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PLEISTOCENE DIATOMS FROM LONG ISLAND, NEW YORK

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PLEISTOCENE DIATOMS FROM LONG ISLAND NEW YORK

BY

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CONTENTS

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By K. E. Lohman

ABSTRACT

A large number of samples from wells and outcrops on Long Island, N. Y., were examined for diatoms as part of a Public Works Administration project to study the ground-water supplies of the vicinity of New York. Diatoms were found in only four samples from one well and in two outcrop samples. All three diatom floras indicate deposition under near-shore marine conditions during a mild climate similar to the present. As all the species, with one exception, are represented in living floras in about the same latitude, an age no older than some interglacial stage of the Pleistocene is indicated. The similarity of the diatom floras suggests contemporaneous deposition, and a tentative correlation of the Gardiners clay (from which the outcrop samples came) with the Cape May formation of New Jersey is proposed. No evidence was revealed by these floras for the existence of Miocene beds on Long Island.

INTRODUCTION

During January and a part of March 1934 I examined a large number of samples from wells and outcrops on Long Island, N. Y., for diatoms. The work was done as part of a Public Works Administration project to study ground-water supplies of the vicinity of New York; and particularly to study problems of the geologic correlations and continuity of the water-bearing and non-water-bearing formations on Long Island and in nearby parts of New Jersey.

Macroscopic fossils are rare and in fact almost entirely absent in most of the sedimentary beds on Long Island. Early reports by Ries [1] and Edwards [2] indicated, however, that fossil diatoms had been found in Cretaceous and Tertiary beds. As there were no other authentic records of Miocene rocks on Long Island, it was desirable to check the reports of their occurrence and to seek further evidence bearing on the question. The present work has shown that there were errors in the age determination of these early occurrences, which are discussed later in this report. The fact that diatoms occur in some of the surface sediments on Long Island suggested that they might furnish a basis for determining general age relations and also might be of use in correlating the various beds in the different wells.

A total of 222 samples from 30 wells and 11 outcrop localities were cleaned and the diatoms, if any, concentrated and studied. Several hundred other samples from the same wells were rejected after brief inspection indicated that they consisted of clean washed sand or gravel and hence were not at all likely to contain diatoms. Out of this large number of samples, diatoms were found in only four samples from one well and in two outcrop samples.

ACKNOWLEDGMENTS

D. G. Thompson and F. G. Wells, of the Geological Survey, collected the samples and supplied much information based on their studies of the geology of Long Island extending over several years. I am also indebted to Dr. H. B. Kümmel, State geologist of New Jersey, for supplying samples from New Jersey wells used for comparison, and to Dr. C. P. Berkey, of Columbia University, for supplying samples from the Brooklyn tunnel, New York.

SUMMARY

As the result of the studies of the diatom floras found in samples of the Gardiners clay from the Sag Harbor well, a sample from an outcrop near Montauk Lighthouse, and samples from the Brooklyn tunnel, the following conclusions are offered:

1. All three floras were deposited under marine conditions, either near the shore or in lagoons or bays.
2. With only one exception the diatoms are represented in living floras, indicating an age no older than Pleistocene.
3. All three floras indicate a mild climate similar to the present, suggesting an interglacial stage of the Pleistocene.
4. Contemporaneous deposition seems probable, but the evidence is insufficient for proof, as, with the one exception mentioned above, all the floras contain only living species.
5. The close similarity of the Long Island floras to those found in the Cape May formation, as represented in the New Jersey wells, suggests a correlation of the two sets of deposits, though such a correlation must be only tentative, for the reason cited in paragraph 4.

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[1] Ries, Heinrich, Microscopic organisms in the clays of New York State: New York Acad. Sci. Trans., vol. 13, pp. 165–169, plates 1–4, 1894.

[2] Edwards, A. M., Fossil marine Bacillariaceae on Long Island, New York: Am. Monthly Micr. Jour., vol. 17, pp. 52–57, 1896; On the occurrence of Neocene marine Diatomaceae near New York: Am. Naturalist, vol. 30, pp. 212–216, 1896.

6. No evidence of the existence of Miocene beds was found in any of the wells studied.

SAMPLES CONTAINING DIATOMS

The samples described below were found to contain diatoms. The numbers at the left are United States Geological Survey diatom-locality numbers. Brief lists of the barren samples will be found in the appendix at the end of this report. The samples are:

1795–98. Well S184,[3] Sag Harbor, Long Island, N. Y. Depths from 275 to 295 feet.

