# Pollen And Paleosalinity Analyses From A Holocene Tidal Marsh Sequence, Cape May County, New Jersey.

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POLLEN AND PALEOSALINITY ANALYSES FROM A
HOLOCENE TIDAL MARSH SEQUENCE, CAPE MAY
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POLLEN AND PALEOSALINITY ANALYSES FROM A HOLOCENE TIDAL
MARSH SEQUENCE, CAPE MAY COUNTY, NEW JERSEY

by
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A Dissertation

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Special committee directing

the doctoral work of Mr.

A. Lee Meyerson

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Chairman

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ABSTRACT

Dennis Creek Tidal Marsh was selected for the
site of a study dealing with the application of pollen
analysis and sedimentary phosphate paleosalinity analysis
to problems concerning changes in local sedimentary
environments of deposition. This tidal marsh was chosen
because of the absence of a barrier island to the sea-
ward, and the presence of a cedar swamp which could pro-
vide a good stratigraphic marker, to the landward.

The stratigraphy of the tidal marsh has been
established by collecting 17 core samples, logging changes
in lithology, and by applying sedimentary phosphate
method paleosalinity determinations and pollen analysis
to three selected cores. The presence of the marsh is
related to post-Pleistocene rise in sea level. Fluctu-
ations in the rate of sea-level rise resulted in oscil-
lations in the marsh environment which are reflected
by changes in sedimentary facies. The oscillations in
the marsh environment which are evident in Dennis Creek
can be correlated with similar fluctuations found in
tidal marshes elsewhere along the eastern coast of the
United States.

Several samples collected at varying levels
within the Dennis Creek sequence have been dated by

the radiocarbon method. The dates obtained are related to published sea-level curves, and they support the hypothesis that the slope of the eustatic sea-level curve was not uniform, but rather fluctuated during the last 3000 years.

The determination of the tidal marsh stratigraphy and the correlation of this stratigraphy with other areas establish the validity of the analytical techniques which were utilized in the study.

# INTRODUCTION

## Statement of the problem

Paleoecology is the study of the relationship
of fossil organisms and ancient environments and is,
essentially, the application of the principles of ecology
to the geologic past. Paleoecological studies are hindered
by our inability to find preserved the entire biologic
community which existed at any point in the past, and
our inability to accurately determine all parameters
of the paleoenvironment. Thus, it becomes essential,
in the field of paleoecology, to continually strive
toward a refinement in methodology which will enhance
the elucidation of the fossil community and its envir-
onmental parameters.

In the transitional environment, which is of
extreme importance to the geologist, two sensitive in-
dicators of change are salinity and vegetation. No
absolutely dependable method which will accurately depict
either factor has as yet been developed. However, in
each case there is a method which although based on
somewhat limited trial has, at least the potential of
being a useful technique: pollen analysis for the
determination of local vegetation, and sedimentary
phosphate analysis for the determination of paleosalinity.

It was the purpose of this study to investigate the
reliability of both pollen and sedimentary phosphate
method paleosalinity analysis in detecting variations
in local environments. An area where both methods can
be employed simultaneously, and, therefore, correlated,
is the tidal marsh. A tidal marsh surrounding Dennis
Creek, in Cape May County, New Jersey, was chosen for
the study. The reasons for choosing this particular
tidal marsh were twofold: (1) the marsh is on Delaware
Bay and does not have a barrier island to the seaward,
which would tend to complicate the facies changes in the
Late Holocene sequence, and (2) landward of the modern
marsh and in the subsurface is a cedar swamp which pro-
vides a distinctive vegetational change which is easily
discernable in the pollen sequence and the peat fabric.

The general approach to the problem has involved
the analysis of pollen distribution, paleosalinity, and
lithology in selected cores from Dennis Creek Tidal
Marsh. By analyzing all parameters from the same core
their relationship to each other can be determined,
thereby providing a check on their reliability. As
a further check, selected samples have been thin-
sectioned and the fabric of the peat examined microscopic-
ally. Utilizing these methods, interpretations of
vegetational change through time can be made and compared

with published descriptions of other tidal marshes obtained
by different analytical techniques. Since the facies
changes in the sequence are due to the rise in sea level
during deglaciation, samples from the cores were dated
utilizing carbon-14 to determine how they relate to
previously published curves for the rate of sea-level
rise.

## Pollen analysis

Although pollen grains were first described
from sedimentary deposits by Fruh in 1885, it was not
until 1916 that pollen analysis became a significant
paleoecological tool (Erdtman, 1943). In 1916 Von Post
described the percent change in pollen distribution
from the top to the bottom of peat deposits and used
this change for correlation and environmental inter-
pretation (Erdtman, 1943). With the work of Von Post
the field of pollen analysis, or palynology, was launched.
Since that time a multitude of workers have applied
palynology to both Pleistocene and pre-Pleistocene
deposits.

The application of pollen distribution to stra-
tigraphy and paleoecology is enhanced by the mode of
dispersion of the pollen grains. Thousands of pollen
grains are produced by each anther in a flower, and

much of this pollen is dispersed by the wind. Due to this wind dispersal, large amounts of pollen are deposited in lakes, bogs, and oceans. These bodies of water are capable of preserving the pollen due to their relatively low oxygen content. If pollen-bearing sediment is exposed to the atmosphere, the grains are rapidly oxidized.

The pollen which rains down on any basin of deposition is essentially representative of the regional vegetation at the time of deposition. Nicholas (1967) has shown that the pollen rain is not exactly equivalent to the regional vegetation. Some species are overrepresented in the pollen rain and others underrepresented. The ability of a species to be accurately represented in the pollen rain is dependent upon: (1) mode of pollination, (2) productivity, (3) adaptation for dispersal, and (4) proximity to the site of deposition.

The laboratory processing of pollen-bearing sediment concentrates the grains and enables identification, counting, and representation in pollen diagrams. Ecological knowledge of vegetation permits reconstruction of the paleoenvironment and stratigraphic correlation.

Most of the investigations in Pleistocene palynology have been done on lakes and fresh-water bogs.

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The intent of these investigations has been to determine regional vegetational changes following deglaciation. This approach has led to the recognition of a zonation in the pollen distribution first advanced by Deevey (1939, 1943) and later recognized throughout New England. The sequence consists of, in order of decreasing age:

Zone A - late glacial spruce pollen zone

Zone B - maximal pine pollen percentages

Subzone B-1 (lower) - characterized by

Abies, Larix, Betula, Alnus, and Pinus

Banksiana or Pinus resinosa

Subzone B-2 (upper) - characterized by

pollen of Quercus and Pinus Strobus

Zone C - extends between zone B and the surface

and is characterized by Tsuga and

deciduous trees

Subzone C-1 - Quercus and Tsuga

Subzone C-2 - Quercus and Carya

Subzone C-3 - Quercus and Castanea

These zones are not recognized south of glaciated eastern North America.

The studies which have been done in tidal marshes (Butler, 1959; Harmon and Tedrow, 1969; Heusser, 1963; Newman and Rusnak, 1965; Newman and Munsart, 1968; Newman et. al., 1968; Ogden, 1959; Potzger, 1952; Rosenwinkel.

1964; and Sears, 1963) utilize pollen distribution for the determination of regional vegetation. Heusser (1963) to some degree, Sears (1963), and Harmon and Tedrow (1969) have attempted to use tidal marsh pollen to reconstruct local vegetation. The hesitancy in the use of pollen for the reconstruction of local environments is due to the wind-dispersal mechanism which raises some doubt as to the site of origin of a specific pollen grain. However, both Sears (1963) and Harmon and Tedrow (1969) have shown that pollen diagrams from tidal marshes do reflect local vegetation. Their work indicates that more investigations are warranted.

Sedimentary phosphate method paleosalinity

A method for determining paleosalinity was proposed by Nelson (1967) which utilized the relative proportions of iron- and calcium phosphate in argillaceous sediments. The concept was based upon work by Pomeroy et. al. (1965) which indicated that an equilibrium existed between the phosphate in sediment and overlying waters, and on work by Chang and Jackson (1957) which indicated that phosphate existed as several distinct mineral species in soils. The proposed sedimentary phosphate method (SPM) was tested in Chesapeake Bay by Nelson (1967) and a linear relationship was established

between the calcium-phosphate fraction (Ca/Fe+Ca) and
salinity, the relationship being:

calcium-phosphate fraction = .09 + 0.26 salinity.
Subsequently, SPM paleosalinities have been determined
by several investigators with varying degrees of success.

Tasch and Gafford (1968) determined the SPM
paleosalinity of Permian deposits in Antarctica and
found the results agreed with other paleosalinity
methods.

Müller (1969) applied the method to European
sediments of Recent, Pleistocene, Tertiary, Permian,
and Carboniferous ages with mixed results. In some
cases SPM paleosalinities agreed with other methods,
while in others SPM paleosalinities were found to be
spurious based upon determinations by other methods.
Müller concluded that the spurious results were due to
(1) introduction of detrital apatite from the source
area and (2) reduction of the iron phosphate in the
presence of $H_2S$ in a lacustrine environment with the
subsequent liberation of phosphate ions. Both processes
would yield SPM paleosalinities greatly in excess of
the true values.

Guber (1969) determined SPM paleosalinities
on Paleozoic sediments in Pennsylvania with incon-
sistent results. In some instances SPM paleosalinities

agreed with values obtained using other methods, while in other instances there were wide divergences. The divergence between methods was found to occur in zones where the brachiopod Lingula was present and was attributed to calcium phosphate contributed by the shells of these organisms. An important aspect of the investigation was the determination of pyritic sulfur occurring with the iron phosphate. The results showed that iron phosphate is not reduced in an $H_2S$-rich lacustrine environment as proposed by Müller (1969).

From the results of these investigators, it is apparent that there are at least two geological constrictions on the use of SPM paleosalinity: (1) the presence in the sediments of detrital apatite, and (2) the presence of calcium phosphate-bearing fossils. Although these restrictions somewhat limit the applicability of SPM paleosalinity, the potential value of the method warrants further investigation. To date there is no method of determining paleosalinity which can approach the accuracy necessary for detailed paleoecologic analysis. Therefore, on this basis alone, SPM paleosalinity analysis must be subjected to exhaustive testing in order to identify the circumstances and degree of its applicability.

# STUDY AREA

## Geography

The tidal marsh surrounding Dennis Creek is
located in the northwestern portion of Cape May County,
New Jersey (Figure 1). Cape May County is located at
the southern end of New Jersey on a peninsula bounded
on the east by the Atlantic Ocean and on the west by
Delaware Bay.

The county lies within the Atlantic Coastal
Plain Province and consists of gently rolling plains
with tidal marshes along the low areas bordering Delaware
Bay and the Atlantic Ocean. Elevations of the high areas
of the county rarely exceed 25 feet. Average temperatures
range from $35^O$F in January to $75^O$F in July. Average
precipitation is 44 inches per year.

The Dennis Creek Tidal Marsh, as defined in this
study, is located between $39^O07'$N and $39^O12'$N, and between
$74^O49'$W and $74^O55'$W (Figure 2). It is bounded on the
northwest by West Creek and on the south by Bidwell's
Ditch. On the west the boundary is Delaware Bay, while
on the other boundaries the marsh grades laterally into
upland vegetation. Major streams traversing the study
area are West Creek, East Creek, Dennis Creek, Sluice
Creek, Goshen Creek, and Bidwell's Ditch. Some areas
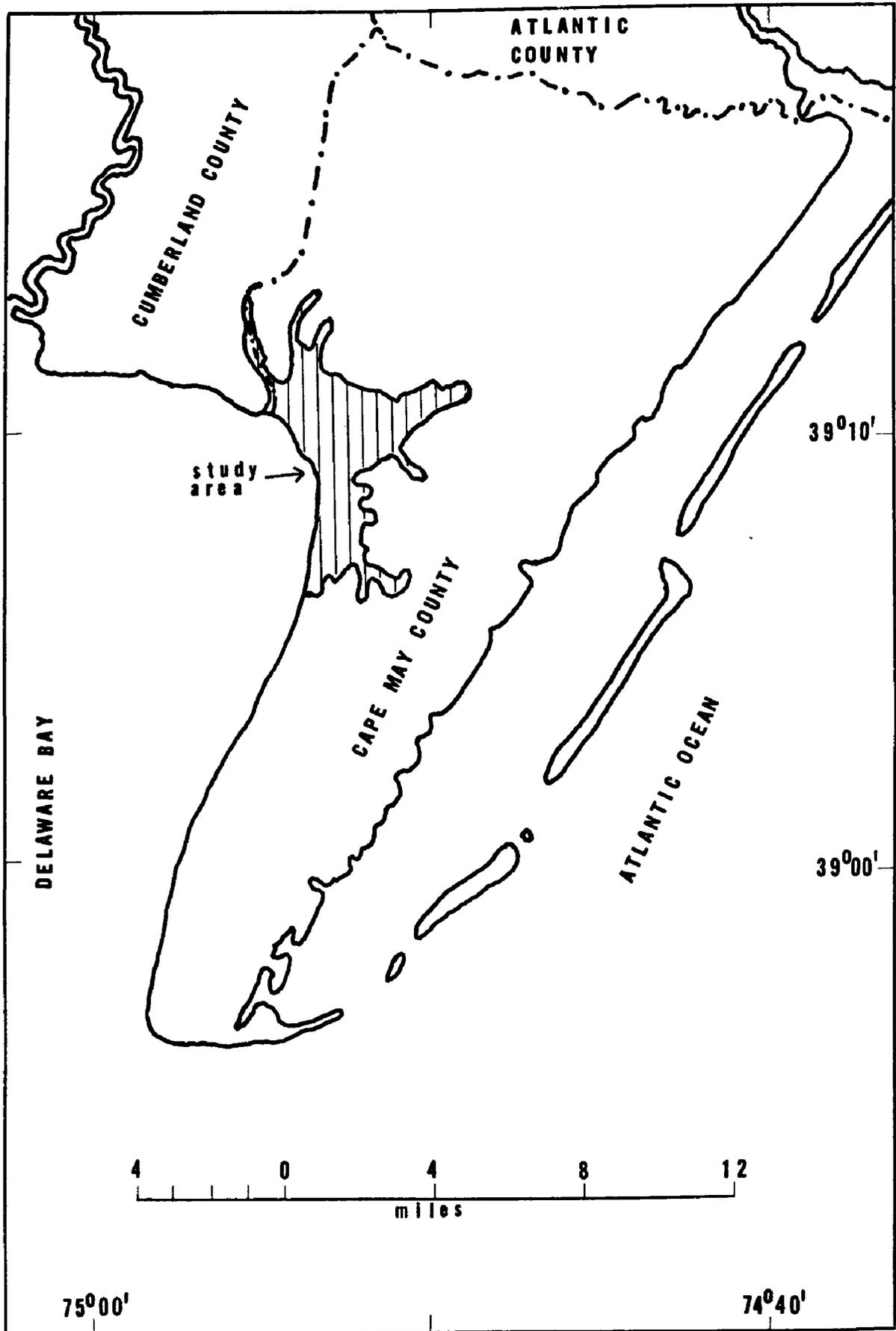
Figure 1.  Map of Cape May County Showing Area of Study.
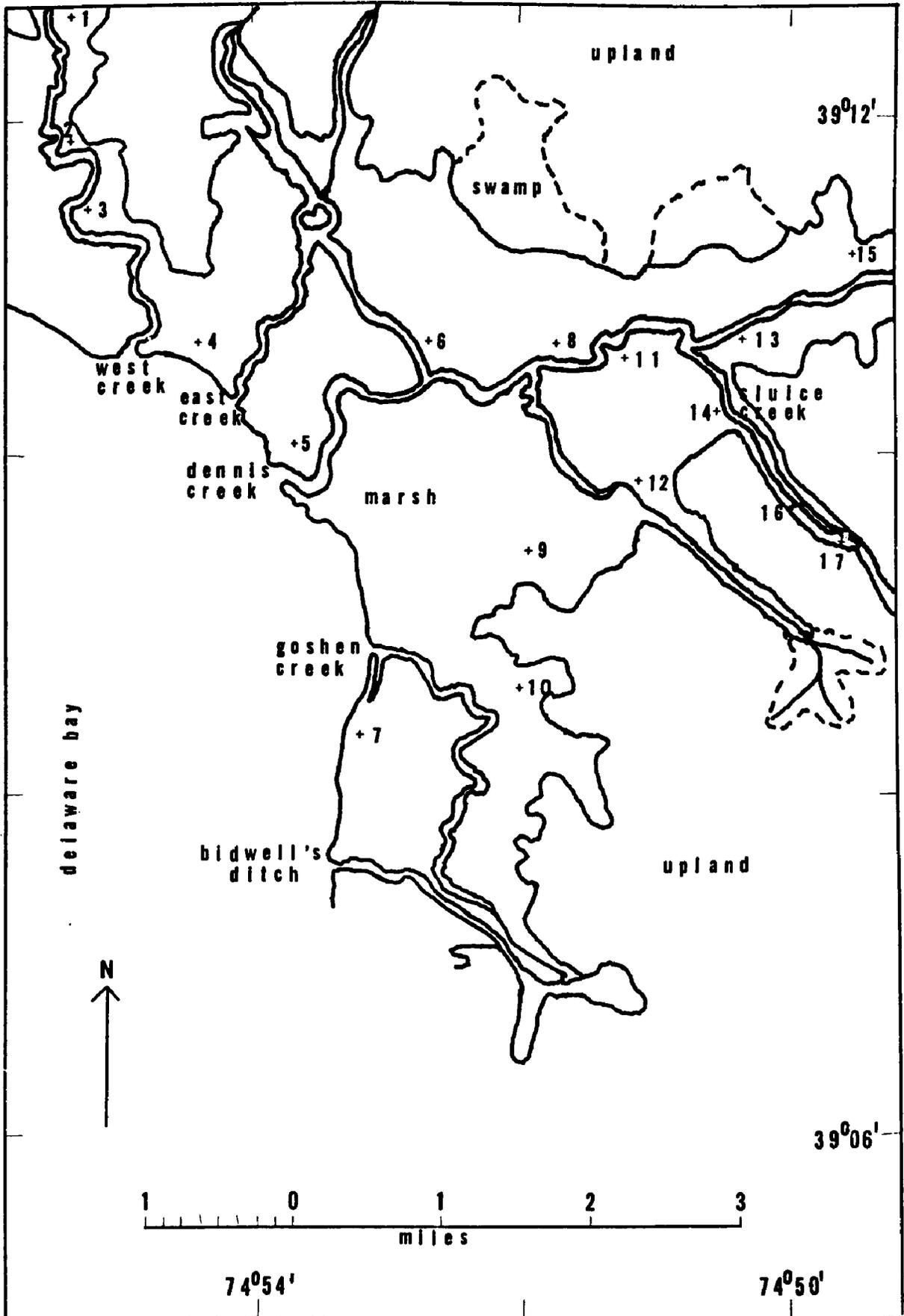
Figure 2.   Map of Dennis Creek Tidal Marsh Showing the Location of Core Holes.

to the north and east of the marsh are occupied by
cedar swamps.

## Geology

Holocene deposits of the Dennis Creek Tidal
Marsh are underlain by the Cape May Formation of Pleistocene
age. This formation consists of coarse sand admixed
with pebbles. During the course of the field work
seventeen core holes were drilled in the marsh at the
locations shown on Figure 2. Although this number of
core holes does not provide an overwhelming amount of
data, the borings are sufficient in number to permit
construction of a map of the topography of the Cape
May surface underlying the marsh area (Figure 3). It
can be seen from this map that major streams traversed
the Cape May surface in approximately the same positions
as modern streams. The modern streams, however, exhibit
considerable meandering.

## Vegetation

A complete vegetational survey was not part
of the present study. However, the marsh surrounding
Goshen Creek has been studied in detail by Good (1965).

contour interval: 1 meter

miles
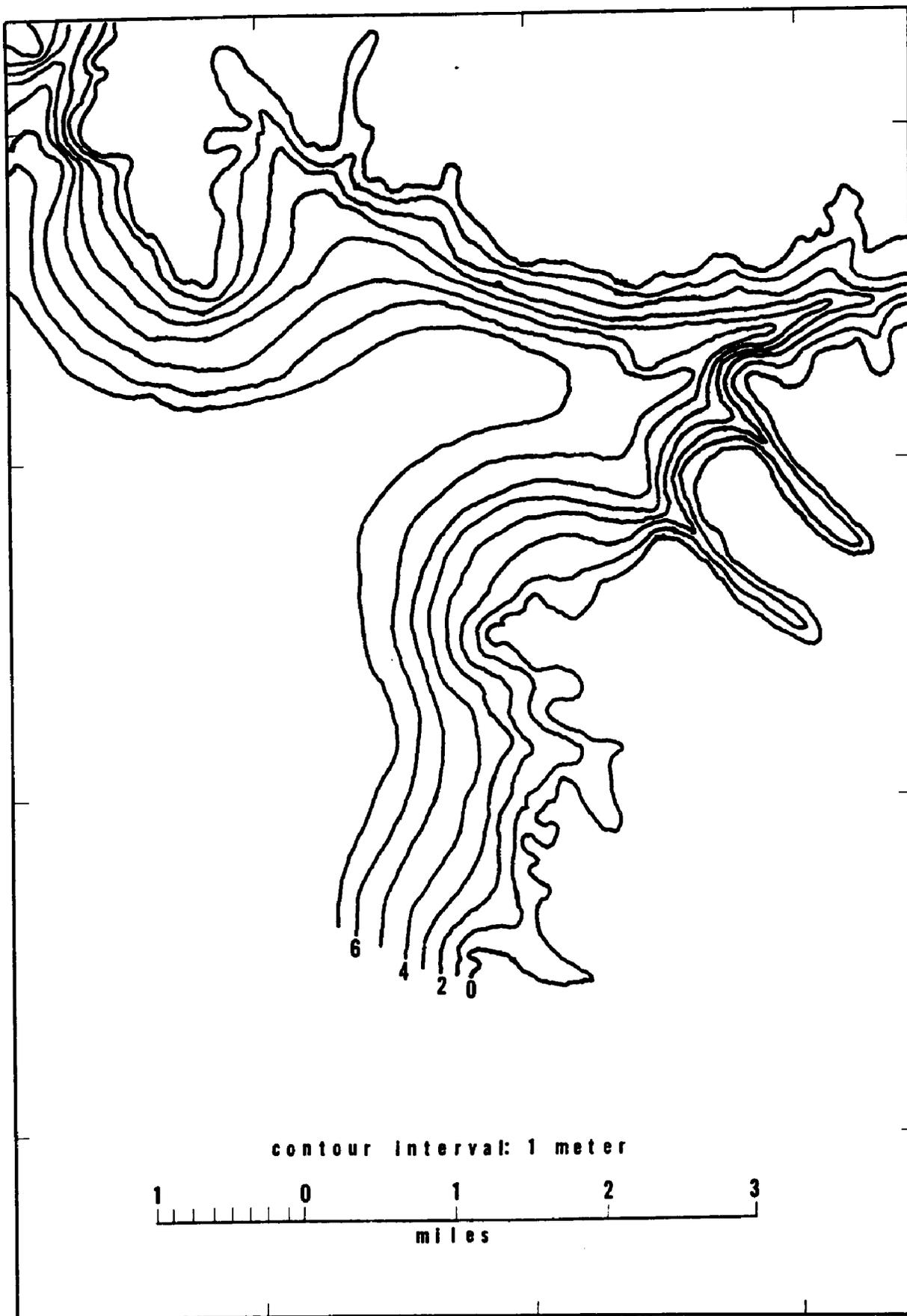
Figure 3.  Map Showing the Topography of the Surface of the
Cape May Formation.  Map area is the same as that of Figure 2.

Good found that the greatest area of the marsh was covered by Spartina alterniflora (See Figures 4 and 5), with a gradation existing between the brackish marsh environment of S. alterniflora and the landward community of Spartina patens, Panicum virgatum, Typha angustifolia, and Phragmites communis. Spread throughout the marsh were members of the Chenopodiaceae such as Salicornia europaea and rarely Acnida cannabina. Spartina alterniflora grows best in those areas where tidal flooding occurs twice daily, whereas Spartina patens grows best in those areas with less frequent flooding. The differences in flooding may be due to slight differences in elevation or proximity to a ditch. The author has observed throughout the marsh and beyond the area described by Good, that Spartina alterniflora is indeed the most abundant form of macrovegetation.

Cook (1856, 1857) reported evidence of marsh erosion at the bayshore and also encroachment of the marsh on the upland vegetation to the east. Such occurrences are still common today. Figure 6 demonstrates the erosion of the marsh surface by wave action in Delaware Bay. Although the blocks of marsh peat broken off in this manner do, in fact, serve to propagate the Spartina alterniflora by the spreading of rhizomes, material is being steadily lost from the marsh. Figure 7 shows the

Figure 4. View of Dennis Creek Tidal Marsh Showing
the Typical Spartina alterniflora Vegetation.



