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CHARLES D. WALCOTT, DIRECTOR

THE EOCENE DEPOSITS

OF THE

MIDDLE ATLANTIC SLOPE

IN

DELAWARE, MARYLAND, AND VIRGINIA

BY

WILLIAM BULLOCK CLARK

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DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Baltimore, Md., February 20, 1896.

SIR: I have the honor to transmit herewith the manuscript of a report upon the Eocene deposits of the Middle Atlantic Slope in Delaware, Maryland, and Virginia, which has been prepared at your request. It is presented with a view to its publication as a bulletin.

Respectfully, yours,

WILLIAM BULLOCK CLARK.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

PREFACE.

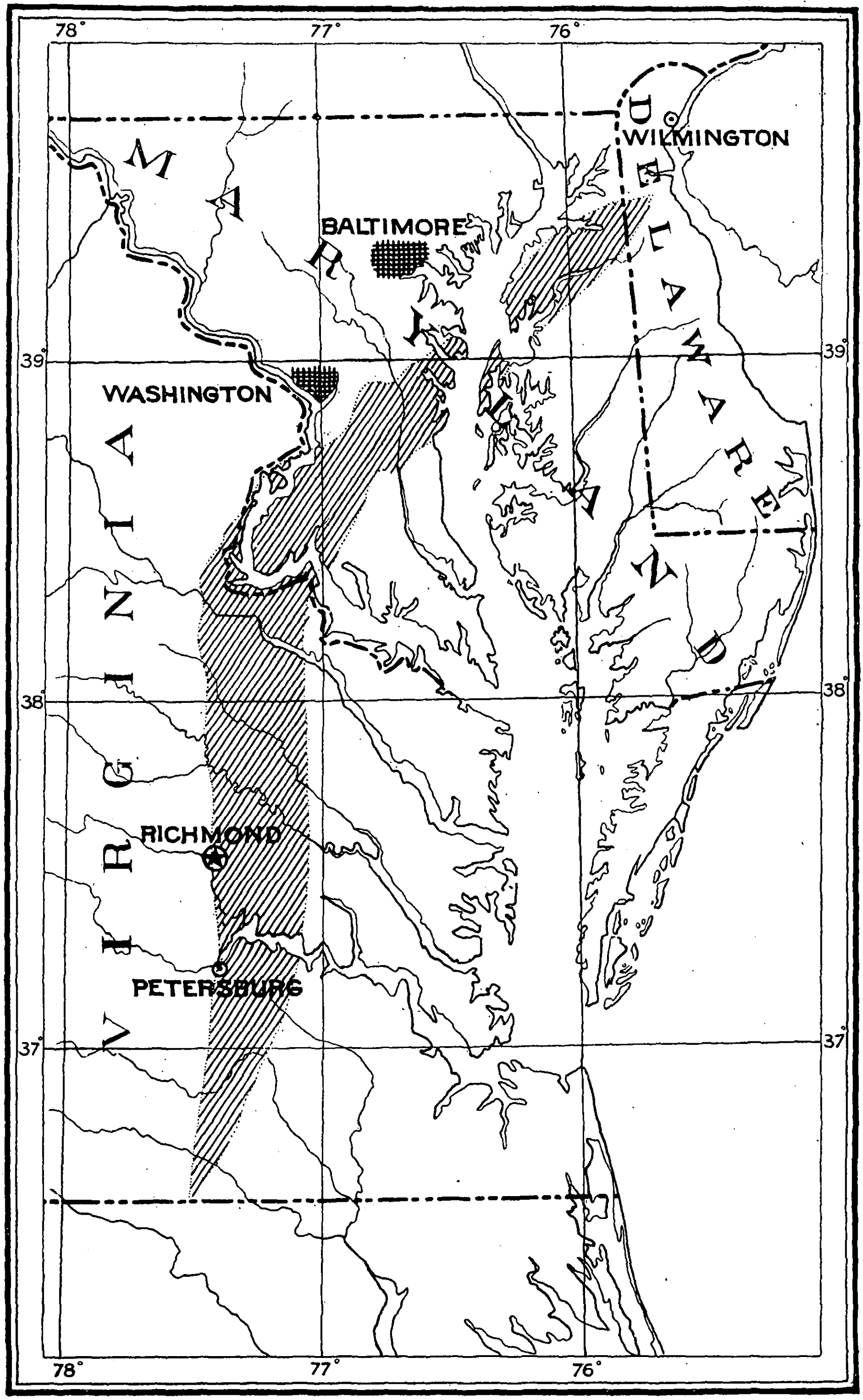
Our knowledge of the Tertiary geology and paleontology of the Middle Atlantic Slope has been largely increased since the days of Conrad and Rogers, yet few fields afford better opportunities for continued observation, and in none is there greater need of a careful revision of results. Very divergent opinions have prevailed and to-day find expression in the different interpretations of the data.

Both the Eocene and the Neocene divisions of the Tertiary in this area have broad surface exposures and are represented by characteristic sections along the leading waterways. Both are also highly fossiliferous, although the Miocene shows a greater diversity of forms than does the Eocene. The difference, however, is not so great as one would infer from a perusal of the literature, since a large number of Eocene species, many of them very common, have been unrecognized, or at least unrecorded.

It is the object of the present report to critically review the characteristics of the Eocene of the Middle Atlantic Slope as represented in the States of Delaware, Maryland, and Virginia. Extensive collections of material were made preparatory to this work, and all the leading fossiliferous localities from central Delaware to the valley of the James River in southern Virginia were visited. The greater amount of material was, however, obtained from the bluffs along the banks of the Potomac River, which afford the finest section of the Eocene in the Middle Atlantic Slope. In general the fossils of this region are difficult of removal, as they readily crumble at the touch, so that some process of hardening must be employed to permanently preserve them. To this fact more than to any other cause has been due the small size of the collections of Eocene specimens found in the various museums of the country as compared with the collections of Neocene forms from the same area. Outside of the collections of the United States National Museum, the Academy of Natural Sciences of Philadelphia, and the Johns Hopkins University very few specimens are found, and the forms figured and described in this report have come, with scarcely an exception, from the museums of these institutions. The collection of the Academy of Natural Sciences of Philadelphia contains several of Dr. Conrad's types, which have been most important in definitely determining the species hitherto described.

The writer desires to express his thanks to Prof. E. D. Cope, of the University of Pennsylvania, for many important suggestions regarding the Vertebrata; to Dr. W. H. Dall, of the United States Geological Survey, who kindly examined many of the determinations of the Mollusca and offered much valuable advice; to Mr. T. Wayland Vaughan, of the United States Geological Survey, who has prepared the chapter relating to the Corals; and to Dr. R. M. Bagg, who is chiefly responsible for the division upon Foraminifera. The accuracy of the determinations has been much enhanced by the cooperation which has been obtained from these several sources.

To Mr. H. C. Hunter, who has made most of the drawings, the writer is under especial obligation. The value of the report has been much enhanced through his skill.



MAP SHOWING DISTRIBUTION OF EOCENE STRATA IN MIDDLE ATLANTIC SLOPE.

THE EOCENE DEPOSITS OF THE MIDDLE ATLANTIC SLOPE.

By William Bullock Clark.

INTRODUCTION.

Much interest has been manifested in the Coastal Plain geology and paleontology of the Middle Atlantic Slope since the very beginning of geological investigation in this country. Many of the most potent illustrations of the older geologists were drawn from this region, and although the relations of the deposits were not altogether comprehended, yet the recorded observations show an appreciation of many of the more difficult problems involved. Later, as the complicated geological history of the Coastal Plain became better known, it was recognized that, if a full understanding of any single formation was to be gained, it was necessary to carefully study not only its lithological and paleontological characteristics but also its relationship to the other members of the series. It was seen that only by an understanding of the broad conditions affecting the whole district could the strata of any one formation be properly interpreted. Recognizing this fact, the writer presents in the later pages a brief discussion of the general relations of the strata composing the Coastal Plain in the Middle Atlantic Slope.

When we come to consider that assemblage of deposits early separated as the Tertiary, we find that it is divisible into several distinct formations. Even at a relatively early date an older and a younger Tertiary were already established, the former being correlated with the Eocene of England and the European continent. Attempts were made then and later to find its exact equivalent in one or another of the already established local formations of the English or continental series, but with very unsatisfactory results.

After the American Eocene strata had received detailed examination in the various sections of the country and local divisions had been established, attempts were made from time to time to determine their equivalency. By common consent the diversified and extensive deposits of the Gulf area came to be regarded as the type for the eastern border region, and the various Eocene deposits of the Atlantic Coast States were assigned to positions in this series. Some authors, recognizing the presence of a few identical species, have referred the strata now under consideration to a single minor division in the scale, while others have regarded the Maryland-Virginia deposits as representing a larger portion of the Gulf series. After a careful consideration of both the paleontological and the geological data, the writer deems the latter conclusion the only tenable one.

In this field attention has been devoted in the past too exclusively to supposed faunal similarities, upon the most insufficient knowledge of the forms, and too little to the character of the sedimentation. Important as the former are when the fauna has been fully investigated, and the writer would be far from disparaging that importance, yet the widely different physical conditions surrounding the accumulation of the deposits in the two areas must at the same time be regarded. Change in a fauna is not to be measured by the time standard alone, but also by the conditions of life, whether constant or variable, to which the forms may be subjected. Persistent conditions must of necessity have less effect than those which are changing. A satisfactory correlation of the strata in districts so widely separated as the Middle Atlantic Coastal Plain and the Gulf region can be attained only by a proper appreciation of the bearing of this factor upon faunal development.

In the Middle Atlantic Slope the very homogeneous nature of the Eocene deposits is a characteristic feature, indicating that throughout the period of deposition the conditions were undisturbed by important physical changes. The fact that the deposits are made up largely of secondary material shows in a general way that the accumulation took place near a coast reached by few large sediment-bearing rivers, and that at the same time the place of deposition was sufficiently removed from the coast line to be unaffected by shore conditions. In the Gulf region, on the other hand, deposition was more rapid, since a great quantity of detrital material was brought to the sea by the large streams draining the interior of the continent. The bearing of these different physical conditions upon the interpretation of the two areas and the correlation of their deposits will be fully considered in the body of the report.

The materials of the Eocene of the Middle Atlantic Slope, which are so largely glauconitic, are of no little interest in themselves outside of their bearing upon the question of correlation, since few areas afford such extensive deposits of greensand. On that account alone they deserve special consideration, and a chapter will be devoted to this phase of the subject.

The description of new species of fossils is of little scientific importance to the geologist unless the object is something other than the mere multiplication of new forms, which has too often been the case in such investigations. When, however, the work has in view the fullest possible representation of a fauna or the clearing up of doubtful points in the synonymy of already described species, as well as a more complete knowledge of their geological and geographical ranges, it becomes of the very greatest value, since one whole class of important criteria for the interpretation of the strata is thus made accessible. The present report includes the results of such an exhaustive study of the fauna of the Eocene of the Middle Atlantic Slope, together with a critical review of the species described by previous authors as well as the description of a large number of new forms. It is believed that a much more accurate idea of the faunal characteristics, as well as of the physical conditions prevailing during the Eocene period on the Middle Atlantic Coast, will result from the methods pursued in this investigation. Certainly the data for the comparison of the fauna with those of other areas will be greatly augmented. The greater portion of the report will be devoted to this phase of the subject.

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CLARK, WILLIAM B. On three geological excursions made during the months of October and November, 1887, into the southern counties of Maryland. Johns Hopkins University Circulars, Vol. VII, 1888, pp. 65–67.

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The author describes the Eocene section of the Potomac River valley in Maryland and Virginia.

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Much the same areas are described in this report as in the preceding paper.

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The author gives a digest of the literature of the Eocene of the Middle Atlantic Slope, as well as a description of the deposits. Correlation is made with the lower and middle divisions of the Gulf series.

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In this report the author gives a description of the Eocene of Maryland.

—— The climatology and physical features of Maryland. First Biennial Report Maryland State Weather Service, 1894, pp. 38–39.

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CLARK, WILLIAM B. Contributions to the Eocene fauna of the Middle Atlantic Slope. Johns Hopkins University Circulars, Vol. XV, 1895, pp. 3-6.

This article contains a list and discussion of the entire Eocene fauna of Maryland and Virginia, with the description of 32 new species. The part upon Corals is prepared by Vaughan, that upon Foraminifera by Bagg.

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The author defines the limits of the "alluvial deposits" and in general terms describes their lithological character.

CONRAD, T. A. On the geology and organic remains of a part of the peninsula of Maryland. Jour. Acad. Nat. Sci., Philadelphia, Vol. VI, 1830, pp. 205-217.

Reference is made to the deposits of Fort Washington and Piscataway, Md., and correlation proposed with London Clay of England. The paper also contains original descriptions of *Monodonta glandula*, *Turritella mortoni*, *Cucullæa gigantea*, and *Crassatella alæformis* from this region.

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The author regards the deposits in the vicinity of Fort Washington, Md., as "Middle Tertiary," and correlates them with the London Clay, Calcaire grossier, and Claiborne beds. He also describes *Cardita planicosta* and *Turritella mortoni* from Piscataway, Md.

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Mention is made of the deposits of Fort Washington, Md., which are considered younger than the strata at Claiborne, Ala., perhaps Miocene in age.

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The deposits at Upper Marlboro and Piscataway, Md., and City Point, Va., are considered, and *Panopæa elongata* and *Turritella humerosa* from Piscatway described.

—— On the Silurian system, with a table of the strata and characteristic fossils. Observations on the Plastic Clay. Am. Jour. Sci., Vol. XXXVIII, 1840, pp. 91-92.

The author discusses the relations of the Plastic Clay to the fossiliferous deposits at Piscataway, Md., which it is regarded in some instances to overlie.

—— Observations on a portion of the Atlantic Tertiary region, with a description of new species of organic remains. Proc. Nat. Inst. Prom. Sci., second bulletin, 1842, pp. 171-194.

The deposits of Upper Marlboro, Piscataway, and Fort Washington, Md., are referred to the Eocene or Lower Tertiary, and at the same time correlated with the London Clay, Calcaire grossier, Claiborne beds, etc. The author also describes *Ostrea sellæformis* from City Point, Va., and *Pholadomya marylandica* and *Pholas petrosa* from Piscataway, Md.

CONRAD, T. A. Observations on the Eocene formation of the United States, with descriptions of species of shells, etc., occurring in it. Am. Jour. Sci., second series, Vol. I, 1846, pp. 209–220, 395–405, pls. 1–4.

The article contains descriptions of *Pholas petrosa, Pholadomya marylandica, Panopæa elongata,* and *Crassatella alæformis* from Piscataway, and *Crassatella palmula* from Upper Marlboro, Md.

—— Observations on the Eocene formation and descriptions of 105 new fossils of that period from the vicinity of Vicksburg, Miss. Appendix: Descriptions of new Eocene fossils in the cabinet of Lardner Vanuxem. Jour. Acad. Nat. Sci., Philadelphia, second series, Vol. I, 1848, pp. 128–134, pl. 14.

The author considers the Maryland and Virginia deposits as "Lower or older Eocene" and correlates them with the "fossiliferous sand of Claiborne and St. Stephens, Ala.," etc., chiefly from the presence of *O. sellæformis.* He also describes *Cytherea subimpressa, C. lenis, C. liciata, C. eversa,* and *Nucula improcera* from Hanover County, Va.; *Cytherea pyga* from Stafford County, Va., and *Nucula parilis* from Upper Marlboro, Md.

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The author describes *Latiarca idonea,* but gives no locality.

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The physical history during the Eocene period is briefly referred to, and the relationship of the deposits to earlier and later formations is stated.

DARTON, N. H. Artesian-well prospects in eastern Virginia, Maryland, and Delaware. Trans. Am. Inst. Min. Eng., 1894, pp. 1-26.

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—— The artesian well at Fort Monroe, Va. The Virginias, Vol. III, 1882, pp. 18-19.

The Tertiary is regarded as having a thickness of 800 feet.

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HAYDEN, H. H. Geological essay, or an inquiry into some of the geological phenomena to be found in various parts of America and elsewhere. Baltimore, 1820, 8°, viii, 412 pp.

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Several forms known to occur in Maryland and Virginia are compared in this article with European species.

—— On the stratigraphical evidence afforded by the Tertiary fossils of the peninsula of Maryland. Proc. Acad. Nat. Sci., Philadelphia, Vol. XXXII, 1880, pp. 20-33.

The author calls attention to the few Eocene fossils in the Maryland strata, and the marked difference between the Eocene and Miocene faunas.

—— Note on the approximate position of the Eocene deposits of Maryland. Ibid., Vol. XXXIII, 1881, pp. 444-447.

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HEILPRIN, A. On some new species of Eocene Mollusca from the southern United States. U. S. Nat. Mus. Proc., Vol. III, 1886, pp. 149–152 and plate.

This article contains a description of *Crassatella declivis.*

—— Contributions to the Tertiary geology and paleontology of the United States. Philadelphia, 1884, 4°, 117 pp. and map.

In this volume the author gives a full discussion of the Eocene deposits of Delaware, Maryland, and Virginia.

HEINRICH, O. J. The Mesozoic formation in Virginia. Trans. Am. Inst. Min. Engs., Vol. VI, 1878, pp. 227–274.

The relations of the Eocene to Mesozoic strata are indicated.

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KALM, PETER. En Resa til Norra America. Stockholm, 1753–1761, 8°, 3 vols., with English, German, and French translations.

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LEA, HENRY C. Catalogue of the Tertiary Testacea of the United States. Proc. Acad. Nat. Sci., Philadelphia, Vol. IV, 1848, pp. 95–107.

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The Fort Washington, Md., deposits are correlated by the author with those of Claiborne, Ala., and a description is given of many forms from the latter locality, some of which have since been found in Maryland.

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The article contains a description of the James River Eocene deposits, and the importance of *Venericardia planicosta* as a type fossil is discussed.

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The author refers to the Eocene in several of the sections that are given.

LYELL, CHARLES. Observations on the white limestone and other Eocene or older Tertiary formations of Virginia, South Carolina, and Georgia. Proc. Geol. Soc., London, Vol. IV, 1845, pp. 563–576; Quart. Jour. Geol. Soc., London, Vol. I, 1845, pp. 429–442.

The author gives a description of the Eocene of the James River, as well as of Richmond and Petersburg, Va. The occurrence of *Venericardia planicosta* and of a form similar to *Ostrea bellovacina* of Europe is mentioned.

MACLURE, W. Observations on the geology of the United States, explanatory of a geological map. Trans. Am. Philos. Soc., Vol. VI, 1809, pp. 411–428.

—— Observations on the geology of the United States of North America, etc. Ibid., new series, Vol. I, 1817, pp. 1–92.

—— Observations on the geology of the United States of America. Philadelphia, 1817, 8°, 130 pp.

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MAURY, M. F. Physical survey of Virginia. Richmond, I, 1868, 8°, 90 pp.; II, 1878, 8°, 142 pp.

This publication contains several references to the stratigraphical relations of the Eocene.

MCGEE, W. J. Three formations of the Middle Atlantic Slope. Am. Jour. Sci., third series, Vol. XXXV, 1888, pp. 120–143, 328–330, 367–388, 448–466.

The author discusses the general features of Coastal Plain stratigraphy and refers to the contact of the Eocene and Potomac in Virginia.

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This map, compiled from various sources, shows on a small scale the distribution of the Eocene deposits upon the Middle Atlantic Slope.

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MORTON, S. G. Geological observations on the Secondary, Tertiary, and Alluvial formations of the Atlantic Coast of the United States of America. Arranged from the notes of Lardner Vanuxem. Jour. Acad. Nat. Sci., Philadelphia, Vol. VI, 1829, pp. 59–71.

The attempt is made by the author, in a general way, to more accurately delimit the several formations of the Atlantic Coastal Plain, although at that time the Eocene was not differentiated.

MORTON, S. G. Synopsis of the organic remains of the Cretaceous group of the United States. Appendix: Catalogue of the fossil shells of the Tertiary formations of the United States. Philadelphia, 8°, 1834, 8 pp.

The author gives in his catalogue the Atlantic Tertiary forms which had been up to that time described.

MURCHISON, R. I. Secondary and Tertiary rocks and superficial deposits of North America. Proc. Geol. Soc. London, Vol. IV, 1843, pp. 127-133.

The author reviews the results of Lyell's investigations upon the Tertiary strata of America, adding his own interpretation of some points.

PIERCE, J. Practical remarks on the shell-marl region of the eastern parts of Virginia and Maryland, and upon the bituminous coal formation in Virginia and the contiguous region. Am. Jour. Sci., Vol. II, 1826, pp. 54-59.

Reference is made to the localities at Upper Marlboro, Md., and Potomac Creek, Va.

ROGERS, W. B. On the discovery of greensand in the calcareous deposits of eastern Virginia, and on the probable existence of this substance in extensive beds near the western limits of our ordinary marl. Farmer's Register, Vol. II, 1834. Reprinted in the Geology of the Virginias, 1884, pp. 3-9.

The author refers in a general way to the greensand deposits of eastern Virginia, which he compares with similar beds in New Jersey.

—— Further observations on the greensand and calcareous marl of Virginia. Farmer's Register, May, 1835. Reprinted in Geology of the Virginias, 1884, pp. 11-20.

In this publication the author makes the first announcement of the occurrence of the Eocene in Virginia.

—— Report of the geological reconnoissance of the State of Virginia, made under the appointment of the Board of Public Works, 1835. Richmond, 1836, 4°, 52 pp. and plate. Reprinted, Philadelphia, 1836, 8°, 143 pp. and plate, and in Geology of the Virginias, 1884, pp. 21-122.

This report contains a general statement regarding the "Eocene Marl District" of eastern Virginia, with a description of the lithologic character of the strata in the different river valleys.

—— Report of the progress of the geological survey of the State of Virginia for 1836. Richmond, 1837, 4°, 14 pp. Reprinted, Philadelphia, 1838, 8°, and in Geology of the Virginias, 1884, pp. 123-145.

The Eocene deposits of the peninsula between the Potomac and Rappahannock rivers are described by the author.

—— Report of the progress of the geological survey of the State of Virginia for 1837. Richmond, 1838, 4°, 24 pp. Reprinted, Philadelphia, 1838, 8°, and in Geology of the Virginias, 1884, pp. 147-188.

Brief mention is made of the Eocene deposits on the James River.

ROGERS, W. B. Report of the progress of the geological survey of the State of Virginia for 1839. Richmond, 1840, 8°, 161 pp. Reprinted in Geology of the Virginias, 1884, pp. 245–410.

In this report the author describes in much detail the "Tertiary Marl region south of the James River."

—— Report of the progress of the geological survey of the State of Virginia for 1840. Richmond, 1841, 8°, 132 pp. Reprinted in Geology of the Virginias, 1884, pp. 411–535.

This report contains a description of the "Tertiary Marl region between the Potomac and the Rappahannock rivers," and also of the "Tertiary beds in the vicinity of Richmond."

—— Infusorial deposit of Virginia in the Fort Monroe artesian well. The Virginias, Vol. III, 1882, pp. 151–152. Reprinted in Geology of the Virginias, 1884, pp. 733–736.

The character of the Eocene strata penetrated in the well-boring is given at various depths.

ROGERS, W. B. and H. D. Contributions to the geology of the Tertiary formations of Virginia. Trans. Am. Phil. Soc., new series, Vol. V, 1837, pp. 319–341; Vol. VI, 1839, pp. 347–370, 371–377, pls. 26–30. Reprinted in Geology of the Virginias, 1884, pp. 659–673, Pls. I–V.

The authors describe *Nucula cultelliformis*, *N. parva*, and *Cytherea ovata* from Coggins Point, James River, *Ostrea sinuosa* from Evergreen, James River, *Cucullæa transversa* and *Venericardia ascia* from King George County, *Cucullæa onochela* and *Crassatella capri-cranium* from the peninsula between the Potomac and Rappahannock rivers, and *Cytherea lenticularis* from "eastern Virginia."

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RUFFIN, EDMUND. Description of a nut found in Eocene marl. Am. Jour. Sci., second series, Vol. IX, 1850, pp. 127–129.

The author describes a nut found in the Eocene marl of the Pamunkey River, Virginia.

SAY, THOMAS. An account of some of the fossil shells of Maryland. Jour. Acad. Nat. Sci., Philadelphia, Vol. IV, 1828, pp. 124–155, pls. 7–13.

In this article *Ostrea compressirostra* is described, but no locality is given.

SCHÖPF, J. D. Beyträge zur mineralogischen Kenntniss des östlichen Theils von Nordamerica und seiner Gebürge. Erlangen, 8°, 1787, 194 pp.

The author gives the result of his observations in the eastern United States, referring to some of the more striking features of the Atlantic Coastal Plain.

TUOMEY, M. Discovery of a chambered univalve fossil in the Eocene Tertiary of James River, Virginia. Am. Jour. Sci., Vol. XLIII, 1842, p. 187.

This article contains some conclusions of the author regarding the stratigraphy of the Eocene, based on a section exposed in a shaft sunk at Evergreen on the James River.

TYSON, PHILIP T. First report of Philip T. Tyson, State agricultural chemist, to the house of delegates of Maryland, January, 1860. Annapolis, 1860, 8°, XI, 145, and 20 pp. and one map.

The author describes the Tertiary formations collectively, stating that the work has not progressed far enough to separate the different divisions, although he refers to the Eocene greensand marl.

—— New topographical atlas of the State of Maryland, etc. 1873.

This work contains a general statement regarding the geology of Maryland, including a description of the Eocene.

UHLER, P. R. Observations on the Eocene Tertiary and its Cretaceous associates in the State of Maryland. Trans. Maryland Acad. Sci., Vol. I, 1888, pp. 10-32.

—— Additions to observations on the Cretaceous and Eocene formations of Maryland. Trans. Maryland Acad. Sci., Vol. I, 1889-1890, pp. 45-72.

—— Notes and illustrations to "Observations on the Cretaceous and Eocene formations of Maryland." Trans. Maryland Acad. Sci., Vol. I, 1890, pp. 97-104.

The above articles contain an extensive description of the Eocene and a discussion of its relations to the Cretaceous.

VAN RENSSELAER, J. Lectures on geology, New York, 8°, 1825, 350 pp.

The author accepts the conclusions of Finch regarding the so-called "Alluvial formation," and describes briefly the Tertiary formations of the Northern Atlantic Coastal Plain.

WILLIAMS, G. H. A preliminary geological map of Maryland. (In World's Fair Book of Maryland.) Baltimore, 1892.

The general limits of the Eocene are given by the author, mainly upon data furnished by N. H. Darton.

GEOLOGICAL FEATURES.

HISTORICAL REVIEW.

On account of its extensive waterways and the ready access thereby gained, the Atlantic Coastal Plain was early visited for purposes of geological investigation. At first the observations were of the most general character, no attempt being made to differentiate the deposits or even to correlate the strata as a whole with those of other districts.

Among the earliest investigators of the region was Prof. Peter Kalm, who was sent out in 1749 under the auspices of the Swedish Royal Academy of Sciences to make a study of the various branches of natural history in America, and who spent considerable time in a study of the northern Coastal Plain.

He was followed in 1777 by Dr. Johann David Schöpf, of Germany, who visited America in order to study the geological features of the eastern portion of the continent. The importance of his observations, which mark considerable advance over those of Kalm, has not been very generally recognized by later writers, but he showed a remarkably keen insight into the geology of eastern North America, which was lacking on the part of some of his successors.

The first attempt to correlate the deposits of the eastern United States with the geological column then established in Europe was made by William Maclure, in 1809, in his Observations upon the Geology of the United States. In this publication the coastal deposits of the Middle Atlantic Slope are collectively referred to the "Alluvial formation," the fourth of the main divisions of geological strata proposed by Werner. The work was subsequently revised and enlarged, appearing in book form in 1817.

In 1820 H. H. Hayden, of Baltimore, published a volume of Geological Essays, in which he attempted to explain the great accumulation of "alluvial deposits" in the Atlantic Coastal Plain. In this volume the stratigraphy of the region is described in much greater detail than by his predecessors, and reference is made to the wide distribution of fossil shells and vertebrate remains, many localities being cited.

A volume of the same character, so far as it relates to the geology, was published in 1822 by Parker Cleveland, entitled An Elementary Treatise on Mineralogy and Geology, in which, on page 785, under remarks on the "Geology of the United States explanatory of the subjoined geological map," the limits and the lithological character of the "alluvial deposits" are described in general terms.

By far the most important contribution to the stratigraphy of the Atlantic Coastal Plain that had up to that time appeared was made by Prof. John Finch, in a "Geological essay on the Tertiary formations in America," in the American Journal of Science and Arts for 1824. This was the first attempt at a division of the deposits of the Coastal Plain and their correlation upon scientific grounds; and although thus early in the history of the subject detailed comparisons (which are always unsatisfactory) were made, yet the knowledge of the formations was materially advanced. The author says:

> In America an immense tract of country, extending from Long Island to the Sea of Mexico, and from 30 to 200 miles in width, is called an alluvial formation. From an examination of fossils brought from that quarter of the United States, from a personal inspection of some of its strata, and the perusal of most of the publications which bear a reference to it, I wish to suggest that what is termed the alluvial formation in the geological maps of Messrs. Maclure and Cleveland is identical and contemporaneous with the newer Secondary and Tertiary formations of France, England, Spain, Germany, Italy, Hungary, Poland, Iceland, Egypt, and Hindostan.

The deposits of various portions of the Middle Atlantic Slope are considered in greater or less detail, and correlations with the strata of other portions of the Coastal Plain and with Europe are attempted. The author states in short that—

> Many more instances might be advanced to establish the identity of what has been called the alluvial district in America with the Tertiary formation of England and the continent of Europe. The fossil shells from the various beds would not, perhaps, be exactly like those of Europe, but a sufficient number would be found so to establish their relation and order of succession.

During the year 1825 Jer. Van Rensselaer delivered in the New York Athenæum a course of geological lectures that were subsequently published in book form. The author adopted the classification proposed by Finch, confining his descriptions, however, more particularly to the formations of the northern Coastal Plain.

The American Journal of Science for 1826 contains a communication by James Pierce "On the shell-marl region of the eastern parts of Virginia and Maryland," in which reference is made to the sections on the James and Potomac rivers and to the "shell rock" at Upper Marlboro, Md.

A few years later (1828) Prof. Lardner Vanuxem, through his friend, Dr. S. G. Morton, presented the criteria for a more complete and definite recognition of the several members of the coastal series, and described both the Cretaceous and Tertiary formations. In this article an attempt is made to more accurately define the limits of the Tertiary. The author states that much that had been designated by that name properly belongs to other formations.

Up to the year 1830 all investigations upon the stratigraphy of the Tertiary had been carried on in the main independently of a study of the fossils. Generic identity had been cited as ground for correlation, and although this aided largely in determining the limits of the Tertiary itself, further subdivisions were impracticable.

The publication of Conrad's article "On the geology and organic remains of a part of the peninsula of Maryland," with an appendix containing descriptions of new species of fossil shells, inaugurated a new era in the investigation of the Coastal Plain strata. It is true that Say had already described several Tertiary species, including the common *Ostrea compressirostra* of the Eocene of the Middle Atlantic Slope, but, as stated in Conrad's paper, he did not "draw any geological inferences from the organic remains examined." Conrad from the first applied the paleontological evidence he had acquired to an interpretation of the stratigraphy; and, although many of his conclusions were erroneous, the knowledge of the geology of the Coastal Plain was very materially advanced by his work. In this first paper such well-known early Tertiary forms as *Turritella mortoni*, *Cucullæa gigantea*, and *Crassatella alæformis* are figured and described, while the presence of *Venericardia planicosta* Lamarck is also noted. By the use of the data afforded by these investigations the strata at Fort Washington, Md., were correlated with the London Clay of England.

In 1832 Conrad began the publication (in parts) of an important work entitled "Fossil shells of the Tertiary formations of North America." This and its companion volume upon the "Middle Tertiary," commenced some years later, must be regarded as the basis of all later work upon American Tertiary paleontology. In the earlier publication Conrad regarded the deposits in the vicinity of Fort Washington, Md., as "Middle Tertiary," and correlated them with the London Clay and Calcaire grossier of Europe, and the Claiborne beds of Alabama.

Before the completion of Conrad's first work above mentioned Lea published his "Contributions to geology," in which a large number of Eocene fossils are described and the stratigraphy of the Tertiary of the Atlantic Coastal Plain is discussed. In this work the term Eocene is first applied to the American Lower Tertiary deposits, although the general position of the deposits had already been recognized by Conrad. The latter, however, in 1834, in his "Observations on the Tertiary and more recent formations of a portion of the Southern States," employs the term Eocene for the Fort Washington deposits, although he there regards them as younger than the Claiborne beds, and even suggests their Miocene age.

During the same year Prof. William B. Rogers made his first contribution to the Eocene geology of Virginia, and although his article contained little of real importance, it is of interest as being the first of a series of important publications upon the geology of Virginia.

Dr. S. G. Morton, whose investigations were chiefly confined to the Cretaceous, gives in his "Synopsis," etc., published at this time, a "Catalogue of the fossil shells of the Tertiary formations of the United States," in which many of the Middle Atlantic Slope forms are included.

During the year 1835 several important contributions were made to the geology of the Atlantic Tertiary region. Conrad published his investigations upon the Maryland-Virginia Tertiary area, including the description of two new species of Eocene fossils. Rogers presented "Further observations on the greensand and calcareous marl of Virginia," in which the lithological similarity of the beds to the greensand deposits of New Jersey is dwelt upon, although he believes that the character of the organic remains shows the strata to be Eocene. Jointly with his brother, H. D. Rogers, he presented to the Philadelphia Academy of Natural Sciences the first portion of "Contributions to the geology of the Tertiary formations of Virginia," in which several new species of Eocene fossils are described.

While the investigations hitherto mentioned were being carried on privately, the three States constituting that portion of the Middle Atlantic Slope now under consideration, viz, Delaware, Maryland, and Virginia, became aroused to the importance of official geological surveys of their areas.

The first to organize such a survey was Maryland, in 1833, J. T. Ducatel being appointed State geologist. Reports were published until 1841, but the information they contain is economic rather than stratigraphic.

The Geological Survey of Virginia began operations in 1835, under William B. Rogers as State geologist, who was thus able to continue much more systematically than hitherto his observations upon the Tertiary belt. The first report, for 1835, which contains a general statement regarding the "Eocene marl district," and most of the subsequent annual reports, which were continued until 1841, include more or less detailed descriptions of the Eocene deposits. Collectively they form the chief source of information regarding the Eocene stratigraphy of Virginia.

The Geological Survey of Delaware was short-lived. Its investigations, under the direction of I. C. Booth, State geologist, extended only over the seasons 1837 and 1838, for which years annual reports were published, and, in addition, a more exhaustive "Memoir" in 1841; but in none of these publications was the Eocene recognized as such.

Conrad, who actively continued his investigations, made an important contribution to the Eocene of the Middle Atlantic Slope in 1842 in his "Observations on a portion of the Atlantic Tertiary region, with a description of new species of organic remains."

During this year the first of Lyell's publications upon the eastern Tertiary belt appeared in the Proceedings of the Geological Society of London. His conclusions were derived from personal observations, and were of special value from his wide knowledge of the Tertiary of Europe. He succeeded in explaining many points in American Tertiary stratigraphy hitherto imperfectly understood. The narrative of his first report contains the following statement:

> Having examined the most important Cretaceous deposits in New Jersey, Mr. Lyell proceeded in the autumn of 1841 to investigate the Tertiary strata of Virginia, the Carolinas, and Georgia, with a view to satisfy himself, first, how far the leading divisions of Tertiary strata along the Atlantic border of the United States agree in aspect and organic contents with those of Europe; and, secondly, to ascertain whether any rocks containing fossils of a character intermediate between those of the Cretaceous and the Eocene beds really exist. The conclusions at which he arrived from his extensive survey are given briefly as follows: (1) The only Tertiary formations which the author saw agree well in their geological types with the Eocene and Miocene beds of England and France; (2) he found no secondary fossils in those rocks which have been called Upper Secondary and supposed to constitute a link between the Cretaceous and Tertiary formations.

The Eocene deposits upon the James River, Virginia, are described in this paper. In his subsequent papers bearing upon the Eocene of the Middle Atlantic Slope the stratigraphy of the Eocene is further considered and references are made to other localities which he visited.

Murchison, in his presidential address before the Geological Society of London in 1843, reviewed the results of Lyell's investigations in America and added his own interpretation of a few points.

During the years immediately subsequent to Lyell's visit many important articles upon the Tertiary appeared from the pens of American geologists, although the publications dealt more largely with the southern than the northern deposits. Conrad, however, made additional observations upon the Eocene strata of the Middle Atlantic Slope and described a number of new species. About this time Henry C. Lea published a Catalogue of the Tertiary Testacea of the United States, in which the Middle Atlantic Slope forms are included.

