Palynology and Stratigraphy of Cretaceous and Pleistocene Sediments on Long Island, New York—A Basis for Correlation with New Jersey Coastal Plain Sediments

U.S. GEOLOGICAL SURVEY BULLETIN 1559

Prepared in cooperation with the Nassau County Department of Public Works and the Suffolk County Department of Health Services

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CONVERSION FACTORS AND ABBREVIATIONS

The following conversion factors may be used to convert the units given in this report to metric units.

Multiply	*By*	*To obtain*
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)

DATUM

NGVD of 1929, National Geodetic Vertical Datum of 1929, formerly called mean sea level. All land-surface elevations reported herein are in feet above NGVD of 1929. NGVD of 1929 is referred to as sea level in this report.

PALYNOLOGY AND STRATIGRAPHY OF CRETACEOUS AND PLEISTOCENE SEDIMENTS ON LONG ISLAND, NEW YORK—A BASIS FOR CORRELATION WITH NEW JERSEY COASTAL PLAIN SEDIMENTS

By L. A. SIRKIN

ABSTRACT

Palynology of sediments from 13 test wells in Suffolk County forms the basis for biostratigraphic zonation of the Late Cretaceous of much of Long Island and correlation with the Raritan embayment in New Jersey. The oldest polleniferous strata correlate with those in the Woodbridge Clay Member of the Raritan Formation (Cenomanian Age) in New Jersey, equivalent to pollen zone IV. Depending on the age of the confining clay layers, the Lloyd aquifer in Long Island is equivalent to the Farrington Sand Member in the lower part of the Raritan, Sayreville Sand Member in the middle part of the Raritan, or Old Bridge Sand Member in the lower part of the Magothy Formation in New Jersey. The most widespread pollen zones are V (equivalent to the South Amboy Fire Clay Member of the Raritan), VII (equivalent to the Amboy Stoneware Clay Member of the Magothy), and CA-1 (equivalent to the informally named Morgan and Cliffwood beds of the Magothy) in New Jersey. Sediments equivalent to the sequence of Merchantville Formation through Mount Laurel Sand (Campanian) in New Jersey are revealed in zones CA-2 through CA-5. Strata in the Monmouth Group in Long Island are associated with pollen zones MA-1/CA-6, thereby extending correlations to the Maestrichtian Navesink Formation and Red Band Sand of the Monmouth Group in New Jersey.

The Upper Cretaceous sediments are found in a troughlike structure that dips southward under the Long Island platform. Upper Pleistocene sediments overlie the Cretaceous units and include beds generally named the Gardiners Clay. These beds contain pollen of temperate floras, but their stratigraphy remains problematical.

INTRODUCTION

PURPOSE AND SCOPE

Identification of stratigraphic zones on the basis of fossil content is an important geologic method for areal correlation of sedimentary deposits where lithologic correlation is ambiguous. This study was undertaken to (1) provide detailed stratigraphic information on the Upper Cretaceous rocks of Long Island and (2) correlate Upper Cretaceous rocks on Long Island with the Cretaceous formations of the Raritan embayment of northeastern New Jersey, where the same pollen zones have been recognized in deposits rich in organic matter. The correlation is based on an evolving palynomorph zonation that revises stratigraphic interpretations. The application of the pollen zonation to the Upper Cretaceous sequence of Long Island clarifies the stratigraphic succession and links its stratigraphy with that of the mid-Atlantic region. Core samples from a row of 11 test wells (fig. 1) spanning western and central Suffolk County were analyzed from 1977 to 1980; two additional well sections in southern Suffolk County were included for correlation and evaluation. The uppermost samples in several boreholes are Pleistocene in age and have been included in this study.

PREVIOUS STUDIES

Geologists and hydrologists who have studied the Long Island region have long relied on lithic correlations as the basis for identifying rock units and aquifers. The recurrence of similar rock types in most wells has facilitated regional correlations at the stratigraphic group level and has also led to simplified interpretations of the geology, as typified by the geologic section depicted in Jensen and Soren (1974, sheet 1, hydrogeologic sections).

Since the mid-1950's, Cretaceous deposits in the mid-Atlantic Coastal Plain have been analyzed for pollen and spore content. A biostratigraphic zonation for the Early Cretaceous was initially proposed by Brenner (1963), who noted a distinct difference in pollen and spore assemblages between the Lower Cretaceous Potomac Group and the lower part of the Upper Cretaceous Raritan Formation of Maryland.

The development of a palynologic zonation for the Late Cretaceous (table 1) was enhanced by evolutionary changes of increasing complexity seen in the Cretaceous angiosperm pollen and the gradual emergence of pollen with more modern characteristics. Palynologic zonations for the Late Cretaceous have been made in several works—for example, Doyle (1969), Sirkin (1974), Wolfe (1976), and Christopher (1979); the last named covers the major contributions in this field since 1973. Other contributors to Late Cretaceous biostratigraphy are Wolfe and Pakiser (1971), Doyle and Robbins (1977), and Christopher (1977). To a large degree, these studies are based on works by Owens and others (1968, 1970, 1977) and Owens and Sohl (1969), who established

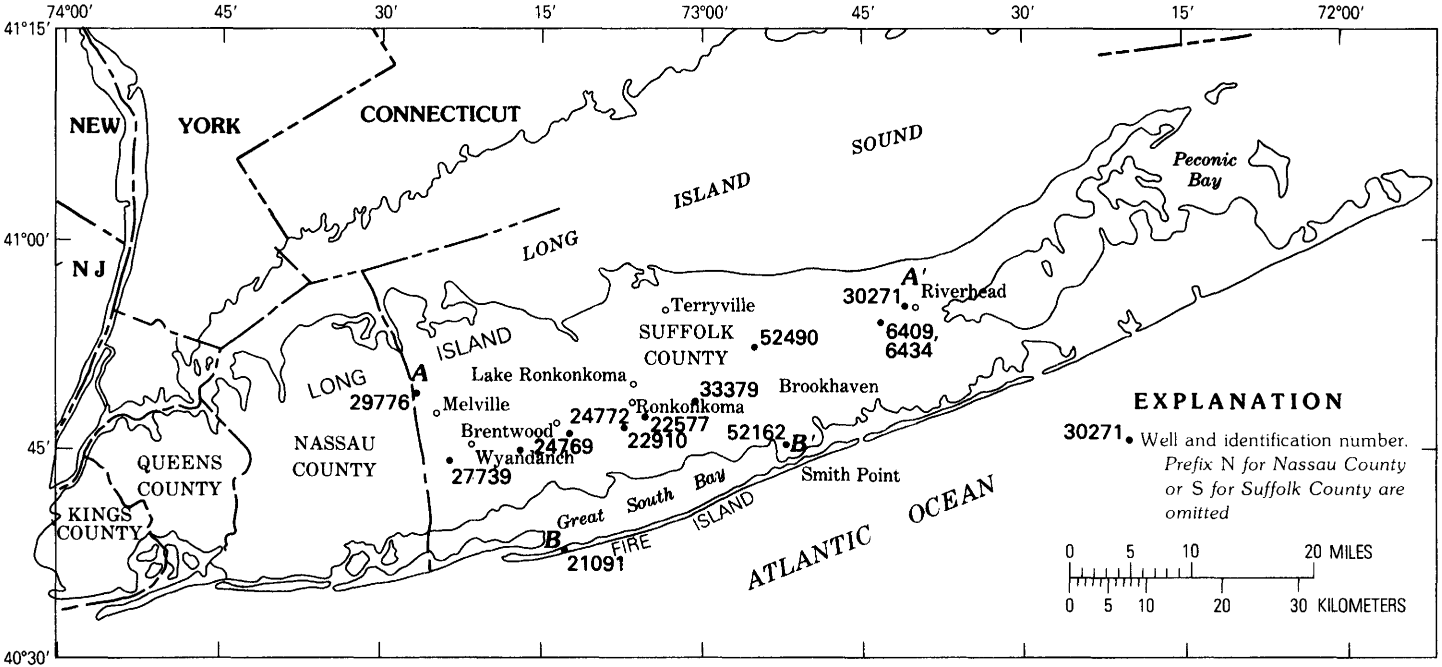


FIGURE 1.—Long Island, showing locations of wells used in this study and trend of geologic sections shown in figure 2.

the physical stratigraphy of Upper Cretaceous formations and delineated field relationships and type sections throughout this region.

The most complete pollen assemblages have been derived from surface exposures or type sections of the Upper Cretaceous formations, particularly where lignite beds are found. Such beds represent wetlands in the vicinity of sea level and have produced varied and abundant pollen assemblages (Christopher, 1979). Because lignite beds are uncommon in well sections from the downdip and more deeply buried marine sediments of the Long Island platform, large concentrations of pollen and complete assemblages are not always available. In marine sediments, palynomorph zones are likely to be based on "first appearance of a species," as used in Wolfe and Pakiser (1971) and Sirkin (1974).

Clay and organically rich sediments of Pleistocene age lie between Upper Cretaceous strata and the overlying glacial deposits. The clay beds are generally included in the Gardiners Clay. However, this unit has not been dated. Analysis of samples from four wells provides data on pollen content for a more detailed study in the future.

METHODS

Core samples used in this study were obtained by the U.S. Geological Survey office in Syosset, Long Island, and were made available to the author. The cores are stored in the Survey's core library in Syosset. Samples were processed by means of standard palynologic techniques but emphasis was on heavy liquid flotation for retrieving pollen from clastic sediments. Identification of pollen taxa is based on taxonomic descriptions and illustrations in the literature, especially the references cited herein.

ACKNOWLEDGMENTS

This study was conducted as an adjunct to studies of the hydrogeology of Nassau and Suffolk Counties; the author is indebted to colleagues in the U.S. Geological Survey for their assistance in administering this project and providing core samples for analysis. Special thanks are extended to Edward Bradley (U.S. Geological Survey, now retired) for his aid at the inception of the study and early support for the project, and to Eleanora Robbins (U.S. Geological Survey, Reston, Va.) for her review of palynological results.

TABLE 1.—*Pollen zones of the Upper Cretaceous sediments in Long Island and correlation with sediments of the Raritan embayment of New Jersey*

[Data are from published sources discussed in text]

Formations and groups recognized in Long Island and New Jersey	Upper Cretaceous stratigraphic units, New Jersey	Long Island pollen zones	Stage
MONMOUTH GROUP ------	Red Bank Sand	MA-1/CA-6	Maestrichtian and Campanian
	Navesink Formation	MA-1/CA-6	Maestrichtian and Campanian
	Mount Laurel Sand	CA-5	Campanian
MATAWAN GROUP -------	Wenonah Formation	CA-5	Campanian
	Marshalltown Formation	CA-5	Campanian
	Englishtown Formation	CA-4	Campanian
	Woodbury Clay	CA-3	Campanian
	Merchantville Formation	CA-2	Campanian
MAGOTHY FORMATION ---	Cliffwood beds	CA-1 *Pseudoplicapollis cuneata-Semioculopollis verrucosa*	Santonian
	Morgan beds		
	Amboy Stoneware Clay Member	VII *Pseudoplicapollis longi-annulata-Plicapollis incisa*	Santonian
	Old Bridge Sand Member		
RARITAN FORMATION ----	South Amboy Fire Clay Member	V *Complexiopollis-Santalacites minor*	Turonian
	Sayreville Sand Member	IV *Complexiopollis-Atlantopollis*	Cenomanian
	Woodbridge Clay Member		
	Farrington Sand Member		

STRATIGRAPHY

Long Island is underlain by a wedge-shaped mass of unconsolidated sedimentary deposits that overlie unconsolidated bedrock. The bedrock dips southeast from near sea level in northwest Queens County to about 2,000 ft below sea level in parts of Suffolk County's south shore. The lower unconsolidated deposits are of Cretaceous age and dip southeast also. They are mantled nearly everywhere on Long Island by Quaternary glacial deposits.

