BULLETIN 52
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The Stratigraphy, Fauna and Correlation of the Vincentown Formation

by

Katherine Fielding Greacen

DEPARTMENT OF
CONSERVATION AND DEVELOPMENT
STATE OF NEW JERSEY

Charles P. Wilber, Director and Chief of the Division of Forests and Parks

Meredith E. Johnson, Chief of the Division of Geology and Topography

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BOARD OF CONSERVATION AND DEVELOPMENT

State House Annex, Trenton, N. J.

LETTER OF TRANSMITTAL

March 15, 1941.

Mr. Charles P. Wilber, Director,
Department of Conservation and Development,
Trenton, N. J.

SIR:

One of the most controversial geological problems in New Jersey is that relating to the age and correlation of the two uppermost greensand beds and the intervening sandy formation—the Vincentown—which outcrop in a relatively narrow belt of the Coastal Plain between Salem and Long Branch. Though they have received much study, authorities have differed as to whether they belong in the Upper Cretaceous of late Mesozoic age, or the Eocene (and Paleocene?) of early Tertiary age. It is through the courtesy and cooperation of Dr. A. O. Hayes and Dr. Helgi Johnson of the Department of Geology, Rutgers University, that we are given this opportunity to publish the fine report made by Dr. Greacen while a graduate student at Rutgers and which we believe represents a long step forward in the solution of a particularly knotty problem. The report should be of assistance to the many workers in Tertiary and Cretaceous stratigraphy in the Atlantic and Gulf coastal regions, as well as in the solving of local geologic and ground-water problems.

I take pleasure in recommending the publication of this report as Bulletin 52 of the Geologic Series of the Department of Conservation and Development.

Respectfully yours,

MEREDITH E. JOHNSON,
State Geologist.

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INTRODUCTION AND DISCUSSION OF PREVIOUS WORK

Introduction.—The sediments of the Atlantic Coastal Plain have long been of interest to geologists. In New Jersey, the Vincentown formation is of particular interest because, except for a few thin beds of small areal extent in the Lockatong formation of Triassic age, it includes the only true limestone younger than the Devonian to be found in the State.

Within recent years, interest in the Vincentown has been renewed by the discussion as to its age. It had been considered Cretaceous for many years, until, in 1928, Cooke and Stephenson advanced convincing evidence in favor of the Tertiary as its period of origin. Scientists in general were willing to be convinced, and the United States Geological Survey has adopted the new classification. Canu and Bassler, however, after making an intensive study of the bryozoan fauna of the Vincentown formation, clung to Weller's older classification, averring that the strong resemblance of the bryozoa to those of the Maestrichtian and Danian of Europe led them to believe the Vincentown of uppermost Cretaceous age.

It is the purpose of the present paper to make an analysis of the Cretaceous and Tertiary relationships of the bryozoa of the Vincentown formation, and to weigh their evidence against that of the rest of the fauna, together with such physical evidence as has been obtained.

Acknowledgments.—The author wishes to express her gratitude to the many people who have assisted in the preparation of this report. The members of the Rutgers University Geology Department have all been kind and cooperative. Especial thanks are due Professor Helgi Johnson, director of the work, whose patience and encouragement have been endless, and who has offered many suggestions. Professor Albert O. Hayes has also shown a special interest. The writer is grateful to him for his comments and for his assistance in the field on several occasions.

Many of the localities visited might not have been found if the writer had not had access to the field notes of the Geological Survey of New Jersey. These were made available by Dr. Henry B. Kümmel, State Geologist until 1937. Thanks are also due Mr. Meredith E. Johnson, formerly Assistant State Geologist, and now State Geologist, who supplied well samples from Farmingdale containing a large fauna.

Kindly aid was offered by Dr. Ray S. Bassler, of the United States National Museum. The writer is grateful for the opportunity of studying the bryozoan collections in the Museum. Dr. Lloyd W. Stephenson, of the United States Geological Survey, sent the writer some unpublished information on the *Venericardia* found in the Hornerstown marl.

The author is indebted to many residents of Blackwood, New Jersey, for information and assistance in finding localities. Mr. Samuel Hagerman and Mr. Walter Ward should be mentioned by name, as should Mr. George Macaltioner of Woodstown. These men all pointed out localities that might not have been recognized otherwise.

The writer is grateful also for the assistance of Professor Thurlow Nelson, of the Zoology Department of Rutgers University, in the study of living forms of bryozoa.

Previous work.—The clays and greensand marls of New Jersey were among the first sediments of the Atlantic Coastal Plain to receive serious attention. Peter Kalm[1] of Sweden, studying the area in 1749, was perhaps the first geologist to write down his theories. An article by Dr. Johann David Schopf[2] followed in 1787, based on his studies ten years earlier. It was not until 1809 that an article concerning the New Jersey deposits appeared in English. William Maclure,[3] writing then on the geology of the United States, called the coastal deposits an alluvial formation. This idea of an alluvial origin persisted for nearly twenty years, and is reflected in the writings of H. H. Hayden (1820), Samuel Akerly (1820), Parker Cleveland (1822), and James Pierce (1823),[4] although John Finch in 1824 tried to show that it was "identical and contemporaneous with the newer Secondary and Tertiary formations"[5] of other regions. In spite of following the "alluvial" nomenclature, Pierce recognized the

[1] Kalm, Peter—En Resa til Norra America, Translated by J. R. Foster in J. Pinkerton's Voyages, Vol. 13, 1812.

[2] Schopf, Johann David—Beitrage Zur Mineralogischen Kentniss des Ostlichen Theils von Nord America und seiner Geburge, 1787.

[3] Maclure, William—Observations on the Geology of the United States, American Philosophical Society, Trans. Vol. VI, pp. 411-428, 1809, and n. s. 1, pp. 1-92, 1817.

[4] See bibliography at end of paper.

[5] Finch, John—American Journal of Science, Vol. VII, 1824, pp. 31-43.

fact that the contained fossils were of marine origin. Somewhat earlier, in 1814, S. L. Mitchell, writing in the first volume of the American Mineralogy Journal, described some New Jersey fossils.

By this time, the interest of scientists in these deposits was thoroughly aroused, and articles began to appear regularly on the deposits of the Atlantic Coast and the fossils contained in them. Most of these articles are found in the Journal and Proceedings of the Academy of Natural Sciences of Philadelphia and in the American Journal of Science under the authorship of Samuel G. Morton, T. A. Conrad and other less prolific writers. The publications of the Academy of Natural Sciences and the American Journal of Science were the main vehicles of the time for articles on geology. Conrad wrote chiefly for the latter, but numerous articles by Morton appear in both.

In 1834 a compilation and expansion of Morton's articles on the Cretaceous fossils appeared.[6] It included the first specific descriptions of bryozoa from the limestone. A Tertiary Appendix was added the next year. This was a very comprehensive work for the time, and was the basis of paleontological classification until Whitfield's work appeared more than fifty years later.[7]

For some time it had been an open question as to whether the greensands were the age of the greensands of Europe or the chalk. Vanuxem[8] had already correlated the New Jersey deposits with the later or Upper Cretaceous, but Morton refers to them as Lower Cretaceous,[9] assigning only to the limestone the age of the chalk. Two years later, he followed Vanuxem in recognizing Upper Cretaceous fossils in the New Jersey greensand. At this time, Morton suggested that the limestone might mark a transition between Secondary and Tertiary beds.[10] It was not until 1848 that the idea was advanced by Conrad that the upper layers of greensand might be younger than Cretaceous.[11]

Except for dividing the series into clays and greensands, there had been little attempt to separate the strata of the Coastal Plain until, in

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[6] Morton, Samuel G.—Synopsis of the Organic Remains of the Cretaceous Groups of the United States, Philadelphia, 1834.

[7] Whitfield, Robert P.—Paleontology of New Jersey, U. S. G. S. Vol. 9 and 18, 1886 and 1892.

[8] Vanuxem, Lardner—Remarks on the Characters and Classification of Certain American Rock Formations. Amer. Jour. of Sci., 1828, Vol. 6, pp. 59-71.

[9] Morton, Samuel G.—Synopsis of the Organic Remains of the Ferruginous Sand Formations of the United States. Amer. Jour. Sci. Vol. XVII, No. 2, 1830, p. 290.

[10] Morton, S. G.—On the Analogy between the Marl of New Jersey and the Chalk of Western Europe. Amer. Jour. Sci., Vol XXII, No. 1, pp. 90-95.

[11] Conrad, F. A.—Philadelphia Acad. Nat. Sci. Journal, New Ser., Vol. 1, 1848, p. 129.

1828, Henry D. Rogers[12] differentiated the clays and sands, greensands, limestone, sand and brown sandstone. At the same time he observed the dip toward the east.

In 1834, Governor Peter D. Vroom of New Jersey authorized a geological survey of the State, and commissioned Rogers, State Geologist of Pennsylvania and professor at the University of Pennsylvania, to undertake the work. The fertility of the marl belt was coming to be realized at this time, and it may have had something to do with the interest of the State in authorizing a survey. Of course, this was the time when all the states were beginning their surveys and it was only natural that New Jersey too should take some interest in her geological background and resources.

Professor Rogers' "Preliminary Report on the Geological Survey of the State of New Jersey" was published in 1836. This was a sizable volume, and the "Final Report," which followed in 1840, repeats most of it word for word, having little in addition except for more details about certain localities.

Rogers' reports are remarkably clear as to the geology of the area. Cook, in 1864, called the 1840 report the best of any state at that time. It is true that Rogers had the wrong conception of the relation between the clays and the marls, believing the former to lie on the latter, but he acknowledged the fact that others thought this might not be so.

Although Rogers did not go into the details of classification which are now recognized in New Jersey, he did set forth the main divisions which are those most readily seen. He called these the blue plastic, sandy and micaceous clays, with plant remains; greensand or marl; yellow granular limestone, sometimes siliceous; yellow ferruginous sandstone and conglomerate. The whole thing was called the greensand series. For the Tertiary he recognized a bluish or lead-colored clay with sand and some calcareous marl, and over everything, sand and gravel.[13]

The yellow granular limestone is described by Rogers as having sometimes siliceous thin layers, only a few inches thick, with calcareous earth between. Secondary fossils (Mesozoic) are abundant, he says, as are their casts in the yellow ferruginous sand, which Rogers places above the limestone although he believes the two intimately related.

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12 Rogers, Henry D.—Philadelphia Acad. Nat. Sci. Jour., Vol. 6, 1828, pp. 59-71.

13 Rogers, Henry D.—Report on the Geological Survey of the State of New Jersey, Phila., 1836, pp. 10-12.
Geology of the State of New Jersey, Final Report. Phila., 1840, p. 177.

It seems rather strange that Knapp,[14] writing on the classification of the New Jersey Cretaceous in Weller's Cretaceous Paleontology, should not have mentioned Rogers' work and ideas. Calling Cook's report of 1868 the only comprehensive description of the New Jersey Cretaceous when he began his work in 1894, he points out that Cook placed the yellow sand above the limestone and below the upper marl (although it was mapped with the limestone earlier) and then cites Clark's ideas as to its age—(1) Manasquan, or (2) later, Miocene. It was Knapp and Kümmel who finally definitely placed the yellow sandstone in the Vincentown formation, but Rogers, in 1836, certainly correlated the two when, after describing the sandstone and the limestone separately, he stated, "In point of relative age to the lower fossiliferous portion of the sandy stratum previously described, I conceive the two deposits to have been formed contemporaneously, and to differ in no respect but in the relatively greater or less share of calcareous matter and sand, which the waters precipitated immediately after the deposition of the underlying green marl, had ceased.[15] He was led to this view by finding the northeastern termination of the limestone to be in the same quarter where the calcareous or lower layer of the sandy bed is most prevalent, and by the fact that both lie directly above the marl and are mixtures, in varying proportions, of sand and calcium carbonate, and contain fossils which are closely analogous. There could be little better statement of our present conception of the Vincentown formation. The progressive increase of deposition or precipitation of calcium carbonate towards the southwest is noted.

Rogers was tremendously interested in the value of both the greensand and the limesand or limestone as fertilizers, and went into great detail in both reports to describe how to use the deposits to best advantage. His final report contains sections from many more marl pits than the preliminary report and it is probable that a considerable number of these were opened following his suggestions and enthusiasm for marl in the first report. The marl industry continued to grow until, by the time of Cook's surveys at the beginning of the latter half of the century, it was flourishing. Enthusiasm waxed high for many years as is evidenced by the memories of marl diggers and haulers who are still living, to say nothing of the information contained in reports of the Geological Survey of New Jersey. One has only to look at the tremendous holes dug in various parts of the State to get an idea of

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[14] Knapp, George N.—Cretaceous Paleontology of New Jersey, Geological Survey of N. J., Paleontology Series. Vol. IV, Trenton, 1907, pp. 15-20.

[15] Rogers, Henry D.—op. cit. 1836, p. 39.

the amount of greensand which must have been spread over the farms of New Jersey and neighboring states.

Because there was less of it, one does not hear quite so much about the use of the limesand and limestone for fertilizer, but those who used it claimed it was even better than the marl, and Rogers and later writers agreed that its value was high. A combination of lime and greensand was especially recommended.

While these pits were in operation the opportunity for viewing the beds was at its best, and it is from the records made at that time that we have gained much of our knowledge.

Shortly after the appearance of Rogers' report, Sir Charles Lyell visited America, and among the accounts of his geological excursions is one concerning the Cretaceous strata of New Jersey.[16] He cites the resemblance of the New Jersey beds to the post-Gault of Europe, thus assigning to the whole series the age of the chalk of Europe. He remarks on the great analogy of the fossils, despite the fact that almost all the species are new.

It is interesting in the light of the recent discussion as to the age of the Vincentown formation, to note Lyell's reaction on his first sight of the limestone. Previous writers had all called it Cretaceous, but Lyell confesses to a feeling on first sight that it was Tertiary, with a strong resemblance to the coralline crag of Sudbourne and Suffolk. In support of this idea, he cites among the fossils found along Timber Creek, several forms of Carcharias, not unlike Tertiary ones, and, from Woodstown, the first Procoelian crocodile known earlier than the Eocene. He was led to follow the opinion of earlier workers, however, in calling the beds Cretaceous and pointed out concerning the Carcharias, that in Europe, too, it is hard to tell Cretaceous Squalidae teeth from Tertiary species.

Lyell goes on to express his belief that the limestone should be correlated with the Maestrichtian. In support of this he cites the works of Forbes—relating the New Jersey echinoids to the Upper Cretaceous of Europe—and that of Morton, citing the resemblance of the corals (bryozoa?) to the Maestrichtian. Lyell places the New Jersey beds in the uppermost Cretaceous, discrediting Morton's and Conrad's correlation with the medial Cretaceous. That had been done due to their belief that there was later Cretaceous represented in the white limestone on the Santee Canal in South Carolina and Georgia. Lyell shows that these deposits are Eocene. He calls the beds at Lewis' Creek, South Washington, South Carolina, the same age as

[16] Lyell, Charles—The Cretaceous Strata of New Jersey. Quarterly Journal of the Geological Society of London, Vol. 1, 1845, pp. 55-60.

the New Jersey beds. Most of the fossils cited occur in beds below the Vincentown. The bryozoan *Cellopora tubulata* was described by Lonsdale[17] as occurring in the limestone along Timber Creek, New Jersey, as well as Lewis' Creek, South Carolina, but it is believed by later workers that the New Jersey specimens were identified erroneously and are probably represented by the species *Leiosoecia parvicella* (Gabb and Horn.[18])

Lonsdale, writing on six species of "Polyparia" brought back from Timber Creek by Lyell, notes the resemblance of the five bryozoans and one coral to the Maestrichtian but states also that one bryozoan resembles a Tertiary species.

Writing on the White Limestone and other Eocene formations of Virginia, South Carolina and Georgia, Lyell[19] expresses his views on the Cretaceous-Tertiary boundary of the United States. He believes there is the same chasm between the two as in Europe. He places the South Carolina White Limestone definitely in the Eocene rather than the Cretaceous, and so claims that all species which had been thought common to the Cretaceous and Tertiary are Eocene. Among the fossils in question are the bryozoa of Eutaw, South Carolina. The genera are in many cases the same as those in the Vincentown and the rock itself is much like the Vincentown formation, so that Lyell says it is no wonder that there is confusion of the Tertiary and Secondary deposits of the Atlantic border. The species are different, however. Other workers had thought the South Carolina deposits intermediate between the limestones of New Jersey and the known Eocene, but Lyell says that the former is Cretaceous and the latter Eocene.

After that there seems to have been little doubt that the limestone was Cretaceous, until recent years. It was so called in the reports of the Geological Survey of New Jersey, by Cook, Whitfield, Clark, and others. The bed that remained in doubt was the yellow sand which Rogers had so shrewdly correlated with the limestone. The marl above the limestone offered a problem, also. It includes the Manasquan and Shark River marls.

The first serious students of the bryozoan fauna of the limestone and limesand of New Jersey were William H. Gabb and George H. Horn. Their "Monograph of the Fossil Polyzoa of the Secondary and

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[17] Lonsdale, William—An Account of Six Species of Polyparia from Timber Creek, N. J., Quat. Jour. Geol. Soc. of London, 1845, Vol. 1, pp. 65-75.

[18] Canu, Ferdinand, and Bassler, Ray S.—The Bryozoan Fauna of the Vincentown Limesand. U. S. Nat. Mus. Bul. 165. Wash., 1933, p. 91.

[19] Lyell, Charles—The White Limestone and Other Eocene Formations of Virginia, South Carolina and Georgia, Quart. Jour., Geol. Soc. of London, Vol. 1, 1845, pp. 429-442.

Tertiary Formations of North America"[20] gives descriptions and illustrations of 36 species from Mullica Hill and Timber Creek, New Jersey. Both of these horizons are in the Vincentown. Gabb and Horn had published two preliminary papers on the Bryozoa or Polyzoa, but the Monograph repeats most of the results of the earlier work.[21]

The Geological Survey of New Jersey was organized in 1854 under the directorship of William Kitchell. George H. Cook was placed in charge of the work in the southern part of the State and it is to his writings and work that we are indebted for much of our present knowledge. The Survey published reports in 1855, 1856 and 1857, and then, due to lack of funds, was inactive for several years. It was established again, on a temporary basis, in 1863, but as the years went on, it was made a fairly permanent thing. Reports were published annually. In 1917 the Survey was made a part of the State Department of Conservation and Development and the reports since then have been published by a division of that Department.

Rogers' reports had done much to arouse the interest of the farmers of southern New Jersey in the agricultural value of the marl. In 1854, when Cook began his survey, the marl industry was in full swing and throughout the years of his work it continued to flourish. He had probably a better opportunity to see the strata of that part of the State than anyone else, before or since. He gave the sections seen in many of these pits, and summarized the stratigraphic divisions as:[22]

4. Upper or Third Marl in three layers
   - Bluish-green marl grains mixed with dark clay
   - Almost all sandy, drab clay
   - Green marl and clay
3. Middle or Second Marl in three layers
   - Little marl: mostly broken shells, corals, etc., and a little sand—some limestone. Sand resembles beach sand
   - Marl mixed with numerous soft white shells
   - Marl grains almost free from earth or shells
2. Sand, colored in upper part by greenish earth or clay; and in lower part with oxide of iron.
   - Where firm, full of shell impressions.
1. Lower or First marl—After exposure ash or slate color
   - Micaceous black clay at top, but marl grains and shells take place of clay toward bottom
   - Black pure marl
   - Marl with many shells and much fine powdery Calcium Carbonate, blue or gray.
   - Black pure marl
   - Very sandy layer, with some marl grains.