Figure 5. Close-up View of Spartina alterniflora.
The coring head is the one used in the field investigation.

Figure 6. Evidence of Erosion at the Mouth of Dennis Creek.



Figure 7. Dead Cedar Trees within the Marsh Environment.

landward encroachment of the tidal marsh on the cedar
swamp community. Dead cedar trees are left standing
in the marsh as the brackish water environment slowly
advances inland. Such an encroachment of tidal marsh
sediments over the cedar swamp must leave cedar swamp
sediments buried beneath the marsh surface. Cook (1856,
1857) reported that the early settlers mined cedar logs
from beneath the marsh surface.

Man also has strongly influenced the marsh surface.
Since colonial times the surface of the marsh has been
ditched for mosquito control and to promote the growth
of Spartina patens which was mowed extensively in the
past to provide salt hay. This was at one time a major
industry in the tidal marsh areas of the state. The
ditching of the marsh drains the marsh surface and,
thus, produces an environment unlike that which would
exist without the ditching. Therefore, the environments
reflected in the deposits formed prior to the influx
of man into the area must be different from those which
exist today.

Cook (1856) reports that since 1691, when the
first settlement of the area was made, the cedar swamps
in the area have been extensively cut for timber. By
about 1750 all trees within the swamps had been cut
down. Since that time it has been usual to cut the

trees every 50 or 60 years. The cedar industry was an important source of income in the early history of Cape May County. The swamp areas quickly replenished themselves and thus sustained the industry. According to Cook (1857) prior to the complete removal of the original trees, cedars of approximately 1000 years age (by tree ring count) could be found in the swamps.

The deposits on the floor of the cedar swamps accumulate with great rapidity. Cook (1857) reports at least one instance where there had been one foot or more of accumulation over a period of sixty years. This accumulation is entirely of vegetative material with no clay being reported in the samples taken.

# SEDIMENTS

## Field sampling

Seventeen holes were drilled and sampled at the locations noted in Figure 2, using a Davis-type peat sampler. This sampler takes a core 20 cm in length and 2 cm in diameter (Figure 5). Through the addition of extension rods to the coring head continuous samples can be obtained for the entire marsh sequence. As the 20-cm cores were extracted from the core-holes they were laid on a 20-cm length of board which had been covered with a sheet of plastic film. The gross stratigraphy of the core was then noted. The lithologies so recorded are presented in Appendix A. Three of the cores (#6, #8, and #16) were later described in detail. In these three cores it was found that the field descriptions were erroneous in some instances due to contamination on the outside of the core.

After logging, the cores were wrapped in plastic film, taped to the board, and numbered. Upon returning from the field, the cores were refrigerated and frozen in preparation for future analysis.

The numbering system for each 20-cm segment was consecutive for each core. Thus, sample 16-1 is the first 20 cm segment of core #16, and sample 16-2 is the

segment from 20 to 40 cm below the surface.

## Laboratory sampling

The three cores chosen for detailed sampling were thawed and then quartered in the lengthwise direction. The colors of the sediments were noted. The cores were described noting the approximate proportions of clastic material and root remains. Any significant features of the cores, such as wood chips, shells, or character-istic root types, were noted.

After the cores were logged, one of the length-wise quarters was cut into 2 cm segments, with each segment being placed in an individual plastic bag and refrozen for future analysis. The numbering system was consecutive for each segment within a core. Thus sample 16-1-1 is the first 2 cm segment of sample 16-1 and sample 16-1-2 is the segment from 2 to 4 cm (See Appendices B and C).

## Lithology

The lithologies of the three cores selected for analysis are depicted diagrammatically in Figure 8. The fiber content refers to the amount of recognizable organic material contained in the samples and represents a visual estimate of the percentage of organic material. This organic material consists primarily of roots,
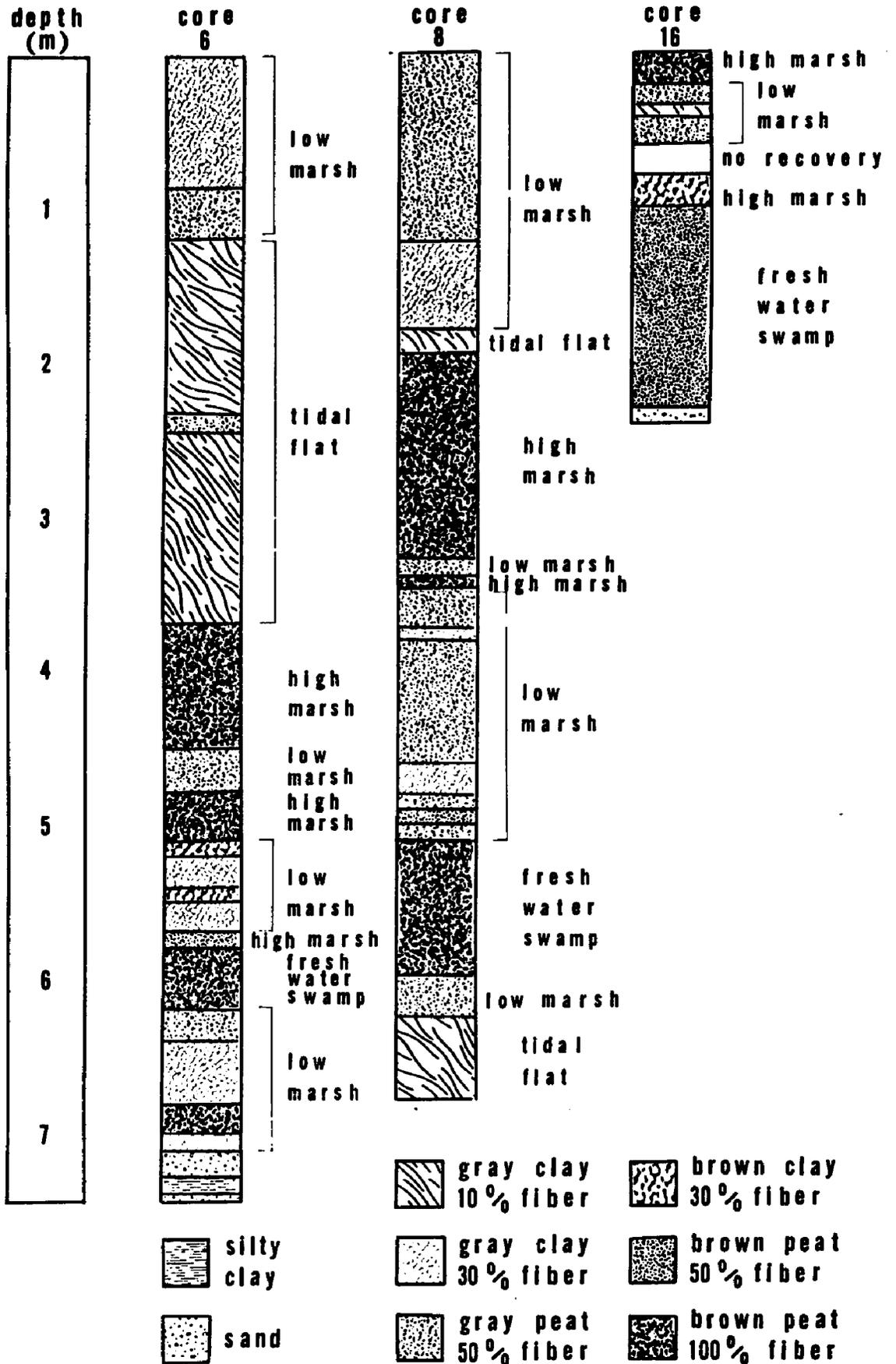
Figure 8. Lithology and Depositional Environment of the Three Analyzed Cores. Interpretation based on lithology. See also Figure 34.

although in some horizons comminuted leaves probably contribute significantly to the total. The diagram also illustrates interpretations of the environments of deposition of the various facies. The distribution of local flora is such that several distinct communities can be recognized, not only on the modern marsh surface, but also in the subsurface deposits.

A. Tidal Flat - This area is sparsely populated by Spartina alterniflora Loisel. and exists at an elevation slightly above or at the mean low tide. The former tidal flat environment can be recognized in the subsurface by the extremely low concentration of root fibers in the sediment.

B. Low Marsh - This area is dominated by the S. alterniflora community, associated with diurnal inundation by tides. This environment can be recognized in sediment samples by the abundance of large, hollow roots which may be S. alterniflora.

C. High Marsh - This environment is dominated by the Spartina patens (Ait.) Muhl. community. This community exists at or slightly above mean high tide. The vegetation is generally much denser than that of the low marsh. Recognition of this environment in the subsurface is based upon the presence

of the wiry roots of S. patens.

D. Phragmites communis Trin. Marsh - This
area is dominated by P. communis which has a wide
salinity tolerance and does not require diurnal
inundation by the tides.  In sediment samples
P. communis roots are similar morphologically to
S. alterniflora.  Therefore, misidentification of
these roots may have occurred causing a misinter-
pretation of environment based on lithology; however,
this would have .no bearing on the correlation
between interpretations based on paleosalinity
measurements and those based on pollen counts.

E. Cedar Swamp - The cedar swamp is a fresh
water environment dominated by the cedar and
other arboreal species.  The subsurface deposits
of this environment consist almost entirely of
comminuted organic material and pieces of wood.

A few thin sections were studied but it was not
possible appreciably to enhance descriptions based on
megascopic analysis.


Core #6.  The lithology suggests fluctuations in
environment (Figure 8).  The gray color of the clay and
the relatively low fiber content of the upper meter of the
core indicates that although marsh conditions existed
through this period of deposition, the vegetation was not

dense. Some of the fiber can be identified as S. alterniflora indicating a low marsh environment.

The gray color and similar fiber compositions persist to a depth of 1.20 meters. The segment between 1.0 and 1.20 meters differs from the first in that the fiber content fluctuates between 30% and 50%. This still indicates a low marsh environment.

Below sediments formed in the low marsh environment are two and a half meters of gray clay with 10% fiber. The gray color of the clay and the low fiber content of the material tend to indicate a tidal flat or open water environment. The fact that in some instances S. alterniflora fibers can be identified tends to indicate that a tidal flat is the more logical interpretation of the depositional environment. S. alterniflora is commonly found in the sparsely vegetated areas of the higher portions of the tidal flat environment.

Below sediments deposited in the tidal flat environment is peat which consists largely of roots of S. patens. This combination tends to indicate a high marsh environment. In the middle of the high marsh peat is a small segment of gray peat with S. alterniflora roots indicating a low marsh environment. Thus, there has been a fluctuation of the environment within the time span represented by this segment of the core.

Sediments below the peat apparently represent deposition in a low marsh environment; this can be ascertained by the low fiber content and the presence of S. alterniflora roots. These sediments, in turn, overlie peat containing abundant S. patens roots suggesting a high marsh environment. Once again there is the indication of a vertical change in facies indicating change in depositional environment. Sediments characteristic of a fresh water swamp underlie those of the high marsh environment. This interpretation is derived from the presence of wood fragments in a peat which is almost completely composed of nondescript organic matter which may consist largely of decomposed leaves.

Below this are sediments again interpreted as being deposited in a low marsh environment. These, in turn, overlie a sand facies which marks the bottom of the section. The interpretation of the low marsh is again based primarily upon the presence of S. alterniflora in the clay and peat.

It is apparent that fluctuations in environment of deposition obviously have taken place in the area represented by this core.

Core #8. The upper two meters of this core consists of a gray clay containing S. alterniflora

roots suggesting deposition in a low marsh environment. For the most part this environment was subjected to less frequent and shallower tidal inundation than the one at the top of core #6 as evidenced by a higher concentration of S. alterniflora. The lower portion of this two-meter segment represents slightly wetter conditions since there is a lower percentage of S. alterniflora.

Immediately below this is a short section of core which is interpreted as tidal flat deposition. This is indicated by the lack of root fiber in the gray clay. This tidal flat facies overlies a rather long section of sediments deposited in a high marsh, as evidenced by the high percentages of S. patens.

Below this high marsh facies is a low marsh facies which exhibits a decrease in the amount of fiber present. Again the interpretation that this material was deposited in a low marsh is based on the relative abundance of S. alterniflora.

The low marsh facies overlies a short section of high marsh facies which in turn overlies a fresh water peat indicating fresh water swamp conditions.

Immediately below the fresh water swamp is a low marsh facies which in turn overlies a tidal flat facies. The percentages of S. alterniflora present

in these segments of the core are indicative of the environments of deposition.

This core, as was the case in core #6, shows that fluctuations in depositional environments are represented throughout the length of this core.

Core #16. The upper 20 cm of this core are represented by a peat which contains abundant S. patens roots indicative of a high marsh environment. This interpretation is substantiated by observations of the vegetation which exists on the surface at the core site.

Below the high marsh facies is a section characterized by S. alterniflora roots and, therefore, indicative of a low marsh environment. The low marsh overlies a high marsh environment based on the change in fiber type to one typical of S. patens.

The high marsh facies is underlain by peat thought to be formed in a fresh water swamp. This section is characterized by the presence of wood throughout and also of decomposed organic material.

Below the fresh water swamp is a sand facies which marks the bottom of the section.

Changes in facies within this core also indicate fluctuations in depositional environment.

# POLLEN ANALYSIS

## Methods

The samples utilized for pollen analysis were
selected from the 2-cm segments which had been separated
and refrozen during the description of the core. The
sample interval utilized in a core was varied between
cores (See Appendix B). The laboratory method used
is the standard procedure of Faegri and Iversen (1964).

Initially the samples were boiled for five minutes
in 5% KOH to deflocculate the material and release the
pollen. The samples were then sieved through a 0.5 mm
sieve to remove the larger particle sizes of mineral
materials and pieces of organic material. Sediment
which passed through the sieve was centrifuged at approxi-
mately 3000 rpm for 5 minutes and the supernatant liquid
discarded. The samples were then washed with distilled
water and again centrifuged, after which supernatant
liquid again was discarded.

In order to remove as much of the inorganic
material as possible the samples were boiled in 52%
technical grade HF for five minutes. While still hot,
the samples were centrifuged and the supernatant liquid
poured off. To prevent precipitation of CaF, the samples
were then heated in 10% HCl and once again centrifuged

while hot. The supernatant liquid was discarded and
the samples were then washed with distilled water and
centrifuged. The supernatant liquid was poured off.

In order to remove as much of the cellulose
as possible, the samples were subjected to acetolysis.
The sample was washed in glacial acetic acid in order
to dehydrate it, centrifuged, and the supernatant liquid
discarded. Then, the sample was heated in a 9:1 mixture
of acetic anhydride and sulfuric acid, centrifuged, and
separated from the supernatant liquid. Once again the
sample was washed with glacial acetic acid and centri-
fuged. Finally the sample was washed with distilled
water, centrifuged, and again separated from the super-
natant liquid.

After acetolysis, the prepared pollen was mounted
in a glycerin-gelatin mounting medium. The mounting
medium was prepared by mixing 28 grams of Knox gelatin,
4 grams of crystalline phenol, 160 ml of glycerine,
and 198 ml of distilled water. The mixture was heated
until all components were completely dissolved and then
allowed to cool. A portion of the prepared medium was
heated in a water bath until liquified and added to the
pollen sample in the centrifuge tube. The pollen was
then allowed to sit in the medium within a water bath
for 15 minutes to allow expansion of the pollen grains.

A drop of the mixture was placed on a slide and the cover glass applied. The edge of the cover glass was rimmed with clear nail polish in order to permantly preserve the slide.

Pollen grains were identified using a reference collection prepared by the investigator. A total of 150-750 pollen grains plus whatever spores were encountered in attaining the pollen sum were counted on each slide and the relative percentages of each species were calculated. The pollen spectra, so determined, were arranged on a standard pollen diagram which depicts variation of pollen percentage with depth (Faegri and Iversen, 1964). Included in the pollen diagrams, herein presented, are all species which comprised 3% or more of a slide from any sample. The percentage of spores in the total spore-pollen count of the slide and the percentage of nonarboreal pollen (NAP) on the slide are also shown on the diagrams. Some grains were grouped by pollen type rather than by genus, i.e., Betuloid-type and Chenopod-type. This method of grouping facilitates identification of those grains which are similar in their characteristics.

The pollen grains included in the diagrams are illustrated in Figures 9 through 27.
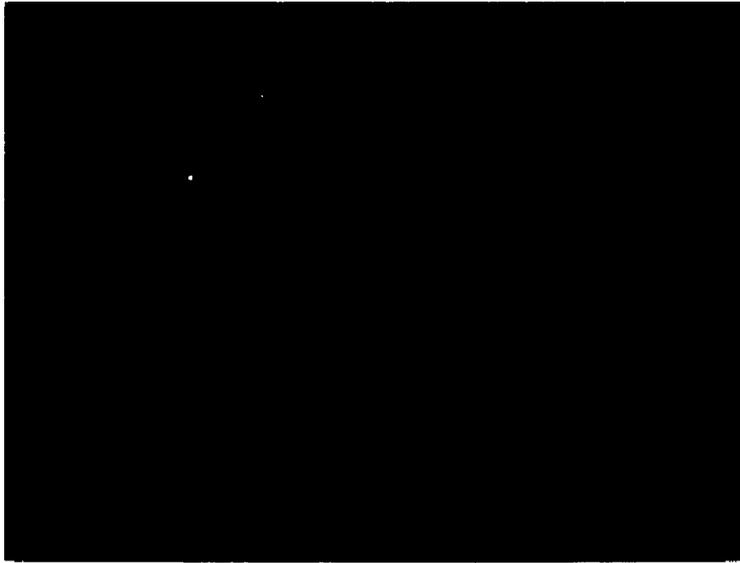
Figure 9.  Photomicrograph of Pollen of Pinus sp.
Magnification 322.5X.
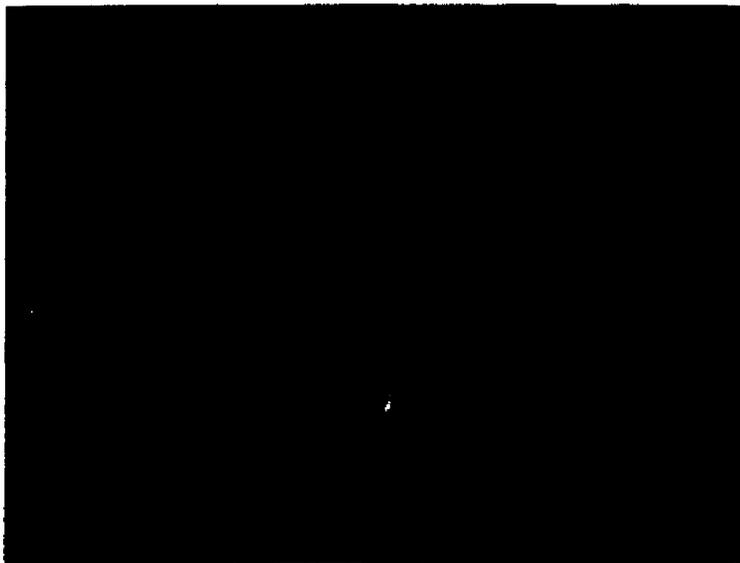


Figure 10.  Photomicrograph of Pollen of Tsuga sp.
Magnification 322.5X.
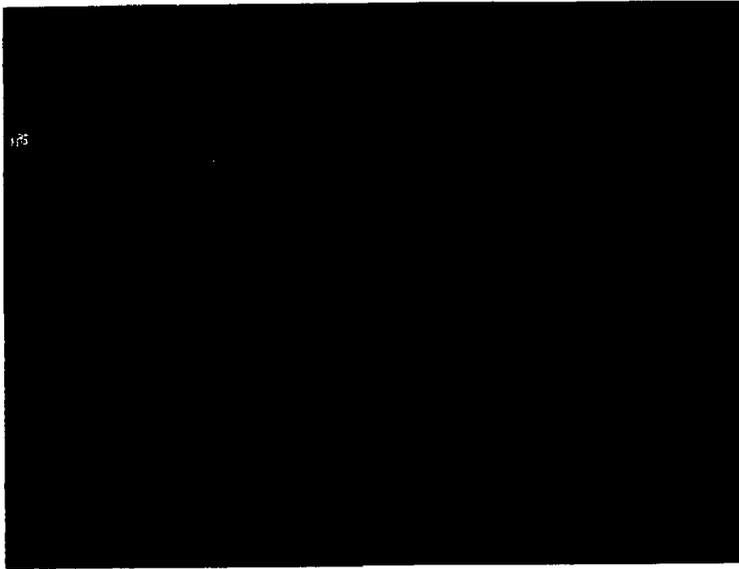
Figure 11. Photomicrograph of Pollen of Carya sp. Magnification 322.5X.



Figure 12. Photomicrograph of Pollen of Betula sp. Magnification 322.5X.
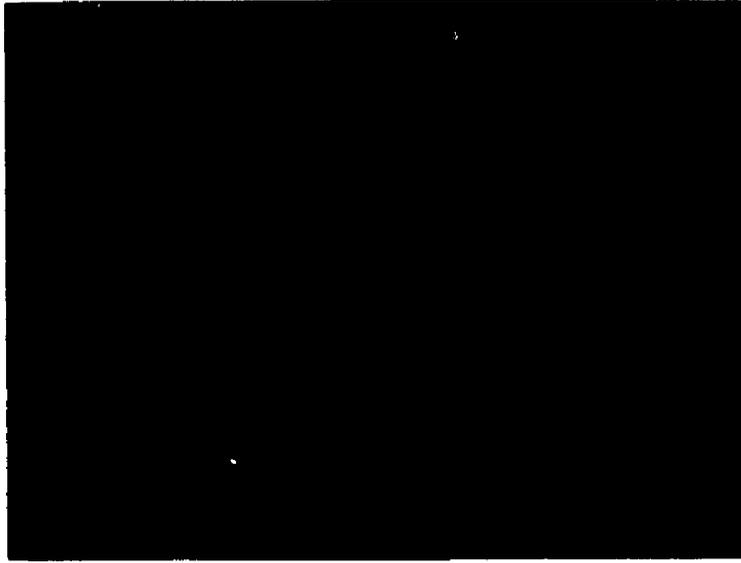
Figure 13. Photomicrograph of Pollen of <u>Alnus</u> sp.
Magnification 322.5X.
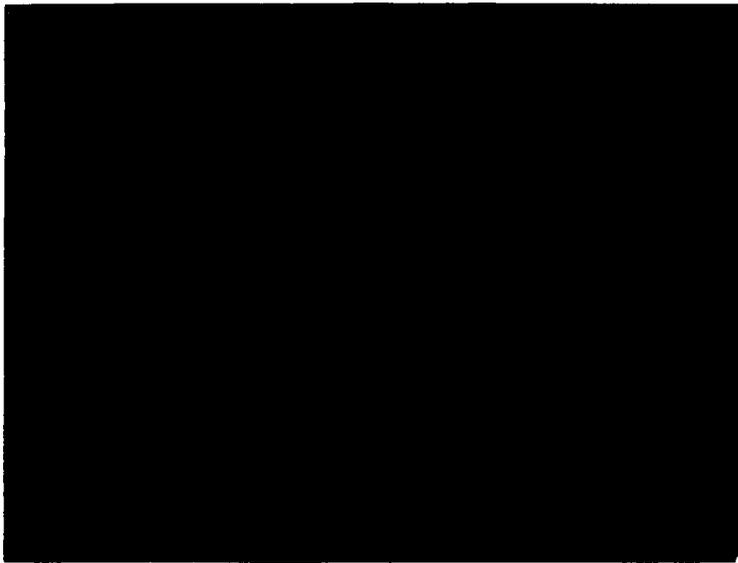


Figure 14. Photomicrograph of Pollen of <u>Castanea</u> sp.
Magnification 322.5X.
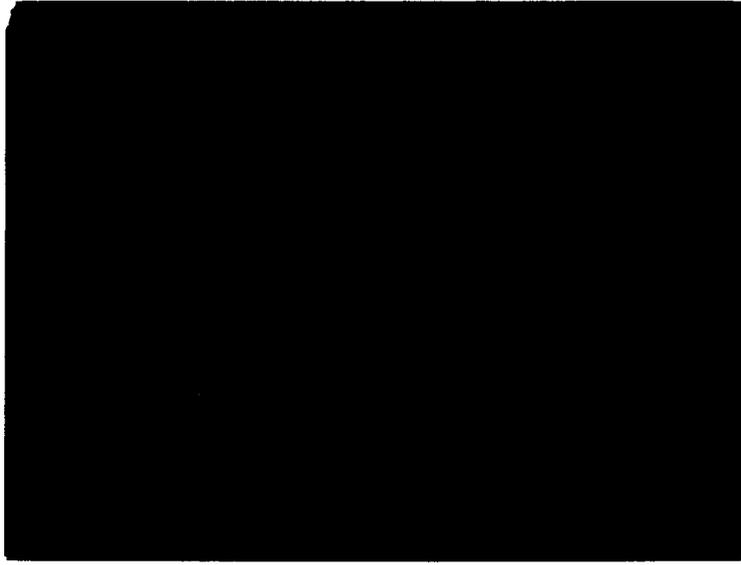
Figure 15. Photomicrograph of Pollen of <u>Quercus</u> sp.
Magnification 322.5X.
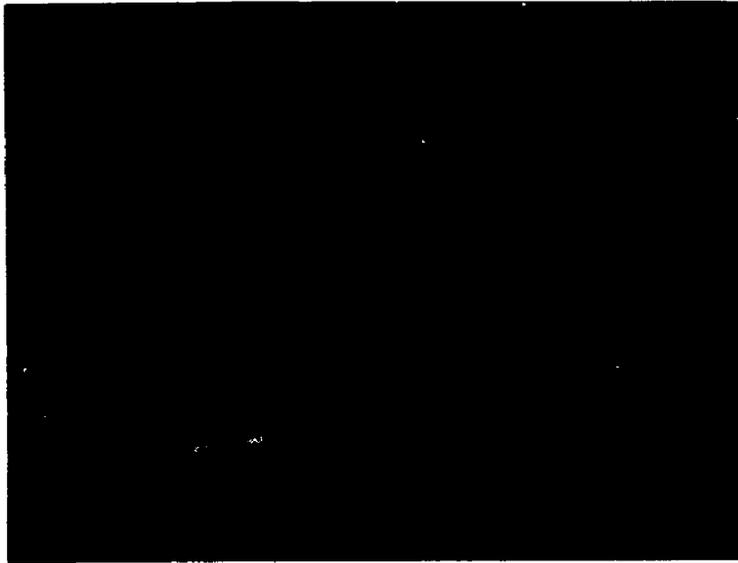


Figure 16. Photomicrograph of Pollen of <u>Ilex</u> sp.
Magnification 322.5X.