Within the hydrologic system of Long Island, the basal Cretaceous sand deposits are traditionally recognized as a hydrologic unit and are referred to collectively as the Lloyd Sand Member of the Raritan Formation, or simply as the Lloyd aquifer. The clay sequence that forms a confining bed over the Lloyd aquifer has been referred to as the Raritan clay, or the clay member of the Raritan. The body of Cretaceous sand and clay overlying the Raritan is generally placed in the Magothy Formation, or the Magothy Formation-Matawan Group, undifferentiated (Perlmutter and Todd, 1965).

At the top of the Cretaceous section, a greensand unit of the Monmouth Group, undivided, the so-called Monmouth greensand, may contain an aquifer, as inferred from a study of Late Cretaceous Foraminifera in these sediments by Perlmutter and Todd (1965). The overlying sediments are of Pleistocene age and have been hydrologically designated as the upper glacial aquifer, which may include one or more thin clay beds. The most prevalent of these clay beds is referred to as the Gardiners Clay—a marine clay presumably of Sangamon age. The above stratigraphic interpretations are revised, in part, in this report.

PALYNOLOGY

Lithologic logs of 13 wells in central and eastern Long Island were zoned on the basis of pollen content; the pollen zones and enclosing strata were then correlated with the formations of New Jersey. The east-west geologic section, which includes the Late Cretaceous pollen zones, is shown in figure 2; table 1 correlates these pollen zones with the stratigraphic names in New Jersey. The stratigraphic distribution of Late Cretaceous index pollen is given in figure 3. A list of index pollen in each well sample is given in table 2.

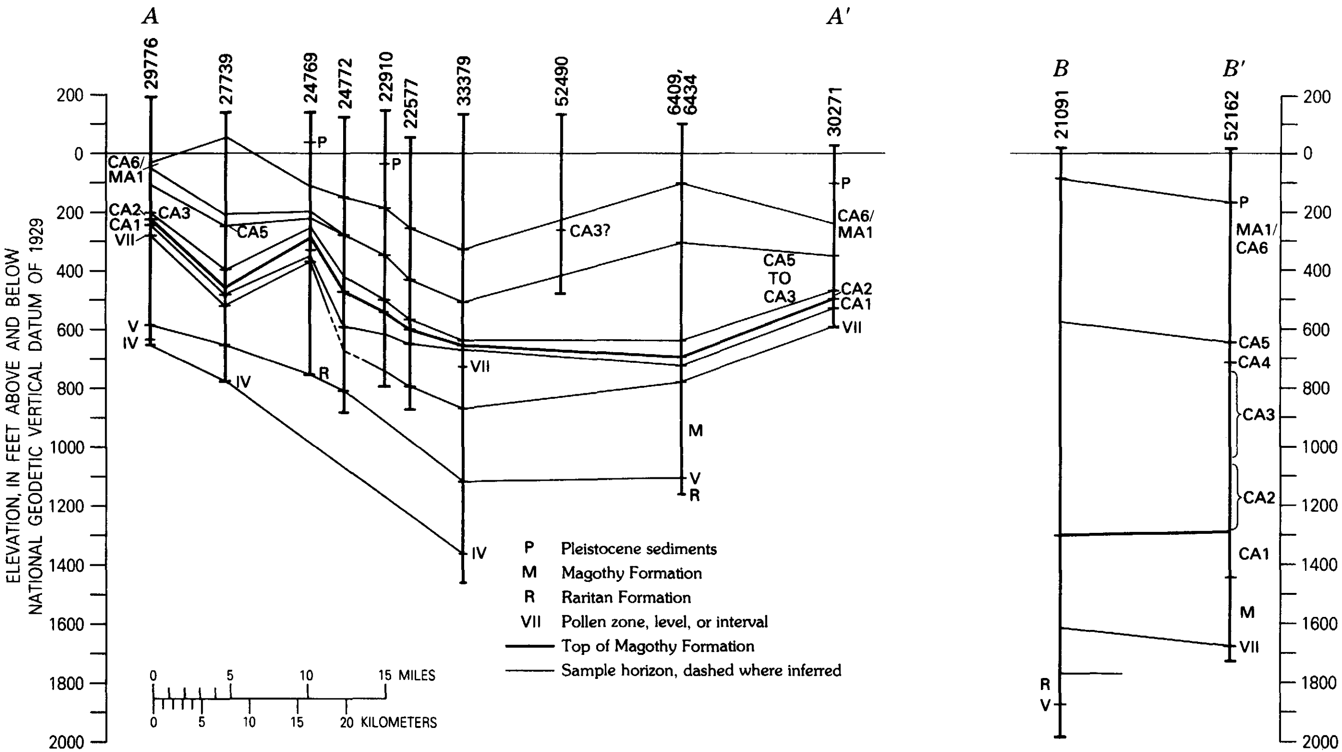
WELL S29776 IN MELVILLE

Nine samples from well S29776, from depths ranging from 246 to 841 ft below land surface (elevation 195 ft above sea level), have significant pollen assemblages. The deepest clay sample,[1] from 840 to 841 ft, contains several species of tricolporate and triporate pollen, especially species of the common Late Cretaceous genus *Complexiopollis* as the main index palynomorph. *Complexiopollis* species identifications are based on Tschudy (1973) and Christopher (1979). The significant number of *Complexiopollis* spp. indicates a Raritan age for this sample. In the absence of more advanced triporate forms, this bed is equivalent in age to at least pollen zone IV and the *Complexiopollis-Atlantopollis* zone of Christopher (1979). Thus, a correlation of these sediments with the Woodbridge Clay and Sayreville Sand Members of the Raritan Formation in the Raritan embayment of New Jersey is suggested. This age is substantiated in the assemblage in the succeeding sample (835–836 ft), where *Atlantopollis* is common and is found with several species of *Complexiopollis*. Both samples also contain a variety of small tricolpate and tricolporate forms and a small tetrad form, all of which are typical of the pollen in the Woodbridge Clay Member. The sample from 835–836 ft also has a number of gymnosperm genera among which bisaccates, pollen grains formed of a body cell and two sacs (vesicles or bladders), are dominant.

Above a relatively barren sequence between 831 and 805 ft, the clay sample from 785–786 ft has a sparse assemblage containing one specimen each of *Plicapollis* and *Minorpollis*. Both forms are found in the South Amboy Fire Clay Member of the Raritan Formation in New Jersey as "first appearance" indices of pollen zone V and typically range into the Magothy Formation. If this sample is an equivalent in age to the South Amboy Fire Clay Member, then the preceding barren sequence probably corresponds to the Sayreville Sand Member of the Raritan. Similarly, the barren zone between 764 and 466 ft could represent the equivalent, in part, of the Old Bridge Sand Member of the Magothy Formation. This correlation is supported by the following data, which show that the succeeding sediments can contain a younger Magothy zone.

The sample from 466–447 ft has a more complex pollen assemblage, which includes *Pseudoplicapollis, Plicapollis, Trudopollis, Momipites* (similar to *Momipites* sp. *L* of Christopher, 1979), *Proteacidites*, and Christopher's (1979) "New Genus D," as well as *Complexiopollis*. Several of these forms are prevalent in pollen zone VII of the late Magothy, particularly in the Amboy Stoneware Clay Member. However, the presence of *Momipites* sp. *L* and *Proteacidites*, genus PR–1 of Wolfe (1976), suggests a latest Magothy age, possibly equivalent to Morgan or Cliffwood beds (informal usage) of the

[1]Sediment types are compared with geologists' logs in Soren (1971).


A
A'
B
B'
29776
27739
24769
24772
22910
22577
33379
52490
6409, 6434
30271
21091
52162
ELEVATION, IN FEET ABOVE AND BELOW NATIONAL GEODETIC VERTICAL DATUM OF 1929
CA6/ MA1
CA2
CA3
CA1
VII
CA5
CA3?
CA5 TO CA3
V
IV
R
M
MA1/ CA6
CA4
P
Pleistocene sediments
M
Magothy Formation
R
Raritan Formation
VII
Pollen zone, level, or interval
Top of Magothy Formation
Sample horizon, dashed where inferred
0 5 10 15 MILES
0 5 10 15 20 KILOMETERS

Magothy in New Jersey and therefore correlative with Christopher's (1979) *?Pseudoplicapollis cuneata-Semioculopollis verrucosa* zone, although specimens of the latter taxon were not found.

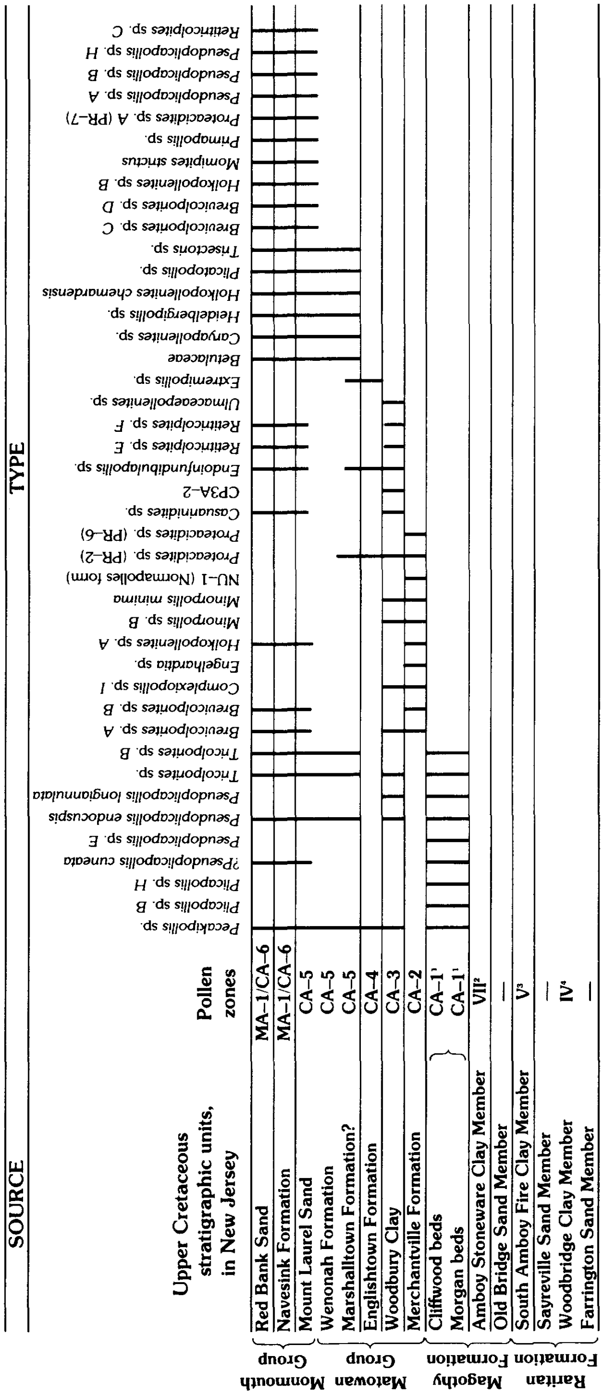
The pollen assemblage from the 426–428-ft depth also supports a latest Magothy age, particularly in the presence of several species of *Pseudoplicapollis*, including *?Pseudoplicapollis cuneata, P. longiannulata, P. endocuspis, P.* sp. *E, Osculapollis, Complexiopollis, Momipites*, including *M. tenuopollis, M.* sp. *I*, and *M. fragilis*, a robust form of Christopher's "New Genus D" and (or) *Triatriopollenites, ?Labrapollis* sp. *D.*, and *Minorpollis*. Although the *?Pseudoplicapollis-Semioculopollis* zone is a possible choice here, even though *Semioculopollis* was not observed, this horizon might be more appropriately placed in pollen zone CA-1 of Wolfe (1976). Similarly, the sample from 406–408 ft, which contains many of the same forms as 426–428 ft, has specimens of *Ulmaceaepollenites, Betulaceoipollenites?*, the tricolpate form *Retitricolpites* sp. *F*, and the tricolporate genus CP3A-2. Wolfe (1976) found both of the tricolpate forms in the Woodbury Clay, which he assigned to pollen zone CA-3. It is possible that the 406-408-ft layer is significantly younger—that is, middle Campanian—than the 426–428-ft layer, which might be early Campanian.

