

*C. bella* Conrad, 1875, in Kerr, Geol. North Carolina, App. A, p. 10, pl. 2, fig. 9. [Weller, p. 530, pl. 58, figs. 10-12.]

From the spoil bank (station 1A). One specimen with broader costae and narrower interspaces than typical *C. bella*. Similar to those from New Jersey.

Del.: MCH N.J.: MAG; MCH; WBY; WEN

### VENIELLA CONRADI Morton

*Venilia conradi* Morton, 1833, Am. Jour. Sci., 1st ser., vol. 23, p. 294, pl. 8, figs. 1-2. [Weller, p. 534, pl. 58-59, figs. 18-19 and 1-3; Gardner, p. 643, pl. 38, figs.2-7.]

Found at Lorwood Grove about 1941; reported by Gardner and Carter.

Del.: MCH; MtL-NAV N.J.: MCH; WEN; MtL-NAV; RB; TIN

### CRASSATELLA CAROLINENSIS Conrad

*C. carolinensis* Conrad, 1875, in Kerr, Geol. Survey North Carolina, vol. 1, App. A, p. 6, pl. 2, fig. 24.

Reported by Carter from the "Crosswicks". Rare; known from New Jersey (formation?) and the Snow Hill member of Peedee formation in North Carolina.

Del.: MCH N.J.: (?)

### CRASSATELLA Sp. Pl. 5, Fig. 4

Biggs Farm (station 6).

### UNICARDIUM UMBONATA Whitfield Pl. 5, Fig. 9

*Sphaeriola umbonata* Whitfield, 1886, New Jersey Geol. Survey Paleontology, Vol. 1, p. 152, pl. 19, figs. 17-18. [Weller, p. 569, pl. 62, figs. 16-17.]

Poorly preserved specimens are fairly common near the Railroad bridge (station 2).

Del.: MtL-NAV N.J.: MARSH; MtL-NAV



### TENEA PARILIS Conrad

[illegible]is (*Diplodonta*) *parilis* Conrad, 1860, Acad. Nat. Sci. Philadelphia Jour., 2nd ser., [illegible]4, p. 278, pl. 46, fig. 16. [Weller, p. 572, pl. 63, figs. 1-6; Gardner, p. 661.]

[illegible] Farm (station 6).

[illegible]: MtL-NAV N.J.: MAG; MCH; WBY; MtL-NAV; RB; TIN

### CARDIUM SPILLMANI Conrad

*C. spillmani* Conrad, 1858, Acad. Nat. Sci. Philadelphia Jour., 2nd ser., vol. 3, p. 326, pl. 34, fig. 3. [Weller, p. 583, pl. 64, figs. 9-11; Gardner, p. 666.]

Reported by Carter from the "Crosswicks".

Del.: MCH N.J.: MCH; MtL-NAV

### CARDIUM DUMOSUM Conrad

*Cardium* (*Criocardium*) *dumosum* Conrad, 1870, Am. Jour. Conch., vol. 6, p. 75. [Weller, p. 590 (part); Gardner, p. 668.]

Reported by Carter from the "Crosswicks".

Del.: MCH N.J.: WBY; WEN; RB

### CARDIUM TENUISTRIATUM Whitfield Pl. 5, Figs. 5,6

*Fragum tenuistriatum* Whitfield, 1886, New Jersey Geol. Survey Paleontology, vol. 1, p. 139, pl. 20, figs. 15, 16. [Weller, p. 591, pl. 65, figs. 13-19; Gardner, p. 669.]

Fairly common at most localities.

Del.: MCH; MtL-NAV N.J.: MCH; MARSH; WEN; MtL-NAV

### CARDIUM cf. LONGSTREETI Weller Pl. 5, Fig. 7

*C. longstreeti* Weller, 1907, New Jersey Geol. Survey Paleontology, vol. 4, p. 579, pl. 63, figs. 21-22.

Specimens questionably referred to this species were found by Carter in the "Crosswicks".

Del.: MCH N.J.: WEN

### PROTOCARDIUM JERSEYENSIS Weller

*P. jerseyensis* Weller, 1907, p. 596, pl. 65, fig. 21.

Spoil bank (station 1A).

Del.: MCH N.J.: MCH

### CYPRIMERIA EXCAVATA Morton Pl. 5, Fig. 12

[illegible]here *excavata* Morton, 1833, Am. Jour. Sci., 1st ser., vol. 23, p. 292, pl. 5, fig. 1. [Weller, p. 602, pl. 67, figs. 1-6.]

[illegible]ly common at station 2.

[illegible]: MtL-NAV N.J.: MARSH; MtL-NAV

### MERETRIX cf. TIPPANA Conrad

[illegible] preserved in Wenonah sand at station 3.

### LEGUMEN CONCENTRICUM Stephenson

*L. concentricum* Stephenson, 1923, North Carolina Geol. & Econ. Survey, vol. 5, p. 319, pl. 80, figs. 6-9.

Reported by Carter from the "Crosswicks"; rare north of North Carolina.

Del.: MCH — N.J.: WBY (?)

### LINEARIA METASTRIATA Conrad — Pl. 5, Fig. 8

*L. metastriata* Conrad, 1860, Acad. Nat. Sci. Philadephia Jour., 2nd ser., vol. 4, p. 279, pl. 46, fig. 7. [Weller, p. 618, pl. 70, figs. 8-9.]

Reported by Carter from the "Crosswicks" and "Marshalltown" (Mount Laurel-Navesink).

Del.: MCH; MtL-NAV — N.J.: MCH; WBY

### SOLYMA LINEOLATUS Conrad

*S. lineolatus* Conrad, 1870, Am. Jour. Conch., vol. 6, p. 75, fig. 9. [Weller, p. 629, pl. 71, figs. 3-6; Gardner, p. 701, pl. 36, figs. 20-21.]

Spoil bank (station 1A).

Del.: MCH — N.J.: MAG; MCH; WBY; WEN; RB; TIN

### CORBULA CRASSIPLICA Gabb

*C. crassiplica* Gabb, 1860, Acad. Nat. Sci. Philadephia Jour., 2nd ser., vol. 4, p. 394, pl. 68, fig. 25. [Weller, p. 641, pl. 72, figs. 27-28; Gardner, p. 713, pl. 43, figs. 6-7.]

Spoil bank (station 1A) and Biggs Farm (station 6).

Del.: MCH; MtL-NAV — N.J.: MCH; WBY; WEN; RB

### CORBULA BISULCATA Conrad — Pl. 5, Fig. 10

*C. bisulcata* Conrad, 1875, in Kerr Geol. Survey North Carolina, App. A, p. 11, pl. 2, figs. 13-14. [Weller, p. 638, pl. 72, figs. 15-22; Gardner, p. 711.]

Del.: MtL-NAV — N.J.: MAG; MCH; WBY

### PANOPEA DECISA Conrad — Pl. 5, Fig. 11

*Panopaea decisa* Conrad, 1853, Acad. Nat. Sci. Philadephia Jour., 2nd ser., vol. 2, p. 275, pl. 24, fig. 19. [Weller, p. 646, pl. 73, figs. 3-5; Gardner, p. 721.]

Fairly common at spoil bank (station 1A).

Del.: MCH: MtL-NAV — N.J.: MCH; WBY; WEN; MtL-NAV; RB

### GASTROCHAENA LINGUIFORMIS Weller

*G. linguiformis* Weller, 1907, New Jersey Geol. Survey Paleontology, vol. 4, p. 649, pl. 73, fig. 9.

Spoil bank (station 1A).

Del.: MCH — N.J.: MCH

### PHOLAS CITHARA Morton

*P. cithara* Morton, 1834, Synop. Org. Rem. Cret. Gr. U. S., p. 68, pl. 9, fig. 10. [Weller p. 651 (part).]