Subsequent to 1850 interest in the Tertiary geology of the Middle Atlantic Slope seems for a time to have waned, and during the next twenty-five years very few investigations were carried on within the district. In Maryland two surveys, partly of a geological but more largely of an agricultural nature, were inaugurated, the first, under James Higgins, producing six reports between 1850 and 1858, and the second under Philip T. Tyson, who presented two reports in 1860 and 1862. In the report for 1860 the Tertiary is described in some detail, although no attempt is made to establish the limits of its several divisions.

Conrad continued, however, to carry on his investigations upon the Atlantic Tertiary belt, adding to the number of new fossil forms and publishing two catalogues of species.

Maury's Physical Survey of Virginia, which appeared in 1869, also contains several references to the Eocene stratigraphy of that State.

During the last twenty years, and particularly in the latter part of that period, many more contributions have been made to the geology of the Middle Atlantic Slope. Among those who have given the subject most attention may be mentioned McGee, Heilprin, Darton, Uhler, and the writer. To the publications of McGee we are indebted more than to any other for a general statement of Coastal Plain conditions. Although some modifications may be deemed necessary upon a detailed study of the formations, the writer is impressed, from a careful examination of portions of the area, with the general correctness of the broad principles enunciated.

Heilprin has devoted considerable attention to Atlantic Coast paleontology, comparing several of the Eocene species of Maryland and Virginia with European forms, and correlating the strata, as a result of these investigations, with the lower members of the English and French series. Both Darton and Uhler have studied the local relations of the Eocene deposits, the former having prepared several United States Geological Survey atlas sheets of the central and southern portions of the district.

Several others have turned their attention from time to time to the area, and from their knowledge of other districts have aided to a greater or less degree in interpreting the problems involved.

GENERAL RELATIONS.

TOPOGRAPHY.

The Atlantic Slope is essentially the area which drains eastwardly into the Atlantic Ocean from the great divide formed by the Appalachian Mountain system. Although affording great variety in topographic relief when viewed in its full extent, this area presents in its central portion—that part to which the name Middle Atlantic Slope is applied—three rather sharply defined districts, viz, the Appalachian region, the Piedmont Plateau, and the Coastal Plain. Regarding the two former, nothing further will be said at the present time. The Coastal Plain, however, will be briefly described, since an understanding of it is essential to an interpretation of many of the questions which will be considered later.

The Coastal Plain as a continuous tract begins in New Jersey, on the south shore of Raritan Bay, where it has a width of about 20 miles, and extends thence southward, constantly broadening, until in Georgia it reaches fully 150 miles.

Within the Middle Atlantic Slope it varies for the most part between 75 and 100 miles in width, in some parts slightly exceeding, in others slightly falling below, the limits given. In this central area it is characterized by broad, level-topped stretches of country, which extend with gradually increasing elevations from the coastal border, where the land is but slightly raised above sea level, to its western edge, where heights of 300 feet and more are found. As the region is cut quite to the border of the Piedmont Plateau with tidal estuaries, the relief becomes more and more pronounced in passing inland from the coast.

Chesapeake Bay extends across nearly its full length from north to south, separating the area into an eastern and a western division. Nowhere except in the extreme north does the eastern division reach 100 feet in elevation, while most of the country is below 25 feet in height. Both on the Atlantic coast and on the shore of the Chesapeake it is deeply indented by bays and estuaries. In elevation the western division stands in striking contrast to the eastern, since it is frequently high even along its eastern margin. In lower Maryland the land reaches an elevation of 100 feet in close proximity to the shore of the Chesapeake, and gradually increases northward. The western division is traversed by numerous large streams which flow from the Piedmont Plateau, most of them tidal in their lower portions.

A characteristic feature in the drainage of the district is the position of the larger tributaries of the rivers, which are almost exclusively along the northeastern banks, those entering from the southwest being few and short.

Upon the west the Coastal Plain is bordered by the Piedmont Plateau, a region of greater elevation and more diversified topography.

Since the topography of the Coastal Plain finds its explanation to a considerable extent in the geological structure of the area, that subject will be next considered.

STRATIGRAPHY.

The Coastal Plain consists geologically of a series of formations that were deposited as moderately thin sheets, one above another, along the eastern border of the crystalline belt already referred to as the Piedmont Plateau. The coastal deposits are slightly inclined eastward, so that successively later members of the series are encountered in passing from the interior of the country toward the coast.

From the beginning of deposition in the coastal region until the present time sedimentation has apparently been constantly in progress over some portions of the area. Oscillation of the sea floor, with its accumulated sediments, took place, however, from time to time, so that the formations present much complexity along their western margins. It is not uncommon there to find certain members of the series lacking, as renewed deposition carried a later formation beyond its predecessors. In the absence of distinctive fossils, the discrimination of the different horizons at such points is often attended with great uncertainty.

Deformation also has affected the region to a limited extent, the strata being slightly warped, so that the plane of bedding does not maintain a uniform strike and dip. This is particularly marked along the western border of the area.

It seems highly probable that every geological epoch from the Cretaceous to the Pleistocene is represented, although in one or two instances the lack of characteristic fossils renders the taxonomic position of certain formations difficult of absolute determination.

CRETACEOUS.

The Cretaceous is extensively developed in the Middle Atlantic Slope. It consists of a basal formation, that has been designated the Potomac, overlain in succession by the Matawan, Navesink, Redbank, and Rancocas formations, although all but the first are sparingly represented in the southern portion of the area, if, indeed, they are present at all. The Potomac formation only has been determined in Virginia.

The Potomac formation consists chiefly of sands and clays, with gravel at certain points where the shore accumulations are still preserved. The sands and clays of the lower Potomac are mainly incoherent and show both a vertical and a horizontal gradation into one another. The sand layers are seldom widely extended, being generally lenticular masses, which rapidly diminish in thickness with distance from their centers. Highly colored and variegated clays abound in the upper portion of the lower Potomac, and have yielded large amounts of nodular carbonate of iron. Thick-bedded and widely extended white sands (Albirupean formation of Uhler) characterize the upper Potomac. The fossils consist chiefly of leaf impressions and the bones of dinosaurian reptiles, and although they are not so numerous or distinctive as might be desired, they show beyond a doubt the Cretaceous age of the deposits.

The Matawan formation is formed largely of fine sands and clays, clearly stratified, and in the case of the clays often laminated. The clays and sandy clays are generally dark, often black, in color. They are commonly micaceous and at times sparingly glauconitic. The very homogeneous and persistent character of the beds is in marked contrast with the deposits of the Potomac formation which they overlie. The fossils consist largely of marine Mollusca that indicate the upper Cretaceous age of the deposits.

The Navesink formation consists chiefly of greensand deposits, although the glauconitic element is not so pronounced or so persistent south of the Chesapeake as in the more northern districts. The strata are more arenaceous, and as a result the materials weather more readily, showing generally in greater or less degree the characteristic reddish color of the hydrated peroxide of iron. The common and characteristic *Gryphæa vesicularis*, *Exogyra costata*, and *Belemnitella americana* are widely found, with other typical forms.

The Redbank formation is composed typically of highly arenaceous greensands of a bright-red color, with which at times are interstratified black micaceous sands and clays. Black sands are found at the base in the north, while an argillaceous bed of greenish color often caps the formation. Although very distinct from the Navesink formation in portions of New Jersey and upon the eastern shore of Maryland, the characteristic features are less pronounced upon the western side of the Chesapeake. The fossils are largely the same as those in the Navesink formation.

The Rancocas formation is also largely composed of greensands, generally more glauconitic than the Navesink formation, although at times somewhat argillaceous. The strata are much weathered where exposed, and often appear as a firm red rock, the grains being cemented by the iron oxide. The deposits have afforded *Terebratula harlani*, *Gryphæa bryani*, and other characteristic species of the New Jersey area.

EOCENE.

The Eocene is an important member in the Middle Atlantic Slope series, and will be fully described in the following pages. It seems best for various reasons to regard the deposits as representing a single formation, and Darton has assigned the name Pamunkey formation to this division, from the Pamunkey River in Virginia, where the strata are typically developed.

The deposits consist largely of a greensand marl, which may, however, by weathering, lose its characteristic green color, and by the deposition of a greater or less amount of hydrous iron oxide become an incoherent red sand or firm red or brown sandstone. At times, notably in Virginia, the strata become highly argillaceous, the glauconitic elements largely or quite disappearing. Infrequently coarse sands and even gravels are found, the latter chiefly toward the base of the formation and near the ancient shore line.

Very commonly the shells of organisms are so numerous as to form the chief constituent of certain beds. Notwithstanding these facts, the deposits are remarkably homogeneous in any given region and afford no satisfactory grounds, either lithological or stratigraphical, for their separation into different horizons. Many of the fossils are somewhat restricted in their range, some being limited to the lower, others to the upper portion of the formation, yet they alone do not seem to afford a satisfactory basis of division in the absence of stratigraphic criteria for the same.

MIOCENE.

The Miocene deposits occupy the region to the southeast of and overlying the Eocene. They have been named the Chesapeake formation, from the superb sections found exposed on the shores of Chesapeake Bay. The Miocene deposits lie unconformably upon those of the Eocene and overlap them along their western border, where they often rest upon the Cretaceous.

The Miocene consists of sands, clays, marls, and diatomaceous beds. The latter, composed almost exclusively of diatoms, are chiefly confined to the lower portion of the formation, where they afford striking, light-colored bluffs along many of the larger stream channels. The pure diatomaceous earth reaches a thickness of 30 or 40 feet, although the remains of diatoms are found scattered in greater or less amounts throughout much of the overlying strata. The greater portion of the Miocene, however, is composed of various-colored sands and clays, with which are frequently mingled vast numbers of molluscan shells. Sometimes the shelly materials form so large a proportion of the deposits as to produce nearly pure calcareous strata, which in a partially comminuted state may become cemented into hard limestone ledges. At other times the deposits are very carbonaceous, even beds of lignite appearing. The organic remains are very numerous and show the Miocene age of the deposits. Their great number early attracted the attention of geologists, in whose writings descriptions of them are frequently found.

PLIOCENE.

Widely covering the deposits of the Middle Atlantic Slope, hitherto described, is a formation composed of gravel, sand, and clay, which thus far has afforded no distinctive fossils upon which to base a determination of its geologic age. From the fact that the deposits rest unconformably upon the underlying Miocene, and are in turn unconformably overlain by the Pleistocene, they have been considered to represent the Pliocene. The similarity of these deposits to those in Mississippi, described by Hilgard under the name of the Lafayette formation, has led to the adoption of the same name for the strata of the Atlantic Coast.

The deposits are very irregularly stratified, and often change rapidly within narrow limits. Toward the ancient shore line the deposits are of coarse gravel, through which is scattered a light-colored sandy loam, the whole cemented at times by hydrous iron oxide into a more or less compact conglomerate. The eastward extension of the formation shows a gradual lessening of the coarser elements and a larger admixture of loam. Arkose materials are also present throughout the formation, while the coloring and manner of weathering are highly characteristic.

PLEISTOCENE.

Superficially overlying the deposits hitherto described, and with marked variations in thickness, composition, and structure, is the Pleistocene, which reaches elevations of 100 to 200 feet in the various portions of the region. From its typical development in the District of Columbia it has received the name of Columbia formation. Three distinct phases have been recognized, viz, the fluvial, the interfluvial, and the low-level.

The fluvial phase is found in its fullest development along the leading waterways. It consists of a lower horizon of coarse materials, pebbles, and bowlders, generally passing upward into a brownish loam.

The interfluvial phase is found typically represented in the country which lies between the waterways, and is characterized by materials of local origin and produced largely by wave action.

The low-level phase is developed throughout the area farthest removed from the ancient shore line. The deposits consist of sands, clays, and loams. They indicate a much less disturbed type of sedimentation than that found in either the fluvial or interfluvial phase. They were scattered as a coating of greater or less thickness over the eastern portion of the district, and have since suffered but little from denudation. The fossils are of recent species and indicate the marine origin of the deposits.

DISTRIBUTION OF THE STRATA.

The Eocene strata of the Middle Atlantic Slope form a belt of varying width, extending from northeast to southwest, somewhat to the west of the center of the Coastal Plain. This belt has been traced almost continuously from the southern portion of Newcastle County, Delaware, to the valley of the Nottoway River, in southern Virginia. Although at times buried beneath later deposits, the Eocene presents fine exposures along all the leading stream channels, while not infrequently broad expanses of the formation outcrop at the surface in the intervening country.

DELAWARE.

In Delaware the Eocene is found only near the Maryland line and slightly to the south of the central portion of Newcastle County, where it occupies a restricted portion of the country between Appoquinimink Creek on the north and Old Duck Creek on the south. Toward Delaware Bay the formation entirely disappears, the Neocene resting directly upon the Cretaceous. Even in the limited area where found the Neocene deposits widely cover the Eocene, so that in the absence of any large streams no satisfactory exposures of the strata are found.

MARYLAND.

In eastern Maryland the conditions of outcrop become more favorable, although the Neocene deposits still cover the higher portions of the country. Numerous sections are found in the drainage basin of the Chester River in both Kent and Queen Anne counties, the width of outcropping beds broadening from a few miles at the boundary to more than 10 miles in some places, and reaching nearly to the valley of the Sassafras River. On the western side of the Chesapeake the Eocene is much more extensively developed than upon the eastern, and covers wide areas in Anne Arundel, Prince George, and Charles counties.

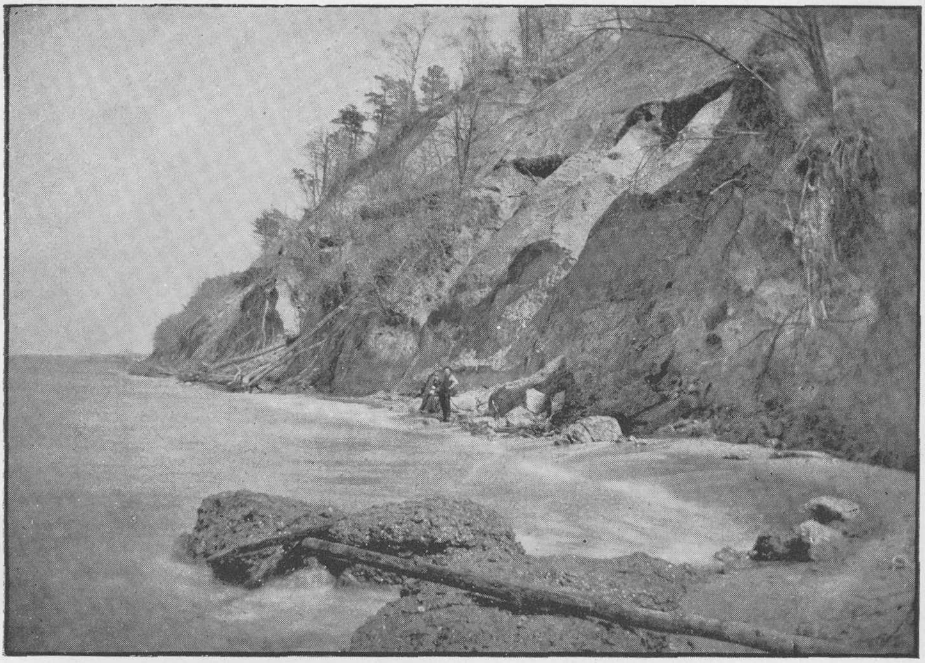
In Anne Arundel County the best sections are found along the Severn and South rivers and their tributaries. The highland forming the neck between the lower Magothy and Severn rivers is largely composed of Eocene beds, the most western exposure being found at Mount Misery, near Round Bay, Severn River, at an altitude of 100 feet, while eastward it reaches almost to water level. The higher portions of the area between the Severn and South rivers are also largely made up of Eocene deposits, as is also the land to the southwest of the latter stream and between it and the valley of the Patuxent River. Throughout the southern portion of the county the Eocene is, however, capped by the Chesapeake and Lafayette formations along the central highland.

Much of the western-central portion of Prince George County is composed of Eocene strata, many fine sections occurring along the western branches of the Patuxent River. Along the Potomac the strata are found in numerous bold bluffs, while broad exposures appear in the valleys of many of the larger tributaries, notably in Piscataway and Mattawoman creeks. Upper Marlboro, on the eastern side, and Fort Washington, on the western side, of the county are among the best-known localities for Eocene fossils in the Middle Atlantic Slope.

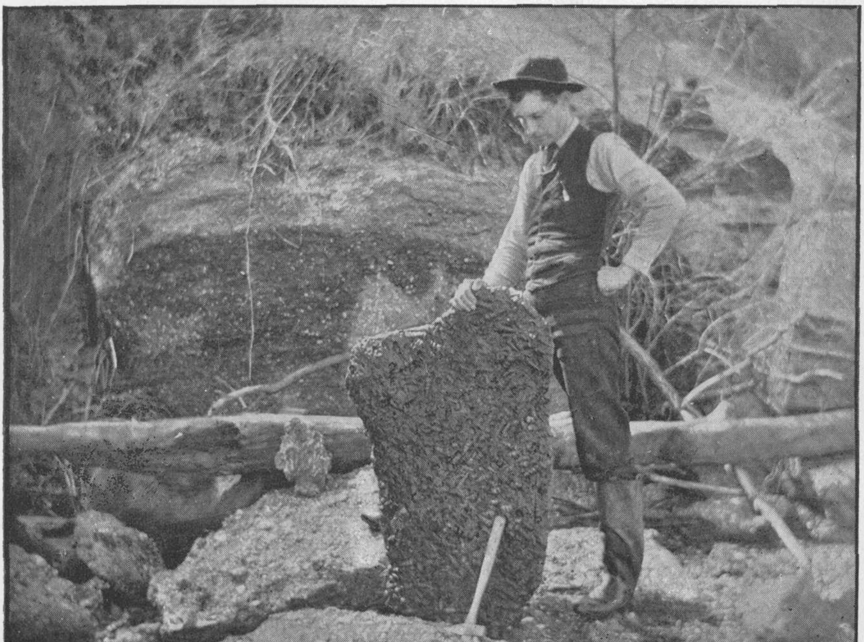
In Charles County the Eocene is confined to its western half, fine sections being found at Clifton Beach, along Port Tobacco River, and at Popes Creek. Since the deposits are in general at lower levels than in Prince George County, on account of the easterly dip of the beds, the surface outcrops are largely covered by the Neocene and Pleistocene formations.

VIRGINIA.

The most complete section of the Eocene in the whole Middle Atlantic Slope is afforded by the series of high bluffs on the western bank of the Potomac River between Aquia Creek and Mathias Point, in eastern Stafford and northern King George counties. The peninsula between



SECTION OF EOCENE STRATA ON POTOMAC RIVER AT MOUTH OF AQUIA CREEK, VIRGINIA.



BLOCKS OF INDURATED EOCENE MARL COMPOSED OF TURRITELLA MORTONI.

the Potomac and Rappahannock rivers is to a large extent formed of the Eocene greensands, which also appear in places along the banks of the latter stream, outcropping beneath the Columbia formation. The higher levels of the intervening country are generally capped by the Neocene formations.

Southward the Eocene deposits are continued in eastern Spottsylvania and in Caroline counties. Fine bluffs of the characteristic marls appear on the south bank of the Rappahannock at several points above Port Royal, but in the valley of the Mattapony they are much less prominent, although occurring at frequent intervals. An extensive cover of Neocene deposits occupies the higher portions of the country.

In the valley of Pamunkey River and its tributaries, particularly in Hanover County, important outcrops of the Eocene are found. Many of the fossils described by Conrad and Rogers were obtained from this area.

Farther south, in the valley of James River, are many of the most notable occurrences of the Eocene in the whole region. At Richmond, City Point, Evergreen, and Tar Bay prominent exposures are found, the two latter localities particularly being rich in organic remains. At Petersburg and vicinity the Eocene is exposed in the valley of the Appomattox, but the sections are in the main poor. South of Petersburg the only exposure so far as known is at Bollings Bridge, on the Nottoway River.

GENERAL CHARACTER OF THE DEPOSITS.

COMPOSITION.

The Eocene deposits of the Middle Atlantic Slope are typically glauconitic, and are found in their unweathered state either as dark-gray or green sands or clays. The glauconite varies in amount from very nearly pure beds of that substance to deposits in which the arenaceous and argillaceous elements predominate, although the strata are generally very homogeneous through considerable thicknesses. At certain horizons the shells of organisms are found commingled with the glauconitic materials in such numbers as largely to make up the beds, producing what is known as a greensand marl. These beds are at times so indurated as to form true limestone bands. This latter phase is seen typically developed both at Fort Washington, Maryland, and Aquia Creek, Virginia, interstratified with the unconsolidated greensand layers.

When the glauconite is weathered the deposits lose their characteristic gray or green color and generally become lighter gray with reddish or reddish-brown streaks or bands, or may become entirely of the latter color. In this condition they are often cemented into a ferruginous sandstone. This change particularly characterizes the Eocene deposits of Delaware and the eastern shore of Maryland, as well as of Anne Arundel County, on the western side of the Chesapeake. A very coarse phase of the consolidated sand rock is seen at Mount Misery, on the Severn River. In the less completely weathered portions of the formation the change is shown in the mottled yellow and brown character of the more superficial beds, the glauconitic grains still showing their green color when crushed. Thin iron crusts at times appear in the strata.

When the glauconite is largely or, more rarely, entirely absent, the deposits consist of black or gray sands or clays, the latter at times micaceous, and in a few instances carbonaceous.

A coarse pebble bed has been found at some localities at the base of the formation.

A microscopical examination of several selected specimens from different portions of the area shows that the land-derived elements of the deposits are mainly quartzose, quartz grains predominating. Fragments of crystalline rocks occur, while numerous constituent and accessory minerals derived from them are found.

Chemical analyses of several typical specimens, made by Peter Fireman, of Columbian University, give the following results:

Analyses of marls.

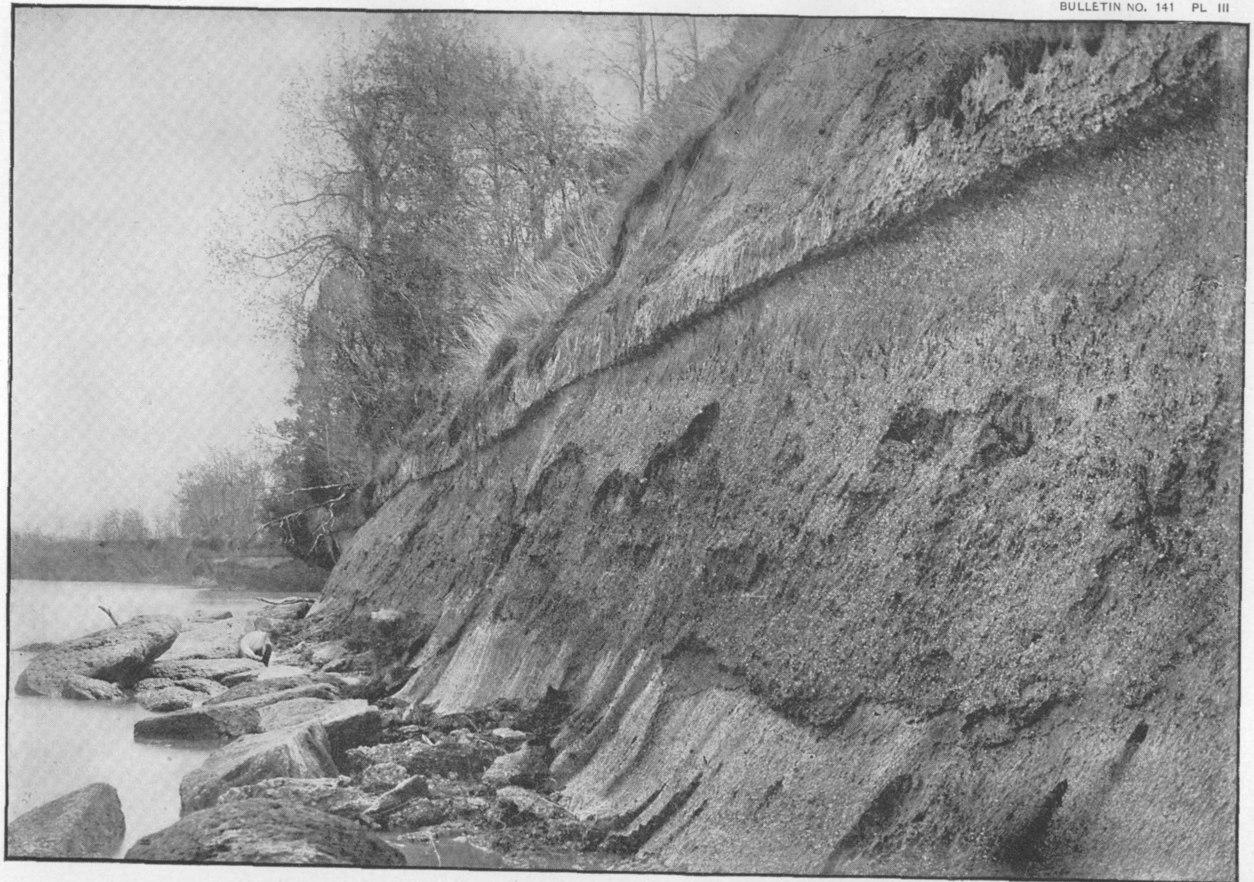
	I. Woodstock, Va.	II. Evergreen, Va.	III. Aquia Creek, Va.	IV. Winchester, Md.
H_2O at 110°	3.58	3.11	0.76	1.31
Volatile at red heat less CO_2	2.84	2.60	.21	6.27
$Al_2O_3+Fe_2O_3$ *a*	22.68	21.50	7.70	41.25
CaO	1.66	2.50	36.78	None.
MgO	2.77	2.06	1.05	.76
K_2O	.77	.61	.37	.39
Na_2O	.23	.31	.59	.42
SiO_2	60.87	63.94	21.58	49.08
CO_2	3.17	3.53	29.79	.55
P_2O_5	None.	None.	.09	.13
	98.57	100.16	98.92	100.16
Siliceous matter	73.48	75.85	25.36	52.30

a Considerable Fe_2O_3 in all samples.

STRIKE AND DIP.

The strike of the Eocene deposits in Delaware and Maryland is approximately northeast to southwest, while in Virginia the prevailing trend is more nearly north to south. This change in direction of strike takes place in the area between the Patuxent and Rappahannock rivers, chiefly in the Potomac basin.

The dip of the strata varies in different portions of the area from 10 to 20 feet to the mile, as shown by section lines and well borings, but along the Potomac River section, where detailed measurements were made by the writer, it is on the average about 12½ feet to the mile.



SECTION OF EOCENE STRATA, SHOWING LOWER INDURATED LAYERS, AT AQUIA CREEK, VIRGINIA.

THICKNESS.

The results obtained from a study of the various section-lines and well-borings show that the average thickness of the deposits is somewhat in excess of 200 feet, although estimates based on the Potomac River section, as well as on well-borings in the area to the east of Fredericksburg, show that it reaches quite 300 feet in this portion of the Middle Atlantic Slope.

The extensive covering of post-Eocene deposits in many portions of the region renders it impossible to obtain data upon which an estimate can be based, and the results of further well-boring will be awaited with interest. From the facts already obtained it seems probable that there is a slight thickening of the beds to the eastward along the line of dip.

ORIGIN OF THE MATERIALS.

As regards their origin, the chief constituents of the Eocene deposits of the Middle Atlantic Slope may be grouped under three heads, viz: First, the arenaceous and argillaceous elements, which are land-derived; second, the calcareous elements, which are of organic origin; and third, the glauconitic elements, which are of secondary formation.

The arenaceous and argillaceous materials were undoubtedly originally derived from the crystalline rocks of the Piedmont Plateau, with an indefinite admixture from the Paleozoic formations of the Appalachian region.

The organic remains, which consist very largely of the shells of mollusks, are generally so slightly worn or broken as to justify the belief that they were little disturbed prior to their burial by the sediments in which they are now found entombed. They have, however, lost considerably by solution since they were deposited, the calcareous matter removed serving as a cement to produce the limestone layers found at several horizons in the southern Maryland and northern Virginia area.

The glauconitic elements are secondary in character and were formed in situ. Since they enter so largely into the formation of the Eocene greensands, their character and origin will be considered somewhat more fully.

ORIGIN OF GREENSAND.

Great light has been thrown upon this subject by the results of the deep-sea dredgings which have been made in recent years by the vessels sent out on scientific expeditions under government auspices. The most important of these expeditions was that of the *Challenger*, sent out by the British Government in the years 1872–76. In the report upon the deep-sea deposits, based upon the dredgings of that expedition, Professors Murray and Renard, the authors, present the results of their researches as to the character and distribution of greensand, and at the same time propose a theory to account for the chemical changes which have taken place to produce the mineral glauconite, its chief constituent.

The glauconite occurs both in existing seas and in geological deposits as minute grains, seldom exceeding 1 millimeter in diameter, although these grains may at times become agglomerated into nodules several centimeters in diameter by means of a phosphatic cement. The grains are always more or less rounded, and at times mammillated, with irregular surface outline. They are generally black or dark-green in color, but become brighter-green upon being crushed. The surface of the grain is sometimes covered with fine punctures, while at other times it is smooth and shining. Some of these glauconite grains are distinct internal casts of Foraminifera and of other calcareous shells; but more often they are only indistinct reproductions of the form of the chambers and show no definite connection with the organisms in which they originated. In the Eocene deposits the foraminiferal casts are less distinctly seen than in the deposits of recent seas, yet even here they are not uncommon.

It is estimated that glauconitic deposits cover approximately 1,000,000 square miles of the sea floor, while they are found at nearly all geological horizons from the Cambrian up. On the present ocean floor they are limited to those portions adjacent to the coasts, and for the most part along the higher parts of the continental slopes, where land-derived materials are deposited in perceptible yet small amounts. The production of glauconite seldom reaches to greater depths than 900 fathoms, and most commonly takes place between 100 and 200 fathoms. The entrance of large rivers into the sea or the prevalence of strong currents bearing sediment tends to interfere with its formation, so that its area of distribution is seldom continuous for great distances.

Although glauconite is not known to be formed except in the presence of land-derived materials, its production is accomplished through the intervention of Foraminifera. Their connection with the formation of glauconite was first shown by Ehrenberg[1] in 1855, as the result of a study of greensand from many deposits in Europe and America. Professor Bailey[2] in the succeeding year stated that the formation of greensand is likewise taking place on the floor of existing seas and probably under the same conditions that existed in past geological time.

According to Murray and Renard, the chambers become filled with muddy sediment, and "if we admit that the organic matter inclosed in the shell, and in the mud itself, transforms the iron in the mud into sulphide, which may be oxidized into hydrate, sulphur being at the same time liberated, this sulphur would become oxidized into sulphuric acid, which would decompose the fine clay, setting free colloid silica, alumina being removed in solution; thus we have colloid silica and hydrated oxide of iron in a state most suitable for their combination."

[1] Abhandl. K. Akad. Wiss. zu Berlin, 1855, pp. 85-176.
[2] Proc. Boston Soc. Nat. Hist. vol. 5, 1856, pp. 364-368.

The potash which is necessary to complete the composition of glauconite is regarded as derived from the decomposition of the fragments of crystalline rocks or their common constituents, orthoclase and white mica.

Two conditions, then, are requisite for the formation of glauconite: First, the deposition of mineral particles of land-derived origin; and second, the presence of Foraminifera. In the absence of either, glauconite will not be produced. On the other hand, it is retarded, and finally ceases altogether, as the amount of deposition of land-derived materials increases adjacent to the coasts. Only, then, within circumscribed limits, which are constantly subject to modification, is the formation of glauconite possible.

Glauconite seldom, if ever, occurs pure in nature, but is mixed with greater or less amounts of arenaceous materials, producing what is known as greensand, a term which is commonly made to embrace the argillaceous deposits as well, particularly when the glauconite grains are visible, although they are more correctly green clays. When the deposits are distinctly calcareous, they are generally known as greensand marls. No definite percentage of any of the constituents is required, and as they are so commonly intermingled the terms just described are used somewhat indiscriminately.

STRATIGRAPHICAL AND PALEONTOLOGICAL CHARACTERISTICS.

The Eocene deposits of the Middle Atlantic Slope constitute a single geological unit, which has been described by Mr. N. H. Darton[1] under the name of the *Pamunkey formation.* It is divisible by means of its contained fossils into two clearly defined stages, which have been already described by the writer[2] as the *Aquia Creek stage* and *Woodstock stage*, the names being given from characteristic localities on the right bank of the Potomac River in Virginia. Several minor fossiliferous zones have also been observed, and in some instances they have been traced for considerable distances.

As previously mentioned, the Eocene deposits in their unweathered condition are very homogeneous, but in local sections the upper beds are often extensively changed, while hard limestone layers are at times produced in the shelly strata. In this way the deposits may be locally separated into clearly defined lithological zones, which sometimes admit of reognition in adjoining regions.

POTOMAC RIVER SECTION.

The most complete section of the Eocene is found in the valley of the Potomac River between Aquia Creek, Stafford County, Va., and Popes Creek, Charles County, Md. Throughout this distance the bluffs afford a nearly complete sequence of the several members of the formation, while the fossils are numerous and well preserved.

[1] Bull. Geol. Soc. Am., Vol. II, 1891, p. 411.

[2] Johns Hopkins University Circulars, Vol. XV, 1895, p. 3; Am. Jour. Sci., 4th series, Vol. I, 1896, pp. 365-371.

The full Potomac River section is given in both cross-section and columnar form on Pls. V and VI. It is made up chiefly from the local sections at Aquia Creek, Potomac Creek, Woodstock, and Popes Creek, but contains additional data obtained at a few points inland.

The local sections are presented in columnar form on Pl. IV, and the numbering corresponds with that given in parenthesis in the description of the sections which follows. The numbering of the zones in the general sections is the same as that in the local sections. The unnumbered zones are post-Eocene.

Section of western portion of bluff at Aquia Creek, Virginia.

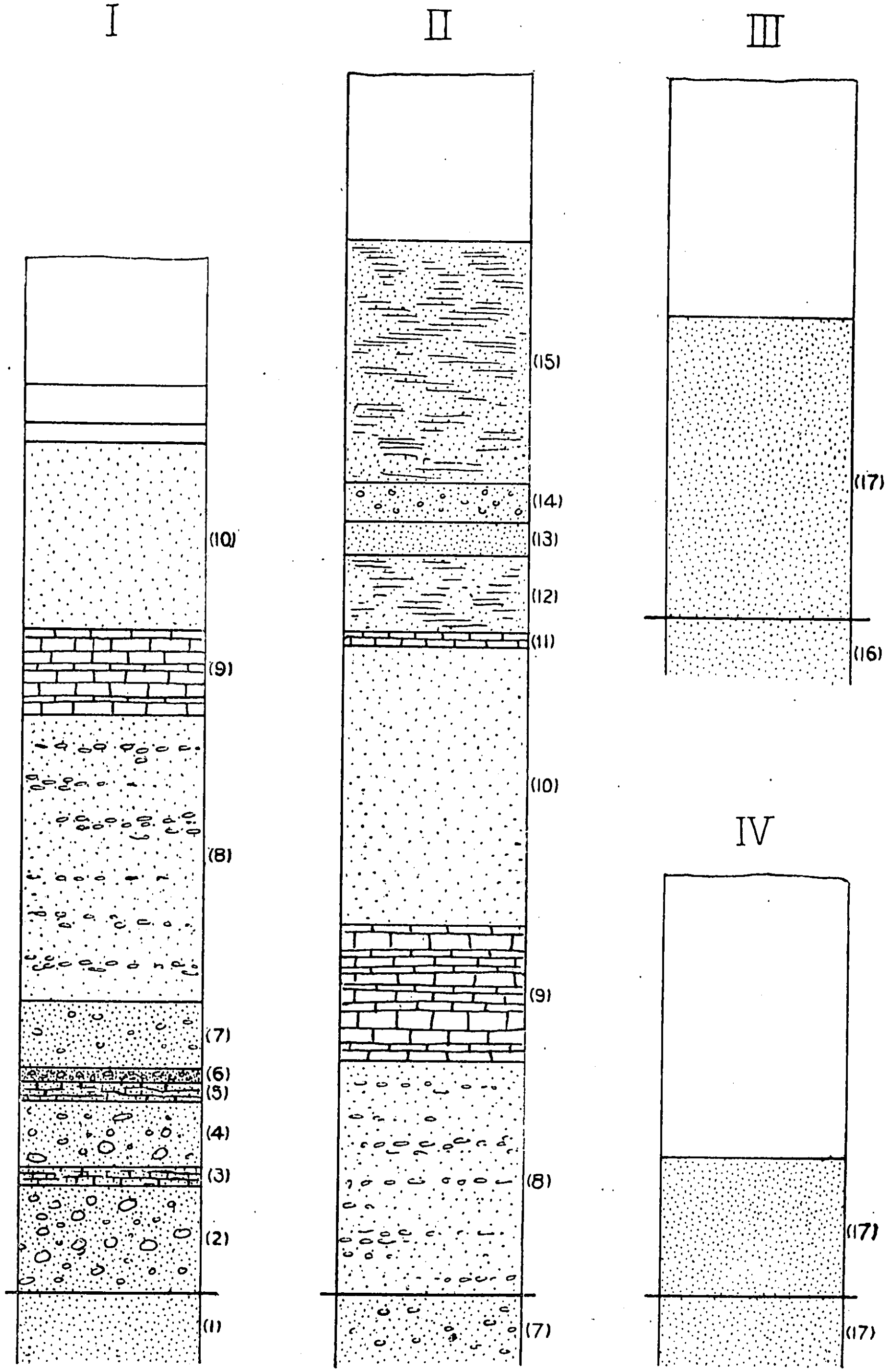
	Feet.
1. Fine sand, light-yellow in color, with white clay near the base and an indurated layer at the bottom	18
2. Fine sand, of light-greenish color, containing a few glauconitic grains (10).	18
3. Thick-bedded, arenaceous, and glauconitic limestone interstratified with unconsolidated layers of partially weathered greensand, the indurated layers largely filled with the shells of *Turritella mortoni* (9)	10
4. Fine sand, of gray or green color, containing several irregular bands of *Turritella mortoni*, also *T. humerosa*, *Cucullæa gigantea*, *Crassatella alæformis*, and *Ostrea compressirostra* (8)	30
5. Dark-colored greensand, chiefly filled with broken shells of *Cytherea ovata* and *Crassatella alæformis* (7)	7
6. Ditto, with same shells in whole condition (6)	1
7. Indurated layer of light-colored greensand filled with *Turritella mortoni*, *T. humerosa*, *Crassatella alæformis*, *Dosiniopsis lenticularis*, *Cytherea ovata*, *Panopæa elongata*, *Pholadomya marylandica* (5)	2
8. Greensand marl containing same forms (4)	8
9. Indurated layer of dark-colored greensand with *Crassatella alæformis*, *Cytherea ovata*, *Dosiniopsis lenticularis*, and *Ostrea compressirostra* (3)	2
10. Greensand marl with *Dosiniopsis lenticularis*, *Cytherea ovata*, and *Crassatella alæformis* (2)	12
	108

Section of center of bluff at Potomac Creek, Virginia.