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[20] Gabb, W. H., and Horn, G. H.—Monograph of the Fossil Polyzoa of the Secondary and Tertiary Formations of North America. Jour. Acad. Nat. Sci., Philadelphia, ser. 2, Vol. 5, pp. 111-178, pls. 19-21, 1862.

[21] Gabb, W. H. and Horn, G. H.—Descriptions of New Cretaceous Corals from New Jersey. Proc. Acad. Nat. Sci., Philadelphia, Vol. 12, pp. 366-367; and Gabb, and Horn—Descriptions of New Species of American Tertiary and Cretaceous Fossils, Journ. Acad. Nat. Sci. Philadelphia, ser. 2, Vol. 4, pp. 375-404.

[22] Cook, George H.—Report on the Geology of the Southern Division, Second Annual Report on the Geol. Surv. of N. J., Trenton, 1856, pp. 57-58.

Cook found the strike of all these beds 56° S.W. or N.E., and the dip S. 34° E., and 30 feet per mile for the first marl, and he assumed that the others were about the same.[23]

Until 1897, when the declining use of marl as a fertilizer was noted, the annual reports on the southern part of the State contained frequent references to the marl pits, recording new ones as they opened, and telling how many tons were dug and shipped from each one. A great deal of space was devoted to chemical analyses and a discussion of the fertilizing properties of the greensand. The limestone too was analyzed. Although fossils were being collected continually, descriptions of them were not given in the annual reports.

In 1868 Cook published his "Geology of New Jersey," a large volume which summarized all that was known of the geology of the State at that time. A list of fossils compiled by Conrad was appended, and a large map showing the main geological divisions of the State accompanied the report. There were also a number of sections across the various strata. These, like his earlier section (1864), showed the proper relationship of the beds, with the clays below the marl and not above as Rogers had thought.

The value of well drilling was recognized in the report of 1883. Records from wells at Ocean Grove and Asbury Park showed a thickening of the middle layer of the upper marl bed and an unconformity of the upper part with the beds below. On this basis, Cook concluded that the upper layer of the upper marl is Eocene, whereas the lower and middle marls are Cretaceous; but he remained in doubt as to the age of the lower and middle layers of the Upper Marl, being certain only that there was an unconformity.[24]

The 1886 report, on the basis chiefly of organic remains, places all but the upper layer of the Upper Marl in the Upper Cretaceous. It is said that the yellow sand bed gradually takes the place of the limestone and is represented some places in Monmouth County by a bit of greenish clay.[25] It is in this report for the first time that the term glauconite is applied to the New Jersey greensands, although the French term "glauconie" had been mentioned by Morton.[26]

Clark in the 1892 report[27] discredited Cook's firm belief in a definite unconformity between the Cretaceous and the Tertiary, or between the

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[23] *Ibid.* pp. 59-60.

[24] Cook, George H.—Geol. Surv. of N. J., Ann. Rep't for 1883, p. 19.

[25] Cook, George H.—Geol. Surv. of N. J., Ann. Rep't for 1886, p. 180.

[26] Morton, Samuel G.—Synopsis of the Organic Remains of the Terrigenous Sand Formations of the United States, Amer. Jour. Sci., Vol. XVII, Jan. 1830, No. 2, pp. 274-295.

[27] Clark, W. B.—Preliminary Report on the Cretaceous and Tertiary Formations of New Jersey. Annual Report of the State Geologist, 1892, pp. 162-217.

Middle Marl and the uppermost layer of the Upper Marl. He says, "A review of the structural and stratigraphic relations of the deposits of the coastal series of New Jersey shows complete conformity from the bottom of the Raritan formation to the top of the Upper Marl Bed, while no wide-reaching dislocations of the strata were observed at any point."[28] He gave the strike of the beds as N. 50° E., almost the same as Cook's N. 56° E., and the dip as 25-30 feet per mile; apparently not recognizing the decrease in the dip of the higher beds, which Cook found to be only 15 feet, although he stated that he believed the dip should be steeper.

William Bullock Clark began his work on the New Jersey Coastal Plain with the report of 1892, in which he called the Upper Marl by the names in current use—Manasquan Marl and Shark River Marl. He included in the Manasquan the yellow sand of Cook (in reality a part of the Vincentown). The name Rancocas was first proposed in 1897 when Clark set forth the following classification:[29]

Eocene	Shark River formation	
Cretaceous	Manasquan formation	
	Rancocas formation	Vincentown limesands Sewell marls
	Monmouth formation	Red Bank sands Navesink marls Mount Laurel sands
	Matawan formation	Hazlet sands Crosswicks clays

The paper included a discussion of the Rancocas-Monmouth contact and offered three possible conclusions: (1) conformability, with the sands of the north being replaced to the south by clays; (2) unconformity, with removal of the upper part of the Monmouth in places; or (3) a combination of thinning and unconformity. If there was an unconformity, it was believed to have been a short one.[30] Clark recognized the fact that the Red Bank sand was not found in the southern part of the State.

The Rancocas beds were traced to Delaware and Maryland. Later, Clark discarded the idea that the formation was present in Maryland.[31]

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[28] *Ibid.* p. 217.

[29] Clark, W. B., Bagg, R. M., and Shattuck, G. B.—Reports on Upper Cretaceous Formations, N. J. Geol. Surv., Ann. Rep. for 1897, p. 174.

[30] *Ibid.* p. 182.

[31] Clark W. B., Berry, E. W., and Gardner, J. A.—Upper Cretaceous. Geol. Surv. of Md. 1916.

The name "Hornerstown marl" was proposed by G. N. Knapp to take the place of Clark's "Sewell marl." He established the Vincentown age of the yellow sand, which was corroborated by the fossils that Weller found.

The formation names now in use in New Jersey are presented in Weller's volume on Cretaceous paleontology. Clark's names are dropped, or rather, given the rank of groups, while the smaller divisions are elevated to formation rank. They are given below,[32] together with the older names used by Cook and Clark:

FORMATION NAMES, NEW JERSEY CRETACEOUS, AFTER:

Cook	*Clark*	*Weller*
Upper Marl (Lower Part)	Manasquan	Manasquan
Middle Marl	Rancocas	Vincentown Hornerstown
Red Sand	Monmouth	Tinton Red Bank
Lower Marl		Navesink Mount Laurel
Clay-Marl series	Matawan	Wenonah Marshalltown Englishtown Woodbury Merchantville
Plastic Clay series	Raritan	Magothy Raritan

Weller found that the fauna of the Hornerstown, Vincentown and Manasquan was quite different from that of the underlying beds, and that it seemed to form a unit which he called the Jerseyan fauna and correlated with the lower Danian or Maestrichtian of Western Europe.[33] It was admitted that comparison of the Hornerstown and Manasquan faunas with foreign ones is not very satisfactory, but the bryozoan fauna of the Vincentown limesand was said to be closely related to similar faunas of the Maestricht. The resemblance is generic rather than specific, but the species were said to be closely allied in the two faunas.

Weller's volume includes a section on Bryozoa by E. O. Ulrich and R. S. Bassler.[34] Sixteen new species are described, as well as the pre-

[32] Weller, Stuart—Cretaceous Paleontology of N. J. Geol. Surv. of N. J., Vol. IV, p. 25, 1907.

[33] *Ibid.*, pp. 179, 184-185.

[34] *Ibid.*, pp. 313-356.

viously known forms. The volumes of the Maryland Geological Survey on the Eocene[35] and the Upper Cretaceous[36] contain descriptions of some bryozoa by Ulrich and Bassler, respectively. These descriptions are approximately the same as those in the New Jersey report.

The entry of the United States into the World War in 1917 caused a revival of interest in the New Jersey greensands because of their percentage of potash. Most of the marl pits had lain idle for 20 years or more. A thorough study of abandoned and operating pits was made by George Rogers Mansfield, of the United States Geological Survey, with the cooperation of the Geological Survey of New Jersey. A number of holes were drilled in order to obtain information about the beds and the work was supplemented by a study of well records.

The results of this study were published by the United States Geological Survey in 1922,[37] and form a valuable aid to any student of the marl series in New Jersey. For this report, the areal geology as worked out by Knapp was placed on topographic maps with a scale of one mile to the inch.

The next important contribution to the stratigraphy of New Jersey and to the knowledge of the Vincentown formation, was the article by Cooke and Stephenson in which they asserted the Eocene age of the Hornerstown, Vincentown and Manasquan formations and correlated them—together with the Shark River marl—with the Pamunkey group of Maryland.[38]

Their correlation follows:

New Jersey			*Maryland*
Shark River Marl; Manasquan marl	Pamunkey group	Nanjemoy formation	Woodstock greensand marl member; Potapaco clay member
Rancocas group: Vincentown sand; Hornerstown marl		Aquia formation	Paspotansa greensand marl member; Piscataway indurated marl member

[35] Ulrich, E. O.—Maryland Geological Survey, Eocene. Vol. 1, pp. 205-222, 1901.

[36] Bassler, Ray Smith—Maryland Geological Survey, Upper Cretaceous, 1916.

[37] Mansfield, George R.—Potash in the Greensands of New Jersey, U. S. Geol. Surv. Bull. 727, Washington, 1922.

[38] Cooke, C. Wythe, and Stephenson, Lloyd W.—The Eocene Age of the Supposed Late Upper Cretaceous Greensands Marls of N. J., Journal of Geol. 1928, Vol. 36, pp. 138-148.

This correlation is based on the lithological similarity of the two series and on the presence of a few identical fossil species. In support of the elevation of the New Jersey beds from the Cretaceous to the Tertiary, the absence of typical Cretaceous species and genera is cited and attention is called to the presence of characteristic Eocene forms, chief among which is a cast identified as *Venericardia* cf. *planicosta* var. *regia* (Conrad), found in the Hornerstown. The total difference of the fauna from the underlying beds is also cited. *Gryphaeostrea vomer* (Morton) is the only species found also in the underlying Cretaceous beds, but it is present also in other Eocene sediments including the Aquia formation of Maryland. The mosasaur bones at the base of the Hornerstown are said to be reworked from the underlying Cretaceous.

The arguments in favor of the Eocene age of the beds in question are convincing and the new classification was accepted by many.

Canu and Bassler, however, in their bulletin on *"The Bryozoan Fauna of the Vincentown Limesand,"* [39] retain the Cretaceous classification and aver once more close similarity of the fauna to that of the Maestrichtian and Danian of Europe. Dr. Bassler's belief in the Cretaceous age of the Vincentown sand has also been expressed personally to the writer. The work of Canu and Bassler on the Vincentown bryozoans constitutes a thorough generic revision of the forms described previously and introduces many new species.

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[39] Canu, Ferdinand, and Bassler, Ray S.—The Bryozoan Fauna of the Vincentown Limesand, U. S. Nat. Mus. Bull. 165, 1933, p. 3.

STRATIGRAPHY

GENERALIZED DESCRIPTION OF WHOLE FORMATION

The Vincentown formation has long been recognized as both a quartzose sand and a calcareous sand or limestone. It has been adequately described by many writers. As the statement by Lewis and Kümmel is concise and brief, it is quoted here:

"The Vincentown sand presents two facies: (1) a calcareous or lime sand, semi-indurated and largely a mass of broken bryozoan, echinoid, coral and other calcareous remains; (2) a glauconitic quartz-sand facies. The two occur in alternating layers, although the former is more common in the basal portion, particularly to the south, while the quartz-sand facies preponderates in Monmouth County. The fauna of the lime-sand facies contains large numbers of bryozoa, echinoids, and foraminifera, while in the siliceous facies elements of the Hornerstown fauna occur in association with forms characteristic of the calcareous facies. Its thickness ranges from 25 to 70 feet, but numerous well borings have shown that it thickens down the dip, that is, toward the southeast. It rests comformably upon the Hornerstown marl and is overlain conformably by the Manasquan marl or overlapped by Miocene (Tertiary) beds. It includes the "lime sand" and "yellow sand" of Cook, the former of which was included by him as a part of the Hornerstown (Middle) marl.[40]

The Vincentown formation lies between two marls, the Hornerstown and the Manasquan, which are lithologically similar to the Navesink. The Hornerstown is characterized by the presence, at its top, of a shell bed several feet thick, composed largely of casts or shells of *Gryphaea dissimilaris* (Weller) and *Terebratula harlani* (Morton).

The Hornerstown marl overlaps the underlying Cretaceous formations so that, below New Egypt, it lies directly on the Navesink, whereas to the north, the two marls are separated by the Red Bank and Tinton sands. This condition of overlap supports the idea that the Mesozoic-Cenozoic boundary may lie beneath the Hornerstown marl.

The Manasquan marl is composed largely of glauconite in the lower portion, but the upper part is a fine sand mixed with greenish-white clay, called the "ash marl." Its fauna shows a recurrence of Hornerstown species, and a number of new forms. The Hornerstown, Vincentown and Manasquan seem to form a unit of which the lime-

40 Lewis, J. Volney, and Kümmel, Henry B. The Geology of New Jersey, Geol. Surv. of New Jersey, Bull. 14, 1915, pp. 68-69.

stone is the shallow water phase, whereas the two marls represent periods of deeper water.

LOCALITIES VISITED IN NEW JERSEY

To obtain a first-hand knowledge of the Vincentown formation, the writer visited as many outcrops as could be found. These include the localities described by Weller[41] and Mansfield,[42] and those recorded in the notes of the Geological Survey of New Jersey. The notes of the Survey were particularly helpful as the sites could easily be located on the map sheets which are a part of the New Jersey Atlas. These notes include practically every accessible place where the Vincentown formation may be seen. Older localities mentioned by Rogers, Cook and Whitfield were sought, but those that are not recorded in the notes of the State Survey could not be found. Indeed, not even at all the places recorded in the Survey notes could the Vincentown be recognized because of a cover of vegetation, slumping of overlying beds, or the lack of fossils and glauconite.

When the formation could be seen it yielded little information as to strike and dip, structure, or conformability with other formations. Exposures are not extensive and because the material is largely unconsolidated, there is a great deal of slumping of higher materials over those below. The beds do not form a positive topographic feature. They are rarely exposed except in stream valleys cutting through the belt.

Most of our information about the relations of the Hornerstown, Vincentown and Manasquan formations was obtained in the days when the marl was being dug and pits were opened along nearly every stream in the area. The banks of these pits have long since slumped down and they are now covered with dense vegetation. In most cases the center of the pit is not only thickly overgrown but is swampy or boggy, or even an actual pond. In the few cases where the floor of the old pit is not wet, it is because it has been filled in. Mansfield,[43] writing of a pit near Sewell, along the east side of Chestnut Run, notes that in 1917 the floor was overgrown with trees 6 inches or more in diameter. They were fully twice that in 1937. Though such rich growth attests to the value of the marl (and the limesand) as fertilizer, it is small help to the geologist seeking exposures. There

[41] Weller, Stuart—Cretaceous Paleontology of New Jersey, Geol. Surv. of N. J., Paleontology, Vol. IV, Trenton, 1907, pp. 161-170.

[42] Mansfield, George Rogers—Potash in the Greensands of New Jersey. U. S. G. S. Bull. 727, 1922.

[43] *Ibid.*, p. 56.

are still a few pits being worked, among them the Permutit Company pit at Birmingham, the Inversand Company pit at Sewell, and the Zeolite Chemical Company's pit at Reeves Station. At these pits it is possible to see the outcropping marl beds. Other information since the decline of the marl industry comes chiefly from records of well borings. This has yielded much information. Digging or boring with an auger is helpful where the Vincentown formation is within a few feet of the surface, but as the writer was not equipped for such work it was necessary to rely on exposures that could be seen, aided by a little digging into beds here or there, and the information obtained by earlier workers under more favorable conditions.

In addition to the yellow quartz sand and the limesand and limestone, several other varieties of the formation have been seen; but they are relatively unimportant, local facies. Among them are the gray sandstone of Woodstown and the reddish sandstone of New Bargain Mills. The sandstone and limestone vary in color from yellow to gray, with a brownish color in some places and a greenish tinge in others.

The places visited by the writer are described briefly below, beginning with the northernmost outcrops and working towards the southwest of the State.

As already noted, the sand is the common phase in Monmouth County. Although early writers mention pieces of limestone washed up on the beach at Long Branch and limey layers have been encountered elsewhere in that area, the writer found no limestone north of a locality between Hornerstown and New Egypt.

The field work north of Hornerstown was the least satisfying. In none of the places visited from Eatontown and Deal southward to Prospertown were any fossils encountered. This is not surprising because for a long time it was believed that the yellow sand was barren of fossils. Weller, however, did obtain a number of typical Vincentown forms from several of the northern localities. The fauna resembles closely that of the Hornerstown, including *Terebratula harlani* (Morton), a species of *Gryphaea*, *Cardium knappi* (Weller), and a number of other genera whose species were not determined. He found only one bryozoan species but it is the most characteristic and widespread of any of the Vincentown forms—*Coscinopleura digitata* (Morton).

Although the writer was unable to find any fossils, the yellow sand was seen about Deal and Eatontown. Weller gave as one of his localities, the base of Gold Hill, one mile southwest of Eatontown. The residents of that place did not seem to know anything about Gold

Hill, but either Sugar Hill or Stony Hill, in the area about one mile southwest of Eatontown, may represent it. The base—and, indeed, almost the entire hill—of both of these is made up of yellow sand. Higher, some layers are cemented by iron oxide, and a great many iron concretions, of all sizes and shapes, but mostly tubular, are found. These are extremely abundant in Stony Hill. Weller mentions these iron-cemented beds and tubular iron concretions in the Vincentown formation, but, as they are a secondary feature found also in later sands of the Coastal Plain, one is hesitant about identifying the Vincentown sand on such a basis. The lack of glauconite grains tends to place this sand in the later Tertiary or Quaternary.

The entire bed exposed in the south bank of the Manasquan River at New Bargain Mills, one and a half miles west of Farmingdale, near West Farms, is cemented by iron oxide, making a reddish-brown sandstone. Weller's account of this site describes the Vincentown sand as well exposed and highly fossiliferous, and with a larger content of glauconite than at Deal or Gold Hill. This description is based on observations made in 1903 or 1904. It says nothing of cementation by iron oxide, which is now general (observed 1936). The rusty sandstone is very crumbly. Even though Weller reported it as very fossiliferous, nothing definite could be detected in the crumbly mass, although a few objects might be very poor remnants of bryozoans or other remains of life. While it seems strange that such a complete change could take place in thirty years—from a fossiliferous, glauconitic sand to an apparently unfossiliferous, rusty, crumbly sandstone—it is entirely possible. The fact that the sand was glauconitic in 1904 lends itself to the idea that water filtering down from above causes an oxidation of the iron which is dissolved and redeposited as a cement. Obliteration of fossils may accompany this process. As long ago as 1836 Rogers noted that this replacement by iron can evidently be very rapid.[44]

Between Deal and Smithburg the Vincentown formation may be recognized here and there as a yellow sand. It is quite glauconitic near Poplar, and at Locust Grove it is somewhat micaceous and sparsely glauconitic. No fossils were observed.