One specimen at Academy of Natural Sciences labeled "Chesapeake and Delaware Canal".

Del.: — N.J.: MCH; WBY; WEN; TIN



### MARTESIA CRETACEA Gabb

*...las cretacea* Gabb, 1860, Acad. Nat. Sci. Philadelphia Jour., 2nd ser., vol. 4, p. 393, ... 68, fig. 18. [Weller, p. 654, pl. 74, figs. 8-11; Gardner, p. 727.]

...tion 3, lower layer.

...l.: WEN — N.J.: MCH; MARSH

## GASTROPODA

### MARGARITES ABYSSINA Gabb

*Solarium abyssinus* Gabb, 1860, Acad. Nat. Sci. Philadelphia Proc., p. 94, pl. 2, fig. 9. [Weller, p. 669, pl. 75, figs. 20-22; Gardner, p. 505.]

A few specimens at Biggs Farm (station 6).

Del.: MtL-NAV — N.J.: MCH; MtL-NAV; TIN

### AMAUROPSIS MEEKANA Whitfield

*A. meekana* Whitfield, 1892, New Jersey Geol. Survey Paleontology, vol. 2, p. 131, pl. 16, figs. 22-25. [Weller, p. 681, pl. 77, figs. 1-3; Gardner, p. 503.]

Reported by Gardner from Post 105 (1/5 mile west of Summit Bridge).

Del.: MCH — N.J.: MCH; WBY

### LUNATIA HALLI Gabb

*L. halli* Gabb, 1860, Acad. Nat. Sci. Philadelphia Jour., 2nd ser., vol. 4, p. 391, pl. 68, fig. 11. [Weller, p. 677, pl. 76, figs. 9-19; Gardner, p. 499, pl. 13, figs. 1-2.]

Biggs Farm (station 6).

Del.: MtL-NAV — N.J.: MCH; WBY

### GYRODES ABYSSINA Morton

*Natica abyssina* Morton, 1834, Synop. Org. Rem. Cret. Gr. U. S., p. 49, pl 13, fig. 13. [Weller, p. 683, pl. 77, figs. 7-9; Gardner, p. 498.]

Reported by Gardner from 2 miles west of Delaware City.

Del.: MtL-NAV — N.J.: MtL-NAV

### GYRODES SUPRAPLICATUS Conrad

*Rapa supraplicata* Conrad, 1858, Acad. Nat. Sci. Philadelphia Jour., 2nd ser., vol. 3, p. 332, pl. 35, fig. 20. [Weller, p. 685, pl. 77, figs. 10-12.]

...orted by Carter from "Crosswicks" and "Marshalltown" (Mount Laurel-Navesink).

...: MCH; MtL-NAV — N.J.: MCH; WBY; WEN

### GYRODES PETROSUS Morton

*... petrosa* Morton, 1834, Synop. Org. Rem. Cret. Gr. U. S., p. 48, pl. 19, fig. 6. ...r, p. 689, pl. 77, figs. 13-18; Gardner, p. 496, pl. 13, fig. 8.]

...n 3 (upper layer).

... MtL-NAV — N.J.: MCH; WEN; MtL-NAV; RB

### GYRODES CRENATA Conrad (?) — Pl. 6, Fig. 1

*...crenata* Conrad, 1860, Acad. Nat. Sci. Philadelphia Jour., 2nd ser., vol. 4, p. 289. ... p. 685, pl. 77, figs. 10-12.]

...tatively referred to this species.

...CH — N.J.: MCH; WBY; WEN

### XENOPHORA LEPROSA Morton

*Trochus leprosa* Morton, 1834, Synop. Org. Rem. Cret. Gr. U. S., p. 46, pl. 15, fig. 6. [Weller, p. 690, pl. 68, figs. 1-3; Gardner, p. 495.]

Reported by Carter from the "Crosswicks".

Del.: MCH — N.J.: MtL-NAV

### ENDOPTYGMA UMBILICATA Tuomey

*Phorus umbilicatus* Tuomey, 1855, Acad. Nat. Sci. Philadelphia Proc., vol. 7, p. 169. [Weller, p. 692, pl. 78, figs. 4-6.]

Spoil bank (station 1A).

Del.: MCH — N.J.: MCH

### TURRITELLA ENCRINOIDES Morton — Pl. 6, Fig. 2

*T. encrinoides* Morton, 1834, Synop. Org. Rem. Cret. Gr. U. S., p. 47, pl. 3, fig. 7. [Weller, p. 694, pl. 77, figs. 10-13; Gardner, p. 492.]

Internal casts, possibly this species, were found at the spoil bank (station 1A). Better preserved specimens at station 3, lower layer, and east of Lorwood Grove.

Del.: MCH; WEN; MtL-NAV — N.J.: MtL-NAV

### TURRITELLA QUADRILIRA Johnson — Pl. 6, Fig. 3

*T. quadrilira* Johnson, 1898, New Jersey Geol. Survey Ann. Rept. for 1897, p. 264. [Weller, p. 695, pl. 78, fig. 7.]

Reported by Carter from the "Crosswicks".

Del.: MCH — N.J.: MAG; WBY

### TURRITELLA MERCHANTVILLENSIS Weller

*T. merchantvillensis* Weller, 1907, New Jersey Geol. Survey Paleontology, vol. 4, p. 704, pl. 79, fig. 13.

Reported by Carter from the "Crosswicks".

Del.: MCH — N.J.: MCH

### TURRITELLA MARSHALLTOWNENSIS Weller

*T. marchalltownensis* Weller, 1907, New Jersey Geol. Survey Paleontology, vol. 4, p. 705, pl. 79, fig. 14.

Reported by Carter from the Marshalltown.

Del.: ? — N.J.: MARSH

### LAXISPIRA LUMBRICALIS Gabb

*L. lumbricalis* Gabb, 1876, Acad. Nat. Sci. Philadelphia Proc., p. 301. [Weller, p. 706, pl. 81, figs. 1-2; Gardner, p. 485.]

Reported by Carter from the "Crosswicks".

Del.: MCH — N.J.: MCH; WBY

### CERITHIUM PILSBRYI Whitfield

*C. pilsbryi* Whitfield, 1893, The Nautilus, vol. 7, pp. 38, 51, pl. 2, fig. 3. [Weller, p. 708, pl. 81, figs. 3-5; Gardner, p. 481.]

Rare at the spoil bank (station 1A).

Del.: MCH — N.J.: MCH



### ANCHURA ROSTRATA Gabb

*Rostellaria rostrata* Gabb, 1860, Acad. Nat. Sci. Philadelphia Jour., 2nd ser., vol. 4, p. 390, pl. 68, fig. 7. [Weller, p. 709, pl. 81, figs. 7-9; Gardner, p. 471.]

Spoil bank (station 1A) and 1/8 mile west of Summit Bridge (Gardner).

Del.: MCH — N.J.: MCH; WBY; WEN

### ANCHURA PENNATA Morton

*Rostellaria pennata* Morton, 1834, Synop. Org. Rem. Cret. Gr. U. S., p. 48, pl. 19, fig. 9. [Weller, p. 711, pl. 81, figs. 10-17; Gardner, p. 472.]

Biggs Farm (station 6).

Del.: MtL-NAV — N.J.: MtL-NAV

### ANCHURA SOLITARIA Whitfield

*A. solitaria* Whitfield, 1892, New Jersey Geol. Survey Paleontology, vol. 2, p. 117, pl. 14, fig. 9. [Weller, p. 714, pl. 81, fig. 6.]

Found on the beach east of Lorwood Grove associated with Navesink species.

Del.: MtL-NAV (?) — N.J.: MCH

### ANCHURA JOHNSONI Stephenson

*A. johnsoni* Stephenson, 1923, North Carolina Geol. and Econ. Survey, vol. 5, p. 370, pl. 92, figs. 1, 4.