37
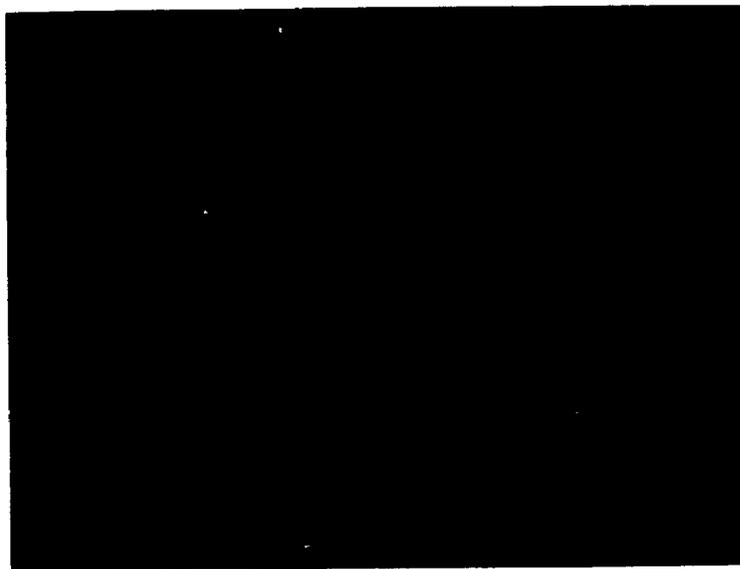


Figure 17. Photomicrograph of Pollen of Fraxinus sp. Magnification 322.5X.
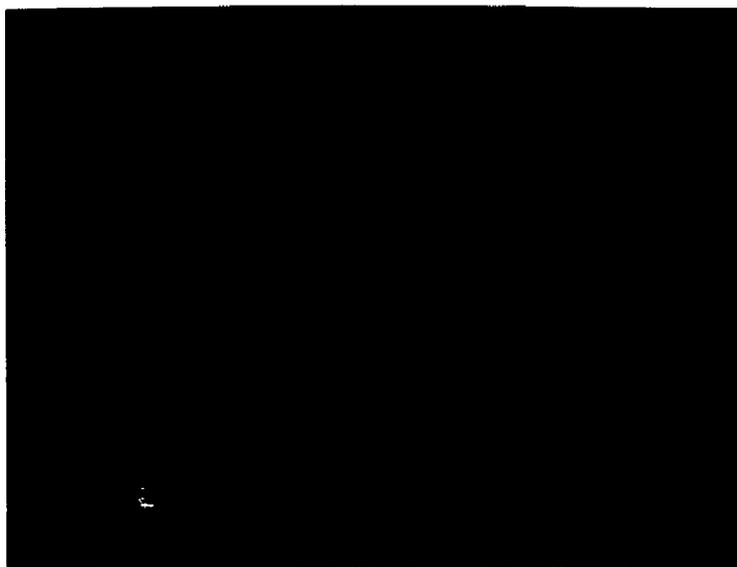


Figure 18. Photomicrograph of Pollen of Acer sp. Magnification 322.5X.

Figure 19.  Photomicrograph of Pollen of _Fagus_ sp.
Magnification 322.5X.
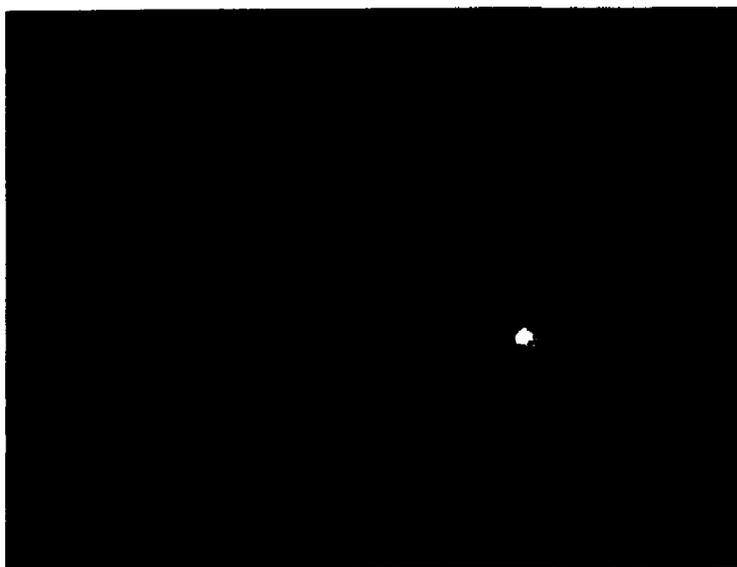


Figure 20.  Photomicrograph of Pollen of Chenopodiaceae.
Magnification 322.5X.
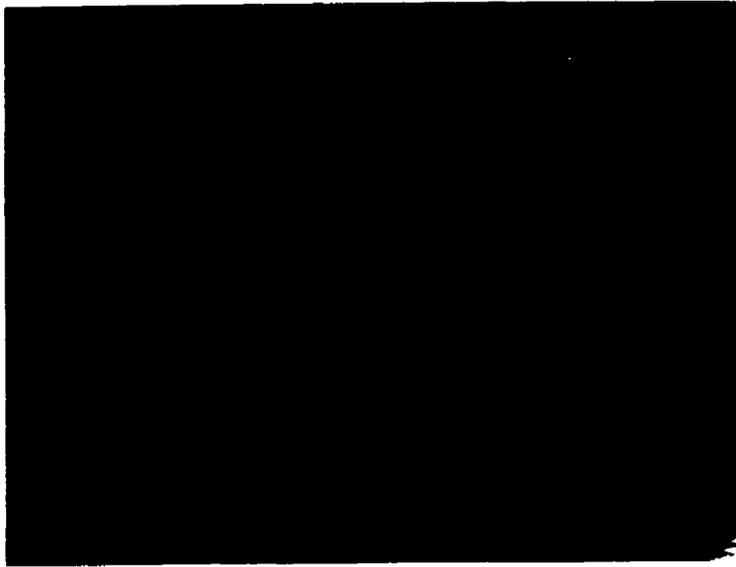
Figure 21. Photomicrograph of Pollen of Compositae. Magnification 322.5X.
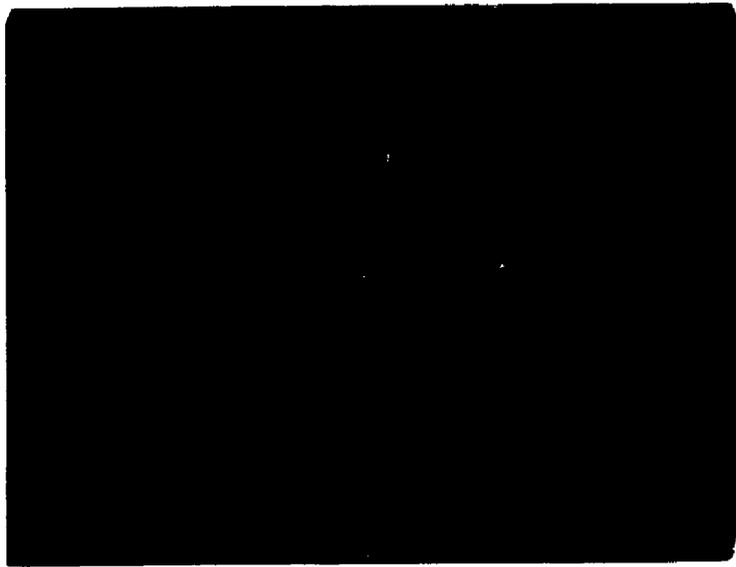


Figure 22. Photomicrograph of Pollen of Gramineae. Magnification 322.5X.
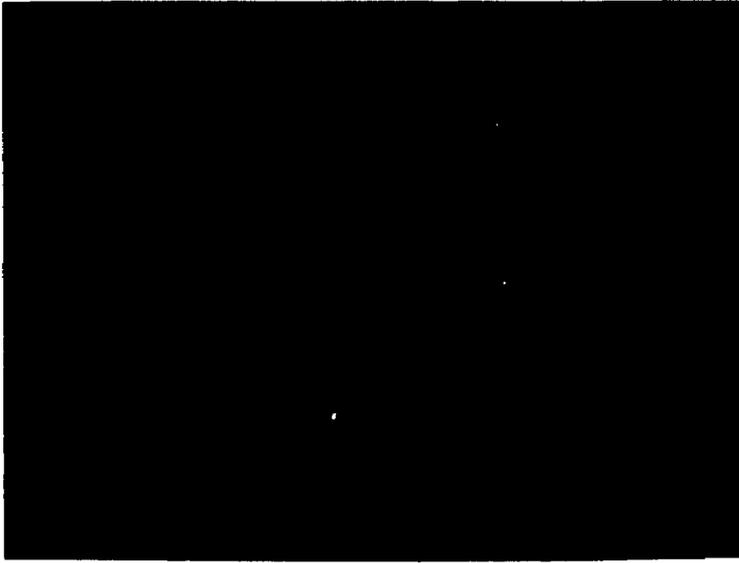
Figure 23. Photomicrograph of Pollen of Cyperaceae.
Magnification 322.5X.



Figure 24. Photomicrograph of Pollen of Plantago sp.
Magnification 322.5X.
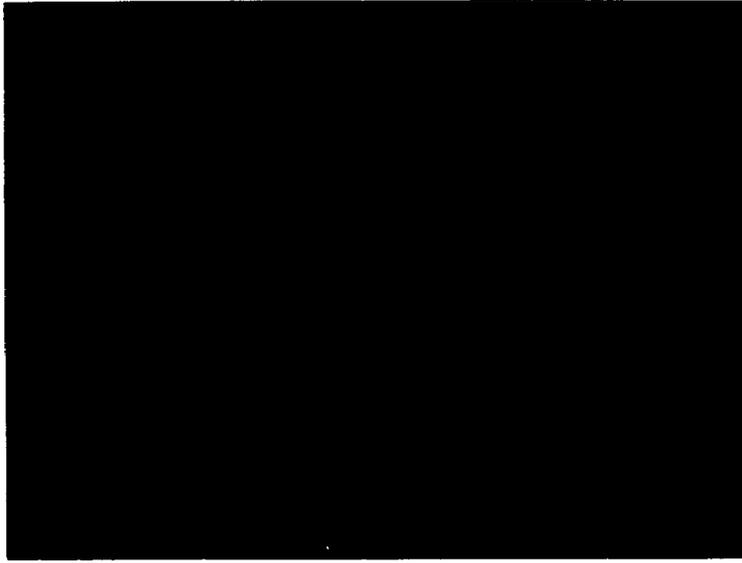
Figure 25. Photomicrograph of Pollen of Ericaceae.
Magnification 322.5X.



Figure 26. Photomicrograph of Polypodiaceae Spore.
Magnification 322.5X.
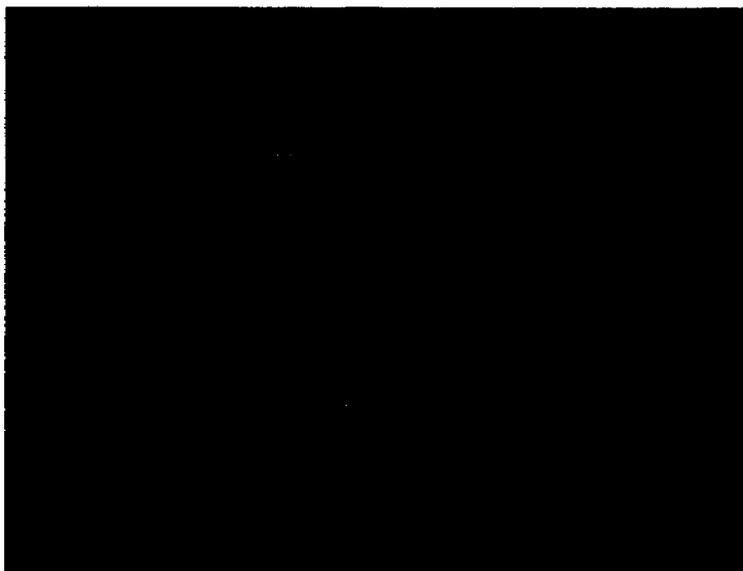
Figure 27.   Photomicrograph of <u>Osmunda</u> sp. Spore.
Magnification 322.5X.

## Pollen distribution

The pollen percentages of all species identified in the slides are presented in Appendix B.

### Core #6. (See Figure 28.)

The pollen distribution in the upper 4.0 meters indicates the existence of a sparsely populated S. alterniflora marsh. The interpretation of the local community from the pollen spectra must take into account only the nonarboreal pollen (NAP) and not the arboreal pollen (AP) which are characteristic of the upland vegetation. The low NAP values throughout this segment would indicate the low marsh community, as opposed to the high marsh community which would be characterized by higher percentages of NAP.

The abrupt increase in NAP at the 4.0 meter level indicates a transition to a high marsh environment. Within the NAP distribution, the increases in Gramineae, Cyperaceae, and spores are especially indicative of a high marsh environment.

The decrease in Gramineae below 5.0 meters is indicative of a transition back to the low marsh environment. The peaks, between 5.0 meters and 6.0 meters, of Cyperaceae and spores would tend to indicate fluctuations between high and low marsh environment.
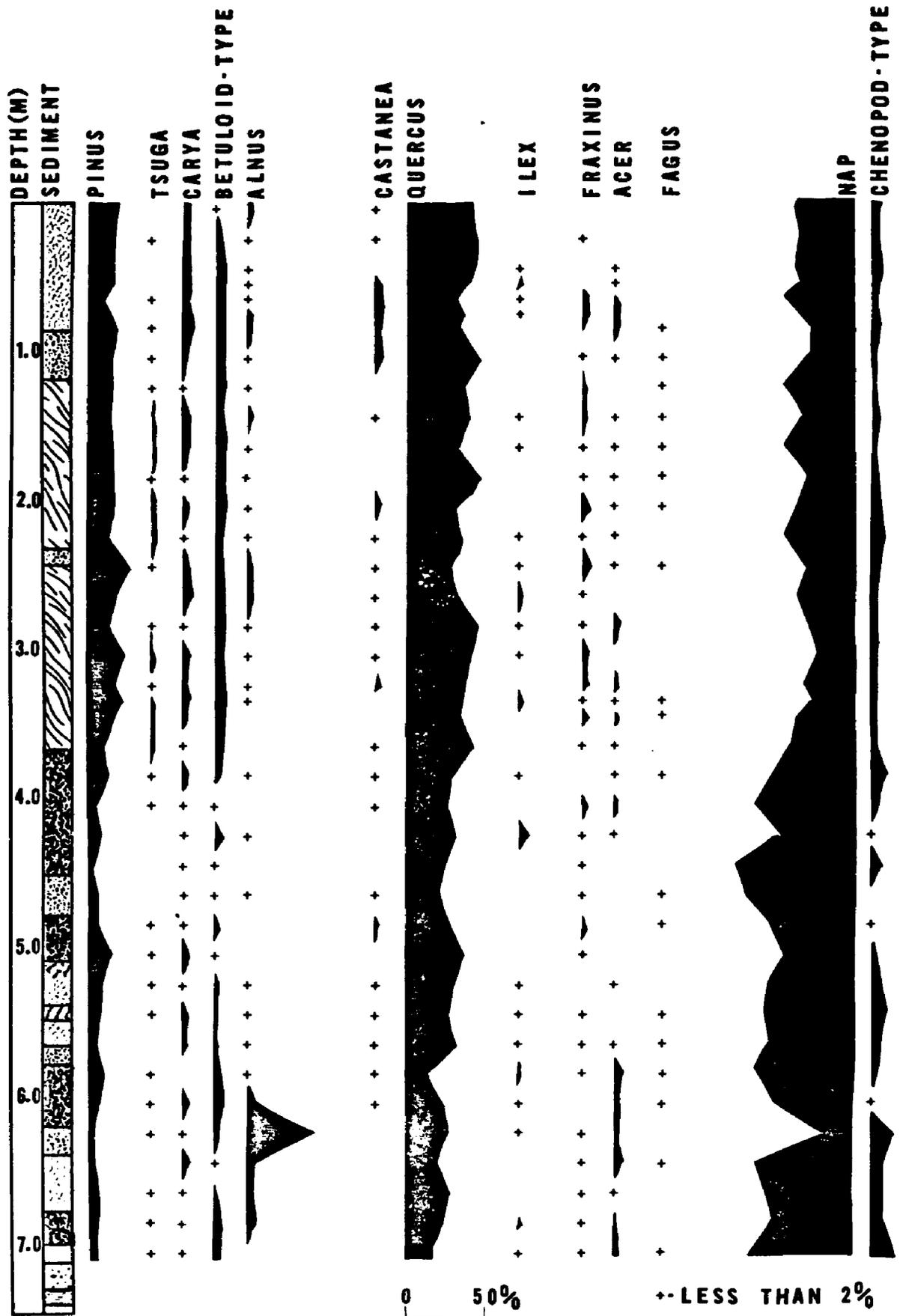
Figure 28. Pollen Spectra and SPM Paleosalinity, Core #6.

COMPOSITAE  GRAMINEAE  +CYPERACEAE  +PLANTAGO ERICACEAE  SPORES  SPM PALEOSALINITY

0    10‰
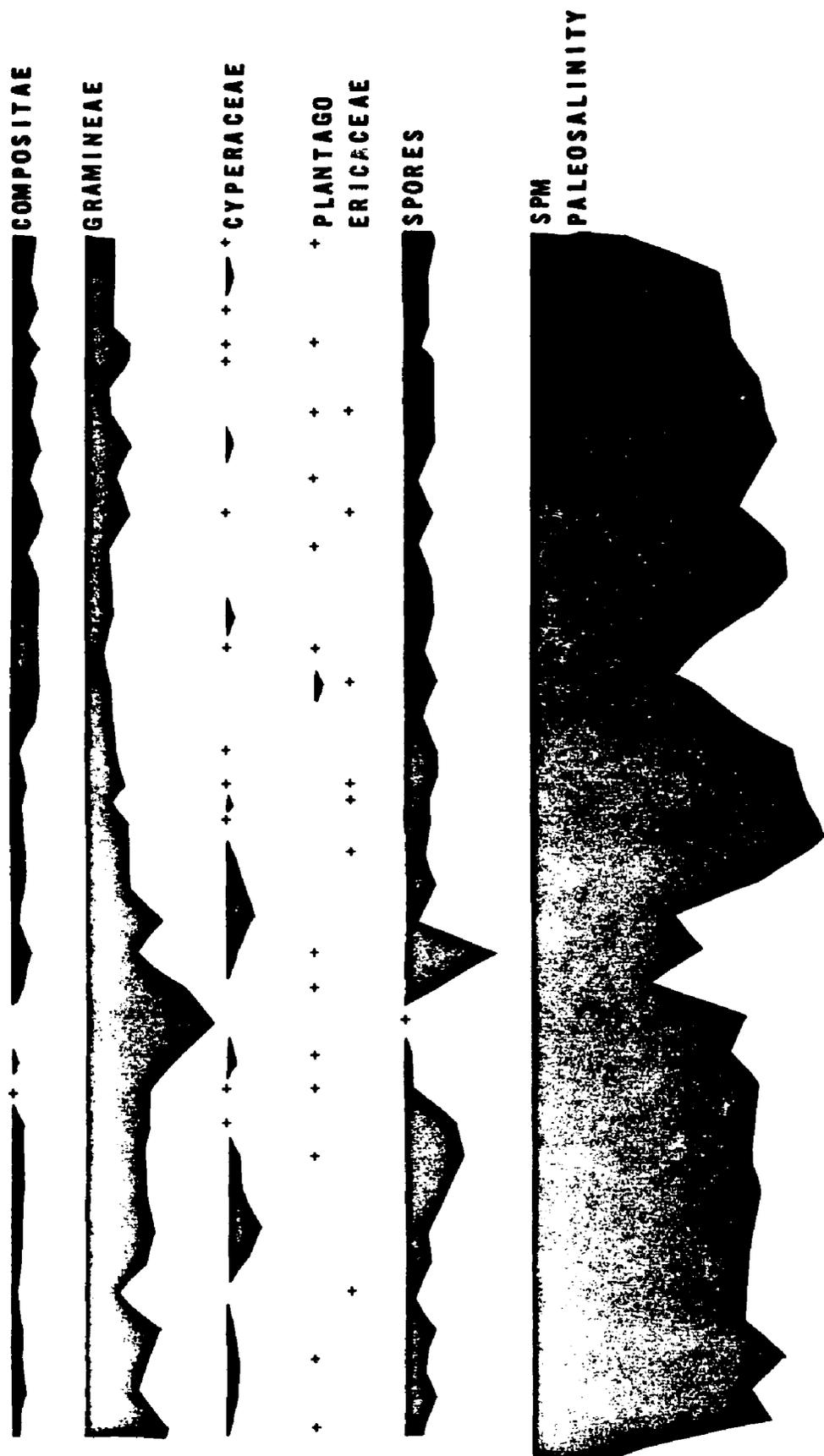
BROWN PEAT 50% FIBER    BROWN PEAT 100% FIBER    SAND    SILTY CLAY

Immediately below 6.0 meters the NAP percentages
drop off significantly and there is a concomittant rise
in the percentages of Alnus. These changes in the pollen
spectra are indicative of a fresh water swamp. In a
swamp environment the NAP would be expected to drop
significantly while typical swamp species such as Alnus
would be expected to increase in abundance.

Below the fresh water swamp facies there is a
low marsh facies, characterized by an increase in NAP
that does not reach the proportions attained in the
high marsh facies.

The interpretations derived from the pollen
spectra compare favorably with those derived from
lithologic analysis.

### Core #8. (See Figure 29.)

The pollen spectra for the upper two meters
of this core tend to indicate a low marsh environment
for this site. The relatively low percentages of NAP
are characteristic of this environment.