Although difficulty was encountered in finding fossils in this northern part of the area, there is no doubt that very fine Vincentown material exists in certain places. Proof of this is the beautiful sample of material which was lent to the writer by the Geological Survey of New Jersey, and which came from a well in Farmingdale at a depth

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[44] Rogers, Henry D.—Report on the Geology of the State of New Jersey. Philadelphia, 1836, p. 34.

of 65 to 70 feet. It is largely composed of bryozoa, with fragments of pelecypod and echinoderm shells, foraminifera, small pieces of lignite and small pebbles.

A similar layer was encountered at a depth of 150 feet at Cassville, east of Prospertown; but in the vicinity of Prospertown, where the Vincentown sand is mapped at the surface, it is an unfossiliferous sand, hardly distinguishable from the overlying Kirkwood sand, except for the presence of glauconite grains which give it a greenish tinge.

Near New Egypt, the Vincentown formation exists as a loose sand and as a compact rock. At several places there is seen the hard fossiliferous layer which marks the top of the underlying Hornerstown. This is a sandy layer, cemented by iron oxide and crowded with casts of *Gryphaea dissimilaris* (Weller) and *Terebratula harlani* (Morton). The layer is three or four feet thick and lies above a bluish greensand marl—the typical Hornerstown—which extends downward two feet to the water's edge and probably goes much deeper. Above the shell layer is about two feet of marly sand—probably the Vincentown. This exposure is perhaps two miles west of New Egypt and a little to the north. Along the road which runs toward New Egypt, to the east, the same relationships may be seen. Just west of Crosswicks Creek, the shell layer is exposed in the ditch along the south side of the road. North of the road it is exposed in the bank of an abandoned marl pit. It is chiefly the Hornerstown marl which may be seen in the pit but a thin veneer of the overlying sand has fallen down near the true surface of the bank. Above the shell layer to the top of the hill, there is a gray-green, marly sand. This is well exposed to the south of the road, where, in 1936, trees were being cleared away and dragged over the surface. This is all of Vincentown age except for two feet of Pleistocene sand and gravel which occurs at the surface. No fossils were observed. The material resembles to some extent that which is found as a hardened limestone about seven or eight feet below the surface in the center of the village of New Egypt.

This limestone was encountered in digging a well for the Isis Theatre. The writer observed only the fragments of rock which were piled up behind the theatre, as the well (for use in air-conditioning) had been completed at the time of her visit. According to the manager of the theatre, the diggers went through 6 or 7 feet of surface soil and then encountered 6 inches of marl, below which lay the limestone. After digging through 10 feet of the limestone without reaching the bottom a plentiful water supply was found, so the digging was stopped. The limestone is a gray, granular, somewhat glauconitic, calcareous rock, sparsely fossiliferous. Because it is only loosely cemented, it disintegrates rapidly. The breaking-down is accompanied by a whitish efflorescence. There are some long, twisting tubes in the rock which may be due to a pelecypod such as *Polorthus* or *Teredo*, or they may represent worm borings. Casts of a small oyster are fairly common. These are probably *Ostrea bryani* or *Gryphaeostrea vomer*. Foraminifera are numerous, but the writer has done little with them except to recognize *Cristellaria* as the most common type. No bryozoa were observed.

Less than a mile north of this spot, however, in a small stream north of the railroad station, bryozoa and other typical Vincentown fossils are common, preserved in the yellowish color characteristic of the fossils from Vincentown and Timber Creek—the color of Lyell's "straw-colored limestone." The fossils here are found in the banks of the stream and in the stream bed itself, where they have been washed. *Leiosoecia parvicella* (Gabb and Horn) is a common species and other typical bryozoa are present. Also to be found in the stream bed are shells of *Gryphaeostrea vomer* (Morton) and *Serpula rotula* (Morton), echinoid spines and nodosarians.

It seems rather strange that two such different facies of the Vincentown should exist so close to one another. If the gray-greensand of the hill west of Crosswicks Creek is also Vincentown, that adds a third facies within a radius of about two miles. This may probably be explained by assigning each of these places to a different level in the Vincentown formation. The sand just above the shell layer would represent the base—the fossiliferous section must be higher in the stratigraphic section as it lies down the dip to the southeast. Also to the southeast is the limestone from the well. Without accurate measurements of dip, direction and distance from the first locality, it is difficult to say whether this hard rock should be correlated with the unconsolidated sand, or placed above the part with the bryozoa. Considering the fact that in a number of wells the hard, slightly fossiliferous limestone has been encountered at the top of the formation, this probably belongs there. The variations may be due to lentils. Considering the variations in the formation from place to place, it seems reasonable to suppose that the layers are lenticular, and interfingering. Such lentils may be due either to changes in depth, or to other variations. It has been suggested that only the large units mark significant differences in depth, while the smaller units should be attributed to the varying proximity of stream mouths and sediment-bearing currents.[45] It seems reasonable to suppose that the sandy

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[45] Clark. W. B., Berry, E. W., and Gardner, J.—Age of the Middle Atlantic Coast Upper Cretaceous Deposits. Nat. Ac. Sci. Proc., 1916, Vol. 2, 181.

lentils were deposited in the vicinity of stream mouths, while the calcareous ones were deposited in quieter waters. The limestone layers with few fossils are probably an intermediate phase—far enough from the stream mouths for considerable lime to be precipitated, but too near for the clear waters necessary for bryozoan and coral life.

The matter of replacement must also be taken into consideration. Replacement by iron oxide has already been mentioned. It is frequently met in the shell layer at the top of the Hornerstown marl. The common fossils of that layer—*Terebratula harlani* (Morton) and *Gryphaea dissimilaris* (Weller) are found in the irony layers as casts, cemented by or replaced almost entirely by iron oxide. Elsewhere the shell material—calcium carbonate—is preserved. Such shells have been found in the Vincentown formation near New Egypt and south of Harrisonville. Near Barnsboro, however, *Terebratula harlani* shells have been replaced by silica. This might lead one to wonder if silica could not replace the calcium carbonate of the limestone, but no such evidence has come to light. A replacement of that sort would tend to produce a quartzite, probably, or at least a firmly cemented sandstone, but the sandstones are all rather loosely cemented, and no recrystallization has been found. Indeed, it seems rather surprising that the sands in which the silicified shells are found are apparently not cemented at all. Evidently the silica in solution in the ground water was precipitated only in connection with the solution of calcium carbonate.

From New Egypt southward, it is more common to find a part of the Vincentown formation bearing fossils. East of the station at Cookstown, a layer of sandstone cemented by iron oxide and bearing *Pinna rostriformis* (Morton) and bryozoans, lies about one foot above the level of the stream south of the railroad trestle. The layer which is recognizably Vincentown is covered by a yellow-brown sand from above and was found by the writer only after digging, on a second trip to the site.

A little northeast of here, where a small stream flows under the railroad tracks, the Vincentown is represented by a compact, micaceous sand, increasingly glauconitic downward. No fossils are visible.

Mansfield,[46] in 1922, noted limesand and some pieces of limestone with numerous bryozoa, near Pemberton, on the dump pile of a hole dug to a depth of about 10 feet. Some of this Vincentown material was strongly cemented with iron oxide, and much vivianite was found on the dump. Vivianite is not generally found in the Vin-

46 Mansfield, G. R.—op. cit., p. 87.

centown, although it is common in the marls below. A little west of here, near the Birmingham Inn, a layer with well preserved casts of *Terebratula harlani* is found along the edge of the creek. The rock is a brown, cemented sandstone, resembling the Vincentown more than the Hornerstown. Also in Birmingham is the Permutit Company, which operates probably the largest active marl pit in New Jersey. Both the Hornerstown and the Navesink marls are mapped here. Quantities of Hornerstown fossils may be found on the dump piles, and the bones of a crocodile were uncovered on the floor of the pit. It seems probable that the Navesink has not yet been reached, and that the entire 10 feet or more of greensand exposed in the sides of the pit belong to the Hornerstown marl. Seven feet, more or less, of yellow sand and gravel lie above the marl. This is part of the Quaternary Cape May formation. Evidently all the Vincentown has been removed from here, and a part of the Hornerstown has been eroded as shown by what appears to be an ancient stream bed in the green sand, filled with cross-bedded yellow sand.

The type locality of the Vincentown formation is the village from which it takes its name. Long before the formation name was given it was customary to compare the limestone or sand and its fauna with the limestone found at Vincentown. Although the rock does crop out along the banks of Rancocas Creek, it is not readily accessible because of slumping of the overlying reddish-brown sand. Small fragments of hard fossiliferous limestone are not uncommon, but only one good exposure of the limestone in place was seen. This was near Stokes Seed Plant on the north bank of Rancocas Creek where a small cut had been made for a waste pipe. The entire bed is not exposed, but a thickness of about 1½ to 2 feet is visible above the water's edge. This is a massive, indurated layer of grayish limestone, filled with bryozoa. It is possible to see similar layers of limestone under the water in one or two places, but it can not be said definitely that they are not merely large pieces buried in the river silt. Good-sized pieces can be taken from the bottom of the stream. This has been done at the site of a Boy Scout camp on Rancocas Creek. Between the camp and the Seed Company, loose bryozoa may be picked up on almost all the bars that have been deposited by the stream. This offers proof of the presence of the fossiliferous sand somewhere upstream. The sand may be seen in the hill across the road from the entrance to the Boy Scout Camp.

The best exposure of the Vincentown limesand in this vicinity is along Little Creek, west of Lippincott's Corner. Alternating with the sands are layers of limestone. Both sand and stone hold myriads of fragments of bryozoa and other fossils. Bryozoans which have been washed from the beds are scattered over the entire flood plain of the brook.

This sandy, limey facies of the Vincentown underlies an area over a mile wide in this vicinity, but it is usually covered by several feet of soil and humus and often by Pleistocene sands and gravels, so that the records of wells and old pits must be relied on for definite information. A few bryozoa were found along Sharps Run, north of Medford, but the rock from which they came was not seen.

Timber Creek is one of the classic localities of the Vincentown limestone. As Timber Creek has many branches which traverse the area underlain by the Vincentown, it is difficult to tell just where the section described by Lyell would be. The sand facies is also present in this area. The sandy variety may be observed along a small tributary to the North Branch of Timber Creek, between Clementon and Garden Lake. The sand has a sprinkling of glauconite, and is quite clayey. The fossils include some bryozoa but are mainly casts of pelecypods and gastropods. The casts are pinkish in color.

Other towns where the Vincentown is or has been found in the Timber Creek area are Laurel Springs, Brownsville and Blackwood. There are some poor outcrops east of Blackwood on the grounds of Lakeland, the Camden County Almshouse and Asylum. The limestone is straw-colored and full of bryozoa.

A few miles to the south, near Hurffville, the gray, sandy, sparsely fossiliferous variety of the Vincentown limestone is found. West of Barnsboro the Vincentown is a yellow sand with the *Terebratula harlani* bed separating it from the underlying Hornerstown marl. As is the case near New Egypt, the several varieties of the Vincentown formation—limestone, sand, and marly rock—occur within a small radius.

The limestone was reported from Mullica Hill, along Raccoon Creek, by Rogers and Cook, but it cannot be seen today. All that can be found now near Harrisonville are some pieces of gray limestone and some fragmentary shells of *Terebratula harlani* and *Gryphaea dissimilaris*.

Limesand and arenaceous limestone occur just under the surface at Woodstown and nearby. They were dug extensively formerly, as was the marl in this vicinity.

The thickest outcrop of limestone recorded was that of William Barber, who quarried the stone about 70 years ago along Swedes Run in Mannington Township.[47] Twenty-five feet of alternating lime-

[47] Cook, George H.—The Geology of N. J. Trenton, 1868, p. 272.

stone and limesand beds could be seen. Nothing of this is visible now except for some limestone boulders in the bed of the run. There are many bryozoa, echinoid spines and *Ostrea bryani* in the Rutgers Geological Museum that must have come from this vicinity. Their locality is given merely as Mannington, a township that covers a large area.

Well records have added considerably to the knowledge of Vincentown stratigraphy and a number of these will be included in the section on detailed stratigraphy.

DESCRIPTION OF SIMILAR BEDS IN DELAWARE

The writer has not studied personally the Rancocas formation in Delaware, but as it lies in the "critical" belt between the New Jersey deposits and the Pamunkey group of Maryland and contains a fauna resembling both though differing from each in certain respects, a brief description of it is given here.

South of Delaware River the limestone and marl are interbedded so that it is impossible to draw a line between the Hornerstown and Vincentown formations. The Rancocas group of New Jersey becomes the Rancocas formation in Delaware. It is described as a dark greensand marl in places, but in general there is less glauconite than in New Jersey. The marl is reddish-gray sometimes, partly because of weathering. *Terebratula harlani* (Morton) is a common fossil and ranges up into the higher limestones instead of being restricted to the lower part, as in New Jersey. Bryozoa are numerous, and other fossils found are *Serpula trigonalis*, echinoid spines, pelecypod casts and fish teeth and bones. The thickness of the formation ranges from 20 feet or less along the outcrop, near Odessa, to 61 feet at a depth of 110 feet near Middletown.[48]

The fauna, though obviously related to that of New Jersey, shows considerable differences. Thirty species of bryozoa have been found in Delaware and almost all of them are also found in New Jersey. The pelecypods characteristic of the formation in New Jersey, however, are absent, with the exception of *Gryphaeostrea vomer*, whereas the most characteristic Delaware species, a small *Gryphaea* is not found in New Jersey. The bryozoa encrust these shells. It is suggested that the Rancocas formation of Delaware represents a fossil oyster bank where the ensemble of life was, as today, very different from the fauna

[48] Clark, W. B., Bagg, R., and Shattuck, G. B.—Upper Cretaceous Formations of New Jersey, Delaware and Maryland. Geol. Soc. of Amer. Bul., Vol. 8, pp. 315-318, 1897; and

Miller, B. L.—Geology of the Dover Quadrangle, U. S. Geol. Surv. Atlas, Folio 137, Washington, 1906.

a short distance away. The localized inshore assemblage is characterized through both the Rancocas and Manasquan stages by the pelecypods *Yoldia noxontownensis* and *Phacoides noxontownensis*.[49]

DETAILED DESCRIPTION OF SECTIONS

1. Weller's locality 122. "In a road-cutting at Deal, just north of Whale Pond Brook, in a slight elevation known locally as California Hill, an excellent exposure of the "yellow sand" may be seen which is abundantly fossiliferous. This exposure is near the summit of the Vincentown formation, since the Manasquan marl occurs only a short distance south, down the dip."[50] In 1936, no fossils were found here, but Weller recognized:

BRACHIOPODA

Terebratula harlani Morton

PELECYPODA

Nemodon sp.
Cucullaea sp.
Axinea sp.
Ostrea sp.
Cardita sp.
Cardium knappi Weller
Caryatis sp.
Tellina sp.

2. Cook reported 14 feet of the "layer with broken shells, corals, etc." in Mr. Pitcher's pit, near Long Branch, without reaching bottom.[51]

3. At Turtle Mill, between Eatontown and Long Branch, he reported that the limesand and part of the shell layer were dug into for 8 to 10 feet.[52]

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[49] Clark, W. B., Berry, E. W., and Gardner, J. A.—Upper Cretaceous, Geol. Surv. of Maryland, 1916, p. 75.

[50] Weller, Stuart, *Cretaceous Paleontology of New Jersey* Geological Survey of N. J., Vol. IV, Paleontology, Trenton, 1907, p. 162.

[51] Cook, George H., Second Annual Report of the State Geologist for the Year 1855, Geol. Surv. of N. J., Trenton, 1856, p. 64.

[52] Cook, George H., Geology of New Jersey, Trenton, 1868, p. 270.

4. Weller's Locality 111. "One mile southwest of Eatontown, at an exposure in the base of Gold Hill, this sand is abundantly fossiliferous, the following species being recognized.

ECHINODERMATA
Spines of Echinoids

BRYOZOA
Coscinopleura digitata Morton

BRACHIOPODA
Terebratula harlani Morton

PELECYPODA
Gryphaea sp."[53]

The writer found no fossils in 1936, although it is possible that the right locality was not found.

5. Two wells at South Elberon, north of Deal Beach, are reported to show 110 feet of Vincentown at a depth between 90 and 200 feet. The lower 70 feet is a quartz and limesand with some limerock and numerous shells, and the upper 40 feet is a quartz sand with some marl grains.[54]

6. At Asbury Park, wells show only 40 feet of the Vincentown, which is there a whitish clay with a thin layer of bryozoan limesand.[a] The formation is at a depth of 200 to 240 feet.[55] The overlying Manasquan marl here is 50 feet thicker than at South Elberon, whereas the Vincentown shows a decrease of 70 feet. The Hornerstown marl becomes thinner also, having a thickness of 100 feet at South Elberon, but only 40 feet at Asbury Park.

7. At Ocean Grove, a well shows the same thinning of the Hornerstown and Vincentown, accompanied by a slight decrease in the thickness of the Manasquan. The record shows:

Manasquan	104 feet between 113 and 227 feet
Vincentown	37 feet between 227 and 264 feet
Hornerstown	20 feet between 264 and 284 feet

[53] Weller, Stuart, op. cit., p. 162.

[54] Mansfield, George Rogers, Potash in Greensands of N. J. U. S. G. S. Bull. 727, 1922, p. 100.

[a] In a well recently drilled at the Keystone Laundry from which an excellent set of samples was preserved, the Vincentown was found to consist of 146 feet of glauconitic, clayey and fossiliferous sand.—Meredith E. Johnson.

[55] *Ibid.*, p. 100.

The Vincentown formation here resembles that found in the Asbury Park wells, being a clay with much greensand, with bryozoa, echinoid species and foraminifera at 261 feet to 264 feet.[56]

8. At Sea Girt, the Vincentown formation is represented by a 50-foot bed of gray marl at a depth of 400 to 450 feet.[57]

9. Well records at Lakewood report the Vincentown at a depth of 355 to 370 feet, with 10 feet of greensand below 5 feet of dark clay. Above the clay is a bed of greensand 75 feet thick, and above that lie 110 feet assigned to the Manasquan. Mansfield thinks it possible that some of the greensand should be ascribed to the Vincentown.[58]

10. A well (Well No. 5) drilled in Mantoloking on Bay Avenue near Arnold Street in April and May, 1931, for the Ocean County Water Company by the Artesian Well Drilling Company, yielded a sample of Manasquan marl at 300 feet. A white hardpan-like limestone and soft marl—probably Vincentown—were encountered at 450 feet. The very hard sand sampled at 410 feet and the clay and marl at 448 feet may also belong to the Vincentown. A little south of here at Normandy Beach, the same company was drilling another well in June, 1937, for the Ocean County Water Company. The gray, hardpan-like rock encountered between 478 and 541 feet probably represents the Vincentown.