Reported by Carter from the "Crosswicks".

Del.: MCH — N. J.: WBY (?)

### ANCHURA ABRUPTA Conrad — Pl. 6, Fig. 10

*A. abrupta* Conrad, 1860, Acad. Nat. Sci. Philadelphia Jour., 2nd ser., vol. 4, p. 284, pl. 47, fig. 1. [Weller, p. 715, pl. 82, figs. 1-6; pl. 83, figs. 3-4.]

Incomplete specimens of this large *Anchura* have been found near the Railroad bridge (station 2).

Del.: MtL-NAV — N.J.: MtL-NAV

### NAPULUS OCTOLIRATUS Conrad — Pl. 6, Fig. 8

*[illegible]s octoliratus* Conrad, 1858, Acad. Nat. Sci. Philadelphia Jour., 2nd ser., vol. 3, [illegible]2, pl. 35, fig. 6. [Weller (*Pyropsis*), p. 751, pl. 88, figs. 17-19.]

[illegible] specimen at station 6.

Del.: MtL-NAV — N.J.: WBY

### NAPULUS RICHARDSONI Tuomey — Pl. 6, Fig. 9

*[illegible]ula richardsoni* Tuomey, 1854, Acad. Nat. Sci. Philadelphia Proc., vol. 7, p. 169. [Weller, p. 739, pl. 86, figs. 2-5.]

[illegible] station 2 (Carter's collection).

[illegible] MtL-NAV — N.J.: MCH; MtL-NAV

### VOLUTOMORPHA Sp.

[illegible] Farm; poorly preserved.

**VOLUTOMORPHA DELAWARENSIS Gabb** **Pl. 6, Fig. 5**

*V. delawarensis* Gabb, 1861, Acad. Nat. Sci. Philadelphia Proc., p. 322.

Originally described from the Chesapeake and Delaware Canal; found during the present survey in the Merchantville (Crosswicks) near the Railroad bridge.

Del.: MCH N.J.: MCH (?)

**VOLUTOMORPHA CONRADI Gabb** **Pl. 6, Fig. 6**

*Volutilithes conradi* Gabb, 1860, Acad. Nat. Sci. Philadelphia Jour., 2nd ser., vol. 4, p. 300, pl. 48, fig. 10. [Weller, p. 780, pl. 92, figs. 6-7; pl. 93, figs. 1-3; pl. 94, figs. 1-6; Gardner, p. 427, pl. 15, fig. 8.]

Spoil bank (station 1A) and near station 2 (Carter's collection).

Del.: MCH; MtL-NAV N.J.: MAG; MtL-NAV

**PIESTOCHILUS BELLA Gabb** **Pl. 6, Fig. 4**

*Volutilithes bella* Gabb, 1860, Acad. Nat. Sci. Philadelphia Jour., 2nd ser., vol. 4, p. 300, pl. 48, fig. 7. [Weller, p. 782, pl. 96, figs. 1-4; pl. 92, figs. 4-5; Gardner, p. 441.]

Reported by Gardner 2 miles west of Delaware City.

Del.: MtL-NAV N.J.: MtL-NAV

**ROSTELLITES NASUTUS Gabb**

*Volutilithes nasuta* Gabb, 1860, Acad. Nat. Sci. Philadelphia Jour., 2nd ser., vol. 4, p. 300, pl. 48, fig. 9. [Weller, p. 786, pl. 97, figs. 1-2; Gardner, p. 422.]

Del.: MtL-NAV N.J.: MCH; MtL-NAV

**AVELLANA BULLATA Morton** **Pl. 6, Fig. 7**

*Tornitella ? bullata* Morton, 1834, Synop. Org. Rem. Cret. Gr. U. S., p. 48, pl. 5, fig. 3. [Weller, p. 808, pl. 99, figs. 9-11; Gardner, p. 403.]

Reported by Gardner and Carter.

Del.: MtL-NAV N.J.: MCH; MtL-NAV

## SCAPHOPODA

**DENTALIUM SUBARCTUATUM Conrad**

*D. subarctuatum* Conrad, 1853, Acad. Nat. Sci. Philadelphia Jour., 2nd ser., vol. 2, p. 276, pl. 24, fig. 13. [Weller, p. 661, pl. 75, fig. 12.]

Spoil bank (station 1A).

Del.: MCH N.J.: MCH; WBY

**CADULUS OBNOTUS Conrad**

*Gadus obnotus* Conrad, 1869, Am. Jour. Conch., vol. 5, p. 101, pl. 1, fig. 18.

Reported from the "Crosswicks" by Carter.

Del.: MCH N.J.: WBY

## CEPHALOPODA

**BACULITES OVATUS Say** **Pl. 7, Fig. 6**

*B. ovatus* Say, 1820, Am. Jour. Sci., 1st ser., vol. 2, p. 41. [Weller, p. 821, pl. 99, fig. 5; Gardner, p. 375, pl. 12, figs. 2-3.]

Fairly common at the spoil bank (station 1) and rare at the Biggs Farm (station 6).

Del.: MCH; MtL-NAV N.J.: MCH; WBY; MtL-NAV



**MENABITES (DELAWARELLA) DELAWARENSIS Morton** **Pl. 7, Fig. 5**

*Ammonites delawarensis* Morton, 1830, Am. Jour. Sci., 1st ser., vol. 18, pl. 2, fig. 4. [Weller, p. 837, pl. 103, fig. 1; pl. 104, figs. 1-5; Gardner, p. 391, pl. 12, fig. 7 (*Mortoniceras*).]

Fragments of this large ammonite are fairly common in the spoil bank at station 1A. In the literature this species is generally referred to the genus *Mortoniceras*, but has recently been assigned to the genus *Menabites* by Collignon.

Del.: MCH N.J.: MCH

**EUTREPHOCERAS DEKAYI Morton**

*Nautilus dekayi* Morton, 1833, Am. Jour. Sci., 1st ser., vol. 23, p. 291, pl. 8, fig. 4. [Weller, p. 817, pl. 100, figs. 1-5; Gardner, p. 372, pl. 13, fig. 9.]

Stations 3 and 6.

Del.: MtL-NAV N.J.: MtL-NAV; RB

**SCAPHITES HIPPOCREPIS De Kay**

*Ammonites hippocrepis* DeKay, 1827, Ann. New York Lyc. Nat. Hist., vol. 2, pp. 273-77, pl. 5, fig. 2. [Weller, p. 826, pl. 107, figs. 3-6; Gardner, p. 382.]

A few specimens from the spoil bank (station 1A) and Biggs Farm (station 6).

Del.: MCH; MtL-NAV N.J.: MCH

**PLACENTICERAS PLACENTA De Kay**

*Ammonites placenta* DeKay, 1827, Ann. New York Lyc. Nat. Hist., vol. 2, p. 278, pl. 5, fig. 2. [Weller, p. 830, pl. 104, fig. 6; pl. 105, fig. 1; Gardner, p. 385, pl. 12A.]

Various fragments in spoil bank (station 1A).

Del.: MCH N.J.: MAG; MCH; WBY; MARSH; WEN

**HETEROCERAS CONRADI Morton**

*Ammonceratites conradi* Morton, 1841, Acad. Nat. Sci. Philadelphia Proc., vol. 1, p. 109. [Weller, p. 833, pl. 108, figs. 5-8.]

One specimen from Biggs Farm (Yale Univ.).

Del.: MtL-NAV N.J.: MtL-NAV

**BELEMNITELLA AMERICANA Morton** **Pl. 7, Figs. 1, 2**

*Belemnites americanus* Morton, 1830, Am. Jour. Sci., 1st ser., vol. 17, p. 28; vol. 18, pl. 1, figs. 1-3. [Weller, p. 839, pl. 109, figs. 1-4; Gardner, p. 394, pl. 12, figs. 4-6.]