1800. Sample collected by F. G. Wells from an outcrop believed to be the Gardiners clay, on the south shore of Long Island, half to three-quarters of a mile west of Montauk Lighthouse.

1828. Sample from tunnel 2, City of New York, Board of Water Supply, 68 to 104 feet below sea level. (Details on p. 232.)

In addition to the above, samples from several New Jersey wells were kindly supplied by Dr. H. B. Kümmel and were examined for purposes of comparison. No lists of species are given here for these wells, as they are outside the scope of the present report. Lists were given for the first three wells in annual reports of the State geologist of New Jersey and are referred to below. These wells are:

Well 198–A. Wildwood, Holly Beach, N. J., depth 35 to 160 feet (5 samples).

Well 196–A. Avalon, Sevenmile Beach, N. J., depth 70 to 230 feet (3 samples).

Well 187–A. Atlantic City, N. J., depth 84 to 258 feet (18 samples).

Well 122–A. Sandy Hook, N. J., depth 125 and 135 feet (2 samples).

DIATOMS FROM LONG ISLAND, THEIR ECOLOGIC FACIES AND GEOLOGIC AGE

Sag Harbor well.—Four samples from the Sag Harbor well yielded diatoms, as follows:

Well S184, Sag Harbor, Long Island, N. Y.:
- 275–280 feet, Geol. Survey diatom locality 1795.
- 280–285 feet, Geol. Survey diatom locality 1796.
- 285–290 feet, Geol. Survey diatom locality 1797.
- 290–295 feet, Geol. Survey diatom locality 1798.

These four samples consisted of fine greenish-gray clayey sand containing numerous diatoms. The diatoms were identified from each sample separately, but as no significant differences were observed, the four samples have been considered as one. The species found are as follows:

Melosira ambigua (Grunow) Müller. Rare.
Melosira fausta Schmidt. Frequent.
Melosira recedens Schmidt. Frequent.
Melosira sulcata (Ehrenberg) Kützing. Common.
Melosira sulcata var. coronata (Ehrenberg) Grunow. Frequent.
Hyalodiscus cf. H. laevis Ehrenberg. Frequent.
Podosira stelliger (Bailey) Mann. Frequent
Cyclotella cf. C. caspia Grunow. Rare.
Cyclotella striata (Kützing) Grunow. Frequent.
Coscinodiscus apiculatus Ehrenberg var. ambigua Grunow Frequent.
Coscinodiscus curvatulus Grunow var. densius-striata Schmidt. Rare.
Coscinodiscus excentricus Ehrenberg. Common.
Coscinodiscus kurzii Grunow. Rare.
Cocsinodiscus nitidus Gregory. Frequent.
Endictya robusta (Greville) Hanna and Grant. Frequent.
Xanthiopyxis oblonga Ehrenberg. Common.
Xanthiopyxis sp. Common.
Actinoptychus undulatus Ehrenberg. Common.
Aulacodiscus argus (Ehrenberg) Schmidt. Rare.
Actinocyclus ehrenbergii Ralfs. Frequent.
Actinocyclus ehrenbergii var. crassa (W. Smith) Hustedt. Frequent.
Auliscus pruinosus Bailey. Frequent.
Auliscus cf. A. grunowii Schmidt. Rare.
Rhizosolenia sp. Rare.
Liradiscus minutus Greville. Frequent.
Liradiscus ovalis Greville. Rare.
Liradiscus sp. Frequent.
Syndendrium diadema Ehrenberg. Frequent.
Hercotheca mammillaris Ehrenberg. Frequent.
Triceratium reticulum Ehrenberg. Frequent.
Rhabdonema sp. Frequent.
Grammatophora oceanica var. macilenta (W. Smith) Grunow. Frequent.
Dimerogramma fulvum (Gregory) Ralfs. Rare.
Plagiogramma sp. Rare.
Rhaphoneis amphiceros Ehrenberg. Rare.
Rhaphoneis amphiceros var. rhombica Grunow. Rare.
Opephora schwartzii (Grunow) Petit. Rare.
Cocconeis diminuta Pantocsek. Rare.
Cocconeis scutellum Ehrenberg. Rare.
Cocconeis scutellum var. baldjikiana Grunow. Rare.
Cocconeis scutellum var. ornata Grunow. Rare.
Cocconeis quarnerensis (Grunow) Schmidt. Frequent.
Campyloneis cf. C. grevillei (Wm. Smith) Grunow. Rare.
Amphora ovalis Kützing var. gracilis (Ehrenberg) Grunow. Rare.
Diploneis cf. D. aestiva (Donkin) Cleve. Rare.
Diploneis bombus Ehrenberg. Frequent.
Diploneis constricta (Grunow) Cleve. Rare.
Diploneis papula (Schmidt) Cleve. Rare.
Diploneis smithii (Brebisson) Cleve. Frequent.
Diploneis sp. Rare.
Navicula hennedyi W. Smith. Rare.
Navicula irrorata Greville. Rare.
Navicula lyra Ehrenberg. Rare.
Navicula pennata Schmidt. Frequent.
Navicula wittii Grunow. Rare.
Pinnularia sp. Rare.
Pleurosigma sp. Rare.
Rhopalodia cf. R. gibberula (Ehrenberg) Müller. Rare.
Nitzschia cf. N. granulata Grunow. Rare.
Nitzschia sp. Rare.
Surirella fastuosa Ehrenberg. Frequent.