From 2.0 meters to 3.5 meters a high marsh
environment is indicated by the increase in NAP. Within
the NAP distribution, the fluctuations between Gramineae
and Cyperaceae would tend to suggest that the site was
close to the transition zone with the upland vegetation,
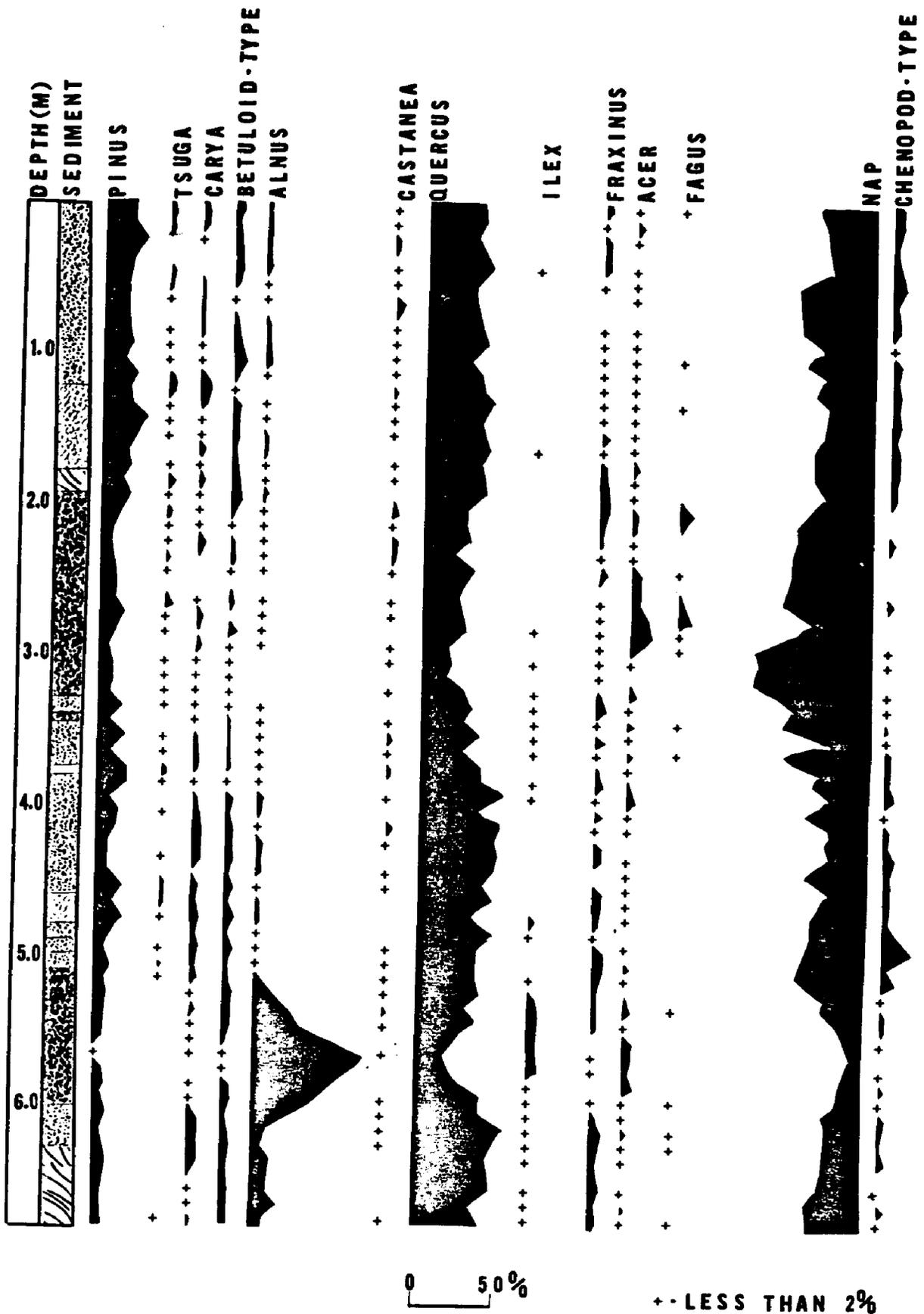
Figure 29. Pollen Spectra and SPM Paleosalinity, Core #8.

COMPOSITAE  GRAMINEAE  CYPERACEAE  PLANTAGO  ERICACEAE  SPORES  SPM  PALEOSALINITY

0  10 ‰

BROWN PEAT
50% FIBER

BROWN PEAT
100% FIBER

since sedges tend to be located in this transition zone.

Below this high marsh sequence is a low marsh
sequence characterized by a drop in the NAP. A fairly
uniform environment for the 3.5 to 5.0 meter segment
is suggested by the consistency of the pollen spectra.

Between 5.0 and 6.0 meters the sharp decrease
in NAP and the increase in <u>Alnus</u> tends to indicate the
presence of a fresh water swamp, much like the one which
is suggested at the bottom of core #6.

The fresh water swamp facies overlies a low
marsh as indicated by the increase in NAP which does
not reach the proportions attained in the high marsh
facies.

The interpretations derived from the pollen
spectra compare favorably with those derived from
lithologic analysis.

### <u>Core #16</u>. (See Figure 30.)

The upper 50 cm of this core are indicative
of a high marsh environment as characterized by the high
percentages of NAP. The presence of high percentages
of Chenopod-type pollen is typical of high marsh sequences
along the coast of eastern North America at the present
time (Harmon and Tedrow, 1969).
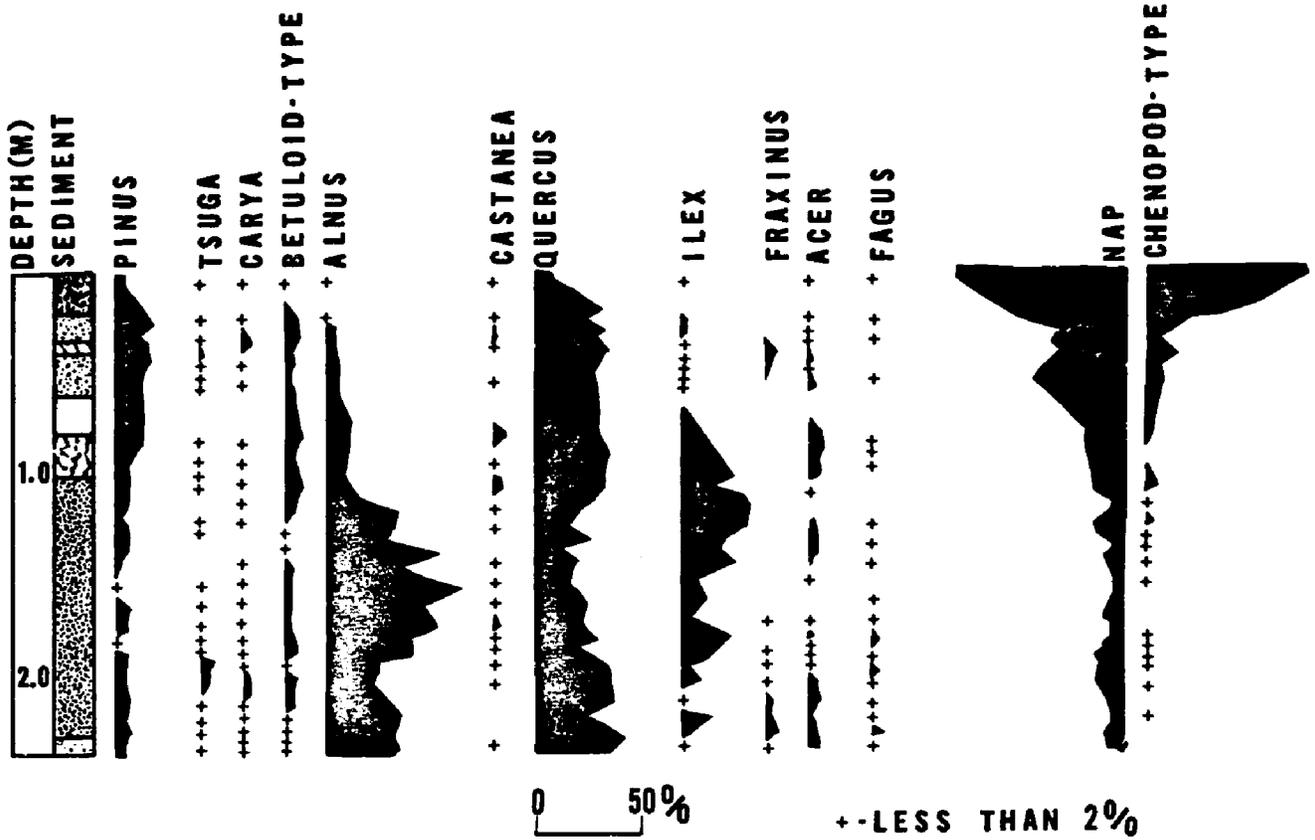
Figure 30. Pollen Spectra and SPM Paleosalinity, Core #16.

COMPOSITAE GRAMINEAE CYPERACEAE PLANTAGO ERICACEAE SPORES SPM PALEOSALINITY

0    10‰
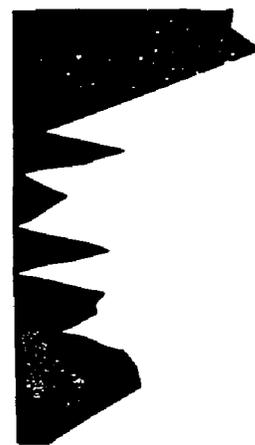
BROWN PEAT 50% FIBER    BROWN PEAT 100% FIBER    SAND

Below the high marsh sequence and extending
to a depth of 1.0 meter is a low marsh sequence. The
drop in NAP is indicative of this environment.

The low marsh facies overlies a fresh water swamp
facies, characterized by high percentages of <u>Alnus</u> and
<u>Ilex</u>, which extends to the bottom of the core.

Biofacies changes in core #16 also demonstrate
fluctuation in environment of deposition. The inter-
pretations based upon the pollen spectra agree with
the interpretations based upon the sediment lithologies.

## SEDIMENTARY PHOSPHATE METHOD PALEOSALINITY

### Methods

Samples utilized for the analysis of sedimentary phosphate were selected from the 2-cm segments which had been separated and stored in the frozen condition. The samples were selected so that the analyzed segments would be immediately adjacent to segments on which pollen distributions had been determined. The laboratory method used was the technique of Nelson (1968).

The samples were dried in an oven and weighed so that 0.5 gram samples could be utilized. Wherever possible, duplicate samples were run to determine precision of the method. The 0.5 gram sample was placed in a 50 ml centrifuge tube and treated with 25 ml of 1 N $NH_4Cl$. The tube was placed on a shaking machine and was shaken for 30 minutes. This procedure removes water-soluble and loosely-bound phosphorus and exchangeable calcium. The suspension was then centrifuged and the supernatant discarded. 25 ml of 0.5 N $NH_4F$ were then added to the sample, and the mixture was placed on the shaking machine for one hour. The suspension was then centrifuged and the supernatant decanted. Since this process extracts the aluminum phosphate which does not enter into the paleosalinity determination,

the supernatant was discarded.

The sample was treated twice with 15 ml of saturated NaCl solution, centrifuged, and the supernatant discarded in order to extract the iron phosphate. Then, 25 ml of 0.1 N NaOH were added and the suspension was placed on the shaker for 17 hours. The suspension was then centrifuged, and the supernatant decanted and saved for analysis. In most cases the solution was highly colored with organic matter. In order to remove the color, 2 ml of 2 N $H_2SO_4$ and 1 or 2 drops of concentrated $H_2SO_4$ were added to precipitate the organic colloids. The suspension was then centrifuged and the supernatant decanted and saved for analysis.

In order to extract the calcium phosphate, the sample was treated twice with 15 ml of saturated NaCl solution, centrifuged, and the supernatant discarded. Then, 25 ml of 0.5 N $H_2SO_4$ was added and the suspension placed on the shaker for one hour. Next, the suspension was centrifuged and the supernatant was decanted and saved for analysis.

To determine the amount of phosphorus in the solutions, an aliquot was placed in a 50 ml volumetric flask. The size of the aliquot used varied according to the concentration of phosphorus in the sample. Water was added to increase the volume to approxi-

mately 20 ml. The solution was then adjusted to a

pH of 3 by adding 2 N NaOH until a 2, 6 dinitrophenol

indicator turned yellow and was brought back to color-

less by 2 N $H_2SO_4$. To the adjusted solution 2.0 ml

of sulfomolybdic acid and enough water to bring the

volume to 48 ml were added; the solution was then

thoroughly mixed. Three drops of chlorostannous re-

ductant B were added to develop the color and enough

water added to increase the volume to 50 ml. The color

of the solution was measured within 5-10 minutes at

660 mμ on a Bausch and Lomb Spectronic 20.

Once the values of phosphorus concentration

were determined for each solution, the sedimentary

phosphate method paleosalinity was calculated using

the method of Nelson (1967). The values for SPM paleo-

salinity are shown on the diagrams with the pollen dis-

tributions (Figures 28, 29, and 30).

## SPM paleosalinity distribution

The concentrations of iron phosphate and calcium

phosphate in each sample as well as the SPM paleosal-

inity values are presented in Appendix C.

### Core #6. (See Figure 28.)

The upper 20 cm of this core are characterized

by gradually increasing paleosalinity values from a

value of below 10 $^o/_{oo}$ to values in excess of 20 $^o/_{oo}$.
The interpretation which must be placed on this change
in values is that there was a change from an environment
which was essentially fresh water to one which approached
a brackish condition. Minor fluctuations within the
paleosalinity distributions cannot be interpreted with
any degree of certainty.

Below this section of increasing paleosalinity
there is a segment of uniformly high paleosalinity per-
sisting to a depth of 2.0 meters. Uniformly high paleo-
salinities most logically occur in the low marsh environ-
ment where daily flooding prevents large fluctuations
in salinity.

Paleosalinity values in the segment from 2.0
to 3.0 meters fall to nearly 10 $^o/_{oo}$. This decrease
in paleosalinity should be indicative of an influx of
fresh water in the area.

In the underlying segment to a depth of 4.0
meters, the paleosalinity values return to above 20 $^o/_{oo}$.
This is indicative of the brackish conditions which
persist within the bay area, i.e., salinities which
are somewhat below normal sea water.

Between 4.0 meters and 4.5 meters, the paleo-
salinity values again are below 20 $^o/_{oo}$. These low
values indicate an influx of fresh water in the area.

From 4.5 meters to the bottom of the core the
paleosalinity values remain above 20 $^o/_{oo}$, normal for
the bay environment. The only deviation from these
values occurs at the bottom of the core where a value
below 10 $^o/_{oo}$ has been recorded. This value is probably
due to the fact that the sand content of the sample
was high, thus, giving an anomalously low value.

The interpretations based on SPM paleosalinity
agree with interpretations derived from the other
techniques of analysis. The only anomalous occurrence
is in the vicinity of 6.0 meters, where high paleosalinity
values correspond to fresh water deposits as intrepreted
from the lithologic and pollen analyses.


Core #8. (See Figure 29.)

The upper 20 cm of this core are characterized
by gradually increasing paleosalinity values from a
value of around 10 $^o/_{oo}$ at the surface to a value in
excess of 20 $^o/_{oo}$ at a depth of 20 cm. This can be
interpreted as an increase in the salinity of the en-
vironment from a nearly fresh-water environment to one
which is indicative of the normal brackish bay environment.

From 20 cm to a depth of around 3.0 meters,
the paleosalinity values are within the range which
would be expected in the bay environment. There are

only minor fluctuations in these values which may or
may not have significance.

The segment of normal bay salinities overlies
a segment, 3.0 to 4.0 meters, where the paleosalinities
are distinctly lower. This suggests an influx of fresh
water sufficient to depress the paleosalinity values
to about 5 $^o/_{oo}$.

The segment from 4.0 meters to 5.5 meters is
characterized by paleosalinities which are indicative
of the normal bay environment.

Paleosalinity values drop to below 10 $^o/_{oo}$ from
5.5 to 6.2 meters, suggesting an influx of fresh water
in the area sufficient to depress the paleosalinity
values.

From 6.2 meters to the bottom of the core SPM
values return to those characteristic of the normal
bay environment.

The interpretations derived from the SPM paleo-
salinity analysis agree with those derived from the
lithologic and pollen analyses.


Core #16. (See Figure 30.)

The high paleosalinity values in the upper portion
of the core are indicative of the normal bay environment
which is to be expected in this area.

Below 1.0 meter the paleosalinity values vary
from 0 °/oo to around 10 °/oo. This range of paleosalinity
values indicates an environment of fresh water or one
in which there was a great influx of fresh water.

The interpretations based on SPM paleosalinity
compare favorably with those based on lithologic and
pollen analyses.

Total P(Fe + Ca). The relationship of total
phosphorus (Fe + Ca) with depth for the three analyzed
cores is presented on Figures 31, 32, and 33.

It is evident from Figures 31 and 32 that the
P(Fe + Ca) values at the surface are significantly
higher than the values below 0.2 meters. Unfortunately,
the top section of core #16 as shown in Figure 33 was
not available for analysis and, therefore, it cannot
be determined whether this trend is persistent in all
three cores. Without doubt, in the time represented
by the upper 20 cm of the cores there has been a con-
centration of total phosphorus (Fe + Ca) far in excess
of the amounts which commonly occur throughout the re-
mainder of the cores. Since the amounts of phosphorus
involved are so great, pollution cannot be ignored as
a possible cause. Further investigation is warranted
to determined whether this concentration of phosphorus
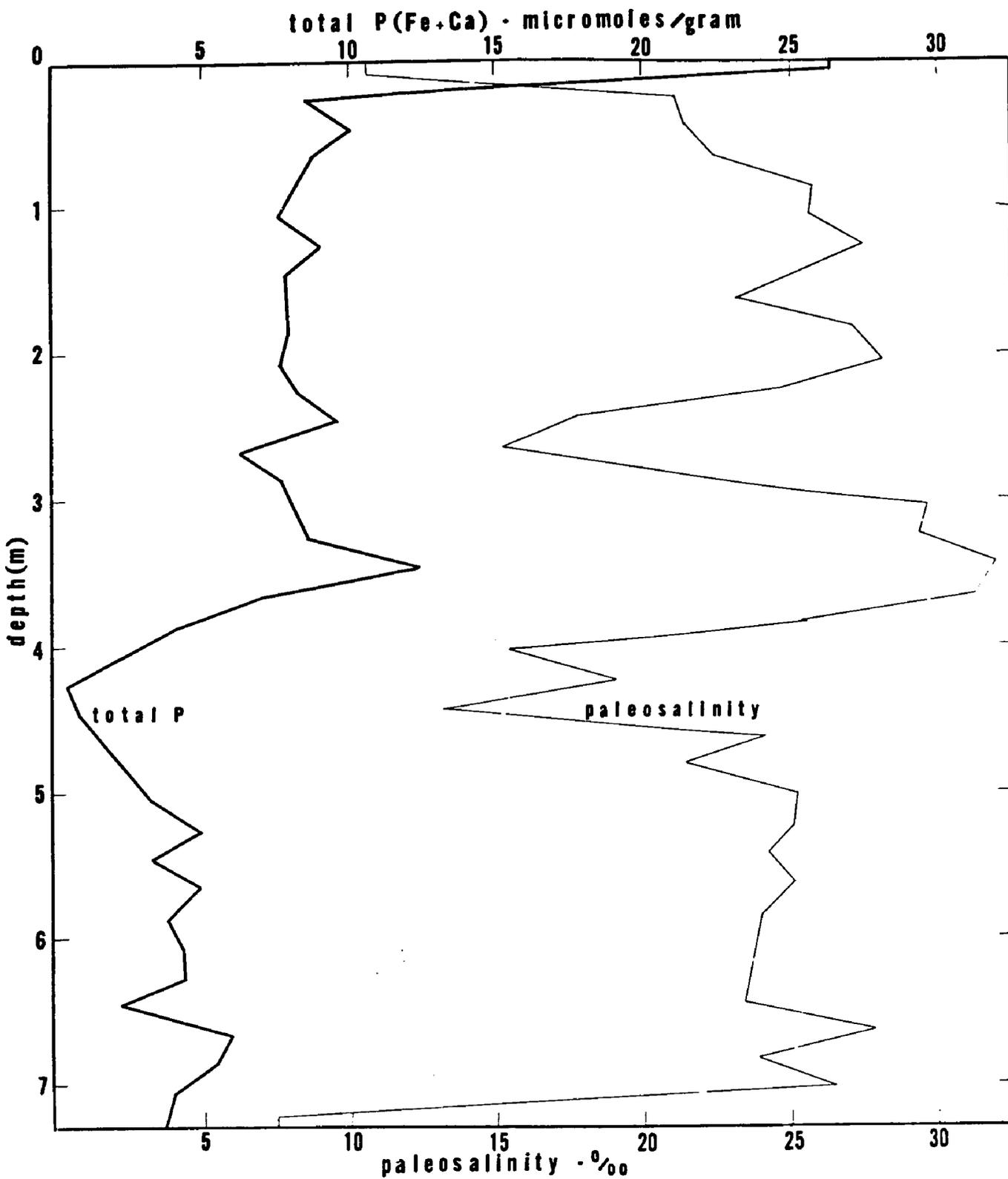
Figure 31. Relationship of Total P and SPM Paleosalinity to Depth, Core #6.
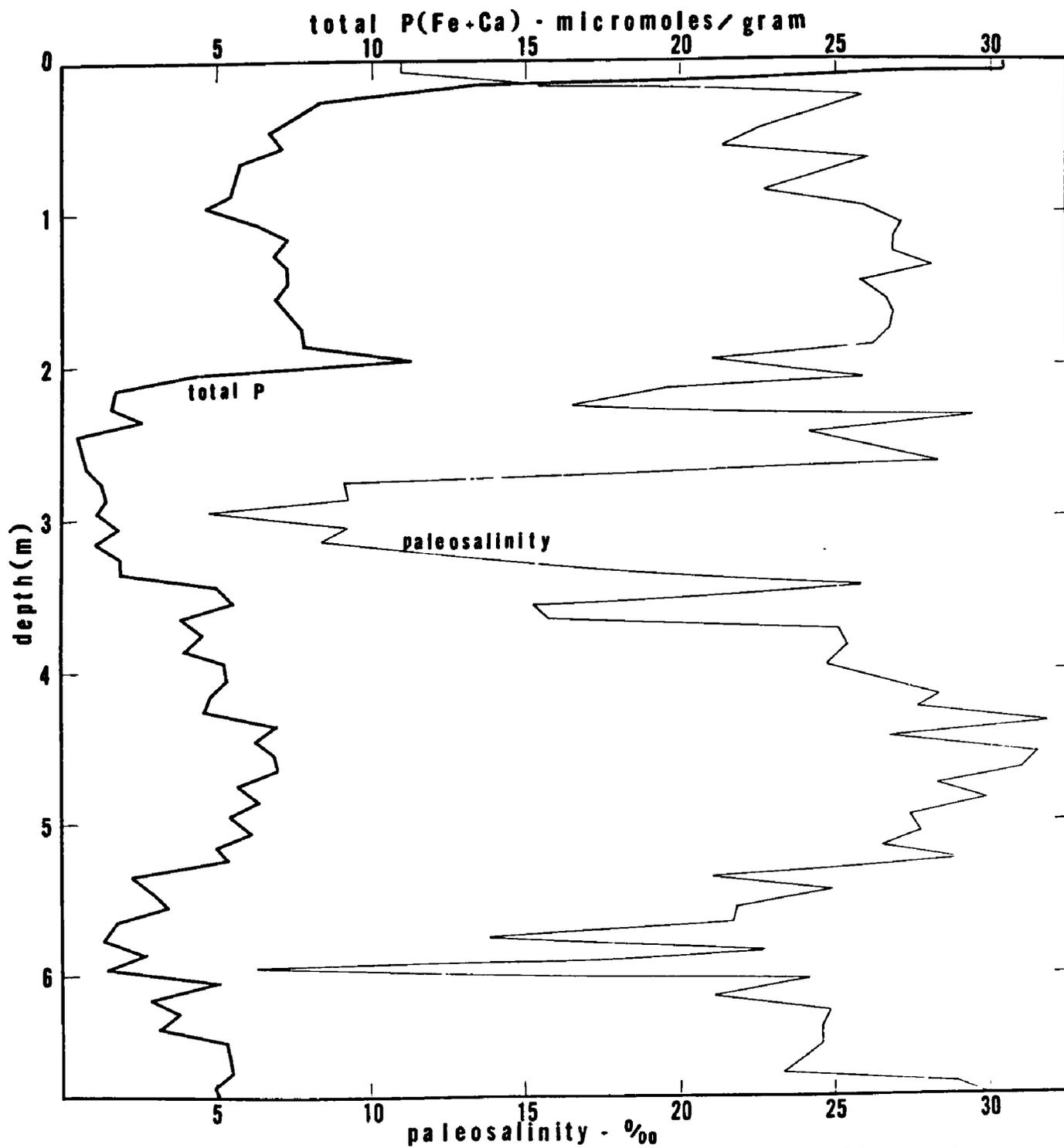
Figure 32. Relationship of Total P and SPM Paleosalinity to Depth, Core #8.
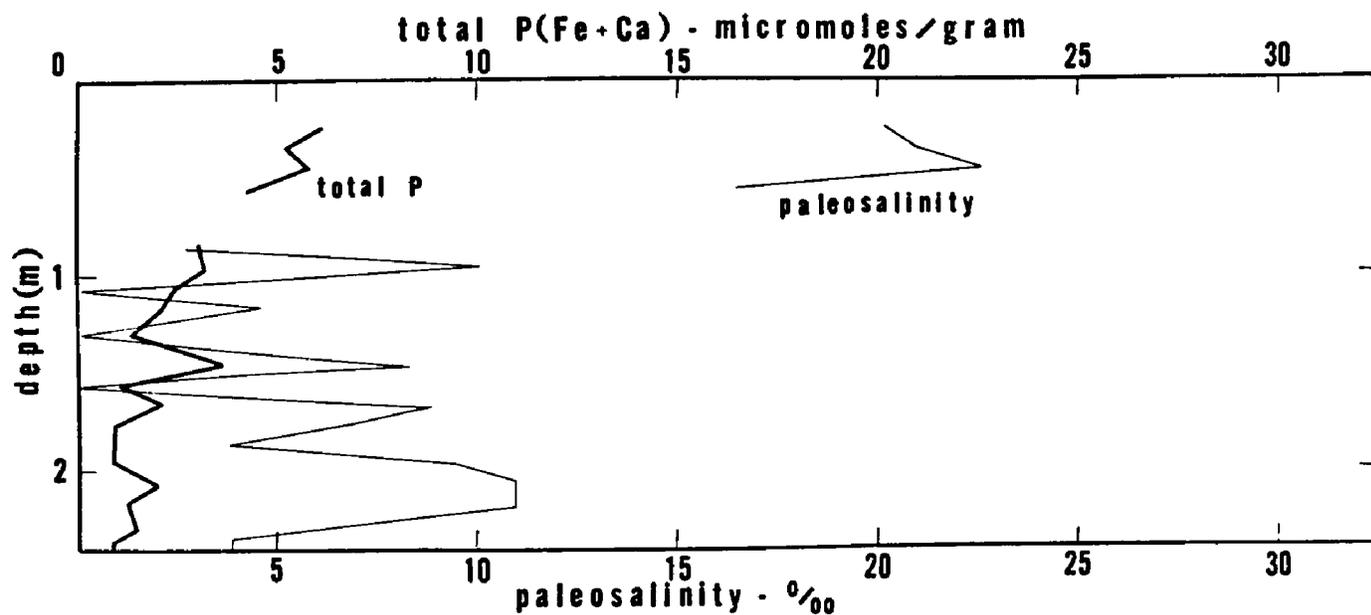
Figure 33. Relationship of Total P and SPM Paleosalinity to Depth, Core #16.

is due to natural biologic activity or is the result
of pollution.