11. Weller's locality 134—"In the south bank of the Manasquan River at New Bargain Mills, 1.5 miles west of Farmingdale, near West Farms,"[59] Weller found a glauconitic, fossiliferous sand containing:

ECHINODERMATA

Salenia sp.
Cardiaster cinctus Morton

BRYOZOA

Coscinopleura digitata Morton

PELECYPODA

Nemodon sp.
Gryphaeostrea vomer Morton
Cardium knappi Weller

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[56] *Ibid.*, p. 101.
[57] *Ibid.*, p. 102.
[58] *Ibid.*, pp. 102-103.
[59] Weller, Stuart, op. cit., pp. 162-163.

In August, 1937, the only rocks along this stream were red, crumbly sandstone, very much rusted and rotten. No fossils could be definitely identified, although it is possible that there were some.

12. Locust Grove. A yellow, glauconitic, micaceous sand was seen here. Although no fossils were observed, this loose sand is very probably a part of the Vincentown. Southward from here, near Poplar, the sand becomes more glauconitic, probably grading into the Manasquan marl. The greensand may be seen along the highway.

13. Rogers reported an exposure on the east side of Crosswicks Creek, one mile southeast of Varminton on the road from Sholltown, on the property of James S. Lawrence.[60] He noted "a calcareous sandy stratum above the marl where the banks of the meadow are high." The sand is yellow, with some marl and many solid casts "some of which do not show themselves in the green marl beneath." This sounds as if it might represent the Vincentown and the Hornerstown, with perhaps the Navesink marl below. The casts are described as being of calcium carbonate in an earthy state, mixed with a little clay and sand. The fossils noted include coprolites, crocodile bones, crocodile teeth, bivalves and univalves, solid internal casts of crab claws, and two species of *Baculites*. Except for the last of these the beds might well be the Hornerstown and Vincentown. Except for a *Baculites* that Whitfield found in the Academy of Natural Sciences of Philadelphia, marked "Vincentown, N. J.,"[61] it is the only mention I have ever seen of any ammonite in New Jersey above the Navesink marl, and for that reason the marl described may be Navesink rather than Hornerstown. Rogers repeats this statement in his Final Report.[62] In the latter he says that Lawrence's is near Varmington. Varmington is shown on the geologic map accompanying the report as a cross-roads 2½ miles west of Prospertown.

14. The area northeast of Prospertown is considered to be underlain by the Vincentown sand. It is frequently difficult to recognize, however, because of a general covering by the Kirkwood sand, derived in part from the Vincentown. The writer visited the place and observed a yellowish greensand along the side of the road in a recent cut near the Lahaway Plantations. The sand contains some concretions of iron oxide. In the grounds of the Lahaway Plantations a yellow, ironstained sand was found under a thin covering of very white sand.

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[60] Rogers, Henry D., *Report on the Geological Survey of the State of New Jersey*, Philadelphia, 1836, p. 68.

[61] Whitfield, R. P., *Paleontology of New Jersey*, Vol. 2, 1892.

[62] Rogers, Henry D., *Geology of the State of New Jersey*—Final Report, Philadelphia, 1840, p. 261.

Whether these are both a part of the Kirkwood, or whether the yellow sand is a part of the Vincentown is uncertain. There did not seem to be any grains of glauconite. Most of my information about the presence of the Vincentown near Prospertown comes from the unpublished notes of the Geological Survey of New Jersey. Their notation of March 5, 1937, for a trenching by a W.P.A. archaeological crew northeast of Prospertown, records:

a. Fine to coarse sand—probably Kirkwood derived from Vincentown, at a surface elevation of 135 feet—2 feet.
b. Greenish, clayey sand—Vincentown.

Another survey note states that the Vincentown may be found 4 to 6 feet below the surface where the ground slopes to Sugar Loaf Hill, an outlier of the Kirkwood sand.

A well drilled at Cassville, east of Prospertown, for the Perron Oil and Gas Company in 1915, encountered the Vincentown at a depth of 150 feet. It was a hard, white limestone, 1 to 2 feet thick, and full of bryozoa.

15. Near New Egypt it is easier to find fossiliferous parts of the Vincentown formation. Rogers mentioned a one-foot stratum of limestone at Snuff Mill on a small tributary to Crosswicks Creek about one mile north of New Egypt.[63] The layer contained the same bryozoa, "alcyonia and shells" as where the limestone is thicker. This might possibly be the same as Weller's locality 143. Here, in the banks of a small stream west of the railroad track a little more than one-half mile northeast of the New Egypt station, are found the following fossils, according to Weller:[64]

ANTHOZOA
Undetermined coral

ECHINODERMATA
Echinoid spines, several species

BRYOZOA
Undetermined species

PELECYPODA
Gryphaea sp.
Gryphaeostrea vomer Morton
Periplomya sp.

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[63] *Ibid.*, p. 262, and Rogers, op. cit. 1836, p. 72.
[64] Weller, op. cit., p. 164.

Tenea sp.
Cardium knappi Weller
Caryatis veta Whitfield
Kummelia americana Gabb

GASTROPODA

Several undetermined species

The present writer found the following species at this locality:

FORAMINIFERA

Nodosaria sp.

ECHINODERMATA

Echinoid spines

ANNELIDA

Serpula rotula Morton

BRYOZOA

Idmonea abbotti Gabb and Horn
Leiosoecia parvicella Gabb and Horn
Eurilina torta Gabb and Horn
Cranosina altimuralis Ulrich and Bassler
Pliophloea sagena Morton
Crassimarginatella intermedia (?) Canu and Bassler
Stichocados mucronatus Canu and Bassler

PELECYPODA

Gryphaeostrea vomer Morton

16. Somewhat west of this spot, on the other side of Crosswicks Creek, is Weller's locality 146.[65] Weller reported a yellow sand resembling the eastern exposures of the Vincentown, yielding *Terebratula harlani* Morton and *Gryphaea* sp. It is believed that the shell bed is the top of the Hornerstown marl, with the Vincentown sand lying above. The following section is given:

	Feet
Vincentown	
Gray quartz and marly sand	12
Hornerstown	
Black marl, full of casts	6
Greensand with yellowish pebbles	6
Black massive greensand	6

65 *Ibid.*, p. 163.

This section may be seen in an old pit north of the road. The shell layer of the Hornerstown is also exposed in the ditch on the south side of the road, and above it lies perhaps 20 feet or more of the gray-green marly sand which is probably the Vincentown, though no fossils could be found.

17. On the north side of this same road, near Jacobstown, there is a good exposure of the shell bed in a small brook. It is so hard that it forms a ledge for a small waterfall. The section follows:

	Feet
Marly sand (probably Vincentown)	±2
Hornerstown shell layer..............................	3 to 4
Hornerstown bluish greensand marl....................	2

Some doubt has been raised as to whether the shell bed is a part of the Hornerstown or the Vincentown. Mansfield calls it definitely Hornerstown at this locality.[66]

18. The limestone and underlying *Terebratula harlani* bed are exposed also along Crosswicks Creek, near New Egypt, and a little farther upstream the broken shells of *Terebratula harlani* have been established as being in situ. So it is assumed that shells of the former bed are also in place although the bed is somewhat higher.

According to notes in the office of the State Survey, Britton, in 1884, found the following section at Horner's pits on Crosswicks Creek:

	Feet	*Inches*
Loam and humus	1	....
Yellow marl	0	5
Limestone	0	6 to 12
Terebratula bed	3	...
Gryphaea bed	2	....
Black marl	6	....

At the second place the *Terebratula* bed was found to be 3 feet thick also but only one foot above the level of the creek. The Vincentown formation was found as gray masses about 5 feet higher.

19. The record of a well at New Egypt does not differentiate the formations from the Vincentown to the Navesink, grouping 112 feet of marl.[67]

A well dug in 1937 to a depth of 20 feet behind the Isis Theatre at New Egypt, struck limestone at about 7 feet. The section was approximately as follows:

	Feet	*Inches*
Surface soil, etc.................	6–7	....
Marl	0	6
Limestone	10	....

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[66] Mansfield, op. cit., p. 92.
[67] *Ibid.*, p. 93.

This massive, crumbly limestone contains many foraminifera and a small number of larger fossils including casts of a small oyster and long tubes of some boring animal. The surface soil around New Egypt consists in part of a reddish-yellow sand. This may be derived from the Vincentown by weathering, or it may be of more recent origin.

20. Weller's locality 151.[68] This exposure of the Vincentown limesand, just south of the railroad trestle east of the station at Cookstown, was found with difficulty as it is now buried under sand which has fallen from the top of the cliff. The exposure, down to the level of the stream, is approximately:

	Feet
Yellow sand (white on top) (Kirkwood?)	5
Greensand marl, mottled with red	3
Fossiliferous layer, cemented by iron oxide	1
Greensand	1

The hard, fossiliferous layer, which crumbles easily, is packed with poorly preserved fragments of *Pinna rostriformis* Morton. Bryozoa are also present according to Weller. On the other side of the tracks, about one-half mile nearer New Egypt, the Vincentown is a compact, micaceous sand. According to the notes of the State Survey, it contains about 33 per cent glauconite just above the level of the stream. It is overlain by 5 feet of relatively clean quartz sand, presumably later than the Vincentown.

21. Near Wrightstown the Vincentown has been found in a well as a hard, concrete sandstone (limestone?), 10 feet thick, at a depth between 20 and 30 feet. Somewhat west of here, two other wells encountered 101 feet of marl above a bed containing characteristic Navesink forms (*Exogyra, Belemnitella*). Mansfield states that Dr. Kümmel thinks that some of that thickness represents the Vincentown sand.[69]

22. In the vicinity of Pemberton, the sand facies of the Vincentown has been found. Rogers mentioned the yellow sand in connection with a large mass of "retinasphaltum" found above the marl, one and a half miles from Pemberton and north of the road to Lisbon[70] (New Lisbon). Cook also noted the sand which was dug for marl at the time of his writing.[71] Mansfield noted a well sunk at North Pemberton, in which the Vincentown exists only as a greensand marl inseparable from the Manasquan. This greensand goes down to a depth of 80 feet.[72]

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[68] Weller, op. cit., p. 164.
[69] Mansfield, op. cit., p. 91.
[70] Rogers, op. cit. 1836, p. 74.
[71] Cook, George H., The Geology of New Jersey. Trenton, 1868.
[72] Mansfield, op. cit., p. 89.

23. Less than two miles from here, at Birmingham, the limey facies of the Vincentown with its characteristic fossils has been found, although little more can be said than that it was observed on the dump of one of the Norcross and Edmunds Company pits.[73] Limesand and some pieces of limestone were found here, and bryozoa were very numerous. This Vincentown material had come from a hole about 10 feet deep. The dump contained also much vivianite from the hole. This is Mansfield's locality 99. The notes of the State Survey state that the bryozoa came from a shallow pit at the bottom of a larger one.

South of the abandoned Birmingham Inn, there is an outcrop along Rancocas Creek of quite a hard brown sandstone bearing casts of *Terebratula harlani.* About half a mile northwest of here, in the pit of the Permutit Company, the Hornerstown marl is apparently overlapped by Pleistocene sand and gravel, as no Vincentown is evident in the exposure. Seven feet or more of this yellow sand and gravel lie above at least 10 feet of greensand. The Hornerstown marl is here 70 feet thick, according to Theodore W. Bozarth, of which 18 feet is above the ground-water level. Numerous fossils typical of the Hornerstown have been found here, including the following:

ANTHOZOA
- *Trochocyathus conoides* Gabb and Horn
- *Flabellum mortoni* Vaughan
- Unidentified species.

BRACHIOPODA
- *Terebratulina atlantica* Gabb

PELECYPODA
- *Cucullaea* cf. *antrosa* Morton
- *Ostrea bryani* Gabb
- *Polorthus tibialis* Morton (?)
- Tubes in wood (not sand) may be *Teredo*
- *Diceras* sp. (?)

GASTROPODA
- Unidentified species

PISCES
- Sharks teeth and plates

REPTILIA
- Crocodile bones

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[73] Mansfield, op. cit., p. 87.

24. The type locality of the Vincentown limestone is the village of that name in Burlington County. Though no good sections remain there are many places where the limestone or the limesand may be seen with the typical assemblage of bryozoans, echinoid plates and spines, and fragments of other fossils. The general section, as found by Britton in 1884 and assumed probably to be located in the old pit of Mrs. M. A. Burr, is as follows:

	Feet	*Inches*
Brown sand and humus	0	6
Yellow and white sand and greensand	2–4	..
Rich red sand	0	6
Limesand, cemented in places, full of "Eschara"	7–9	..
Limestone	10–20	..

The limesand and limestone may be seen outcropping all along the South Branch of Rancocas Creek and its tributary, Jade Run, west of the main road into Vincentown. Although actual outcrops are rather scarce, it is quite common to find loose bryozoa on the bars deposited by the stream. Fragments of hard limestone are also encountered frequently both in the creek and along its sides.

A section similar to that described by Britton may be seen in the north bank of Jade Run where Stokes Seed Plant has cut a place for a waste pipe. There are 2 or 3 feet of limestone exposed above the water's edge, with red sand lying above, then yellow and white sand, and a covering over all of brown sand and humus. The limestone here is massive and gray, weathering yellow. It is crowded with bryozoa and other small fossils.

Some distance down the South Branch of Rancocas Creek, south of the road to Eayrestown, there is an exposure in the side of the hill, 150 feet or so south of the stream, of a white, somewhat glauconitic sand in which numerous loose bryozoans may be found. The bed of the creek here contains numerous fragments of limestone. It is possible that the sand on the hill may be of later origin than the Vincentown and that the bryozoans have been reworked. This idea is supported by the presence in the sand of very small, somewhat rounded lumps of limestone.

Just a short distance from here a well described by Mansfield [74] went through the following beds:

[74] Mansfield, op. cit., p. 82.

Record of Well of William J. Irick, about 1 mile west of Vincentown (Elevation 30 feet. A. G. Dunphey, driller).[75]

	Thickness Feet	*Depth Feet*	*Formation*
Yellow gravel	3	3	Quaternary
Orange-colored sand and fine gravel	6	9	
Yellowish sand with a few greensand grains	9	18	Vincentown
Yellowish limesand with plentiful bryozoa	7	25	
Ash-colored limesand with very few bryozoa	19	44	
Grayish greensand with numerous foraminifera (bryozoa wanting)	5	49	
Dark greensand with *Terebratula harlani* and *Gryphaea*	1	50	
Lighter-colored greensand; no fossils	20	70	
Very dark colored greensand	31	101	Hornerstown and Navesink
Grayish greensand with fossils, including *Gryphaea* and *Belemnitella*.	3	104	
Grayish greensand with belemnites	5	109	Mount Laurel (?)

As this well is less than one mile from the exposure seen by the writer, and as the bed of sand seen was at an elevation nearer 15 or 20 feet than 30, it seems probable that the sand is not Quaternary, despite the small limestone pebbles, but that it is one of the upper beds of the Vincentown. The pebbles may have come from a lower bed of the same formation, but the bryozoa are more likely in situ.

According to Rogers, there were only two thin layers of limestone along the Rancocas, only 6 to 8 inches thick and separated by 18 inches of sand.[76] It is evident that he did not see the whole exposure. Cook noted the succession of beds along the South Branch of Rancocas Creek between Vincentown and Eayrestown when many pits were in operation, those nearest Vincentown yielding the limesand and yellow limestone and those downstream being dug in the shell layers; whereas the green marl (Hornerstown) was the topmost bed exposed nearest Eayrestown. The same order of layers could be seen at that time along Haines Creek between Medford and Eayrestown.

The fauna from Vincentown has been studied more thoroughly than that from any other place where the limestone or limesand is found. Weller[77] gives a long list of foraminifera and bryozoa from here, with smaller numbers of other fossils. There follows Weller's

75 New Jersey Geol. Survey. Ann. Rept. for 1901 p. 71.

76 Cook, G. H., The Geology of New Jersey, 1868.

77 Weller, Stuart, op. cit., pp. 165-168.

list of species found at Vincentown, exclusive of foraminifera and bryozoa. A list of bryozoa will be found in a later section.

ECHINODERMATA
- *Rhizocrinus cylindricus* Weller
- *Goniaster mammillata* Gabb
- *Cidaris splendens* Morton
- *Pseudodiadema diatretum* Morton
- *Cardiaster cinctus* Morton
- *Pentacrinus bryani* Gabb
- *Pentaceros asperulus* Clark
- *Salenia tumidula* Clark
- *Trematopygus crucifer* Morton
- *Ananchytes ovalis* Clark
- *Hemiaster ungula* Morton
- *Linthia tumidula* Clark

ANNELIDA
- *Serpula rotula* Morton

BRACHIOPODA
- *Cistella beecheri* Clark
- *Platidia cretacea* Weller

PELECYPODA
- *Gryphaea sp.*
- *Gryphaeostrea vomer* Morton
- *Polorthus tibialis* Morton

GASTROPODA
- *Pleurotrema solariformis* Whitfield

CRUSTACEA
- *Callianassa sp.*

The writer has also found the pelecypod *Kummelia americana* Gabb at Vincentown. Weller's long list of Vincentown foraminifera is not given because there has since been considerable revision of the species and genera which has not been consulted in the present study. The most common genera represented are *Nodosaria, Globigerina, Textularia, Cristellaria, Frondicularia, Flabellina, Vitrewebbina,* and *Polymorphina*. The last named genus is a typically Tertiary form according to Galloway and Morrey.[78]

[78] Galloway, J. J. and Morrey, Margaret, *Late Cretaceous Formaninifera from Tabasco, Mexico,* Journal of Paleontology, Vol. 5, No. 43, pp. 329-330, 1931.

The records of two other wells near Vincentown should be cited. That of Richard Ridgeway, about 1.75 miles south of Vincentown [79] at an elevation of about 40 feet, encountered a dark-green marl after going through 12 feet of low, soggy ground (Quaternary). There are 20 feet of dark marl and 70 feet of light-green marl above the top of the Hornerstown at 112 feet. The 70 feet of marl is believed to include both the Manasquan and the Vincentown.

Henry I. Budd's well [80] within 2 miles of Vincentown, and 2 miles south of Birmingham, at an elevation of 50 feet, goes through 71 feet of unclassified loam, clay, marl and ironstone before striking a marl assigned tentatively to the Vincentown. Between this depth and that of 99 feet, where the shell bed of the Hornerstown is reached, there are 12 alternating layers of "marl" and "hard crust"—very probably limesand and limestone. This 28 feet is believed to represent the Vincentown formation.

25. An excellent exposure of the Vincentown limesand may be seen along Little Creek west of Lippincott's Corner. Loose bryozoans, washed from the sand, may be found over almost the entire flood plain; but the hill that forms the west side of the valley has been cut into, exposing a layer which is a mass of *Coscinopleura digitata*, together with other fossils and sand. According to the writer's estimate, the following section is exposed:

	Feet	Inches
Sand and gravel with boulders of Vincentown limestone and gneiss	5–6	
Red sticky clay containing glauconite	0	6-12
Bryozoan sand	0	4
Alternating layers of limestone and limesand, at least	10–15	

This is approximately the same as the description given in the notes of the State Survey:

Sand and fine gravel, mixed with more or less marl—a stream deposit	4–6	
Red-brown sticky clay (disintegrated limestone)	0	6–12
Limesand, with bryozoa, etc	5	
Limestone, with bryozoa, etc	1	

Upstream, toward the road to Wilkins Station, the overburden increases in thickness to 10 feet or more.