This species is abundant in both the upper and lower layers at the Biggs Farm (station 6). It is probable that the slender form (fig. 2) is a distinct variety, but more details on the species must await the completion of a report by Dr. J. A. Jeletzky on the belemnites of New Jersey.*

Del.: MtL-NAV; RB N.J.: MtL-NAV

## CRUSTACEA

**HOPLOPARIA GABBI Pilsbry**

*. gabbi* Pilsbry, 1901, Acad. Nat. Sci. Philadelphia Proc., p. 115, pl. 1, figs. 11-14. eller, p. 846, pl. 110, figs. 12-15.]

ws are fairly common at the spoil bank (station 1A).

.: MCH N.J.: MCH

* be included in a report on the Cretaceous invertebrates of w Jersey in preparation by the Geological Survey of New Jersey.

### CALLIANASSA MORTONI Pilsbry — Pl. 7, Figs. 3, 4

*C. mortoni Pilsbry*, 1901, Acad. Nat. Sci. Philadelphia Proc., p. 112, pl. 1, figs. 1-7. [Weller, p. 849, pl. 111, figs. 1-15.]

Claws are common in concretions at the spoil bank (station 1A) and in place in the Merchantville formation ("Crosswicks") near the Railroad bridge.

Del.: MCH

N.J.: MCH; MtL-NAV; TIN

## INSERTAE SEDIS

### HALYMENITES MAJOR Lesquereux — Pl. 7, Fig. 7

*H. major* Lesquereux, 1873, U. S. Geol. Survey of the Territories, pt. 1, p. 373.

These tubes have been variously identified as worm tubes, mollusk borings and remains of plant origin. They are widespread in Cretaceous and Tertiary formations. Tubes, apparently this species, have been found in the Wenonah formation of New Jersey, especially near Runnemeade and Matawan, and in the Wenonah formation in the Chesapeake and Delaware Canal. Except for some thinner and more fragile tubes, in the Red Bank near the Railroad bridge (station 2A) probably also referable to *H. major*, no other such tubes have been observed in the Cretaceous deposits of New Jersey or Delaware.

Pl. 7, Fig. 8

Tubes, somewhat less corrugated than those of *H. major*, have been found in the Red Bank sand near the railroad bridge (station 2). These are somewhat similar to tubes found in the Red Bank and Tinton formations at Beers Hill, Monmouth County, New Jersey.

---

In addition various shark teeth, fish vertebrae, reptile bones and petrified wood have been found at various places along the canal.



## REFERENCES


Bascom, Florence, and Miller, B. L., 1920, U. S. Geol. Survey Geol. Atlas, Elkton-Wilmington folio (no. 211).

Berry, Edward W., 1906, Fossil plants along the Chesapeake and Delaware Canal: New York Bot. Garden Bull., vol. 7, pp. 5-7.

Booth, James C., 1841, Memoir of the Geological Survey of the State of Delaware; Including the application of the geological observations to agriculture, Dover.

Carter, Charles William, 1937, The Upper Cretaceous deposits of the Chesapeake and Delaware Canal: Maryland Geol. Survey, vol. 13, pp. 237-281.

Chester, Frederick D., 1884, Preliminary notes on the geology of Delaware; Laurentian, Paleozoic, and Cretaceous areas: Acad. Nat. Sci. Philadelphia Proc., vol. 84, pp. 237-259.

Clark, Wm. Bullock, 1892, A preliminary report on the Cretaceous and Tertiary formations of New Jersey with special reference to Monmouth and Middlesex Counties; New Jersey Geol. Survey Ann. Rept. for 1892, pp. 167-239.

———, 1894, Cretaceous and Tertiary geology; Report of Progress: New Jersey Geol. Survey Ann. Rept. for 1893.

———, 1895, Cretaceous deposits of the northern half of the Atlantic Coastal Plain: Geol. Soc. Amer. Bull., vol. 6, pp. 479-482.

———, 1904, The Matawan formation of Maryland, Delaware, and New Jersey, and its relations to the overlying and underlying formations: Johns Hopkins Univ. Studies in Geology, no. 172.

———, 1907, The classification adopted by the U. S. Geological Survey for the Cretaceous deposits of New Jersey, Delaware, Maryland, and Virginia: Johns Hopkins Univ. Studies in Geology, vol. 26, pp. 589-592.

———, 1916, The Upper Cretaceous deposits of Maryland: Maryland Geol. Survey Upper Cretaceous, pp. 23-105.

———, Bagg, R. M., and Shattuck, G. B., 1897, Upper Cretaceous formations of New Jersey, Delaware, and Maryland: Geol. Soc. Amer. Bull., vol. 8, pp. 315-358.

Cooke, C. Wythe, 1953, American Upper Cretaceous Echinoidea: U. S. Geol. Survey Prof. Paper 254A.

———, and Stephenson, L. W., 1928, The Eocene age of the supposed later Upper Cretaceous greensand marls of New Jersey: Jour. Geology, vol. 36, pp. 139-148.

Durand, Elias, 1832, On the green color and nature of the coloring agent of the water of the Delaware and Chesapeake Canal near the first lock of the Chesapeake side: Jour. Phila. Col. of Pharmacy, vol. 3, pp. 276-277.

Gabb, W. M., 1859, Description of some new species of Cretaceous fossils: Acad. Nat. Sci. Philadelphia Proc., 2nd series, vol. 4, pp. 300, 302, 303.

Gardner, Julia, 1916, Mollusca [of the Upper Cretaceous of Maryland]: Maryland Geol. Survey Upper Cretaceous, pp. 371-773.

Johnson, Meredith E., and Richards, Horace G., 1952, Stratigraphy of the Coastal Plain of New Jersey: Am. Assoc. Petroleum Geologists Bull., vol. 36, pp. 2150-2160.

Kummel, Henry B., 1940, The geology of New Jersey: New Jersey Geol. Survey Bull. 40.

———, and Knapp, G. N., 1904, The stratigraphy of the New Jersey clays: New Jersey Geol. Survey Final Rept., vol. 6, pp. 117-209.

Livermore, Daniel, and Dexter, A., 1829, A collection of fossil earths and minerals from the deep cut of the Delaware and Chesapeake Canal, with memoir and profile of geological strata developed in progress of work: Amer. Philos. Soc. Proc., vol. 22, p. 594.

Lyell, Charles, 1845, Notes on the Cretaceous strata of New Jersey and other parts of the United States bordering the Atlantic (Abstract): Am. Jour. Sci., vol. 47, pp. 213, 214.

Miller, Benjamin L., 1926, Kent County: Maryland Geol. Survey, pp. 66-70.

Morton, S. C., 1829, Description of the fossil shells which characterize the Atlantic Secondary Formation of New Jersey and Delaware; including four new species: Acad. Nat. Sci. Philadelphia Jour., vol. 6, pp. 72-100.

———, 1829, Additional observations of the geology and organic remains of New Jersey and Delaware: Acad. Nat. Sci. Philadelphia Jour., vol. 6, pp. 189-204.

Richards, Horace G., 1945, Subsurface stratigraphy of the Atlantic Coastal Plain between New Jersey and Georgia: Am. Assoc. Petroleum Geologists Bull., vol. 24, pp. 885-955.

———, 1950, Geology of the Coastal Plain of North Carolina: Trans. Amer. Philos. Soc., new series, vol. 40, part 1, pp. 1-83.

Roberts, D. E., 1895, Note on the Cretaceous formations of the Eastern Shore of Maryland: Johns Hopkins Univ. Circ. no. 121, vol. 40, p. 16.

Salisbury, R. D., 1899, Surface geology: New Jersey Geol. Survey Ann. Rept. for 1898, pp. 1-41.

Shattuck, George B., 1902, The geology of the Coastal Plain Formation: Maryland Geol. Survey Cecil County, pp. 157-163.