1. Fine yellowish sand containing red and brown bands, with white clay at base.	25
2. Greenish-gray argillaceous sand, slightly glauconitic (15)	27
3. Argillaceous sand containing bands of selenite crystals (14)	4
4. Light-gray glauconitic sand with *Venericardia planicosta* (13)	3
5. Greenish-gray argillaceous sand (12)	8
6. Indurated greensand with *Venericardia planicosta* (11)	1
7. Greenish-gray argillaceous sand, glauconitic, with casts of *Cytherea* sp. (10)	25
8. Thick-bedded arenaceous and glauconitic limestone interstratified with layers of partially weathered greensand, the indurated strata largely composed of the shells of *Turritella mortoni* (9)	12
9. Greensand bed, much weathered in its upper portions, and filled chiefly with *Turritella mortoni* in several thick layers; also *T. humerosa*, *Cucullæa gigantea*, *Crassatella alæformis*, *Ostrea compressirostra*, and many other species (8)	25
	130

Section of center of bluff at Woodstock, Virginia.

1. Yellow and orange-colored sand and gravel	30
2. Dark greensand with *Ostrea sellæformis*, *Protocardia virginiana*, *Pectunculus idoneus*, *Cytherea subimpressa*, *Pecten rogersi*, *Corbula nasuta*, *Corbula oniscus*, *Leda* (*Adrana*) *cultelliformis*, and other forms (17)	32
	62



DETAILED COLUMNAR SECTIONS OF EOCENE STRATA.

I. Aquia Creek. II. Potomac Creek. III. Woodstock. IV. Popes Creek.

Section of bluff 1 mile south of Popes Creek, Maryland.

1.	Diatomaceous earth	40
2.	Dark greensand with *Protocardia virginiana, Cytherea subimpressa, Modiola potomacensis, Venericardia planicosta, Corbula nasuta,* and other forms (17)	15
		55

Careful measurements made at each of the local sections show the uniform dip of the strata to be about 12½ feet to the mile. The Turritella bed (9), which has an elevation of 62 feet at its base in the Aquia Creek section, has descended to 25 feet in the Potomac Creek section, 3 miles distant, while the indurated layer (5), which stands at 24 feet at the western end of the Aquia Creek section, has passed below tide level 2 miles to the southeastward. Similar measurements made at Woodstock and in some of the intervening ravines do not change the average estimate of the dip found at the two points first mentioned. It is evident, therefore, that on this basis of calculation the thickness of the Eocene strata in this area will not fall far short of 300 feet, the amount claimed by Darton upon the evidence afforded by well borings.

The different members of the Potomac River series will be now considered in detail. (See Pl. V.)

Zone 1.—The thickness of the Eocene deposits beneath the basal beds of the Aquia Creek section can not fall far short of 60 feet. Some exposures are seen in the ravines to the west of the bluff, but no complete sequence of the beds has been found. The almost entire absence of fossils renders the faunal relations of the strata undeterminable. The deposits are typical greensands, at times somewhat argillaceous, and with a basal pebble bed overlying the Cretaceous at some points.

Zone 2.—This bed has been observed both at the base of the Aquia Creek section and also on the opposite bank of the Potomac River at Clifton Beach, at both of which localities it outcrops at tide level. The bed is about 12 feet in thickness, but entirely disappears below the water line a little beyond the middle of the Aquia Creek bluff. The dark greensand of which the bed is mainly composed is packed with the shells of *Crassatella alæformis, Dosiniopsis lenticularis,* and *Cytherea ovata.*

Zone 3.—The limestone ledge composing this bed is much less persistent than in zones 5 and 6, which overlie it, and at times it nearly or quite disappears. It is 2 to 3 feet in thickness, highly glauconitic, and of dark color, and is filled with shells or, more commonly, casts of shells, among which the forms of zone 2 are conspicuous, together with *Ostrea compressirostra* and a few *Turritella mortoni.*

Zone 4.—This bed is a highly typical greensand, containing in the main the forms mentioned above as occurring in zone 3. It reaches about 8 feet in thickness.

Zone 5.—This limestone bed is very persistent and forms a conspicuous ledge, about 2 feet in thickness, along the face of the Aquia Creek bluff until it passes below tide water near its eastern extremity. In addition to the species already mentioned as characteristic for zones 2 to 5, which still remain the most common forms, it is packed with fossils, among which the following are conspicuous, viz: *Pholadomya marylandica*, *Panopæa elongata*, *Tellina virginiana*, *Pholas* (?) *petrosa*, *Calyptræa trochiformis*, *Fusus trabeatus*, *Fusus* sp., *Caricella* sp., etc.

Zone 6.—This thin layer, generally about 1 foot in thickness, of dark characteristic greensand, is packed with the common forms of the previous beds. It thickens somewhat to the eastward along the face of the bluff, and near Marlboro Point contains, among other forms, several species of corals, including *Eupsammia elaborata*, *Turbinolia acuticostata*, and *Paracyathus* (?) *clarkeanus*.

Zone 7.—The bed of greensand overlying the preceding layer is really a continuation of it, although the fossils are few in number and much broken. Fragments of the common forms of previous beds are present. This bed is about 7 feet thick.

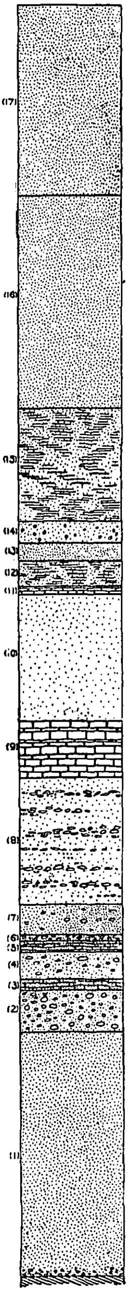
Zone 8.—The highly characteristic greensands and greensand marls are succeeded by a zone, some 30 feet in thickness, in which the grains of glauconite have been extensively weathered, giving the strata a greenish-gray appearance, which changes to a reddish-brown in the upper layers. Several irregular bands packed with *Turritella mortoni* are present in both the Aquia Creek and Potomac Creek sections, while associated with that species at both localities are *Turritella humerosa*, *Cucullæa gigantea*, *Crassatella alæformis*, *Ostrea compressirostra*, and other forms. The upper portions of this bed have afforded most of the species obtained from the Potomac Creek bluff.

Zone 9.—The thick-bedded limestone layers which compose this zone are almost exclusively made up of the shells of *Turritella mortoni*, forming a Turritella rock. Between the indurated layers are interstratified layers of unconsolidated and much weathered greensand, which contain few fossils of any description. Great masses of this Turritella rock strew the shore at the base of both the Aquia Creek and Potomac Creek bluffs. The bed is about 10 feet thick in the Aquia Creek bluff, but reaches 14 feet at Potomac Creek.

Zone 10.—The greenish-gray sand which overlies the Turritella rock is more argillaceous than the underlying beds of the Eocene. The glauconite grains have been much weathered and nearly all trace of the shell substance has been removed from the few forms recognized. The casts found at the Potomac Creek bluff are chiefly those of a *Cytherea*, probably *Cytherea ovata*. No fossils were observed at the Aquia Creek bluff. The bed is about 25 feet in thickness.

Zone 11.—A thin, highly indurated layer of argillaceous greensand was observed at the Potomac Creek bluff, in which a few specimens of *Venericardia planicosta* were found. It was not present in the Aquia Creek section.

Zone 12.—A greenish-gray argillaceous sand, containing still some unweathered grains of greensand, overlies the indurated layers, but no fossils were obtained. The bed is about 8 feet thick.



Greensand, with *Ostrea sellæformis*, *Pectunculus idoneus*, *Protocardia virginiana*, etc. Thickness, 40 feet (17)

Greensand, with few fossils, chiefly *Venericardia planicosta*. Thickness, 50 feet (16)

Greenish-gray argillaceous sand. Thickness, 25 feet (15)

Greenish-gray argillaceous sand, with bands of gypsum crystals. Thickness, 4 feet (14)

Light gray greensand, with *Venericardia planicosta*. Thickness, 3 feet (13)

Greenish-gray argillaceous sand. Thickness, 8 feet (12)

Indurated argillaceous greensand. Thickness, 2 feet (11)

Greenish-gray sand, somewhat argillaceous. Thickness, 25 feet (10)

Thick-bedded indurated greensand, with *Turritella mortoni*. Thickness, 14 feet (9)

Light greenish-gray greensand, with *Turritella mortoni*, *Cucullæa gigantea*, *Crassatella alæformis*, *Ostrea compressirostra*, etc. Thickness, 30 feet (8)

Greensand, with fragments of shells of lower beds. Thickness, 7 feet (7)

Greensand, with corals. Thickness, 1 foot (6)

Indurated greensand. Thickness, 2 feet (5)

Greensand, with *Crassatella alæformis*, *Cytherea ovata*, *Dosiniopsis lenticularis*, etc. Thickness, 8 feet (4)

Indurated greensand, with same fossils as zone above. Thickness, 3 feet (3)

Dark colored greensand filled with same fossils as zones above. Thickness, 12 feet (2)

Greensand, at times argillaceous and with basal pebble bed. Thickness, 60 feet (1)

GENERAL COLUMNAR SECTION OF EOCENE STRATA IN THE POTOMAC RIVER REGION.

Zone 13.—This bed consists of a light-gray glauconite sand somewhat weathered. It is filled almost exclusively with *Venericardia planicosta*. This zone is very persistent, outcropping in several of the ravines to the east and south of Potomac Creek. It is 3 feet thick.

Zone 14.—Overlying the Venericardia layer is a bed of greenish-gray argillaceous sand, some 4 feet in thickness, that contains a great number of bands filled with gypsum crystals. No fossils were observed.

Zone 15.—This bed consists of greenish-gray argillaceous sand, in which the glauconite grains have been extensively weathered. No fossils were found. The bed has a thickness of 25 feet.

Zone 16.—In this zone have been placed the strata intervening between the upper layers of the Potomac Creek section and the base of the Woodstock section. Comparatively little is known regarding this portion of the series, but the deposits are estimated to reach about 50 feet in thickness. They appear in an unfossiliferous condition in some of the ravines to the west of the Woodstock area.

Zone 17.—The highly glauconitic beds at Woodstock, Va., and Popes Creek, Md., are grouped together in this zone. They are very homogeneous, although an inconstant indurated layer appears about 6 feet above the base of the Woodstock section, with a band of *Venericardia planicosta* 2 feet below it, while a thin bed of *Ostrea sellæformis* also occurs in the lower part of the zone, although evidently not always at the same horizon. Otherwise, so far as observed, the fossils are the same in the several parts of the two sections. The most common forms are *Protocardia virginiana*, *Pectunculus idoneus*, *Cytherea subimpressa*, *Corbula nasuta*, *Corbula oniscus*, *Leda* (*Adrana*) *cultelliformis*, *Pecten rogersi*, *Leda improcera*, *Leda parva*, *Nucula magnifica*, *Lucina dartoni*, *Lucina uhleri*, *Lucina whitei*, *Ringicula dalli*, and *Cylichna venusta*.

The lithological characteristics of zones 10 to 15, which have been observed only in the Aquia Creek and Potomac Creek bluffs, may be quite different under less weathered conditions.

The paleontological characteristics of the several zones, so far as can be determined, indicate two very distinct faunal stages, the first typically developed in the zones 2 to 9 and the second in zone 17. The characteristics of zone 1 and of zones 10 to 16 can not be readily made out in the Potomac River area on account of the extensive weathering of the beds, although in some of the adjoining districts there is an intermingling of some of the forms of the two stages in the intervening beds between zones 9 and 17.

AQUIA CREEK STAGE.

The Aquia Creek stage, which is most characteristically shown in zones 2 to 9, has a great variety of forms. The most common species are *Turritella mortoni* Conrad, confined chiefly to zones 8 and 9; *Cytherea ovata* Rogers and *Crassatella alæformis* Conrad, confined largely to zones 2 to 7; *Cucullæa gigantea* Conrad, mainly found in zone 8; *Ostrea* *compressirostra* Say[1], most common in zones 6 and 7; and *Dosiniopsis lenticularis* Rogers, largely limited to zones 2 to 5.

Other species found in this stage are *Thecachampsa marylandica* Clark, *Trionyx virginiana* Clark, *Ischyrhiza* (?) *radiata* Clark, *Myliobatis copeanus* Clark, *Carcharodon polygurus* Agassiz, *Lamna* (?) *obliqua* (Agassiz), *Oxyrhina hastalis* Agassiz, *Odontaspis elegans* (Agassiz), *Galeocerdo contortus* Gibbes, *Nautilus* sp., *Tornatella bella* (Conrad), *Pleurotoma harrisi* Clark, *Volutilithes petrosa* Conrad, *Volutilithes* (*Athleta*) *tuomeyi* Conrad, *Volutilithes* sp., *Caricella* sp., *Fusus* (*Levifusus*) *trabeatus* Conrad, *Fusus* (*Strepsidura*) *perlatus* Conrad, *Fusus* sp., *Fulgur argutus* Clark, *Lunatia marylandica* Conrad, *Natica cliftonensis* Clark, *Turritella humerosa* Conrad, *Calyptræa trochiformis* Lamarck, *Vermetus* sp., *Scala virginiana* Clark, *Gibbula glandula* (Conrad), *Solarium* sp., *Gastrochæna* sp., *Pholas* (?) *petrosa* Conrad, *Tellina williamsi* Clark, *Panopæa elongata* Conrad, *Pholadomya marylandica* Conrad, *Lucina aquiana* Clark, *Venericardia planicosta* Lamarck, *Crassatella aquiana* Clark, *Leda protexta* Conrad, *Modiola potomacensis* Clark, *Pecten johnsoni* Clark, *Pecten* sp., *Ostrea* sp., *Serpula* sp., *Paracyathus clarkeanus* Vaughan, *Turbinolia acuticostata* Vaughan, *Eupsammia elaborata* Conrad, besides many species of Foraminifera.

WOODSTOCK STAGE.

The Woodstock stage is found typically developed at zone 17.

The most common forms are *Protocardia virginiana* Conrad, *Pectunculus idoneus* Conrad, *Cytherea subimpressa* Conrad, *Corbula nasuta* Conrad, *Corbula oniscus* Conrad, *Ostrea sellæformis* Conrad, *Leda* (*Adrana*) *cultelliformis* (Rogers), *Leda improcera* (Conrad), *Leda parva* (Rogers), *Nucula magnifica* Conrad, *Venericardia planicosta* Lamarck, *Lucina dartoni* Clark, *Fusus* (*Levifusus*) *trabeatus* Conrad, *Ringicula dalli* Clark, and *Cylichna venusta* Clark.

Among other species found at this horizon may be mentioned *Mangilia* (*Pleurotomella*) *bellistriata* Clark, *Turritella* sp., *Cadulus bellulus* Clark, *Teredo virginiana* Clark, *Solemya petricoloides* (Lea), *Lucina whitei* Clark, *Lucina uhleri* Clark, *Modiola potomacensis*, and numerous species of Foraminifera.

OTHER SECTIONS.

Along none of the other drainage lines is the sequence of Eocene strata so complete as in the Potomac River area. Several important local sections, composed of one or more members of the series, have been observed at different points and may be correlated with one or the other of the stages previously referred to.

Along the Chester River weathered greensands outcrop in many of the low bluffs and have been found to contain casts of several of the more common Eocene fossils, among which *Turritella mortoni* and *Venericardia planicosta* are most conspicuous.

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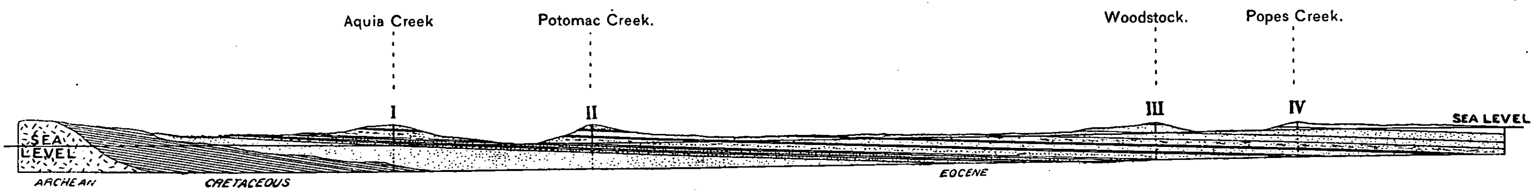
[1] Several immature oysters found at this horizon bear a strong resemblance to the young of *Ostrea sellæformis*.



CROSS SECTION OF EOCENE STRATA IN THE POTOMAC RIVER REGION.

The Severn River section is composed of highly weathered beds, of a deep-brown color, in which iron crusts are common. The strata cap the high bluffs which extend almost continuously from Round Bay to the mouth of the river at Annapolis. *Cucullæa gigantea*, *Ostrea compressirostra*, *Cytherea ovata*, *Turritella mortoni*, *Venericardia planicosta*, *Dosiniopsis lenticularis*, and other forms occur.

The Patuxent and its tributaries cut deeply into the Eocene deposits. The section at Upper Marlboro is particularly noteworthy on account of the highly fossiliferous character of the strata, and has been frequently referred to in geological literature.

Section at Upper Marlboro, Maryland.

	Feet.
1. Reddish gravelly loam	18
2. Fine loose sand of light-yellow color	20
3. Dark-gray greensand, slightly argillaceous, with few ferruginous crusts, yellow mottled in places	55
4. Brownish sands with casts of *Turritella mortoni*	3
5. Greenish-gray marl with *Venericardia planicosta* and other forms	2
6. Indurated layer of light greenish-gray sand filled with *Turritella mortoni*, *Cucullæa gigantea*, *Cytherea ovata*, *Dosiniopsis lenticularis*, *Pectunculus idoneus* *Venericardia planicosta*, *Calyptrophorus jacksoni*, *Astarte marylandica*, *Ostrea compressirostra*, and other forms	8
7. Loose, greenish, ash-colored sands containing many of the same species as the overlying bed	10
	116

Along the tributaries entering the Potomac River on the western side of Charles County, Md., several extensive outcrops are found. Among them the section at Fort Washington is the most important and best known.

Section in ravine north of Fort Washington, Maryland.

	Feet.
1. Red loam with gravel and sand at base	25
2. Brownish weathered greensand	20
3. Firm, dark greensand	4
4. Dark greensand densely crowded with *Turritella mortoni*	5
5. Fine dark greensand filled with *Crassatella alæformis*, *Cytherea ovata*, *Turritella mortoni*, and many other species	7
6. Greensand of dark-gray color, with *Cucullæa gigantea*, *Crassatella alæformis*, *Dosiniopsis lenticularis*, *Cytherea ovata*, *Turritella mortoni*, and other species.	14
7. Partially indurated bed crowded with *Cucullæa gigantea*, *Ostrea compressirostra*, and other forms	10
8. Dark greenish-gray sands	20
	105

The numerous bluffs along the Rappahannock River, in King George and Caroline counties, Va., combined give an excellent section of the Eocene. Moons Mount, on the south bank of the river, about 5 miles above Port Royal, is the most extensive bluff, and affords at its base 50 feet of homogeneous greensand, which is very fossiliferous and in which occur *Lamna* (?) *obliqua*, *Odontaspis elegans*, *Lunatia marylandica*, *Corbula oniscus*, *Corbula aldrichi*, *Cytherea ovata*, *Venericardia planicosta*, *Leda protexta*, *Pecten rogersi*, *Ostrea sellæformis*, and other species.

On the Pamunkey River a moderately extensive section of the Eocene occurs. At Newcastle, a short distance below Hanoverville, the following highly fossiliferous exposure is found:

Section below Hanoverville, Pamunkey River, Virginia.

	Feet.
1. Gravel and sand	3
2. Reddish mottled greensand crowded with *Ostrea sellæformis*	3
3. Gray greensand, weathered in the upper part, with *Cadulus bellulus, Corbula aldrichi, Corbula oniscus, Tellina virginiana, Cytherea subimpressa, Lucina whitei, Diplodonta hopkinsiensis, Venericardia planicosta, Nucula magnifica, Leda improcera, Modiola potomacensis, Pectunculus idoneus,* and *Ostrea sellæformis*	30
4. Black greensand	10
	46

Next to the Potomac River section, the James River section is the most complete in the Middle Atlantic Slope. A large number of outcrops are found in the bluffs between Richmond and Coggins Point, although the most extensive and fossiliferous localities are at City Point, Evergreen, and Tar Bay.

Section at City Point, Virginia.

	Feet.
1. Reddish gravelly loam	30
2. Light greensands containing layer of *Ostrea compressirostra* at base	3
3. Dark greensand crowded with *Turritella mortoni* and few *Cytherea ovata*	3
4. Partially indurated greensand marl, with *Crassatella alæformis, Mytilus potomacensis, Corbula* sp., and other indeterminable fragments	5
	41

Divisions 3 and 4 are obtained in pits and well openings below tide level.

Section at Evergreen, Virginia.

	Feet.
1. Red loam	50
2. Yellowish sands filled with characteristic Miocene fossils	10
3. Greensands, at times argillaceous, with *Lamna* (?) *obliqua, Carcharodon polygurus, Oxyrhina hastalis, Odontaspis elegans, Galeocerdo contortus, Lunatia marylandica, Corbula oniscus, Corbula aldrichi, Cytherea ovata, Diplodonta hopkinsiensis, Venericardia planicosta, Leda parva, Leda* (*Adrana*) *cultelliformis, Cucullæa gigantea,* and *Ostrea sellæformis*	25
	85

Section at Tar Bay, Virginia.

1. Light-colored sands	20
2. Red loam	50
3. Yellowish sands with characteristic Miocene fossils	10
4. Bed of *Ostrea sellæformis*	5
5. Loose, light-colored greensand, mottled with yellow	15
6. Argillaceous greensand with gypsum crystals	10
7. Greensands	30
	140

Division 6 is below water level.

CORRELATION OF THE STRATA.

CRITERIA EMPLOYED IN THE CORRELATION OF THE SEDIMENTARY ROCKS.

An examination of the diverse physical and faunal conditions prevailing at the present time on the various portions of the earth's surface shows as nothing else can the difficulty of satisfactorily correlating widely separated deposits of a given age. It clearly indicates the necessity of using not one but every class of criteria, if the chronological interpretation is to be made with even an approximate degree of correctness.

It too often happens that the geologist employs one class of criteria to the exclusion of all the others, and thus finds himself at variance with those who are attempting to interpret the facts by other methods. Not only is this disparity of view found among those who base their conclusions on the one hand entirely upon physical and on the other entirely upon biological grounds, but among those who make use of the different subclasses of criteria under each of these heads. Thus the conclusions based upon similarity of materials alone are often at variance with those based upon similarity of structural relations, while the evidence of vertebrate paleontology often differs in a marked degree from that of paleobotany, and that in turn from the evidence derived from invertebrate paleontology. Each, of course, can not be altogether right, although in most cases each is partly right. Under some conditions one set of criteria may be more important than another, and in any particular case results of real value can be obtained only by carefully ascertaining the relative significance of each.

It should be kept clearly in mind that the chronological classification of the sedimentary rocks has its primary basis in the order of superposition of the strata. In most cases it is only as the latter has been determined that the major and minor divisions of the geological scale have been established and correlation thus rendered possible.

At the same time the duality of geological classification must be recognized, although for purposes of correlation in closely contiguous districts the stratigraphical and chronological divisions may not require an independent nomenclature. Over wider areas and in different provinces the formation terms are no longer adequate to express the chronological facts, and the prefixing of the syllables *Eo-*, *Meso-*, and *Neo-* to the name of the era, as proposed by Prof. H. S. Williams,[1] may be appropriately adopted.

GEOLOGICAL CRITERIA.

CRITERIA DERIVED FROM A STUDY OF THE STRATA.

The direct method of correlation of the sedimentary rocks upon geological grounds is based upon a study of the strata in different areas and a comparison of their various physical characters one with another. This comparison may be between strata of closely contiguous areas or

[1] Jour. of Geol., Vol. II, 1894, pp. 145-160.

between those of more distant regions, or it may even be of a universal nature. Thus the various classes of criteria are found to have varying values, some being of local, others of wide application. It is only as the limitation of each is ascertained that its importance for correlative purposes is determined in any particular case.

Continuity of deposits.—Where it can be determined, the continuity of the deposits affords the simplest and surest means of correlation; but lithological variation, deformation, erosion, and subsequent burial of the strata make its universal application impossible. It is, however, very generally employed within limited areas where structural disturbance has been slight, and to the geologist engaged in areal mapping it affords one of the most satisfactory means of correlation. As the distinguishing characters of the various geological formations become more fully recognized, this method of correlation can be more successfully employed, but at the best it can be used only within relatively narrow limits.

Similarity of materials.—In the earlier days of geological investigation lithological similarity was almost universally employed for purposes of correlation, and even world-wide chronological comparisons were often attempted on this basis. As it came to be recognized that similar deposits had been formed under similar conditions during nearly every geological epoch, this method became much restricted in its application. Still, similarity of materials may be of great value for correlative purposes if controlled in other ways, since it sometimes happens that strata almost identical in composition are found over considerable areas. More often, however, the diverse conditions of sedimentation caused such a change in the character of the materials, even within short distances, that this method can be employed with safety only within very limited districts.

In general, the deposits formed in deep water are more persistent than those formed in proximity to the shore or upon the land, since the character of sedimentation would be less affected by slight physical changes.

Some formations are characterized by certain lithologic elements peculiar to themselves, although at the same time they may contain others common to associated deposits. In absence of other means this has at times afforded the opportunity of wide correlations even when the strata have been found under quite diverse conditions or in widely separated areas.

Similarity of sequence.—The same sequence of deposits commonly occurs throughout the area where sedimentation has taken place under the same set of physical conditions. It is seldom that such conditions were sufficiently persistent to make correlation upon these grounds possible throughout any considerable territory, although there are cases now and then where it is feasible. When this method is employed for the individual beds of a single formation, it is much more restricted in its application than when used for larger units, although in the latter instance there is greater liability to error.

Similarity of change.—Not infrequently rocks may be correlated upon the basis of the amount of induration or metamorphism to which they have been subjected. That this can not be of universal and frequently not of wide application is shown by the fact that rocks of the same age may be in one place unaltered while under other conditions they may be indurated or even metamorphosed. Still, it not infrequently happens that in local areas some form of alteration in the original character of the strata may serve as the most simple means of correlation. It has been employed among the pre-Cambrian rocks as the most satisfactory basis of major classification and correlation.

Similarity of structural relations.—Deposits of a particular age are commonly changed from their original plane of sedimentation by either local or general elevations or depressions. When brought above sea level, they may be subjected to processes of erosion, resulting first in surfaces of marked relief, which may ultimately become baseleveled if the same conditions prevail sufficiently long.

In any event unconformity occurs by subsequent deposition. In unaltered sediments the line of unconformity is often obscured, and it is largely by a study of the intrinsic characters of the formations themselves that unconformity is inferred. Such unconformities, whether readily observable or not, are of much importance for correlative purposes when viewed in connection with the data afforded by the adjacent land surfaces.

As elevations and depressions have not been of universal occurrence at the same period, unconformity is not a sure index of age for distant provinces. It is a recognized fact, however, that widely extended unconformities indicate general continental movements, and thus may afford a basis of correlation over extended areas even when the physical and faunal conditions have been different.

CRITERIA DERIVED FROM A STUDY OF THE ADJACENT LAND AREAS.

The indirect method of correlation of the sedimentary rocks upon geological grounds is based upon a study of the conditions which existed in the adjacent land areas during the time of deposition of the strata. Such indices of age may not be employed with the definiteness that is possible in the direct method, yet they often afford satisfactory criteria for wide correlation when controlled in other ways.

Similarity of land movement.—The effects of either continental or local movement during any particular geological period are often seen in the character and volume of the sediments laid down along the border of the land, as well as in the relations which these deposits hold to associated formations. If the land surface of a drainage basin lies near the water level, the degradation is largely of a chemical nature, while if it stands high above the water level it is more largely mechanical.

The attitude of the continent and the extent and character of deformation at different periods during geological history thus become most important guides in determining the age of deposits, and when they are known to have been of wide extent, aid materially in bringing into a consistent grouping strata formed under widely different conditions.

Similarity of topographic form.—The different phases in the degradation of the land likewise afford criteria for the correlation of the sedimentary rocks, but the conditions of topographic form are so far determined by land movement that this method of correlation is closely allied to the preceding. Each region, as it is elevated above the sea level, is subjected to degradation, which ceases only when the whole area is worn down to sea level again or is interrupted by further land movements. Generally remnants of the earlier surfaces are left for a time, so that it may be possible to reconstruct the ancient topography of a particular period and show the relation which it bears to the rocks of the same period, thus affording a means of correlation for the latter. It may also afford an independent method of determining geological history.

PALEONTOLOGICAL CRITERIA.

The paleontological criteria have been generally regarded as the most important, although fossils are often absent from a given area or from a whole formation, or, when present, may lack sufficiently distinctive characters to be of any value for correlative purposes. Nevertheless, when not too narrowly interpreted, fossils afford by far the most trustworthy guides in the chronological interpretation of geological strata. It must be borne in mind, however, that change in physical conditions has an important influence upon the character and range of organic forms, and when distant areas are compared with one another the effects of migration must also be taken into consideration. Such factors of possible variation, however, must not be allowed too largely to affect conclusions, since there has been the same general succession of faunas and floras over great areas, and even throughout the world.

With these preliminary considerations the various methods of paleontological correlation will be further considered.

Identity of species.—It not infrequently happens that the same group of species may be found to characterize a definite horizon over considerable areas. The number of these identical forms generally decreases as the distance from the first-studied locality increases. Some species are thus found to be more persistent in their geographical distribution than others, and, where restricted in their vertical range, these characteristic or type forms become most important for correlative purposes.

Difference in physical conditions and distance from the first-observed locality must be taken into consideration, however, as under other conditions the same species may have changed more or less widely in time, while its generally slow migration may have caused its appearance at a much later period in one locality than in another. "Similarity or identity of fossils among formations geographically far apart, instead of proving contemporaneity, may be compatible with great discrepancies in the relative epochs of deposit." (Geikie.) Still, there are forms which, on account of their rapid migration, are almost worldwide in their geographical distribution, and which appear at apparently the same horizon wherever found.

It is thus only, as all the conditions, physical and biological, are taken into consideration, that the value of specific identity for correlative purposes can be determined.

Similarity of faunas and floras.—Of much greater significance in the correlation of the strata of distant areas are the conclusions derived from a study of the whole assemblage of forms or the comparison of the general facies of the fauna or flora, including the species, genera, and families. It is the general, not the specific, character of the fauna or flora that thus becomes the basis of correlation. There are forms which range through an entire group of deposits and which serve to characterize the division as a whole, while there are others which are confined in range and which serve to characterize definite horizons or zones in the major division. The prevalence of such particular forms constitutes what are known as "life zones," and all the great divisions are capable to some extent of being broken up into them, although they may not be detected at all points. Such life zones may be local in character, or constant over wide areas, or even universal. The forms which have been of most value in characterizing life zones of wide extent have been the graptolites, the brachiopods, the ammonites, and the trilobites.

The subdivisions of a general fauna do not always, however, afford the same grouping of forms. Regarding such geological subdivisions Sir Archibald Geikie says: "They must not be assumed to be strictly applicable elsewhere. Advancing into another district or country where the petrographical characters of the same formation or system indicate that the original conditions of deposits must have been very different, we ought to be prepared to find a greater or less departure from the first observed or what we unconsciously and not unnaturally come to look upon as the normal order of organic succession. There can be no doubt that the appearance of new organic forms in any locality has been in large measure connected with such physical changes as are indicated by diversities of sedimentary materials and arrangements. The Upper Silurian stages, for example, as studied by Murchison in Shropshire and the adjacent counties, present a clear sequence of strata well defined by characteristic fossils; but within a distance of 60 miles it becomes impossible to establish these subdivisions by fossil evidence. Such facts warn us against the danger of being led astray by an artificial precision of paleontological detail. Even where the paleontological sequence is best established it rests, probably in most cases, not merely upon the actual chronological succession of organic forms, but also, far more than is actually imagined, upon original accidental differences of local physical conditions." Prof. H. S. Williams says upon this point, in the article previously cited: "The life period of species is not uniform, and the wider the distribution the longer is, as a rule, the range; so we find in practice that with the greatest knowledge of fossils it is rarely possible to discriminate age to a finer degree than that indicated by the periods Eocambrian, Mesocambrian, and Neocambrian, or similar periods for the other eras."

The intermittent occurrence of particular assemblages of species is often brought about by varying physical conditions by which certain portions of a common fauna find alternately a favorable and an unfavorable habitat. Thus deposits composed of sandstones and limestones not infrequently show such repetitions of forms. They must not be confounded with life zones.

Although faunas may remain moderately constant over considerable areas during approximately the same period, the time involved in their migration to distant regions must likewise be taken into consideration, as it is evident that the appearance of the same fauna in two widely separated districts can not have been synchronous. It is thus even within the range of possibility for an inversion of faunas to occur as the result of intermigration.

Zoological provinces also have been found at all periods since the Cambrian, and, except where clearly defined life zones occur, only the general characters of the contained faunas can be compared.

Stage of evolution.—This method of correlation, which depends upon a very intimate knowledge of the succession of organic types, has been long employed in a general way to indicate the approximate age of formations whose stratigraphic position is unrecognized and which contain hitherto unknown species and genera. Recently some attempts have been made to restrict this method to the more definite determination of geological horizons. The claim is made by Professor Marsh that in the Mammalia the position of the fauna in the geological column can be determined from its stage of evolution. Although this method is undoubtedly of great importance within certain limits, varying physical conditions have so largely affected the development of life that it is impossible to conceive of its reaching the same stage of evolution everywhere. This is clearly brought out when the varying rates of progress in floral and in faunal evolution in the different portions of the globe are contrasted. It has been found that a certain stage of evolution in plant life, which was found to be contemporaneous with a certain stage in animal life in one portion of the globe, has become contemporaneous with a higher or lower stage, as the case may be, in another portion. Similar inequality in the rate of evolution is frequently seen, also, when vertebrate and invertebrate life are compared. It seems highly probable that the same inequality in the rate of evolution of each group of animal and plant forms may occur under changed conditions of life.

This method, therefore, must lack precision, but it may at times be employed advantageously when other methods fail.