Also notable in the distribution of these values
is that P(Fe + Ca) values are generally higher in the
upper portion of the cores than in the lower portions.
In cores #6 and #8 where sufficient detail is present,
a rather significant peak occurs at the boundary between
the high and low values. This distinct change in values
suggests a fairly rapid introduction of phosphorus into
the environment, which most logically would have been
derived from the bay waters. If so, a transgression
occurred in this area at the time indicated by the change
in total phosphorus values. This is in good agreement
with interpretations based on SPM paleosalinity measurements.

Another feature which seems to be present in
all the cores is that below the area of very low values
of P(Fe + Ca) there is a gradual increase in values
as the bottom of the core is approached. This gradual
change in the total phosphorus values would tend to
indicate a gradual change in the influence of the bay
waters on the area. The higher values at the bottom
of the core would indicate a greater influence of the
bay waters than the lower values further up in the core.

Thus, as was the case with sediment lithology
and pollen spectra, the SPM paleosalinities and total

phosphorus values tend to suggest fluctuations in the environments represented by the analyzed cores.

# RADIOCARBON DATING

Samples were taken from segments of the three analyzed cores and submitted for radiocarbon dating to Teledyne Isotopes of Westwood, New Jersey. The segments were selected on the basis of lithology, pollen distribution, and SPM paleosalinity values.

Sample I-4754 was selected from the bottom of core #16 and came from sample 16-12. This sample was chosen so that a date could be obtained at the bottom of the fresh water sequence. The date obtained was $1760 \pm 120$ years B.P. This date agrees well with dates from a comparable level at Brigantine City, New Jersey (Stuiver and Daddario, 1963).

Samples I-4925(from 8-28), I-4753(from 8-29), and I-5188(from 8-30) were selected from the fresh water sequence in the lower portion of core #8. These samples were chosen to determine the rate of deposition within the fresh water sequence and to provide a base for correlation with other cores. The dates obtained were $3030 \pm 130$ years B.P. (I-4925), $2840 \pm 110$ years B.P. (I-4753), and $3145 \pm 120$ years B.P. (I-5188). It can be seen from the dates that the rate of deposition was very rapid, so much so, that the radiocarbon technique was unable to distinguish among the samples.

Sample I-5444(from 8-15) was taken from a high marsh sequence within core #8. This date is particularly significant in that it is immediately below the change in values of P(Fe + Ca). The date obtained for this sample was 1335 $\pm$ 95 years B.P. A strong possibility exists that this sample was subject to contamination from above. Thus, the true age of the sample is probably older than the one specified.

Sample I-5190(from 6-36) was taken from the bottom of core #6 which, on the basis of the sediment lithology, pollen distribution, and SPM paleosalinity, is in a tidal marsh sequence which can be characterized as a low marsh. This date can provide a means of correlation with other cores and establish the onset of deposition at site #6. The date which was obtained was 2150 $\pm$ 110 years B.P. This dates the onset of deposition at site #6 as occurring after the onset of deposition at site #8 and within 300 years of the onset of deposition at site #16; this despite the fact that core #6 is longer than the other two cores.

The establishment of the radiocarbon age of the samples selected from the three analyzed cores assists in correlation within the area of study, and also provides a means of correlation with sediments in other areas which have been investigated by others. The dates and

their stratigraphic relationships are presented on Figure
34, p. 79.

# DISCUSSION

## Relationship of pollen to SPM paleosalinity

There is a distinct relationship between the
pollen distribution and the SPM paleosalinity in the
three cores studied. Areas of low paleosalinity consis-
tently coincide with distinct changes within the pollen
spectra. The fact that this relationship does exist
is an indication that both methods of analysis are valid
within the restricted environment in which they were
applied.

A further indication of the validity of the
SPM paleosalinity is the distribution of total phosphorus
(Fe + Ca) with depth as indicated on Figures 31, 32,
and 33. It is evident from close examination of these
graphs that the original assumption of Nelson (1967),
that the paleosalinity values obtained were independent
of the total phosphorus content of the sediment, is
correct. Although there initially may seem to be some
correlation between total phosphorus and paleosalinity,
careful examination of the graphs shows that in some
instances paleosalinity is directly proportional to
total phosphorus and in other instances inversely pro-
portional. Thus, it appears that SPM paleosalinity
is independent of total phosphorus and as such is a

valid indicator of paleosalinity.

It is also evident that the distributions of total phosphorus are quite similar in each core, even though the similarities occur at different depths. The similar behavior of these distributions would indicate similar cause and effect relationships. The dates from the cores in question, as indicated on Figure 34, preclude the possibility that the peaks are contemporaneous. However, the similarities in lithology of the two cores at the positions of the phosphorus peaks would tend to indicate that the reason for the appearance of the peak is the same at each locality. In both instances the peaks occur where the lithologies change from a brown peat with essentially 100% fiber to a gray clay with approximately 10% fiber. Thus, the evidence drawn from total phosphorus, lithology, and radiocarbon dates indicates that these peaks are due to the same cause, although they are probably not contemporaneous.

The exact relationship between the pollen distribution and the SPM paleosalinity can be better appreciated if these relationships are discussed in detail for each of the three cores analyzed and environmental reconstruction attempted on the basis of these relationships.

Core #6. The paleosalinity values for the upper
4.0 meters of this core are relatively uniform (between
20 $^o/_{oo}$ and 30 $^o/_{oo}$) except for two areas: the top of
the core and the segment between 2.0 and 3.0 meters.
The pollen spectra for this 4.0 meter depth interval
are also remarkably uniform. The pollen spectra are
characterized by relatively high Pinus and Quercus and
a relatively low NAP.

The low values of SPM paleosalinity at the top
of the core can be explained as the equilibration time
required to establish the Ca:Fe ratio. This interpre-
tation is substantiated by the fact that the paleosal-
inity value at the surface is below the values obtained
in Dennis Creek on an ebb tide in July (14 $^o/_{oo}$). It
would seem reasonable that, due to evaporation, the
salinity values on the marsh would be much higher than
those in the stream. This is supported by data collected
by Good (1965) and Chapman (1960). Thus, the anomalously
low values at the surface are, in all probability, an
indication of phosphate equilibration. This equilibration
time, is instantaneous geologically, and would have
no bearing on the analysis of sedimentary rocks by the
SPM paleosalinity technique.

The low SPM paleosalinity values in the 2.0-
3.0 meter segment are not so easily explained. However,

there appears to be an indication from the pollen spectra
of a reason for these low values. The only change with-
in the pollen distribution is a decrease in Gramineae
and an increase in Compositae. Since the sediment at
this level is not rich in organic material, it can be
assumed that much of this change, which is indicative
of drier conditions on the marsh surface or open spaces
in the upland vegetation, occurred upstream of this
site and the pollen was carried in. The change in _Pinus_
and _Quercus_ percentages within this segment are indic-
ative of change in the upland vegetation and not of what
was occurring on the marsh surface. These changes in
pollen spectra can, however, be indicative of the cause
of the paleosalinity anomaly. Since the vegetational
change in the upland at the beginning of the low salinity
period was an increase in oak, this could indicate a
wetter climatic episode, thereby producing increased
runoff and lower salinity. Another possibility is that
the influence of man's colonization by clearing the
upland yielded greater runoff and also open areas for
an increased growth of the Compositae. Ditching of the
marsh would also provide greater opportunity for the
growth of the Compositae. Thus, it appears that this
segment of the core represents a change in the upland
area which is reflected in the paleosalinity values.

The changes were not at the site of this core, as can be seen by the lack of an increase of Gramineae in the samples.

The overall environment represented by sediments in the upper 4.0 meters, as reflected by the pollen and paleosalinity distributions, was one of open water or a rather sparsely populated marsh dominated by Spartina alterniflora. The existence of this type of marsh, designated by Chapman (1960) as the S. alterniflora community, is further substantiated by the absence of Spartina patens roots in the sediment and the general lack of organic material of any type in the sediment. Where recognizable roots were found in the sediment, they were of S. alterniflora.

The segment of the core between 4.0 and 5.0 meters is characterized by SPM paleosalinity values generally below 20 $^o/_{oo}$, although in the lower 30 cm of the segment the paleosalinities slightly exceed this value. The pollen spectra change simultaneously with the SPM paleosalinities. At the 4.0 meter level there is an abrupt increase in the NAP consisting primarily of increases in the Gramineae and Cyperaceae. Corresponding with the NAP increase is a decrease in arboreal pollen. There is also an increase of spores between 4.0 and 4.5 meters.

The combination of decreased paleosalinity and increased NAP pollen indicates a marsh environment which is much more densely populated with grasses than the upper 4.0 meters. This is substantiated by the lithology of the sediment which consists of brown peat with essentially 100% fiber except for the segment between 4.5 and 4.8 meters which consists of a gray peat with approximately 50% fiber. The fibers within the peat are, for the most part, small wiry roots indicative of Spartina patens. Thus, this segment of the core appears to represent the S. patens community of Chapman (1960).

In the upper 40 cm of this segment there are pronounced peaks of Cyperaceae and spores. These groups tend to indicate an environment that is less saline than the marsh surface proper. The sedges and spore producers tend to inhabit the marsh fringe in the transition zone with the upland vegetation.

Thus, the segment between 4.0 and 5.0 meters suggests an environment which is not subject to daily inundation by the tides and, in the upper portion an environment which was at least near the transition zone with the upland environment.

The SPM paleosalinity values of the bottom segment of the core are rather uniform in the range between

20 °/oo and 30 °/oo. The pollen spectra within this
segment, however, are not uniform. There are pronounced
peaks of Alnus, Cyperaceae, spores, and Chenopod-type
grains within the segment. The lithology also is not
uniform, but rather fluctuates between several sediment
types.

The top meter of this segment has generally
high paleosalinities and peaks of Cyperaceae and spores,
with a moderate percentage of Gramineae. This assem-
blage tends to indicate a transitional environment be-
tween the S. alterniflora community and the S. patens
community. The fluctuations of the lithologies within
this segment tend to substantiate this view.

The lower portion of this segment is anomalous
in that there are peaks of Alnus and Chenopod-type grains
occurring together and the SPM paleosalinity values
are high. The presence of the Alnus would tend to in-
dicate a fresh water swamp environment, while the Cheno-
pod-type pollen indicates a marsh environment which
is indicated by the SPM paleosalinity.

The anomaly of the lower portion of the core
can be explained when the radiocarbon date of sample
6-36 is considered. This sample dated at 2150 ± 110
years B.P., while samples from slightly higher in core
#8 dated at an average of about 3000 years B.P. There-

fore, the lower section of core #6 is younger than the lower section of core #8 although the greater length of core #6 suggests that its lower section should be older than the lower section of core #8. The best explanation for this is that either Dennis Creek or one of its tributaries occupied this site and removed by erosion at least 1000 years of deposition. This would then mean that the lower segment of the core was deposited as the stream meandered to a new position and does not represent autochthonous deposition in the marsh environment, but, rather allochthonous deposition by a meandering stream. The pollen spectra derived from an allochthonous deposit would not be expected to reflect local vegetation, however, the SPM paleosalinity from such a deposit would reflect local conditions. Thus, the discrepancy between the pollen spectra and the SPM paleosalinity values can be explained, by assuming the fresh water pollen species were brought in by the meandering stream. This view is supported by the sediment lithology, for the fresh water pollen does not occur in a sediment type which is indicative of such an environment.

Core #8. The SPM paleosalinity values in the upper 1.9 meters are fairly uniform between 25 $^o/oo$ and

30 °/oo except for the first 20 cm and the segment be-
tween 0.30 and 0.90 meters. The pollen spectra are also
fairly uniform in this segment of the core except for
changes which occur simultaneously with the paleosalinity
changes.

The low paleosalinity values in the upper 20
cm of the core can be attributed to equilibration as
discussed in the section on core #6.

The slight decrease in paleosalinity between
0.30 and 0.90 meters coincides with an increase in NAP
pollen which primarily occurs in the Cyperaceae. There
is also in this segment a slight increase in Quercus.
It appears that this section correlates with the 2.0
to 3.0 meter section of core #6. This would then re-
flect possible increased runoff and clearing of the
upland area promoting growth of the Compositae. The
effect of the activities of colonization would not be
as drastic in this core, as the site is not in proximity
to a major tributary. Therefore, the influx of upland
pollen and the effect on salinity would not be as great
as in the case of core #6 (Figure 2).

The overall environment represented by the upper
1.9 meters, as reflected in the pollen spectra and the
SPM paleosalinity values, is one of a S. alterniflora
community or of open water in the lower 20 cm of this

segment. This interpretation is supported by the nature of the sediments which consist of gray mud with varying amounts of fiber, from 10% in the lower 20 cm to 50% in the upper 1.2 meters. In instances where the fibers were identifiable, the roots appeared to be S. alterniflora.

The segment of the core between 1.9 meters and 3.7 meters is characterized by relatively low SPM paleosalinity values except for the section from 2.3 to 2.7 meters and at 3.5 meters. In all other horizons the paleosalinity values were below 20 $^o/_{oo}$ and in some cases dropped below 10 $^o/_{oo}$. The pollen spectra within this segment are extremely variable; however, the variation occurs primarily within the NAP while the arboreal species remain fairly uniform.

The variation of the pollen spectra in this segment involves the Cyperaceae, Gramineae, Compositae, and spores. The Cyperaceae, Compositae, and spores increase together while the Gramineae reacts in a reciprocal manner. This type of variation is to be expected in a transitional environment between the marsh and the upland vegetation. The Cyperaceae assemblage occurs nearer the marsh fringe while the Gramineae assemblage occurs on the marsh proper. This Gramineae assemblage would consist primarily of S. patens. This

is substantiated by the sediment lithology which consists primarily of a brown peat with essentially 100% fiber. The fibers in all cases consist of roots which can be attributed to S. patens. The low SPM paleosalinity values are in agreement with this interpretation.

The bottom portion of the core consists of sediments having uniform SPM paleosalinity values in the range 25-33 $^o/oo$ except for the segment between 5.3 meters and 6.1 meters. The pollen spectra is also uniform consisting of low NAP and high arboreal pollen. The only change in the pollen spectra occurs in the segment between 5.3 and 6.1 meters where there is a peak of Alnus and a slight rise in spores.

The presence of a high percentage of Alnus in the pollen spectra indicates a fresh water swamp environment. This interpretation is supported by the decrease of SPM paleosalinity in this segment. It is further supported by the sediment lithology which consists of a brown peat containing many wood chips and no fibers which are recognizable as marsh grasses.

The other segments of the bottom portion of this core appear to represent a marsh or open water environment where the dominant grass was S. alterniflora. This interpretation is indicated by the sediment type, pollen population, and SPM paleosalinity.

Core #16. The SPM paleosalinity values in the
upper 0.5 meters are uniformly high at about 20 $^o/_{oo}$.
The pollen spectra in this region are also quite uniform
with a generally high percentage of NAP pollen.

The high percentages of Chenopod-type pollen
grains in the upper 30 cm of the core combined with
the high paleosalinity values indicate a fairly dry
marsh environment such as is typical in the S. patens
community. This community is, in fact, the community
which exists at the surface. The maintainence of this
type of community is enhanced by continued ditching
of the marsh surface.

The high concentration of the Compositae at
the lower end of this segment is probably caused by
the same conditions which gave rise to similar peaks
in core #6 and core #8, i.e. the clearing of the upland
areas. Thus, the influence of man's colonization shows
up in all three cores.

The SPM paleosalinity measurements and the pollen
distribution in this segment of the core indicate a
marsh environment. The sediment lithology and the
sparsity of Gramineae pollen in the lower segment in-
dicates a S. alterniflora community, while the S. patens
community is indicated for the upper portion of the core.
Thus, during the period represented by this segment

there has been a change in the marsh environment from conditions of daily flooding to drier conditions without the flooding.

The SPM paleosalinity values in the remainder of the core from 0.5 meters to the bottom at 2.4 meters are consistently low. Although some variability is present in this segment, the paleosalinity values remain below 10 $^o/_{oo}$ for the most part. The pollen spectra are also fairly uniform with the arboreal pollen dominating the distribution. The variation which does occur within this segment is between a domination by Ilex and a domination by Alnus.

The low paleosalinities and the domination of the pollen distribution by arboreal pollen indicate a fresh water environment for sediments in this portion of the core. This interpretation is supported by the sediment lithology which consists of brown peat with abundant wood chips, and no recognizable grass roots. The change in the pollen distribution from an Alnus dominance to an Ilex dominance reflects a change from wet conditions to drier conditions. This change may be equivalent to the ones which occur in core #6 and core #8 between the areas of brown peat and gray clay. In both of these cores the upward change from gray clay to brown peat signifies a change from the wetter S.

alterniflora community to the drier S. patens community.
Since core #16 is further inland than the other two cores,
it seems logical that this change would be reflected
in changes in upland vegetation. Thus, the change from
wet to drier conditions is reflected in the parameters
determined for all three cores.

## Interpretation of community succession

Although insufficient radiocarbon dates are
available for detailed stratigraphic correlation, ten-
tative correlations of sedimentary units within the
three cores can be made. The correlations are presented
in Figure 34. The reader is also referred to Figure
8, p. 23, which illustrates changes in lithology of
the three cores and interpretations discussed in this
section concerning environments of deposition.

It is evident from the relationships between
pollen distribution, SPM paleosalinity, and sediment
lithology that there has been a succession of commun-
ities in the Dennis Creek area since the commencement
of deposition prior to 3200 years B.P. The initial
environment of deposition is, as of yet, unknown because
core #8 which represents the oldest deposit does not
reach to the surface of the Cape May Formation. However,
since core #6 is only slightly longer and does reach
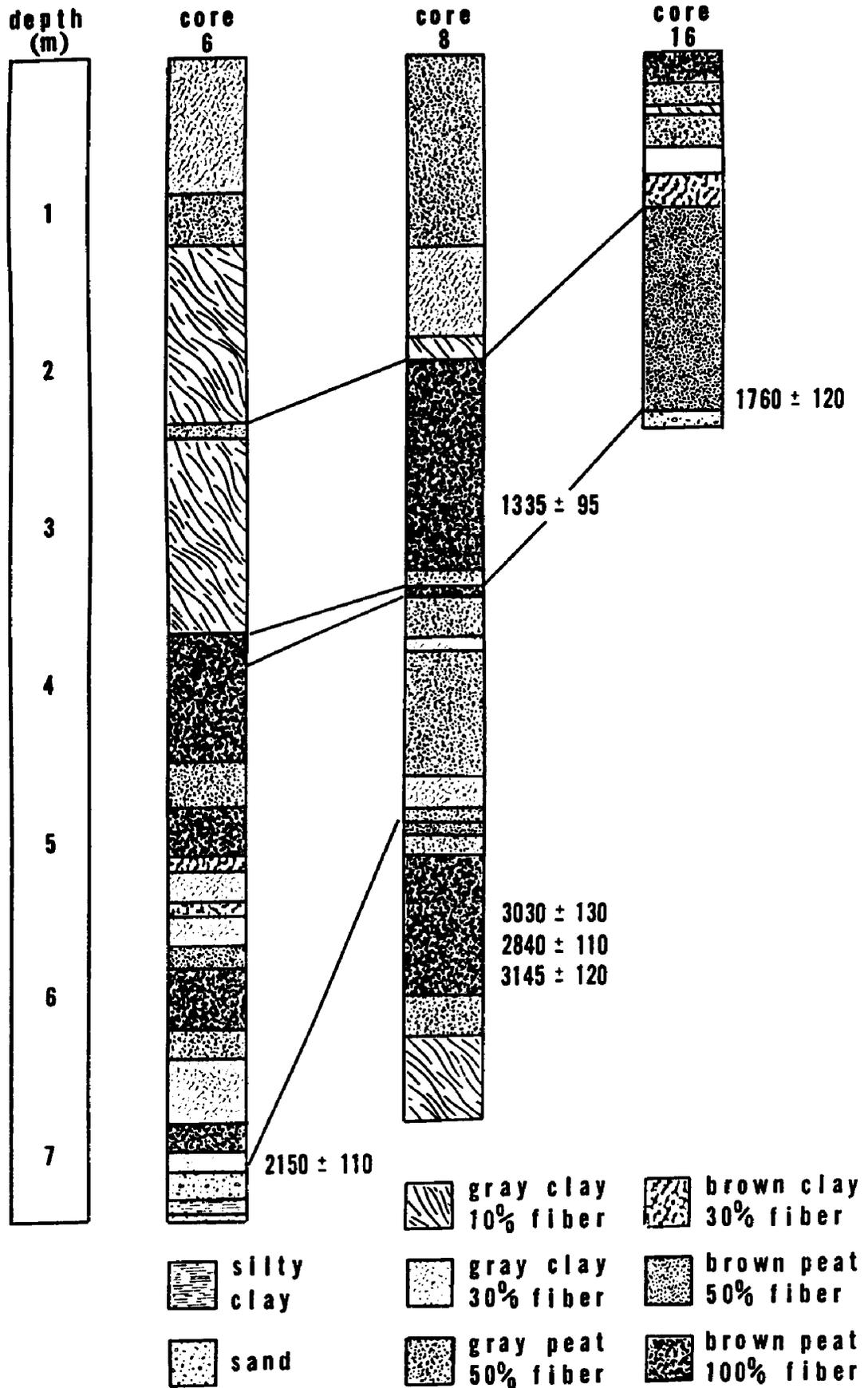
Figure 34. Radiocarbon Dates and Correlations.
See also Figure 8.

the Cape May surface, it is reasonable to assume that
the Cape May surface is not a great distance below the
bottom of core #8. Thus, sediments at the bottom of
core #8 are among the oldest in the marsh and represent
the earliest recognizable Holocene environment.

The initial environment reflected in core #8
is a marine environment that was, in all probability,
open water or a tidal flat. There is no evidence of
fresh water deposition at the base of the core, nor
is there evidence of the transition environment between
marsh vegetation and upland vegetation. Thus, assuming
that nothing has been lost from the bottom of the core
by erosion, it appears that rising sea level initially
flooded the area and produced a shallow-water marine
environment which is in evidence from the bottom of
the core up to a depth of 6.3 meters. This episode
of deposition is much older than any represented in
core #16, indicating that the initial flooding did not
reach the site of core #16. Since the deposits at the
bottom of core #6 are allochthonous (See p. 72) there
is no way to reconstruct the initial environment at
that site. However, because of its proximity to core
#8 and its similar depth, it is reasonable to assume
that the initial environments at that site were not
unlike those of core #8.

The bottom deposit is followed by the establishment of a S. alterniflora marsh as reflected in core #8. Core #6 is still allochthonous in the region of this environment and the bottom of core #16 is younger than this depositional episode. Thus, once again, the only evidence for this period of deposition is in core #8. Therefore, on the basis of the cores analyzed in detail, one cannot establish stratigraphic correlation within this part of the marsh sequence. However, since no deposition was occurring at the site of core #16 it is probable that the water level had not yet reached that site.