The forms above listed make up an assemblage of marine and brackish-water diatoms such as might be found today in a lagoon or bay partly closed by a bar. The water was sufficiently saline to favor the growth of marine forms and to inhibit almost completely the growth of fresh-water and brackish-water forms.

[3] Records of wells, Suffolk County, N. Y.: New York Dept. Cons., Water Power and Control Comm., Bull. GW-4, pp. 90-91, 1938.

Only one species in the assemblage, *Melosira ambigua*, is found at present only in fresh water. As only one lone valve was found in the Sag Harbor well samples, most probably it was carried into the basin of deposition by some small stream, and hence its presence has little or no ecologic significance. Species that now live under truly marine conditions dominate the assemblage, with the remainder made up of forms which live in both marine and brackish water.

Melosira recedens Schmidt, the only extinct species in the flora, was first reported [4] from the Eocene Cementstein on the island of Mors, Jutland. I have also found it in the San Joaquin formation, of Pliocene age, in the Kettleman Hills, Calif.[5] In California it is known only from the Pliocene, and the Long Island occurrence extends the known geologic range of this diatom from Eocene to Pleistocene. As all the other diatoms in the Long Island flora are represented in living floras in about the same latitudes, the presence of this one long-ranging species does not appear to have much age significance. An age no older than Pleistocene is therefore indicated for the beds. The very small number of cold-water species present strongly indicates an interglacial stage.

Woolman [6] observed diatoms in material obtained at depths of 70 to 100 feet in a well bored at Avalon, N. J., and the diatoms were identified by C. S. Boyer. This diatom assemblage contained 21 species, 52 percent of which also occur in the Sag Harbor well. The marked similarity in these two diatom assemblages is strongly suggestive of contemporaneous deposition, although two different interglacial stages may be represented by these floras.

Woolman [7] also published a list of diatoms found in samples obtained at depths ranging from 78 to 181 feet in a well bored at Wildwood, N. J. (about 10 miles south of Avalon), and correlated the flora with that occurring in the Avalon well. The diatoms found in the Avalon well were all marine, but about 80 percent of those found in the Wildwood well were fresh-water forms. Woolman suggested that the large influx of fresh-water forms at Wildwood was due to the influence of the Delaware River, which carried down large numbers of fresh-water forms, and this suggestion appears to be correct. Of the marine forms in the Wildwood well 50 percent are represented in the Sag Harbor well, a percentage which is in very close agreement with that obtained from the Avalon well.

Outcrop near Montauk Lighthouse.—One diatom-bearing sample was collected by F. G. Wells from an outcrop, believed to be the Gardiners clay, on the south shore of Long Island, half to three-quarters of a mile west of Montauk Lighthouse (U. S. G. S. diatom locality no. 1800). This sample consisted of a bluish to greenish-gray clay in which the following diatoms were identified:

Melosira distans (Ehrenberg) Kützing. Rare.
Melosira italica (Ehrenberg) Kützing var. valida Grunow Frequent.
Melosira sulcata (Ehrenberg) Kützing. Frequent.
Melosira undulata (Ehrenberg) Kützing var. normanii Arnott. Rare.
Stephanopyxis sp. Rare.
Cyclotella sp. Rare.
Coscinodiscus excentricus Ehrenberg. Rare.
Coscinodiscus lineatus Ehrenberg. Rare.
Coscinodiscus cf. C. radiatus Ehrenberg. Rare.
Thalassiosira sp. Rare.
Actinoptychus undulatus Ehrenberg. Frequent.
Actinocyclus ehrenbergii Ralfs. Rare.
Fragilaria pinnata Ehrenberg. Rare.
Rhaphoneis amphiceros Ehrenberg var. rhombica Grunow. Frequent.
Eunotia praerupta Ehrenberg. Rare.
Eunotia monodon Ehrenberg. Rare.
Cocconeis cf. C. placentula Ehrenberg. Rare.
Amphora sp. Rare.
Cymbella cistula (Hemprich) Kirchner. Rare.
Cymbella ventricosa Kützing. Rare.
Gomphonema acuminatum Ehrenberg var. coronata (Ehrenberg) W. Smith. Rare.
Gomphonema sp. Rare.
Didymosphenia cf. D. geminata (Lyngbye) M. Schmidt. Rare.
Caloneis trinodis (Lewis) Meister. Rare.
Caloneis ventricosa (Ehrenberg) Meister. Rare.
Diploneis smithii (Brebisson) Cleve. Rare.
Pinnularia dactylus Ehrenberg. Frequent.
Pinnularia sp. Rare.
Epithemia turgida (Ehrenberg) Kützing. Frequent.
Epithemia zebra (Ehrenberg) Kützing var. porcellus (Kützing) Grunow. Frequent.
Nitzschia circumsuta (Bailey) Grunow. Rare.
Nitzschia cf. N. tryblionella Hantzsch. Rare.
Campylodiscus echeneis Ehrenberg. Common.

This assemblage represents a mingling of marine, brackish-water, and fresh-water species in about equal proportions, all of which are living at present in the same region. The most logical inference that can be drawn from such an assemblage is that it was deposited in a lagoon or near the mouth of a small stream. A small stream is distinctly indicated rather than a large one, which would be expected to introduce a larger proportion of fresh-water species. This assemblage can be no older than Pleistocene and, as it represents climatic conditions similar to those of the present or even warmer, an interglacial stage is indicated.

As the flora from the Sag Harbor well is dominantly marine, the comparison of the well flora and the flora near Montauk should be made on the basis of marine species only. This method is not strictly accurate but is more nearly so than one including the nonmarine species. In each locality under consideration in this report, the diatom flora indicates deposition under marine conditions, in some places modified by the influx

[4] Schmidt, Adolf, Atlas der Diatomaceenkunde, pl. 176, fig. 54; pl. 177, figs. 62–64, 1892.

[5] Lohman, K. E., Pliocene diatoms from the Kettleman Hills, Calif.: U. S. Geol. Survey Prof. Paper 189–C, p. 82, pl. 22, figs. 13, 14, in 1938.

[6] Woolman, Lewis, Artesian well at Avalon, with notes on the tidal rise and fall of the water therein: New Jersey State Geologist Ann. Rept., 1898, pp. 78–83, 1899.

[7] Woolman, Lewis, Artesian well at Wildwood, N. J.: New Jersey State Geologist Ann. Rept., 1894, pp. 159–180, 1895.

of large numbers of fresh-water forms from nearby streams and in the beds near Montauk apparently modified by a distinctly brackish-water element. The fresh-water and brackish-water species represent local facies, whereas the marine elements form the more nearly constant part of the flora and are the ones which may have a time significance. On this basis, 66 percent of the marine species in the Montauk sample occur in the Sag Harbor well and 67 percent occur in the Pleistocene beds in the well at Wildwood, N. J., at depths of 78 to 181 feet. The high percentage of species common to these three localities strongly suggests contemporaneity. The beds at all three were deposited in interglacial stages, and the similarity in the floras suggests the same stage, although this cannot be proved, nor can the stage be named with the data at hand.

Outcrop in Brooklyn tunnel.—One diatom-bearing sample came from tunnel no. 2, City of New York Board of Water Supply (from shaft 15A, Fort Green Park, Brooklyn, 68 to 70 feet below sea level; or shaft 17A, Hamilton Ave. and Hicks St., Brooklyn, 91 to 104 feet below sea level; collected by Dr. Horace R. Blank, 1929; U. S. G. S. diatom locality 1828). Several other samples from this tunnel, all of which were kindly supplied by Dr. C. P. Berkey, of Columbia University, were examined and found to contain no diatoms. The labels on some of the samples had been misplaced at the university, and the only one which was found to contain diatoms bore a label that read "17A or 15A." However, as both of these samples were considered as coming from the Gardiners clay by Dusenbury,[8] who studied the larger fossils and the Foraminifera in them, no great damage has resulted from this confusion. The following diatoms were identified from this sample:

Melosira ambigua (Grunow) Müller	Rare.
Melosira octagona Schmidt	Rare.
Melosira recedens Schmidt	Common.
Melosira sulcata (Ehrenberg) Kützing	Common.
Melosira sulcata var. coronata (Ehrenberg) Grunow	Frequent.
Hyalodiscus cf. H. laevis Ehrenberg	Rare.
Cyclotella striata (Kützing) Grunow	Frequent.
Coscinodiscus asteromphalus Ehrenberg	Rare.
Coscinodiscus denarius Schmidt	Frequent.
Coscinodiscus excentricus Ehrenberg	Frequent.
Coscinodiscus cf. C. kurzii Grunow	Rare.
Coscinodiscus lineatus Ehrenberg	Frequent.
Coscinodiscus cf. C. oculus-iridis Ehrenberg	Rare.
Coscinodiscus radiatus Ehrenberg	Frequent.
Actinoptychus undulatus Ehrenberg	Abundant.
Actinoptychus summissus Schmidt	Rare.
Aulacodiscus argus (Ehrenberg) Schmidt	Rare.
Actinocyclus ehrenbergii Ralfs	Frequent.
Eupodiscus radiatus Bailey	Rare.
Auliscus reticulatus Greville	Rare.
Rhizosolenia sp	Rare.
Xanthiopyxis cingulata Ehrenberg	Rare.
Triceratium reticulum Ehrenberg	Frequent.
Biddulphia cf. B. aurita (Lyngbye) Brebisson var. obtusa (Kützing) Hustedt	Rare.
Biddulphia rhombus (Ehrenberg) Wm. Smith	Rare.
Biddulphia subaequa (Kützing) Ralfs	Rare.
Trinacria cf. T. pileolus (Ehrenberg) Grunow	Rare.
Grammatophora oceanica Ehrenberg	Frequent.
Plagiogramma staurophorum (Gregory) Heiberg	Rare.
Rhaphoneis amphiceros Ehrenberg var. rhombica Grunow	Frequent.
Eunotia sp	Rare.
Achnanthes subsessilis Kützing	Rare.
Cymbella sp	Rare.
Diploneis bombus Ehrenberg	Rare.
Diploneis elliptica (Kützing) Cleve	Frequent.
Diploneis gründleri (Schmidt) Cleve	Rare.
Diploneis papula (Schmidt) Cleve	Rare.
Diploneis smithii (Brebisson) Cleve	Frequent.
Navicula cf. N. lacustris Gregory	Rare.
Navicula cf. N. lyra Ehrenberg	Rare.
Navicula sp	Rare.
Pinnularia sp	Rare.
Epithemia cf. E. turgida (Ehrenberg) Kützing)	Rare.
Rhopalodia gibba (Ehrenberg) Müller	Rare.
Nitzschia granulata Grunow	Rare.
Nitzschia circumsuta (Bailey) Grunow	Frequent.
Nitzschia sigma W. Smith	Frequent.
Cymatopleura elliptica (Brebisson) W. Smith	Rare.

This assemblage is dominantly marine in aspect, only a few brackish-water and fresh-water species being present, and the beds may have been deposited in a bay or along an exposed coast not far from shore. The only extinct species in this flora is *Melosira recedens*, which is mentioned on page 231.

Of the species above listed 48 percent occur in the Sag Harbor well samples and 25 percent occur in the Montauk sample. The small percentage occurring in the Montauk sample is due in part to the fact that only about one-third of the species from Montauk are marine and in part to the fact that the total number of species found near Montauk is much less than at the tunnel locality. Here, again, an interglacial stage of the Pleistocene is strongly indicated.

CORRELATIONS

When all allowances are made, a good degree of correspondence between all three Long Island assemblages is obtained. The same holds true for the Long Island assemblages and those from the New Jersey wells. Little doubt is felt in assigning them all to some interglacial stage of the Pleistocene, but no reliable evidence is available for definitely assigning any of the assemblages to any particular interglacial stage. Their general agreement, however, makes it seem probable that they all represent the same stage. Dusenbury,[9] as a result of his studies of the fauna obtained from the Brooklyn tunnel locality, agrees with Fuller [10] in considering the Gardiners clay, to which these beds are assigned, to belong to the second (Yarmouth) interglacial stage of the Pleistocene. His evidence for assigning the Gardiners clay to some inter-

[8] Dusenbury, A. N., Jr., Notes on the fossil content of certain samples of Gardiners clay from Brooklyn (ms. report), 1933.

[9] Dusenbury, A. N., Jr., op. cit., p. 1.