A Late Cretaceous age can also be indicated for the highest samples in this section. The sample from 266–268 ft contains the tricolporate genera *Brevicolporites* and *Holkopollenites*, and *Retitricolpites*, and the sample from 246–248 ft has *Brevicolporites* (CP3F-1 of Wolfe, 1976), along with the triporates cited above. The latter sample also contains *Momipites fragilis, Proteacidites* (genus PR-1), and a betuloid form. This bed may reach as high as pollen zone MA-1/CA-6 and thereby represent an equivalent of the Navesink Formation in New Jersey.

WELL S27739 AT WYANDANCH

Samples from well S27739 (fig. 1) were found at depths ranging from 95 to 907 ft below land-surface elevation (140 ft). The lowest clay

◄FIGURE 2.—Geologic sections *A-A'* and *B-B'*. Lines of correlation between wells are based on pollen zonation and indicate tentative correlations between zones in intervening wells. Well elevations have been adjusted to land-surface elevation above sea level. The two south-shore well sections (well S21091 on barrier island and well S52162 on the mainland) are plotted to the right of the cross section and show the succession of Cretaceous pollen zones from oldest (V in S21091) to youngest (MA-1/CA-6 in S52162). (Well locations are shown in fig. 1; boundaries between all stratigraphic units are not shown.)



[1]*Pseudoplicapollis cuneata-Semioculopollis verrucosa* zone
[2]*Pseudoplicapollis longiannulata-Plicapollis incisa* zone
[3]*Complexiopollis-Santalacites minor* zone
[4]*Complexiopollis-Atlantopollis* zone

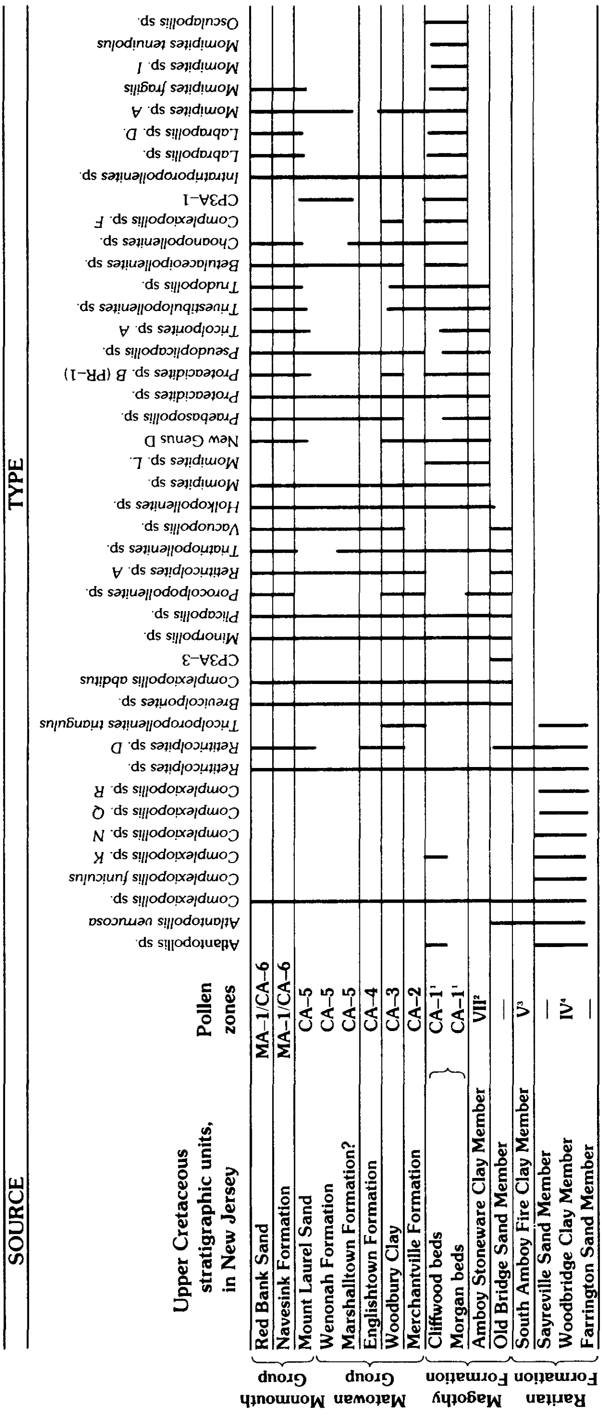


FIGURE 3.—Stratigraphic distribution of Late Cretaceous index angiosperm pollen in core samples from Suffolk County wells and correlation with sediments of the Raritan embayment of New Jersey.

sample available for study and another sample that contains abundant pollen are from a depth of 905 to 907 ft. The indicator pollen at this depth are species of *Complexiopollis* and *Atlantopollis*, which provide a ready correlation with the zone IV pollen assemblage. Zone IV is the *Complexiopollis-Atlantopollis* zone of Christopher (1979), but was found in the Woodbridge Clay Member of the Raritan Formation in the Raritan embayment of New Jersey. Samples from this zone were not available from 807 to 905 ft, and the next two samples, from 805–807 ft and 685–687 ft, both of which are sand, are barren.

A marked change in the pollen content was noted in the sample from 565–567 ft as an increase in number and type of triaperturate pollen. The assemblage includes *Brevicolporites* sp. *A* and sp. *B* and species of *Holkopollenites*, as well as triporate species (for example, *Proteacidites*, compare with PR–2 of Wolfe (1976), and a *Momipites*-type such as *Engelhardtia*). On the basis of Wolfe's (1976) criteria for the Campanian and Maestrichtian pollen zones of the Raritan embayment, this sample could represent the Campanian zone, CA–2, or a somewhat younger zone.

The next polleniferous sample is at 395–397 ft, where *Momipites* is found with *Proteacidites* genus PR–1, *Praebasopollis, Complexiopollis* spp., *Pseudoplicapollis, Vacuopollis, Brevicolporites* spp., *Holkopollenites* sp., and a multiporate form, possibly *Casuarinidites*, which Wolfe (1976) found in the Wenonah Formation. This assemblage is consistent with a still younger Campanian zone.

The middle-to-late Campanian age that is assumed for the section from 395 to 567 ft is supported by the appearance in the sample from 355–357 ft of *Holkopollenites chemardensis* and *Plicatopollis* sp., compare with genus NN–2, both of which Wolfe (1976) found in the Monmouth Formation (of former usage) of the Salisbury embayment. A Campanian zone CA–5 age appears to be reasonable here, although a MA–1/CA–6 correlation is also possible. Samples from 335–337 ft and 315–317 ft have similar assemblages, especially in the tricolporate forms, and contain numerous specimens of the CP3B type, of which *Tricolporites* sp. *B* is abundant.

Samples from 215 ft, 115–117 ft, and 95–97 ft have much the same representation but have abundant *Brevicolporites* spp., *Holkopollenites*, and a variety of triporate species. The uppermost sample (95–97 ft) contains a range of triporate forms, including those in the Betulaceae. This uppermost section can be placed in the MA–1/CA–6 pollen zone. The fact that index pollen of Tertiary age were not found indicates that Tertiary strata are not present here.

WELL S24769 IN BRENTWOOD

The section in well S24769, one of several wells from Brentwood, yielded five samples from depths between 160 and 848 ft below land-surface elevation (138 ft). The clay sample from 846–848 ft has abundant spores and gymnosperm pollen but only a few tricolpate and tricolporate angiosperm forms. The most advanced of the triaperturates are in the CP3A-3 genus of Wolfe (1976). Although no triporates were found, the tricolporate forms indicate a Raritan age for this layer.

The pollen record contains a gap of nearly 380 ft between the lowest sample and the sample from 466–468 ft. In the clay at this level, *Pseudoplicapollis* sp., *Triatriopollenites*, and *Complexiopollis abditus* are the triporate index genera along with the tricolporates *Brevicolporites* and *Holkopollenites*. This assemblage may be assigned to the late Magothy and suggests a correlation with Wolfe's (1976) Campanian pollen zone CA-1 and Christopher's (1979) *?Pseudoplicapollis-Semioculopollis* zone. As such, this part of the core could represent an equivalent of the Cliffwood beds of the Magothy in the New Jersey section.

The sample from 386–387 ft has abundant pollen assemblage in which all major groups are well represented. The tricolporate and triporate pollen, however, are the definitive forms. *Holkopollenites* and *Brevicolporites* sp. *A* and sp. *B* are rare here, whereas *Complexiopollis* sp., *Pseudoplicapollis* sp., *Praebasopollis* or genus NI-1 of Wolfe (1976), *Choanopollenites, Pecakipollis, Momipites*, and a quadraporate form, probably *Casuarinidites*, make up the assemblage. A late Campanian age is suggested for this layer, possibly as high as pollen zone MA-1/CA-6.

The succeeding polleniferous sample from 246–248 ft adds CP3B, *Holkopollenites chemardensis, Betulaceoipollenites, Proteacidites,* and *Triatriopollenites* to the list of advanced Cretaceous forms. A tentative Maestrichtian age is indicated for this horizon.

The uppermost sample in this section contains a pollen and spore flora that is distinctly different from that of the preceding samples. This level has a late Pleistocene pollen assemblage, composed predominantly of tree and shrub species, including pine (*Pinus*, two sizes), birch (two or three species of *Betula* or related genera), alder (*Alnus*), and trace amounts of pollen of several deciduous trees. Pollen of herbs are sparse, but spores of *Sphagnum* and *Lycopodium* are abundant. The aboreal assemblage, as well as the abundance of these spore genera, indicate a cool-temperate vegetation and wetland habitats, which represent a nonglacial environment comparable to the pine pollen zone—subzone B2 of the postglacial, post-Wisconsinan.

This bed, 160 ft beneath glacial overburden, could be a middle Wisconsinan equivalent of the Portwashingtonian warm interval, which is an informal designation for an interstade in the Wisconsinan about 30,000 years ago (Sirkin and Stuckenrath, 1980), or a possible Sangamon age, Gardiners Clay, equivalent. Stratigraphic studies of Long Island would be clarified if the age of this bed were determined more precisely.

WELL S24772 IN BRENTWOOD

The pollen zonation of the well S24772 section is based on three samples taken between 567 and 727 ft below land-surface elevation (120 ft). The deepest of these, from 726–727 ft, contains palynomorphs typical of the *?Pseudoplicapollis cuneata-Semioculopollis verrucosa* zone in the presence of *Pseudoplicapollis* along with *Intratriporopollenites, Minorpollis, Complexiopollis,* and *Momipites* sp. *A*. Thus, this horizon apparently correlates with the Morgan and Cliffwood beds of the late Magothy in New Jersey. The 626–627 ft sample has only one indicator specimen, *Complexiopollis* sp. *F*, which ranges from the uppermost Raritan through the Magothy.