As reflected in core #8, the environment which followed the S. alterniflora marsh was a fresh water swamp. This swamp deposit has been dated at three different levels within the one meter sequence. These dates are $3030 \pm 130$, $2840 \pm 110$, and $3145 \pm 120$ years B.P. It is quite evident from these three dates that the deposition in this environment was extremely rapid. This is in agreement with the data which were collected by Cook (1856, 1857) indicating very rapid deposition within the cedar swamp environment. Once again, this environment is not represented in the other cores. Thus, when the site of core #8 was a fresh water swamp, the site of core #16 was still covered with upland

vegetation and clastic sedimentation was not taking
place.

Above the sediments representing this fresh
water environment is a sequence representing a succession
of marsh environments which alternated among a sparse
S. alterniflora marsh, a fairly dense S. alterniflora
marsh, and a S. patens marsh. The alternation of these
environments is evident in core #8. Deposition still
was not taking place at the site of core #16. The erosion
of the material from the bottom of site #6 occurred
during the period of fluctuation of marsh environments
evident in core #8. Any previous deposition which had
occurred at site #6 was erased during the period of
erosion. In all probability the period of deposition
which followed the erosion was characterized by a very
rapid rate of deposition. This rapid deposition is to
be expected in these circumstances and can be observed
in the present day on the inside curve of a meandering
stream. This depositional period at site #6 raised the
level of the marsh in that locality to an elevation
which was very close to that of site #8. However, the
elevation of the marsh surface at site #6 remained slightly
below that of site #8. This conclusion is based on slight
differences in pollen population between the two local-
ities which tend to indicate that site #6 was slightly

wetter at that time, and continued to be so throughout the remainder of its depositional history.

The fluctuations in marsh environment which are evident in core #8 appear to have been rather rapid. The thicknesses of the deposits representing each individual environment are not very great, thus indicating that no single environment persisted for an extremely long period of time.

Tentative correlations can be made between the cores in the sections which overlie those just discussed. The period of rapid deposition at site #6 seems to have ended with the establishment of a high marsh environment which can be discerned from the deposits which begin at a depth of about 4.5 meters. This section of high marsh sediment persists to a depth of 3.7 meters. Tentative correlation indicates that the thin layer of high marsh sediment at a depth of 3.5 meters in core #8 was deposited at about the same time as the upper high marsh sequence of core #6, in the vicinity of 4.0 meters. Thus, at this point in time, similar environments existed at the two sites. Site #16 was, as yet, not receiving any deposition.

The high marsh environment was succeeded by environments at the sites studied which were caused

by a marine transgression. At site #6 the high marsh
environment gives way to an environment which appears
to have been an open water or tidal flat environment.
Sediments deposited in this tidal flat environment
appear at 3.7 meters in the core. In core #8 sediments
deposited in the high marsh environment give way to
sediments representing a low marsh environment which
persisted for only a short time. These are overlain
by a high marsh facies. Thus, the evidence from both
cores indicates a marine transgression which is more
extensive than any other represented in the depositional
history of the analyzed cores. This transgression was
so extensive that site #16 felt the influence of a raised
water table and developed into a swamp. At this point
in time, which is dated at 1760 ± 120 years B.P. from
core #16, deposition took place simultaneously at all
three sites.

The transgression, while extensive, did not
continue with rate unchanged for a long period of time.
Although the tidal flat facies of core #6 is quite thick,
it can be seen that there is a thin low marsh facies
within the sequence at about 2.3 meters. This would
indicate a slowing of the transgression to the point
of the reestablishment of a marsh at that site. The
low marsh facies of core #8 immediately grades into

a high marsh facies, again indicating a slowing of the
transgression. The abatement of the transgression is
also represented in core #16 where an influx of Ilex
pollen at the top of the fresh water swamp sequence
would tend to indicate drier conditions. Thus, the
indications are that the transgression, although initially
extensive, began to slow very rapidly and eventually
slowed to the point that site #6 could support a low
marsh environment.

The level in core #6 at which it is suggested
that the bottom of the tidal flat facies appears coin-
cides with the level at which the rapid increase in
total phosphorus (Fe + Ca) begins. Comparison of the
P(Fe + Ca) curve with sediment lithology indicates that
sediment composition with regard to clay percentages
exerts little control on total phosphorus. Therefore,
such an increase in total phosphorus could logically
come from a marine transgression.

The period of abatement of the marine trans-
gression was followed by a rejuvenation of that trans-
gression. This renewed transgression is evident at
the 2.2 meter level of core #6, the 2.0 meter level
of core #8, and the 1.1 meter level of core #16. In
all three cores the changes in evidence reflect wetter
conditions. In core #6 the tidal flat environment

returned and was extended for a short time to site #8, while at site #16 the fresh water swamp gave way to a low marsh sequence.

After the initial invasion of the area by the bay waters, the environments present at all three sites became progressively drier. This is quite evident in the lithologies and pollen spectra which indicate the establishment of a more dense growth on the low marsh first at site #16, then at site #8, and finally at site #6 which is located nearest the bay. This drying tendency could be due to a change in the rate of transgression or an increase in marsh sedimentation.

Shortly after the reinvasion of the marsh by bay water, the upland area was colonized by man as evidenced in the pollen spectra. The fact that the colonization essentially coincided with a renewed marine transgression accounts for the reports of marsh erosion and encroachment of the marsh into the swamp environment cited by Cook (1856, 1857). The subsequent ditching of the marsh for the harvesting of salt hay is clearly evident in the core from site #16. This ditching produced a S. patens marsh in the vicinity of site #16. Although the other two sites were ditched, they never were occupied by the S. patens community.

<u>Comparison with other areas</u>

<u>Massachusetts</u>.  Barnstable Marsh in Massachusetts
has been described by Butler (1959) and by Redfield
(1964).

The study by Redfield involved the determination
of marsh environment through the utilization of the
water content of the peat.  This method assumes that
peat formed in the environment of the <u>S</u>. <u>patens</u> community
has a higher water content than that formed in the <u>S</u>.
<u>alterniflora</u> community.  Redfield's reconstruction of
the Barnstable Marsh during the Holocene does not reveal
the alternation of environments that is evident in Dennis
Creek.

The reason that alternations were not found
in Barnstable may be twofold: (1) the sampling inter-
val used and (2) the sensitivity of the method.  Al-
though the sampling interval used in the study was not
given, the distribution of data utilized in the study
indicates that there was a fairly wide vertical spacing
of samples.  As illustrated by the data collected from
Dennis Creek, if the samples utilized are too far apart,
the detail of the environmental fluctuations becomes
obliterated.  The sensitivity of the method employed
by Redfield is also open to question with regard to
detecting small fluctuations within the marsh environ-

ment. It is evident from Redfield's data that there is
an overlap in the water contents between the S. patens
marsh and the S. alterniflora marsh. This overlap may
prevent the determination of fluctuations within the
marsh.

The paper by Butler is a brief summary of his
work published after his death. It is unfortunate that
he was not able to complete his pioneer investigations
in the utilization of pollen analysis in tidal marshes.
The published summary includes a pollen diagram for
Barnstable Marsh and a brief interpretation oriented
toward the classical use of pollen analysis for the
elucidation of regional vegetation following deglaciation.
Unfortunately, a description of the sediment lithologies
does not accompany the pollen diagram. However, it
appears that marsh peat was encountered throughout the
entire length of the core (about 20 feet). The gross
lithology is not unlike that found in the Dennis Creek
area. Although the interpretation of the pollen deals
only with regional patterns of vegetation, there are
two aspects of the pollen spectra which are pertinent
to the interpretations made at Dennis Creek. There
is present in the upper portion of the diagram, a
distinct peak of Chenopod-type pollen which has been
dated at $400 \pm 100$ years B.P. There is also a distinct

change in the NAP percentages from high values in the
bottom of the core to low values closer to the surface.
This change in percentage of NAP has been dated at 1880
± 100 years B.P. which corresponds extremely well with
similar changes in the cores from Dennis Creek.

The similarity in the changes in marsh vegetation
in New Jersey and Massachusetts indicates that these
changes are not due to local conditions but rather to
changes that have affected a wide area. The alterna-
tions found by Butler also support the conclusion that
the method of investigation utilized by Redfield was
not sensitive enough to detect the changes in marsh
vegetation which have occurred.

Connecticut. An investigation of Connecticut
tidal marsh stratigraphy has been carried out by Bloom
(1961, 1964). These studies do not indicate an alter-
nation in marsh environments within the sedimentary
sequence. The only changes indicated in these studies
are from fresh or brackish water peat to estuarine muds
and then to salt marsh peat. However, these interpre-
tations are based on general textural characteristics
of the sediments. No detailed studies involving careful
measurement were made. Thus, some subtle changes in

the lithology may have been overlooked. There also is
no indication of the sampling interval used in the studies.
As indicated earlier, the sampling interval utilized
in a study of marsh stratigraphy has a definite bearing
on the detail which one is able to ascertain concerning
the alternation of marsh environments.

Sears (1963) studied the pollen spectra in
tidal marsh sediments at Guilford, Connecticut. Al-
though the pollen diagram presented in this study does
not include all pollen species or a description of sedi-
ment lithology, a distinct alternation between high
percentages of Gramineae and Cyperaceae is apparent.
These changes indicate oscillations in water level similar
to those present in Dennis Creek, although the lack
of radiocarbon dates does not permit correlation of
specific oscillations. The fact that these fluctuations
are present in the pollen spectra substantiates the
earlier conclusion that a purely stratigraphic study
not based on a detailed analysis is not satisfactory
for the determination of the changes in tidal marsh
stratigraphy which have occurred.

New Jersey. Three tidal marshes in other areas
of New Jersey have been studied stratigraphically:
Hackensack, Cheesequake, and Tuckerton.

Heusser (1949a, 1949b, 1963) investigated the
Hackensack Tidal Marsh through examination of peat and
vegetative remains in the peat and also using pollen
analysis. A fresh water peat underlies a marsh peat,
similar to the situation which exists at Dennis Creek.
The bottom of one core has been dated at 2025 $\pm$ 300
years B.P. The deposit from which the dated sample was
taken was a fresh water peat. Sediments located approxi-
mately one meter above the dated horizon apparently
were deposited in a marsh environment. This agrees
with the data accumulated at Dennis Creek.

A further investigation of the Hackensack Tidal
Marsh has been conducted by Harmon and Tedrow (1969).
In this study the primary focus was on the vegetation
of the marsh in the upper few feet of sediment as de-
termined by investigation of the peat and pollen anal-
ysis. Since the pollen diagrams included in this study
do not indicate arboreal pollen, a complete comparison
with Dennis Creek is not possible. However, there is
an indication in the NAP that there has been an alter-
nation of environments in the peat deposits which form
the upper portions of the sections studied.

Cheesequake Tidal Marsh has been investigated
by Rosenwinkel (1964), who has included in his study
a pollen analysis of selected cores within the tidal

marsh. Investigation of the pollen spectra from Cheese-
quake indicates a succession of communities similar
to that which has been recognized at Dennis Creek.
The bottom of the core is in fresh water swamp deposits
and is succeeded by tidal marsh sediments. It is quite
evident from the relationship of pollen of Gramineae
and Cyperaceae within the upper portion of the diagrams
that there has been an alternation of marsh environments
at Cheesequake similar to the alternations which have
occurred at Dennis Creek. No radiocarbon dates were
determined on the Cheesequake sediments, so that absolute
correlation between the two areas is not possible.

Force (1968) studied the Tuckerton Tidal Marsh
through a study of the peat, clastic sediments, and the
Foraminifera contained therein. The sample interval
for the investigation was one meter, which as indicated
earlier is not sufficiently close to determine the fluc-
tuations which occur within the marsh environment.
However, a fresh water peat was found to underlie the
marsh sequence. There is also some indication in the
lternation of foraminiferal assemblages and percentages
of organic material in the cores that changes in deposi-
tional environment occurred in the Tuckerton area.
There are no radiocarbon dates for sediment from the
Tuckerton area. This combined with the large sampling

interval precludes the correlation between Tuckerton and Dennis Creek. The indication, however, of alternation suggests that further work might be done.

Other studies have been undertaken in New Jersey tidal marshes which have no applicability to this study, e.g., Waksman, 1942.

Virginia. The tidal marsh of Wachapreague Lagoon, Virginia has been investigated by Newman and Munsart (1968). Included in the study are investigations of the peat of the area and pollen analyses of the cores. The sampling interval was one foot which, although a closer interval than that employed in many other studies, still does not permit a sufficiently detailed analysis of marsh environment fluctuations. However, vertical variations in the Foraminifera and the pollen assemblages do suggest some fluctuation in environment.

Significance with respect to sea-level curves

The eustatic rise of sea level due to Pleistocene deglaciation has been studied by many investigators producing a plethora of papers on the subject. The history of these investigations has been ably summarized by Guilcher (1969). In essence, the eustatic rise of sea level due to deglaciation is universally

recognized, however, the details of this rise are the
subject of much debate. There are those who believe
that the rise of sea level has been an oscillatory one,
reaching present level about 6000 years ago and oscil-
lating about that level since then (Fairbridge, 1961).
Another point of view holds that the rise of sea level
has been oscillatory prior to about 4000 years ago and,
since that time, has risen steadily to its present level
(Curray, 1960, 1961). Still another theory holds that
sea level has risen steadily until 3000 years ago, at
which time it reached its present level which has been
maintained since that time (Gould and McFarlan, 1959).
Finally, the theory established especially along the
eastern coast of North America is that sea level has
risen at a relatively rapid rate until about 3000 years
ago at which time the rate of rise decreased as the sea
advanced to its present position (Bloom, 1960, 1961,
1963, 1964, 1970; Bloom and Stuiver, 1963; Stuiver and
Daddario, 1963; Scholl and Stuiver, 1967; Scholl et.
al., 1969). It is this last theory which has gained
the widest acceptance.

Despite the wide acceptance of this theory,
there is not wide agreement among investigators on
certain details concerning the rise. Curves derived

from different areas, some of which are located quite
close together, differ in slope. There is general
agreement concerning a marked change in slope which
occurs at 3000-4000 years. In order to bring the many
curves into agreement, tectonic and isostatic processes
have been utilized (Bloom, 1965a, 1965b, 1967; Fair-
bridge and Newman, 1968; Newman and March, 1968; Red-
field, 1967).

In general, the method of study utilized by
most investigators consists of coring a tidal marsh
and dating by radiocarbon method the lowermost sediment
which rests directly on the Pleistocene surface. The
assumption is that this lowermost sample represents
the transition zone between marsh and upland vegetation
and, as such, the date obtained from it marks the high
tide level at that time. In most instances, detailed
studies of the entire marsh sequence are not undertaken.

Significance of Dennis Creek succession. The
succession of environments which has been elucidated
for the Dennis Creek Tidal Marsh has a direct bearing
on the sea-level curves which have been previously
proposed. Since, as indicated by the radiocarbon dates,
the oldest sediments collected from Dennis Creek are
about 3000 years old, the fluctuations in environment

which have been recorded at Dennis Creek must relate to that portion of the sea-level curve beginning 3000-4000 years ago and which heretofore has been considered to have a uniform slope.

The interpretations which may be placed on these fluctuations are: (1) that sea level has oscillated about the mean which is represented by the uniform slope of the published curves, or (2) that there have been changes in the slope of the curve (i.e., rate of sea-level rise) during the last 3000 years, with the published curves representing only the mean rate. Since there appears to be little or no evidence of erosion within the marsh sequence which could be due to oscillations of sea level about the mean, the latter interpretation seems to be the most valid.

Changes in the rate of sea-level rise without changing the rate of sediment supply would allow the marsh environment to transgress upon the bay environment, or vice versa. Thus, it appears from the Dennis Creek data that the rate of sea-level rise has not been uniform, but rather has fluctuated throughout the past 3000 years. A major fluctuation appears to have occurred at around 1800 years B.P. This major fluctuation is quite evident from the phosphate concentrations in the Dennis Creek cores, as well as the pollen sequence.

It is also evident in the pollen spectra which have
been obtained from Barnstable, Massachusetts.

Significance of Dennis Creek radiocarbon dates.
Since some of the horizons at Dennis Creek have been
dated, they have a direct relationship to the published
sea-level curves. The date from the bottom of core
#16 of 1760 ± 120 years B.P. falls directly on the curve
which had been previously published for New Jersey
(Stuiver and Daddario, 1963). However, caution must
be exercised in the interpretation of this date since
it is at the bottom of a rather long fresh water se-
quence. It is evident from the stratigraphy of the
Dennis Creek area that during formation of this fresh
water sequence sea level had fluctuated somewhat, and
therefore did not maintain a constant relationship to
the fresh water deposit. Thus, this date is actually
of an environment which is above the high tide level
by an unknown distance. The level which has been dated
does not, then, represent the high tide level and does
cause some questions to be asked concerning the details
of the published sea-level curve for this area.

The radiocarbon date of 2150 ± 110 years B.P.
from the bottom of core #6 does not fall on any of the
published sea-level curves. This is to be expected

considering the interpretation of this horizon as an allochthonous deposit due to the meandering of a tributary of Dennis Creek. This date, therefore, has no direct bearing on the published sea-level curves, except that it does serve to indicate the care which must be taken when obtaining samples for dating. Unless a detailed analysis of the peat stratigraphy is undertaken, dates could be obtained from samples which have absolutely no bearing on the eustatic rise of sea level.

The other dates which have been included in this study cannot be used to date sea level since they were not obtained from the bottom of the cores. The compaction of peat is well known and all investigators recognize that samples from within the marsh seouence are not in their original position. This compaction factor is the reason that only those samples are utilized which rest directly on the Pleistocene sands and are, therefore, in essentially their original position.

## SUMMARY

Evaluation of sediment types, SPM paleosalinity
values, and pollen spectra for the Dennis Creek Tidal
Marsh indicates fluctuation of marsh environments re-
lated to rate of sea level rise.  The rise of sea level
which initiated and accompanied the deposition was not
constant, but, rather changed throughout the period
of time represented by the Dennis Creek sequence.

Somewhat prior to 3000 years ago rising sea
level first affected the Dennis Creek area.  Initially,
deposition took place in an open water environment.
This was followed by the development of a _Spartina_ _alter-_
_niflora_ marsh.  A decrease in the rate of sea-level rise
allowed a fresh water environment to move out over the
established marsh.

A later increase in the rate of sea-level rise
produced a marine transgression which once again estab-
lished the marsh in the area.  This renewed transgres-
sion did not affect the entire marsh area.  Areas
immediately adjacent to major tributaries responded to
the transgressions, and fluctuations therein, to a greater
degree than those areas further away from major tribu-
taries.  Thus, isolated cores from a marsh system may
not contain the complete record of all that has happened

in the area.

A major transgression of the sea occurred at around 1800 years B.P. as determined from a change in the total phosphorus content in the cores and also in the pollen spectra. This transgression is also indicated by changes in pollen spectra of sediments from Barnstable, Massachusetts. Thus, the sea-level curves which have been published are actually mean rates of sea-level rise, and do not reflect fluctuations in rate which have occurred.

The evidence of the colonization of the area by man is quite clear in the pollen record. The influx of the Compositae in the pollen spectra for the cores indicates the deforestation of the area, allowing these weed plants to become abundant. The high percentages of the Chenopodiaceae in core #16 is the result of ditching of the marsh. The upper 20 cm of the cores shows a drastic increase in the total phosphorus present in the sediment, which may be due to pollution of the bay waters which inundate the marsh area daily.

The elucidation of the stratigraphy of Dennis Creek Tidal Marsh and the correlation of this stratigraphy with adjacent areas indicates that the methods utilized are, in fact, valid for this type of study. Pollen analysis can be utilized for the determination

of local vegetation when used in conjunction with other methods. Also, the SPM paleosalinity technique is valid when used within a single vertical sequence, where there has been no variation in the source area of the sediment. The absolute salinity values obtained by this method may not be exact; however, the trends established are extremely valuable in the interpretation of paleo-ecology.

APPENDIX A

LITHOLOGY OF DENNIS CREEK CORES

## CORE #1

0.0 to 0.87 meters fibrous gray mud

0.87 to 2.34 meters brown peat

2.34 to 2.40 meters sand

## CORE #2

0.0 to 0.4 meters no return

0.4 to 1.48 meters gray mud with varying amounts of fibers

1.48 to 4.52 meters brown peat

4.52 to 4.60 meters sand

## CORE #3

0.0 to 1.4 meters gray peat with varying amounts of fibers

1.4 to 1.51 meters brown peat

1.51 to 2.4 meters sand

## CORE #4

0.0 to 0.2 meters gray marsh peat

0.2 to 3.0 meters gray mud

3.0 to 3.12 meters sand

3.12 to 3.33 meters brown clay

3.33 to 3.54 meters brown peat

3.54 to 4.10 meters sand and sandy clay

## CORE #5

0.0 to 2.0 meters gray marsh peat

2.0 to 2.2 meters gray mud

2.2 to 2.44 meters gray marsh peat

2.44 to 7.2 meters gray mud with variable fiber content

7.2 to 7.4 meters brown peat

## CORE #6

0.0 to 0.2 gray marsh peat

0.2 to 0.88 meters gray mud

0.88 to 1.0 meters marsh peat

1.0 to 3.6 meters gray mud

3.6 to 5.2 meters brown peat

5.2 to 5.68 meters gray mud with large brown fibers

5.68 to 6.2 meters brown peat

6.2 to 7.12 meters gray mud with brown fibers

7.12 to 7.42 meters sand and silty clay

## CORE #7

0.0 to 0.2 meters no recovery

0.2 to 0.8 meters marsh peat

0.8 to 6.68 meters gray mud with variable fiber content

6.68 to 7.4 meters brown peat

## CORE #8

0.0 to 1.0 meters gray marsh peat

1.0 to 1.91 meters gray mud

1.91 to 1.99 meters black mud

1.99 to 3.31 meters brown peat

3.31 to 4.8 meters gray mud with variable fiber content

4.8 to 6.6 meters brown peat

6.6 to 6.8 meters gray mud


## CORE #9

0.0 to 0.4 meters no recovery

0.4 to 0.95 meters gray mud

0.95 to 1.4 meters brown peat

1.4 to 1.8 meters sand


## CORE #10

0.0 to 1.0 meters marsh peat


## CORE #11

0.0 to 0.4 meters gray marsh peat ·

0.4 to 2.35 meters gray mud

2.35 to 3.09 meters brown peat

3.09 to 3.3 meters gray mud

3.3 to 4.78 meters brown peat

4.78 to 5.0 meters sand

## CORE #12

0.0 to 0.17 meters gray marsh peat

0.17 to 0.31 meters gray mud

0.31 to 0.88 meters gray peat

0.88 to 1.52 meters gray mud

1.52 to 1.74 meters gray peat

1.74 to 2.8 meters brown peat

2.8 to 4.74 meters gray mud

4.74 to 5.2 meters brown peat

5.2 to 5.4 meters brown sandy peat


## CORE #13

0.0 to 0.6 meters gray marsh peat

0.6 to 2.6 meters gray mud

2.6 to 2.86 meters brown peat with gray clay

2.86 to 5.2 meters gray mud

5.2 to 5.24 meters brown peat

5.24 to 5.3 meters sand


## CORE #14

0.0 to 0.4 meters no recovery

0.4 to 1.0 meters gray mud

1.0 to 3.4 meters brown peat

3.4 to 3.8 meters sand

## CORE #15

0.0 to 0.4 meters no return

0.4 to 0.7 meters brown peat


## CORE #16

0.0 to 0.6 meters gray marsh peat

0.6 to 0.8 meters no recovery

0.8 to 2.31 meters brown peat

2.31 to 2.38 meters brown clay

2.38 to 2.4 meters gray sand


## CORE #17

0.0 to 0.2 meters marsh peat

0.2 to 0.4 meters no recovery

0.4 to 0.66 meters gray mud

0.66 to 0.71 meters sand

0.71 to 0.76 meters clay

0.76 to 0.80 meters brown sandy peat

0.80 to 1.2 meters brown peat

APPENDIX B

POLLEN PERCENTAGES

| SAMPLE NO. | PINUS | PICEA | TSUGA | CARYA | BETULA-TYPE | ALNUS | CASTANEA | QUERCUS | ILEX | FRAXINUS | ACER |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6-1-2 | 17.3 | --- | --- | 2.7 | 1.3 | 2.7 | .7 | 39.3 | --- | --- | --- |
| 6-2-2 | 15.3 | --- | .7 | 3.3 | 2.7 | 1.3 | .7 | 41.3 | --- | 1.3 | --- |
| 6-3-3 | 12.7 | --- | --- | 4.0 | 4.0 | .7 | --- | 40.7 | .7 | --- | .7 |
| 6-3-7 | 13.3 | --- | --- | 4.7 | 5.3 | 1.3 | 3.3 | 37.3 | 2.0 | --- | 1.3 |
| 6-4-3 | 8.0 | --- | 1.3 | 2.7 | 5.3 | 1.3 | 4.0 | 32.0 | .7 | 2.7 | --- |
| 6-4-8 | 12.0 | --- | --- | 3.3 | 4.0 | 2.7 | 3.3 | 34.7 | .7 | 2.7 | 2.0 |
| 6-5-3 | 17.1 | --- | .9 | 4.3 | 4.3 | 3.4 | 2.7 | 32.5 | --- | --- | 2.7 |
| 6-6-3 | 12.7 | --- | 1.3 | 2.7 | 3.3 | 1.3 | 3.3 | 45.3 | --- | .7 | .7 |
| 6-7-3 | 12.7 | --- | .7 | 1.3 | 4.7 | .7 | --- | 34.7 | --- | 2.0 | --- |
| 6-8-3 | 11.3 | --- | 2.0 | 4.0 | 4.7 | 3.3 | .7 | 37.3 | .7 | 2.7 | .7 |
| 6-9-3 | 12.7 | .7 | 2.7 | 2.0 | 3.3 | .7 | --- | 30.7 | .7 | 1.3 | 1.3 |
| 6-10-3 | 14.7 | --- | 1.3 | .7 | 5.3 | .7 | --- | 46.0 | --- | .7 | 1.3 |
| 6-11-3 | 15.3 | .7 | 2.7 | 2.0 | 5.3 | 1.3 | 2.0 | 29.3 | --- | 4.7 | .7 |
| 6-12-3 | 12.7 | --- | 2.0 | 1.3 | 2.0 | 1.3 | 1.3 | 33.3 | .7 | 1.3 | .7 |
| 6-13-2 | 26.0 | --- | .7 | 3.3 | 3.3 | 2.0 | .7 | 28.7 | .7 | 3.3 | 1.3 |
| 6-14-3 | 17.3 | --- | --- | 4.0 | 5.3 | 2.0 | .7 | 31.3 | 2.7 | 1.3 | --- |
| 6-15-3 | 11.3 | 1.3 | .7 | .7 | 5.3 | 1.3 | 1.3 | 45.3 | .7 | 1.3 | 2.0 |
| 6-16-3 | 22.0 | --- | 2.7 | 3.3 | 3.3 | 1.3 | 1.3 | 40.0 | .7 | 2.0 | --- |
| 6-17-3 | 17.3 | .7 | .7 | 2.7 | 4.0 | .7 | 2.0 | 36.0 | --- | 2.7 | 2.0 |
| 6-17-8 | 22.7 | .7 | 2.0 | 4.7 | 5.3 | .7 | --- | 36.0 | 2.0 | .7 | .7 |