The layer of red-brown clay at the top of the limestone, derived from it by decomposition, is rather general in this area. It is encountered in places along the South Branch of Rancocas Creek toward Eayrestown.

[79] Mansfield, op. cit., p. 82.
[80] Woolman, Lewis, New Jersey Geol. Surv. Ann. Rept. for 1896, p. 143.

26. The Zeolite Chemical Company now operates the pits near Reeves Station, which formerly were operated by the R. S. Ryan Company. As is the case with The Permutit Company at Birmingham, the marl is dug for use as a water softener. It is from the Hornerstown of these two pits, at Reeves Station and Birmingham, that casts have been found [80A] which Cooke and Stephenson believe may be *Venericardia planicosta* var. *regia,* and which played a large part in convincing them of the Eocene age of the Hornerstown, Vincentown and Manasquan.

The main pit of the Zeolite Chemical Company is in the Hornerstown, and no Vincentown is present. Mansfield found the following section:[81]

	Feet
Quaternary	
Brown soil with pebbles	2
Light-colored consolidated glauconitic sand	1
Hornerstown	Feet
Ironstone, full of shell casts and with local strongly ferruginous bands	3
Black to greenish marl (1 inch strongly ferruginous layer at base)	1-1½
Black marl with greenish streaks	3

Below this, the marl is covered with water, but it is said to be 40 feet thick. Mansfield reports that the ironstone or shell layer thins to 6 inches at the south end of the pit where the shells are missing but pebbles are present. (The author observed a similar thinning of the upper beds of the Hornerstown farther south on the grounds of the Camden County Institution.) When the writer visited the pit at Reeves Station an enormous amount of the shell layer had been cleared from the pit and dumped in the stream valley on the other side of the road. A fairly large space had been filled and the surface and sides were littered with casts of pelecypods—probably *Gryphaea* —and also, casts of *Terebratula harlani.* The material is so friable that it is very hard to get good specimens.

Mansfield reports 8 feet of Vincentown under some Pleistocene in a small pit on Haynes Creek about 0.4 mile southeast of the Zeolite Chemical Company pit. The formation is a "lime and quartz sand" with hard, cemented masses of limesand 6 inches to 1 foot thick, irregularly distributed through it. There are also large bodies of dark-greenish clay, grading into sand and here and there containing small masses of limestone. Clay bodies 10 feet or more long and 2

[80A] Stephenson, L. W., The Stratigraphic Significance of Kummelia, a New Eocene Bivalve Genus from New Jersey, Journ. Wash. Acad. Sci., Vol. 27, no. 2, 1937, p. 59.

[81] Mansfield, op. cit., p. 80.

or 3 feet thick lie near the base of the cut."[81A] The notes of the Geological Survey of New Jersey describe the sand as of pale straw color and composed largely of foraminifera. This is probably the site of Charles Haines' mill, said by Rogers to be 2 miles below Medford on Rancocas Creek.[82] The Zeolite Company pits are 2 miles north of Medford, downstream, on Haynes Creek, part of which is also called the Southwest Branch of Rancocas Creek. Rogers, writing more than 100 years ago, recognized only 2 feet of straw-colored limestone but the several feet of gray sand with some greensand which he mentions would be a part of the Vincentown. A well 0.5 mile from this place is also recorded in which about 6 feet of sand and limestone in alternating layers was found 7 or 8 feet below the surface. It had the same fossils as the sand and limestone exposed on the Creek.

27. North of Medford, along Sharps Run, the State Survey reports the limestone under 10 feet of glauconitic, brown sand and loam and fine gravel. A few fragments of limestone can be found near the bridge—probably having been dug during the laying of some water pipes. Upstream from the bridge it is not uncommon to find bryozoans and shell fragments in the bed of the stream and on the flood plains. These must have been washed from an exposure toward the west but no such outcrop was found. It may be covered with silt. Among the species found in this stream are:

ANNELIDA
Serpula rotula Morton

BRYOZOA
Coscinopleura digitata Morton
Crassimarginatella intermedia Canu and Bassler

The writer was unable to find Weller's locality 161, unless it was that just described. Weller cites an exposure of the Vincentown limesand along the creek just west of the town of Medford and records the following species.[83]

ECHINODERMATATA
Pseudodiadema diatrema Morton
Echinoid spines

VERMES
Serpula rotula Morton

81A *Ibid.*, p. 81.
82 Rogers, op. cit. 1836, p. 76.
83 Weller, op. cit., p. 169.

BRYOZOA

Coscinopleura digitata Morton
Retelea ovalis Gabb and Horn
Several undetermined species.

PELECYPODA

Polorthus tibialis Morton

A well drilled northeast of Medford for Joshua S. Wills went through the Vincentown limesand between 35 and 50 feet. This site is 63 feet above sea level. Joseph Hinchman's well, also near Medford, encountered 16 feet of limestone between 57 and 73 feet.[84]

28. Most of the area between Medford and Marlton has the Vincentown formation not far below the surface, but a Quaternary covering is quite general, so that there is little record of the deposit except from wells. There is a good deal of difference in the thicknesses of the Vincentown and the Quaternary within short distances, as is to be expected, considering the erosion that occurred between the deposition of the two. This is well shown by two holes drilled on the farm of Alphonso Fusco on the Elmwood Road. One spot is at an elevation of 65 feet, has an overburden of 17 feet of Quaternary, and only 5 feet of Vincentown—glauconite beds, with fine quartz sand and dark greenish-drab clay. The other site has a surface elevation of 61 feet, and an overburden of only 7 feet 8 inches of Quaternary, while the Vincentown is 11 feet 4 inches thick, and has two beds. The basal 3 feet is a clay, glauconitic and sandy, greenish-gray to black. The other 8 feet 4 inches in a clayey, dark grayish-green sand, principally quartz but with much glauconite, increasing in proportion with depth, while the quartz becomes coarser. It is almost a quicksand. The thickness of the Hornerstown in these two holes varies less than 2 feet, being between 21 and 23 feet.[85]

The artesian well records of the Geological Survey of New Jersey show the presence of the Vincentown in many wells about Marlton.[86]

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[84] Woolman, Lewis, New Jersey Geol. Survey. Annual Rept. for the year 1894, p. 216.

[85] Mansfield, op. cit., pp. 70-71.

[86] Woolman, Lewis, Geol. Surv. of N. J., Ann. Rept. for 1894, pp. 206-216.

A brief summary follows:

Owner	*Thickness of Vincentown*	*Depth, Feet*
Samuel Lippincott	3 ft. limestone	23-26
William J. Evans	10 ft. limestone and white sand crust	40-50
Bowman S. Lippincott	12 ft. limestone and white sand crust with bryozoa and fragments of *Terebratula harlani* (and *Exogyra costota*?)	38-50
Joseph Evans	14 ft. sand, 9 in. crust	70-93
Jacob L. Evans	5 ft. yellowish marly sand and	25-30
	5 ft. limestone with bryozoa	30-35
Davis Rogers	28 ft. limestone with bryozoa	30-58

A well at Peter Schwin's near Jenney's Mill, one mile east of Milford, encountered limestone at a depth of 53 feet. After going through 11 feet of limestone and 3 feet of water-bearing sand, the drill struck what is believed to be another limestone layer of the Vincentown.[87]

Other wells near Marlton have gone through a yellow sand and gravel and quicksand and a black mud, called Kirkwood, but which might be a part of the Vincentown.[88]

A well at Gibbsboro, drilled for John Lucas, was one of the first to draw water from the Vincentown formation. The water came from an 8 foot bed of limesand and limestone, between 63 and 71 feet. The bed contained bryozoa.[89]

A year later other wells were drawing water from the Vincentown.[90] W. R. Kelley's well at Lindenwold, at an elevation of 100 feet, entered the Vincentown formation at a depth of 71 feet, and, below 7 feet of gravel, met both water and bryozoa, between 78 and 82 feet.

29. Laurel Springs, Clementon, Brownsville and Garden Lake are small villages running into each other so that it is hard to tell where one ends and the other begins. Although they are situated in the Tertiary and Quaternary belt, some of the streams in the area do cut into the Vincentown formation. One of the best localities for collecting fossils other than bryozoa from this formation is found along a small tributary to the North Branch of Timber Creek, just west of the railroad tracks, between Clementon and Garden Lake. Britton, in 1884, found the limestone exposed for 500 feet upstream, just below the mouth of a small creek from the northeast.[91] He found:

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87 Woolman, Lewis, Geol. Surv. of N. J., Ann. Rept. for 1897, p. 261.
88 *Ibid.*, pp. 258-261, and Mansfield, op. cit., pp. 73-74.
89 Woolman, Lewis, N. J. G. S. Ann. Rept. for 1895, p. 66.
90 Woolman, Lewis, N. J. G. S. Ann. Rept. for 1896, p. 135.
91 Notes on file in the office of the Geol. Surv. of N. J.

	Feet
Kirkwood sand	15
Vincentown limesand (above stream level).....	12
Greensand	

The measurements of the above beds were made in different places and it is thus improbable that the true section is represented. The limesand outcrop was said to be one-half mile wide along the creek, and fragments of limestone were found to be common for one-quarter mile along the stream.

The site was visited by the writer in 1937 and the section found was approximately as follows:

	Feet
Gravelly soil	1
White sand (Kirkwood?)....................	4
Yellow, clayey sand, with fossils..............	6
Greensand, more glauconite....................	2
Stream level	

These beds are found in a cliff 10 to 15 feet high which forms the west bank of the creek near the railroad trestle. The bank is very steep, much of the sand having been washed away from the roots of a large tree growing on top. The roots have gone into the Vincentown sand (which is not very calcareous here) and many fossils may be drawn out of the sand beneath the tree. Collecting is better in the stream bed, however, where the fossils have fallen and been washed clean. Among the forms found are:

ANTHOZOA
Flabellum mortoni Vaughan
(Britton noted *Montivaltia*)

BRYOZOA
Hippaliosina aspera (?) Gabb and Horn

PELECYPODA
Arca quindecemradiata Gabb
Etea delawarensis Gabb
Veniella (?) *rhomboidea* Conrad
Ostrea bryani Gabb
Gryphaea dissimilaris Weller
Polorthus tibialis (?) Morton
Several unidentified species.

GASTROPODA
Caricella plicata Whitfield
Unidentified species.

No fossils were found farther downstream by the writer although a yellow sand with iron tubules and a greensand were found to the north.

30. North of the Blackwood-Clementon road, near Brownsville, there is an excellent exposure of yellow limestone full of bryozoa and other fossils, all along the tributary of the North Branch of Timber Creek. There are three or four feet of limestone and limesand exposed above the water level under only ten inches of soil and gravel. Both the sand and the limestone exhibit the characteristic features of the calcareous facies of the Vincentown. Besides numerous bryozoa, among which the most common are *Coscinopleura digitata* Morton and *Euritina torta* Gabb and Horn, the outstanding fossil found here is a coral. Similar specimens in the Rutgers Geological Museum, in the George H. Cook collection, are labelled "*Montivaltia caryophyllata*—Cretaceous, Timber Creek, N. J." This is, presumably, what Morton described as *Anthophyllum atlanticum* and what Lonsdale assigned to the genus *Montivaltia*.[92]

A short distance south of here, where the road to Hidden Lake crosses the same stream, a new bridge was being built in July, 1937. Some of the sand brought up from the stream bed contained poorly preserved bryozoan fragments. Although this appeared to be a greensand at the time when it was obtained, it assumed a yellow-brown color on drying, so that it is presumably the same as the yellow sand found near the Clementon road.

The section here is as follows:

Above water	*Feet*
Gravel and yellow sand	4-5
Greensand	1

Under water

Greensand, clayey in places
Gravel
Hard layer, full of bryozoa

[92] Lonsdale, William, Account of Six Species of Polyparia from Timber Creek, N. J. Quarterly Journal of the Geological Society of London, 1845. Vol. I, p. 65.

31. An old marl pit lies to the west of the road from the last locality to Brownsville and Laurel Springs. The marl was probably dug on both sides of the stream. The strata are now hidden by a lush growth of grass and reeds. Nothing more can be seen than 2 feet or less of greensand at the stream's edge and some yellow sand high on the hill. For figures, we must resort to the notes of the Geological Survey of New Jersey. The section on the north side of the creek, where the surface is 44 feet above sea level, is given as:

	Feet
Pleistocene sand	4-6
Yellow marly sand (Vincentown).............	16-14
Marl, top just above level of creek at about level of floor of old pit..............................	1

32. About one-half mile northeast of here on the same road is Garden Lake, at one time called Tomlinson's millpond. Cook, writing of this place and the middle Marl, said "Ephraim Tomlinson has in his bank full 30 feet of the bed"—both the lime sand and yellow limestone showing above the shell layers and green marl.[93] This bank is west of the road and the notes of the Survey record about 28 feet of marl, covered by 2 feet of green clay, earth and gravel. Above the dam a boring on the shore of the lake struck an impenetrable crust (limestone?) 2 feet below the level of the pond. This should show below the dam as there is a fall of 18 feet. The fact that the limestone is under the marl implies that the marl is either Pleistocene reworked material or Manasquan, probably the former. Limestone fragments have been found along the stream below the same, but the writer was unable to find any fragments except of iron-cemented greensand and conglomerate. Although no fossils are apparent here now, this must be near the place described by Rogers,[94] on the North Branch of Timber Creek, near Clementon, which is probably also the place where Lyell saw the limestone. Rogers mentions 25 feet of strata (Vincentown alone or with Hornerstown?) above the level of the stream, overlain by about 5 feet of "diluvial matter." Layers of limestone about 6 inches thick alternate with beds of sand up to 2½ feet in thickness. In places, Rogers says, the calcareous sand forms tall narrow cones or eminences, rising almost through the overlying stratum, which fills the intervals between. Some cones are 4 feet high and 2 or 3 feet in diameter. Structures similar to these were recalled by Robert Montgomery, of Blackwood, who hauled marl from David

[93] Cook, George H. The Geology of New Jersey, 1868.
[94] Rogers, op. cit., 1840, p. 222.

Marshall's pits. He described the inverted cones as empty, smooth-sided, and as long as his arm. Mr. Montgomery could not tell whether the cones were in the Vincentown or the Hornerstown marl, but it is probable that they were in the same bed as those at Clementon, 4 miles away.

The Clementon locality, according to Rogers, had "beautiful, highly preserved fossils," with vast quantities of *Coscinopleura digitata* Morton, *Pliophloea sagena* Morton and other "zoophytes," and also *Hemiaster parastatus* Morton, *Cardiaster cinctus* Morton and echinoid spines; *Anthophyllum atlanticum* or *Montivaltia atlantica* Morton, *Cavoscala annulata* Morton, *Gryphaea convexa* Say (probably *G. dissimilaris* Weller), *Gryphaeostrea vomer* Morton, a teredo (probably *Polorthus tibialis* Morton), and other shells.

A number of wells in this vicinity offer further information as to the depth and thickness of the Vincentown formation. The elevation of the surface, of course, makes a difference in the depth of a given bed, and as that elevation is not known for all these wells, the information is of questionable value. At Laurel Springs, the records of five wells[95] show a thickness of at least 18 feet for the Vincentown—probably more, because the limesand here is water-bearing and the wells did not penetrate the entire thickness in most cases. The limestone was encountered at depths varying from 32 to 75 feet below the surface. The maximum elevation in Laurel Springs is about 80 feet. It has already been stated that the Vincentown crops out just above stream level near the town. A well at Gibbsboro encountered the Vincentown—a pepper and salt sand—between 76 and 82 feet. The surface here is higher, with a thicker covering of Tertiary or Quaternary sands. A well at Kirkwood struck 2 feet of hard lime rock at a depth of 82 feet.[96]

East of Clementon the Vincentown is buried even more deeply as shown by the records of five more wells.[97] The deepest of these does not strike the limestone until it reaches a depth of 203 feet, but the

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[95] Woolman, Lewis, Artesian Wells, Geol. Surv. of N. J., Ann. Rep't. for 1896, p. 133.
Ibid., 1899, p. 65.
Ibid., 1901, p. 88.
Ibid., 1903, p. 87.
Ibid., 1909, p. 88.

[96] Woolman, Lewis, Artesian Wells, Geol. Surv. of N. J., Ann. Rep't. for 1897, p. 255.

[97] Woolman, Lewis, Artesian Wells, Geol. Surv. of N. J., Ann. Rep't. for 1896, p. 135.
Ibid., for 1901, p. 89.
Ibid., for 1903, p. 87.

surface elevation is 150 feet and the site of the well is about half-way between Clementon and Berlin. The other wells show an average thickness of about 10 feet of limestone (probably more, not drilled through) at depths between 58 and 105 feet. In almost every case bryozoa are found, and the sand is a grayish one with a fair sprinkling of glauconite. A well at Milford, drilled for Adam Olt, struck a limestone with bryozoa and echinoids at 50 feet.[98] The layer was 6 feet thick and below it lay 2 feet of gray "pepper and salt" sand with water, also assigned to the Vincentown.

34. Blackwood—called Blackwoodstown long ago—is one of the "lost localities" mentioned by Canu and Bassler from which exquisite bryozoan material was obtained at one time.[99] The enormous old pits of David Marshall along the South Branch of Rancocas Creek are now thickly overgrown and the bottom is a veritable swamp, partly from the encroachment of the creek which forms a small lake west of the village of Blackwood.

Cook wrote that the whole Middle Marl bed could be seen "by going along upstream from Good Intent toward the southeast."[100] His figures for the section exposed in Marshall's pits are:

	Feet
Red or gray marl	6-12
Pale green marl	7
Green marl	18-20
Chocolate marl	

Dr. Kümmel observed the following section in these pits in 1917:[101]

	Feet
Yellow sand and gravel	13-14
Brownish and clayey sand: weathered marl (?)	1
Marl, about half quartz and half glauconite	15
Bottom of banks	

The Vincentown, if in this pit, must be represented by the yellow sand and gravel, or by Cook's "red or gray marl," and apparently is not fossiliferous. A number of men who used to work in the marl pits recalled as much as they could for me, and, while they remembered

98 Woolman, Lewis, Artesian Wells, Geol. Surv. of N. J., Ann. Rep't. for 1899, p. 70.

99 Canu, Ferdinand and Bassler, Ray S. "The Bryozoan Fauna of the Vincentown Limesand," U. S. Nat. Mus. Bull. 165, p. 3, Washington, D. C.

100 Cook, op. cit., p. 272, 1868.

101 Mansfield, op. cit., p. 58.

well the shell layer of the Hornerstown, they did not remember any sort of fossils in the yellow sand, or "gray marl" as it was called. That there are fossiliferous beds of the Vincentown near here is a fact, and it may be that the bryozoa are too small to have made any impression on the man who recalled such things as reptile bones, teeth and large shells, all of which are found in the Hornerstown.

One piece of Vincentown limestone with the characteristic bryozoa was found by the writer in a field in Blackwood. There is doubt as to how the boulder, about a foot in diameter, got there.