In the uppermost sample from this section, 566–567 ft, a more advanced pollen spectrum appears with the tricolpate genus *Retitricolpites*, represented by three species, the tricolporate *Brevicolporites*, six species of the triporate *Complexiopollis, Minorpollis* spp., "New Genus D" of Christopher (1979), genus NU-1 of Wolfe (1976), and *Momipites* sp. These advanced forms indicate a Campanian age, possibly equivalent to pollen zone CA-2 or CA-3, and a correlation with the Merchantville Formation and Woodbury Clay in New Jersey.

WELL S22910 IN BRENTWOOD

In well S22910, 12 samples were first studied. However, the basal section, from 705 to 915 ft below land-surface elevation (about 160 ft), was barren. Pollen data from seven samples are available from 665 ft upward to 215 ft. The sample from 665 ft contains two stratigraphically important tricolporate genera, *Brevicolporites* sp. and *Holkopollenites* sp. *A*, along with several triporate forms, including *Complexiopollis* and *Triatriopollenites*. These triaperatuate genera are in an assemblage dominated by spores and gymnosperm pollen. A Campanian-age pollen zone CA-2 or CA-3 and a Woodbury Clay correlation are suggested in this clay bed. *Choanopollenites* and several species of *Complexiopollis* appear in the pollen flora in the sample from 625 ft, and *Momipites* sp. in the sample from 605 ft.

The uppermost Cretaceous strata may be found between 525 and 365 ft in this section, as indicated by the presence of *Momipites, Proteacidites,* and *Betulaceoipollenites* at 525 ft. Also, the sample from 405 ft includes *Casuarinidites* and *Primipollis*, and the sample from 365 ft has *Betulaceoipollenites* and *Endoinfundibulapollis.*

A distinct change in pollen taxa is seen in the sample from 215 ft. At this level, a few Pleistocene forms were observed in the birch and Compositae pollen, the best represented forms.

WELL S22577 IN RONKONKOMA

Unlike the previous sections, in which abundant index pollen were recorded, the section from well S22577 (elevation 61 ft) has not contributed significantly to the stratigraphic interpretation of the Cretaceous in central Long Island. Even though many of the samples are barren or badly degraded, enough triaperturate pollen was found at 895–897 ft and 876–877 ft to indicate a Late Cretaceous age for these sediments, which places this section within the limits of the Late Cretaceous correlations (fig. 2).

WELL S33379 NEAR LAKE RONKONKOMA

Well S33379 is one of the longer sections sampled. The 26 samples selected for processing represent the section between 450 and 1,500 ft below land-surface elevation (134 ft). Only three of these samples, 450 ft, 739–740 ft, and 928–929 ft, are barren.

The sample from 1,500 ft contains several tricolpate and tricolporate forms, including the small, triangular *Tricolporopollenites triangulus* and a variety of tricolpates, such as *Retitricolpites* sp. *D* of Christopher (1978) (genus C3A–5 of Wolfe, 1976). A Raritan age is indicated here, probably pollen zone IV, equivalent to the Woodbridge Clay Member.

At the 1,265–1,267-ft depth, several additional triaperturate forms appear in the clay unit, including another *Retitricolpites* species, *R.* sp. *A* (or genus C3A–1). The most advanced pollen here are *Complexiopollis* sp. and *Plicapollis* sp., which are the basis for assigning a late Raritan, pollen zone V, age to this stratum. No major changes are seen in the assemblages in samples from 1,243–1,245 ft or 1,220–1,222 ft, in which another retitricolpate (genus C3A) form and *Complexiopollis* appear in a suite of pollen dominated by bisaccate gymnosoperm pollen.

In the sample from 1,176–1,178 ft, both *Complexiopollis* and a coarsely verrucate *Atlantopollis*, compare with *A. verrucosa*, were counted. Samples from 1,154–1,156 ft, 1,108–1,110 ft, 1,041–1,042 ft, and 1,018–1,019 ft also contain this assemblage, with the addition of

Brevicolporites at 1,041–1,042 ft. Although the sequence from 1,018 to 1,267 ft might be readily assigned to the Woodbridge Clay Member of the Raritan on the basis of the *Complexiopollis-Atlantopollis* zonal affinity, zone IV was recognized in the 1,500 ft level and zone V at 1,256–1,267 ft, where *Plicapollis* first appears. Furthermore, *Holkopollenites* is found at 1,198–1,200 ft, and *Retitricolpites* and *Brevicolporites* are in the gymnosperm-dominated assemblage at 1,041–1,042 ft. Thus, because of the persistence of *Complexiopollis* and *Atlantopollis*, the pollen assemblage could be misleading in terms of zonation. The addition of more advanced forms indicates that a zone V age is more likely for the section between 1,018 and 1,267 ft. The sample containing a zone IV assemblage at 1,500 ft then correlates with the typical Raritan Formation stratigraphic sequence of the Woodbridge Clay Member, and the samples between 1,267 and 1,500 ft then correlate with the Sayreville Sand Member. The interval from 1,081 to 1,267 ft then correlates with the South Amboy Fire Clay Member, although the South Amboy is nowhere that thick in the Raritan embayment to the south. On the basis of lithological and palynological data, the South Amboy Fire Clay Member could be represented from 1,222 to 1,267 ft. The section from 1,018 to 1,222 might include the Old Bridge Sand and Amboy Stoneware Clay Members of the Magothy Formation, and contain pollen zone VII.

Above 928 ft, the angiosperm pollen include more advanced taxa. Several species of *Complexiopollis*, including *C. abditus*, are found at 869–870 ft along with *Minorpollis* and *Praebasopollis*. These forms are consistent with pollen zone VII and possible correlation with the Amboy Stoneware Clay Member of the Magothy in the Raritan embayment. However, the guide fossils of the *Pseudoplicapollis-Plicapollis* assemblage zone, established by Christopher (1979) for this bed, are not present.

In the sample from 802–803 ft, *Pseudoplicapollis* and *Choanopollenites* compare with genus NA-2 of Wolfe (1976), and *Trivestibulopollenites* and *Pecakipollis* are found along with a coarsely reticulated *Holkopollenites*(?) species and *Brevicolporites*. This sample also contains numerous specimens of an hystrichosphaerid dinoflagellate. A late Magothy pollen zone CA-1 age is suggested for this bed, with a possible equivalence to the Morgan or Cliffwood beds.

The sample from 780–782 ft also contains *Proteacidites* (PR-6), a betuloid form (*Trivestibulopollenites?*), and a unique stephanocolpate form. The sample may be assigned to a post-Magothy zone, possibly within the CA-2 to CA-3 interval, and therefore may be equivalent to the Merchantville or Woodbury strata in New Jersey.

No significantly different triporates, except perhaps *Trudopollis*, appear between 712 and 760 ft. At 688–689 ft, *Holkopollenites* is found with *Momipites, Choanopollenites,* the *Normapolles* genera NU-1 and NP-2 (*Vacuopollis*), and an advanced triporate form (compare with *Caryapollenites*). A late Campanian age, possibly pollen zone CA-4 or higher, may be assigned to this interval. Similarly, the overlying section would, by superposition, be stratigraphically younger—that is, equivalent to zones CA-5 and MA-1/CA-6, respectively. For example, *Proteacidites, Betulaceoipollenites, Intratriporopollenites*, and *Retitricolpites* appear at 645-647 ft, and *Momipites* is in the triporate-tricolporate assemblage at 472-473 ft.

WELL S52490 IN TERRYVILLE

One sample from a depth of 390 ft below land-surface elevation (137 ft) in well S52490 indicates a Late Cretaceous age for the section. This sample contains several tricolporate forms, including *Tricolporites* sp. *B* (genus CP3B-8) and genus CP3A, as well as the triporates *Pseudoplicapollis* sp. and *Complexiopollis* sp. These forms suggest a late Magothy to early Campanian age, possibly equivalent to the Morgan or Cliffwood beds in pollen zone CA-1, or else to the Campanian zones CA-2 and CA-3, which would indicate a Merchantville Formation or Woodbury Clay correlation. This section is considerably north of the line formed by the Suffolk County wells described previously.

WELLS S6409 AND S6434 IN BROOKHAVEN

The physical stratigraphy at these test wells, S6409 and S6434, drilled from land-surface elevations of 110 ft and 85 ft, respectively, was initially studied by de Laguna (1963), who recognized the Lloyd Sand Member and overlying clay member of the Raritan Formation, the "basal Magothy(?)," and the "Magothy(?)" as stratigraphic units in the well sections. Core samples from these wells were studied by Steeves (1959), who found that pollen of dicotyledonous angiosperms represented as much as 82 percent of the total of pollen and spores above the 400-ft depth and that numerous advanced forms, such as Betulaceae, Juglandaceae, Myrtaceae, and Rhamnaceae, among others, were represented. Below 400 ft, pollen of both angiosperms and gymnosperms decrease to levels between 38 and 75 percent. A further reduction in these groups to 24 percent was noted below 1,050 ft.

The Brookhaven samples were reviewed by J. A. Doyle (U.S. Geological Survey, written commun., 1973). Although more recent studies on the Late Cretaceous zonation have been made, Doyle's notes indicate that several of the index genera and assemblages may be found in the Brookhaven sediments. Newer interpretations, together with Steeves (1959) and Doyle's observations, confirm that (1) the entire section is of Late Cretaceous age, and *Complexiopollis* is found as low as 1,400 ft, and (2) the Raritan-Magothy boundary is as deep as 1,200 ft, where numerous genera including *Choanopollenites* spp., *Complexiopollis* spp. (probably with *C. abditus* and *C. longiannulata*), and *Santalacites*, associated with the *Complexiopollis-Santalacites* zone of Christopher (1979), were observed. The section from 800 to 600 ft (or possibly 700 ft) contains a late Magothy pollen assemblage, including *C. abditus, Plicapollis, Minorpollis, Momipites, Pseudoplicapollis, Proteacidites, Brevicolporites, "Retitricoilpites,"* and *Intratriporopollenites*, similar to those described by Christopher (1979). The Campanian pollen assemblages characteristic of zones CA–2 through CA–5 of Wolfe (1976) may be found in the secton between 600 and 200 ft, including *Brevicolporites, Casuarinidites, Choanopollenites, Holkopollenites, Intratriporopollenites, Minorpollis*, and Myracoid forms, whereas the uppermost zone, MA–1/CA–6, apparently is found in sediments from 200 ft in well S6409.

WELL S30271 NEAR RIVERHEAD

The 16 samples analyzed from well S30271 were found at depths ranging from 964 to 120 ft below land-surface elevation (26 ft); eight of these samples are barren, including the lower part of the section from 964 to 666 ft. Most of the remaining samples contain usable assemblages of pollen and spores.

The pollen assemblage in the sample from 604 ft is sparse and contains only four triaperturate specimens, the most advanced of which is the triporate *Triatriopollenites*. The pollen indicates that this interval may be assigned to pollen zone VII, possibly as an equivalent of the Amboy Stoneware Clay Member of the Magothy Formation. In the clay sample from 564 ft, spores and pollen are well represented. The most significant forms are a species of *Retitricolpites*, three species of *Complexiopollis*, including *C. abditus*, and a triporate form, probably *Betulaceoipollenites*. This level either may be a late Magothy equivalent of pollen zone CA–1 or may represent the Merchantville Formation and Woodbury Clay slightly higher in the section and zones CA–2 to CA–3.

The sample from 444 ft contains additional representation in the triporates, such as *Minorpollis* and *Intratriporopollenites*. A possible correlation can be made with pollen zone CA–4 of Wolfe (1976). Additional triporates are also noted in the sample from 405 ft, but in general the affinities are with the Campanian pollen zones, perhaps CA–4.