POLLEN PERCENTAGES CORE #6

| FAGUS | JUGLANS | ULMUS | SALIX | TILIA | MIMOSA | NAP | CHENOPOD-TYPE | COMPOSITAE | GRAMINEAE | CYPERACEAE | TRIGLOCHIN | PLANTAGO |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| --- | --- | --- | --- | --- | --- | 36.0 | 3.3 | 11.3 | 18.7 | .7 | 1.3 | .7 |
| --- | --- | --- | --- | --- | --- | 32.7 | 4.7 | 9.3 | 17.3 | 2.0 | --- | --- |
| --- | --- | --- | --- | --- | --- | 36.7 | 6.0 | 11.3 | 18.0 | 1.3 | --- | --- |
| --- | --- | --- | --- | --- | --- | 31.3 | 5.3 | 8.0 | 17.3 | --- | --- | --- |
| --- | --- | --- | --- | --- | --- | 42.0 | 2.0 | 13.3 | 24.0 | .7 | .7 | 1.3 |
| --- | --- | --- | --- | --- | --- | 34.7 | 2.0 | 9.3 | 22.7 | .7 | --- | --- |
| .9 | --- | --- | --- | --- | --- | 25.3 | 4.3 | 11.1 | 17.1 | --- | --- | --- |
| .7 | --- | --- | --- | --- | --- | 28.0 | 2.7 | 8.7 | 14.7 | --- | --- | .7 |
| .7 | --- | --- | --- | --- | --- | 42.7 | 2.0 | 14.7 | 24.0 | 2.0 | --- | --- |
| .7 | --- | --- | --- | --- | --- | 32.0 | 5.3 | 9.3 | 16.7 | --- | --- | .7 |
| .7 | --- | --- | --- | --- | --- | 43.4 | 2.0 | 16.0 | 23.3 | 1.3 | --- | --- |
| .7 | --- | --- | --- | --- | --- | 28.7 | 4.7 | 9.3 | 13.3 | --- | --- | .7 |
| 1.3 | --- | --- | --- | --- | --- | 34.7 | 5.3 | 13.3 | 14.7 | --- | --- | --- |
| --- | --- | --- | --- | --- | --- | 43:3 | 9.3 | 13.3 | 17.3 | 3.3 | --- | --- |
| .7 | --- | --- | --- | --- | --- | 29.3 | 4.0 | 14.0 | 9.3 | .7 | --- | 1.3 |
| --- | --- | --- | --- | --- | --- | 35.3 | 3.3 | 14.7 | 14.0 | --- | --- | 2.0 |
| --- | .7 | --- | --- | --- | --- | 28.0 | 2.7 | 11.3 | 14.0 | --- | --- | --- |
| --- | --- | --- | --- | --- | --- | 23.3 | 4.7 | 2.7 | 15.3 | .7 | --- | --- |
| --- | --- | --- | --- | --- | --- | 31.4 | 2.0 | 8.0 | 20.0 | .7 | --- | --- |
| .7 | --- | --- | --- | --- | --- | 24.0 | 2.0 | 4.7 | 13.3 | 2.7 | --- | --- |

#6

| MIMOSA | NAP | CHENOPOD-TYPE | COMPOSITAE | GRAMINEAE | CYPERACEAE | TRIGLOCHIN | PLANTAGO | CARDAMINE | TYPHA | ERICACEAE | SPORES |
|---|---|---|---|---|---|---|---|---|---|---|---|
| -- | 36.0 | 3.3 | 11.3 | 18.7 | .7 | 1.3 | .7 | --- | --- | --- | 14.7 |
| -- | 32.7 | 4.7 | 9.3 | 17.3 | 2.0 | --- | --- | --- | --- | --- | 10.6 |
| -- | 36.7 | 6.0 | 11.3 | 18.0 | 1.3 | --- | --- | --- | --- | --- | 10.0 |
| -- | 31.3 | 5.3 | 8.0 | 17.3 | --- | --- | --- | .7 | --- | --- | 11.1 |
| -- | 42.0 | 2.0 | 13.3 | 24.0 | .7 | .7 | 1.3 | --- | --- | --- | 9.6 |
| -- | 34.7 | 2.0 | 9.3 | 22.7 | .7 | --- | --- | --- | --- | --- | 12.8 |
| -- | 25.3 | 4.3 | 11.1 | 17.1 | --- | --- | --- | --- | --- | --- | 13.3 |
| -- | 28.0 | 2.7 | 8.7 | 14.7 | --- | --- | .7 | --- | --- | 1.3 | 13.3 |
| -- | 42.7 | 2.0 | 14.7 | 24.0 | 2.0 | --- | --- | --- | --- | --- | 15.1 |
| -- | 32.0 | 5.3 | 9.3 | 16.7 | --- | --- | .7 | --- | --- | --- | 7.4 |
| -- | 43.4 | 2.0 | 16.0 | 23.3 | 1.3 | --- | --- | --- | --- | .7 | 14.3 |
| -- | 28.7 | 4.7 | 9.3 | 13.3 | --- | --- | .7 | .7 | --- | --- | 7.4 |
| -- | 34.7 | 5.3 | 13.3 | 14.7 | --- | --- | --- | .7 | .7 | --- | 12.3 |
| -- | 43.3 | 9.3 | 13.3 | 17.3 | 3.3 | --- | --- | --- | --- | --- | 13.7 |
| -- | 29.3 | 4.0 | 14.0 | 9.3 | .7 | --- | 1.3 | --- | --- | --- | 9.1 |
| -- | 35.3 | 3.3 | 14.7 | 14.0 | --- | --- | 2.0 | --- | --- | 1.3 | 13.7 |
| -- | 28.0 | 2.7 | 11.3 | 14.0 | --- | --- | --- | --- | --- | --- | 8.0 |
| -- | 23.3 | 4.7 | 2.7 | 15.3 | .7 | --- | --- | --- | --- | --- | 12.8 |
| -- | 31.4 | 2.0 | 8.0 | 20.0 | .7 | --- | --- | --- | --- | .7 | 12.8 |
| -- | 24.0 | 2.0 | 4.7 | 13.3 | 2.7 | --- | --- | --- | --- | 1.3 | 8.6 |

| SAMPLE NO. | PINUS | PICEA | TSUGA | CARYA | BETULA-TYPE | ALNUS | CASTANEA | QUERCUS | ILEX | FRAXINUS | ACER |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6-18-3 | 16.7 | --- | 2.0 | 2.0 | 4.7 | --- | --- | 32.7 | --- | 3.3 | 2.0 |
| 6-19-3 | 9.3 | --- | 2.0 | .7 | 4.7 | --- | 1.3 | 40.0 | --- | 1.3 | .7 |
| 6-20-3 | 12.0 | --- | 1.3 | 2.0 | 2.7 | .7 | 1.3 | 27.3 | .7 | --- | .7 |
| 6-21-3 | 6.0 | --- | 1.3 | .7 | 1.3 | --- | .7 | 24.7 | --- | 2.0 | 2.0 |
| 6-22-2 | 9.3 | --- | --- | .7 | 7.3 | .7 | --- | 28.0 | 7.3 | 1.3 | 1.3 |
| 6-23-3 | 2.7 | --- | --- | 1.3 | .7 | --- | --- | 22.7 | --- | .7 | --- |
| 6-24-3 | 4.7 | --- | --- | 1.3 | .7 | .7 | .7 | 20.0 | --- | .7 | --- |
| 6-25-3 | 7.3 | 1.3 | 1.3 | 1.3 | 2.7 | --- | 2.0 | 28.7 | --- | 2.0 | --- |
| 6-26-3 | 15.3 | --- | .7 | 3.3 | 1.3 | --- | --- | 36.0 | --- | 1.3 | --- |
| 6-27-3 | 9.3 | --- | .7 | 1.3 | 2.7 | 1.3 | .7 | 28.7 | .7 | --- | 1.3 |
| 6-28-3 | 8.7 | --- | .7 | 2.0 | 2.0 | 1.3 | 1.3 | 24.0 | 1.3 | 1.3 | --- |
| 6-29-3 | 5.3 | 1.3 | --- | 2.7 | 2.0 | 1.3 | 1.3 | 30.0 | .7 | 1.3 | .7 |
| 6-30-2 | 9.3 | 1.3 | 1.3 | --- | 3.3 | .7 | 1.3 | 11.3 | 2.7 | .7 | 4.7 |
| 6-31-3 | 8.7 | 1.3 | .7 | 2.0 | 6.0 | 4.0 | .7 | 22.7 | .7 | --- | 2.7 |
| 6-32-3 | 2.0 | .7 | 1.3 | 1.3 | 2.0 | 42.0 | --- | 26.7 | 1.3 | .7 | 2.0 |
| 6-33-2 | 3.3 | .7 | --- | 2.7 | 1.3 | 3.3 | --- | 19.3 | --- | .7 | 4.7 |
| 6-34-3 | 7.3 | --- | 1.3 | .7 | 2.7 | 2.0 | --- | 27.3 | --- | .7 | 1.3 |
| 6-35-3 | 6.7 | .7 | .7 | 1.3 | 4.7 | 4.7 | --- | 22.0 | 2.7 | 1.3 | 2.7 |
| 6-36-3 | 4.0 | .7 | 1.3 | 1.3 | 4.0 | --- | --- | 16.0 | 1.3 | .7 | 4.0 |

POLLEN PERCENTAGES CORE #6

| FAGUS | JUGLANS | ULMUS | SALIX | TILIA | MIMOSA | NAP | CHENOPOD-TYPE | COMPOSITAE | GRAMINEAE | CYPERACEAE | TRIGLOCHIN | PLANTAGO |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.3 | --- | .7 | --- | --- | --- | 34.7 | 2.7 | 8.0 | 23.3 | .7 | --- | --- |
| .7 | --- | .7 | --- | --- | --- | 38.7 | 2.0 | 8.0 | 24.7 | 3.3 | --- | --- |
| .7 | --- | --- | --- | --- | --- | 50.7 | 9.3 | 6.0 | 25.3 | 10.0 | --- | --- |
| --- | --- | --- | --- | --- | --- | 61.3 | 2.0 | 2.7 | 42.7 | 14.0 | --- | --- |
| --- | --- | --- | --- | --- | --- | 44.0 | .7 | 10.0 | 29.3 | 3.3 | --- | .7 |
| --- | --- | --- | --- | --- | --- | 72.0 | 5.3 | 4.7 | 60.0 | --- | --- | 1.3 |
| .7 | --- | --- | --- | --- | --- | 70.7 | --- | --- | 70.7 | --- | --- | --- |
| .7 | --- | --- | --- | --- | --- | 52.7 | .7 | 2.0 | 46.0 | 2.7 | --- | 1.3 |
| --- | --- | --- | --- | --- | --- | 42.0 | 2.7 | 1.3 | 35.3 | 1.3 | --- | 1.3 |
| --- | --- | --- | --- | --- | --- | 53.3 | 6.7 | 6.0 | 38.7 | .7 | --- | --- |
| 1.3 | --- | --- | --- | --- | --- | 56.0 | 9.3 | 5.3 | 32.7 | 8.0 | --- | .7 |
| .7 | --- | --- | --- | --- | --- | 52.7 | 4.7 | 6.0 | 34.0 | 8.0 | --- | --- |
| .7 | --- | --- | --- | --- | --- | 62.7 | 3.3 | 3.3 | 38.7 | 17.3 | --- | --- |
| .7 | --- | --- | --- | --- | --- | 50.7 | 3.3 | 3.3 | 34.7 | 9.3 | --- | --- |
| --- | --- | --- | --- | --- | --- | 20.0 | 1.3 | 2.7 | 15.3 | --- | --- | --- |
| .7 | --- | --- | --- | --- | --- | 63.3 | 14.0 | 6.0 | 40.0 | 3.3 | --- | --- |
| --- | --- | --- | --- | --- | --- | 56.7 | 7.3 | 4.7 | 36.0 | 7.3 | --- | 1.3 |
| --- | --- | --- | .7 | --- | --- | 52.0 | 7.3 | 6.7 | 30.7 | 7.3 | --- | --- |
| .7 | --- | --- | --- | --- | --- | 66.0 | 12.0 | 2.7 | 47.3 | 2.0 | --- | 1.3 |

| | NAP | CHENOPOD-TYPE | COMPOSITAE | GRAMINEAE | CYPERACEAE | TRIGLOCHIN | PLANTAGO | CARDAMINE | TYPHA | ERICACEAE | SPORES |
|---|---|---|---|---|---|---|---|---|---|---|---|
| -- | 34.7 | 2.7 | 8.0 | 23.3 | .7 | --- | --- | --- | --- | --- | 10.2 |
| -- | 38.7 | 2.0 | 8.0 | 24.7 | 3.3 | --- | --- | --- | --- | .7 | 8.5 |
| -- | 50.7 | 9.3 | 6.0 | 25.3 | 10.0 | --- | --- | --- | --- | --- | 14.3 |
| -- | 61.3 | 2.0 | 2.7 | 42.7 | 14.0 | --- | --- | --- | --- | --- | 4.4 |
| -- | 44.0 | .7 | 10.0 | 29.3 | 3.3 | --- | .7 | --- | --- | --- | 52.1 |
| -- | 72.0 | 5.3 | 4.7 | 60.0 | --- | --- | 1.3 | --- | .7 | --- | 11.2 |
| -- | 70.7 | --- | --- | 70.7 | --- | --- | --- | --- | --- | --- | .6 |
| -- | 52.7 | .7 | 2.0 | 46.0 | 2.7 | --- | 1.3 | --- | --- | --- | 3.8 |
| -- | 42.0 | 2.7 | 1.3 | 35.3 | 1.3 | --- | 1.3 | --- | --- | --- | 2.6 |
| -- | 53.3 | 6.7 | 6.0 | 38.7 | .7 | --- | --- | --- | 1.3 | --- | 27.8 |
| -- | 56.0 | 9.3 | 5.3 | 32.7 | 8.0 | --- | .7 | --- | --- | --- | 30.2 |
| -- | 52.7 | 4.7 | 6.0 | 34.0 | 8.0 | --- | --- | --- | --- | --- | 21.4 |
| -- | 62.7 | 3.3 | 3.3 | 38.7 | 17.3 | --- | --- | --- | --- | --- | 10.7 |
| -- | 50.7 | 3.3 | 3.3 | 34.7 | 9.3 | --- | --- | --- | --- | --- | 11.2 |
| -- | 20.0 | 1.3 | 2.7 | 15.3 | --- | --- | --- | --- | --- | .7 | 3.7 |
| -- | 63.3 | 14.0 | 6.0 | 40.0 | 3.3 | --- | --- | --- | --- | --- | 13.7 |
| -- | 56.7 | 7.3 | 4.7 | 36.0 | 7.3 | --- | 1.3 | --- | --- | --- | 9.0 |
| -- | 52.0 | 7.3 | 6.7 | 30.7 | 7.3 | --- | --- | --- | --- | --- | 13.7 |
| -- | 66.0 | 12.0 | 2.7 | 47.3 | 2.0 | --- | 1.3 | --- | .7 | --- | 9.1 |

| SAMPLE NO. | PINUS | PICEA | TSUGA | CARYA | BETULA-TYPE | ALNUS | CASTANEA | QUERCUS | ILEX | FRAXINUS | ACER |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 8-1-1 | 16.5 | .5 | 2.5 | 2.0 | 3.5 | 2.0 | .5 | 34.0 | --- | 2.5 | .5 |
| 8-1-3 | 18.5 | --- | 2.0 | 2.0 | 2.5 | 2.0 | 1.5 | 34.5 | --- | 1.0 | 4.5 |
| 8-2-2 | 23.0 | 1.5 | --- | 1.5 | 3.0 | 2.5 | 2.0 | 32.5 | --- | 2.0 | 1.0 |
| 8-3-3 | 15.8 | .7 | 2.0 | --- | 4.6 | 2.6 | 1.3 | 40.7 | 1.3 | 2.0 | .7 |
| 8-3-6 | 11.0 | .5 | 2.5 | 2.0 | 3.0 | 1.5 | 1.0 | 30.0 | --- | .5 | 1.0 |
| 8-4-2 | 11.5 | 1.5 | .5 | 2.0 | 1.0 | 1.0 | 5.0 | 30.5 | --- | --- | 1.0 |
| 8-5-3 | 12.5 | 1.0 | 1.0 | 2.5 | 2.5 | 2.0 | 1.0 | 31.0 | --- | 1.5 | 1.5 |
| 8-5-8 | 16.5 | 1.0 | 1.0 | 1.0 | 4.5 | 2.0 | .5 | 38.0 | --- | .5 | .5 |
| 8-6-3 | 12.5 | .6 | 1.8 | 1.2 | 7.1 | 3.6 | .6 | 27.4 | --- | 1.2 | 1.8 |
| 8-6-6 | 19.1 | 1.2 | 3.5 | 2.3 | 2.9 | 1.2 | .6 | 35.3 | --- | 1.2 | 1.7 |
| 8-7-3 | 14.6 | --- | 4.0 | 4.6 | .7 | 2.0 | 2.0 | 34.4 | --- | 1.3 | 1.3 |
| 8-7-7 | 16.0 | 1.3 | 1.3 | 2.7 | 4.7 | 1.3 | .7 | 40.6 | --- | .7 | 1.3 |
| 8-8-3 | 23.1 | 1.3 | 1.3 | 1.3 | 3.8 | 1.3 | 1.3 | 36.5 | --- | 1.3 | .6 |
| 8-8-8 | 20.5 | 1.0 | 1.5 | 1.5 | 3.0 | 2.0 | .5 | 36.5 | --- | 4.0 | .5 |
| 8-9-3 | 14.0 | .5 | 2.0 | 2.5 | 2.0 | 2.5 | --- | 40.0 | .5 | 1.0 | .5 |
| 8-9-7 | 15.0 | 1.5 | 1.5 | 1.5 | 4.0 | 1.0 | .5 | 32.0 | --- | 3.0 | 3.5 |
| 8-10-3 | 10.7 | 1.3 | 4.0 | 2.0 | 4.0 | 1.3 | .7 | 36.0 | --- | 4.7 | 1.3 |
| 8-10-6 | 14.0 | 1.3 | 1.3 | .7 | 7.3 | 2.7 | --- | 37.3 | --- | 4.0 | 1.3 |
| 8-11-3 | 10.0 | --- | 2.0 | 1.3 | 2.0 | .7 | 3.3 | 24.6 | --- | 4.0 | 3.3 |
| 8-11-6 | 8.5 | --- | 1.0 | 1.5 | .5 | .5 | .5 | 23.0 | --- | 2.5 | 2.0 |

POLLEN PERCENTAGES CORE #8

| FAGUS | JUGLANS | ULMUS | SALIX | TILIA | MIMOSA | NAP | CHENOPOD-TYPE | COMPOSITAE | GRAMINEAE | CYPERACEAE | TRIGLOCHIN | PLANTAGO |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.0 | --- | --- | .5 | --- | --- | 33.5 | 6.0 | 7.0 | 18.5 | .5 | .5 | --- |
| --- | --- | ---- | .5 | --- | --- | 30.0 | 6.5 | 8.0 | 12.5 | 1.0 | .5 | 1.0 |
| --- | --- | --- | .5 | --- | --- | 30.5 | 2.5 | 15.5 | 11.5 | --- | --- | .5 |
| --- | --- | --- | .7 | --- | --- | 27.8 | 3.3 | 11.8 | 11.8 | --- | --- | .7 |
| --- | --- | --- | --- | --- | --- | 46.5 | 8.5 | 20.5 | 16.5 | --- | .5 | .5 |
| --- | --- | --- | .5 | --- | --- | 45.0 | 2.5 | 27.5 | 15.0 | --- | --- | --- |
| --- | --- | --- | --- | --- | --- | 43.5 | 3.0 | 22.0 | 17.0 | --- | .5 | 1.0 |
| --- | --- | --- | 1.0 | --- | --- | 33.5 | 1.5 | 15.5 | 15.5 | --- | --- | 1.0 |
| .6 | --- | --- | .6 | --- | --- | 41.0 | 3.6 | 9.5 | 28.0 | --- | --- | --- |
| --- | --- | --- | .6 | --- | --- | 30.6 | 2.3 | 12.2 | 15.6 | .6 | --- | --- |
| --- | --- | --- | --- | --- | --- | 35.1 | 3.3 | 13.9 | 15.9 | --- | 1.3 | .7 |
| .7 | --- | --- | --- | --- | --- | 28.7 | 2.0 | 16.7 | 9.3 | --- | .7 | --- |
| --- | --- | --- | --- | --- | --- | 28.2 | 3.8 | 5.1 | 17.9 | --- | .6 | .6 |
| --- | --- | --- | --- | --- | --- | 29.0 | 2.5 | 7.5 | 17.5 | 1.0 | --- | .5 |
| --- | --- | --- | --- | --- | --- | 34.5 | 4.5 | 9.5 | 19.0 | --- | .5 | 1.0 |
| --- | --- | --- | --- | --- | --- | 36.5 | 4.0 | 9.0 | 23.0 | --- | --- | --- |
| --- | --- | --- | --- | --- | --- | 34.0 | 2.7 | 8.7 | 21.4 | .7 | --- | .7 |
| --- | --- | --- | .7 | --- | --- | 29.3 | 2.0 | 7.3 | 20.0 | --- | --- | --- |
| 8.0 | --- | --- | --- | --- | --- | 40.7 | --- | 2.7 | 30.0 | 7.0 | --- | .7 |
| 2.0 | --- | --- | --- | --- | --- | 58.0 | --- | 1.0 | 51.5 | 4.0 | --- | 1.5 |