South of Blackwood, about a quarter of a mile beyond Mansfield's locality 48 (in Marshall's pits), he and Dr. Kümmel found 4 or 5 feet of limesand about 5 feet above the swamp, overlying the greensand marl and under 15 to 20 feet of Pleistocene sand and gravel.[102] This is probably near the place where Rogers recorded:[103]

		Feet
Pleistocene ?	Diluvium sand and gravel......................	3
	Yellow ferruginous sand......................	1
	Dark ferruginous clay, very tough............	1
Vincentown	Gray siliceo-calcareous sand with fossils similar to those of underlying limestone............	2
	Yellowish-gray limestone in thin, irregular flaggy layers with several species of shells and *Coscinopleura digitata* in considerable abundance..	2½
Hornerstown	Greensand marl, at level of stream	

35. The Camden County Almshouse and Asylum covers most of the area between Blackwood and Grenloch west of the South Branch of Rancocas Creek. The community is called "Lakeland" and is easily recognized by its large red brick buildings and the smokestack bearing the name. The Vincentown limestone and limesand occur at several places on the institution grounds. One of these is by the road at the pumping station. Large pieces of limestone may be seen in the bank but, as the whole place has been used for a dump and is littered with coal, bricks and so forth, it was impossible to tell whether there was a thick bed of limestone in the sand, or merely boulders. It appeared as if there might be a layer of limestone 5 feet thick or more. Bryozoa are numerous.

A short distance downstream from here the limestone cannot be located at all. Four feet of greensand (Hornerstown) is exposed in the bottom of a gully and above it lies a considerable thickness of yellow-red and white sand. Yellow sand and gravel, probably Pensauken or Kirkwood, are higher. Is the yellow-red and white flecked

[102] *Ibid.*, p. 59.

[103] Rogers, Henry D., Geology of the State of New Jersey, Final Report, Philadelphia, 1840, p. 221.

sand a part of the Vincentown? It has not fallen from above and its bedding can be seen. If it is Vincentown, it shows a rapid change from the limestone to the sand facies. If it is not a part of the Vincentown, what has happened to that formation within this short distance? It must have been stripped away before deposition of the later sand. In either case the local expression of the limestone is emphasized.

The presence of the Vincentown is questionable also in the bank of a small stream nearby where the shell layer of the Hornerstown is exposed. The section follows:

		Feet
Loam and gravel		1
Sand—grayish to yellow, with some glauconite		3-5
Blue-black marl, including		4-6
Iron-stone layer—variable		
Shell layer	6-12 inches	
Greensand	3 feet or more	
Stream bed		

There is little that can be recognized in the shell layer except white patches that were once shells. It is sufficient evidence to establish the top of the Hornerstown, however. It is not as easy to be sure that the overlying sand is of Vincentown age. The ironstone layer in this section gives the appearance of an unconformity but it is readily seen to be due to secondary cementation since the irregular line formed by it crosses the bedding.

The limesand can be seen again about three-quarters of a mile south of here along the west bank of a small stream just north of the mouth of a small tributary where there is a sort of amphitheatre in a bend of the stream. Near the north end of the bend there are many badly weathered boulders of Vincentown limestone crowded with *Coscinopleura digitata* Morton. The weathering has caused a banding of iron oxide which gives these pieces an appearance very similar to that of the yellow-red and white-flecked sand seen in the gully downstream from the pumping station. It cannot be stated definitely that the pieces of limestone are in place but there seems to be little doubt about it. Because of deposition by the stream on its flood plain neither the base of the Vincentown nor the top of the Hornerstown is exposed. The section at this spot is given below:

	Feet
Pensauken (?) gravel and sand	6-7
Vincentown, sand and limestone	5
Vincentown (?) gray sand	4
Stream deposits, black clayey sand and muck	1
Stream level	

Reddish sand and gray-green clay take the place of the sand and limestone along the small tributary. This is probably due largely to weathering, although why the weathering should not be the same along both streams is a legitimate question.

The well of S. R. Bateman at Grenloch, seven-eighths of a mile southeast of Lakeland, went through 22 feet of Vincentown gray sand from the surface down to the *Terebratula harlani* layer of the Hornerstown.[104]

West of Lakeland, 1½ miles south of Fairview, a well drilled for Mrs. Wolf [105] went through:

	Feet
Yellow quicksand	35
Steel-gray quicksand	20
Marl	7
Black and white sand	10

This must be quite near the well of Thomas Burroughs, near Hurffville,[106] the record of which follows:

(Elevation, about 90 feet)

		Feet
Pleistocene gravel		10
Kirkwood yellow fine sand		50
Vincentown (?) to Navesink	Green marl	60
	Shale	4
	Gray sand	6
	Shale	2
Mount Laurel and Wenonah	Green coarse rice gravel, full of belemnites	15

A comparison of the two records suggests that the steel-gray quicksand of Mrs. Wolf's well may be the Vincentown sand. This is supported by the data of John Schmidt's well, near Salina.[107] This well, at an elevation of 60 feet goes through 14 feet of yellow sand—probably Kirkwood—and 10 feet of gray marl, called Vincentown.

36. Hurffville has at least one locality where the Vincentown formation may be seen today. This is below Brickett's mill, north of the road just above a small lake on Mantua Creek. Limestone boulders are strewn along the side of the creek and there is an outcrop in the bed of the stream just below the water level. This shows for a very short distance downstream. In one place it reaches about

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104 Mansfield, op. cit., p. 59.

105 Woolman, Lewis, Geol. Surv. of N. J., Ann. Rep't. for 1901, p. 91.

106 Mansfield, op. cit., p. 55.

107 *Ibid.*, p. 54.

one foot above the water level. The water is about one foot deep where the limestone shows. The limestone is gray, but weathers to the more characteristic yellow-brown. It is not very fossiliferous here, but a few specimens of *Coscinopleura digitata* Morton were found in the massive limestone.

Mansfield describes some old pits near Hurffville[108] but it is now impossible to see anything of the strata there because of slump and vegetation. In 1886 there were measured 9 feet of limesand and 13 feet of greensand marl.

It is equally impossible to learn anything now of the strata at the old marl pits on Bees Branch. These pits are filled with water and nothing but yellow gravel shows on the sides. The Vincentown has not been reported here. Some greensand shows along the brook but the shell layer was not recognizable.

The Vincentown is mapped along Bethel Run, near Porch Run, but the writer was unable to find it.

Weller collected the following species from Mantua Creek, just below the mouth of Bethel Run, near Hurffville:[109]

BRYOZOA
Coscinopleura digitata Morton

PELECYPODA
Arca quindecemradiata Gabb
Gryphaeostrea vomer Morton
Polorthus tibialis Morton

One-half mile up the creek he found in addition:

ANNELIDA
Serpula rotula Morton

PELECYPODA
Ostrea bryani Gabb?

CRUSTACEA
Scalpellum conradi Gabb

37. Three or four feet of Vincentown limesand have been reported in the angle formed by the road and Chestnut Branch between Sewell and Barnsboro.[110] The writer found marly earth with some concretions but nothing to prove the presence of the Vincentown.

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[108] *Ibid.*, p. 57.
[109] Weller, Stuart, op. cit., p. 169.
[110] Notes of the Geological Survey of New Jersey.

38. West of Barnsboro the Vincentown sand and the *Terebratula* bed at its base may be seen. Silicified shells of *Terebratula harlani* Morton are very numerous along the south bank of a small tributary to Edwards Run on both sides of the road east of the Run. The section, combined from Mansfield's figures[111] and other notes in the office of the State Survey, follows:

	Feet
Pleistocene—Sand and gravel	2
Miocene—	
Kirkwood—Clay and fine white sand	2-4
Eocene—	
Vincentown—Yellow-green marly sand much more marly in lower 6 to 8 inches; not limy	5
Hornerstown—*Terebratula harlani* shell bed, in matrix of marl	6-8 inches
Green marl down to flood plain	15

The shells are strewn down the hillside so that the casual observer might think they represent a thickness of 5 to 8 feet. No species other than *Terebratula harlani* Morton were found.

Farther west, where the road to Jefferson crosses Edwards Run, Mansfield found two other exposures of the Vincentown.[112] One of these places was in an old pit near an ice house north of the road, where, beneath 4 feet of Kirkwood sand, 5 to 6 feet of Vincentown sand was found above the Hornerstown marl. Just to the north, in a pit near the pond, the Hornerstown was seen, but no Vincentown. Overgrowth made it impossible for the writer to distinguish either of these sections in 1937 and 1936. A good section was found, however, along the road. A new cut in 1937 exposed the following beds:

	Feet	Inches
Bridgeton (Pleistocene)—Gravel with some white sand		
Kirkwood (Miocene)—Yellow sand	0	6-8
Vincentown—Gray sand	3	
Fine glauconitic, quartzitic gravel	0	6
Hornerstown—*Terebratula* layer	0	6
Dark greensand marl		

An interesting feature, in view of the lack of the Vincentown at one of the pits north of the road, is the fact that it disappears toward the west in this road cut. The thinning is noticeable above the shell layer so that finally the Kirkwood or Bridgeton (uncertain which) lies unconformably over the Hornerstown. It must be admitted that this effect might be due to slump or filling in of the bank, but it seemed to be an actual thinning. The overlying sand and gravel is probably a part of the Kirkwood, deposited after the tilted Vincen-

111 Mansfield, op. cit., p. 43.

112 *Ibid.*, p. 42.

town beds had been beveled. The gravel is finer than one might expect to find over such an unconformity.

The Vincentown and Hornerstown are mapped by Knapp along most of Edwards Run upstream from here. The writer was unable to recognize either, unless a gray sand about 20 feet thick and weathering to yellow and white, is the Vincentown. It might be either that or a later sand.

Mansfield gives the record of a well south of Barnsboro in which a light green marl—probably the Vincentown—is met at a depth of 40 feet. The base was not distinguished, 105 feet of marl and shale being thought to include the Hornerstown and Navesink.[113]

39. Three wells drilled at Pitman show 20 feet of Vincentown limesand. At the lowest point (110 feet above sea level) it was found between 80 and 100 feet beneath the surface.[114] In another well it was found between 110 and 129 feet under the surface;[115] and in the third [116] it occurred at a depth of 115 to 125 feet. In each case the sand is full of bryozoa, echinoid spines and nodosarians.

A little farther south, at Glassboro, the Vincentown has increased greatly in thickness. The log of the New Jersey Packing Company's well was not recorded carefully, but it was established that the top of the Upper Marl was at a depth of 145 feet. The Middle Marl was met at 240 feet. In this record the limestone was included in the Upper rather than the Middle Marl. It may be represented by the blue clay found between 190 and 240 feet, although this is doubtful. The upper 45 feet assigned to the Upper Marl is a black sandy marl, with *Ostrea bryani* and *Nodosaria*.[117]

40. In the vicinity of Mullica Hill the writer was unable to find anything resembling the Vincentown except a yellow sand, although notes on file in the office of the Geological Survey of New Jersey mention an exposure of the Vincentown-Hornerstown contact at some pits on the west side of Raccoon Creek about one mile southeast of Mullica Hill. The contact is said to be in a 6 to 8 foot zone of slightly glauconitic sand lying above a 2 foot bed of calcareous-quartzitic-glauconitic sand full of *Terebratula harlani* Morton.

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113 *Ibid.*, p. 44.

114 Woolman, Lewis, Artesian Wells, Geol. Surv. of N. J., Ann. Rep't. for 1896, p. 129.

115 Woolman, Lewis, Artesian Wells, Geol. Surv. of N. J., Ann. Rep't. for 1900, p. 134.

116 Woolman, Lewis, Artesian Wells, Geol. Surv. of N. J., Ann. Rep't. for 1901, p. 84.

117 Woolman, Lewis, Geol. Surv. of N. J., Ann. Rep't. for 1893, pp. 407-408.

When N. T. Stratton's marl pits were in operation, however, a thick bed of limestone was exposed above the shell layer of the Hornerstown. Cook recorded the following section:[118]

	Feet	
Gray calcareous marl	3	Vincentown 7¾ feet
Gray limestone	½	
Gray calcareous marl	¾	
Gray limestone	½	
Gray calcareous marl and greensand	3	
Shell layers	4	Hornerstown
Pale-green marl	16	
Best green marl	12-16	Hornerstown or Navesink?
Chocolate marl........bottom not reached		

A wood-cut showing these pits may be found in Cook's Annual Report for 1855.[119] In the same report he describes a calcareous sand with belemnites found by William Snowden in the bottom of Raccoon Creek. This is probably the Mount Laurel sand.

Rogers recorded a section, including limestone, seen in the banks of Charles Batton's meadow on Raccoon Creek, one and a half miles southwest of Mullica Hill.[120] There is no Vincentown mapped in such an area today. Rogers' figures follow:

	Feet	Inches
Dark micaceous earth—thickness variable		
Similar bed, abounding in fragments of white friable shells	1	6
Soft, porous, fossiliferous limestone	0	4
Calcareous sand, with shells	0	10
Gray, compact, subcrystalline limestone	1	0
Calcareous sand	2	6
Hard subcrystalline limestone, not fully penetrated	0	8+

41. The Vincentown formation is exposed along Oldman's Creek in the vicinity of Harrisonville. Along the south side of the creek, west of the dam, pieces of hard, sandy, somewhat crystalline, gray limestone can be found. It is fossiliferous, but bryozoa are not abundant. There is a gray sand just above the level of the stream, which might also be a part of the Vincentown. It is fine and clayey, stained with iron oxide.

An old pit about a mile and a quarter southwest of Harrisonville is now filled with water but a number of Vincentown fossils were found in the bank about 10 feet above the water. These are:

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[118] Cook, George H., *The Geology of New Jersey,* Trenton, 1868. Also in Geol. Surv. of N. J., Ann. Rep't. for 1886, p. 180.

[119] Cook, Geo. H., New Jersey Geological Survey, Ann. Rep't. for 1855, Trenton, 1856, p. 66.

[120] Rogers, H. D., *The Geology of the State of New Jersey—Final Report,* Philadelphia, 1840, p. 220.

BRACHIOPODA

Terebratula harlani Morton ($CaCo_3$ here, not SiO_2 as at Barnsboro)

PELECYPODA

Gryphaea dissimilaris Weller (?—fragmental)
Kümmelia americana Gabb

West of the road and across the stream, there is a heavy covering of late Tertiary or Pleistocene sand and gravel, but a few pieces of Vincentown limestone are present showing that the formation is nearby.

Another old pit, a short distance downstream on the north side, shows the sandy facies of the Vincentown. The notes of the State Survey give the following section:

	Feet	*Inches*
Cape May ?—Light-yellow, sandy gravel	4-8	0
Kirkwood—Very fine, white, powdery, compact sand....	2	6
Vincentown—Medium, green to yellow glauconitic sand..	2	6

The base of the Vincentown is 15 feet above the stream. Probably that entire thickness and more is occupied by the Hornerstown which can be seen in the pit. A shark's tooth was found in this marl by the writer.

A well drilled at Harrisonville went down 90 feet before striking the top of 28 feet of limestone made up largely of Vincentown bryozoa and foraminifera. It is possible that 10 feet of sand above this layer and 4 feet below should be included, giving the Vincentown a total thickness of 42 feet.[121] The elevation of this well over Oldman's

Twenty-eight feet of limestone, shell layer and green marl were visible in 1886 along a branch of Oldman's Creek near the road from Woodstown to Mullica Hill.[122] The writer was unable to see anything in the way of an outcrop in April, 1938.[a]

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121 Woolman, Lewis, Geol. Surv. of N. J., Ann. Rep't. for 1894, p. 196.
Creek must be considerable.

122 Cook, G. H., Geol. Surv. of N. J., Ann. Rep't. for 1886, p. 179.

a Following section observed by Meredith E. Johnson in a small pit 1 mile southwest of Oldman's Creek on northwest side of road, Aug. 9, 1935:

a. 4 to 8 ft. light yellow sandy gravel—Cape May
b. 2½ ft. very fine-grained white sand—Kirkwood
c. 2½ ft.+ medium-grained, yellow glauconitic sand—Vincentown
Bottom of pit about 15 ft. above stream level at elevation ± 40.

42. Woodstown is in the Vincentown belt, but the limestone is almost entirely hidden by Miocene and Pleistocene sands and gravels. Pieces of limestone may be found here and there, but the writer was unable to find an outcrop. Knapp in 1905 saw an outcrop just below the old mill pond.[123] It is inaccessible now, perhaps because of the concrete dam built since that time.

Mr. George Macaltioner furnished some interesting information about the limestone which was quarried by his father, Joseph Macaltioner, for many years prior to 1898. The quarry was located in the meadow back of their house along a branch of Salem Creek. After operations were stopped the quarry was filled in and the meadow restored; so that there is no trace left of the former industry. In the process of filling the stream was moved from the north to the south side of the meadow. Pieces of limestone may be found along the bed of the stream but they are not numerous. Bed rock lies 2 or 3 feet beneath the surface of the meadow.

Macaltioner began to quarry the limestone after he noticed it outcropping in his meadow and he went down at least 15 feet without finding the bottom of it. At this depth pumps were necessary to keep the quarry free of water. Throughout the quarry layers of limestone and limesand alternated. The limestone layers were about 4 inches thick toward the top and crumbled easily. With depth, the thickness of the beds increased to 12 inches and the limestone was much harder. Both sand and stone were used as fertilizer, the latter being burned for lime first. Mr. Macaltioner lauded its efficiency.

The fossils in the pieces of limestone that I took from the brook are rather poor and nothing has been definitely identified. There are some small pelecypods and some borings similar to those in the limestone from New Egypt. This rock resembles the New Egypt limestone being coarse and gray. It has less lime and more quartz sand.

According to Mr. Macaltioner, fossils were numerous. He recalled "clams; conch shells the size of a fist or double that; bones, heaps of very fine, needle-like bones; honeycomb-like things, with many hollow bones in the holes; and birds' feet, 8 to 10 inches long." The "clams" would include the different pelecypod species. The "heaps of very fine, needle-like bones" are very probably echinoid spines. The "honeycomb-like things" might also be echinoids, but that is problematical. Unfortunately, Mr. Macaltioner had not preserved any of the fossils seen and his descriptions cannot now be interpreted very satisfactorily.

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[123] Field notes in the office of the Geological Survey of New Jersey.

Mansfield's well records from Woodstown show a thickness of from 10 to 15 feet for the Vincentown; the depth below the surface ranges from 6 feet to 50 feet, the latter figure coming from a well a mile west of Woodstown.[124] It is surprising that the well records show such a slight thickness of the Vincentown. Perhaps some of the marl included in the Hornerstown belongs to the Vincentown. The type of rock found in the wells is not as uniform as the thickness. The varieties are a glauconitic, clayey, pebbly sand; limesand mixed with marl; limestone; and limesand with foraminifera.

The old pits along Nihomus Run between Sharptown and the Woodstown-Salem Road were visited, but without satisfaction. Where the State Survey notes indicate 1 foot of yellow glauconitic Vincentown sand under 6 feet of yellow-brown clayey Cape May sand, a little bit of greensand was seen along a small tributary to Nihomus Run. It is probably the Vincentown. Downstream, stagnant pools were all that remained of the old marl pits. The section exposed at one time is as follows:[125]

	Feet
Limesand and limestone	9
Shell bed	4–6
Green marl	15
Chocolate marl	

A similar section was said to be exposed along Major's Run.