Spangler, Walter B., and Peterson, Jahn J., 1950, Geology of Atlantic Coastal Plain in New Jersey, Delaware, Maryland, and Virginia: Am. Assoc. Petroleum Geologists Bull., vol. 24, pp. 1-100.

Stephenson, L. W., 1923, The Cretaceous formations of North Carolina: North Carolina Geol. and Econ. Survey, vol. 5.

———, 1933, The zone of *Exogyra cancellata* traced twenty-five hundred miles: Am. Assoc. Petroleum Geologists Bull., vol. 17, pp. 1351-61.

———, Cooke, C. Wythe, and Mansfield, Wendell C., 1932, Chesapeake Bay region: Sixteenth International Geol. Cong. Guidebook 5, Washington.

———, King, Philip B., Monroe, Watson H., Imlay, R. W., 1942, Correlation of the outcropping Cretaceous formations of the Atlantic and Gulf Coastal Plain and Trans-Pecos Texas: Geol. Soc. of America Bull., vol. 53, pp. 435-448.

Vanuxem, Lardner, 1829, Geological observations on Secondary, Tertiary, and Alluvial formations of the Atlantic coast of the United States of America; Arranged from the notes of Lardner Vanuxem by S. G. Morton: Acad. Nat. Sci. Philadelphia Jour., vol. 6, pp. 189-204.

Weller, Stuart, 1907, A report on the Cretaceous paleontology of New Jersey: New Jersey Geol. Survey, vol. 4, Paleontology series.

## PLATE 3

Fig. 1 *Cliona cretacica* Fenton and Fenton on *Exogyra* sp. (x1)
Station 2, Mount Laurel-Navesink formation. ANSP[1]

Fig. 2 *Faujasia geometricus* (Morton) (x1)
Station 3, Wenonah formation. DGS[2]

Fig. 3 *Gervilliopsis ensiformis* (Conrad) (x1)
Station 1A, Merchantville. USGS[3]

Fig. 4, 5 *Cucullaea neglecta* Gabb (x1)
Station 2, Mount Laurel-Navesink formation. ANSP

Fig. 6 *Cucullaea vulgaris* Morton (x1)
Station 1A, Merchantville formation. ANSP

Fig. 7 *Glycymeris mortoni* (Conrad) (x5/8)
Station 1A, Merchantville formation. ANSP

Fig. 8 *Inoceramus proximus* Tuomey (x1)
Station 2, Wenonah formation. ANSP

Fig. 9 *Inoceramus ? perovalis* Conrad (x1)
Chesapeake and Delaware Canal. ANSP

Fig. 10 *Pteria laripes* (Morton) (x1)
Chesapeake and Delaware Canal. ANSP

Fig. 11 *Pulvinites argenteus* (?) Conrad (x1)
Station 1A, Merchantville formation. USGS

Fig. 12 *Ostrea monmouthensis* Weller (?) (x1)
2000 feet west of St. Georges, Mount Laurel-Navesink formation. USGS

Fig. 13 *Ostrea falcata* Morton (x1)
Station 4, Mount Laurel-Navesink formation. DGS

Fig. 14 *Ostrea mesenterica* Morton (x1½)
Station 6, Mount Laurel-Navesink formation. JHU[4]

1. Academy of Natural Sciences of Philadelphia
2. Delaware Geological Survey
3. U. S. Geological Survey
4. Johns Hopkins University



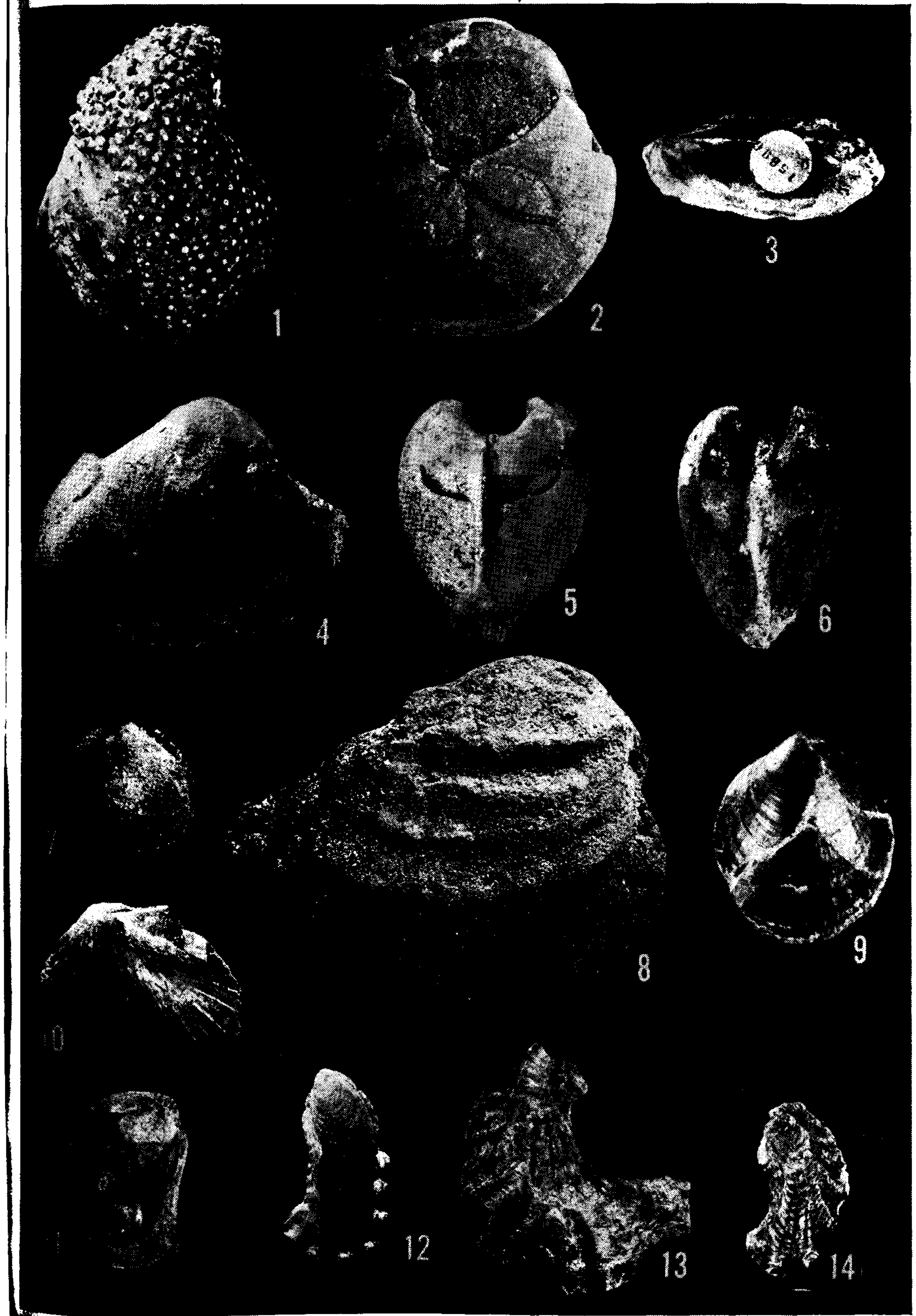
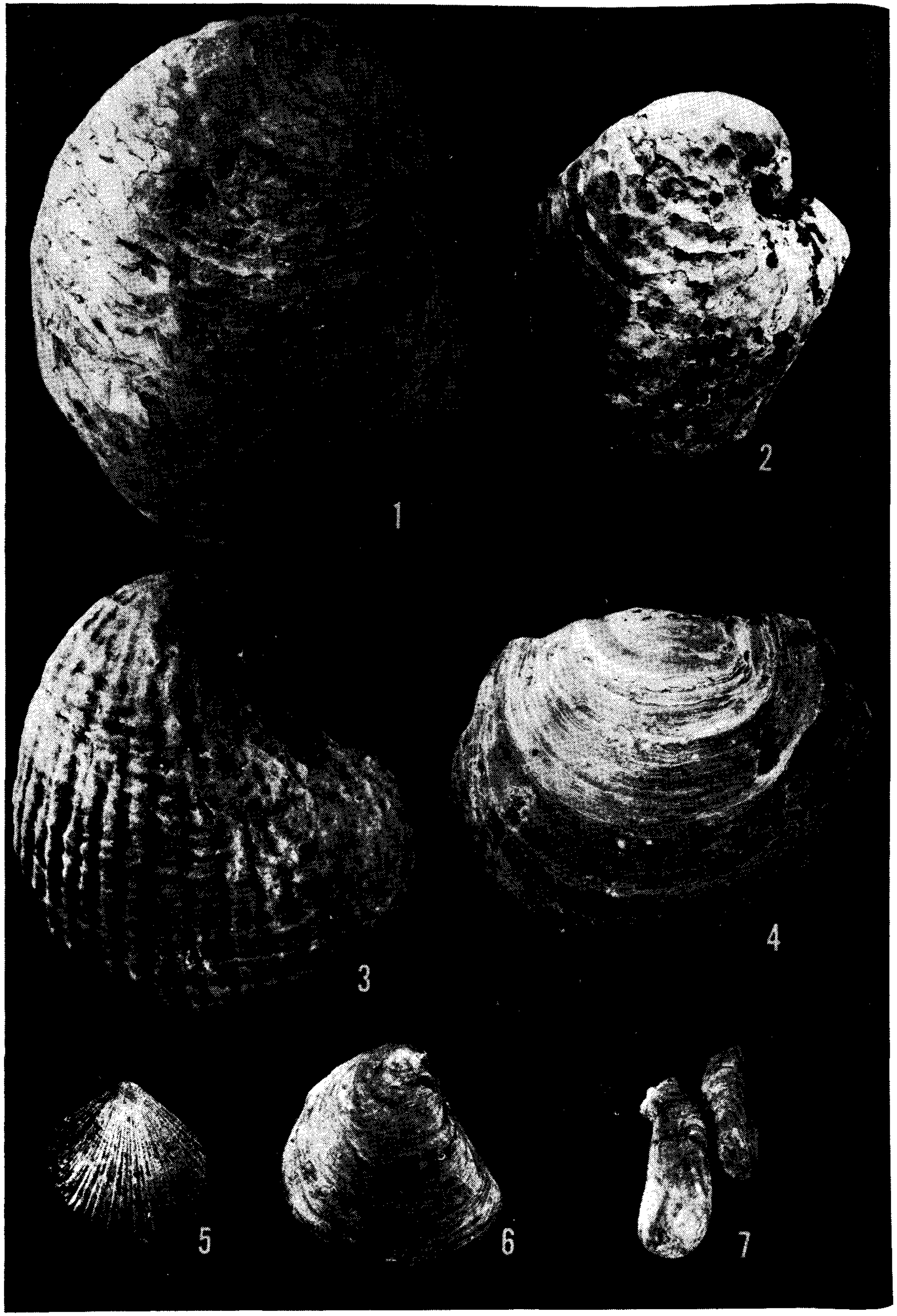