Although the sample from 384 ft is similar in triporate content to the sample from 405 ft, the advanced tricolporate genus *Brevicolporites* appears here. Thus, a younger pollen zone may be inferred—perhaps zone CA-5. Above this level, no advanced forms of zonal significance are found in the Upper Cretaceous sediments. Although the two samples from 264 ft and 224 ft are barren, lithologically a Red Bank or Navesink, zone MA-1/CA-6, correlation is suggested.

The sediments from 120 to 140 ft, however, contain a Pleistocene-Holocene assemblage represented by oak (*Quercus*), birch, black gum (*Nyssa*), poplar (*Populus*), hickory (*Carya*), sweet gum (*Liquidambar*), elm (*Ulmus*), alder, and pine in the arboreal pollen group, and grass (Gramineae), ragweed (*Ambrosia*), *Polygonum*, and *Amaranthus* in the nonarboreal pollen. This sample is Pleistocene in age and may be a Gardiners Clay equivalent or a deposit of middle Wisconsinan or Port-washingtonian age (Sirkin and Stuckenrath, 1980). The pollen assemblage indicates a temperate climate and an oak-hickory forest association.

WELL S21091 ON FIRE ISLAND

Two additional wells (S21091 and S52162) incorporated in this study are on or near the south shore of Long Island, south of the line of section, and reveal a thick sequence of sediments between land-surface elevation (10 ft) and bedrock. The Fire Island well is on the barrier beach and penetrates a stratigraphic section of nearly 2,000 ft. The initial palynologic study of this well indicated that the entire section was of Late Cretaceous age, that the lowest samples are in pollen zone V, and that the section may correlate with the South Amboy Fire Clay Member of the Raritan Formation in New Jersey (Sirkin, 1974). The use of the first appearance of triaperturate angiosperm pollen made the zonation of this section and the correlation of the stratigraphy with the Raritan embayment a possibility. The publication of recent studies (Christopher 1977, 1978; Doyle and Robbins, 1977; Wolfe, 1976) relevant to this stratigraphy make it possible at this time to revise the zonation of S21091, particularly in the late Magothy and Campanian units where the distribution of tricolporate and triporate pollen genera is better known.

The deepest pollen-bearing sediments, represented by the samples from 1,800 ft and 1,873 ft, contain several important triporate genera such as *Complexiopollis* spp., including *C. abditus, Plicapolllis, Triatriopollenites,* and *Vacuopollis* (or *Osculapollis*), and the tricolporate, *Brevicolporites*. The assignment of this interval to pollen zone V and its correlation with the South Amboy Fire Clay Member of the late Raritan Formation of the Raritan embayment by Sirkin (1974) are substantiated by the ranges of these genera as determined or reaffirmed by Christopher (1979).

Similarly, the abundant and varied spectra in the section between 1,440 and 1,585 ft indicate a Magothy age. The polleniferous fine-grained sediments at 1,585 ft provide a triaperturate angiosperm pollen assemblage that includes *Complexiopollis* spp., *Plicapollis* spp., *Proteacidites, Triatripollenites, Trivestibulopollenites, Momipites, Praebasopollis, Pseudoplicapollis, Trudopollis,* and *Pecakipollis*. Most of these forms are associated with the Magothy Formation and appear in the Amboy Stoneware Clay Member. Species of *Holkopollenites* and *Brevicolporites* are found at 1,560 ft, and *Choanopollenites* and *?Pseudoplicapollis cuneata* are in the 1500-ft sample. Although it is reasonable to include this entire sequence in pollen zone VII, the presence of these taxa indicate that the boundary between the Amboy Stoneware Clay Member and the Morgan and Cliffwood beds of the late Magothy is below 1,500 ft rather than at 1,400 ft, the level selected by Perry and others (1975) for this member.

Although a few thin clay beds are logged in the section above 1,400 ft (for example, at 1,380, 1,285, 1,260, and 1,225 ft), they do not contain diagnostic or abundant assemblages. The sample from 1,178 ft contains few pollen, in which *Momipites, Complexiopollis,* and *Brevicolporites* represent the advanced forms.

Because of the lack of pollen data and the coarse, clastic nature of the sediments between 1,170 and 695 ft, the Magothy-Merchantville boundary cannot be determined here. The increase in pollen abundance above 695 ft and taxa found as high as 240 ft indicate that the section between 695 and 240 ft is in the Campanian. The resurgence of abundant *Holkopolenites* and *Breviocolporites* species at 580 ft suggests an equivalence to pollen zone CA-5 and to the Marshalltown and Wenonah Formations.

Campanian zonal boundaries between 240 and 1,440 ft can be tentatively assigned on comparison with the stratigraphy of the other wells in this study. Thus, the section from 1,440(?) ft through 695 ft apparently correlates with the Cliffwood, Merchantville, and Woodbury units and pollen zones CA-1 through CA-3; the section from 665 to 595 ft with the Englishtown Formation and CA-4; and that from 595 to 490 ft with the Wenonah Formation and zone CA-5. The Navesink and Red Bank units and pollen zones MA-1/CA-6 would then be incorporated in the 440- to 240-ft section.

WELL S52162 ON SMITH POINT

Well S52162 was cored to a depth of 1,711 ft below land-surface elevation (about 10 ft) and sampled from 1,659 to 146 ft. The deepest of the 41 samples taken for pollen analysis is from 1,657–1,659 ft and has a rich spore, gymnosperm, and triaperturate pollen assemblage. The tricolpate C3A and C3C type (from Wolfe, 1976) are common, along with a few thick-walled tricolporate forms such as *Holkopollenites*. Although triporates constitute only a small percentage of the pollen sum, they are represented by several genera, such as *Trudopollis, Proteacidites, Praebasopollis,* and *Minorpollis*. It is apparent that this sample, from deep in a sandy part of the section, contains advanced angiosperm pollen of Late Cretaceous age, probably as young as late Magothy. The pollen spectrum falls in pollen zone VII but could range as high as the Campanian zone, CA-1.

The succeeding samples, from 1,595–1,597 and 1,534–1,536 ft, do not contain significant index forms. However, the samples from 1,470–1,471, 1,439–1,440, and 1,380–1,381 ft, which are incorporated in a clay and silt sequence, include species of *Complexiopollis* and *Holkopollenites*. Tricolporate and triporate angiosperm pollen represent over half of the total number of pollen in the sample from 1,255–1,256 ft. Several varieties of the genus CP3B of Wolfe (1976) appear at this level along with *Holkopollenites* in the tricolporates and *Retitricolpites* in the tricolpates. Triporate genera include species of *Complexiopollis*; for example, *C. abditus, Choanopollenites, Plicapollis*, and a possible *Pseudoplicapollis* species. An early Campanian pollen zone, CA-1 or CA-2, is indicated for this level.

In the overlying sample from 1,222–1,223 ft, the tricolporate form *Tricolporites* sp., which was designated CP3B-4 by Wolfe (1976), appears. Several *Tricolporites* species also are present in the 1,159–1,160 ft level, including several specimens of CP3B-8, along with *Brevicolporites* (CP3F), *Holkopollenites* (CP3D), and *Tricolporopollenites* spp. The triporates continue in diversity with *Complexiopollis* spp., including *C. abditus, Plicapollis, Pseudoplicapollis, Trudopollis,* and *Choanopollenites*. This horizon indicates an early Campanian age, a time when, according to Wolfe (1976), tricolporate forms flourished.

In the predominantly sandy sequence from 1,064 to 939 ft, fewer pollen are found, although the assemblages show little change. For example, *Vacuopollis* and *Minorpollis* appear in the triporate group in sample 1,063–1,064 ft. *Pseudoplicapolis endocuspis, Praebasopollis, Triatriopollenites,* and *Trivestibulopollenites* are in the 1,001–1,002 ft level, along with abundant, small triangular tricolporates. At 970–972 ft, where bisaccate gymnosperm pollen are the most varied and abundant forms, the triporate *Intratriporopollenites* and the tricolpate *Retitricolpites* are added to the assemblage. The clay sample from 938–939 ft has a signicant number and species of triporates, mainly the persistent forms *Plicapollis, Complexiopollis* spp., and

Pseudoplicapollis. Praebasopollis, Pecakipollis, Trudopollis, Proteacidites compare with P. sp. *B.* (or genus PR-2); *Retitricolpites* sp. *D., Holkopollenites* sp., and the CP3B-8 form are all also important in this assemblage. Similarly, the lignite-streaked clay samples at 780–782 ft and 750–752 ft have the *Pseudoplicapollis-Complexiopollis* dominated microflora, with most of the above triporates and the addition of *Extremipollis* and *Minorpollis.* At the 720–722 ft level, *Vacuopollis* is again present and *Momipites* appears. The diversity of the triporate and tricolporate forms indicate a Campanian age—perhaps CA-3 to CA-4—for this section, although it incorporates a greater thickness than comparable strata in New Jersey. However, this sequence probably does include the equivalent of the Woodbury Clay.

Traces of lignite are present in the sand of the sample from 688–690 ft. At this level, *Endoinfundibulapollis* (genus NM-1 of Wolfe, 1976) is found in the predominantly triporate assemblage, along with most of the triaperturates cited above, as well as *Triatriopollenites* and *Proteacidites* (compare with genera NQ-1, PR-7). A possible Campanian zone, CA-4, is reasonable here, and a resulting correlation with the Englishtown Formation may be inferred.

Triporate representation declines somewhat in the 626–628 ft sample, a banded sand with traces of lignite. Of note here is the introduction of *Trisectoris*, which Wolfe (1976) found in the Wenonah Formation and Monmouth Formation (of former usage) or Group and a betuloid pollen grain. If this first appearance is accurate, a correlation can be made between this level and pollen zone CA-5.

In the sandy section between 598 and 190 ft, most of the triaperturate species that have already been cited are found in the *Complexiopollis-Plicapollis* assemblage. However, *Retitricolpites* spp., such as *R.* spp. *C, E,* and *F, Holkopollenites* spp., including *H. chemardensis*, and *Brevicolporites* sp. are increasingly prominent. Samples from 596–598 and 534–535 ft have particularly good representation of the genera cited, but the triaperturate pollen population declines between 504 and 377 ft. *Momites, Betulaceoipollenites*, and *Trisectoris* are in the sample from 534–535 ft. *Trisectoris* again appears at 405–409 ft, and *Momipites* sp. (compare with *M. microfoveolatus*) is in the sample from 377–379 ft.

Momipites is common in the upper samples, alone at 222–224 ft, with a betuloid form at 253–255 ft, and with *Trisectoris* at 190–192 ft. In the 190–192-ft sample, a specimen of *Caryapollenites* was found. Also of significance is the presence of a dinoflagellate, *Svalbardella lidiae*, which is limited to the Navarro Group of Maestrichtian age in Texas, according to Zaitzeff and Cross (1970).

This upper section (598 to 190 ft) possibly can be included in pollen zone MA-1/CA-6 of Wolfe (1976) on the basis of the pollen evidence, and would, therefore, be Maestrichtian in age and would correlate with the Navesink Formation and the Red Bank Sand in the Raritan embayment. Although the sand at the 190-192-ft level is gray and could be a marine facies of the red beds, a greensand that contains Foraminifera does appear at 223-224 ft. Glauconitic sand at this stratigraphic level in Long Island wells commonly is referred to as Monmouth greensand, from the work of Perlmutter and Todd (1965).

The uppermost sample in this well, at 146-147 ft, contains a sparse mixture of Cretaceous and Pleistocene-Holocene forms. These latter pollen types include pine, Ericaceae, elm, and grass, and provide a probable late Pleistocene age (Sangamon or Portwashingtonian) for this sediment.