43. The Vincentown limestone was worked in two or more quarries along Swedes Run in Mannington Township 50 to 75 years ago. William Barber's quarry was described as "perhaps the finest in the state,"[126] 25 feet of alternating layers of tabular yellow limestone and limesand having been dug without finding bottom. The layers are comparable with those at the Woodstown quarry, the stone ranging from 4 to 12 inches in thickness, and the sand from 8 inches to 2 feet. Nearby, David Petit's bank showed 20 feet of Vincentown above a 4 foot shell layer and 18 feet of greensand.[127] When visited in 1937 no limestone could be found except for some pieces in the bed of the bank. The side of the hill seemed to be as follows:

	Feet
Pleistocene (Cape May) gravel	15-20
Kirkwood ?—Gray-white, clayey sand, full of iron oxide nodules	10-15
Fine blue clay, greener near water	2½

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124 Mansfield, G. R., op. cit., pp. 33-37.

125 Cook, G. H., *The Geology of New Jersey*, 1868, p. 272.

126 *Ibid.*, p. 273.

127 *Ibid.*, p. 273.

The limestone must begin at about the leval of the brook as it certainly is not exposed in the banks.

This presumably is Weller's locality 196 "Along a small stream northwest of Alloway station."[128] He gives the following list of fossils from there:

ANTHOZOA
Undetermined coral

PELECYPODA
Nemodon sp.
Arca sp.
Gryphaeostrea vomer Morton
Pecten sp.
Cardium knappi Weller
Carvatis veta Whitfield

GASTROPODA
Calyptraea sp.
Several undetermined species

Numerous bryozoa have been found some place in this vicinity. Collections in the Rutgers Geological Museum, together with shells of *Ostrea bryani* Gabb, *Gryphaea dissimilaris* Weller and echinoid spines, are labeled simply "Middle Marl, Mannington, N. J." Their dark gray color distinguishes them from the collections of most other localities.

44. The Vincentown formation is not far below the surface in a large area east of Salem, but because of the low, marshy topography, there are no outcrops. Records of wells and of holes drilled under the direction of Mansfield show the presence of the sand.[129] Ten to twenty feet are shown, just under the surface except where covered by Pleistocene deposits. Farther east the Kirkwood also covers it so that near Hagerville it is 85 feet under the surface. This well penetrated 15 feet of sand and "coral" at a depth of 85 to 100 feet and stopped in the coral, so that the entire thickness of the limestone is unknown. It is probably considerably more than 15 feet because 108 feet of alternating limesand and limerock were found about 3 miles to the northeast in a well drilled at Quinton.[130] The Vincentown is within 38 feet of the surface here, lying under Kirkwood and Re-

128 Weller, Stuart, op. cit., p. 170.
129 Mansfield, G. R., op. cit., pp. 22-26.
130 Woolman, Lewis, Artesian Wells, Geol. Surv. of N. J., Ann. Rep't. for 1893, p. 415.

cent sediments. Until this well record was known, the maximum thickness of the Vincentown in the region of its outcrop was believed to be little more than 25 feet [a] as shown in Barber's quarry in Mannington Township. The material from the Quinton well contained bryozoa, large and small foraminifera and corals, and Woolman interpreted the deposit as having been deposited close to the shores of the ancient sea.[131]

Nearer Salem, at Penton Abbey, 22 layers of stone interbedded with sand were found between 80 and 189 feet below the surface. This 109 feet is thought to include the Hornerstown and Navesink marls and possibly the Manasquan, but probably is mostly Vincentown.[132]

Two wells along the road to Daretown, 2¼ miles east of Alloway, show 83 feet of Vincentown sand including 7½ feet of gray rock and some marl at a depth of 108 to 191 feet.[133]

45. A well drilled in 1901 at Atlantic City under Young's Pier is about 45 miles from the nearest outcrop in the direction of the dip. It shows the remarkable thickness of 460 feet of yellow calcareous rock which may be said with little doubt to be the Vincentown.[134] The section as given by Mansfield, follows:[135]

	Thickness Feet	*Depth Feet*	*Age or Formation*
Floor of pier to mean tide level......	20	20	
(Mean tide level to bottom of water)	(15)	35	
Sands, clays, etc....................	237	272	Post-Miocene
Sands, clays, diatom beds, gravel, greensand, etc., including at 780-860 feet the Atlantic City 800-foot water horizon	945±	1,215	Tentatively Miocene
Greensand marl	25	1,240	(Shark River?)
Very hard, tough, light and dark slate or ash-colored clays with coccoliths and foraminifera	200	1,440	(Probably Manasquan)
Yellowish calcareous rock, soft or hard; two-thirds consists of nearly equal mixture of greensand and quartz; the other third is carbonate of lime, the cementing material; contains foraminifera; (no bryozoa)	460	1,900	(Probably Vincentown)
Glauconitic greensand marl............	40	1,940	(Probably Hornerstown and Navesink)
Clay mixed with a little greensand....	70	2,010	
Indurated ash-colored clay, "hard almost as rock"......................	60	2,070	
Glauconitic greensand marl similar to that at 1,900 to 1,940 feet..........	80	2,150	
Dark or micaceous sandy clays........	156	2,306	(Mount Laurel and Wenonah?)

[a] See footnote on p. 31.
[131] *Ibid.*, 1894, p. 194.
[132] *Ibid.*, 1901, p. 104.
[133] *Ibid.*, p. 102.
[134] *Ibid.*, pp. 58, 114.
[135] Mansfield, op. cit., p. 103.

46. Two wells near Farmingdale have furnished interesting fossils. The well of the Dittmar Powder Works, one mile south of the Farmingdale railroad station, showed the following strata, simplified from Woolman's record:[136]

(Elevation 70 feet)

	Thickness Feet	*Depth Feet*
Recent	40	40
Miocene	35	75
Shark River marl	35	110
Manasquan marl		
Ash marl	40	150
Greensand marl and clay	60	210
Vincentown sands		
Greenish-gray sandy clay, lighter than next above; mixture of greensand marl and ash-colored clay. Bryozoa, large foraminifera (*Nodosaria*, etc.) and *Echinus* spines	25	235
Dull greenish glauconitic sand (marl) with same foraminifera as next above	25	260
Rancocas marl (including part of Vincentown as well as Hornerstown?)		
Nearly pure greensand marl	30	290
Greensand marl with large proportion white quartzose sand, bryozoa, *Nodosaria*, *Frondicularia*	10	300
Greensand and ash-colored clay	10	310
Nearly pure greensand marl, somewhat clayey at base, where occur bryozoa, *Nodosaria* and *Frondicularia*	10	320
Also, at 320 feet, a bivalve *Pteropsis papyria* Conrad		
Monmouth		
Greensand marl and gray sand	55	375
Matawan		
Micaceous clays and sands	165	540

The presence of what Woolman identified as "probably *Pteropsis (Lutraria) papyria* Conrad (?)" at the base of the Hornerstown is especially interesting because the type is from the Lower Claiborne (Eocene) of Alabama.[137] The presence of bryozoa throughout the Hornerstown marl is rather unusual for New Jersey, but the relations of sand and greensand in this well are not unlike those of the undivided Rancocas formation of Delaware.

The State Geologist of New Jersey, Meredith E. Johnson, has provided the writer with a sample obtained from a Farmingdale well at a depth of 65 to 70 feet. It is composed almost entirely of bryozoa, but has also yielded foraminifera, small shells of *Gryphaeostrea vomer* Morton, fragments of other pelecypod shells, echinoid spines and

[136] Woolman, Lewis, Geol. Surv. of N. J., Ann. Rep't. for 1898, pp. 98-100.
[137] *Ibid.*, p. 98.

plates, a few ostracods and parts of a few tiny crab claws, *Serpula rotula* Morton and another worn tube resembling *Serpula trifonalis,* which is found in the Rancocas formation of Delaware. Small pieces of lignite are found in the Farmingdale material. There are a good many small quartz pebbles about 2mm. in diameter. They are frosted, and stained a greenish color by the associated glauconite. The grains of glauconite and the fossils frequently have incrustations of pyrite.

47. A well at Wildwood, N. J., encountered at a depth of 1104 feet, under Miocene rock, 140 feet of dark olive green clayey sand which Woolman called "Eocene? Pamunkey?"[138] It is unfortunate that the well ends in this sand at a depth of 1,244 feet, for if it had gone down into the underlying formation, it might have been possible to establish definitely whether or not the Pamunkey beds are identical with the Manasquan and Rancocas. The only fossils mentioned from the "Pamunkey" horizon in the Wildwood well are the coral *Phacocyathus* and foraminiferal casts of glauconite. The only other suggestion known to the author of Pamunkey beds in New Jersey (prior to 1928) is Woolman's correlation with the basal Wildwood beds of a glauconitic deposit encountered between 955 and 1,095 feet in an Atlantic City well. This horizon is called "tentatively Miocene" by Mansfield, in his interpretation of the Young's Pier well.

SEDIMENTATION

The picture of deposition conditions of the Vincentown sand and limestone suggested to the writer by the foregoing account is one of slight emergence at the close of Hornerstown time, and then slow submergence, proceeding more rapidly toward the southeast, so that there was a progressive overlap toward the west. The overlap is not marked toward the southeast where deposition was under deep water. Near the old shoreline, however, the Vincentown is represented by thin beds of sand with a basal layer containing pebbles and broken shells of *Terebratula harlani* Morton which have probably been reworked from the top bed of the Hornerstown. Such a bed may be seen near Barnsboro.

The old shoreline did not conform with the present line of outcrop, the strike of which is about N. 55° E; for the shallow water, sandy facies and the deeper water facies with bryozoa may both be seen along that line.

Weller believed that the variations in sedimentation were due to minor oscillations of the sea bottom. Clark, Berry and Gardner, writ-

[138] Woolman, Lewis, Artesian Wells, Geol. Surv. of N. J., Ann. Rep't. for 1894, p. 178, Pl, 5.

ing on the Upper Cretaceous of Maryland, discard that idea and suggest that the different facies were caused by the varying proximity of stream mouths and sediment-bearing currents. It seems likely that the latter explanation could account for the sandy and limy lentils of the Vincentown formation, but that the changes from greensand beds to quartz and limesand beds and back to greensand, between the Hornerstown and Vincentown and Manasquan, must have been caused by changes in the depth of the sea bottom.

Bryozoa flourish usually at a depth between 100 and 300 feet, whereas glauconite is seldom formed at a depth less than 600 feet. Therefore, there must have been oscillations of at least 300 feet. The sandier, near-shore beds of the Vincentown, without bryozoa, may have been formed in less than 100 feet of water, while the glauconite may have been deposited at a depth of 1,200 feet or more.

Such great changes in depth and type of deposition leave little doubt in the mind of the author that the Hornerstown and Vincentown are distinct formations and not merely members of the Rancocas formation. The Rancocas in New Jersey must definitely represent a group, if the term is to be retained in the State. The fact that Rancocas is used as a formation name in Delaware, although the type locality is in New Jersey, indicates that the name should not be discarded. It must, therefore, be established as a group name, together with Monmouth and Matawan. These three names are little used by the State Survey, but their relations should be established as follows:

Cretaceous and Eocene Formations of New Jersey

System	*Series*	*Group*	*Formation*
Tertiary	Eocene		Shark River marl Manasquan marl
		Rancocas	Vincentown formation Hornerstown marl
Cretaceous	Upper Cretaceous	Monmouth	Tinton sand Red Bank sand Navesink marl Mount Laurel sand
Cretaceous	Upper Cretaceous	Matawan	Wenonah sand Marshalltown formation Englishtown sand Woodbury clay Merchantville clay
		?	Magothy formation Raritan formation

It is proposed that the Vincentown be called "Vincentown formation" rather than Vincentown sand, limesand or limestone, because no one of those terms covers all the lithology of the formation. Sand, limesand, limestone and sandstone all form a part of the Vincentown formation. It is questionable whether the different facies should be called members, lentils or tongues. As the author believes they are somewhat lenticular, the term lentil has been employed occasionally in this report. There seems to be no need to assign names to these lentils.

The rate of sedimentation must have varied almost as much as the types of deposited material during the time that the Vincentown beds were being laid down.

The bryozoa alone offer conflicting evidence, as may be seen from two statements by Canu and Bassler:

(1) Concerning fragments of *Coscinopleura digitata* Morton:

". . . as the incrustation is never very thick, we must conclude that the sedimentation was rapid and that all these fragments were rapidly covered and fossilized."[139]

(2) Concerning *Hippaliosina aspera* Gabb and Horn:

"The largest colony observed measures 3cm. in length and contains five superposed lamellae. As it surrounds some fragment that rested on the sea bottom, sedimentation must have been very slow."[140]

The average temperature of the water, as estimated by Canu and Bassler, was about 20° C. The depth of deposition of the strata containing bryozoa may have been anywhere between 75 and 300 feet. It must have been deep enough to escape the action of the waves and have clear water, but current action was necessary to provide the bryozoans with food.

Actual contacts of the Vincentown with the Hornerstown and Manasquan are hard to find, but the condition of overlap implies that the lowest beds of the Vincentown are not represented along the line of outcrop. After the close of Shark River time the beds were tilted and eroded prior to deposition of the Miocene or later deposits which now rest on the Vincentown; therefore, it is probable that some of the top beds of the Vincentown have been removed. The average thickness of 25 to 70 feet, therefore, probably represents only the middle portion of the Vincentown beds. The thickness of 460 feet found in the well at Atlantic City probably includes the whole formation.

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[139] Canu and Bassler, op. cit., p. 45.
[140] *Ibid.*, p. 81.

PALEONTOLOGY

THE BRYOZOA AND THEIR IMPORTANCE IN CORRELATION

Canu and Bassler have recognized 85 species of bryozoa from the Vincentown limesand.[141] They have failed to find ten of the species described by Gabb and Horn.[142] There have then been at least 85 species described or identified prior to this paper. The author in a study of Vincentown bryozoa from Vincentown and from a well at Farmingdale, together with small collections from other localities, has recognized 60 of the described species.

A study has been made of the Cretaceous and Tertiary affinities of the Vincentown bryozoa. Nine species are common to the Vincentown and the Aquia formation (Eocene) of Maryland. These are:

Coscinopleura digitata Morton
Ellisinidra heteropora Gabb and Horn
Euritina torta Gabb and Horn
Hippaliosina aspera Gabb and Horn
Membraniporella modesta Ulrich
Lekythiona dichotoma Gabb and Horn
Plagioecia subramosa Ulrich
Plagioecia varians Ulrich
Stamenocella cylindrica (?) Canu and Bassler

A comparison of the species found in the Rancocas group of Delaware with the Vincentown formation of New Jersey and the Aquia of Maryland gives these results:

30 Species of bryozoa identified (Canu and Bassler, 1933)
6 species confined to Delaware
2 species common to Vincentown, Aquia and Rancocas of Delaware

Ellisinidra heteropora Gabb and Horn
Hippaliosina aspera Gabb and Horn

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141 Canu, Ferdinand and Bassler, Ray S. op. cit., pp. 6-8.

142 Gabb, W. H. and Horn, G. H., Monograph of the Fossil Polyzoa of the Secondary and Tertiary Formations of North America, Journ. Acad. Nat. Sci., Phila., Pa. ser. 2, vol. 5. pp. 111-178, 1862.

It is surprising that only two of the nine Vincentown species found in the Aquia beds of Maryland occur in the Rancocas formation of Delaware. Another surprising feature of the Delaware fauna is the absence of such typical Vincentown forms as *Coscinopleura digitata* Morton and *Euritina torta* Gabb and Horn, both of which are present in the Aquia formation. This suggests that conditions in Delaware must have been quite different from those in New Jersey and Maryland.

The writer has no first-hand knowledge of the Delaware deposits but from reading it has been learned that the characteristic New Jersey species of pelecypods are missing in the Delaware Rancocas. These are *Cardium knappi* Weller, *Caryatis veta* Whitfield, and *Polorthus tibialis* Morton.[143] The most characteristic of the Delaware forms—a small *Gyphaea, Yoldia noxontownensis* and *Phacoides noxontownensis* are not known in New Jersey.[144] It is suggested that the Rancocas formation of Delaware represents a fossil oyster bank where the ensemble of life was, as today, very different from the fauna a short distance away.[145] It seems reasonable to the author that such an environmental barrier might also explain why the Vincentown and Aquia formations have not more species in common, if it is true that they are equivalent in age. Only the more hardy forms, such as *Coscinopleura digitata* Morton and *Terebratula harlani* Morton would have been able to get around or through the place where conditions of deposition, food supply and possibly temperature were so different from those in New Jersey and Maryland.

The Delaware bryozoa are all encrusting forms. This suggests that the water may have been shallower than in New Jersey, where it was deep enough (200 to 300 feet) for the growth of large, erect, branching colonies such as *Coscinopleura digitata* Morton and *Euritina torta* Gabb and Horn.

The presence of such a barrier between New Jersey and Maryland makes plausible the lithological and paleontological differences between the Vincentown and Aquia beds, but at the same time it makes positive correlation difficult.

No Eocene formation other than the Aquia has bryozoan species identical with those of the Vincentown so far as the writer is aware. Cooke has correlated the Black Mingo formation of South Carolina

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143 Clark, W. B., Berry, E. W. and Gardner, J. A.: Upper Cretaceous, Maryland Geol. Surv. p. 323, 1916.

144 *Ibid.*, pp. 75, 91.

145 *Ibid*, p. 75.

with the Aquia and the Rancocas beds, and lists bryozoa among its fossils, but gives no specific nor generic determination.[146]

On the other hand, as far as the writer knows there is no Cretaceous formation in North America that contains Vincentown bryozoa. A few colonies of bryozoa have been found in the Wenonah sand and the Navesink marl of New Jersey, but they are not species found in the Vincentown. The Cretaceous rocks of France have two species identical with forms in the Vincentown formation. These are *Alderina rustica* D'Orbigny and *Lichenopora papyracea* D'Orbigny. Two species related to *Exochella septentrionalis* Canu and Bassler have been found in the Rocanean of Argentina.[147] This is another formation placed indefinitely between the Cretaceous and the Tertiary.

The fact that the Cretaceous beds of America lack bryozoa in any numbers,[148] while in Europe the bryozoa of the Lower Eocene are unknown,[148A] makes any comparison with the fauna of the Vincentown incomplete. A study of the genera found in the Vincentown formation with those of the European Cretaceous and the American Tertiary yields the following information:

CHEILOSTOMATA	
(a) Allied closely with Cretaceous	17 genera
(b) Allied closely with Tertiary	16 genera
(c) Indeterminate	16 genera
CYCLOSTOMATA	
(a) Allied closely with Cretaceous	3 genera
(b) Allied closely with Tertiary	2 genera
(c) Indeterminate	16 genera

Two or three genera are listed under both Cretaceous and Tertiary as they have strong affinities with both. A detailed list follows:

Bryozoa Indicating Correlation with:

CRETACEOUS	TERTIARY
CHEILOSTOMATA	
Vincularia	*Membranipora*
Alderina rustica D'Orbigny	*Ellisinidra heteropora* Gabb and Horn

[146] Cooke, C. Wythe, Geology of the Coastal Plain of South Carolina, U. S. Geol. Survey Bull. 867, Washington, 1936, p. 40.

[147] Canu and Bassler, op. cit., p. 80.

[148] *Ibid.*, p. 1.

[148A] Canu and Bassler, American and European Tertiary Bryozoa, Geol. Soc. Amer. Bull., vol. 35, 1924, p. 847.