Plate 3




## PLATE 4

Fig. 1 *Exogyra ponderosa* Roemer (x½)

North bank between Railroad bridge and Station 3, Marshalltown formation. DGS[1]

Fig. 2 *Exogyra cancellata* Stephenson (x½)

Station 3, Mount Laurel-Navesink formation. DGS

Fig. 3 *Exogyra costata* Say (x1)

Briar Point, Mount Laurel-Navesink formation. JHU[2]

Fig. 4 *Gryphaea mutabilis* Morton (x½)

Station 3, Mount Laurel-Navesink formation. DGS

Fig. 5 *Pecten whitfieldi* Weller (x2)

Station 4, Mount Laurel-Navesink formation. ANSP[3]

Fig. 6 *Anomia tellinoides* Morton (x1)

Station 6, Mount Laurel-Navesink formation. JHU

Fig. 7 *Lithophaga ripleyana* Gabb (x1½)

Near Lorwood Grove, Mount Laurel-Navesink formation. JHU

---

1. Delaware Geological Survey
2. Johns Hopkins University
3. Academy of Natural Sciences of Philadelphia

## PLATE 5

Fig. 1 *Pholadomya occidentalis* Morton (x1)
Near Station 1A, Merchantville. JHU[1]

Fig. 2 *Liopistha protexta* (Conrad) (x1)
Station 2, Mount Laurel-Navesink formation. ANSP[2]

Fig. 3 *Cymella bella* Conrad var. (x3)
Station 1A, Merchantville formation. ANSP

Fig. 4 *Crassatella* sp.
Near Lorwood Grove, Mount Laurel-Navesink formation. JHU

Fig. 5, 6 *Cardium tenuistriatum* (Whitfield) (x1)
Station 2, Mount Laurel-Navesink formation. DGS[3]

Fig. 7 *Cardium* cf. *longstreeti* Weller (x2)
Station 1A, Merchantville formation?. USGS[4]

Fig. 8 *Linearia metastriata* Conrad (x1)
Station 1A, Merchantville formation. ANSP

Fig. 9 *Unicardium umbonata* (Whitfield) (x1)
1 1/3 miles west of St. Georges Bridge, Mount Laurel-Navesink formation. USGS

Fig. 10 *Corbula bisulcata* Gabb (x1½)
Station 6, Mount Laurel-Navesink formation. JHU

Fig. 11 *Panopea decisa* Conrad (x1)
Station 1A, Merchantville formation. USGS

Fig. 12 *Cyprimeria* cf. *excavata* (Morton) (x1)
Station 2, Mount Laurel-Navesink formation. ANSP

---

1. Johns Hopkins University
2. Academy of Natural Sciences of Philadelphia
3. Delaware Geological Survey
4. U. S. Geological Survey