DISCUSSION

STRATIGRAPHIC CORRELATIONS

From figure 1 it can be inferred that the Early Cretaceous is not represented in sections in Long Island. The oldest pollen zones are of Raritan age, equivalent to the Woodbridge Clay or the South Amboy Fire Clay Members in New Jersey. The pollen data indicate that the oldest beds are present in well sections S29776 and S27739 to the west, and in S33379, the deepest well, in the central part of the traverse (fig. 1). Furthermore, the oldest strata are equivalent in age to pollen zone IV and the Woodbridge Clay Member of the Raritan Formation in New Jersey.

Stratigraphic equivalents of both the Woodbridge Clay and South Amboy Fire Clay Members of the Raritan in New Jersey may be present as thin clay units in the Lloyd Sand Member of the Raritan in Long Island. The overlying clay member of the Raritan in Long Island may be equivalent to the South Amboy Fire Clay Member of the Raritan or the Amboy Stoneware Clay Member of the Magothy in New Jersey; consequently, the Lloyd Sand Member becomes a "floating" stratigraphic unit that could be the correlative of the Farrington Sand Member in the lower part of the Raritan, the Sayreville Sand Member in the middle part of the Raritan, or the Old Bridge Sand Member of the Magothy in New Jersey, depending on the age of the overlying confining clay member of the Raritan in Long Island.

Through the application of pollen stratigraphy, the age of a clay unit in a sand sequence as well as that of a clay unit capping the sequence can be determined. In the present study it has been possible to more consistently locate the top of both the Raritan and the Magothy Formations. Identification of the top of the Magothy also provides a basis for subdividing the Magothy Formation-Matawan Group undifferentiated as used in Long Island, and, to some extent, the Matawan Group undivided, itself.

The Late Cretaceous Campanian and Maestrichtian pollen zones and equivalent rock units definitely are in the Long Island subsurface, and a broad geologic structure dominates the Long Island platform. As Owens and others (1970) have shown, several formations (Merchantville through Mount Laurel) in the Raritan embayment of northeastern New Jersey are recognized in the Salisbury embayment in the northern Delmarva Peninsula. These units have been assigned a Campanian age by Owens and others (1970), and this age is supported by the pollen zonation of Wolfe (1976). However, the lateral variation in depositional facies in this sequence results in considerable variation in sediment type between the Raritan embayment and the Long Island platform.

Some formations can be identified by lithology and pollen zones. For example, the Woodbury Clay equivalent, which contains the assemblage of pollen zone CA-3 of Wolfe (1976), has been identified in this study in several sections. Location of this horizon also lends support to the selection of the position of the boundary between the Magothy Formation and the Merchantville Formation equivalent in the Matawan. Because boundaries of the individual formations of the Campanian are set with much less certainty, units are grouped. Where diagnostic pollen are abundant, however, there is still a good correlation of the Campanian zones.

Zone CA-1, which is assigned to the Morgan and Cliffwood beds of the late Magothy by Wolfe (1976), appears in most of the well sections. This zone is set off from pollen zone CA-2 and therefore provides additional data for establishing the Magothy-Merchantville boundary. Zones CA-2 and CA-3 generally are separated lithologically where the Woodbury Clay is evident. Similarly, pollen zones CA-4 and CA-5 are not readily differentiated, mainly because the pollen evidence is incomplete. Zone MA-1/CA-6, however, is more readily determined from pollen content, as the so-called Monmouth greensand in Long Island is identified where present on the basis of lithology.

Sediments containing Pleistocene pollen assemblages define the upper limits of the Cretaceous strata and show that Tertiary sediments are not present in the sequences studied.

Only Pleistocene deposits, mainly outwash, have been found to directly overlie the Cretaceous strata. Marine sediments or sediments rich in organic matter are uncommon in the glacial units. However, in four wells, S24769, S22910, S30271, and S52162 (fig. 2), polleniferous sediments of late Pleistocene age were found. In general practice, these sediments have been placed in the Gardiners Clay. This clay bed is generally believed to be a marine deposit that originated during a high stand of the sea in the Sangamon interglacial stage. Recent studies of some presumed Gardiners Clay samples and of similar clay elsewhere on Long Island and in New England have shown that some of the clay beds may be of freshwater lacustrine origin and that some may be Wisconsinan in age (Gustavson, 1976; Lonnie, 1977; Sirkin and Stuckenrath, 1980; and Sirkin, 1982).

The depth of burial of the clay samples, for example, to 215 ft in well S22910, indicates that the clay beds may be older than the last glaciation in late Wisconsinan or Woodfordian time (Sirkin, 1968, 1971, 1982; Sirkin and Mills, 1975; Sirkin and Stuckenrath, 1980). The pollen assemblages in the four samples differ somewhat but generally indicate vegetation of temperate environments. In three of the samples, pine or birch are dominant, and in one section, S30271, oak is the most abundant pollen, along with birch and forest taxa of warm-temperate environments. In the Atlantic Coastal Plain, temperate environments and relatively high stands of the sea occurred during the Sangamon and the early and middle Wisconsinan (Owens and Denny, 1979; Sirkin, 1977; and Sirkin and Stuckenrath, 1980). Thus, the Pleistocene assemblages described in this study could represent episodes and environments of deposition other than those traditionally associated with the Gardiners Clay. Further study is necessary to more adequately characterize these units.

STRUCTURAL IMPLICATIONS

As figure 2 indicates, all identified horizons conform to a general synclinal structure for the Long Island strata. For example, the Campanian pollen zones are found at much deeper levels in the central sections of Long Island, such as at wells S22910, S22577, and S33379, than in the eastern or western sections. Although the pollen zones in wells S6409 and S6434, farther east, are inferred from earlier studies, the S30271 section still farther east provides support for the same overall pattern—that is, pollen zones VII through MA-1/CA-6 are at higher elevations at this well, particularly compared with the zones at well S33379. The more southerly sections, well S21091 on Fire Island and S52162 at Smith Point, also contain the zoned lithofacies but at greater depths than in the landward wells, which indicates that the structure either deepens or dips southward toward the Continental Shelf. The late Raritan pollen zone V, associated with the South Amboy Fire Clay Member, and pollen zone VII of the Amboy Stoneware Clay Member of the Magothy Formation of New Jersey, are found in most of the wells and consistently enough to indicate the presence of a structural downwarping that may have affected the mode of deposition.

The consistent and orderly appearance of the sequential pollen zones in the numerous wells studied here indicates that the sediments were deposited into a depression in the marine platform. Pollen evidence shows that deposition began early in the Late Cretaceous, or at least as early as middle Cenomanian time, and concluded in the Maestrichtian. The fact that Tertiary sediments were not found in this study suggests recession of the sea and deposition of Tertiary units farther out on the shelf. Although it was not the purpose of this study to determine whether formation of the structure accompanied or preceded sedimentation, the thickening of the Upper Cretaceous units, as defined by the pollen zonation, in the central part of the depression (for example in wells S33379 and S52162, fig 2) suggests deposition into a subsiding trough. Also, a fault may be indicated by the offset of pollen zones in the middle of well S24769 (fig. 2) and from zones of the same age in wells S27739 and S24772. Movement on a fault contemporaneous with deposition could account for subsidence of part of the Long Island platform and might be related to the reactivation of a basement structure, such as an early Paleozoic fault or a Triassic graben.

CONCLUSIONS

The palynologic zonation that has been developed from sections along the Atlantic coastal margin for New Jersey and Long Island is useful in correlating the stratigraphy of the Cretaceous of Long Island. Cretaceous sediments from 13 test wells across central and eastern Long Island contain pollen that range in age from middle Cenomanian to Maestrichtian. Furthermore, assemblages provide correlations with the Upper Cretaceous strata of the Raritan embayment to the south in New Jersey. The oldest Cretaceous sediments on Long Island contain pollen of zone IV and are equivalent to the Woodbridge Clay Member of the Raritan Formation in New Jersey. Succeeding sediments correlate with zone V and the South Amboy Fire Clay Member of the Raritan; with zone VII and the Amboy Stoneware Clay Member of the Magothy Formation; with zone CA-1 of the Morgan and Cliffwood beds (informal usage) in the upper part of the Magothy; with zones CA-2 through CA-5 in strata correlative with the Merchantville Formation through Mount Laurel Sand; and with zones MA-1/CA-6 correlative with the Navesink Formation and Red Bank Sand in New Jersey.

The sediments on the Long Island platform were deposited in a basin or troughlike structure that dips to the south. Whether the structure represents downwarping or a fault basin has not been determined. The absence of Lower Cretaceous sediments in the sections suggests that the area was inactive or undergoing erosion until Late Cretaceous time. Downwarping or reactivation of a grabenlike structure and filling in of the basin occurred in the Late Cretaceous.

Upper Pleistocene sediments in these sections contain pollen spectra that indicate vegetation in a temperate climatic setting. However, the stratigraphic age of these strata has not been determined with certainty.

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TABLE 2

TABLE 2.—*List of index palynomorphs in Long Island well samples*

[Terms in parentheses designate correlative genera of Wolfe, 1976; depth interval is in feet below land surface]

Depth interval	Name
	WELL S29776 AT MELVILLE
246 - 248 ft	Brevicolporites sp. B Christopher 1978 (CP3F-2)
	Complexiopollis abditus Tschudy 1973
	Momipites fragilis Frederiksen and Christopher 1978
	Proteacidites sp. B Christopher 1978 (PR-1)
	Pseudoplicapollis sp.
	New Genus D sp. Christopher 1979
266 - 268 ft	Brevicolporites sp. A Christopher 1978 (CP3F-1)
	Brevicolporites sp. B Christopher 1978
	Complexiopollis sp.
	Complexiopollis abditus Tschudy 1973
	Holkopollenites sp.
	Intratriporopollenites sp.
	Labrapollis sp. D Christopher 1979
	Momipites sp.
	Momipites sp. A Christopher 1979
	Momipites fragilis Frederiksen and Christopher 1978
	Pecakipollis sp.
	Plicapollis sp.
	Pseudoplicapollis sp.
	Pseudoplicapollis sp. A Christopher 1978
	Pseudoplicapollis sp. B Christopher 1978
	Pseudoplicapollis sp. H Christopher 1979
	?Pseudoplicapollis cuneata Christopher 1979
	Pseudoplicapollis endocuspis Tschudy 1975
	Retitricolpites sp.
	"Retitricolpites" sp. F Christopher 1978
	Trudopollis sp.
406 - 408 ft	Betulaceoipollenites sp.
	Complexiopollis sp. F Christopher 1979
	Momipites sp.
	New Genus D (Christopher, 1979) sp.
	Plicapollis sp.
	Pseudoplicapollis longiannulata Tschudy 1975
	Pseudoplicapollis endocuspis Tschudy 1975
	"Retitricolpites" sp. F Christopher 1978
	Ulmaceaepollenites sp.
426 - 428 ft	Complexiopollis spp.
	Complexiopollis sp. K Christopher 1979
	Labrapollis sp. D Christopher 1979
	Momipites sp. I Christopher 1979
	Momipites fragilis Frederiksen and Christopher 1978
	Momipites tenuipollis Group Frederiksen 1979
	Minorpollis sp.
	New Genus D sp.
	Osculapollis sp. A Christopher 1979
	Plicapollis sp.
	?Pseudoplicapollis cuneata Christopher 1979
	Pseudoplicapollis endocuspis Tschudy 1975
	Pseudoplicapollis longiannulata Christopher 1979
	Pseudoplicapollis sp. E Christopher 1979
	Pseudoplicapollis sp. H Christopher 1979
	"Retitricolpites" sp. E Christopher 1978
	Triatriopollenites sp.