Relative number of living species.—This method of correlation, which was proposed by Sir Charles Lyell, depends upon the percentages of forms belonging to living species found in the deposits. It was applied to the Tertiary, certain standard percentages being assumed to indicate the divisions proposed. It is at times useful, in the later formations, where other methods can not be employed, but as faunal change has not been the same in all regions, conclusions derived by this method can be approximate only.

GENERAL CONCLUSIONS.

As the different methods of correlation are examined in retrospect, the interdependence which exists between the various classes of physical and biological criteria becomes clearly manifest.

The faunal and floral characteristics of a formation find their full interpretation only as the physical factors are clearly understood, since the geological and geographical range of forms is determined to a large extent by conditions of sedimentation. The physical characters of a formation therefore bear a close relationship to its contained fossils, and can not be ignored in the correlation of the deposits.

Although the most trustworthy correlations are based upon paleontological data, the possibilities of variation in the succession of organic forms in two distant areas are so great that detailed correlations can seldom be satisfactorily attempted, even where general equivalence is recognized.

The geologist therefore must take into consideration both the geological and the paleontological criteria in the correlation of the sedimentary rocks. No class of facts can be ignored.

APPLICATION OF THE CRITERIA TO THE CORRELATION OF THE EOCENE STRATA OF THE MIDDLE ATLANTIC SLOPE.

When we come to employ one or another of the several classes of criteria above described in the correlation of the Eocene deposits of the Middle Atlantic Slope we find that they have varying values—values dependent upon whether the attempted correlation is made between deposits within the province or with distant regions.

CORRELATION WITHIN THE PROVINCE.

GEOLOGICAL CRITERIA.

As has been already indicated, the Eocene strata of the Middle Atlantic Slope can be traced almost continuously from central Delaware to southern Virginia, and in their unweatherd state they are also remarkably similar in lithological characters throughout this distance. At the same time their relations to underlying and overlying formations are everywhere much the same, although in passing from Delaware southward into Virginia, where the basal beds rest unconformably upon the Potomac, the Eocene deposits encroach more and more upon older formations.

Similar effects of change by weathering and induration are widely found in the strata, but the weathered beds and indurated layers are not always present at the same horizon throughout the area. In consequence the same sequence of deposits dependent upon these changes is generally limited in extent. On the other hand, when the materials are unweathered their homogeneous nature renders this method of correlation of little value.

From the above statements it is evident that the deposits within the province may be correlated on physical grounds alone when they are viewed as a single geological unit, while their individual members can generally be traced only for short distances.

PALEONTOLOGICAL CRITERIA.

Two clearly marked stages have been already described in the Potomac River section, each characterized by a particular assemblage of forms, viz, the Aquia Creek stage and the Woodstock stage.

The Aquia Creek stage is the most widely developed, and has been traced all the way from central Delaware to southern Virginia. It occurs with its typical fauna along the Chester River, on the eastern shore of Maryland, and in the bluffs of the Severn River, South River, Piscataway Creek (including the Fort Washington section), at Glymont, at Clifton Beach, and at many other points on the western side of the Chesapeake. These localities afford one or more of the zones from 2 to 9 of the Potomac section, although the local sequence of beds is somewhat different in each case. In general, however, *Cytherea ovata*, *Crassatella alæformis*, and *Dosiniopsis lenticularis* may be regarded as most common in the lower part of the series, while *Turritella mortoni* particularly characterizes the upper layers, as in the Potomac area.

Portions of the South River region and the area about Upper Marlboro afford a few forms not found in the lower beds, including *Calyptrophorus jacksoni* and *Pectunculus idoneus*, the latter being common in the Woodstock stage. Otherwise the species agree most closely with the lower fauna, although they may represent a horizon slightly higher than the typical beds of that stage. An examination of the Upper Marlboro section will show the main fossiliferous zones to be succeeded by over 50 feet of Eocene greensands, in which the few traces of fossils have been insufficient to show their faunal relations.

South of the Potomac area the Aquia Creek stage has been observed on the Rappahannock, Pamunkey, and James rivers, the best locality along the latter stream being found at City Point and vicinity.

Upon faunal grounds the Woodstock stage has been identified only in Maryland, in southern Charles County, at Popes Creek and vicinity, although the position and lithological nature of some of the beds on the Patuxent River and the Chesapeake Bay shore indicate the presence of beds of that horizon.

To the south of the Potomac area are highly fossiliferous strata containing fossils of this stage, both above and below Front Royal on the Rappahannock, in the vicinity of and below Hanoverville on the Pamunkey, and at Evergreen and Tar Bay, as well as at other points on the James River.

The Evergreen section is less distinctive than that at Tar Bay and probably underlies the base of 17 in the Woodstock area, and it should therefore probably be correlated with the upper portions of 16.

The thick bed of *Ostrea sellæformis* at Tar Bay has its approximate equivalent in the thinner layers of the same species at Hanoverville and Woodstock.

CORRELATION WITH OTHER PROVINCES.

By common consent the diversified and extensive deposits of the Gulf area have come to be regarded as the type for the eastern border region, and the various Eocene deposits of the Atlantic Coast States have been assigned to a position in this series, although very different limits have been given by the different authorities.

The Eocene deposits of the Middle Atlantic Slope have been regarded by some as representing a single minor division of the Gulf section, while others have regarded them as the equivalent of a larger portion of that series. The latter conclusion seems to the writer, after a consideration of both the geological and the paleontological data, to be the only tenable position. In the past too little attention has been given to the geological phenomena, while at the same time the knowledge of the fossils has been wholly insufficient for a proper interpretation of the faunal characteristics of the formation.

GEOLOGICAL CRITERIA.

The lithological and stratigraphical characteristics of the Eocene deposits of the Middle Atlantic Slope afford some important criteria for the correlation of the strata. In the first place, the homogeneous nature of the materials, already referred to, is a significant feature, and indicates conditions undisturbed by important physical changes throughout the period of Eocene deposition. Again, the fact that the strata are so largely made up of secondary materials shows that the position of accumulation was in the vicinity of a coast reached by no large rivers bearing sediment, while also, for the most part, sufficiently removed from the coast line to be unaffected by shore conditions. It is further evident that these deposits, which are so largely glauconitic, were very slowly accumulated, as has been shown in the case of the formation of greensand upon the beds of seas now existing.

Now, when we compare these conditions of accumulation in the Middle Atlantic Slope with the conditions that prevailed in the Gulf region marked differences appear. In the latter area numerous rivers draining the interior of the continent discharged great quantities of material throughout much of Eocene time, making the deposits highly diversified. Instead of the greensands and greenish and black clays of the Middle Atlantic Slope, which no longer to any large extent characterize the strata, are found coarser beds of sand and clay, often partly calcareous, which give every indication of more rapid accumulation. To compare, therefore, the 200 to 300 feet of greensands and clays of the Middle Atlantic Slope with one or two subdivisions of hardly equal thickness in the Gulf region would scarcely be attempted, even upon geological grounds, without the aid of fossils. The strata of the Middle Atlantic Slope must be represented in the Gulf by deposits many times their thickness.

The general relations of the strata, occurring as they do between the Cretaceous and Neocene along both the Atlantic and the Gulf coasts, give some indications of the continental movements to which each province was subjected. Although the movements may not have been absolutely contemporaneous, they nevertheless afford satisfactory criteria for the broad correlation of the deposits, their more exact parallelism being determined on other grounds.

PALEONTOLOGICAL CRITERIA.

The value of fossils in the correlation of the sedimentary rocks has been discussed in the preceding chapter. Although life zones are frequently of great extent and may be accepted as the most trustworthy evidence of geological contemporaneity, yet the subdivisions of a fauna recognized in one area under one set of physical conditions may not be found in another area distant from the first where the conditions are wholly different. It is scarcely to be expected that the vertical range of the species will be the same in the two regions, while the time occupied in migration is a factor that can not be ignored in most classes of organism.

Likewise, forms which from their persistence under one set of physical conditions may be regarded as typical may be entirely wanting in an adjacent province. The presence also of a large number of new species is of itself evidence of change in physical surroundings, and renders it necessary to proceed with great caution when detailed correlation of the strata is attempted. Especially is this true when the areas are widely separated in latitude, so that temperature differences occur.

When the faunal characteristics of the Eocene of the Middle Atlantic Slope are compared with those of the Gulf, it is found, first of all, that the assemblage of forms is very different in the two areas. The great majority of the species are unlike, while the identical forms are mainly of wide vertical range. Most of those regarded as the same also show certain differences as the result of the dissimilar conditions under which they lived, so that the determination of the Middle Atlantic Coast forms often involves certain doubts as to their identity with Gulf species. The sequence of forms is likewise different, a differentiation into the great number of subdivisions recognized in the Gulf not occurring in Maryland and Virginia.

The Aquia Creek fauna, which is typically developed in zones 2 to 9 in the Potomac area, occupies, so far as it can be with certainty determined, only about 70 feet of strata some 60 feet from the base of the formation, and contains, among other Gulf species, *Turritella mortoni*, *Turritella humerosa*, *Tornatella bella*, *Volutilithes* (*Athleta*) *tuomeyi*, *Fusus* (*Strepsidura*) *perlatus*, *Dosiniopsis lenticularis*, *Venericardia planicosta*, *Cucullæa gigantea*, and *Ostrea compressirostra*. The general aspect of this assemblage is Lignitic, some of the forms being found in the Gulf area, in the middle, or in the middle and lower, members of that division, while others range into its upper portions, and are also found in higher horizons. At the same time, quite 60 feet of strata are found beneath the Aquia Creek fossiliferous beds, in which as yet only a few indistinct casts of *Turritella* sp. have been observed. If the fossiliferous zones represent approximately the middle or the middle and upper Lignitic, this lower zone may be regarded in a general way as the equivalent of the lower Lignitic.

The Woodstock fauna, on the other hand, is typically represented in zone 17 of the Potomac section, and, so far as can be determined with certainty, embraces about 45 feet at the top of the series. It contains, among other Gulf forms, *Fusus* (*Levifusus*) *trabeatus*, *Solemya petricoloides*, *Corbula nasuta*, *Corbula oniscus*, *Venericardia planicosta*, *Nucula magnifica*, *Pectunculus idoneus*, and *Ostrea sellæformis*, the latter species increasing in number toward southern Virginia and affording thick beds on the Pamunkey and James rivers. At the same time, the common forms of the Aquia Creek stage are wanting. Although not possessing the number of distinctive forms found in the preceding divisions, the Woodstock stage is nevertheless in all probability the representative of the Claiborne of the Gulf, showing a closer parallelism perhaps with the beds beneath the fossiliferous sands than with the upper horizon.

Between the fossiliferous beds carrying the faunas of the two stages are very nearly 125 feet of strata, in which few fossils have been found except *Venericardia planicosta*. Many of the beds seem to be wholly barren of organic remains, while in others only a few undeterminable casts appear. No satisfactory paleontological data for correlation are therefore afforded by these deposits.

If the Aquia Creek fauna should be held to be sufficiently similar to the Bells Landing fauna to warrant its restriction to that substage (middle Lignitic), and the *Ostrea sellæformis* bed of the Woodstock stage should be held to be the exact equivalent of the *Ostrea sellæformis* zone of the Claiborne, then the 600 feet between those horizons in central Alabama are represented by only 125 feet in the Middle Atlantic Slope, and perhaps by considerably less. The representatives of the Woods Bluff and Hatchetigbee stages of the Lignitic, together with the Buhrstone and lower portion of the Claiborne, would thus be here included. The upper beds of the Woodstock stage might then be regarded, perhaps, as the equivalent of the Upper Claiborne, while the 60 feet below the Aquia Creek stage would then approximately represent the earlier portions of the Lignitic. As these lower beds are much more glauconitic than the beds above the Aquia Creek stage, they were doubtless accumulated more slowly.

It is apparent, therefore, that the sequence of organic remains in the Middle Atlantic Slope Eocene does not afford the necessary data for a detailed parallelism of the subdivisions of that area with those of the Gulf. It seems altogether probable that the Pamunkey formation is the equivalent in a broad way only of the lower and middle divisions of the Eocene of the Gulf, and may even represent portions of the upper divisions as well. Regarding the latter reference there is little paleontological evidence, but undoubtedly less change in faunal development would be produced under the stable conditions that prevailed in Eocene time in the Middle Atlantic Slope than under the conditions which prevailed in the Gulf, so that the more highly developed fauna of the upper portions of the series in the latter area may have existed contemporaneously with older forms outside the region. Without a much fuller knowledge of the characteristics of the Eocene fauna in the intermediate district this can not be definitely determined, although it seems highly probable.

Considering all the facts, the writer is decidedly of the opinion that the Eocene deposits of the Middle Atlantic Slope represent the greater portion of the Eocene series of the Gulf, its upper members alone excepted. Compared with the section originally described by Prof. E. A. Smith in the Alabama area, it undoubtedly comprises all or the major part of the Lignitic, Buhrstone, and Claiborne, and perhaps also portions of higher horizons, but, as previously stated, regarding the latter point the necessary paleontological evidence is lacking. This reference does not, however, necessarily involve the assumption that the basal beds of the Potomac section are the exact equivalent of the basal beds of the Lignitic, since deposition may have commenced in the one area somewhat earlier than in the other, although the difference in time was probably not great.

DESCRIPTION OF SPECIES.[1]

VERTEBRATA.

REPTILIA.

CROCODILIA.

Genus THECACHAMPSA Cope.

THECACHAMPSA MARYLANDICA Clark.

PL. VII, fig. 1.

Thecachampsa marylandica Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 4.

Fragment of jaw moderately thick, the single complete and one partially preserved alveoli not far removed from one another. Teeth with

[1] The synonymy is confined to Middle Atlantic Slope references, with the exception of original descriptions.

elongate, slightly curved, conic crowns; basis circular, its diameter about one-third the length of the tooth; apex acute, circular; surface with fine longitudinal striations.

Three specimens of this species were obtained from Maryland localities. The form taken as the type consists of a single tooth set in a fragment of the jaw, and was obtained at Clifton Beach, Maryland.

The teeth of this species are most closely related to the forms described by Cope[1] as Sericodon, from the Miocene, but are somewhat less curved and elongate, and rather more coarsely striated.

Dimensions.—Length of tooth, 38 mm.; diameter at base, 12 mm.

Localities.—Clifton Beach, Upper Marlboro, Maryland.

Collection.—Johns Hopkins University.

CHELONIA.

Genus EUCLASTES Cope.

EUCLASTES (?) sp.

Euclastes (?) sp. Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 4.

Several fragments of the carapace of a large sea turtle were found at Clifton Beach, but they are not sufficiently well preserved to identify the genus with certainty. The fragments of the costals show that the surface was smooth and the edges of the plates more or less rounded. The shields were relatively thin. It seems probable that they belong to Euclastes.

Locality.—Clifton Beach, Maryland.

Collection.—Johns Hopkins University.

Genus TRIONYX G. St. Hilaire.

TRIONYX VIRGINIANA Clark.

PL. VIII, figs. 1*a*, 1*b*.

Trionyx virginiana Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 4.

Fragments of costals with tuberculated and ridged surfaces characteristic of the genus Trionyx. The longitudinal ridges are prominent, at times irregular and inosculate; relatively remote and separated by intervals about twice their width; generally entirely disappear near the margins of the plates.

A number of fragments of the plates of this large species were found in the vicinity of Aquia Creek, Virginia. This species shows some points of similarity with *T. cariosus* Cope, from the Eocene of New Mexico, but is undoubtedly a different form.

Dimensions.—Length of largest fragment, 130 mm.; width, 45 mm.; thickness, 18 mm.

Locality.—Aquia Creek, Virginia.

Collection.—Wagner Free Institute of Science.

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[1] Proc. Acad. Nat. Sci., Philadelphia, 1867, p. 143.

COPROLITES.

PL. VII, fig. 4.

Well-preserved specimens of coprolites showing the intestinal lines are not uncommon in the Eocene, and doubtless belong to some one of the reptilian types. The form figured is a very perfect specimen, with a fracture at one extremity. It is from Clifton Beach.

Localities.—Clifton Beach, Maryland; Aquia Creek, Virginia.

Collection.—Johns Hopkins University.

PISCES.

TELEOSTOMI.

Genus ISCHYRHIZA Leidy.

ISCHYRHIZA (?) RADIATA Clark.

PL. VII, figs. 2*a*–2*c*.

Ischyrhiza (?) radiata Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 4.

It is with some uncertainty that the remarkable specimens here described are referred to *Ischyrhiza*, which is represented by teeth in both the Cretaceous and Tertiary deposits of the Atlantic Coastal Plain.

The present species is based upon the caudal vertebra with its coalesced spines, and two detached vertebræ situated just prior to the same. They were found in the greensand strata at Clifton Beach, Maryland.

The caudal vertebra is remarkable in having firmly coalesced to it both the hæmal and neural spines, so as to form a single solid piece. This remarkable feature has been observed in other forms from the Miocene, but nothing identical has been hitherto described.

The precaudal vertebræ are elongated, deeply amphicœlous, and bear delicate neural spines. All the parts indicate a medium-sized teleostean fish.

Dimensions.—Length of caudal vertebra, 25 mm.; height of coalesced portion, 40 mm.

Locality.—Clifton Beach, Maryland.

Collection.—Johns Hopkins University.

OTOLITHS.

Numerous otoliths of teleostean fish have been found in the Eocene deposits at different locations along the Potomac River in Maryland and Virginia. The specimens vary in size from 3 mm. to 10 mm. in longest diameter, but apparently represent the same type of fish, the relations of which it is, however, impossible to determine, although it is not improbable that they belong to the form just described.

Localities.—Clifton Beach, Maryland; Aquia Creek, Woodstock, Va.

Collection.—Johns Hopkins University.

ELASMOBRANCHII.

Genus MYLIOBATIS Cuvier.

MYLIOBATIS COPEANUS Clark.

PL. VII, figs. 3*a*, 3*b*.

Myliobatis copeanus Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 4.

Portions of both the upper and lower dentition of this species were found. Only four of the median teeth of the upper jaw, somewhat worn about the margins, were obtained united. They show the strongly arched arrangement in an antero-posterior direction, which is so characteristic of the dentition of this jaw. The dental crowns are distinctly striated, while the attached surface of the root is deeply ridged and grooved in a longitudinal direction.

The dentition of the lower jaw is relatively flat. In one very large specimen portions of the lateral teeth are attached to the median series. The median teeth are about five times as broad as long. The lateral teeth are somewhat longer than wide. Numerous detached teeth of the lower jaw, apparently of the same species, were found.

By comparison with the species of *Myliobatis* hitherto described the present form shows points of difference in outline and structure.

Dimensions.—Length of median teeth in lower jaw, 9 mm.; width, 40 mm.

Localities.—Clifton Beach, Maryland; Aquia Creek, Virginia.

Collection.—Johns Hopkins University.

Genus CARCHARODON Smith.

CARCHARODON POLYGYRUS Agassiz.

Carcharodon polygyrus Agassiz, 1843, Poiss. Foss., Vol. III, p. 253, Pl. XXX, figs. 9-12.
Carcharodon polygyrus Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 4.

This species is of moderate size and presents many points of similarity to *Carcharodon megalodon*, with which it has been placed by A. S. Woodward. The presence upon the teeth examined of very clearly defined denticles, often partially separated, distinguishes it from that species. On the other hand, it is much too broad for reference to *C. auriculatus*. It is the largest of the Eocene sharks, although none of the teeth attain the dimensions of the specimens figured by Agassiz.

Localities.—Evergreen, Potomac Creek, Virginia.

Collection.—Johns Hopkins University.

Genus LAMNA Cuvier.

LAMNA (?) OBLIQUA Agassiz.

Otodus obliquus Agassiz, 1843, Poiss. Foss., Vol. III, p. 267, Pl. XXXI.
Lamna (?) obliqua Woodward, 1889, Foss. Fishes Brit. Mus., Pt. I, p. 404.
Lamna (?) obliqua Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 4.

The very robust teeth assigned to this species have been generally regarded as belonging to *Otodus*, a genus which A. S. Woodward holds to be synonymous with *Lamna*, although by Noetling the species here described is considered as connecting that genus with *Carcharodon*, since the edges of the teeth at times show fine serrations. On that account the reference of the species to *Lamna* is made with some uncertainty.

Localities.—Aquia Creek, Evergreen, Front Royal, Virginia.

Collection.—Johns Hopkins University.

Genus OXYRHINA Agassiz.

OXYRHINA HASTALIS Agassiz.

Oxyrhina hastalis Agassiz, 1843, Poiss. Foss., Vol. III, p 277, Pl. XXXIV.
Oxyrhina hastalis Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV., p. 4.

Several medium-sized teeth of this very widespread Tertiary species have been found in the Virginia Eocene. They are broad and compressed, the crowns slightly curved outward just at the apex, the roots short and blunt. All of the specimens obtained are somewhat worn or broken, but they show the characteristic features of the species.

Localities.—Evergreen, Aquia Creek, Virginia.

Collection.—Johns Hopkins University.

Genus ODONTASPIS Agassiz.

ODONTASPIS ELEGANS (Agassiz).

Lamna elegans Agassiz, 1843, Poiss. Foss., Vol. III, p. 289, Pl. XXXV, figs. 1-5.
Odontaspis elegans Woodward, 1889, Foss. Fishes Brit. Mus., Pt. I, p. 361.
Odontaspis elegans Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 4.

This species, which is by far the most common of the Eocene sharks in the Maryland and Virginia deposits, is mainly represented by very small teeth, although a few large and fine specimens have been obtained. The small lateral denticles are often worn to such an extent that their presence is not easily discerned. The coronal eminence is long and narrow, marked in perfect specimens with a large number of clearly defined longitudinal striations.

Localities.—Fort Washington, Clifton Beach, Popes Creek, Maryland; Aquia Creek, Evergreen, Front Royal, Virginia.

Collection.—Johns Hopkins University.

Genus GALEOCERDO Müller and Henry.

GALEOCERDO CONTORTUS Gibbes.

Galeocerdo contortus Gibbes, 1849, Jour. Acad. Nat. Sci., Philadelphia, second series, Vol. I, p. 193, Pl. XXV, figs. 71-74.
Galeocerdo contortus Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 4.

This small form has very robust teeth for its size. The apex of the teeth is much elongated above the posterior notch, generally produced to a sharp point and more or less twisted. The anterior margin is angulated and finely serrated. The margin below the posterior notch has many fine serrations. This species is not uncommon in the Virginia Eocene.

Localities.—Aquia Creek, Evergreen, Virginia.

Collection.—Johns Hopkins University.

ARTHROPODA.

CRUSTACEA.

Minute crustaceans of the genera *Cythere* and *Cythereidea*, as well as other forms, have been found in considerable numbers in the Woodstock stage. They will receive special study at a later time.

Localities.—Woodstock, Hanoverville, Virginia.

Collection.—Johns Hopkins University.

MOLLUSCA.

CEPHALOPODA.

Genus NAUTILUS Breyn.

NAUTILUS sp.

Pl. IX, fig. 1.

Nautilus sp. Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 4.

Several fragments of a nautiloid shell have been obtained from the Maryland Eocene deposits, undoubtedly belonging to the genus *Nautilus*, although many of the characteristic features are lacking. The specimens obtained represent a form moderately large and somewhat flattened at the sides.

Locality.—Clifton Beach, Maryland.

Collection.—Johns Hopkins University.

GASTEROPODA.

Genus TORNATELLA Lamarck.

TORNATELLA BELLA (Conrad).

Tornatellæa bella Conrad, 1860, Jour. Acad. Nat. Sci., Philadelphia, new series, Vol. IV, p. 294, pl. 47, fig. 23.

Tornatella bella Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 4.

Shell small, solid, ovate in profile, six-whorled; surface with uniform, punctate, spiral grooving, crossed only by lines of growth; spines short, conical, acuminate; whorls slightly convex; body whorl more than half the length of the shell, moderately convex; suture distinct; outer lip simple; columella with two pronounced oblique plicæ.

The specimens of this species obtained in the Middle Atlantic Slope are generally somewhat less ventricose than the Gulf forms, but otherwise are practically the same.

Localities.—Aquia Creek, Front Royal, Virginia.

Collection.—United States National Museum.

Genus CYLICHNA Loven.

CYLICHNA VENUSTA Clark.

Pl. IX, figs. 2*a*, 2*b*.

Cylichna venusta Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 4.

Shell small, elongate-ovate, rather globose; surface spirally striate; spire depressed; columella with small obscure plait. This very delicate species is not uncommon in the upper portion of the Eocene in the Potomac River region, although the exceedingly fragile character of the shell renders it difficult to obtain complete specimens.

Dimensions.—Length, 3 mm.; width, 2 mm.

Localities.—Woodstock, Virginia; Popes Creek, Maryland.

Collection.—Johns Hopkins University.

Genus RINGICULA Deshayes.

RINGICULA DALLI Clark.

Pl. IX, figs. 3*a*, 3*b*.

Ringicula dalli Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 4.

Shell small, five-whorled; surface of last four whorls strongly striate spirally; spire elevated, acuminate; body whorl much inflated; outer lip much thickened and crenulate within; columella with thick callous and with two strong plaits.

None of the species of *Ringicula* hitherto described show the form or characteristic surface markings of the present type. This species has been found only in the Woodstock stage.

Dimensions.—Length, 3 mm.; width, 1.5 mm.

Locality.—Woodstock, Virginia.

Collection.—Johns Hopkins University.

Genus PLEUROTOMA Lamarck.

PLEUROTOMA HARRISI Clark.

Pl. IX, figs. 4*a*, 4*b*.

Pleurotoma harrisi Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 4.

Shell of moderate size, elongate, five or six whorled; surface with distinct, revolving lines of varying size, crossed by transverse ridges; aperture narrow, with long straight canal.

In its general form this species is very much like *P. nasuta*, Whitfield. It shows a difference, however, in both the number and size of its transverse ribs and spiral threads, the latter being numerous and prominent. This species has been found only in zone 8 of the Aquia Creek stage.

Dimensions.—Length, 22 mm.; width, 7 mm.

Locality.—Potomac Creek, Virginia.

Collection.—Johns Hopkins University.

Genus MANGILIA (Leach) Risso.

Subgenus PLEUROTOMELLA Verrill.

MANGILIA (PLEUROTOMELLA) BELLISTRIATA Clark.

PL. IX, fig. 5.

Mangilia (*Pleurotomella*) *bellistriata* Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 4.

Shell small, subfusiform, with a rather short pointed spire and about five whorls; body whorl large, somewhat inflated, earlier whorls nearly flat; surface sculptured with numerous alternating larger and smaller spiral threads crossed by fine wavy lines and by irregularly spaced oblique ribs, about twenty in number on the body whorl; ribs strongest at the shoulder, gradually disappearing both posteriorly and anteriorly; behind the shoulder somewhat excavated; aperture narrow. This form is from the Woodstock stage.

Dimensions.—Length, 25 mm.; width, 12 mm.

Locality.—Popes Creek, Maryland.

Collection.—Johns Hopkins University.

Genus VOLUTILITHES Swainson.

Subgenus ATHLETA Conrad.

VOLUTILITHES (ATHLETA) TUOMEYI Conrad.

PL. X, figs. 1*a*, 1*b*.

Athleta tuomeyi Conrad, 1853, Proc. Acad. Nat. Sci., Philadelphia, Vol. VI, p. 449.
Volutilithes (*Athleta*) *tuomeyi* Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 4.

This species, which plays so important a rôle in the Gulf Eocene, being represented throughout most of the series, is not wanting in the Middle Atlantic Slope. Several excellent specimens have been found in zone 8 of the Aquia Creek stage. The callosity of the columella is very pronounced in the forms obtained. The specimen figured has a length of 45 mm. and a width of 30 mm.

Locality.—Potomac Creek, Virginia.

Collection.—Johns Hopkins University.

VOLUTILITHES sp.

PL. X, figs. 2*a*, 2*b*.

Volutilithes sp. Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 4.

A fine cast of a large species of *Volutilithes* was obtained from the indurated ledge, zone 3, at the Aquia Creek bluffs. It is evidently unlike any of the species of *Volutilithes* hitherto described, but from the fact that the shell substance is lacking no attempt will be made to assign a specific name. It has a somewhat compressed form.

Dimensions.—Length, 75 mm.; width, 53 mm.

Locality.—Aquia Creek, Virginia.

Collection.—Johns Hopkins University.

Genus CARICELLA Conrad.

CARICELLA sp.

PL. XI, fig. 1.

Caricella sp. Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 4.

A cast of a *Caricella* occurs among other gasteropods in the indurated layer, zone 5, at Aquia Creek. The spire is very short and the body whorl inflated. It is impossible, however, to assign the specimen to any species hitherto described. In all probability it represents a new species, but the state of preservation is such that it does not seem best to employ a new name.

Dimensions.—Length, 55 mm.; width, 22 mm.

Locality.—Aquia Creek, Virginia.

Collection.—Johns Hopkins University.

Genus MITRA Lamarck.

MITRA MARYLANDICA Clark.

PL. XI, figs. 3*a*, 3*b*.

Mitra marylandica Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 4.

Shell small, rather thick, with six (?) whorls; surface with numerous, thickly-set spiral threads, crossed by fine wavy lines, giving a finely reticulated appearance; spine moderately high; suture distinct, appressed; shoulder not prominent; aperture elongated; columella nearly straight, with three plaits.

This very delicate form is represented only by broken specimens, although with the exception of the earlier whorls the type is fairly well preserved.

Dimensions.—Length, 20 (?) mm.; width, 7 mm.

Locality.—Pamunkey Neck, Maryland.

Collection.—United States National Museum.

MITRA sp.

PL. XI, figs. 4*a*, 4*b*.

Mitra sp. Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV. p. 4.

A fragment of a second species of *Mitra*, somewhat like the preceding in form, but with numerous, distinct, transverse riblets, and less clearly defined spiral lines, was collected at Pamunkey Neck, Maryland. In the absence of more satisfactory material it is not named.

Dimensions.—Length, 25 mm.; width, 10 mm.

Locality.—Pamunkey Neck, Maryland.

Collection.—United States National Museum.

Genus PYROPSIS Conrad.

PYROPSIS sp.

PL. XI, figs. 2*a*, 2*b*.

Pyropsis (?) *sp.* Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 4.

Several casts which show a highly flattened spire and much angulated shoulder have been referred to *Pyropsis.* They are remarkably like some of the New Jersey Cretaceous types in outline, although are undoubted Eocene species. They are found at zone 5 in the Aquia Creek stage.

Dimensions.—Length, 24 mm.; width, 45 mm.

Localities.—Crownsville, Maryland; Aquia Creek, Virginia.

Collection.—Johns Hopkins University.

Genus FUSUS Lamarck.

Subgenus LEVIFUSUS Conrad.

FUSUS (LEVIFUSUS) TRABEATUS Conrad.

Fusus trabeatus Conrad, 1833, Fossil Shells, p. 29; second edition, p. 53, pl. 18, fig. 1.
Fusus (*Levifusus*) *trabeatus* Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 4.

Several fragments of molds of the exterior of this species, as well as less clearly defined casts of the interior, have been found. The latter are very common in the indurated layer, zone 5, at Aquia Creek, Virginia.

Localities.—Popes Creek, Maryland; Aquia Creek, Virginia.

Collection.—Johns Hopkins University.

Subgenus STREPSIDURA Swainson.

FUSUS (STREPSIDURA) PERLATUS Conrad.

Fusus perlatus Conrad, 1835, Fossil Shells, second edition, p. 54, pl. 18, fig. 5.
Fusus (*Strepsidura*) *perlatus* Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 4.

Several shells showing all the essential characters of this species were obtained in the Potomac region, as well as numerous casts that apparently belong to the same form. The Virginia shells show a somewhat larger number of varices upon the spire than do those from Alabama. All of the specimens are somewhat fragmentary.

Locality.—Aquia Creek, Virginia.

Collection.—Johns Hopkins University.

FUSUS sp.

PL. XI, fig. 6.

Fusus sp. Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 4.

The cast of a *Fusus* with prominent spiral bands and strongly accentuated transverse ribs occurs with the forms hitherto described in the indurated layer at Aquia Creek. The earlier whorls are lost and the canal is broken, but the impression of the surface decoration shows distinctly on the body whorl and the one preceding it. It occurs in zone 5 of the Aquia Creek stage.

Locality.—Aquia Creek, Virginia.

Collection.—Johns Hopkins University.

Genus FULGUROFICUS Montfort.

FULGUROFICUS ARGUTUS Clark.

Pl. XII, figs. 1*a*, 1*b*.

Fulgur argutus Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 4.

Shell moderately short, with four or five whorls; first two whorls apparently smooth; third whorl with faintly impressed spiral lines and minute transverse riblets; later whorls with spinous tubercles at the shoulder; body whorl also with two lower rows of tubercles arranged along strongly elevated spiral ridges and transversely placed vertically above one another; ten to fourteen tubercles in each row; numerous fine spiral threads also pass over the spinous ridges and interspaces; lines of growth somewhat irregular; canal rather long, narrow.

This species shows some points of relationship to *F. triserialis* Whitfield, but both its form and surface markings as shown by description and figure hinder its reference to that type.

Dimensions.—Length, 30 mm.; width, 18 mm.

Localities.—Potomac Creek, Virginia; Pamunkey Neck, Maryland.

Collections.—Johns Hopkins University; United States National Museum.

Genus CALYPTROPHORUS Conrad.

CALYPTROPHORUS JACKSONI Clark.

Pl. XII, figs. 2*a*, 2*b*.

Calyptrophorus jacksoni Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 4.

Shell large, solid, many whorled; spire prolonged, acuminate; surface of adult covered with thick, calcareous deposit, entirely enveloping the whorls; inner lip thickened with extensive callosity.

This very remarkable form is quite distinct from any other species, none of the Gulf types approaching it in size or amount of callosity. Some of the largest specimens of *C. trinodifera* Conrad show certain points of similarity, but the Maryland species can not be confounded with it. In the absence of young shells, the character of the surface decoration is unknown. A large number of specimens have been found in the South River area.

Dimensions.—Length, 75 mm.; width, 30 mm.

Localities.—South of Annapolis, near South River, Upper Marlboro, Md.

Collections.—Johns Hopkins University; Museum of Comparative Zoology, Cambridge.

Genus LUNATIA Gray.

LUNATIA MARYLANDICA Conrad.

PL. XII, figs. 3*a*–3*c*.

Lunatia marylandica Conrad, 1865, Am. Jour. Conch., Vol. I, pp. 26, 211, pl. 21, fig. 11.
Lunatia marylandica Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 4.

This species, first described by Conrad without a reference to its locality beyond the name assigned to it, was in a later list classed as from Alabama. Numerous specimens of this species have been found widely distributed both in Maryland and in Virginia, and it may be regarded as one of the most common of Eocene fossils, although its delicate shell renders it unsuited for good preservation.

Dimensions.—Most of the specimens are small, seldom exceeding 15 mm. in length and 15 mm. in width. A few forms were obtained, however, that attained 25 mm. in length and 25 mm. in width.

Localities.—Fort Washington, Upper Marlboro, Maryland; Evergreen, Front Royal, Potomac Creek, Virginia.

Collections.—United States National Museum; John Hopkins University; Philadelphia Academy of Natural Science.

Genus NATICA Lamarck.

NATICA CLIFTONENSIS Clark.

PL. XII, fig. 4.

Natica cliftonensis Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 4.

Shell small, with four or five whorls; spire low; body whorl much inflated; suture well marked; surface smooth, except for lines of growth; aperture large, with thick callus.

Only a single specimen of this very delicate form was found.

Dimensions.—Length, 10 mm.; width, 12 mm.

Locality.—Clifton Beach, Maryland.

Collection.—Johns Hopkins University.

Genus TURRITELLA Lamarck.

TURRITELLA MORTONI Conrad.

PL. XIII, figs. 1*a*–1*e*.

Turritella mortoni Conrad, 1830, Jour. Acad. Nat. Sci., Philadelphia, Vol. VI, p. 221, pl. 10, fig. 2.
Turritella mortoni Conrad, 1832, Fossil Shells of the Tertiary, p. 40, pl. 15, fig. 11.
Turritella mortoni Morton, 1834, Synopsis Organ. Rem. Cretaceous Group, App., p. 4.
Turritella mortoni H. C. Lea, 1848, Proc. Acad, Nat. Sci., Philadelphia, Vol. IV, p. 107.
Turritella mortoni Conrad, 1865, Am. Jour. Conch., Vol. I, p. 32.
Turritella mortoni de Gregorio, 1890, Ann. Geol. et Pal., p. 122, pl. 11, fig. 7.
Turritella mortoni var. postmortoni Harris, 1894, Am. Jour. Sci., third series, Vol XLVII, p. 303.
Turritella mortoni Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 4.

This important species was one of the first to be recognized in the Maryland Eocene, and has been generally regarded as one of the most characteristic as it is one of the most common forms. At times it makes up whole beds, as shown in zones 8 and 9 of the Aquia Creek stage at Aquia Creek, Potomac Creek, and other neighboring localities. It is also common in zones 5 to 7 in the same area.