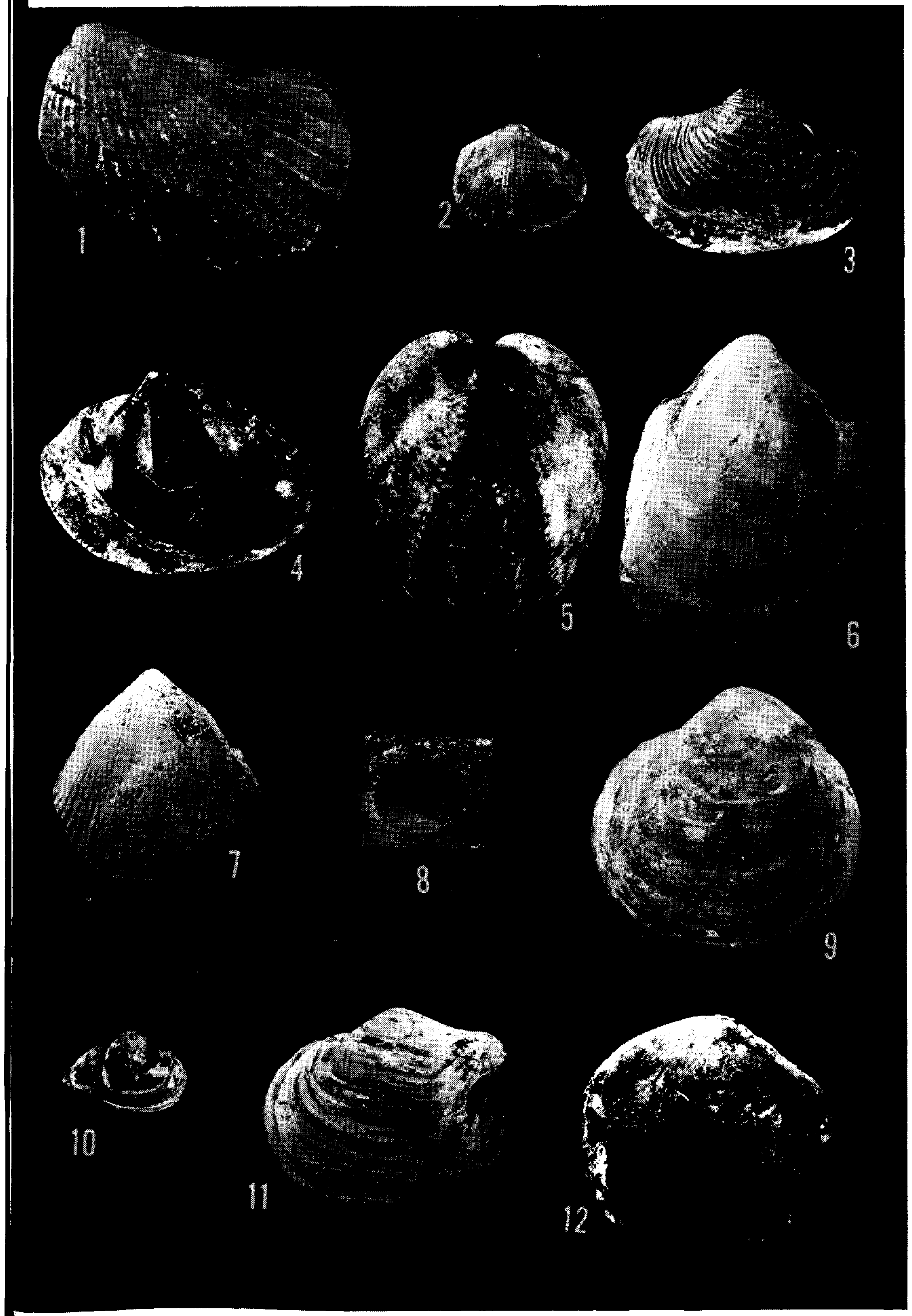
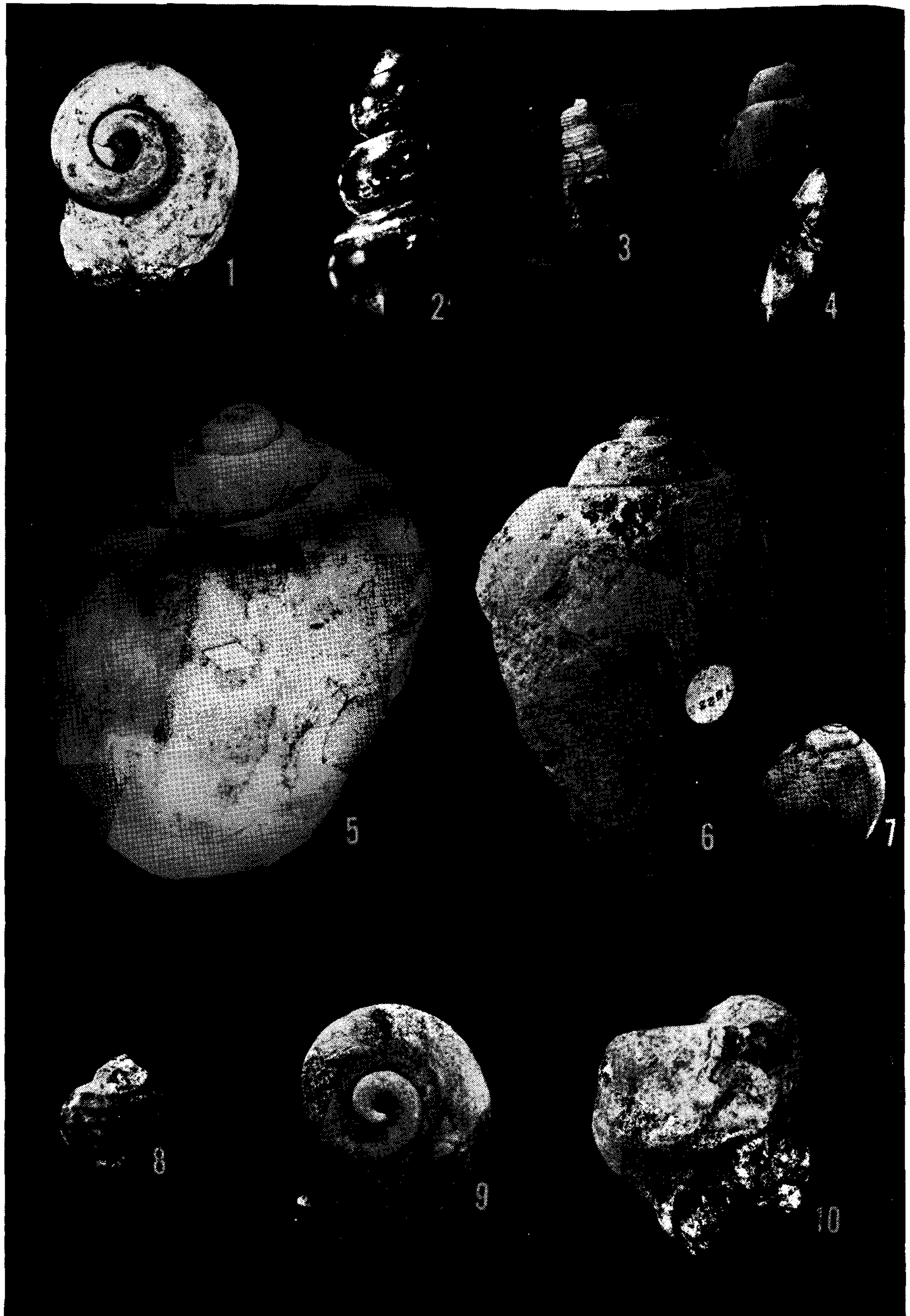



Plate 5




## PLATE 6

Fig. 1 *Gyrodes crenata* (Conrad) ? (x1)
Station 3, Mount Laurel-Navesink formation. ANSP[1]

Fig. 2 *Turritella encrinoides* Morton ? (x1½)
Station 4, Mount Laurel-Navesink formation. ANSP

Fig. 3 *Turritella quadrilira* Johnson (x2)
1 1/2 miles east of St. Georges Bridge, Mount Laurel-Navesink formation. USGS[2]

Fig. 4 *Piestochilus bella* (Gabb) (x1)
Station 1A, Merchantville formation. USGS

Fig. 5 *Volutomorpha delawarensis* Gabb (x1)
Chesapeake and Delaware Canal. ANSP

Fig. 6 *Volutomorpha conradi* (Gabb) (x1)
Near Station 1A, Merchantville. USGS

Fig. 7 *Avellana bullata* (Morton) (x1)
Near Station 2, Mount Laurel-Navesink formation. USGS

Fig. 8 *Napulus octoliratus* (Conrad) (x1½)
Station 4, Mount Laurel-Navesink formation. ANSP

Fig. 9 *Napulus richardsoni* (Tuomey) (x1)
Near Station 2, Mount Laurel-Navesink formation. DGS[3]

Fig. 10 *Anchura abrupta* Conrad? (x1)
Station 2, Mount Laurel-Navesink formation. DGS

---

1. Academy of Natural Sciences of Philadelphia
2. U. S. Geological Survey
3. Delaware Geological Survey

## PLATE 7

Fig. 1 *Belemnitella americana* (Morton) (x1)
Station 6, Mount Laurel-Navesink formation. ANSP[1]

Fig. 2 *Belemnitella americana* (Morton) (x1)
Marl pit 1 mile east of St. Georges, Mount Laurel-Navesink formation. JHU[2]

Fig. 3, 4 *Callianassa mortoni* Pilsbry (x1)
Station 2, Merchantville formation. DGS[3]