TABLE 2.—*List of index palynomorphs in Long Island well samples*—Continued

Depth interval	Name
	WELL S29776 AT MELVILLE (continued)
446 - 447 ft	Complexiopollis sp.
	Complexiopollis abditus Tschudy 1973
	Momipites sp.
	New Genus D (Christopher, 1979) sp.
	Plicapollis sp.
	Plicapollis sp. B Christopher 1979
	Pseudoplicapollis sp.
	Proteacidites sp. (PR-1)
	Trudopollis sp. K Christopher 1979
	Trudopollis sp. (NF-1)
785 - 786 ft	Complexiopollis sp.
	Minorpollis sp.
	Plicapollis sp.
	Pseudoplicapollis sp.
835 - 836 ft	Atlantopollis sp.
	Antlantopollis verrucosa (Groot and Groot 1962) Goczan, Groot, Krutzsch and Pacltova 1967
	Complexiopollis spp.
	Complexiopollis sp. K Christopher
	Complexiopollis sp. N Christopher 1979
	Complexiopollis sp. P Christopher 1979
	Complexiopollis sp. R Christopher 1979
	Complexiopollis funiculus Tschudy 1973
840 - 841 ft	Complexiopollis sp.
	Complexiopollis sp. K Christopher 1979
	Complexiopollis sp. N Christopher 1979
	Complexiopollis sp. Q Christopher 1979
	WELL S27739 AT WYANDANCH
95 - 97	Betulaceae, one specimen
	Brevicolporites sp.
	Choanopollenites sp. (NA-7)
	Complexiopollis abditus Tschudy 1973
	Endoinfundibulapollis sp.
	Holkopollenites sp. (CP3D-2)
	Holkopollenites chemardensis Fairchild 1966
	Minorpollis sp.
	Momipites sp.
	Plicapollis sp.
	Pseudoplicapollis sp.
	Triatripollenites sp.
	Trudopollis sp.
	Vacuopollis sp. (NA-3)
115-117	Brevicolporites sp.
	Complexiopollis sp.
	Holkopollenites sp.
	Holkopollenites chemardensis Fairchild 1966
	Momipites sp.
	Plicatopollis sp. (NN-2)
	Proteacidites sp. A Christopher 1978 (PR-7)
	"Retitricolpites" sp. A Christopher 1978
	Triatripollenites sp.

TABLE 2.—*List of index palynomorphs in Long Island well samples*—Continued

Depth interval	Name
	WELL S27739 AT WYANDANCH--continued
215 ft	Brevicolporites sp. A Christopher 1978 (CP3F-1)
	Brevicolporites sp. B Christopher 1978 (CP3F-2)
	Choanopollenites sp.
	Complexiopollis abditus Tschudy 1973
	Holkopollenites spp.
	Plicapollis sp.
	Proteacidites sp. B Christopher 1978 (PR-1)
	Pseudoplicapollis sp.
	"Retitricolpites" sp. E Christopher 1978
	Triatriopollenites sp.
	Trivestibulopollenites sp.
	Trudopollis sp.
315 - 317 ft	Brevicolporites sp.
	Brevicolporites sp. A Christopher 1978
	Brevicolporites sp. B Christopher 1978
	Complexiopollis abditus Tschudy 1973
	Endoinfundibulapollis sp.
	Holkopollenites sp.
	Momipites sp.
	Plicapollis sp.
	Praebasopollis sp.
	Proteacidites sp. A Christopher 1978 (PR-7)
	Pseudoplicapollis sp.
	"Retitricolpites" sp. A Christopher 1978
	"Retitricolpites" sp. D Christopher 1978
	Triatriopollenites sp.
	Tricolporites sp. A Christopher 1978 (CP3B-5)
	Trivestibulopollenites sp.
	Trudopollis sp.
335 - 337 ft	Brevicolporites sp. A Christopher 1978
	Complexiopollis abditus Tschudy 1973
	Complexiopollis spp.
	Holkopollenites sp.
	Holkopollenites chemardensis Fairchild 1966
	Retitricolpites sp.
	Pecakipollis sp.
	Praebasopollis sp.
	Pseudoplicapollis sp.
	Tricolporites sp.
	Vacuopollis sp.
355 - 357 ft	Complexipollis spp.
	Complexiopollis abditus Tschudy 1973
	Holkopollenites sp.
	Holkopollenites chemardensis Fairchild 1966
	Plicapollis sp.
	Plicatopollis sp.
	Porocolpopollenites sp.
	"Retitricolpites" sp. E Christopher 1978
	Triatriopollenites sp.

TABLE 2.—*List of index palynomorphs in Long Island well samples*—Continued

Depth interval	Name
	WELL S27739 AT WYANDANCH--continued
395 - 397 ft	Betulaceae, one specimen Brevicolporites sp. A Christopher 1978 Brevicolporites sp. B Christopher 1978 Casuarinidites sp. Complexiopollis spp. Complexiopollis abditus Tschudy 1973 Endoinfundibulapollis sp. Holkopollenites sp. Momipites sp. Praebasopollis sp. Proteacidites sp. B Christopher 1978 (PR-1) Pseudoplicapollis sp. Vacuopollis sp.
565 - 567 ft	Brevicolporites sp. A Christopher 1978 Brevicolporites sp. B Christopher 1978 Complexiopollis abditus Tschudy 1973 Holkopollenites sp. Momipites sp. Porocolpopollenites sp. Proteacidites sp. (PR-2) Triatriopollenites sp.
905 - 907 ft	Atlantopollis sp. Complexiopollis sp.
	WELL S24769 IN BRENTWOOD
160 - 162 ft	Pinus - 26 percent of the pollen sum Picea - 2 percent Betulaceae - 32 percent Alnus - 14 percent Ulmus - 4 percent Tilia - 1 percent Ericaceae - 2 percent Gramineae - 3 percent Compositae - 3 percent Spores: Sphagnum - abundant Lycopodium - common Polypodiaceae - rare
246 - 248 ft	Betulaceoipollenites sp. Brevicolporites sp. Complexiopollis spp. Complexiopollis abditus Tschudy 1973 Holkopollenites sp. Holkopollenites sp. B Christopher 1978 Holkopollenites chemardensis Fairchild 1966 Intratriporopollenites sp. Minorpollis sp. Praebasopollis sp.

TABLE 2.—*List of index palynomorphs in Long Island well samples*—Continued

Depth interval	Name
	WELL S24769 IN BRENTWOOD--continued
	Proteacidites sp.
	Triatripollenites sp.
	Trivestibulopollenites sp.
	Trudopollis sp.
	Vacuopollis sp.
386 - 387 ft	Brevicolporites sp. A Christopher 1978
	Brevicolporites sp. B Christopher 1978
	Choanopollenites sp.
	Complexiopollis sp.
	Complexiopollis abditus Tschudy 1973
	Holkopollenites sp.
	Momipites sp.
	Pecakipollis sp.
	Plicapollis sp.
	Praebasopollis sp.
	Pseudoplicapollis sp.
	Triatriopollenites sp.
466 - 468 ft	Brevicolporites sp.
	Complexipollis abditus Tschudy 1973
	Holkopollenites sp.
	Pseudoplicapollis sp.
	Triatriopollenites sp.
846 - 848 ft	CP3A-3
	Miscellaneous tricolporate forms
	WELL S24772 IN BRENTWOOD
566 - 567 ft	Brevicolporites sp.
	Brevicolporites sp. A Christopher 1978
	Complexiopollis spp.
	Complexiopollis abditus Tschudy 1973
	Intratriporopollenites sp.
	Minorpollis sp.
	Minorpollis minima Krutzsch 1959
	Minorpollis sp. B Christopher 1978
	Momipites sp. A Christopher 1979
	New Genus D Christopher 1979
	Porocolpopollenites sp.
	Proteacidites sp.
	Pseudoplicapollis sp. B Christopher 1979
	"Retitricolpites" sp. E Christopher 1978
	Rhoipteleaceae specimen?
	Triatriopollenites sp.
626 - 627 ft	Complexiopollis sp. F Christopher 1979
726 - 727	Atlantopollis sp.
	Complexiopollis sp.
	Heidelbergipollis sp.
	Minorpollis sp. A Christopher 1979
	Momipites sp. A Christopher 1979
	New Genus D Christopher 1979
	?Pseudoplicapollis cuneata Christopher 1979

TABLE 2.—*List of index palynomorphs in Long Island well samples*—Continued

Depth interval	Name
	WELL S22910 IN BRENTWOOD
215 ft	Betula
	Fagus
	Compositae
365 ft	Betulaceoipollenites sp.
	Complexiopollis abditus Tschudy 1973
	Endoinfundibulapollis sp.
	Minorpollis sp.
	Plicapollis sp.
	Pseudoplicapollis sp.
	Trudopollis sp.
405 ft	Betulaceae, one specimen
	Brevicolporites sp.
	Brevicolporites sp. A Christopher 1979
	Brevicolporites sp. D Christopher 1979
	Casuarinidites sp.
	Complexiopollis sp.
	Complexiopollis abditus Tschudy 1973
	Heidelbergipollis sp.
	Holkopollenites sp.
	Minorpollis sp.
	Momipites sp.
	Pecakipollis sp.
	Plicapollis sp.
	Praebasopollis sp.
	Primipollis sp.
	Pseudoplicapollis sp.
	"Retitricolpites" sp. E Christopher 1978
	Triatriopollenites sp.
	Trudopollis sp.
	Vacuopollis sp.
525 ft	Betulaceoipollenites sp.
	Complexiopollis abditus Tschudy 1973
	Minorpollis sp.
	Momipites sp.
	Proteacidites sp.
	Pseudoplicapollis sp.
	Triatriopollenites sp.
	Vacuopollis sp.
605 ft	Brevicolporites sp.
	Complexiopollis sp.
	Complexiopollis abditus Tschudy 1973
	Holkopollenites? sp. (CP3E-1)
	Holkopollenites sp. B Christopher 1978 (CP3D-2)
	Momipites sp.
	Porocolpopollenites sp.
	Pseudoplicapollis sp.
	Retitricolpites sp.
	Triatriopollenites sp.
	Trudopollis sp.

TABLE 2.—*List of index palynomorphs in Long Island well samples*—Continued

Depth interval	Name
	WELL S22910 IN BRENTWOOD--continued
625 ft	Brevicolporites sp.
	Choanopollenites sp. A Christopher 1978
	Complexiopollis spp.
	Complexiopollis abditus Tschudy 1973
	Holkopollenites? sp. (CP3E-1)
	Holkopollenites chemardensis Fairchild 1966
	Porocolpopollenites sp.
	Triatripollenites sp. (NP-2)
665 ft	Brevicolporites sp.
	Complexiopollis abditus Tschudy 1973
	Holkopollenites sp. A Christopher 1978
	Triatriopollenites sp.
	WELL S33379 NEAR LAKE RONKONKOMA
472 - 473 ft	Complexiopollis spp.
	Complexiopollis abditus Tschudy 1973
	Heidelbergipollis sp.
	Holkopollenites sp.
	Intratriporopollenites sp.
	Minorpollis sp.
	Momipites sp.
	Porocolpopollenites sp.
	Praebasopollis sp.
	Pseudoplicapollis sp.
	"Retitricolpites" sp. A Christopher 1978
	"Retitricolpites" sp. B Christopher 1978
	Triatriopollenites sp.
559 - 560 ft	Brevicolporites sp. B Christopher 1978
	Holkopollenites sp.
	Minorpollis sp.
	Pecakipollis sp.
	"Retitricolpites" sp. F Christopher 1978
645 - 647 ft	Betulaceoipollenites sp.
	Intratriporopollenites sp.
	Proteacidites sp.
	Pseudoplicapollis sp.
	Retitricolpites sp.
688 - 689	Brevicolporites sp.
	Brevicolporites sp. A Christopher 1978
	Caryapollenites sp.
	Choanopollenites sp.
	Complexiopollis spp.
	Complexipollis abditus Tschudy 1973
	Holkopollenites sp.
	Momipites sp.
	"Normapolles" sp. (NU-1)
	Pecakipollis sp.
	Plicapollis sp.
	Porocolpopollenites sp.
	Pseudoplicapollis sp.