[10] Fuller, M. L., The geology of Long Island, New York: U. S. Geol. Survey Prof. Paper 82, p. 106, 1914.

glacial stage of the Pleistocene is of the same order of validity as that given in the present report, but he gives no additional evidence for calling it specifically Yarmouth.

Woolman [11] studied cuttings from a well near Rock Hall, Md., in which he found, at depths of 109 to 130 feet, a bed containing a mixture of fresh-water and marine diatoms. On the basis of its diatom flora he correlated this bed with the similar bed occurring in the well at Wildwood, N. J., at depths of 78 to 181 feet. Woolman believed that both of these diatom-bearing beds were older than the Cape May formation, and that they were overlain by it. MacClintock and Richards,[12] after a study of Woolman's well logs and of surface outcrops, consider the diatomaceous bed occurring in the Wildwood well at depths of 78 to 181 feet to belong in the Cape May formation. As the diatom floras in the Long Island localities studied for the present report are quite similar to those in the Wildwood and Rock Hall wells, and if MacClintock and Richards are correct in their interpretation, the Gardiners clay on Long Island should be correlated with the Cape May formation in New Jersey.

The Long Island diatom floras also bear a striking resemblance to the flora which Boyer [13] obtained from the "blue clay" of Philadelphia. According to Strock,[14] this clay is in the upper part of the Pensauken formation, of Yarmouth age. MacClintock and Richards,[15] on the other hand, place the "blue clay" in the base of the Cape May formation.

Thus the evidence offered by the diatoms indicates that the Gardiners clay on Long Island was deposited during an interglacial stage of the Pleistocene and suggests a correlation with the Cape May formation or with the upper part of the Pensauken formation, assigned to the Sangamon and Yarmouth interglacial stages respectively, according to the interpretation of MacClintock and Richards.[16]

MacClintock and Richards also recognized this difficulty when they placed the upper part of the Gardiners clay in the Sangamon and the lower part doubtfully in the Yarmouth. The most acceptable correlation of that part of the Gardiners clay represented by the Long Island diatom floras appears to be with the Cape May formation, but whether the Gardiner clay belongs to the Sangamon or Yarmouth interglacial stage cannot be determined on the evidence considered in this paper. Myron L. Fuller, [16a] in a discussion of MacClintock and Richards' paper, summarizes the difficulties encountered in making correlations with either the Cape May or Pensauken formations, one of which is the uncertainty surrounding the position of the two formations.

Some doubts are cast on the correlation by the following considerations. The diatoms indicate that both the Gardiners clay and the Cape May formation were deposited in interglacial stages. The evidence that they represent the same interglacial stage depends upon the rather striking similarity in their diatom floras, but in view of the fact that the floras from each formation are made up, with one exception, of living species, it would be entirely possible for the same assemblage to have occurred in two different interglacial stages. The degree of similarity between the different diatom floras from Long Island is sufficiently strong to suggest contemporaneity but not sufficient for absolute assurance.

Both the Wildwood and Rock Hall localities contain a warm-water diatom, *Polymyxus coronalis* Bailey, which has not been found on Long Island. It is living at present along the east coast of South America, off the mouth of the Pará River, but has not been found living off the coast of North America. It occurs abundantly in a diatom flora which I obtained from a sample of the Horry clay, of Pleistocene age, from South Carolina, submitted to me by C. Wythe Cooke,[17] of the Geological Survey. The most northern occurrence of this species has been recorded by Boyer [18] from the "blue clay" (Cape May formation, according to MacClintock and Richards) of Philadelphia, where it occurs rarely. The absence of *Polymyxus coronalis* in the Long Island floras may be explained on the ground that it is a distinctly warm-water diatom and hence may not have migrated as far north as Long Island. MacClintock and Richards [19] invoke a similar explanation for certain features shown by a study of the mollusks. They say:

> The fauna of the Gardiners * * * indicates a mild climate, similar to that prevailing in the region today. It is similar to that indicated by the Cape May formation of New Jersey; it does, however, suggest slightly cooler water than the Cape May. This is undoubtedly partly due to its slightly higher latitude, for even today the fauna of Long Island is quite different from that of southern New Jersey.

Although the presence of *Polymyxus coronalis* would have strengthened the correlation, its absence does not materially weaken the conclusions as drawn.

Another species which Woolman [20] considered to be a good marker for the Pleistocene is *Triceratium favus* Ehrenberg. Although this species occurs in older beds elsewhere in the world it is not known from pre-Pleistocene beds along the Atlantic coast. It was

[11] Woolman, Lewis, Artesian wells at and near Rock Hall, Md.: New Jersey State Geologist Ann. Rept., 1898, pp. 116-121, 1899.