Allantopora

Crassimarginatella
Floridina

Micropora (?) pulchra Ulrich and Bassler
Mollia
Monoporella (?)

Coscinopleura digitata Morton
Pliophloca

Rhiniopora
Hesperopora
Stichocados
Diacanthopora (?)
Dacryopora
Psilesecos
Eschariopora (?)

Stamenocella oculata Ulrich and Bassler
Periporosella
Euritina torta Gabb and Horn
Floridina

Micropora
Coscinopleura digitata Morton
Kelostoma
Tricephalopora acutirostris Canu and Bassler
Hippothoa
Diplotresis
Exochella
Perigastrella
Hippaliosina
Kleidionella

CYCLOSTOMATA

Lichenopora papyracea D'Orbigny
Retelea
Discocytis

Lekythiona

Callopora (?)

Genera of little help in determining Cretaceous or Tertiary Age

CHEILOSTOMATA

Aplousina
Cranosina
Callopora
Amphiblestrum
Rhagasostoma
Setosinella
Lagynopora
Aelopora
Distansescharella
Nannopora
Rhiniopora
Tricephalopora
Polycephalopora
Anornithopora
Beisselina
Acanthionella

CYCLOSTOMATA

Stomatopora
Entalophora
Mecynoecia
Oncousoecia
Plagioecia
Stathmepora
Diaperoecia
Diplosolon
Idmonea
Filifascigera
Crisina
Spiropora
Reptomulticava
Reticulipora
Flustrella (?)
Acerviclausa (?)

The results are remarkably even, with 20 genera or species suggesting a Cretaceous age, as against 17 that imply a Tertiary (Eocene) age. Thirty-two genera are of little help in deciding to which period the Vincentown should be assigned. The Cyclostomata are less helpful than the Cheilostomata.

A majority of three genera for the Cretaceous does tend to suggest that as the age of the formation. On the other hand, nine Vincentown species have been found in Eocene rocks, as opposed to two species in the Cretaceous. The fact that the latter are found in the uppermost Cretaceous rocks of Europe, while the Eocene species are found in Maryland, lends support to the belief that the Vincentown formation is of Eocene age. The problem of time versus space is involved, and suggests the question: by the time that European Danian species reached New Jersey, were those same forms still living in their place of origin, or had they been superseded by Tertiary species? This is a question involved in establishing the boundary between any two periods in different places around the world. *Alderina rustica* D'Orbigny is characterized by a great many ovicells, so that free-swimming larvae were probably being produced constantly. Therefore the same species might well exist contemporaneously on both sides of the Atlantic Ocean. The same characteristic of numerous ovicells, however, would contribute to the survival of a species at a time when other species were being extinguished. *Alderina rustica* is found only rarely in the Vincentown, and so it seems likely that those specimens might represent the last hardy survivors of a decadent fauna.

CORRELATION ON BASIS OF OTHER FOSSILS

The question of the age of the Vincentown formation cannot be settled by means of the bryozoa alone. Cooke and Stephenson, in proposing the Eocene age of the formation, based their conclusions on the absence of typical Cretaceous species or genera, and on the presence of forms with Eocene affinities.[149] The Cretaceous mollusks that are cited as being absent are *Inoceramus, Exogyra, Trigonia, Sphenodiscus, Scaphites, Belemnitella* and *Baculites*. These genera are also lacking in the Danian deposits, as has been said by Scott,[150] writing on the "Age of the Midway Group" of the Gulf Coastal Plain.

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[149] Cooke, C. Wythe and Stephenson, Lloyd W., The Eocene Age of the Supposed Late Upper Cretaceous Greensand Marls of New Jersey, Journal of Geology, vol. 36, 1928, pp. 139-148.

[150] Scott, Gayle, Age of the Midway Group, Bull. Geol. Soc. Am., vol. 45, 1934, pp. 1151-1152.

The positive evidence of the marls' Eocene age is more convincing than the negative. It includes the presence of Eocene corals; the resemblance of *Serpula rotula* Morton to a Texan Eocene *Serpula*; casts of *Venericardia* of the *planicosta* group; the presence of an Eocene snake; probable Eocene affinities of foraminifera, echinoids, gastropods and nautiloids; the presence of three Aquia ostracods; the identity of nine bryozoan species with Aquia forms; the presence in the Maryland Eocene of *Gryphaea dissimilaris* Weller (variety of *G. Vesicularis* Lamarck) and *Gryphaeostrea vomer* Morton—the only species which are found both below and above the base of the Hornerstown.

Later work has added additional evidence for the Eocene age of the Hornerstown, Vincentown and Manasquan. Wetmore believes it more logical that the birds found in the Hornerstown and Manasquan should be Eocene than Cretaceous, as they have been classified under modern families, and it is not probable that they had teeth as was general with Cretaceous birds.[151]

Stephenson has found *Kümmelia americana* Gabb in the Aquia formation of Maryland as well as in the Vincentown limesand.[152] He states also that the conclusions of Jennings, "based on the microfauna of the Monmouth group and of the Hornerstown marl . . . add confirmatory evidence of the Eocene age of the Hornerstown,[153] and, accordingly, of the Vincentown.

Mook's studies of the crocodilian fauna of the Hornerstown marl have led him to believe it is a Paleocene formation.[154] This is not in accordance with the conclusions of Cooke and Stephenson that the Hornerstown, Vincentown, Manasquan and Shark River formations should be correlated through the Pamunkey Group of Maryland, with the Wilcox and Claiborne groups of the Gulf Coast Eocene. These are classified as Lower Eocene (Sparnacian and Ypresian) and not with the Paleocene (Montian and Thanetian).

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151 Wetmore, Alexander, "The Age of the Supposed Cretaceous Birds from New Jersey," Auk, vol. no. 2, 1930, pp. 186-188.

152 Stephenson, L. W., "The Stratigraphic Significance of Kümmelia, a New Eocene Bivalve Genus from New Jersey, Journ. Wash. Acad. Sci., vol. 27, no. 2, 1937, pp. 58-64.

153 *Ibid.*, p. 60. The writer has not been able to obtain a copy of the paper by Philip H. Jennings, A Microfauna from the Monmouth and Basal Rancocas Groups of New Jersey, Bull. Am. Paleontology 23 (78), pp. 3-76, 1936.

154 Dr. Charles C. Mook, personal communication.

LISTS OF BRYOZOA FROM THE VINCENTOWN FORMATION

Those identified by the Author

(V—Vincentown; F—Farmingdale; M—Medford; Ma—Mannington; B—Blackwood; C—Clementon; N—New Egypt.)

CHEILOSTOMATA

Acanthionella typica Gabb and Horn (V, F)
Aelopora grandis Canu and Bassler (V)
Alderina rustica D'Orbigny (V, F)
Allantopora annuloidea Ulrich and Bassler (F)
Allantopora irregularis Gabb and Horn (F, Ma)
Amphiblestrum (?) abortivum Gabb and Horn (V, F, Ma)
Aplousina contumax Canu and Bassler (V)
Aplousina disjuncta Gabb and Horn (F)
Beisselina intermedia Canu and Bassler (V, F)
Beisselina labiata Gabb and Horn (V, F)
Beisselina lonsdalei Canu and Bassler (F)
Beisselina mortoni Canu and Bassler (V, F)
Callopora jerseyensis Ulrich and Bassler (V, F)
Callopora noxontownensis Canu and Bassler (F?)
Coscinopleura digitata Morton (V, F, M, Ma, B)
Cranosina altimuralis Ulrich and Bassler (V, F, Ma)
Crassimarginatella intermedia Canu and Bassler (V, F, M)
Dacryopora (?) orbifera Canu and Bassler (F?)
Diacanthopora distans Gabb and Horn (F)
Diplotresis sparsiporosa Ulrich and Bassler (F)
Distanseschavella pumila Gabb and Horn (V, F)
Ellisinidra heteropora Gabb and Horn (F, Ma)
Euritina torta Gabb and Horn (V, F, C, B)
Exochella septentrionalis Canu and Bassler (V, F)
Hippaliosina aspera Gabb and Horn (V, Ma C)
Hippothoa tenuichorda Ulrich and Bassler (V, F, Ma)
Membraniporella modesta Ulrich (F?)
Membraniporidra perampla Gabb and Horn (V, F)
Micropora ogivalina Canu and Bassler (V, F)
Micropora parva Canu and Bassler (V)
Mollia lacessitor Canu and Bassler (V)
Mollia parvicella Canu and Bassler (Ma)
Monoporella (?) vincentownensis Ulrich and Bassler (F)
Perigastrella exserta Gabb and Horn (V, F)
Periporosella (?) plebeia Gabb and Horn (F)

Pliophloea sagena Morton (V, F, Ma)
Pliophloea ventricosa Canu and Bassler (V)
Polycephalopora birostrata Canu and Bassler (V)
Psilesecos muralis Gabb and Horn (V, F)
Rhiniopora parvirostrata Canu and Bassler (F)
Setosinella prolifica Canu and Bassler (F?)
Stamenocella oculata Ulrich and Bassler (V)
Stichocados mucronatus Canu and Bassler (N)
Tricephalopora incrassata Canu and Bassler (F)
Tricephalopora prolifica Gabb and Horn (F)

CYCLOSTOMATA

Diaperoecia americana Gabb and Horn (V, F)
Diplosolon lineatum Gabb and Horn (V, F)
Discocytis eccentrica Ulrich and Bassler (V, F)
Filifascigera meguera Lonsdale (V, F, Ma)
Idmonea abbotti Gabb and Horn (V, F, N)
Leiosoecia parvicella Gabb and Horn (V, M, N)
Lekythiona dichotoma Gabb and Horn (V)
Lichenopora papyraces D'Orbigny (V, F, Ma)
Mecynoecia (Entalophora) conradii Gabb and Horn (V, F)
Oncousoecia bifurcata Ulrich and Bassler (V)
Oncousoecia contortilis Lonsdale (V, F)
Plagioecia americana Ulrich and Bassler (V, F, Ma)
Plagioecia subramosa Ulrich (F)
Plagioecia varians Ulrich (V)
Retelea ovalis Gabb and Horn (V, F)
Stathmepora gabbiana Ulrich and Bassler (V, F)
Stomatopora kümmeli Ulrich and Bassler (V, F, Ma)
Stomatopora regularis Gabb and Horn (V, F)

Bryozoan Species Reported by Others from the Vincentown Formation but not Identified by the Author

Canu and Bassler (1933)

CHEILOSTOMATA

Alderina welleri Canu and Bassler
Crassimarginatella nematoporoides Ulrich and Bassler
Diacanthopora abbottii Gabb and Horn
Diacanthopora convexa Canu and Bassler
Diacanthopora marginata Gabb and Horn

Distansescharella lata Canu and Bassler
Floridina subscutata Canu and Bassler
Hesperopora occidentalis Lang
Kelostoma simplex Canu and Bassler
Kleidionella (?) trabeculifera Canu and Bassler
Lagynopora americana Canu and Bassler
Membranipora nellioides Canu and Bassler
Micropora cylindraces Ulrich and Bassler
Micropora (?) pulchra Ulrich and Bassler
Monoporella (?) laticella Canu and Bassler
Nannopora (?) minimora Canu and Bassler
Pliophloea elegans Canu and Bassler
Rhagasostoma americana Canu and Bassler
Rhiniopora tubulosa Canu and Bassler
Stichocados compositus Lang
Tricephalopora acutirostris Canu and Bassler
Vincularia acutirostris Canu and Bassler

CYCLOSTOMATA

Diaperoecia saillans Canu and Bassler

Gabb and Horn (1860)
Acerviclausa vermicularis
Cellopora bilabiata (changed to C. prolifica in 1862)
Cellopora carinata
Reticulipora sagena
Reptomulticava cepularis

(1862)

Cellopora prolifica (*C. bilabiata* of 1860)
Entalophora quadrangularis (possibly *Ochetosella jacksonica* of the Eocene)
Escharipora immersa
Flustrella capistrata (possibly *Stamenocella oculata* Ulrich and Bassler, 1907)
Spiropora calamus

Lonsdale (1845)
Cellopora tubulata (probably *Leiosoecia parvicella* Gabb and Horn)

Ulrich and Bassler (1904)
Crisina striatopora (Vincentown identification believed erroneous; species occurs in Miocene of Maryland)

The information given above is compiled from:

Canu, F., and Bassler, R. S., The Bryozoan Fauna of the Vincentown Limesand, U. S. Nat. Mus. Bull. 165, Washington, 1933.

Gabb, W. H., and Horn, G. H., Descriptions of New Cretaceous Corals from New Jersey, Proc. Acad. Nat. Sci. Philadelphia, Vol. 12, pp. 366-367, 1860.

Monograph of the Fossil Polyzoa of the Secondary and Tertiary Formations of North America, Jour. Acad. Nat. Sci. Philadelphia, ser. 2, Vol. 5, pp. 111-178, 1862.

Lonsdale, William, Account of Six Species of Polyparia Obtained from Timber Creek, New Jersey, Quart. Jour. Geol. Soc. London, Vol. 1, pp. 65-75, 1845.

CONCLUSIONS

The following conclusions have been reached in the course of this study:

1. The Vincentown sand and limestone is a unit of formational rank. It should probably be classed with the Hornerstown marl in the Rancocas group. The identity of many Manasquan species with those of the two lower formations suggests that it, too, should be a part of the Rancocas group. The Manasquan marl occurs in Rancocas Valley near Vincentown so that its classification under that name would not be inappropriate.

2. The bryozoa of the Vincentown formation do not offer positive proof of its stratigraphic position. The even distribution of Cretaceous and Tertiary forms suggests a transition period. The evidence is slightly heavier on the side of the Maestrichtian and Danian than the Eocene.

3. Most of the Vincentown fauna is indicative of the Eocene as its time of origin. The slight inclination of the bryozoans toward the Cretaceous does not seem sufficient to outweigh the evidence of the other forms.

4. The Vincentown formation is of early Tertiary age. The author has formed no conclusions as to whether it should be called Eocene or Paleocene.

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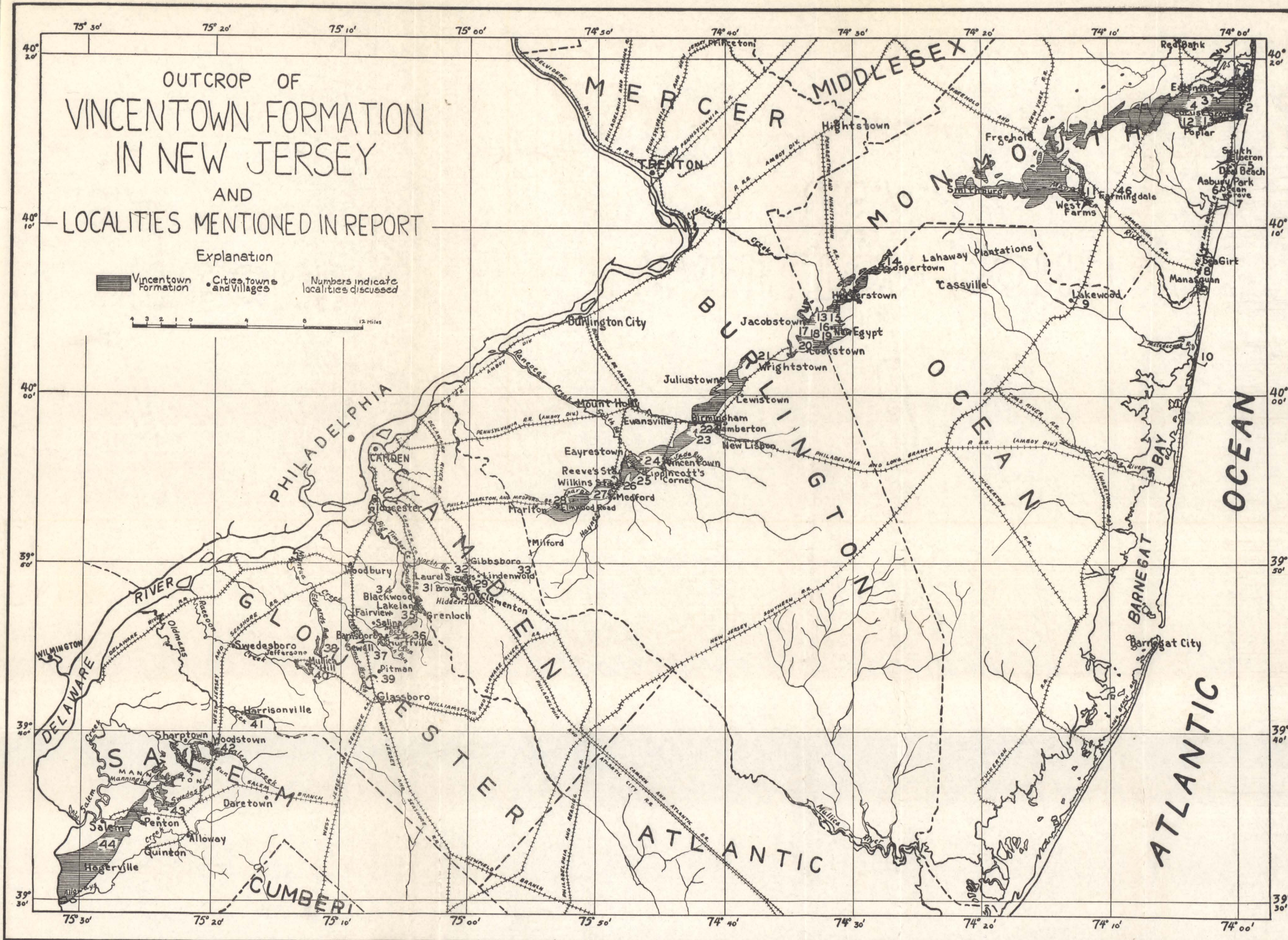
OUTCROP OF
VINCENTOWN FORMATION
IN NEW JERSEY
AND
LOCALITIES MENTIONED IN REPORT
Explanation
Vincentown Formation
Cities, towns and Villages
Numbers indicate localities discussed
12 Miles
MERCER
MIDDLESEX
MONMOUTH
BURLINGTON
OCEAN
CAMDEN
GLOUCESTER
SALEM
ATLANTIC
CUMBERL
PHILADELPHIA
ATLANTIC OCEAN
DELAWARE RIVER
BARNEGAT BAY
Trenton
Princeton
Hightstown
Freehold
Red Bank
Eatontown
Poplar
Asbury Park
Farmingdale
West Farms
Lakewood
Manasquan
Sea Girt
Cassville
Lahaway Plantations
Hornerstown
Jacobstown
New Egypt
Cookstown
Wrightstown
Juliustown
Lewistown
Birmingham
Pemberton
New Lisbon
Burlington City
Mount Holly
Evansville
Eayrestown
Vincentown
Reeve's Sta.
Wilkins Sta.
Lippincott's Corner
Medford
Marlton
Milford
Camden
Gloucester
Woodbury
Gibbsboro
Laurel Springs
Lindenwold
Clementon
Blackwood
Grenloch
Fairview
Sewell
Pitman
Glassboro
Swedesboro
Harrisonville
Sharptown
Woodstown
Daretown
Salem
Penton
Alloway
Quinton
Hagerville
Wilmington
Barnegat City
Mullica River