TABLE 2.—*List of index palynomorphs in Long Island well samples*—Continued

Depth interval	Name
	WELL S33379 NEAR LAKE RONKONKOMA--continued
	Retitricolpites sp.
	"Retitricolpites" sp. A Christopher 1978
	Triatriopollenites sp.
	Vacuopollis sp. (NP-2)
712 ft	Brevicolporites sp.
	Complexipollis abditus Tschudy 1973
	Porocolpopollenites sp.
	Retitricolpites sp.
	Trudopollis sp.
758 ft	Brevicolporites sp.
	Complexiopollis abditus Tschudy 1973
	Trudopollis sp.
780 - 782 ft	Complexiopollis spp.
	Proteacidites sp. (PR-6)
	Pseudoplicapollis sp.
	Trivestibulopollenites sp.
802 ft	Brevicolporites sp.
	Choanopollenites sp.
	Complexiopollis sp.
	Complexiopollis abditus Tschudy 1973
	Minorpollis sp.
	Pecakipollis sp.
	Pseudoplicapollis sp.
	Trivestibulopollenites sp.
869 - 870 ft	Complexiopollis spp.
	Complexiopollis abditus Tschudy 1978
	Minorpollis sp.
	Praebasopollis sp.
1,018 - 1,019 ft	Complexiopollis sp.
1,041 ft	Atlantopollis verrucosa (Groot and Groot, 1962) Goczan, Groot, Krutzsch and Pacltova 1967
	Complexiopollis sp.
	Complexiopollis abditus Tschudy 1973
1,108 - 1,110 ft	Atlantopollis verrucosa (Groot and Groot, 1962) Goczan, Groot, Krutzsch and Pacltova
	Complexiopollis sp.
	Complexiopollis abditus Tschudy 1973
1,154 - 1,156 ft	Complexiopollis sp.
	Retitricolpites sp.
	"Retitricolpites" sp. B Christopher 1978
1,176 - 1,178 ft	Atlantopollis verrucosa (Groot and Groot, 1962) Goczan, Groot, Krutzsch and Pacltova, 1967
	Complexiopollis sp.
1,198 ft	Complexiopollis sp.
	Retitricolpites sp.

TABLE 2.—*List of index palynomorphs in Long Island well samples*—Continued

Depth interval	Name
	WELL S33379 NEAR LAKE RONKONKOMA--continued
1,265 - 1,267 ft	Complexiopollis sp. Plicapollis sp. Porocolpopollenites sp.
1,500 ft	"Retitricolpites" sp. D Christopher 1978 (C3A-5)
	WELLS 6409 AND 6434 IN BROOKHAVEN
	Index palynomorphs listed in text.
	WELL S30271 NEAR RIVERHEAD
120 - 140 ft	Pinus (3 specimens), Betula (5), Alnus (1) Quercus (12), Ulmus (1), Carya (4), Populus (4), Nyssa (5) Liquidambar (2), Castanea (1), Fraxinus (1), Potomogeton (5), Gramineae (5), Ambrosia (4), Rumex (1), Polygonum (2)
384 ft	Brevicolporites sp. B Christopher 1978 Complexiopollis sp. Minorpollis sp. Momipites sp. Pseudoplicapollis sp.
405 ft	Complexiopollis sp. Momipites spp. Momipites sp. A Christopher 1979 Pseudoplicapollis sp. ?Pseudoplicapollis cuneata Christopher 1979 Pseudoplicapollis endocuspis Christopher 1979
444 ft	Complexiopollis abditus Tschudy 1973 Intratriporopollenites sp. Minorpollis sp.
564 ft	Betulaceoipollenites sp. Complexiopollis spp. Complexiopollis abditus Tschudy 1973 Retitricolpites sp.
604	Triatriopollenites sp.
	WELL S21091 ON FIRE ISLAND
580 ft	Brevicolporites sp. Holkopollenites sp.
1,178 ft	Brevicolporites sp. Complexiopollis sp. Momipites sp.

TABLE 2.—*List of index palynomorphs in Long Island well samples*—Continued

Depth interval	Name
	WELL S21091 ON FIRE ISLAND--continued
1,560 ft	Brevicolporites sp. Choanopollenites sp. Holkopollenites sp. ?Pseudoplicapollis cuneata Christopher 1979
1,585 ft	Complexiopollis spp. Momipites sp. Pecakipollis sp. Praebasopollis sp. Proteacidites sp. Pseudoplicapollis sp. Triatriopollenites sp. Trivestibulopollenites sp. Trudopollis sp.
1,800 - 1,873 ft	Brevicolporites sp. Complexiopollis spp. Complexiopollis abditus Tschudy 1973 Plicapolis sp. Triatriopollenites sp. Vacuopollis sp.
	WELL S52162 ON SMITH POINT
146 - 147 ft	Pinus (1), Ericaceae (1), Ulmus (1), Gramineae (1)
190 - 192 ft	Caryapollenites sp. Momipites sp. (NK-3) Trisectoris sp. (MPD-2) Trudopollis sp. Dinoflagellate: Svalbardella lidiae
222 - 224 ft	Momipites strictus Frederiksen and Christopher 1978
253 - 255 ft	Betulaceoipollenites? Momipites spp.
377 - 379 ft	Brevicolporites sp. Complexiopollis sp. Momipites microfoveolatus Frederiksen and Christopher 1978 Pseudoplicapollis sp. Trudopollis sp. Vacuopollis sp.
407 - 409 ft	Brevicolporites sp. Complexiopollis sp. Minorpollis sp. Momipites sp. Pseudoplicapollis spp. "Retitricolpites" sp. A Christopher 1978 Trisectoris sp. (MPD-2)

TABLE 2.—*List of index palynomorphs in Long Island well samples*—Continued

Depth interval	Name
	WELL S52162 ON SMITH POINT--continued
467 - 469 ft	Brevicolporites sp. Complexiopollis sp. Complexiopollis abditus Tschudy 1973 Praebasopollis sp. Retitricolpites sp.
534 - 535 ft	Betulaceoipollenites sp. (NO-3) Brevicolporites sp. Momipites sp. Pecakipollis sp. Plicapollis sp. "Retitricolpites" sp. C Christopher 1978 "Retitricolpites" sp. F Christopher 1978
596 - 598 ft	Brevicolporites sp. Choanopollenites sp. Complexiopollis sp. Complexiopollis abditus Tschudy 1973 Holkopollenites sp. Holkopollenites chemardensis Fairchild 1966 Momipites sp. Pecakipollis sp. Plicapollis sp. Praebasopollis sp. Pseudoplicapollis sp. "Retitricolpites" sp. E Christopher 1978 "Retitricolpites" sp. F Christopher 1978 Triatriopollenites sp. Trivestibulopollenites sp.
626 - 628 ft	Betulaceae, one specimen Complexiopollis abditus Tschudy 1973 Minorpollis sp. Momipites sp. Trisectoris sp. Trivestibulopollenites sp. Vacuopollis sp.
688 - 690 ft	Atlantopollis sp. Brevicolporites sp. A Christopher 1978 (CP3F-1) Complexiopollis sp. Complexiopollis abditus Tschudy 1973 Endoinfundibulapollis sp. (NM-1) Holkopollenites sp. Momipites sp. Plicapollis sp. Praebasopollis sp. Proteacidites sp. A Christopher 1978 (PR-7) Proteacidites sp. B Christopher 1978)PR-1) Proteacidites sp. (NQ-1) Pseudoplicapollis sp. Triatriopollenites sp. (NP-2) Trudopollis sp. Vacuopollis sp.

TABLE 2.—*List of index palynomorphs in Long Island well samples*—Continued

Depth interval	Name
	WELL S52162 ON SMITH POINT--continued
720 - 722 ft	Betulaceae, one specimen Choanopollenites Complexiopollis sp. Complexiopollis abditus Tschudy 1973 Holkopollenites sp. Minorpollis sp. Momipites sp. Pecakipollis sp. Plicapollis sp. Praebasopollis sp. Pseudoplicapollis sp. Trivestibulopollenites sp.
750 - 752 ft	Complexiopollis sp. Complexiopollis abditus Tschudy 1973 Extremipollis sp. Minorpollis sp. Pecakipollis sp. Plicapollis sp. "Retitricolpites" sp. D Christopher 1978 Vacuopollis sp.
780 - 782 ft	Choanopollenites sp. Complexiopollis spp. Complexiopollis abditus Tschudy 1973 Extremipollis sp. Holkopollenites sp. Minorpollis sp. Proteacidites sp. Pseudoplicapollis sp. Trivestibulopollenites sp. Trudopollis sp.
938 - 939 ft	Choanopollenites sp. Complexiopollis sp. Complexiopollis abditus Tschudy 1973 Holkopollenites sp. Proteacidites sp. Pecakipollis sp. Plicapollis sp. Pseudoplicapollis spp. "Retitricolpites" sp. D Christopher 1978 Triatriopollenites sp. Trivestibulopollenites sp. Trudopollis sp.
970 - 972 ft	Complexiopollis sp. Complexiopollis abditus Tschudy 1973 Intratriporopollenites sp. Minorpollis sp. "Retitricolpites" sp. D Christopher 1978

TABLE 2.—*List of index palynomorphs in Long Island well samples*—Continued

Depth interval	Name
	WELL S52162 ON SMITH POINT--continued
1,001 - 1,002 ft	Complexiopollis sp. Complexiopollis abditus Tschudy 1973 Pecakipollis sp. Plicapollis sp. Praebasopollis sp. Pseudoplicapollis endocuspis Tschudy 1975 Pseudoplicapollis sp. Triatriopollenites sp. Trivestibulopollenites sp. Vacuopollis sp.
1,063 - 1,064 ft	Complexiopollis sp. Complexiopollis abditus Tschudy 1973 Minorpollis sp. Plicapollis sp. Pseudoplicapollis sp. Vacuopollis sp.
1,159 - 1,161 ft	Brevicolporites sp. Choanopollenites sp. Complexiopollis spp. Complexiopollis abditus Tschudy 1973 Holkopollenites sp. A Christopher 1978 Pecakipollis sp. Plicapollis sp. Pseudoplicapollis sp. Triatriopollenites sp. Trudopollis sp.
1,222 - 1,223 ft	Complexiopollis sp. Tricolporites sp. (CP3B-4)
1,255 - 1,256 ft	Choanopollenites sp. Complexiopollis sp. Complexiopollis abditus Tschudy 1973 Holkopollenites sp. Plicapollis sp. Pseudoplicapollis sp.
1,380 - 1,381 ft	Complexiopollis sp.
1,439 - 1,440 ft	Complexiopollis sp. Complexiopollis abditus Tschudy 1973
1,470 ft	Atlantopollis sp. Complexiopollis spp. Complexiopollis abditus Tschudy 1973
1,657 - 1,659 ft	Holkopollenites sp. Minorpollis sp. Porocolpopollenites sp. Praebasopollis sp. Proteacidites sp. Trudopollis sp. A Christopher 1978 (NF-1)

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