[12] MacClintock, Paul, and Richards, H. G., Correlation of late Pleistocene marine and glacial deposits of New Jersey and New York: Geol. Soc. America Bull., vol. 47, pp. 311-12, 1936.

[13] Boyer, C. S., The Diatomaceae of Philadelphia and vicinity, 143 pp., 40 pls., Philadelphia, J. B. Lippincott Co., 1916.

[14] Strock, L. W., A study of the Pensauken formation: Wagner Free Inst. Sci. Bull., vol. 4, no. 1, p. 8, 1929.

[15] MacClintock, Paul, and Richards, H. G., op. cit., p. 302.

[16] Idem, p. 335.

[16a] Fuller, M. L., Comment on "Correlation of Late Pleistocene marine and glacial deposits of New Jersey and New York," by Paul MacClintock and Horace G. Richards: Geol. Soc. America Bull., vol. 47, Supplement, pp. 1982-1992, 1937.

[17] Cooke, C. W., The Pleistocene Horry clay and Pamlico formation near Myrtle Beach, S. C.: Washington Acad. Sci. Jour., vol. 27, no. 1, p. 2, 1937.

[18] Boyer, C. S., The Diatomaceae of Philadelphia and vicinity, p. 25, pl. 4, fig. 7; pl. 5, fig. 2, 1926.

[19] MacClintock, Paul, and Richards, H. G., op. cit., p. 330.

[20] Woolman, Lewis, New Jersey state Geologist Ann. Rept., 1894, p. 162, 1895; idem, 1898, p. 118, 1899.

found sparingly in the New Jersey wells but not in the Long Island samples. As it is still living along the Atlantic coast, finding it in the Long Island samples would have been merely additional evidence that the beds were no older than Pleistocene.

Samples from two wells at Sandy Hook, N. J., were examined, and one of them, well 122-A, yielded diatoms at depths of 125 and 135 feet. The upper sample contained marine diatoms that showed excellent agreement with those of the Long Island samples and those of the Pleistocene samples from the other New Jersey wells mentioned previously, thus forming a good tie between Long Island and New Jersey. The assemblage included *Triceratium favus*, Woolman's Pleistocene marker. The diatom flora from a depth of 135 feet in the same well contained a large majority of brackish-water and fresh-water species, presenting a somewhat anomalous situation. Time was not available for a detailed study of this sample, but it should be undertaken in the future, as it might throw additional light on the Pleistocene history of Long Island.

EARLY REPORTS OF TERTIARY AND CRETACEOUS DIATOMS ON LONG ISLAND

Edwards [21] recorded the finding of marine diatoms at Rockaway, Long Island, which he then considered late Miocene in age on purely lithologic grounds, as "lower Miocene and Oligocene are as a rule lighter in color." The following year Edwards [22] again discussed the same occurrence and considered it to be "upper Neocene or Pleistocene." In the same paper he published a list of diatoms from this bed, including marine, brackish-water, and fresh-water species here considered to be of Pleistocene or later age.

The studies of over 200 well and outcrop samples from Long Island and of a large number from New Jersey disclosed no evidence for the existence of Miocene beds on Long Island. A great many of the wells from which samples were obtained went through the younger beds and into red clays which D. G. Thompson and F. G. Wells [23] considered on lithologic composition to be Cretaceous. Although all the samples studied were carefully concentrated and examined, no Miocene or earlier forms were found.

Woolman [24] reported Miocene diatomaceous beds in the well at Wildwood, N. J., at depths between 370 and 793 feet, with another isolated diatomaceous bed at depths between 1,040 and 1,060 feet. The diatom flora in the lower bed can be definitely correlated with that of the lower part of the Calvert formation, of medial Miocene age, in Maryland. The "great 400-foot marine Miocene diatomaceous bed of the Atlantic Coastal Plain", as Woolman called the interval between 370 and 793 feet in the Wildwood well, contains correlatives of a large part of the Chesapeake group (Calvert, Choptank, and St. Marys formations) of medial and late Miocene age in Maryland. This bed contains many diatoms of short geologic range and wide geographic distribution. The absence of all these characteristic species in the Long Island wells is at least very strong negative evidence against the existence of Miocene beds on Long Island. This is further supported by the fact that in many places on Long Island the Pleistocene beds rest directly on Cretaceous beds.[25]

Ries [26] reported the finding of diatoms in some supposedly Cretaceous clays at Wyandance, Northport, Center Island, Glen Cove, and Cold Spring Harbor, Long Island.