Turritella mortoni shows very great variations in the form and decoration of the whorls, and if it were not for the great number of intermediate types one might readily establish several independent species.

Some specimens have nearly equally rounded whorls with evenly spaced spiral lines, while others are prominently carinated toward the base of the whorl and the spiral threads are irregularly spaced, varying in prominence and number.

A variety named *postmortoni* by Harris is characterized by its rather smaller size, plainer surface, and extremely sharp basal carina.

Localities.—Richmond, City Point, Aquia Creek, Potomac Creek, Virginia; Clifton Beach, Fort Washington, Upper Marlboro, Maryland.

Collections.—Johns Hopkins University; United States National Museum; Philadelphia Academy of Natural Sciences.

TURRITELLA HUMEROSA Conrad.

PL. XIV., Fig. 1.

Turritella humerosa Conrad, 1835, Trans. Geol. Soc. Penn., p. 340, pl. 13, fig. 3.
Turritella humerosa H. C. Lea, 1848, Proc. Acad. Nat. Sci., Philadelphia, Vol. IV, p. 107.
Turritella humerosa Conrad, 1865, Am. Jour. Conch., Vol. I, p. 32.
Turritella humerosa Conrad, 1866, Smith. Misc. Coll. (200), p. 11.
Turritella humerosa Harris, 1894, Am. Jour. Sci., third series, Vol. XLVII, p. 303.
Turritella humerosa Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 4.

Turritella humerosa, although not an uncommon species, is far less frequent than *T. mortoni*. It is very readily separated from the latter by its flat whorls and prominent subsutural carina, which makes the whorls of nearly equal diameter above and below.

This species apparently never reaches the dimensions of *T. mortoni*, but is commonly associated with it. Like *T. mortoni*, it is largely confined to zones 8 and 9 of the Aquia Creek stage.

Localities.—Fort Washington, Clifton Beach, Maryland; Aquia Creek, Virginia.

Collections.—Johns Hopkins University; United States National Museum; Philadelphia Academy of Natural Sciences.

Genus CALYPTRÆA Lamarck.

CALYPTRÆA TROCHIFORMIS Lamarck.

Calyptræa trochiformis Lamarck, 1804, Ann. Mus. d'Hist. Nat., Vol. I, p. 15, fig. 3.
Calyptræa trochiformis Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 4.

This widely distributed species, found both in Europe and America, ranging throughout much of the Tertiary series, was obtained at numerous localities in Maryland and Virginia. The shell has been found in a perfect condition only in young forms, but many casts of maturer individuals were obtained from the indurated layers at Aquia Creek.

Localities.—Fort Washington, Clifton Beach, Maryland; Aquia Creek, Potomac Creek, Virginia.

Collection.—Johns Hopkins University.

Genus VERMETUS Adanson.

VERMETUS sp.

Pl. XIV, figs. 2*a*, 2*b*.

Vermetus sp. Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 4.

Fragmentary masses of this form are found at various points in the Potomac River region, but no specimen sufficiently well preserved for specific determination has been obtained. The fragments probably represent a new species, however. The form is characterized by longitudinal furrows, giving it a somewhat angulated appearance, and by transverse scaly lines interrupted by the furrows. The average diameter of the tubes is about 2 mm.

Localities.—Piscataway Creek, Maryland; Potomac Creek, Virginia.

Collections.—United States National Museum; Johns Hopkins University.

Genus SCALA Humphrey.

SCALA VIRGINIANA Clark.

Pl. XIV, figs. 3*a*, 3*b*.

Scala virginiana Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 4.

Shell probably seven or eight whorled; surface covered with a uniform, fine, spiral striation; varices fifteen to the whorl, inflected forward and prominent; some of the varices are more prominent than others, and in a few instances are partially divided by a central groove; aperture nearly round.

The single specimen of this species is from the Aquia Creek stage.

Dimensions.—Length of five whorls, 20 mm.; diameter of largest whorl, 15 mm.

Locality.—Aquia Creek, Virginia.

Collection.—United States National Museum.

Genus SOLARIUM Lamarck.

SOLARIUM sp.

Pl. XIV, figs. 4*a*, 4*b*.

Solarium sp. Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

The cast here figured and described represents a very much flattened *Solarium*, but the characters are not sufficiently distinct to admit of specific determination. It is from zone 5 of the Aquia Creek stage.

Dimensions.—Length, 6 mm.; width, 16 mm.

Locality.—Aquia Creek, Virginia.

Collection.—Johns Hopkins University.

Genus GIBBULA Risso.

GIBBULA GLANDULA (Conrad).

Pl. XIV, fig. 5.

Monodonta glandula Conrad, 1830, Jour. Acad. Nat. Sci., Philadelphia, Vol. VI, p. 220. pl. 9, fig. 15.
Monodonta glandula H. C. Lea, 1848, Proc. Acad. Nat. Sci., Philadelphia, Vol. IV, p. 102.
Monodonta glandula Conrad, 1866, Smith. Misc. Coll. (200), p. 11.
Gibbula glandula Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

Three very perfect specimens of this rare form, described by Conrad from Maryland only, were obtained at Potomac Creek. The numerous, uniform, revolving striæ are highly characteristic of the species.

Locality.—Potomac Creek, Virginia.

Collections.—Johns Hopkins University; Philadelphia Academy of Natural Sciences.

SCAPHOPODA.

Genus CADULUS Philippi.

CADULUS BELLULUS Clark.

Pl. XIV, fig. 6.

Cadulus bellulus Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

Shell of moderate size, thin, polished, slightly arched; much contracted near the anterior extremity; anterior opening subcircular, posterior simple.

This species is not far removed from *C. subcoarctatus* Gabb, yet it shows certain constant differences in form, which renders it impossible to associate it with that species. On account of the fragile nature of the shell it has not been possible to obtain perfect specimens, although the form is common in the Woodstock stage.

Dimensions.—Length, about 10 mm.; diameter, 2 mm.

Locality.—Woodstock, Va.

Collection.—Johns Hopkins University.

PELECYPODA.

Genus TEREDO Linné.

TEREDO VIRGINIANA Clark.

Pl. XV, figs. 5a–5c.

Teredo virginiana Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

Shell unknown; tube thick, cylindrical, irregularly curved, rapidly tapering; surface smooth, or with fine lines of growth; prominent transverse segment near posterior extremity of the tube in some of the forms.

A comparison of this type with the forms described from the Alabama Tertiary shows various points of dissimilarity, and even in the absence of the valves seems, from its common occurrence, worthy of a name.

Dimensions.—Diameter of tube, 2 to 3 mm.

Localities.—Woodstock, Potomac Creek, Evergreen, Virginia; Clifton Beach, Maryland.

Collection.—Johns Hopkins University.

Genus PHOLAS Linné.

PHOLAS (?) PETROSA Conrad.

PL. XV, figs. 1*a*–1*c*.

Pholas petrosa Conrad, 1842, Proc. Nat. Inst. Promotion Science, second bulletin, p. 193, pl. 2, fig. 4.
Pholas petrosa Conrad, 1846, Am. Jour. Sci., second series, Vol. I, p. 213, pl. 1, fig. 1.
Pholas petrosa H. C. Lea, 1848, Proc. Acad. Nat. Sci., Philadelphia, Vol. IV, p. 104.
Pholas petrosa Conrad, 1865, Am. Jour. Conch., Vol. I, p. 2.
Pholas petrosa Conrad, 1866, Smith. Misc. Coll. (200), p. 9.
Pholas (?) *petrosa* Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

This very peculiar form has been hitherto referred to *Pholas*, but certainly does not belong to that genus. So far as can be judged from the casts, which alone have been obtained, it is probably more closely related to *Pholadomya*. It apparently represents a new genus, but in the absence of the shell its characters can not be with sufficient certainty discerned to warrant its establishment.

It is not uncommon in zone 5 of the Aquia Creek stage.

Localities.—Fort Washington, Maryland; Aquia Creek, Virginia.

Collections.—Philadelphia Academy of Natural Sciences; Johns Hopkins University.

Genus GASTROCHÆNA Spengler.

GASTROCHÆNA sp.

PL. XV, fig. 6.

Gastrochæna sp. Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

Casts of the tubes of *Gastrochæna* are common in the indurated layer, zone 5, of the Aquia Creek stage, but also occur at higher horizons. Few of the specimens obtained show any traces of the shell substance and rarely impressions of the transverse striations of the tube wall.

Localities.—Aquia Creek, Virginia; Upper Marlboro, Maryland.

Collection.—Johns Hopkins University.

Genus CORALLIOPHAGA Blainville.

CORALLIOPHAGA BRYANI Clark.

PL. XV, figs. 2*a*, 2*b*.

Coralliophaga bryani Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

Shell transversely oblong, thin, slightly gaping posteriorly; prominent fold from umbo to lower margin; surface with delicate lines of growth and fine radial rows of minute granules, obsolete over much of the surface; teeth consisting of two small cardinal and one long posterior lateral; pallial line with shallow sinus.

Only a single right valve, and that somewhat damaged, has been thus far discovered. It was found by the late Mr. Oliver Bryan, of Marshall Hall, Md., from whose collection many of the more unusual lower Eocene forms of western Prince George County, Md., now in the United States National Museum were obtained.

Dimensions.—Length, 20 mm.; height, 16 mm.

Locality.—Pamunkey Neck, Maryland.

Collection.—United States National Museum.

Genus SOLEMYA Lamarck.

SOLEMYA PETRICOLOIDES (Lea).

Byssomia petricoloides Lea, 1833, Cont. to Geology, p. 48, pl. 1, fig. 16.
Solemya petricoloides Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

Shell elongated, very inequilateral, slightly gaping, thin; surface nearly smooth with fine lines of growth; umbones very posteriorly situated; hinge edentulous; pallial line obscure.

A complete specimen of this rather peculiar form was not obtained; but the fragments leave little doubt of the identity of the species.

Locality.—Woodstock, Virginia.

Collection.—Johns Hopkins University.

Genus CORBULA Bruguière.

CORBULA ALDRICHI Meyer.

Corbula aldrichi Meyer, 1885, Am. Jour. Sci., third series, Vol. XXX, p. 67.
Corbula aldrichi Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

This remarkable form, with its radiating lines upon the umbonal portions of the shell, is very common. The Virginia form differs in no essential particulars from the Gulf type.

Localities.—Evergreen, Hanoverville, Front Royal, Virginia.

Collection.—Johns Hopkins University.

CORBULA NASUTA Conrad.

Corbula nasuta Conrad, 1833, Fossil Shells, p. 38, pl. 19, fig. 4.
Corbula nasuta Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

This species is very common in the Virginia Eocene. Its slightly elevated umbones and the absence of rostrated posterior surface separate it from the other species of this genus.

Locality.—Woodstock, Virginia.

Collection.—Johns Hopkins University.

CORBULA ONISCUS Conrad.

Corbula oniscus Conrad, 1833, Am. Jour. Sci., Vol. XXIII, p. 342.
Corbula oniscus Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

This species, characterized by its solid form and numerous concentric, wrinkled, approximate lines and prominently rostrated posterior surface, is common at several localities in the Virginia Eocene. None of the specimens obtained reach the size of the larger individuals in the Gulf Eocene.

Localities.—Evergreen, Front Royal, Virginia.

Collection.—Johns Hopkins University.

Genus PHOLADOMYA Sowerby.

PHOLADOMYA MARYLANDICA Conrad.

PL. XIX, fig. 2.

Pholadomya marylandica Conrad, 1842, Proc. Nat. Inst. Promotion Science, second bulletin, p. 193, pl. 1, fig. 3.
Pholadomya marylandica Conrad, 1846, Am. Jour. Sci., second series, Vol. I, p. 214, pl. 2, fig. 9.
Pholadomya marylandica H. C. Lea, 1848, Proc. Acad. Nat. Sci., Philadelphia, Vol. IV, p. 104.
Pholadomya marylandica Conrad, 1865, Am. Jour. Conch., Vol. I, p. 3.
Pholadomya marylandica Conrad, 1866, Smith. Misc. Coll. (200), p. 8:
Pholadomya marylandica Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

The very fragile shell of this species was found only partially preserved in a few instances, although numerous casts were obtained from the indurated layer, zone 5, at Aquia Creek.

Localities.—Fort Washington, Maryland; Aquia Creek, Virginia.

Collections.—Philadelphia Academy of Natural Sciences; Johns Hopkins University; United States National Museum.

Genus PANOPÆA Menard.

PANOPÆA ELONGATA Conrad.

PL. XIX, figs. 1*a*–1*c*.

Panopæa elongata Conrad, 1835, Trans. Geol. Soc. Pennsylvania, Vol. I, p. 339, pl. 13, fig. 1.
Panopæa elongata Conrad, 1846, Am. Jour. Sci., second series, Vol. I, p. 215, pl. 1, fig. 2.
Panopæa elongata H. C. Lea, 1848, Proc. Acad. Nat. Sci., Philadelphia, Vol. IV, p. 103.
Glycimeris elongata Conrad, 1865, Am. Jour. Conch., Vol. I, p. 2.
Glycimeris elongata Conrad, 1866, Smith. Misc. Coll. (200), p. 8.
Panopæa elongata Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 4.

Numerous casts of this species were collected from the indurated layers of the lower portion of the Eocene, particularly in the Potomac River region. They vary considerably in size.

Localities.—Fort Washington, Winchester, Maryland; Aquia Creek, Virginia.

Collections.—Johns Hopkins University; United States National Museum; Philadelphia Academy of Natural Sciences.

Genus TELLINA Linné.

TELLINA VIRGINIANA Clark.

PL. XV, fig. 4.

Tellina virginiana Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

Shell elongated, thin, compressed; posteriorly very short, angular, and slightly folded; anteriorly rounded and elongated; umbones posteriorly situated; two small cardinal teeth and indistinct lateral teeth; pallial sinus obscure. Exterior covered with fine concentric lines following lines of growth.

On account of their fragile nature the shells are easily broken, so that few perfect specimens could be preserved intact. The forms found vary much in size, several casts of apparently the same species reaching large dimensions.

Dimensions.—Shells: Length, 8 to 15 mm.; height, 5 to 10 mm. Some of the casts are much larger.

Localities.—Hanoverville, Aquia Creek, Virginia; Fort Washington, Maryland.

TELLINA WILLIAMSI Clark.

PL. XV, figs. 3*a*, 3*b*.

Tellina williamsi Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

Shell small, rather solid, not strongly inequilateral; posterior shorter; surface ornamented with elevated, close-set ridges or lamellæ, increasing in size toward the basal margin; posteriorly subangulated; two cardinal teeth, posterior bifid; lateral teeth strongly developed; pallial sinus deep.

This highly decorated form is very uncommon, but is very distinct from other species.

Dimensions.—Length, 8 mm.; height, 5 mm.

Locality.—Potomac Creek, Virginia.

Collection.—Johns Hopkins University.

Genus CYTHEREA Lamarck.

CYTHEREA OVATA Rogers.

PL. XVI, figs. 1*a*–1*f*.

Cytherea ovata Rogers, 1837, Trans. Am. Phil. Soc., Vol. V, p. 340; Vol. VI, pl. 27, fig. 2.

Cytherea liciata Conrad, 1848, Jour. Acad. Nat. Sci., Philadelphia, new series, Vol. I, p. 131, pl. 14, fig. 20.

Cytherea pyga Conrad, 1848, Jour. Acad. Nat. Sci., Philadelphia, new series, Vol. I, p. 131, pl. 14, fig. 20.

Cytherea ovata H. C. Lea, 1848, Proc. Acad. Nat. Sci., Philadelphia, Vol. IV, p. 99.
Cytherea liciata H. C. Lea, 1848, Proc. Acad. Nat. Sci., Philadelphia, Vol. IV, p. 99.
Cytherea pyga H. C. Lea, 1848, Proc. Acad. Nat. Sci., Philadelphia, Vol. IV, p. 99.
Dione ovata Conrad, 1865, Am. Jour. Conch., Vol. I, p. 6.
Dione liciata Conrad, 1865, Am. Jour. Conch., Vol. I, p. 6.
Dione pyga Conrad, 1865, Am. Jour. Conch., Vol. I, p. 6.
Dione ovata Conrad, 1866, Smith. Misc. Coll. (200), p. 7.
Dione liciata Conrad, 1866, Smith. Misc. Coll. (200), p. 7.
Cytherea ovata Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

This widely distributed species shows great variation in outline and has been described under several names. The type of Rogers *C. ovata* was evidently an immature shell. It is much less ventricose and lacks the rounded basal margin shown in the larger forms to which Conrad gave the name of *C. pyga*. Every variation is shown, from forms with a rounded posterior margin to those with a sloping, slightly angulated outline like *C. liciata*, so it seems practically certain that this form can be regarded only as a variety of *C. ovata*. Some of the shells also approach *C. lenis* in form, but as this can not be definitely determined and no specimens have been obtained which agree with it in all particulars, that-species will be considered at the end of this chapter, under doubtful forms.

Localities.—Fort Washington, Glymont, Clifton Beach, Maryland; Aquia Creek, Potomac Creek, Woodstock, Front Royal, Evergreen, Virginia.

Collections.—Johns Hopkins University; Philadelphia Academy of Natural Sciences; United States National Museum.

CYTHEREA EVERSA Conrad.

PL. XVII, figs. 2*a*–2*d*.

Cytherea eversa Conrad, 1848, Jour. Acad. Nat. Sci., Philadelphia, new series, Vol. I, p. 130, pl. 14, fig. 19.
Cytherea eversa H. C. Lea, 1848, Proc. Acad. Nat. Sci., Philadelphia, Vol. IV, p. 19.
Dione eversa Conrad, 1865, Am. Jour. Conch., Vol. I, p. 6.
Dione eversa Conrad, 1866, Smith. Misc. Coll. (200), p. 7.
Cytherea eversa Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

This species is very rare, and does not differ widely from some of the more rounded individuals of *C. ovata*. No specimens were found by the writer. The forms figured are the type specimens of Conrad, and were collected by Ruffin on the Pamunkey River, Virginia.

Localities.—Pamunkey River, Hanover County, Virginia.

Collection.—Philadelphia Academy of Natural Sciences.

CYTHEREA SUBIMPRESSA Conrad.

PL. XVII, figs. 1*a*–1*h*.

Cytherea subimpressa Conrad, 1848, Jour. Acad. Nat. Sci., Philadelphia, new series, Vol. I, p. 130, pl. 14, fig. 26.
Cytherea subimpressa H. C. Lea, 1848, Proc. Acad. Nat. Sci., Philadelphia, Vol. IV, p. 99.
Cytherea subimpressa Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

Conrad's types of this species are unusually large individuals, the majority of the forms found by the writer being small, apparently immature shells. They are very numerous in the later beds of the Potomac River section as well as at the same horizon farther south.

Localities.—Popes Creek, Maryland; Woodstock, Hanoverville, Evergreen, Virginia.

Collections.—Philadelphia Academy of Natural Sciences; Johns Hopkins University.

Genus DOSINIOPSIS Conrad.

DOSINIOPSIS LENTICULARIS (Rogers).

PL. XVIII, figs. 1*a*–1*g*.

Cytherea lenticularis Rogers, 1839, Trans. Am. Phil. Soc., Vol. VI, p. 372, pl. 28, fig. 1.
Cytherea lenticularis H. C. Lea, 1848, Proc. Acad. Nat. Sci., Philadelphia, Vol. IV, p. 99.
Dosiniopsis meekii Conrad, 1864, Proc. Acad. Nat. Sci., Philadelphia, Vol. XVI, p. 213, and figure in text.
Dosiniopsis lenticularis Conrad, 1865, Am. Jour. Conch., Vol. I, p. 6.
Dosiniopsis meekii Conrad, 1865, Am. Jour. Conch., Vol. I, p. 6.
Dosiniopsis meekii Conrad, 1866, Smith. Misc. Coll. (200), p. 6.
Dosiniopsis lenticularis Conrad, 1866, Smith. Misc. Coll. (200), p. 6.
Dosiniopsis lenticularis Harris, 1894, Am. Jour. Sci., third series, Vol. XLVII, p. 302.
Dosiniopsis lenticularis Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

The type of the species, as figured and described by Rogers, is a much less common form than the variety later described by Conrad under the name of *D. meekii*. Rogers's type represents a moderately thin shell with a weak hinge, while the form described by Conrad is a heavy shell with a broad, solid hinge. Every possible gradation between these extremes was obtained by the author.

Localities.—Fort Washington, Glymont, Clifton Beach, Maryland; Aquia Creek, Potomac Creek, Virginia.

Collections.—Johns Hopkins University; United States National Museum; Philadelphia Academy of Natural Sciences.

Genus LUCINA Bruguière.

LUCINA AQUIANA Clark.

PL. XX, figs. 1*a*, 1*b*.

Lucina aquiana Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

Shell of moderate size, somewhat compressed; surface covered with numerous concentric striæ; umbones depressed and acuminate on account of prominent, deeply incised lunules; anterior side elongate; posterior side rounded; hinge with two cardinal and two lateral teeth.

This moderate sized form is the largest of the *Lucinas* from the Eocene of the Middle Atlantic Slope, and is much less common than the other species.

Dimensions.—Length, 18 mm.; height, 18 mm.

Locality.—Aquia Creek, Virginia.

Collection.—United States National Museum.

LUCINA DARTONI Clark.

PL. XX, figs. 2*a*–2*c*.

Lucina dartoni Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

Shell rather small, suborbicular, thin; surface with fine, thin, distant concentric, lamellated striæ, crossed by numerous radial, fine, irregular lines less distant than the concentric lamellæ; anteriorly and posteriorly high shouldered and angulated; lunules large; hinge area narrow; ligament small; muscle impressions shallow; margin simple.

This species is the most delicate and beautiful of all the *Lucinas* from the Virginia Eocene. It is a rather common form.

Dimensions.—Length, 7 mm.; height, 5.5 mm.

Locality.—Woodstock, Virginia.

Collection.—Johns Hopkins University.

LUCINA WHITEI Clark.

PL. XX, figs. 3*a*–3*c*.

Lucina whitei Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

Shell small, suborbicular, globose; surface with prominent concentric lamellæ, interrupted posteriorly by shallow fold, extending from umbones to posterior basil margin; lunules deeply depressed; anterior side high shouldered, rounded; posterior high shouldered, angulated; margin crenulated.

Dimensions.—Length, 4 mm.; height, 3.5 mm.

Localities.—Woodstock, Hanoverville, Virginia.

Collection.—Johns Hopkins University.

LUCINA UHLERI Clark.

PL. XXI, figs. 1*a*–1*d*.

Lucina uhleri Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV. p. 5.

Shell small, orbicular, slightly tumid; surface with numerous uniform, elevated, concentric ridges; anterior and posterior sides rounded; lunules slightly depressed; interior with radiating striæ; margin simple.

Dimensions.—Length, 5 mm.; height, 4 mm.

Locality.—Woodstock, Virginia.

Collection.—Johns Hopkins University.

Genus DIPLODONTA Brown.

DIPLODONTA HOPKINSENSIS Clark.

PL. XXII, figs. 1*a*–1*d*.

Diplodonta hopkinsensis Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

Shell small, suborbicular, globose; surface with fine indistinct striations; anteriorly and posteriorly rounded.

Many of the specimens described in this bulletin were obtained on expeditions sent out by the Johns Hopkins University, and are now placed in the geological museum of that institution. The present species is named *hopkinsensis* in recognition of that fact.

Dimensions.—Length, 16 mm.; height, 15 mm.

Locality.—Evergreen, Virginia.

Collection.—Johns Hopkins University.

Genus ASTARTE Sowerby.

ASTARTE MARYLANDICA Clark.

PL. XXI, fig. 2.

Astarte marylandica Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

Shell small, roundedly trigonal, somewhat compressed, thick, nearly equilateral; surface concentrically costated and with superimposed fine striæ; umbones prominent.

Dimensions.—Length, 16 mm.; height, 15 mm.

Locality.—Upper Marlboro, Maryland.

Collection.—Johns Hopkins University.

Genus VENERICARDIA Lamarck.

VENERICARDIA PLANICOSTA Lamarck.

PL. XXI, fig. 3; PL. XXII, fig. 2; PL. XXIII, figs. 1*a*–1*c*; PL. XXIV, figs. 1*a*–1*c*; PL. XXV, figs. 1*a*–1*c*.

Venericardia planicosta Lamarck, 1807, Ann. de Mus., T. VII, p. 55; T. IX, p. 31, fig. 10.
Cardita planicosta Conrad, 1832, Fossil Shells, p. 20, pl. 5, fig. 2.
Cardita planicosta Morton, 1834, Syn. Org. Rem. Cretaceous Group, App., p. 7.
Venericardia ascia Rogers, 1839, Trans. Am. Phil. Soc., Vol. VI, p. 374, pl. 29, fig. 2.
Venericardia planicosta H. C. Lea, 1848, Proc. Acad. Nat. Sci., Philadelphia, Vol. IV, p. 107.
Venericardia ascia H. C. Lea, 1848, Proc. Acad. Nat. Sci., Philadelphia, Vol. IV, p. 107.
Venericardia ascia Conrad, 1865, Am. Jour. Conch., Vol. I, p. 7.
Venericardia planicosta var. *regia* Conrad, 1865, Am. Jour. Conch., Vol. I, p. 8.
Venericardia planicosta Conrad, 1866, Smith. Misc. Coll. (200), p. 5.
Venericardia regia Conrad, 1866, Smith. Misc. Coll. (200), p. 5.
Venericardia ascia Rogers, 1884, Geology of the Virginias, p. 671, Pl. IV, fig. 2.
Cardita planicosta Heilprin, 1884, Contrib. Tert. Geol. and Pal., p. 87.
Venericardia planicosta var. *regia* Harris, 1894, Am. Jour. Sci., third series, Vol. XLVII. p. 302.
Venericardia planicosta Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

Numerous representatives of this important type fossil are found widely distributed in the Eocene deposits throughout the Middle Atlantic Slope. They are much more numerous in Virginia, however, than in Maryland and Delaware, and especially characterize the middle and upper portions of the series, being seldom found in the lower beds.

Localities.—Sassafras River, Severn River, South River, Fort Washington, Popes Creek, Maryland; Aquia Creek, Potomac Creek, Woodstock, Front Royal, Hanoverville, Evergreen, Virginia.

Collections.—Philadelphia Academy of Natural Sciences; United States National Museum; Johns Hopkins University.

Genus PROTOCARDIA Beyrich.

PROTOCARDIA VIRGINIANA Conrad.

PL. XXVI, figs. 1*a*–1*c*.

Protocardia virginiana Conrad, 1864, Proc. Acad. Nat. Sci., Philadelphia, Vol. VI, p. 211.
Protocardia virginiana Conrad, 1866, Smith. Misc. Coll. (200), p. 6.
Protocardia virginiana Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

Great numbers of individuals of this species are found in the upper member of the Eocene in the Potomac River region, although seldom obtained entire on account of their delicate structure.

Localities.—Popes Creek, Maryland; Woodstock, Virginia.

Collections.—Philadelphia Academy of Natural Sciences; Johns Hopkins University.

Genus CRASSATELLA Lamarck.

CRASSATELLA ALÆFORMIS Conrad.

PL. XXVII, figs. 1*a*–1*k*.

Crassatella alæformis Conrad, 1830, Jour. Acad. Nat. Sci., Philadelphia, Vol. VI, p. 228, Pl. X, fig. 1.
Crassatella alæformis Morton, 1834, Syn. Org. Rem. Cretaceous Group, App., p. 7.
Crassatella capri-cranium Rogers, 1839, Trans. Am. Phil. Soc., new series, Vol. VI, p. 375, pl. 30, fig. 2.
Crassatella alæformis Conrad, 1846, Am. Jour. Sci., second series, Vol. I, p. 396, pl. 3, fig. 3.
Crassatella alæformis H. C. Lea, 1848, Proc. Acad. Nat. Sci., Philadelphia, Vol. IV, p. 98.
Crassatella capri-cranium H. C. Lea, 1848, Proc. Acad. Nat. Sci., Philadelphia, Vol. IV, p. 98.
Crassatella alæformis D'Orbigny, 1850, Prodrome, Vol. II, p. 383.
Crassatella capri-cranium Conrad, 1865, Am. Jour. Conch., Vol. I, p. 10.
Crassatella alæformis Conrad, 1865, Am. Jour. Conch., Vol. I, p. 10.
Crassatella alæformis Conrad, 1866, Smith. Misc. Coll. (200), p. 5.
Crassatella capri-cranium Conrad, 1866, Smith. Misc. Coll. (200), p. 5.
Crassatella declivis Heilprin, 1880, Proc. U. S. Nat. Museum, Vol. III, pp. 151, 152, pl. facing p. 150, fig. 9.
Crassatella protexta de Gregorio, 1890, Ann. Géol. et Pal., pl. 25, fig. 12.
Crassatella alæformis Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

The variations in *C. alæformis* Conrad are so great that in the absence of connecting forms one would be led to consider the existence of several well-defined species. After a careful study of a large amount of material belonging to this important species, I feel confident that the forms figured and described by Rogers and Heilprin as distinct species are only varieties of Conrad's *C. alæformis.* The species is largely represented in the lower portion of the Middle Atlantic Coast series, especially in zones 2 to 7 of the Aquia Creek stages of the Potomac River region.

Localities.—Fort Washington, Glymont, Clifton Beach, Maryland; Aquia Creek, Potomac Creek, City Point, Virginia.

Collections.—Philadelphia Academy of Natural Sciences; United States National Museum; Johns Hopkins University.

CRASSATELLA AQUIANA Clark.

PL. XXVI, figs. 2*a*–2*c*.

Crassatella aquiana Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

Shell moderately large, attenuated posteriorly; surface with a few broad, shallow, concentric furrows, indicating periods of growth, and fine concentric lines, often obscure; lunules broad, deeply depressed.

This species differs from *C. alæformis* by its shorter, broader posterior extremity; by the absence of deep, prominent furrows on the umbones, and by the umbones themselves being higher.

Dimensions.—Length, 45 mm.; height, 35 mm.

Locality.—Aquia Creek, Virginia.

Collection.—Johns Hopkins University.

Genus NUCULA Lamarck.

NUCULA MAGNIFICA Conrad.

Nucula magnifica Conrad, 1833, Fossil Shells, p. 37.
Nucula magnifica Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

Most of the collected shells of this very beautiful species are small and immature. A single large specimen, with both valves intact, shows all the characteristic features of the Gulf forms, the radial lines upon the exterior of the shell standing out clearly.

Localities.—Woodstock, Hanoverville, Virginia.

Collection.—Johns Hopkins University.

Genus LEDA Schumacher.

LEDA PROTEXTA (Conrad).

Nuculana protexta Conrad, 1865, Am. Jour. Conch., Vol. I, p. 147, pl. 11, fig. 6.
Leda protexta Clark, 1895, Johns Hopkins Univ. Circ., Vol., XV, p. 5.

Shell large, transverse, elongate, anterior side rounded, posterior somewhat longer, attenuated, terminating in an obtuse beak; surface with numerous concentric striations somewhat interfered with on the rostrated portion of the posterior side, where the riblets become more lamellated and wavy and at times even disappear.

This form is especially numerous in the Rappahannock Valley, although occurring also in the Potomac River section.

Localities.—Front Royal, Potomac Creek, Virginia.

Collection.—Johns Hopkins University.

LEDA PARVA (Rogers).

PL. XXVIII, figs. *2a–2d*.

Nucula parva Rogers, 1837, Trans. Am. Phil. Soc., Vol. V, p. 340.
Nucula parva H. C. Lea, 1848, Proc. Acad. Nat. Sci., Philadelphia, Vol. IV, p. 102.
Nuculana parva Conrad, 1865, Am. Jour. Conch., Vol. I, p. 3.
Nuculana parva Conrad, 1866, Smith. Misc. Coll. (200), p. 3.
Leda parva Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

Very considerable variation is noticeable in the surface ornamentation of this species. The concentric striation produces in some forms a broadly rounded costated surface, while in others it is more like thin laminæ.

It is a common form, although not so numerous as the preceding species.

Dimensions.—Length, 8 mm.; height, 5 mm.

Localities.—Pamunkey River, Woodstock, Va.

Collections.—Philadelphia Academy of Natural Sciences; Johns Hopkins University.

LEDA IMPROCERA (Conrad).

PL. XXVIII, figs. 1*a*–1*e*.

Nucula improcera Conrad, 1848, Jour. Acad. Nat. Sci., Philadelphia, new series, Vol. I, p. 131, pl. 14, fig. 23.
Nuculana improcera Conrad, 1865, Am. Jour. Conch., Vol. I, p. 13.
Nuculana improcera Conrad, 1866, Smith. Misc. Coll. (200), p. 3.
Leda improcera Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

The shell of this much elongated and very inequilateral form is so fragile that, notwithstanding its comparative frequency in the upper portions of the beds, few perfect valves have been obtained. It appears to have a nearly smooth polished surface until examined with a magnifying glass, when numerous delicate striations are readily recognized.

Dimensions.—Length, 6 mm.; height, 3 mm.

Localities.—Popes Creek, Maryland; Woodstock, Evergreen, Virginia.

Collection.—Johns Hopkins University.

Subgenus ADRANA Adams.

LEDA (ADRANA) CULTELLIFORMIS (Rogers).

PL. XXVIII, figs. 3*a*, 3*b*.

Nucula cultelliformis Rogers, 1837, Trans. Am. Phil. Soc., new series, Vol. V, p. 339.
Nucula cultelliformis H. C. Lea, 1848, Proc. Acad. Nat. Sci., Philadelphia, Vol. IV, p. 102.
Nuculana cultelliformis Conrad, 1865, Am. Jour. Conch., Vol. I, p. 13.
Nuculana cultelliformis Conrad, 1866, Smith. Misc. Coll. (200), p. 3.
Nucula cultelliformis Rogers, 1884, Geology of the Virginias, p. 667.
Yoldia cultelliformis Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

This small form is short and much attenuated posteriorly, and is characteristically ornamented with strong concentric striæ. It is the most numerous of the *Ledas*, and its relatively thick shell serves to preserve it. It is restricted to the upper portion of the series.

Dimensions.—Length 4.5 mm.; height, 3 mm.

Localities.—Woodstock, Evergreen, Va.

Collection.—Johns Hopkins University.

Genus PECTUNCULUS Lamarck.

PECTUNCULUS IDONEUS Conrad.

Pl. XXIX, figs. 1*a*–1*d*.

Pectunculus idoneus Conrad, 1833, Fossil Shells, p. 39.
Pectunculus idoneus Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

Shell moderately thick, obliquely orbicular, rather ventricose, slightly inequilateral, equivalve, with faint radiations; hinge with few prominent teeth; margins crenulated; beaks depressed.

The higher beds of the Eocene series in Maryland and Virginia are very rich in shells of *Pectunculus*. Although in some features they at times show slight variations from *P. idoneus* of the Gulf, the differences are too slight to warrant specific distinction.

Dimensions.—Length, 42 mm.; height, 42 mm.

Localities.—Upper Marlboro, South River, Maryland; Woodstock, Hanoverville, Virginia.

Collections.—Philadelphia Academy of Natural Sciences; Johns Hopkins University.

Genus CUCULLÆA Lamarck.

CUCULLÆA GIGANTEA Conrad.

PL. XXX, figs. 1*a*, 1*b*; PL. XXXI, figs. 1*a*, 1*b*; PL. XXXII, figs. 1*a*–1*c*; PL. XXXIII, figs. 1*a*–1*c*.

Cucullæa gigantea Conrad, 1830, Jour. Acad. Nat. Sci., Philadelphia, Vol. VI, p. 227, pl. 10, fig. 4.
Cucullæa onochela Rogers, 1839, Trans. Am. Phil. Soc., Vol. VI, p. 372, pl. 28, fig. 2.
Cucullæa transversa Rogers, 1839, Trans. Am. Phil. Soc., Vol. VI, p. 373, pl. 29, fig. 1.
Cucullæa gigantea H. C. Lea, 1848, Proc. Acad. Nat. Sci., Philadelphia, Vol. IV, p. 98.
Cucullæa onochela H. C. Lea, 1848, Proc. Acad. Nat. Sci., Philadelphia, Vol. IV, p. 98.
Cucullæa transversa H. C. Lea, 1848, Proc. Acad. Nat. Sci., Philadelphia, Vol. IV, p. 98.
Latiarca gigantea Conrad, 1865, Am. Jour. Conch., Vol. I, p. 11.
Latiarca onochela Conrad, 1865, Am. Jour. Conch., Vol. I, p. 11.
Latiarca transversa Conrad, 1865, Am. Jour. Conch., Vol. I, p. 11.
Latiarca gigantea Conrad, 1866, Smith. Misc. Coll. (200), p. 4.
Latiarca onochela Conrad, 1866, Smith. Misc. Coll. (200), p. 4.
Latiarca transversa Conrad, 1866, Smith. Misc. Coll. (200), p. 4.
Latiarca idonea Conrad, 1872, Proc. Acad. Nat. Sci., Philadelphia, p. 53, pl. 2, fig. 1.
Cucullæa onochela Rogers, 1884, Geology of the Virginias, p. 669, Pl. III, fig. 2.
Cucullæa transversa Rogers, 1884, Geology of the Virginias, p. 670, Pl. IV, fig. 1.
Arca onochela Heilprin, 1884, Contrib. Tert. Geol. and Pal., p. 87.
Cucullæa transversa Harris, 1894, Am. Jour. Sci., third series, Vol. XLVII, p. 302.
Cucullæa gigantea Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

A careful examination of the various forms of *Cucullæa* from the Maryland and Virginia Eocene shows them to be modifications of a single species that possesses great variability in outline and surface decoration. The most profound changes appear upon comparison of young and adult forms. The immature shells are relatively not as high or as tumid and possess much narrower ligament areas than the adults. Rogers gave the name of *C. transversa* to these young forms. Casts of the larger shells are not uncommon and are locally known as "turtle heads."