Fig. 5 *Menabites delawarensis* (Morton) (x1)
Station 1A, Merchantville formation. ANSP

Fig. 6 *Baculites ovatus* Say (x1)
Station 1A, Merchantville formation. ANSP

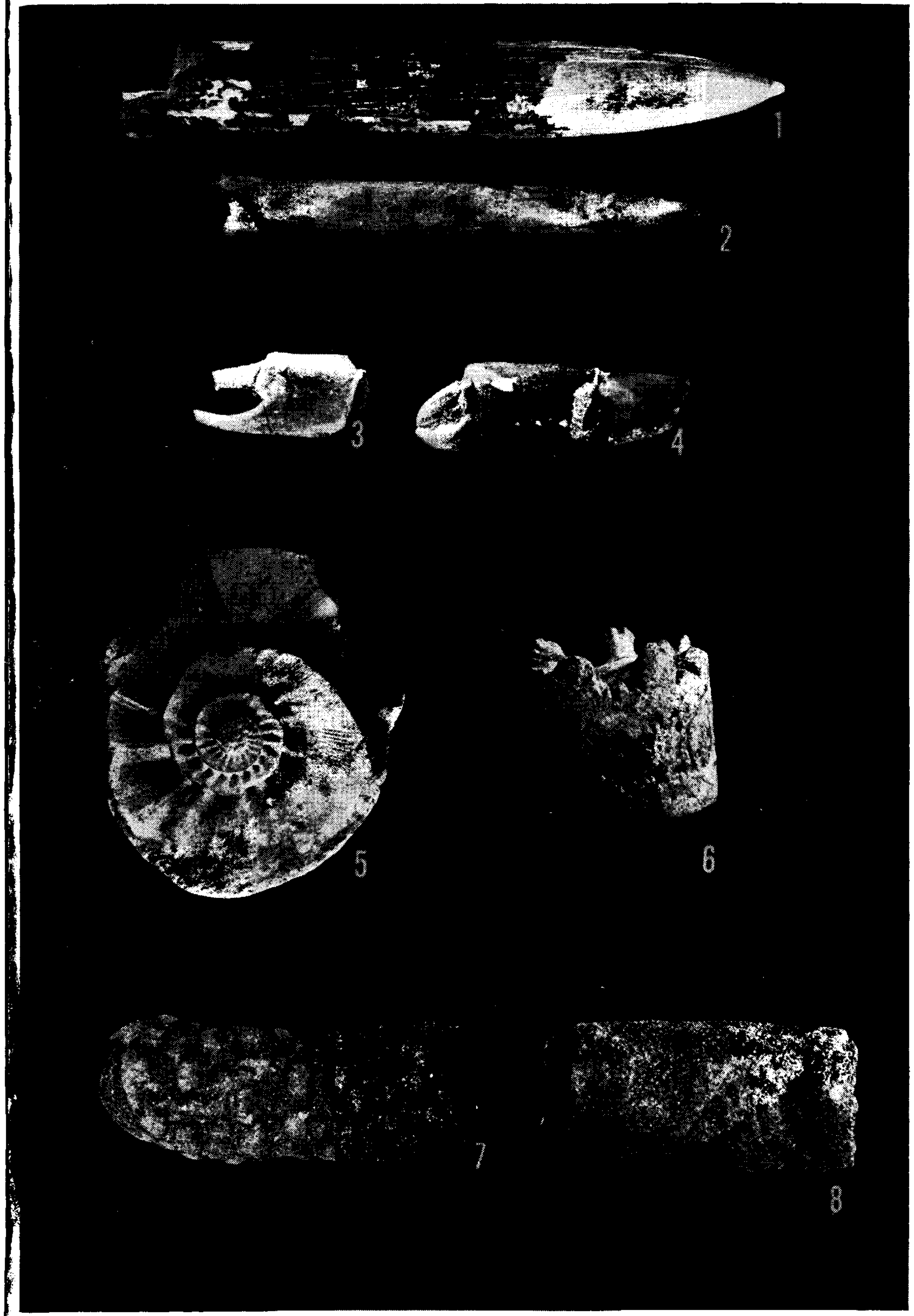
Fig. 7 *Halymenites major* Lesquereux (x1)
Station 3, Wenonah formation. ANSP

Fig. 8 Tube (x1)
Station 2, Red Bank formation. ANSP

---

1. Academy of Natural Sciences of Philadelphia
2. Johns Hopkins University
3. Delaware Geological Survey





# Third Annual Report
# of the
# Delaware Geological Survey
# 1953 - 1954

Geological work is time-consuming, and the results of geological and ground-water studies, although of immediate use, become increasingly beneficial as time goes on and more and more data are accumulated. The Delaware Geological Survey, which began its work three years ago, has now gathered sufficient data to make interpretations of the geology and ground-water resources of parts of the State possible. Since it is the Survey's duty to make these data, and their interpretation, available to all people of Delaware, the Survey is happy to have published Bulletin No. 2, *Geology and Ground-Water Resources of the Newark Area*, and Bulletin No. 3, *The Marine Upper Cretaceous Formations of the Chesapeake and Delaware Canal.* Other publications are scheduled to appear in the near future.

In addition to the preparation of these publications, the Survey answered numerous requests for data, primarily with regard to obtaining ground-water supplies for domestic, industrial and irrigation use. Requests for rock samples from schools throughout the State were answered as promptly as possible. Members of the staff frequently gave talks to members of service clubs on subjects related to the Survey's work. The State Geologist made a study of the possible effects of additional diversion of water from the Delaware River by the City of New York on Delaware's ground-water resources and presented testimony in the U. S. Supreme Court relative to this problem. Meetings were held with representatives of the Corps of Engineers, U. S. Army, in order to safeguard ground-water supplies in the vicinity of the Chesapeake and Delaware Canal against possible future salt water encroachment when the widening and deepening of this Canal takes place and, simultaneously, pumpage of ground water increases with further industrialization of the area.

The program of investigations which is being carried out by the Survey at present includes:

1. a project on the sedimentary petrology of New Castle County designed to facilitate further ground-water studies;

2. a ground-water program in cooperation with the U. S. Geological Survey consisting of:

    a. the continued collection of water-well data throughout Delaware;

    b. a study of the ground-water resources of Sussex County involving the determination of water use and the main sources of water supply in the area.

3. a program designed to discover the presence of sand, gravel, and rock materials north of the Chesapeake and Delaware Canal in cooperation with the State Highway Department and the U. S. Geological Survey.

## Survey Publications

Bulletin No. 1 Ground-Water Problems in Highway Construction and Maintenance by William C. Rasmussen and Leon B. Haigler, 1953.

Bulletin No. 2 Geology and Ground-Water Resources of the Newark Area, Delaware by Johan J. Groot and William C. Rasmussen, 1954.

Bulletin No. 3 Marine Upper Cretaceous Formations of the Chesapeake and Delaware Canal by Johan J. Groot, Donna M. Organist, and Horace G. Richards, 1954.

First Annual Report, 1951-1952 (out of print)

Second Annual Report, 1952-1953

Third Annual Report, 1953-1954 In Bulletin No. 3.

Water Level Report No. 1 Water Levels and Artesian Pressures in Delaware — 1952 by I. W. Marine, 1954.

To be published in the near future:

Bulletin No. 4 Preliminary Report on the Geology and Ground-Water Resources of Delaware by I. W. Marine and William C. Rasmussen.

Water Level Report No. 2 Water Levels and Artesian Pressures in Delaware — 1953 by D. H. Boggess and O. J. Coskery.



ERRATA

page 12, paragraph 11, line 2

Hazlet Sands (Wenonah)

read: Hazlet Sands (Englishtown

page 42

GERVILLIPOSIS ENSIFORMIS Conrad

read: GERVILLIOPSIS ENSIFORMIS Conrad