Fuller [27] reproduced the list of diatoms under the heading "Cretaceous diatoms." A total of 23 species of living fresh-water diatoms were listed and figured from these various localities. The evidence upon which Ries considered these beds to be Cretaceous is not at all conclusive, and the diatoms themselves indicate a Pleistocene to Recent age. It is entirely possible that these beds may have been reworked during Pleistocene time, so that Pleistocene diatoms became mixed with Cretaceous clays. Whatever view is accepted regarding the age of the clays, the diatoms are definitely not Cretaceous.

APPENDIX

With the idea that a brief listing of the samples cleaned and examined and found to be barren of diatoms might narrow the field for future work, the following list of outcrop and well samples is given:

Outcrop samples barren of diatoms.—Samples of greensand, gray clay, white clay, buff clayey sand, and white sand taken at different points on the Gayhead Cliffs and Nashaquitsa Cliffs, on Marthas Vineyard, were examined but did not contain diatoms. Some of the samples from the Nashaquitsa Cliffs came from beds believed to be those described by other writers as Gardiners clay.

Well samples barren of diatoms.—The well numbers given in the following table refer to those used in Geological Survey Professional Paper 44, and the samples are some of those collected during the investigation for that report and preserved in the collections of the Geological Survey.

[21] Edwards, A. M., On the occurrence of Tertiary clay on Long Island, N. Y.: Am. Jour. Sci., 3d ser., vol. 50, p. 270, 1895.

[22] Edwards, A. M., On the occurrence of Neocene marine Diatomaceae near New York: Am. Naturalist, vol. 30, pp. 212-216, 1896.

[23] Oral communication.

[24] Woolman, Lewis, Artesian well at Wildwood, N. J., its geology and paleontology: New Jersey State Geologist Ann. Rept., 1894, pp. 159-180, 1895.

[25] Wells, F. G., personal communication.

[26] Ries, Heinrich, Microscopic organisms in the clays of New York State: New York Acad. Sci. Trans., vol. 13, pp. 165-169, pls. 1-4, 1894.

[27] Fuller, M. L., The geology of Long Island: U. S. Geol. Survey Prof. Paper 82, pp. 78-79, 1914.

Samples from wells on Long Island found to be barren of diatoms

Location	Well no. used in Prof. Paper 44	Number of samples	Depth (feet)
Barren Island	(?)	4	395–709
Bridgehampton, Jas. A. Sanford	897	2	70–165
Cold Spring Harbor	(?)	4	15–275
Deer Park, Alart & McGinnis	(?)	1	10–20
Eaton's Neck, L. A. Bevin	670	3	159–300
Governors Island	10	4	13–60
Huntington, F. Galienne	649	5	15–130
Lake Success, W. K. Vanderbilt	317	1	560–660
Laurelton	(?)	1	96–97
Peacock Point, C. O. Gates	470	14	45–210
Port Jefferson, F. B. Rogers	267	2	325–340
Queens County Water Co., Valley Stream	273	7	33–125
Sag Harbor, J. K. Moins	901	2	110–132
Smithtown, C. E. Pedrick	711	1	165
Wheatley Hill, E. D. Morgan	431	7	251–398

The samples from the following wells were obtained by the Geological Survey during the period 1932 to 1936, and the numbers are those used by R. M. Leggette, of the Geological Survey, and published by the New York Department of Conservation, Water Power and Control Commission, in "Records of wells," as follows: Suffolk County, Bull. GW–4, 1938; Nassau County, Bull. GW–5; and Queens County, Bull. GW–6. The letter S preceding a well number indicates a well in Suffolk County; N, Nassau County; and Q, Queens County.

Samples from wells on Long Island found to be barren of diatoms

Location	Well no.	Number of samples	Depth (feet)
Bayside, City of New York test well	Q461	28	90–359
Belmont Lake State Park, test well 1	S78	4	0–110
Belmont Lake State Park, test well 2	S88	7	0–116
Flushing pumping station, City of New York	Q283	33	70–310
Heckscher State Park, test well	S74	1	107–109
Heckscher State Park, service well	S75	2	0–35
Jones Beach State Park, well 2	N129	20	8–1, 010
Sag Harbor, test well of South Bay Consolidated Water Co	S184	25	60–475
South Huntington Water Department, well 2R	S29	1	198–211
Sunken Meadow State Park, test well	S53	6	60–179
Sunken Meadow State Park, service well	S52	2	55–65
Wildwood State Park, service well	S139	6	0–178

INDEX