This species is very common in the lower portion of the Eocene series in the Middle Atlantic Slope, being especially numerous in zone 8 at Potomac Creek.

Localities.—Severn River, Fort Washington, Clifton Beach, Maryland; Aquia Creek, Potomac Creek, Evergreen, Virginia.

Collections.—Johns Hopkins University; Philadelphia Academy of Natural Sciences; United States National Museum.

Genus MODIOLA Lamarck.

MODIOLA POTOMACENSIS Clark.

PL. XXXIV, figs. 1*a*–1*c*.

Modiola potomacensis Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

Shell small, oblong, thin, tumid, anterior side somewhat contracted; surface with fine costated striæ nearly obsolete anteriorly and less strongly accentuated posteriorly than in the center, crossed occasionally by irregular lines of growth; umbones prominent, curved.

Dimensions.—Length transversely, 14 mm.

Localities.—Popes Creek, Maryland; Potomac Creek, Woodstock, Pamunkey River, Virginia.

Collection.—Johns Hopkins University.

Genus PECTEN Klein.

PECTEN JOHNSONI Clark.

PL. XXXIV, figs. 3*a*, 3*b*.

Pecten johnsoni Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

Shell small, suborbicular, equilateral; surface with about twenty uniform, distant, rounded costæ, separated by broad interspaces, with a few short costæ at basal margin, the whole crossed by fine lines of growth; ears prominent, unequal.

The few specimens found are from zone 8.

Dimensions.—Length, 14 mm.; height, 15 mm.

Locality.—Potomac Creek, Virginia.

Collection.—Johns Hopkins University.

PECTEN ROGERSI Clark.

PL. XXXIV, figs. 2*a*–2*c*.

Pecten rogersi Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

Shell small, orbicular, subpellucid, nearly equilateral, thin; surface shining with fine, delicate concentric lines and rather obscure, in places obsolete, radial ribs that show most strongly near the anterior margins; umbones approximate and acute; auricles very unequal and costated.

This very beautiful species shows some points of similarity to *P. calvatus* Conrad in form and surface features, but the radial striæ are lacking upon the latter. Several specimens were obtained from zone 8 at Potomac Creek.

Dimensions.—Length, 16 mm.; height, 18 mm.

Localities.—Potomac Creek, Front Royal, Virginia.

Collection.—Johns Hopkins University.

PECTEN sp.

PL. XXXIV, fig. 4.

Pecten sp. Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

Shell small, orbicular; surface with about twenty broad, flat costæ, dividing in most cases in passing downward, so that over thirty appear at the margin; umbones compressed; ears unequal.

Dimensions.—Length, 10 mm.; height, 11 mm.

Locality.—Potomac Creek, Virginia.

Collection.—Johns Hopkins University.

Genus ANOMIA Linné.

ANOMIA MCGEEI Clark.

PL. XXXIV, figs. 5*a*, 5*b*.

Anomia mcgeei Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

Shell of left valve rather solid, convex, nearly equilateral; surface strongly lamellar, with faint radial plaits, stronger in the latter than in the earlier portions of the shell.

A few young forms, probably of the same species, were found at several localities in Maryland and Virginia.

Dimensions.—Length, 50 mm.; height, 48 mm.

Locality.—Hanover County, Virginia.

Collections.—Philadelphia Academy of Natural Sciences; Johns Hopkins University.

Genus OSTREA Linné.

OSTREA COMPRESSIROSTRA Say.

PL. XXXVII, figs. 1, 2*a*–2*c*; PL. XXXVIII, figs. 1*a*, 1*b*, 2*a*–2*c*; PL. XXXIX, figs. 1, 2*a*, 2*b*; PL. XL, fig. 1.

Ostrea compressirostra Say, 1824, Jour. Acad. Nat. Sci., Philadelphia, Vol. IV, p. 132, pl. 8, figs. 20–26.

Ostrea compressirostra Morton, 1834, Syn. Org. Rem. Cretaceous Group, App., p. 2.

Ostrea sinuosa Rogers, 1837, Trans. Am. Phil. Soc., Vol. V, p. 340; Vol. VI, pl. 27, fig. 1.

Ostrea compressirostra H. C. Lea, 1848, Proc. Acad. Nat. Sci., Philadelphia, Vol. IV, p. 103.

Ostrea sinuosa H. C. Lea, 1848, Proc. Acad. Nat. Sci., Philadelphia, Vol. IV, p. 103.

Ostrea compressirostra Conrad, 1865, Am. Jour. Conch., Vol. I, p. 15.
Ostrea sinuosa Conrad, 1865, Am. Jour. Conch., Vol. I, p. 15.
Ostrea compressirostra Conrad, 1866, Smith. Misc. Coll. (200), p. 3.
Ostrea compressirostra Heilprin, 1883, White's Fossil Ostreidæ; Fourth Ann. Rept. U. S. Geol. Surv., p. 309, pl. 65, figs. 1, 2.
Ostrea compressirostra Heilprin, 1884, Contrib. Tert. Geol. and Pal., p. 85.
Ostrea sinuosa Rogers, 1884, Geology of the Virginias, p. 668, pl. 2, fig. 1.
Ostrea compressirostra de Gregorio, 1890, Ann. Geol. et Pal., t. 2, p. 177, pl. 20, figs. 1, 8.
Ostrea compressirostra Harris, 1894, Am. Jour. Sci., third series, Vol. XLVII, p. 302.
Ostrea compressirostra Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

No single species, except perhaps *Turritella mortoni*, occurs in such vast numbers in the Middle Atlantic Slope Eocene as *Ostrea compressirostra*. In the younger forms the radial ribbing is clearly marked and the shell can be with difficulty separated from the immature individuals of *O. sellæformis*. It is confined so far as known to the lower portion of the series.

Localities.—Severn River, Crownsville, Fort Washington, Piscataway, Glymont, Clifton Beach, Maryland; Aquia Creek, Potomac Creek, City Point, Virginia.

Collections.—Johns Hopkins University; United States National Museum; Philadelphia Academy of Sciences.

OSTREA SELLÆFORMIS Conrad.

PL. XXXV, figs. 1*a*–1*d*; PL. XXXVI, figs. 1*a*, 1*b*.

Ostrea sellæformis Conrad, 1832, Fossil Shells, p. 27, pl. 13, fig. 2.
Ostrea sellæformis Morton, 1834, Syn. Org. Rem. Cretaceous Group, App., p. 6.
Ostrea sellæformis Conrad, 1842, Proc. Nat. Inst. Promotion Science, second bulletin, pp. 192, 193, pl. 1, fig. 1.
Ostrea sellæformis H. C. Lea, 1848, Proc. Acad. Nat. Sci., Philadelphia, Vol. IV, p. 103.
Ostrea sellæformis Conrad, 1865, Am. Jour. Conch., Vol. I, p. 15.
Ostrea sellæformis Conrad, Smith. Misc. Coll. (200), p. 3.
Ostrea sellæformis Heilprin, 1883, White's Fossil Ostreidæ; Fourth Ann. Rept. U. S. Geol. Surv., p. 311, pl. 62, figs. 1, 2; pl. 63, fig. 1.
Ostrea sellæformis Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 5.

This important Gulf species occurs sparingly in the Middle Atlantic Slope Eocene, except in the more southern localities, where, on the Pamunkey and James rivers, it forms beds several feet in thickness. Although commonly showing a marked difference from *O. compressirostra* in the adult specimens, the younger forms approach that species very closely. *Ostrea sellæformis* is probably confined to the Woodstock stage, although some of the small oysters at Aquia Creek and Potomac Creek can not be separated from it.

Localities.—Woodstock, Front Royal, Hanoverville, Tar Bay, Evergreen, Virginia.

Collections.—Johns Hopkins University; Philadelphia Academy of Natural Sciences.

OSTREA sp.

PL. XXXIX, figs. 3a–3c.

Ostrea sp. Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 6.

Several specimens of a small oyster with slightly recurved beaks and highly inflated lower valve were obtained that may be only abnormal forms of *Ostrea compressirostra* above described. It may prove to be the species that Conrad named *O. subeversa*, but never figured or described, and which he subsequently regarded as a synonymn of *O. eversa* of Europe. The present form approaches that species in some particulars.

Localities.—Glymont, Maryland; Aquia Creek, Virginia.

Collection.—Johns Hopkins University.

OSTREA sp.

PL. XXXVIII, fig. 3.

Ostrea sp. Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 6.

A second oyster with much elongated shell and with a prominent medial ridge occurs at two localities, but, like the preceding form, may be only a modified type of *Ostrea compressirostra*. The medial ridge may prove to be the result of growth upon some foreign substance.

Localties.—Clifton Beach, Maryland; Aquia Creek, Virginia.

Collection.—Johns Hopkins University.

VERMES.

ANNELIDA.

Genus SERPULA Linné.

SERPULA sp.

Serpula sp. Clark, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 6.

Fragments of unidentifiable annelid tubes and borings have been obtained at many points in the Eocene deposits of the Middle Atlantic Slope. They probably belong to the genus *Serpula*, but their further description and naming would be of doubtful value.

ECHINODERMATA.

ECHINOIDEA.

Several fragmentary plates and spines of sea urchins have been found in the Virginia Eocene, but even their generic identification can not be satisfactorily made.

A single large spine from Potomac Creek, Virginia, belongs apparently to some diadematoid form, but it is impossible further to identify it.

Several fragments of interambulacral with attached ambulacral plates of spatangoid character were obtained at Evergreen, James River, Virginia, but the genus can not be with certainty determined.

Other fragments were obtained, the nature of which can only be surmised.

CŒLENTERATA.[1]

ANTHOZOA.

HEXACORALLA.

Genus PARACYATHUS Edwards and Haime.

PARACYATHUS (?) CLARKEANUS Vaughan.

Paracyathus (?) *clarkeanus* Vaughan, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 6.

Corallum conical, usually slightly curved; cross section elliptical, nearly always showing a distinct area of detachment, which is variable in size; costæ not very prominent, forty-eight in number, corresponding to all the cycles of the septa, nearly equal in size; in young specimens those corresponding to the last cycle of septa are smaller than those earlier developed. No epitheca was observed, and is most probably absent. Septa thin, not projecting beyond the upper margin of the corallum wall, sides granulated, forty-eight in number, arranged in six systems of four cycles each; those of the first three cycles reach the columella; the fourth cycle fuse by their inner margins to the sides of the third cycle. Calicular fossa shallow. Pali apparently before all of the cycles of the septa except the last, small and thin, difficult to distinguish from the papillate upper surface of the columella. Rudimentary disseppiments apparently present. Columella fasicular; upper surface papillate.

The measurements of two specimens are:

	I.	II.
	Mm.	*Mm.*
Greater diameter of calice	7	7.75
Lesser diameter of calice	6	5.5
Height of corallum	12.5	9.75

The specimens are not very well preserved, and the generic determination was extremely difficult, the pali in most cases having been broken off and the septa being so rotten that good ground sections could not be made. It is reasonably certain that it belongs to the genus to which it is referred here.

Locality.—Aquia Creek, Virginia, zone 6.

Collection.—Johns Hopkins University.

Genus TURBINOLIA Lamarck.

TURBINOLIA ACUTICOSTATA Vaughan.

Turbinolia acuticostata Vaughan, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 6.

[1]This section is prepared by Mr. T. Wayland Vaughan. The figures and fuller descriptions will be given in his report upon Eocene corals, which will shortly appear.

Conical in shape, as is usual in the genus; size small. Costæ tall and thin, with irregular margins. Beginning with six, six more are soon developed, making twelve, between which in the intercostal furrows are double rows of perforations. From the base the twelve-costal condition exists for about one-sixteenth of an inch, when twelve more costæ are introduced. The costæ on the basal portion of the corallum are very slightly larger than they are on the upper portion; they are not so prominent on the basal portion as in *Turbinolia pharetra.* In the extreme upper portion twenty-four more small costæ are introduced, making the total number forty-eight, twice as many costæ as septa. In the intercostal furrows, after the development of the forty-eight costæ, there are only single rows of perforations. During the twenty-four-costal stage there are double rows of alternating perforations in the intercostal furrows. The septa are twenty-four in number, in three cycles. Those of the third cycle fuse, about halfway between the corallum wall and the columella, by their margins to the sides of the septa of the first cycle. Their sides are beset with distant, sharp, small spines. All of the septa except those of the first cycle are thin and weak. Columella probably pillar-like, without a star as in *T. pharetra*, but the specimens are too much broken to enable one to decide positively. Height, 6.5 mm.; diameter of calice, 3 mm.

The characters of the costæ described above separate this species easily from *T. pharetra* Lea.

Locality.—Aquia Creek, Virginia, zone 6.

Collection.—Johns Hopkins University.

Genus EUPSAMMIA Edwards and Haime.

EUPSAMMIA ELABORATA (Conrad).

Turbinolia elaborata Conrad, 1846, Proc. Acad. Nat. Sci., Philadelphia, Vol. III, p. 22, pl. 1, fig. 30.

Osteodes elaborata Conrad, 1866, Smith, Misc., Coll. (200), p. 2.

Osteodes elaborata de Gregorio, Mon. de la faune éoc. de l'Alabama, p. 255, 1890.

Eupsammia elaborata Vaughan, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 6.

It is probable that De Gregorio's *Placosmilia* (*Trochosmilia*) *connivens*, Mon. de la faune éoc. de l'Alabama, p. 255, 1890, is a synonym of *E. elaborata.*

Locality.—Aquia Creek, Virginia.

Collection.—Johns Hopkins University.

EUPSAMMIA (?) PILEOLUS (Conrad).

Turbinolia pileolus Conrad, 1843, Proc. Acad. Nat. Sci., Philadelphia, Vol. I, p. 327.

Turbinolia pileolus Conrad, 1846, Proc. Acad. Nat. Sci., Philadelphia, Vol. III, p. 22, pl. 1, fig. 26.

Eupsammia (?) *pileolus* Vaughan, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 6.

This species was described from a single much worn specimen, whose exact affinities can not be determined. Apparently no specimen except the type has been collected.

Locality.—Conrad in his original description gives the locality as Pamunkey River, Kent County, Virginia.

Collection.—Philadelphia Academy of Natural Sciences (?).

There is another species from Fort Washington, Md., represented by one specimen that is too poor for determination.

PROTOZOA.[1]

RHIZOPODA.

FORAMINIFERA.

SPIROPLECTA CLARKI Bagg.

Spiroplecta clarki Bagg, 1895, Johns Hopkins Univ. Circ., Vol. XV, p. 6.

Test elongate, textulariform, finely arenaceous and firmly cemented; compressed strongly, lateral margins sharp and very slightly lobed; surface of shell rough, of a dull-gray color; chambers at first plano-spiral, then arranged biserially with nine or ten, respectively, upon each side; aperture, a median arched opening.

Dimensions.—Length, 0.53 mm.; width, 0.2 mm.

Locality.—Woodstock, Virginia.

NODOSARIA AFFINIS d'Orbigny.

Locality.—Woodstock, Virginia.

NODOSARIA BACILLUM Defrance.

Locality.—Woodstock, Virginia.

NODOSARIA COMMUNIS d'Orbigny.

Locality.—Sunnyside, Maryland.

NODOSARIA FARCIMEN (Soldani).

Locality.—Pamunkey River, Virginia.

VAGINULINA LEGUMEN (Linné).

Locality.—Sunnyside, Maryland.

CRISTELLARIA RADIATA Reuss.

Locality.—Woodstock, Virginia.

POLYMORPHINA AMYGDALOIDES (Reuss).

Locality.—Pamunkey River, Virginia.

POLYMORPHINA AUSTRIACA d'Orbigny.

Locality.—Woodstock, Virginia.

[1] This section is prepared by Dr. R. M. Bagg. The figures and fuller descriptions will appear in his forthcoming report upon Cretaceous and Eocene Foraminifera.

POLYMORPHINA COMMUNIS d'Orbigny.

Localities.—Woodstock, Pamunkey River, Virginia.

POLYMORPHINA COMPLANATA d'Orbigny.

Locality.—Pamunkey River, Virginia.

POLYMORPHINA COMPRESSA d'Orbigny.

Locality.—Woodstock, Virginia.

POLYMORPHINA ELEGANTISSIMA Parker and Jones.

Locality.—Woodstock, Virginia.

POLYMORPHINA GIBBA d'Orbigny.

Locality.—Woodstock, Virginia.

POLYMORPHINA PRÆLONGA Terquem.

Locality.—Woodstock, Virginia.

GLOBIGERINA BULLOIDES d'Orbigny.

Locality.—Woodstock, Virginia.

DISCORBINA BERTHELOTI d'Orbigny.

Locality.—Woodstock, Virginia.

TRUNCATULINA LOBATULA Walker and Jacob.

Locality.—Woodstock, Virginia.

PULVINULINA ELEGANS d'Orbigny.

Locality.—Pamunkey River, Virginia.

PULVINULINA SCHREIBERSII d'Orbigny.

Locality.—Woodstock, Virginia.

NONIONINA AFFINIS Reuss.

Locality.—Woodstock, Virginia.

NONIONINA DEPRESSULA Walker and Jacob.

Locality.—Pamunkey River, Virginia.

AMPHISTEGINA LESSONII d'Orbigny.

Locality.—Woodstock, Virginia.

DOUBTFUL SPECIES.

CRASSATELLA PALMULA Conrad.

Crassatella palmula Conrad, 1846, Am. Jour. Sci., second series, Vol. I, p. 396, pl. 4, fig. 1.

This species is founded upon a fragment of a single valve, so that it is impossible to judge of its complete characters. The species is therefore debarred from the list of Eocene fossils of the Middle Atlantic Slope. Conrad obtained the specimen described at Upper Marlboro, Md.

NUCULA PARILIS Conrad.

Nucula parilis Conrad, 1848, Jour. Acad. Nat. Sci., Philadelphia, new series, Vol. I, p. 132, pl. 14, fig. 31.

No other specimens similar to the poorly preserved *Leda* which Conrad described under the name of *Nucula parilis* having been obtained from the Eocene, it is impossible to decide whether it is really an independent species or not. It seems best to omit the name from the list of species until suitable material is obtained to definitely characterize the form. The specimen described by Conrad came from Upper Marlboro, Md.

ANOMIA RUFFINI Conrad.

Anomia ruffini Conrad, 1835, Fossils Medial Tertiary, p. 74, pl. 42, fig. 6.

This species, originally described by Conrad in a work devoted almost exclusively, if not entirely, to Miocene fossils, was later, by that author and by others, placed in lists of both Eocene and Miocene forms. It is extremely doubtful if the species has ever been found in the Eocene.

OSTREA SUBEVERSA Conrad.

Ostrea subeversa Conrad, 1865, Am. Jour. Conch., Vol. I, p. 15.

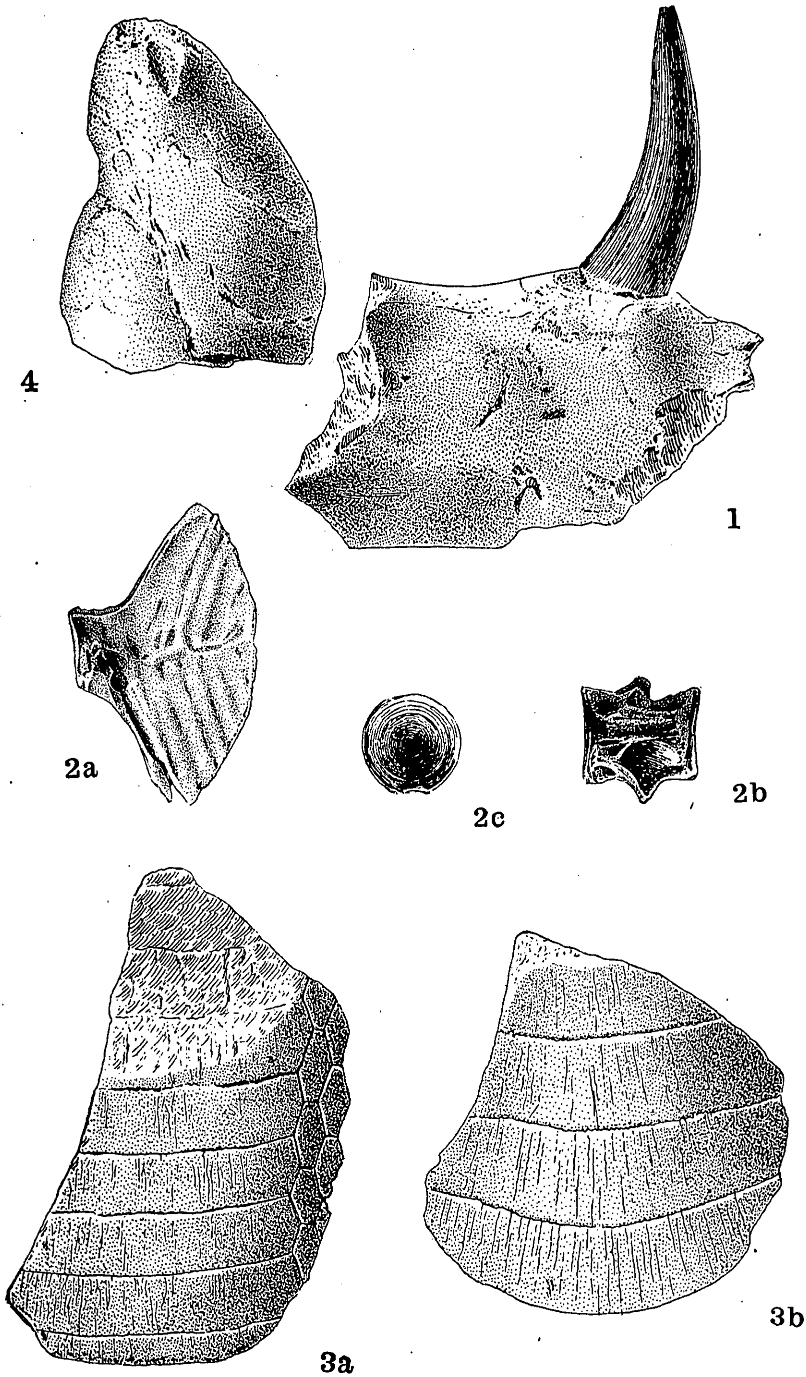
No description or figure were given of this species, and in the following year Conrad regarded it, in a note in his Check List of Eocene Fossils, Smithsonian Miscellaneous Collections, as a synonym of *O. eversa* (Melleville) of Europe. The form has not been recognized by the writer in the Middle Atlantic Slope Eocene.

In addition to the four species above considered, a few others, for the most part originally based upon Gulf forms, have been reported from the Eocene of the Middle Atlantic Slope. After a careful study of a large amount of material from nearly all the known localities, they have not been detected by the writer.

PLATES SHOWING FOSSILS.

PLATE VII.

PLATE VII.

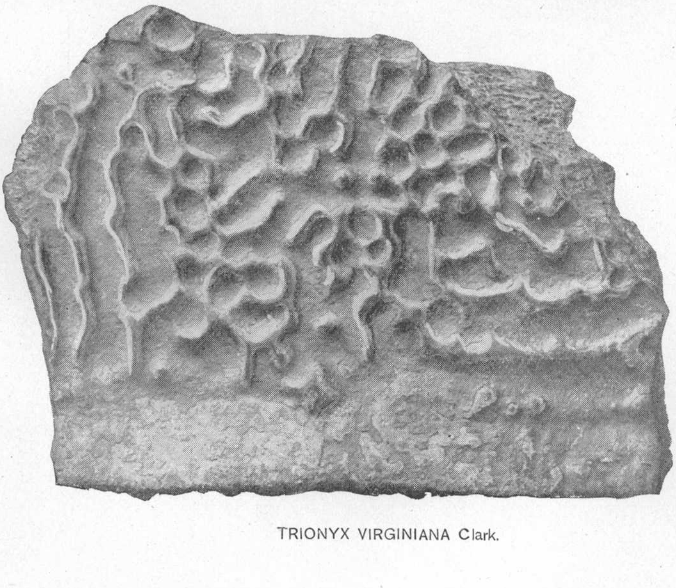


1. THECACHAMPSA MARYLANDICA Clark
2. ISCHYRHIZA (?) RADIATA Clark.
3. MYLIOBATIS COPEANUS Clark.
4. COPROLITE.

PLATE VIII.

PLATE VIII.

1a

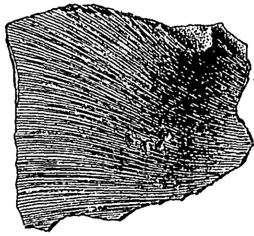


1b

TRIONYX VIRGINIANA Clark.

PLATE IX.

PLATE IX.



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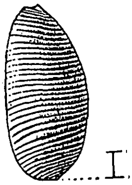

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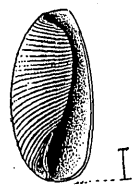
4b



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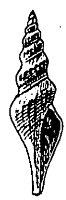

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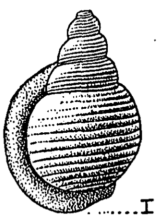

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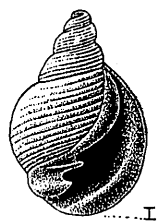

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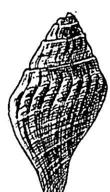
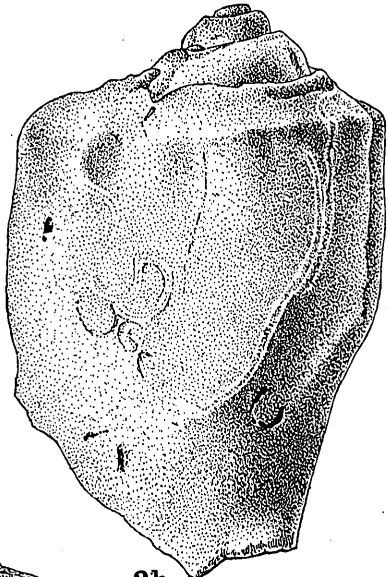


5

1. NAUTILUS sp.
2. CYLICHNA VENUSTA Clark.
3. RINGICULA DALLI Clark.
4. PLEUROTOMA HARRISI Clark.
5. MANGILIA (PLEUROTOMELLA) BELLISTRIATA Clark.

PLATE X.

PLATE X.



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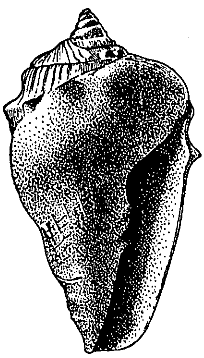

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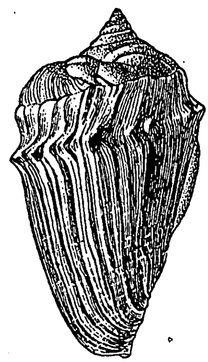

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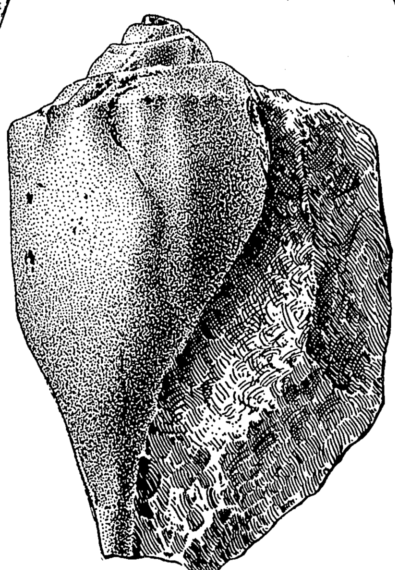

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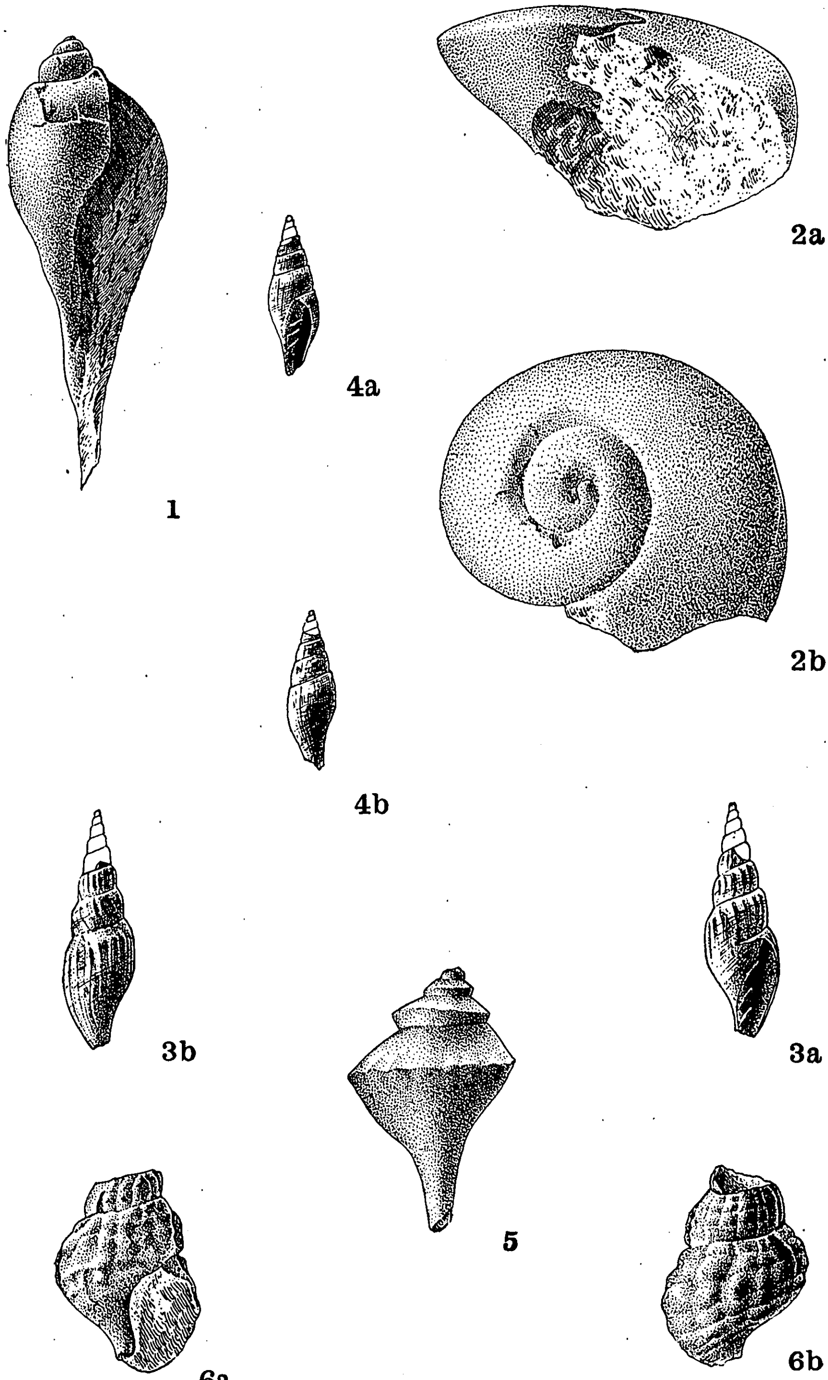
1. VOLUTILITHES (ATHLETA) TUOMEYI Conrad.

2. VOLUTILITHES sp.

PLATE XI.

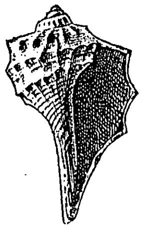
PLATE XI.



1. CARICELLA sp.
2. PYROPSIS sp.
3. MITRA MARYLANDICA Clark
4. MITRA sp.
5. FUSUS sp.
6. FUSUS sp.

PLATE XII.

PLATE XII.



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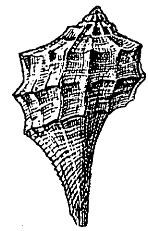

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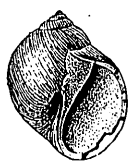

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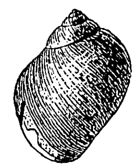

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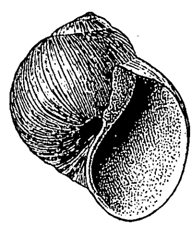

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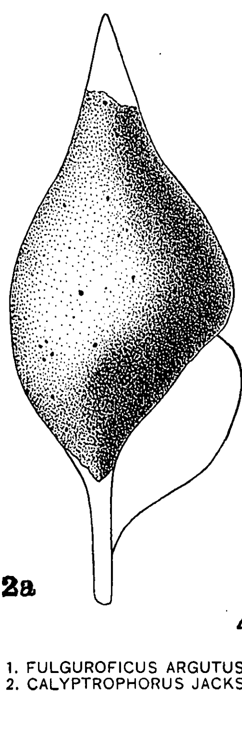

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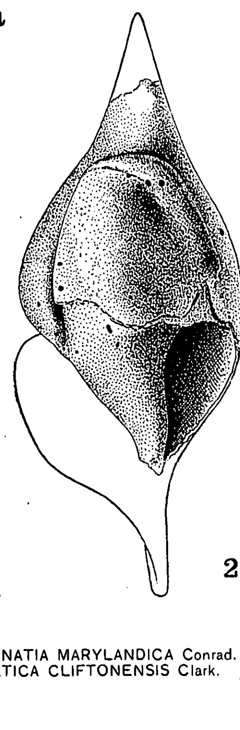

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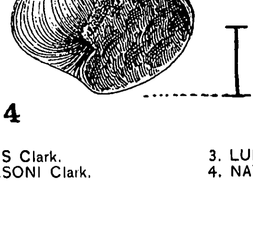


4

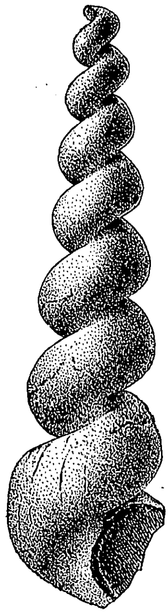
1. FULGUROFICUS ARGUTUS Clark.
2. CALYPTROPHORUS JACKSONI Clark.
3. LUNATIA MARYLANDICA Conrad.
4. NATICA CLIFTONENSIS Clark.

PLATE XIII.

PLATE XIII.

Page.

FIGS. 1*a*–1*e*. TURRITELLA MORTONI Conrad.................................... 69



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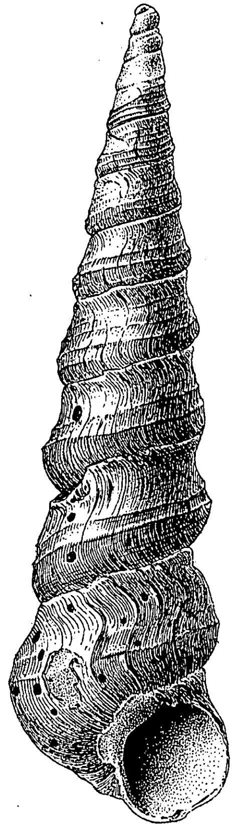

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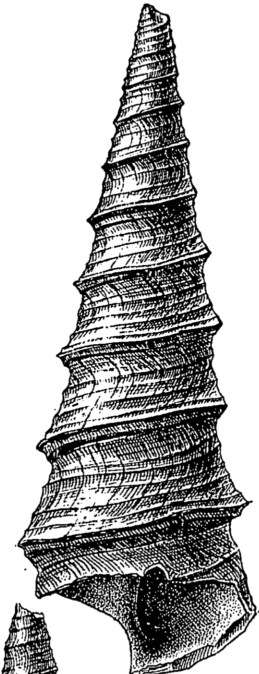

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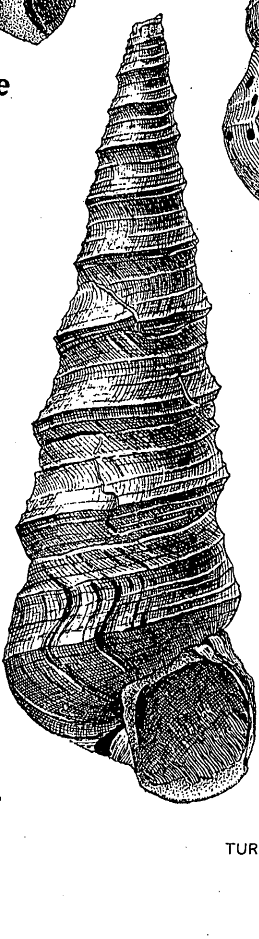

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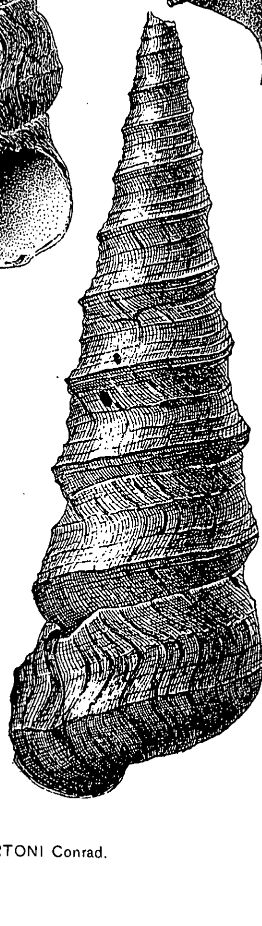
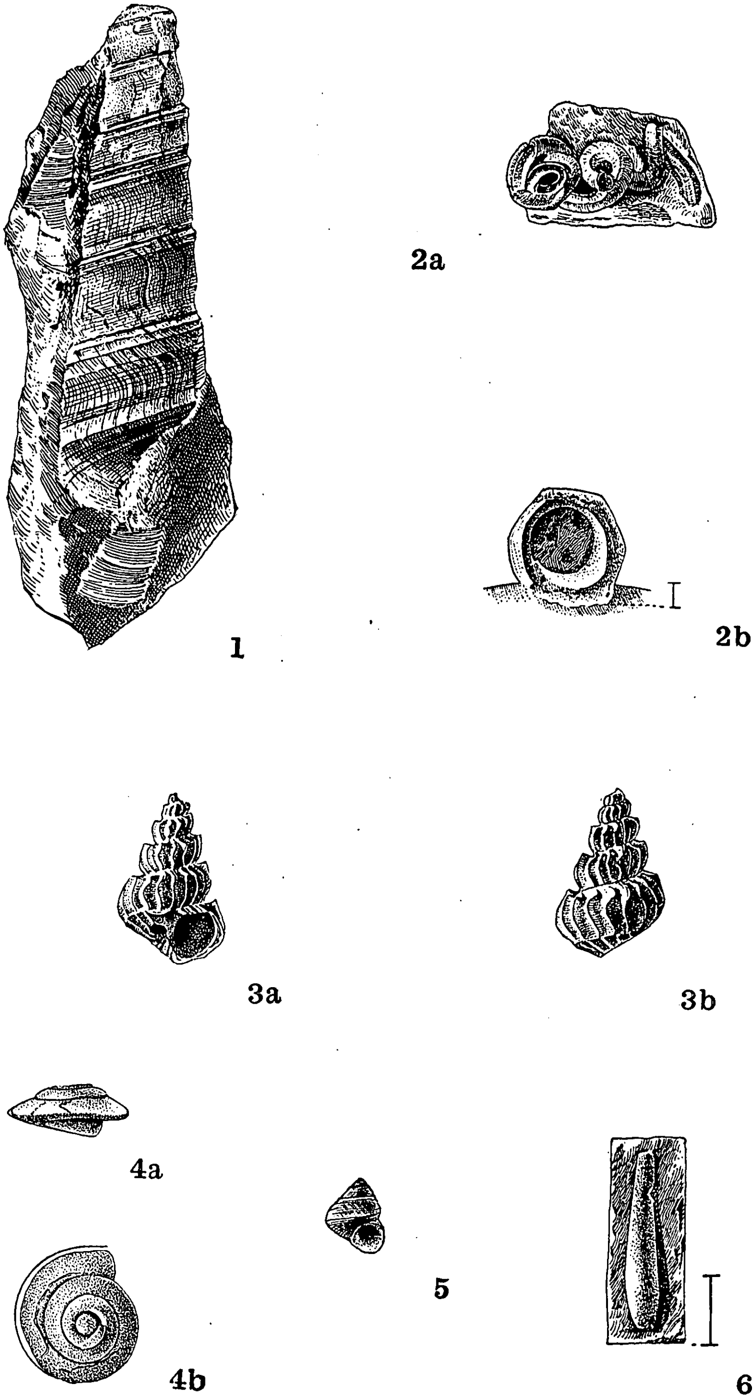


1b

TURRITELLA MORTONI Conrad.

PLATE XIV.

PLATE XIV.

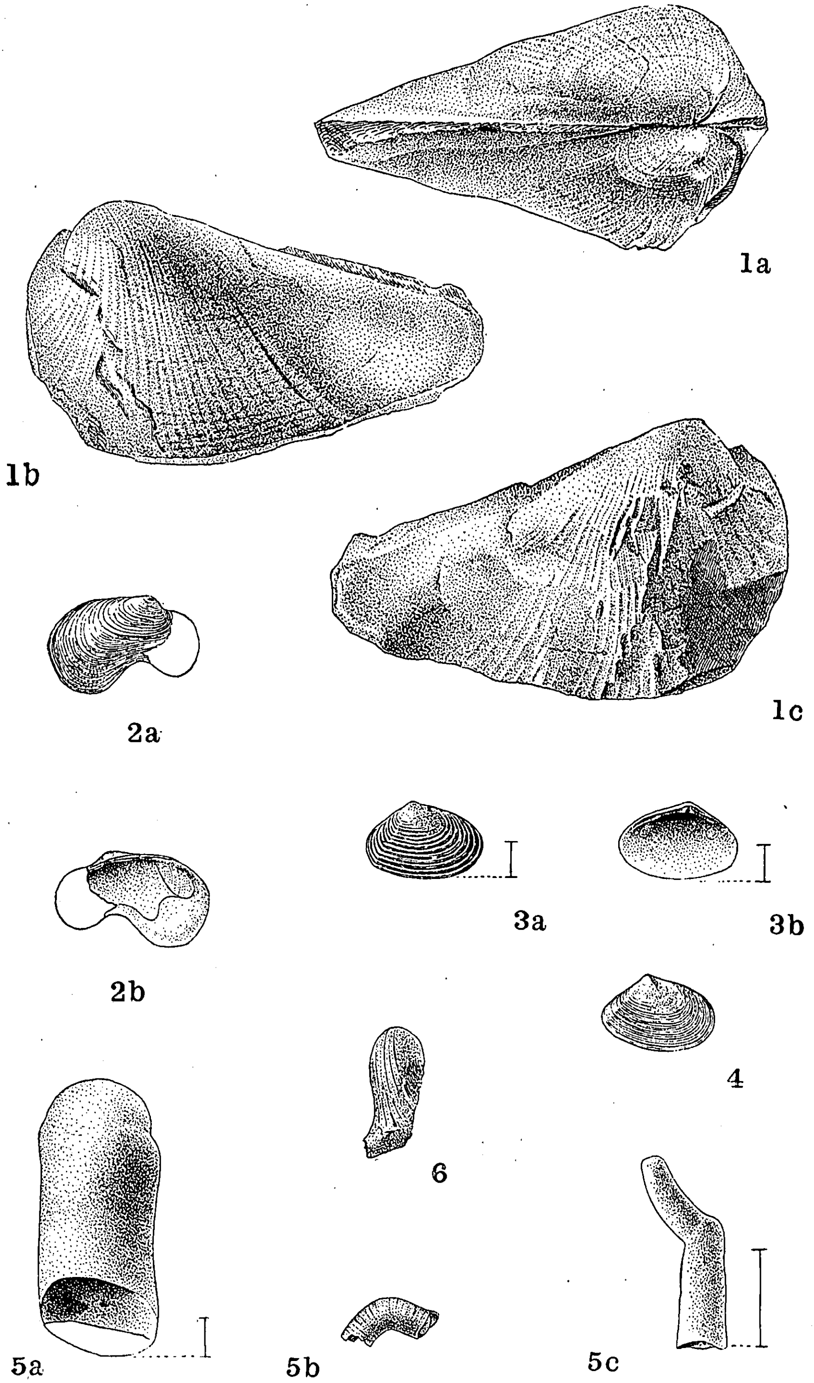


1. TURRITELLA HUMEROSA Conrad.
2. VERMETUS sp.
3. SCALA VIRGINIANA Clark.
4. SOLARIUM sp.
5. GIBBULA GLANDULA (Conrad).
6. CADULUS BELLULUS Clark.

PLATE XV.

PLATE XV.

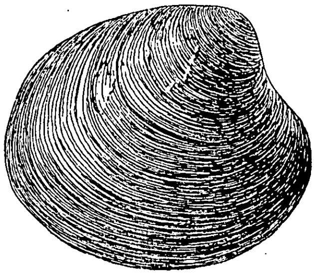
	Page.
FIGS. 1*a*–1*c*. PHOLAS (?) PETROSA Conrad	73
FIGS. 2*a*, 2*b*. CORALLIOPHAGA BRYANI Clark	73
FIGS. 3*a*, 3*b*. TELLINA WILLIAMSI Clark	76
FIG. 4. TELLINA VIRGINIANA Clark	76
FIGS. 5*a*–5*c*. TEREDO VIRGINIANA Clark	72
FIG. 6. GASTROCHÆNA sp.	73



1. PHOLUS (?) PETROSA Conrad.
2. CORALLIOPHAGA BRYANI Clark.
3. TELLINA WILLIAMSI Clark.
4. TELLINA VIRGINIANA Clark.
5. TEREDO VIRGINIANA Clark.
6. GASTROCHÆNA sp.

PLATE XVI.

PLATE XVI.



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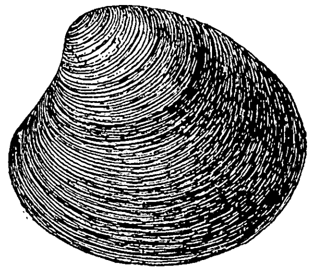

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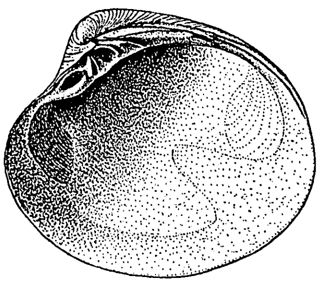

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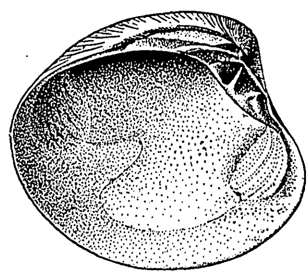

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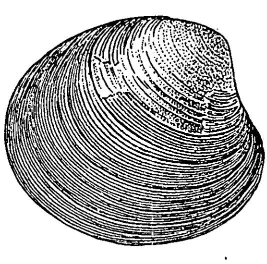

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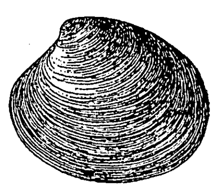
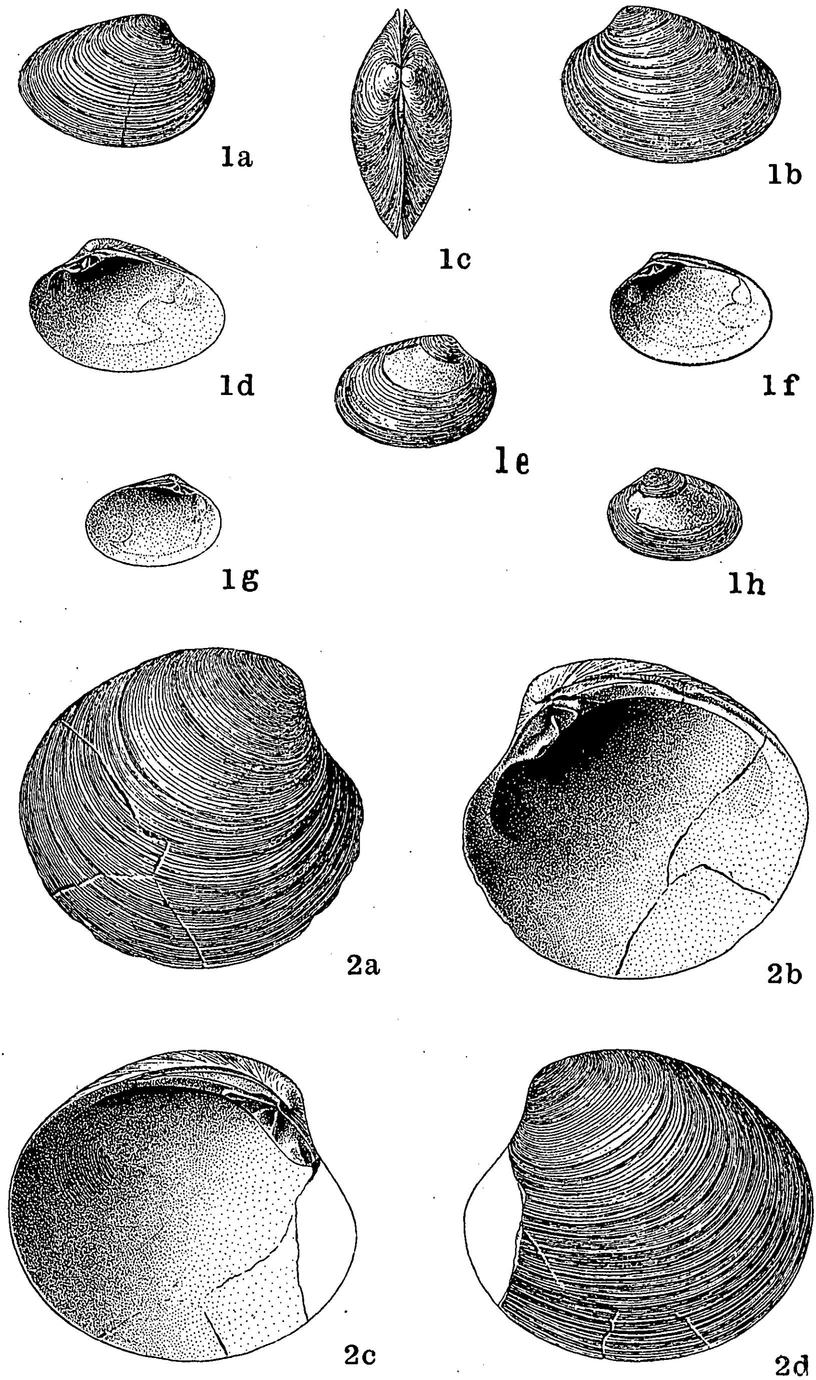


1f

CYTHEREA OVATA Rogers.

PLATE XVII.

PLATE XVII.

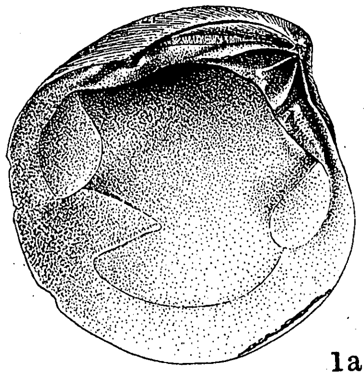


1. CYTHEREA SUBIMPRESSA Conrad.

2. CYTHEREA EVERSA Conrad.

PLATE XVIII.

PLATE XVIII.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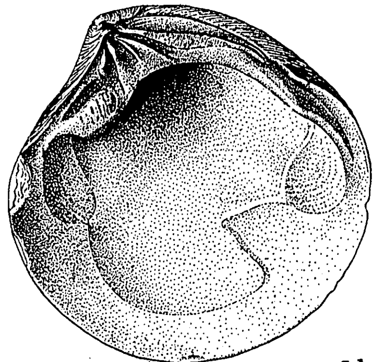
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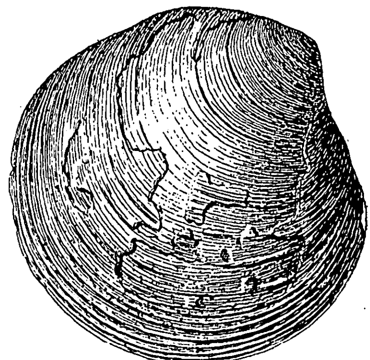
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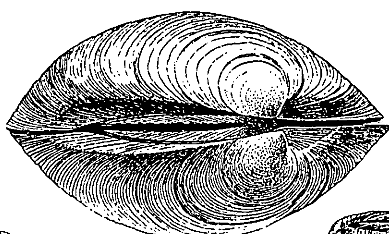
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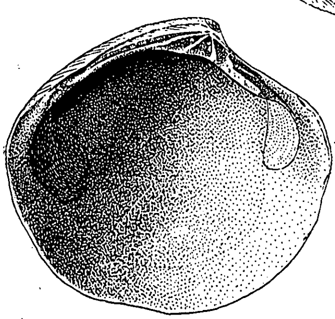
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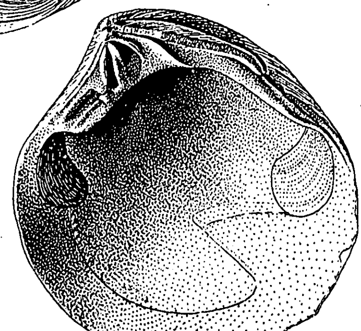
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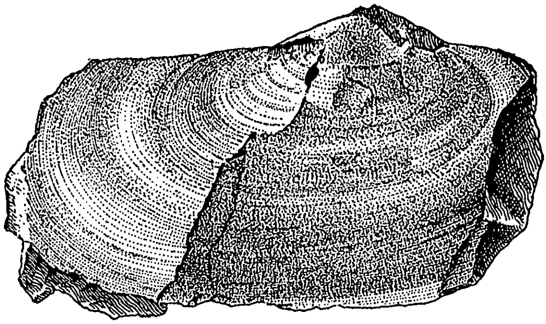
DOSINIOPSIS LENTICULARIS Rogers.

PLATE XIX.

PLATE XIX.



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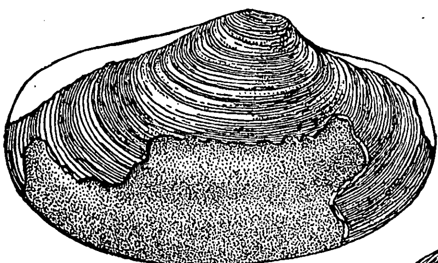

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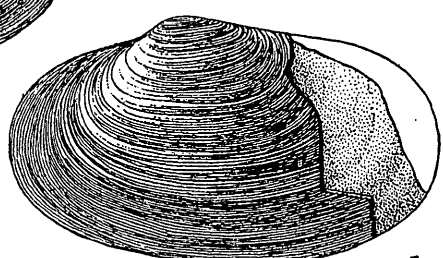

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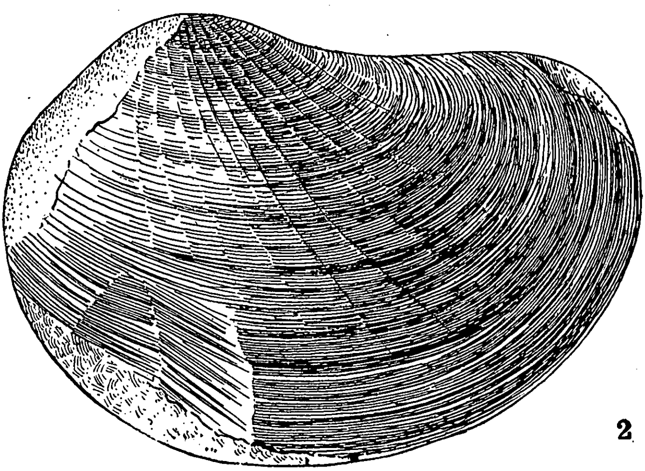


2

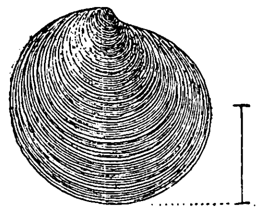
1. PANOPÆA ELONGATA Conrad.

2. PHOLADOMYA MARYLANDICA Conrad.

PLATE XX.

PLATE XX.

124



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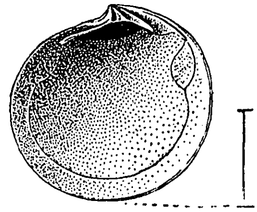

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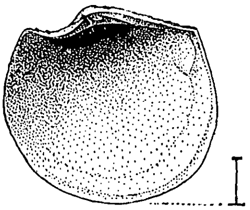

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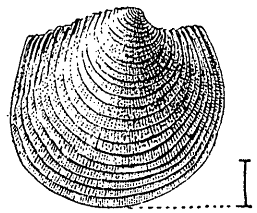

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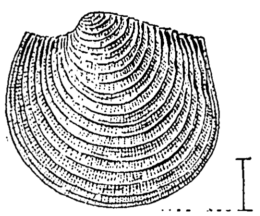

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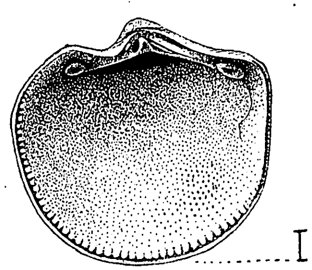

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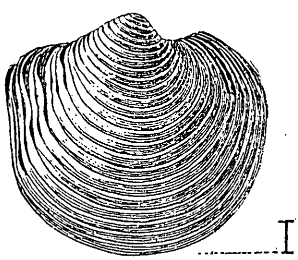

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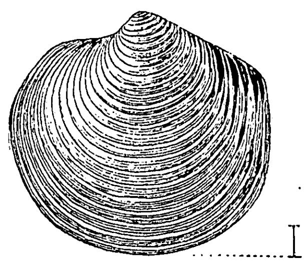
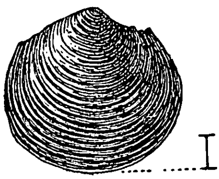


3c

1. LUCINA AQUIANA Clark.
2. LUCINA DARTONI Clark.
3. LUCINA WHITEI Clark.

PLATE XXI.

PLATE XXI.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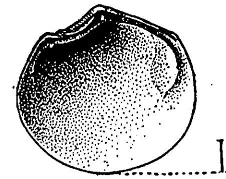
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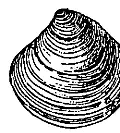
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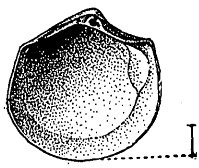
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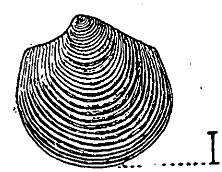
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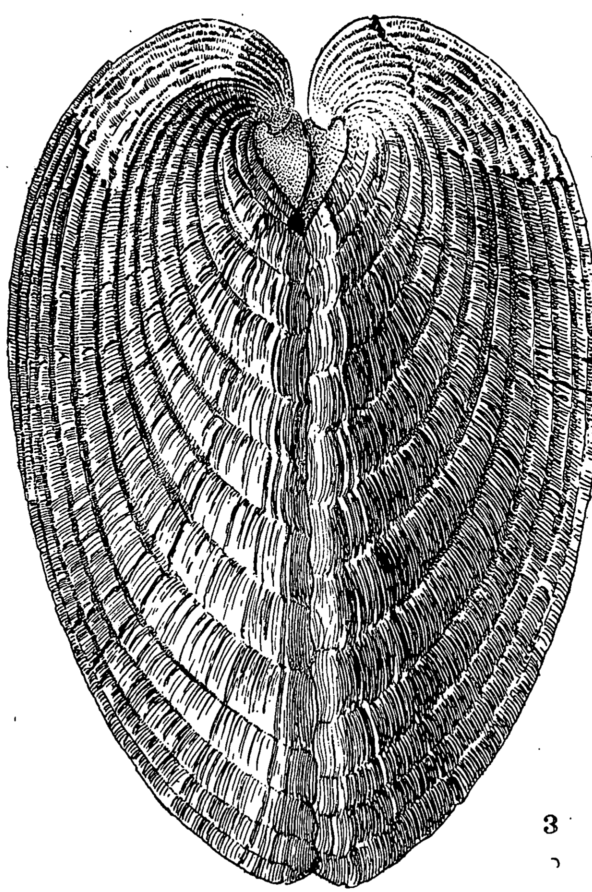
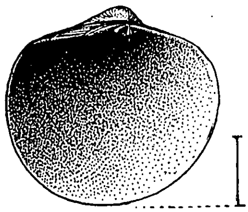

3

1. LUCINA UHLERI Clark.
2. ASTARTE MARYLANDICA Clark.
3. VENERICARDIA PLANICOSTA Lamarck.

PLATE XXII.

PLATE XXII.



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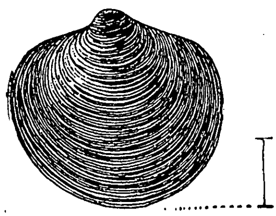

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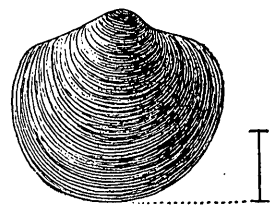

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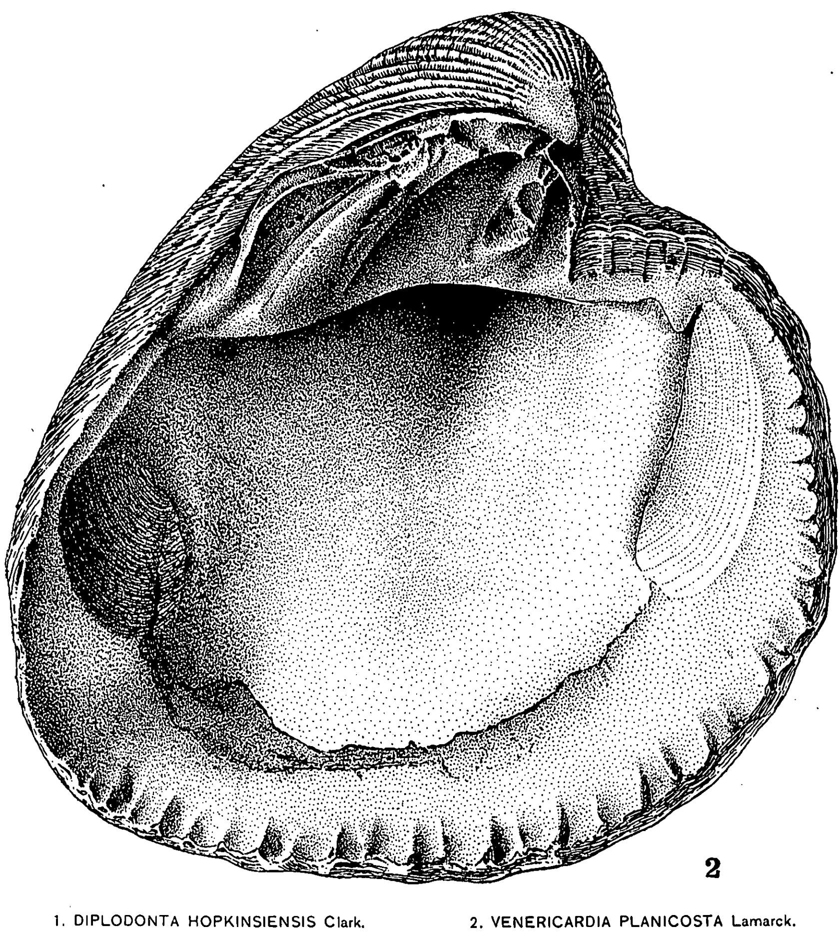


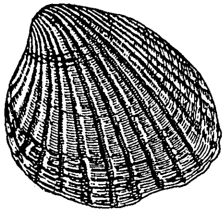
2

1. DIPLODONTA HOPKINSIENSIS Clark.

2. VENERICARDIA PLANICOSTA Lamarck.

PLATE XXIII.

PLATE XXIII.



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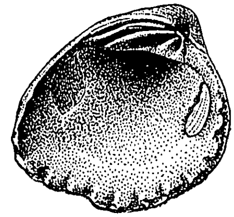

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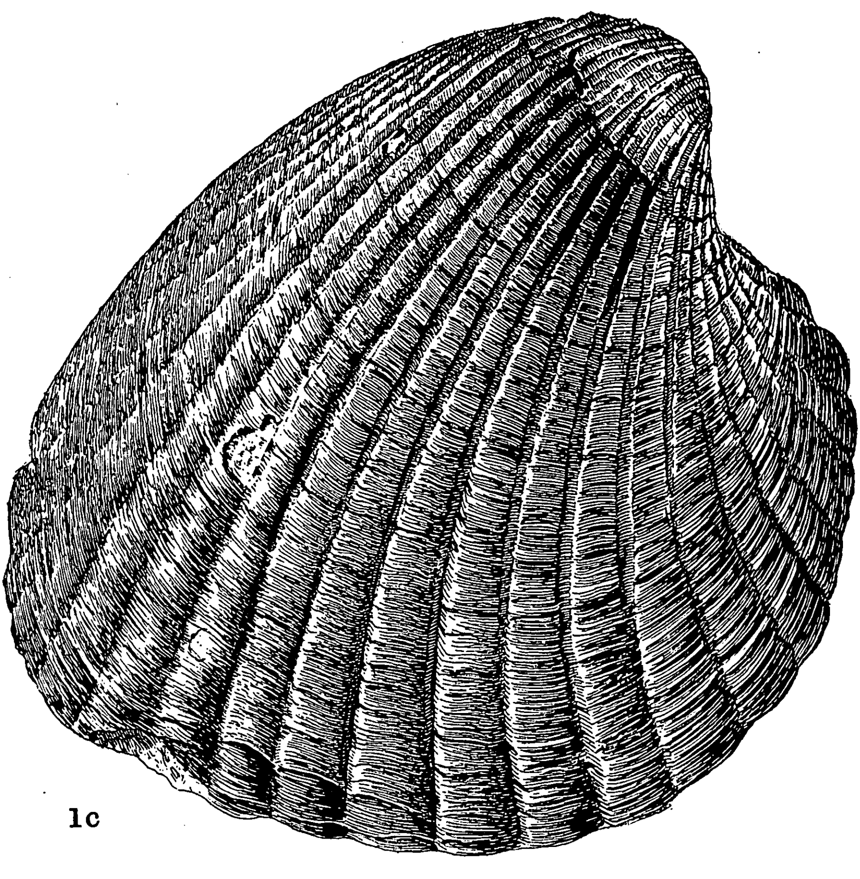
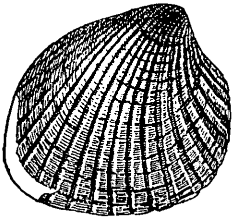


1c

VENERICARDIA PLANICOSTA Lamarck.

PLATE XXIV.

PLATE XXIV.



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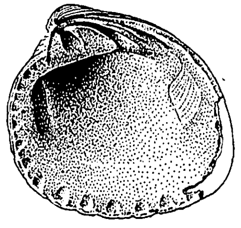

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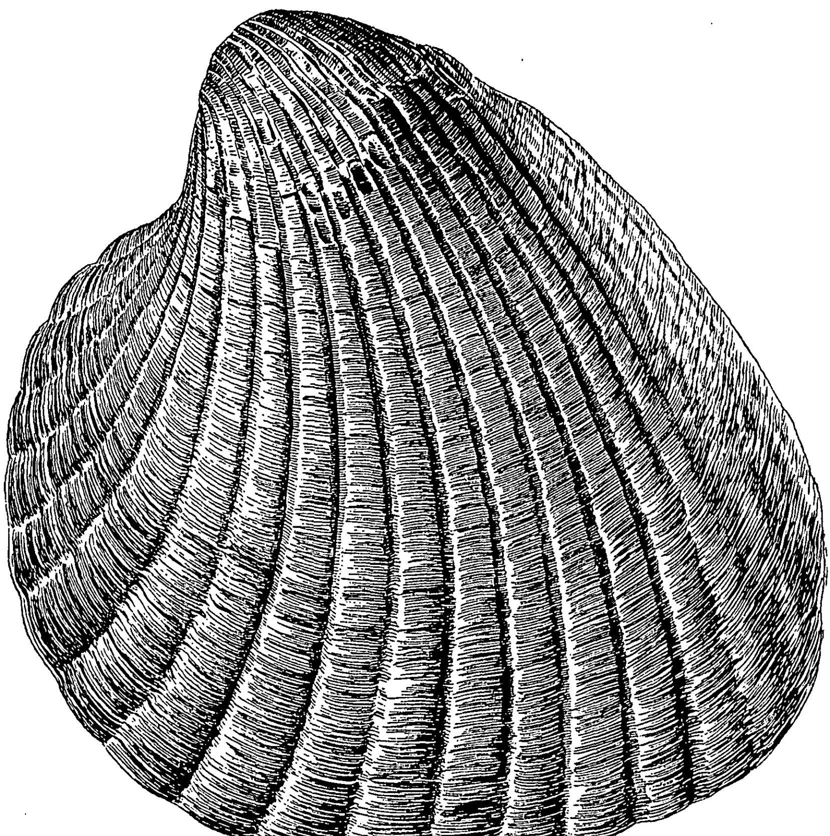

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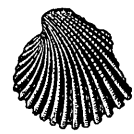
VENERICARDIA PLANICOSTA Lamarck.

PLATE XXV.

133

PLATE XXV.

1a



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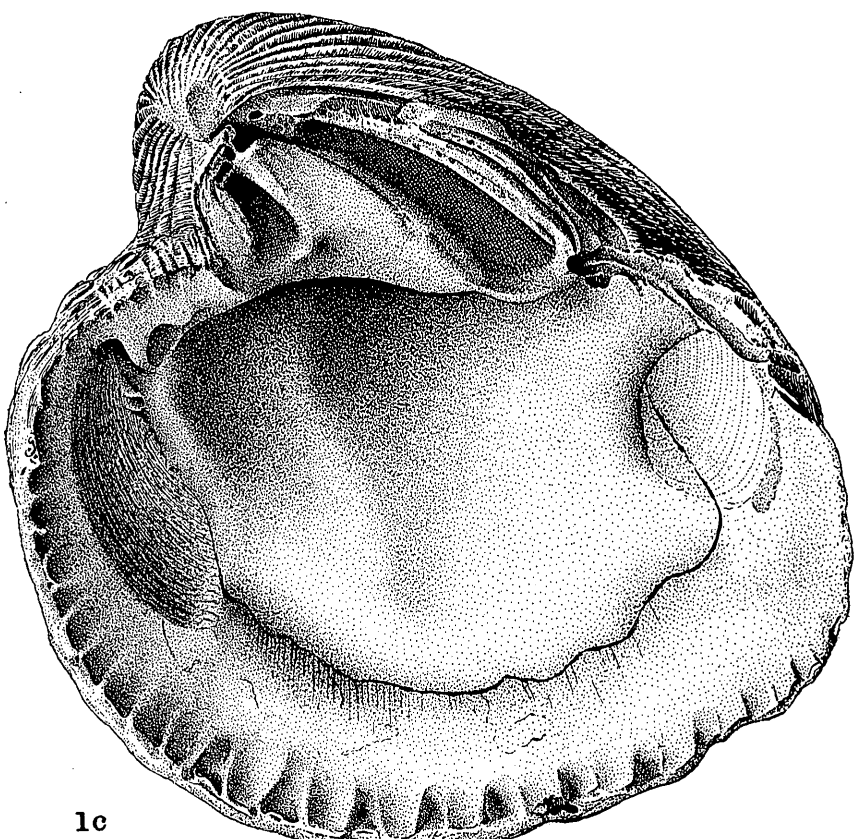

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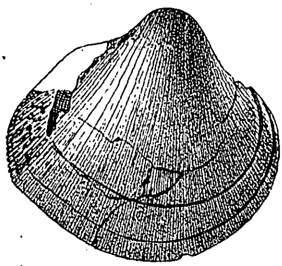
VENERICARDIA PLANICOSTA Lamarck.

PLATE XXVI.

PLATE XXVI.



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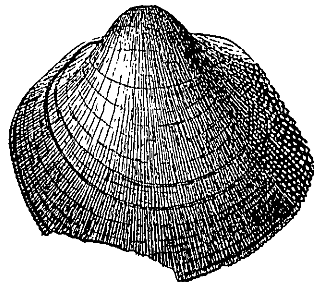

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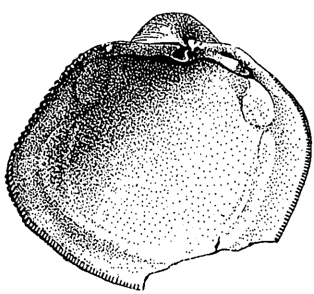

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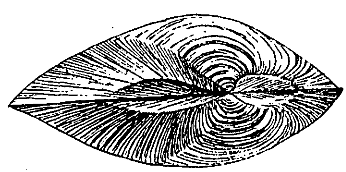

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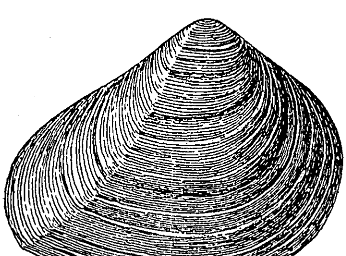

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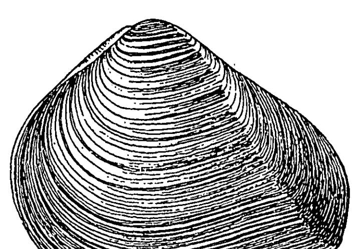


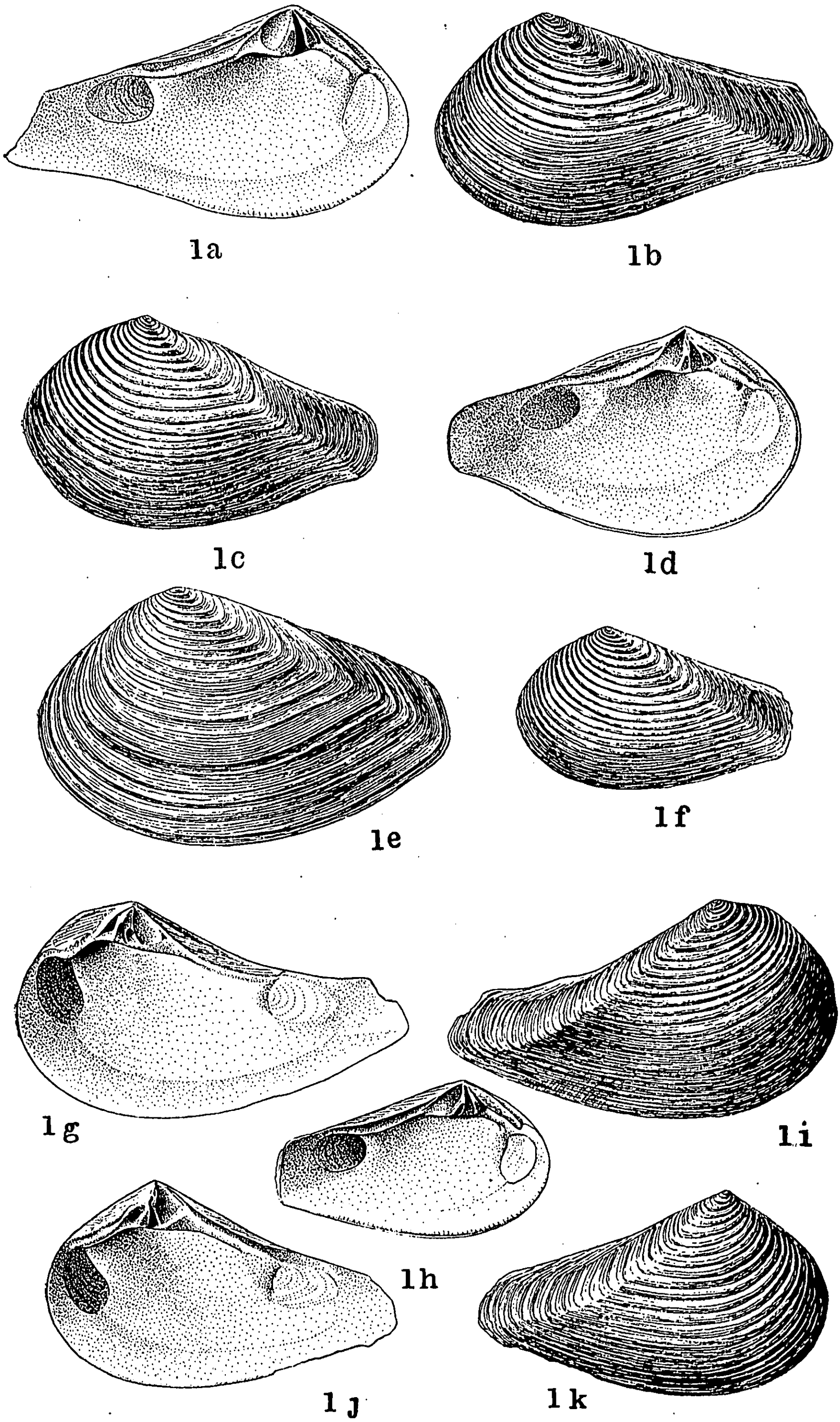
2c

1. PROTOCARDIA VIRGINIANA Conrad.

2. CRASSATELLA AQUIANA Clark.

PLATE XXVII.

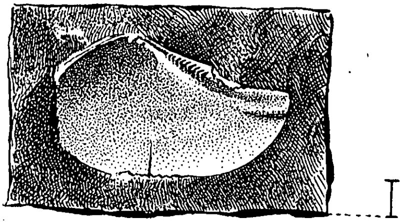
PLATE XXVII.



CRASSATELLA ALÆFORMIS Conrad.

PLATE XXVIII.

PLATE XXVIII.



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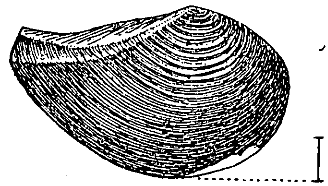

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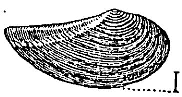

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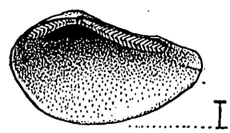

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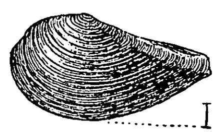

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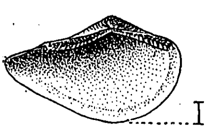

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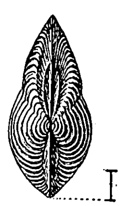

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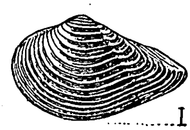

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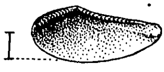


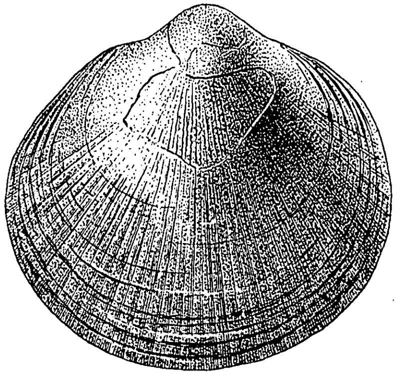
3a

3b

1. LEDA IMPROCERA (Conrad).
2. LEDA PARVA (Rogers).
3. LEDA (ADRANA) CULTELLIFORMIS (Rogers).

PLATE XXIX.

PLATE XXIX.



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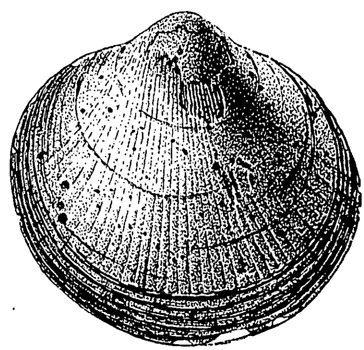

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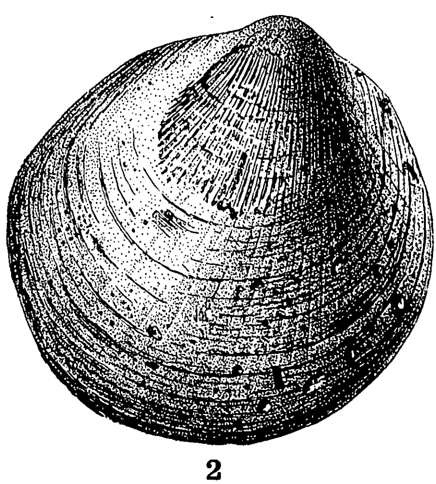


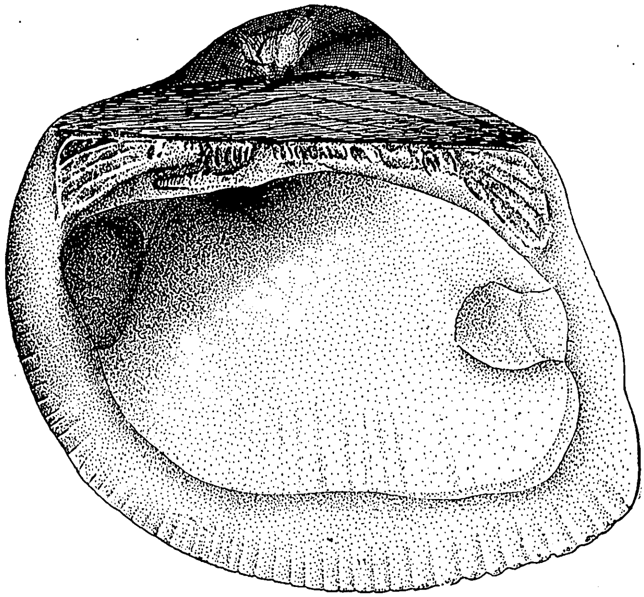
2

1. PECTUNCULUS IDONEUS Conrad.

2. PECTUNCULUS sp.

PLATE XXX.

PLATE XXX.



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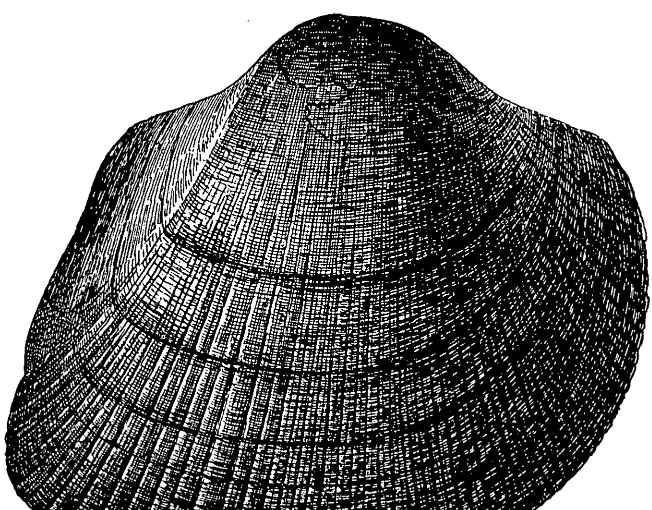

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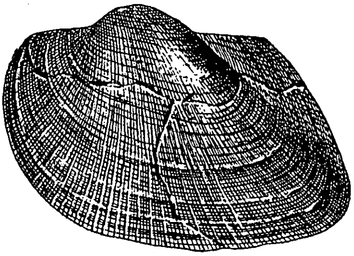
CUCULLÆA GIGANTEA Conrad.

PLATE XXXI.

PLATE XXXI.



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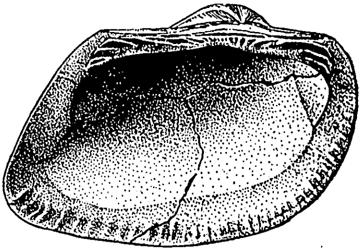

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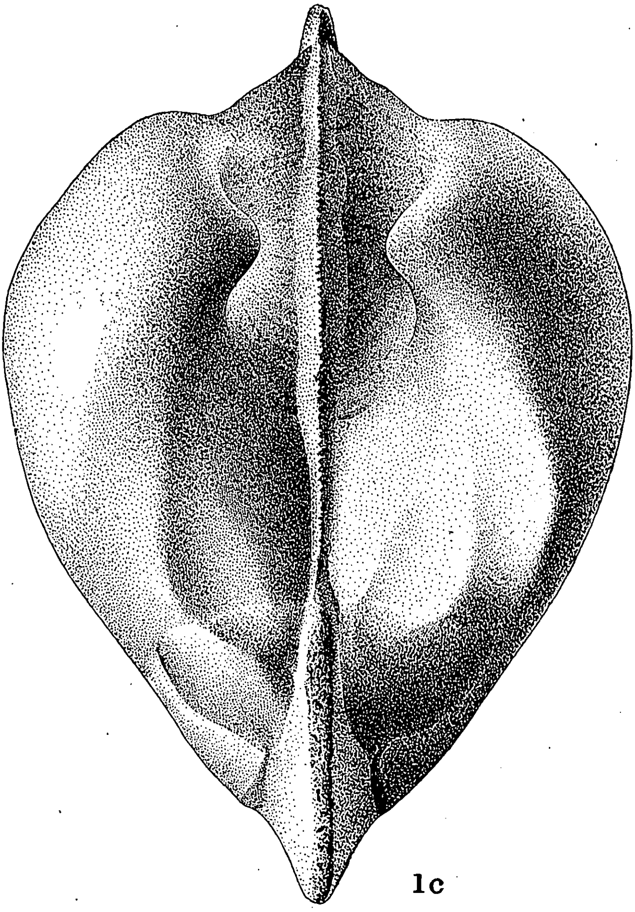

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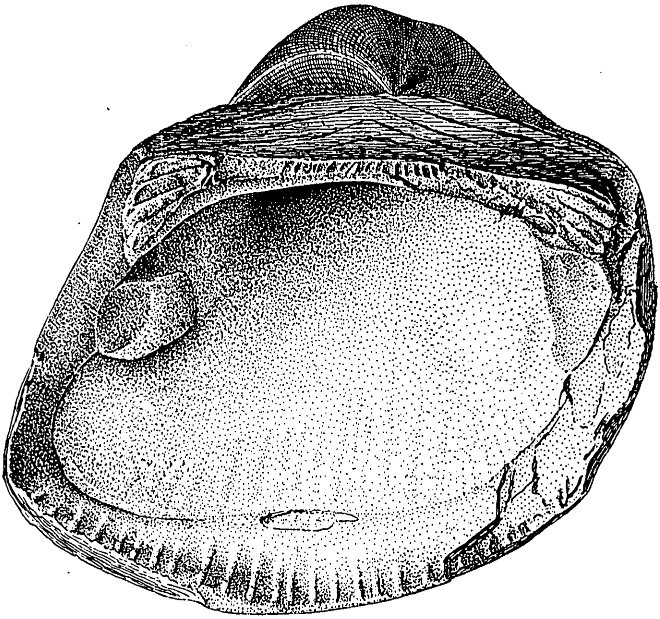
CUCULLÆA GIGANTEA Conrad.

PLATE XXXII.

PLATE XXXII.



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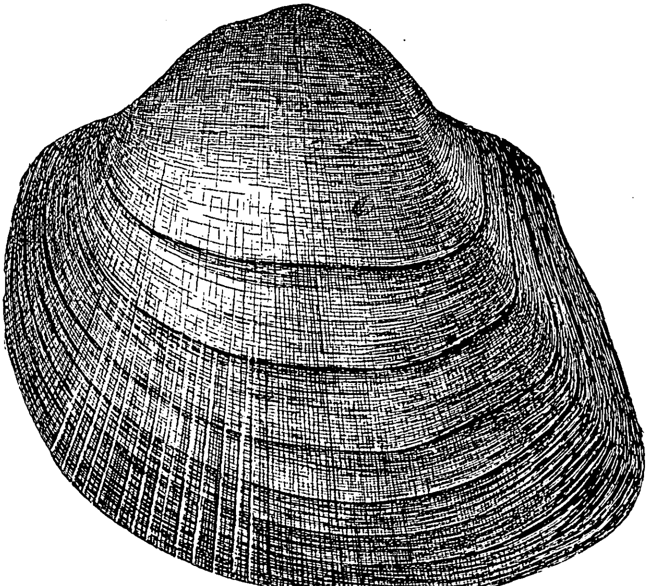

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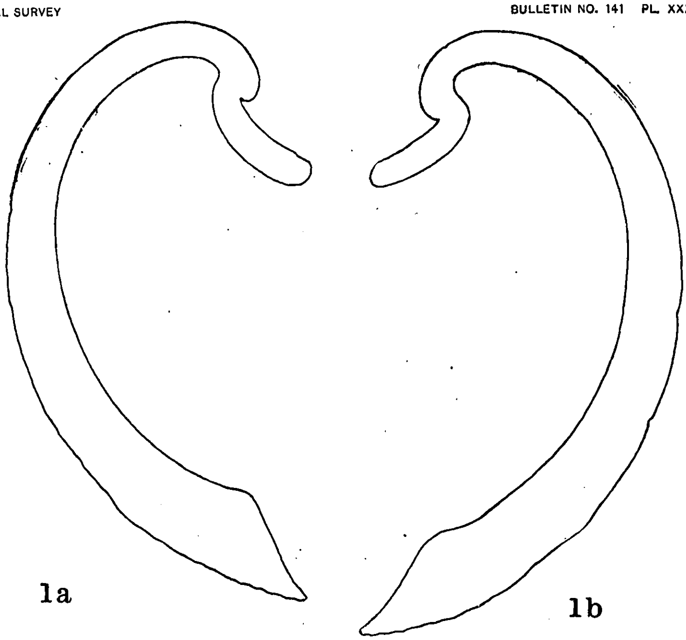
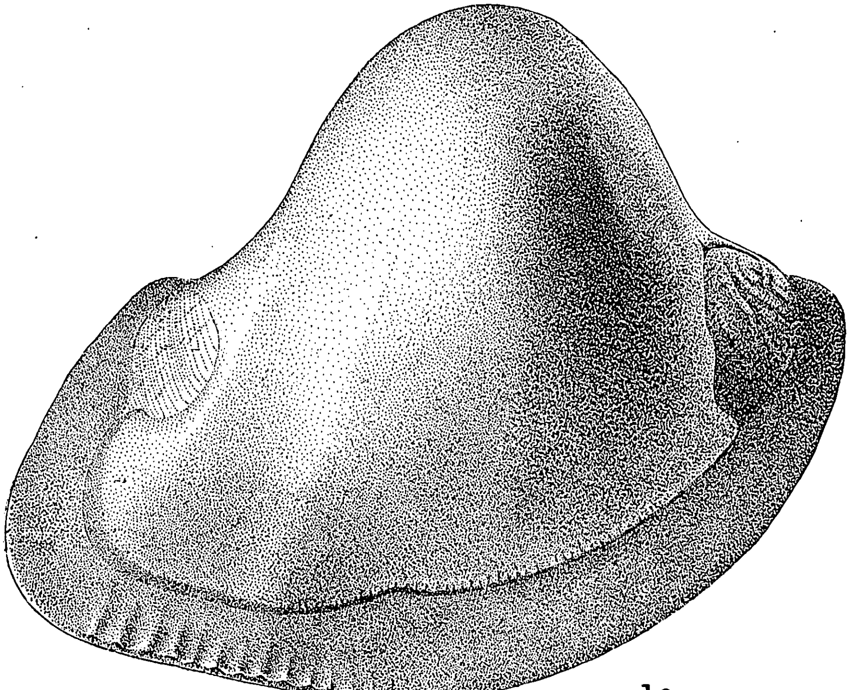
CUCULLÆA GIGANTEA Conrad.

PLATE XXXIII.

PLATE XXXIII.



1a 1b



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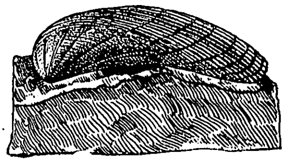
CUCULLÆA GIGANTEA Conrad.

PLATE XXXIV.

PLATE XXXIV.



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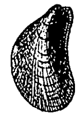

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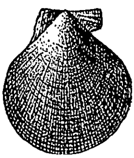

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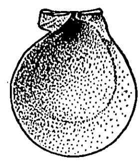

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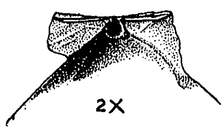

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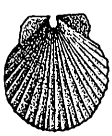

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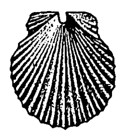

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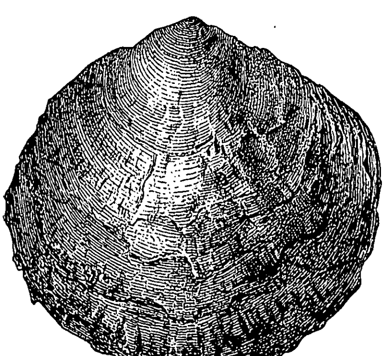

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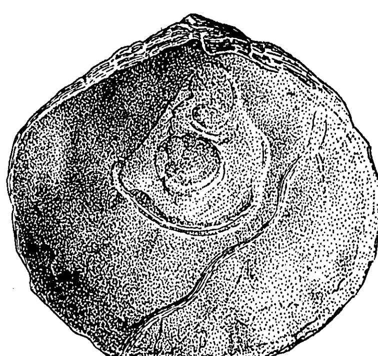


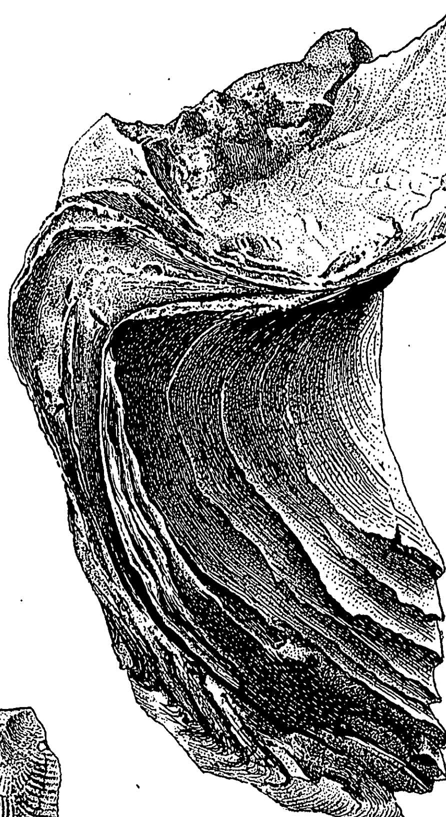
5b

1. MODIOLA POTOMACENSIS Clark.
2. PECTEN ROGERSI Clark.
3. PECTEN JOHNSONI Clark.
4. PECTEN sp.
5. ANOMIA McGEEI Clark.

PLATE XXXV.

PLATE XXXV.

	Page.
FIGS. 1*a*–1*d*. OSTREA SELLÆFORMIS Conrad	87



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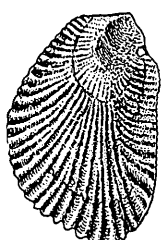

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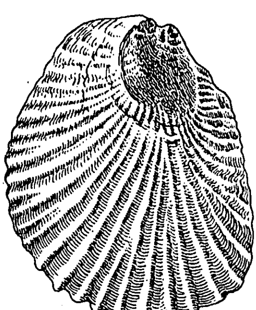

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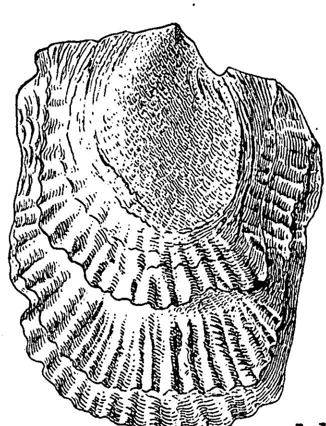
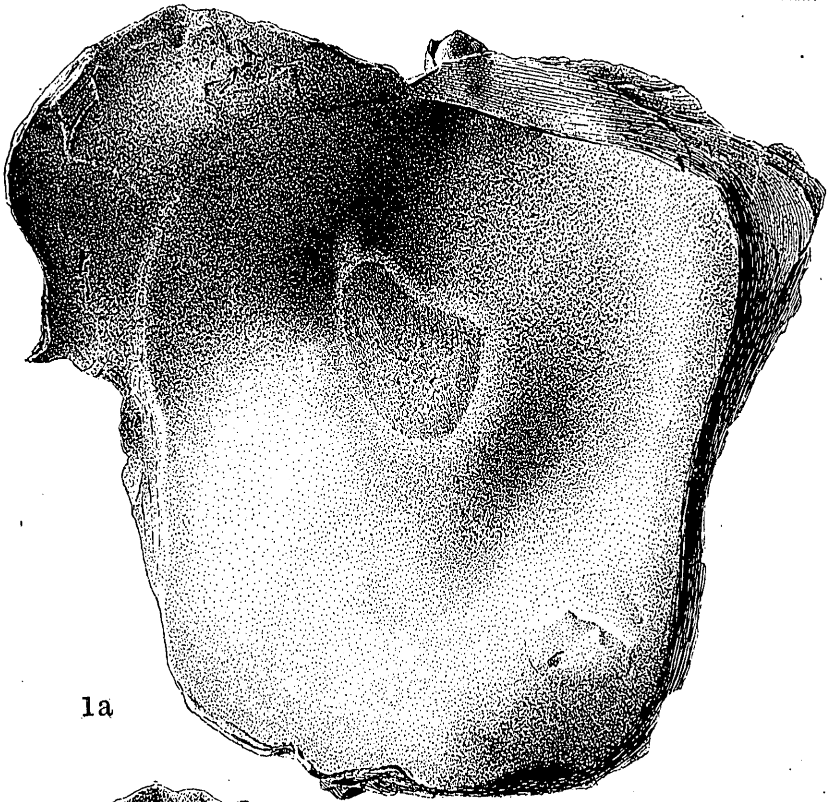


1d

OSTREA SELLÆFORMIS Conrad.

PLATE XXXVI.

PLATE XXXVI.



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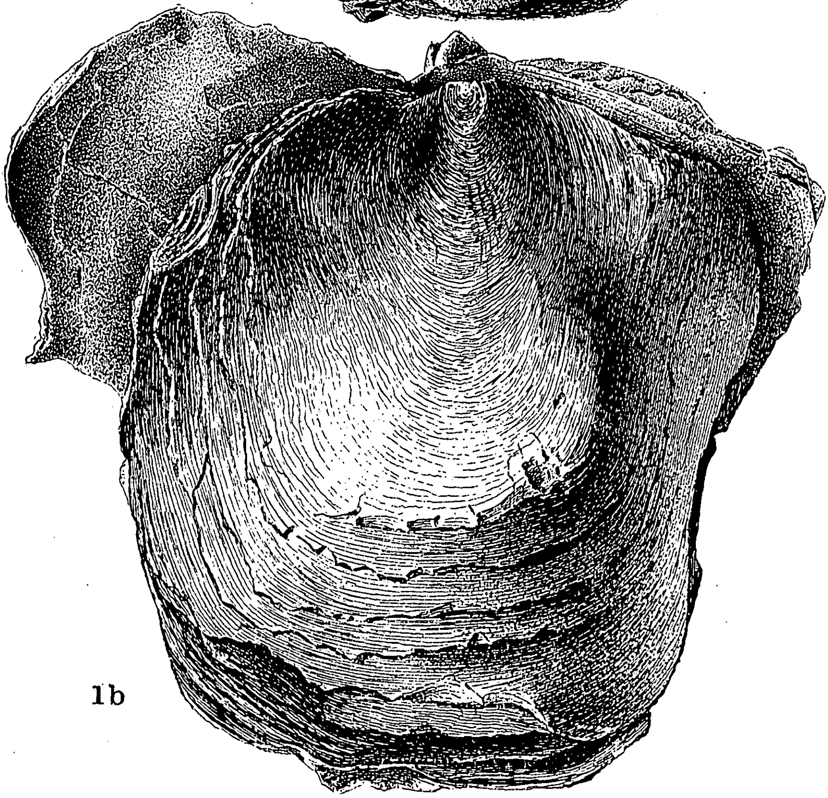


1b

OSTREA SELLÆFORMIS Conrad.

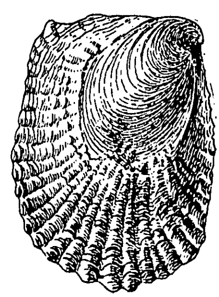
PLATE XXXVII.

PLATE XXXVII.

1

2a

2b

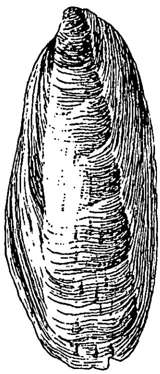


2c

OSTREA COMPRESSIROSTRA Say.

PLATE XXXVIII.

PLATE XXXVIII.



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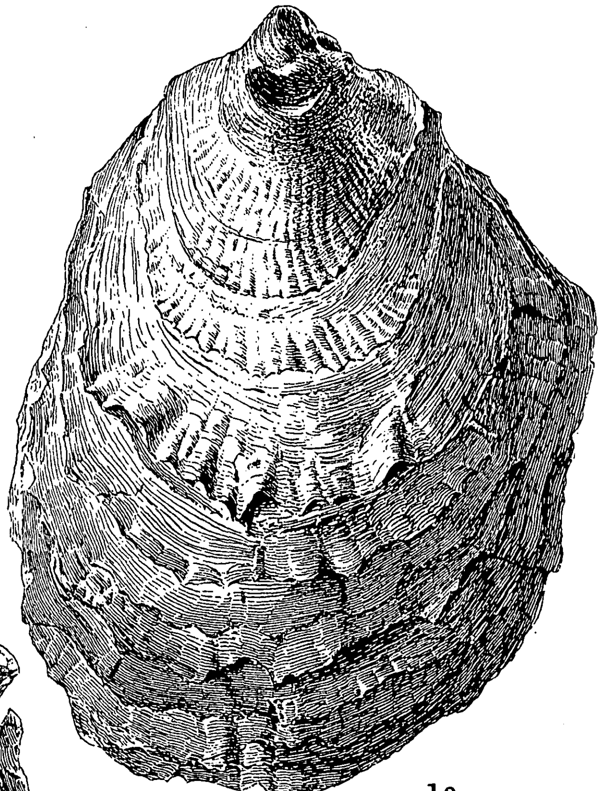

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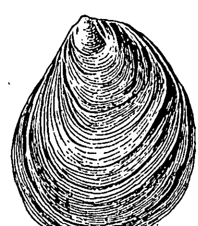


2a

2b

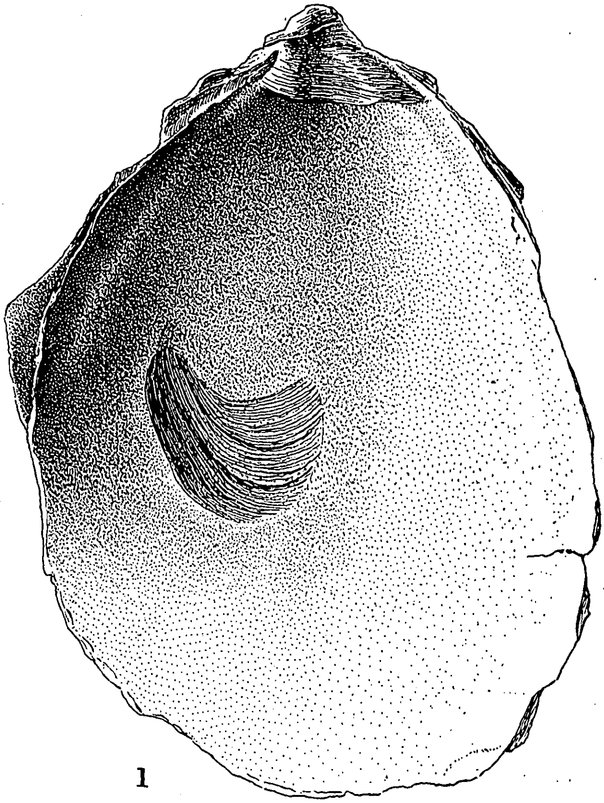
2c

1-2. OSTREA COMPRESSIROSTRA Say.

3. OSTREA sp.

PLATE XXXIX.

PLATE XXXIX.



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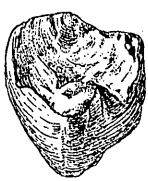

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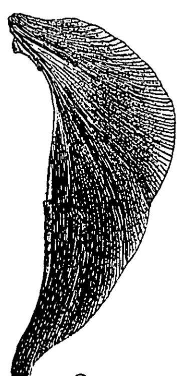

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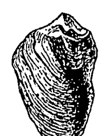

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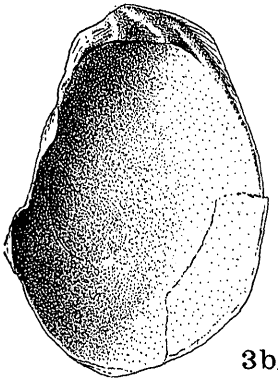

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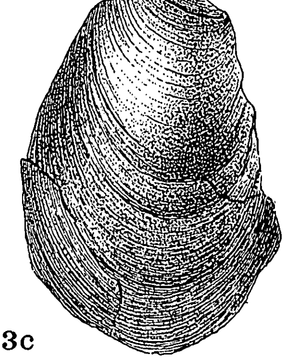


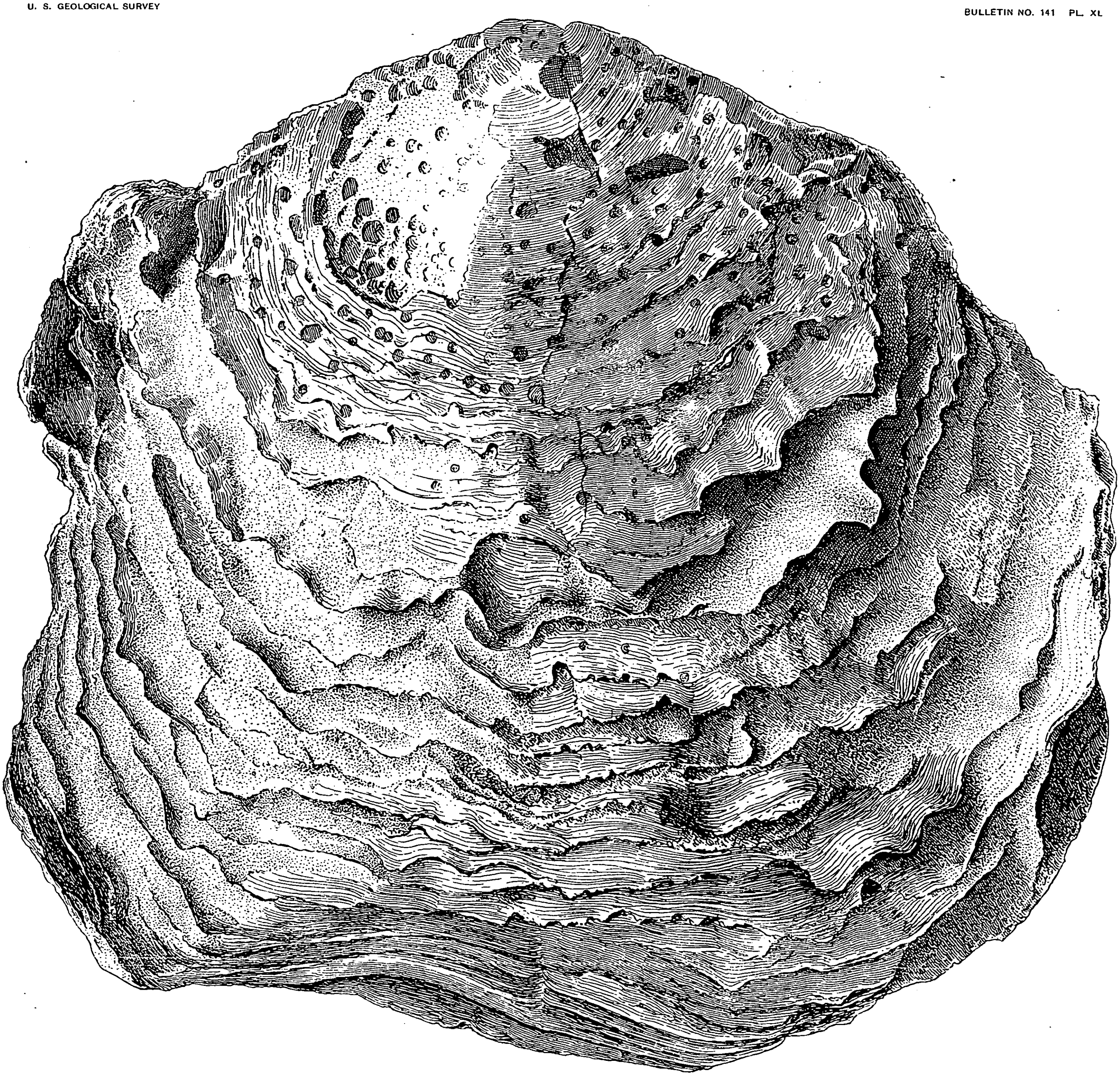
3c

1-2. OSTREA COMPRESSIROSTRA Say.

3. OSTREA sp.

PLATE XL.

PLATE XL.



OSTREA COMPRESSIROSTRA Say.

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[Descriptions or figures of fossils appear at pages indicated by italic numbers.]

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