| MIMOSA | NAP | CHENOPOD-TYPE | COMPOSITAE | GRAMINEAE | CYPERACEAE | TRIGLOCHIN | PLANTAGO | | CARDAMINE | TYPHA | ERICACEAE | SPORES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| --- | 33.5 | 6.0 | 7.0 | 18.5 | .5 | .5 | --- | | .5 | --- | .5 | 21.7 |
| --- | 30.0 | 6.5 | 8.0 | 12.5 | 1.0 | .5 | 1.0 | | --- | --- | .5 | 21.0 |
| --- | 30.5 | 2.5 | 15.5 | 11.5 | --- | --- | .5 | | --- | .5 | --- | 12.7 |
| --- | 27.8 | 3.3 | 11.8 | 11.8 | --- | --- | .7 | | --- | --- | --- | 18.2 |
| --- | 46.5 | 8.5 | 20.5 | 16.5 | --- | .5 | .5 | | --- | --- | --- | 14.9 |
| --- | 45.0 | 2.5 | 27.5 | 15.0 | --- | --- | --- | | --- | --- | --- | 11.9 |
| --- | 43.5 | 3.0 | 22.0 | 17.0 | --- | .5 | 1.0 | | --- | --- | --- | 14.1 |
| --- | 33.5 | 1.5 | 15.5 | 15.5 | --- | --- | 1.0 | | --- | --- | --- | 5.7 |
| --- | 41.0 | 3.6 | 9.5 | 28.0 | --- | --- | --- | | --- | --- | --- | 16.5 |
| --- | 30.6 | 2.3 | 12.2 | 15.6 | .6 | --- | --- | | --- | --- | --- | 12.0 |
| --- | 35.1 | 3.3 | 13.9 | 15.9 | --- | 1.3 | .7 | | --- | --- | --- | 12.7 |
| --- | 28.7 | 2.0 | 16.7 | 9.3 | --- | .7 | --- | | --- | --- | --- | 12.8 |
| --- | 28.2 | 3.8 | 5.1 | 17.9 | --- | .6 | .6 | | --- | --- | --- | 14.2 |
| --- | 29.0 | 2.5 | 7.5 | 17.5 | 1.0 | --- | .5 | | --- | --- | --- | 9.5 |
| --- | 34.5 | 4.5 | 9.5 | 19.0 | --- | .5 | 1.0 | | --- | --- | --- | 10.7 |
| --- | 36.5 | 4.0 | 9.0 | 23.0 | --- | --- | --- | | --- | --- | .5 | 12.6 |
| --- | 34.0 | 2.7 | 8.7 | 21.4 | .7 | --- | .7 | | --- | --- | --- | 10.2 |
| --- | 29.3 | 2.0 | 7.3 | 20.0 | --- | --- | --- | | --- | --- | --- | 13.8 |
| --- | 40.7 | --- | 2.7 | 30.0 | 7.0 | --- | .7 | | --- | .7 | --- | 6.8 |
| --- | 58.0 | --- | 1.0 | 51.5 | 4.0 | --- | 1.5 | | --- | --- | --- | 5.2 |

| SAMPLE NO. | PINUS | PICEA | TSUGA | CARYA | BETULA-TYPE | ALNUS | CASTANEA | QUERCUS | ILEX | FRAXINUS | ACER |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 8-12-3 | 4.0 | --- | 1.0 | 3.0 | 2.5 | .5 | 2.0 | 27.0 | --- | 2.0 | 1.5 |
| 8-12-7 | 8.0 | --- | 2.5 | 2.5 | 3.0 | .5 | 2.0 | 19.5 | --- | 1.5 | 1.5 |
| 8-13-3 | 8.5 | .5 | 1.5 | --- | .5 | 1.5 | 1.5 | 30.5 | --- | 2.0 | 4.5 |
| 8-14-3 | 7.0 | --- | 3.0 | .5 | 2.0 | 1.0 | 1.5 | 22.0 | --- | 1.0 | 5.5 |
| 8-14-8 | 12.0 | --- | .7 | 2.0 | --- | .7 | 1.3 | 25.3 | --- | .7 | 10.7 |
| 8-15-3 | 8.5 | --- | .5 | --- | 3.5 | 1.5 | --- | 25.0 | .5 | 1.5 | 12.5 |
| 8-15-8 | 3.5 | --- | --- | 2.0 | .5 | .5 | .5 | 15.5 | --- | .5 | 3.0 |
| 8-16-3 | 6.5 | --- | 1.0 | .5 | .5 | --- | .5 | 18.5 | .5 | 1.0 | .5 |
| 8-16-8 | 7.5 | --- | .5 | 1.0 | 1.5 | --- | --- | 16.0 | --- | 1.0 | --- |
| 8-17-3 | 5.5 | .5 | .5 | .5 | 1.5 | --- | 1.0 | 25.0 | .5 | 2.0 | 3.0 |
| 8-17-8 | 12.0 | --- | 1.3 | .7 | .7 | 1.3 | --- | 30.7 | .7 | 4.7 | .7 |
| 8-18-3 | 6.7 | --- | --- | 1.3 | 2.0 | .7 | 1.3 | 24.7 | .7 | 1.3 | 4.0 |
| 8-18-8 | 16.0 | .7 | 1.3 | 2.7 | 2.7 | .7 | 2.0 | 38.6 | 1.3 | 6.7 | 1.3 |
| 8-19-3 | 8.0 | .5 | .5 | 2.0 | 2.0 | 1.0 | .5 | 23.5 | 1.0 | 1.0 | 3.5 |
| 8-19-8 | 16.7 | .7 | 2.0 | 2.0 | 3.3 | 1.3 | 2.0 | 38.0 | --- | 2.0 | 1.3 |
| 8-20-3 | 17.3 | --- | .7 | 1.3 | .7 | 1.3 | --- | 37.3 | .7 | 3.3 | 2.0 |
| 8-20-8 | 8.0 | --- | --- | 2.0 | 4.0 | 3.3 | .7 | 52.6 | 1.3 | 1.3 | 3.3 |
| 8-21-3 | 12.7 | .7 | .7 | 2.7 | 2.7 | 2.0 | --- | 33.3 | --- | 3.3 | 1.3 |
| 8-21-8 | 10.0 | --- | --- | 5.3 | 4.0 | 1.3 | 3.3 | 49.3 | --- | 1.3 | .7 |
| 8-22-3 | 8.7 | .7 | --- | 4.0 | 4.7 | 3.3 | 1.3 | 44.0 | --- | 4.7 | --- |
| 8-22-8 | 8.0 | .7 | .7 | 4.0 | 6.7 | 2.0 | --- | 48.0 | --- | 4.0 | 1.3 |

POLLEN PERCENTAGES CORE # 8 (CON'T.)

| FAGUS | JUGLANS | ULMUS | SALIX | TILIA | MIMOSA | NAP | CHENOPOD-TYPE | COMPOSITAE | GRAMINEAE | CYPERACEAE | TRIGLOCHIN | PLANTAGO |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| --- | --- | --- | --- | --- | --- | 56.5 | 2.0 | 2.0 | 49.5 | 2.5 | --- | .5 |
| --- | --- | --- | --- | --- | --- | 59.0 | --- | 6.0 | 14.0 | 38.0 | ---- | .5 |
| .5 | --- | --- | --- | --- | --- | 48.5 | --- | 14.0 | 10.0 | 24.0 | --- | --- |
| 2.0 | --- | --- | .5 | --- | --- | 54.0 | 2.0 | 13.5 | 20.5 | 18.0 | --- | --- |
| 8.0 | --- | --- | .7 | --- | --- | 38.0 | --- | 4.0 | 22.0 | 10.7 | --- | --- |
| .5 | --- | --- | --- | --- | --- | 46.0 | --- | 7.0 | 20.0 | 18.5 | --- | --- |
| 1.5 | --- | --- | --- | --- | --- | 72.5 | .5 | .5 | 68.5 | 1.0 | --- | 1.5 |
| --- | --- | --- | --- | --- | --- | 70.5 | 1.5 | 2.5 | 63.5 | 2.0 | --- | .5 |
| --- | --- | --- | --- | --- | --- | 72.5 | --- | 5.5 | 62.0 | 4.0 | --- | .5 |
| --- | --- | --- | .5 | --- | --- | 59.5 | 1.0 | 7.5 | 42.5 | 8.5 | --- | --- |
| --- | --- | --- | --- | --- | --- | 47.3 | .7 | 2.0 | 43.3 | 1.3 | --- | --- |
| 1.3 | --- | --- | .7 | --- | --- | 55.4 | 2.0 | 11.6 | 33.3 | 8.7 | --- | --- |
| --- | --- | --- | --- | --- | --- | 26.0 | 1.3 | 1.3 | 21.3 | 2.0 | --- | --- |
| 1.0 | --- | --- | --- | --- | --- | 55.5 | 3.0 | 9.5 | 39.5 | 3.0 | --- | .5 |
| --- | --- | --- | --- | --- | --- | 30.7 | 3.3 | 2.0 | 24.0 | 1.3 | --- | --- |
| --- | --- | --- | --- | --- | --- | 35.3 | 2.0 | 2.7 | 28.6 | 1.3 | --- | .7 |
| --- | --- | --- | .7 | --- | --- | 22.7 | 5.3 | 2.0 | 13.3 | 2.0 | --- | --- |
| --- | --- | --- | .7 | --- | --- | 40.0 | 1.3 | 8.0 | 24.7 | 4.7 | --- | 1.3 |
| --- | --- | --- | --- | --- | --- | 24.7 | 3.3 | --- | 17.3 | 4.0 | --- | --- |
| --- | --- | --- | --- | --- | --- | 28.0 | 2.7 | 3.3 | 18.7 | 4.0 | --- | --- |
| --- | --- | --- | --- | --- | ---- | 24.7 | 7.3 | 2.7 | 10.7 | 4.0 | --- | --- |

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| NAP | CHENOPOD-TYPE | COMPOSITAE | GRAMINEAE | CYPERACEAE | TRIGLOCHIN | PLANTAGO | CARDAMINE | TYPHA | ERICACEAE | SPORES |
|---|---|---|---|---|---|---|---|---|---|---|
| 56.5 | 2.0 | 2.0 | 49.5 | 2.5 | --- | .5 | --- | --- | --- | 7.8 |
| 59.0 | --- | 6.0 | 14.0 | 38.0 | ---- | .5 | --- | --- | .5 | 19.3 |
| 48.5 | --- | 14.0 | 10.0 | 24.0 | --- | --- | --- | --- | .5 | 46.1 |
| 54.0 | 2.0 | 13.5 | 20.5 | 18.0 | --- | --- | --- | --- | --- | 12.6 |
| 38.0 | --- | 4.0 | 22.0 | 10.7 | --- | --- | --- | --- | .7 | 40.9 |
| 46.0 | --- | 7.0 | 20.0 | 18.5 | --- | --- | --- | .5 | --- | 21.3 |
| 72.5 | .5 | .5 | 68.5 | 1.0 | --- | 1.5 | --- | .5 | --- | 5.6 |
| 70.5 | 1.5 | 2.5 | 63.5 | 2.0 | --- | .5 | --- | .5 | --- | 20.4 |
| 72.5 | --- | 5.5 | 62.0 | 4.0 | --- | .5 | --- | .5 | --- | 7.9 |
| 59.5 | 1.0 | 7.5 | 42.5 | 8.5 | --- | --- | --- | --- | --- | 20.3 |
| 47.3 | .7 | 2.0 | 43.3 | 1.3 | --- | --- | --- | --- | --- | 5.0 |
| 55.4 | 2.0 | 11.6 | 33.3 | 8.7 | --- | --- | --- | --- | --- | 16.1 |
| 26.0 | 1.3 | 1.3 | 21.3 | 2.0 | --- | --- | --- | --- | --- | 4.5 |
| 55.5 | 3.0 | 9.5 | 39.5 | 3.0 | --- | .5 | --- | --- | --- | 11.9 |
| 30.7 | 3.3 | 2.0 | 24.0 | 1.3 | --- | --- | --- | --- | --- | 6.2 |
| 35.3 | 2.0 | 2.7 | 28.6 | 1.3 | --- | .7 | --- | --- | --- | 6.2 |
| 22.7 | 5.3 | 2.0 | 13.3 | 2.0 | --- | --- | --- | --- | --- | 9.2 |
| 40.0 | 1.3 | 8.0 | 24.7 | 4.7 | --- | 1.3 | --- | --- | --- | 9.7 |
| 24.7 | 3.3 | --- | 17.3 | 4.0 | --- | --- | --- | --- | --- | 7.4 |
| 28.0 | 2.7 | 3.3 | 18.7 | 4.0 | --- | --- | --- | --- | --- | 6.8 |
| 24.7 | 7.3 | 2.7 | 10.7 | 4.0 | --- | --- | --- | --- | --- | 9.6 |

| SAMPLE NO. | PINUS | PICEA | TSUGA | CARYA | BETULA-TYPE | ALNUS | CASTANEA | QUERCUS | ILEX | FRAXINUS | ACER |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 8-23-3 | 8.0 | .7 | --- | --- | 2.0 | 2.0 | .7 | 44.0 | --- | 1.3 | 1.3 |
| 8-23-8 | 15.3 | .7 | 2.0 | 3.3 | 6.7 | 1.3 | .7 | 38.0 | --- | 4.7 | 1.3 |
| 8-24-3 | 10.0 | --- | 2.0 | 2.7 | 2.7 | 2.0 | --- | 44.0 | --- | 5.3 | .7 |
| 8-24-8 | 15.4 | .7 | .7 | 3.3 | 4.0 | 2.7 | --- | 32.7 | 2.0 | 2.0 | 1.3 |
| 8-25-3 | 9.3 | --- | --- | 2.0 | 2.0 | 1.3 | --- | 50.0 | .7 | 1.3 | --- |
| 8-25-8 | 4.7 | --- | 1.3 | 4.0 | 4.7 | .7 | 1.3 | 36.0 | --- | 7.3 | 1.3 |
| 8-26-3 | 9.3 | --- | 2.0 | 2.0 | 2.7 | 1.3 | .7 | 34.0 | --- | 4.7 | 2.0 |
| 8-26-8 | 5.3 | .7 | .7 | 3.3 | 2.0 | 3.3 | .7 | 35.3 | .7 | 3.3 | .7 |
| 8-27-3 | 8.7 | 1.3 | --- | 1.3 | 4.0 | 11.3 | 1.3 | 38.7 | 2.7 | 2.7 | 2.0 |
| 8-27-7 | 6.7 | --- | --- | 2.7 | 4.0 | 21.3 | 2.0 | 26.7 | 4.7 | 2.0 | 3.3 |
| 8-28-3 | 6.0 | --- | --- | .7 | 4.0 | 28.7 | .7 | 35.3 | 6.7 | 2.0 | 1.3 |
| 8-28-8 | 4.0 | .7 | --- | .7 | 2.7 | 48.0 | --- | 20.7 | 6.0 | --- | 6.0 |
| 8-29-3 | 1.3 | --- | --- | .7 | 1.3 | 66.7 | .7 | 12.7 | 6.7 | .7 | 4.0 |
| 8-29-7 | 4.5 | --- | --- | --- | 1.0 | 54.5 | --- | 18.0 | 8.0 | .5 | 2.5 |
| 8-30-3 | 4.0 | --- | --- | 1.3 | 4.7 | 43.3 | --- | 28.0 | .7 | --- | 3.3 |
| 8-30-8 | 4.7 | --- | --- | .7 | 5.3 | 32.0 | .7 | 38.0 | .7 | .7 | 1.3 |
| 8-31-3 | 8.0 | --- | --- | 4.0 | 2.0 | 15.3 | 1.3 | 38.0 | .7 | 2.0 | 1.3 |
| 8-31-8 | 3.3 | --- | --- | 4.0 | 3.3 | 7.3 | 1.3 | 50.0 | .7 | 5.3 | 2.0 |
| 8-32-3 | 9.3 | .7 | --- | 3.3 | 4.7 | 4.7 | .7 | 45.3 | 1.3 | 4.0 | .7 |
| 8-32-8 | 9.3 | --- | --- | 4.0 | 5.3 | 10.7 | --- | 42.0 | 1.3 | 2.0 | 1.3 |

| FAGUS | JUGLANS | ULMUS | SALIX | TILIA | MIMOSA | NAP | CHENOPOD-TYPE | COMPOSITAE | GRAMINEAE | CYPERACEAE | TRIGLOCHIN | PLANTAGO |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| --- | --- | --- | .7 | --- | --- | 39.3 | 3.3 | 2.7 | 31.3 | .7 | --- | 1.3 |
| --- | --- | --- | .7 | --- | --- | 25.3 | 3.3 | .7 | 10.7 | 10.7 | --- | --- |
| --- | --- | --- | --- | --- | --- | 30.7 | 2.7 | 2.7 | 20.0 | 5.3 | --- | --- |
| --- | --- | --- | --- | --- | --- | 35.3 | 2.7 | 1.3 | 22.0 | 8.7 | --- | --- |
| --- | --- | --- | --- | --- | --- | 33.3 | 11.3 | 2.0 | 9.3 | 9.3 | --- | 1.3 |
| --- | --- | --- | --- | --- | --- | 38.7 | 19.3 | 1.3 | 2.7 | 13.3 | --- | 2.0 |
| --- | --- | --- | --- | --- | --- | 41.3 | 2.0 | 4.7 | 26.0 | 7.3 | --- | .7 |
| --- | --- | --- | --- | .7 | --- | 43.3 | 8.7 | 1.3 | 18.7 | 14.7 | --- | --- |
| --- | --- | --- | 1.3 | --- | --- | 24.7 | .7 | .7 | 16.7 | 6.7 | --- | --- |
| .7 | --- | --- | --- | --- | --- | 26.0 | 2.7 | .7 | 17.3 | 3.3 | --- | --- |
| --- | --- | --- | --- | --- | --- | 14.7 | 2.7 | 2.7 | 7.3 | 2.0 | --- | --- |
| --- | --- | --- | --- | --- | --- | 11.4 | .7 | 3.3 | 3.3 | 3.3 | --- | --- |
| --- | --- | --- | --- | --- | --- | 5.3 | --- | --- | 2.7 | 2.7 | --- | --- |
| --- | --- | --- | --- | --- | --- | 11.0 | .5 | 4.0 | 4.0 | 2.0 | --- | .5 |
| --- | --- | --- | --- | --- | --- | 14.6 | 2.0 | 4.0 | 5.3 | 1.3 | --- | .7 |
| 1.3 | --- | --- | --- | --- | --- | 16.7 | 1.3 | 4.7 | 6.0 | 4.0 | --- | --- |
| --- | --- | --- | --- | --- | --- | 27.3 | 3.3 | 5.3 | 14.0 | 4.7 | --- | --- |
| .7 | --- | --- | --- | --- | --- | 22.0 | 2.7 | 5.3 | 10.7 | 2.7 | --- | .7 |
| .7 | --- | --- | --- | --- | --- | 24.7 | 2.7 | 2.7 | 10.7 | 6.7 | --- | --- |
| --- | --- | --- | --- | --- | --- | 24.0 | 5.3 | 4.0 | 10.0 | 2.0 | --- | 2.0 |

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| NAP | CHENOPOD-TYPE | COMPOSITAE | GRAMINEAE | CYPERACEAE | TRIGLOCHIN | PLANTAGO | CARDAMINE | TYPHA | ERICACEAE | SPORES |
|---|---|---|---|---|---|---|---|---|---|---|
| 39.3 | 3.3 | 2.7 | 31.3 | .7 | --- | 1.3 | --- | --- | --- | 15.3 |
| 25.3 | 3.3 | .7 | 10.7 | 10.7 | --- | --- | --- | --- | --- | 8.0 |
| 30.7 | 2.7 | 2.7 | 20.0 | 5.3 | --- | --- | --- | --- | --- | 9.5 |
| 35.3 | 2.7 | 1.3 | 22.0 | 8.7 | --- | --- | .7 | --- | --- | 8.6 |
| 33.3 | 11.3 | 2.0 | 9.3 | 9.3 | --- | 1.3 | --- | --- | --- | 3.2 |
| 38.7 | 19.3 | 1.3 | 2.7 | 13.3 | --- | 2.0 | --- | --- | --- | 4.4 |
| 41.3 | 2.0 | 4.7 | 26.0 | 7.3 | --- | .7 | --- | .7 | --- | 11.7 |
| 43.3 | 8.7 | 1.3 | 18.7 | 14.7 | --- | --- | --- | --- | --- | 7.4 |
| 24.7 | .7 | .7 | 16.7 | 6.7 | --- | --- | --- | --- | --- | 4.4 |
| 26.0 | 2.7 | .7 | 17.3 | 3.3 | --- | --- | --- | --- | 2.0 | 11.2 |
| 14.7 | 2.7 | 2.7 | 7.3 | 2.0 | --- | --- | --- | --- | --- | 4.4 |
| 11.4 | .7 | 3.3 | 3.3 | 3.3 | --- | --- | --- | --- | .7 | 5.1 |
| 5.3 | --- | --- | 2.7 | 2.7 | --- | --- | --- | --- | --- | 4.4 |
| 11.0 | .5 | 4.0 | 4.0 | 2.0 | --- | .5 | --- | --- | --- | 5.7 |
| 14.6 | 2.0 | 4.0 | 5.3 | 1.3 | --- | .7 | --- | --- | 1.3 | 6.8 |
| 16.7 | 1.3 | 4.7 | 6.0 | 4.0 | --- | --- | --- | --- | .7 | 28.8 |
| 27.3 | 3.3 | 5.3 | 14.0 | 4.7 | --- | --- | --- | --- | --- | 12.3 |
| 22.0 | 2.7 | 5.3 | 10.7 | 2.7 | --- | .7 | --- | --- | --- | 6.2 |
| 24.7 | 2.7 | 2.7 | 10.7 | 6.7 | --- | --- | --- | --- | 2.0 | 8.0 |
| 24.0 | 5.3 | 4.0 | 10.0 | 2.0 | --- | 2.0 | --- | --- | .7 | 6.8 |

| SAMPLE NO. | PINUS | PICEA | TSUGA | CARYA | BETULA-TYPE | ALNUS | CASTANEA | QUERCUS | ILEX | FRAXINUS | ACER |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 8-33-6 | 5.3 | --- | --- | 1.3 | 4.0 | 7.3 | --- | 44.0 | 1.3 | 4.0 | 1.3 |
| 8-34-3 | 6.7 | --- | --- | 1.3 | 4.0 | 15.3 | --- | 29.3 | 1.3 | 3.3 | 2.0 |
| 8-34-8 | 7.3 | --- | 1.3 | 2.7 | 4.7 | 5.3 | .7 | 37.3 | .7 | 3.3 | 1.3 |

| FAGUS | JUGLANS | ULMUS | SALIX | TILIA | MIMOSA | NAP | CHENOPOD-TYPE | COMPOSITAE | GRAMINEAE | CYPERACEAE | TRIGLOCHIN | PLANTAGO |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .7 | --- | --- | --- | --- | --- | 30.0 | 1.3 | 4.0 | 22.0 | 2.0 | --- | --- |
| --- | --- | --- | --- | --- | --- | 36.7 | 4.0 | 4.0 | 23.3 | 4.0 | --- | 1.3 |
| .7 | --- | --- | --- | --- | --- | 34.7 | .7 | .7 | 30.7 | 2.0 | --- | --- |

'T.)

| NAP | CHENOPOD-TYPE | COMPOSITAE | GRAMINEAE | CYPERACEAE | TRIGLOCHIN | PLANTAGO | CARDAMINE | TYPHA | ERICACEAE | SPORES |
|---|---|---|---|---|---|---|---|---|---|---|
| 30.0 | 1.3 | 4.0 | 22.0 | 2.0 | --- | --- | --- | --- | .7 | 10.2 |
| 36.7 | 4.0 | 4.0 | 23.3 | 4.0 | --- | 1.3 | --- | --- | --- | 10.7 |
| 34.7 | .7 | .7 | 30.7 | 2.0 | --- | --- | --- | --- | .7 | 3.8 |

| SAMPLE NO. | PINUS | PICEA | TSUGA | CARYA | BETULA-TYPE | ALNUS | CASTANEA | QUERCUS | ILEX | FRAXINUS | ACER |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 16-1-1 | 3.8 | .1 | .3 | .1 | 1.6 | .4 | .3 | 8.1 | .5 | ---- | .4 |
| 16-2-1 | 16.8 | .3 | .3 | 1.3 | 4.7 | 1.7 | .7 | 20.2 | 2.0 | ---- | 1.0 |
| 16-2-3 | 18.0 | --- | --- | 2.2 | 4.9 | 3.3 | 2.7 | 30.6 | 2.2 | ---- | .5 |
| 16-2-4 | 10.1 | 1.4 | 1.9 | 8.1 | 6.7 | 3.9 | 2.4 | 26.8 | 2.9 | ---- | .5 |
| 16-2-6 | 15.9 | 1.2 | 2.5 | 1.2 | 4.5 | 3.2 | .6 | 33.1 | 1.2 | ---- | 1.2 |
| 16-3-1 | 17.9 | .5 | .9 | 2.0 | 4.5 | 5.9 | --- | 29.4 | 1.5 | 3.5 | 2.5 |
| 16-3-4 | 13.6 | 1.0 | 1.0 | 1.9 | 3.4 | 5.8 | ---- | 33.0 | .5 | 2.4 | 1.0 |
| 16-3-6 | 11.9 | .5 | 1.0 | 1.5 | 4.9 | 4.5 | 1.0 | 28.2 | 1.0 | 1.5 | 3.5 |
| 16-5-1 | 12.7 | .5 | .9 | .5 | 9.0 | 10.8 | 5.2 | 30.2 | 9.9 | ---- | 4.2 |
| 16-5-6 | 7.5 | .5 | 1.4 | 1.4 | 5.1 | 8.4 | .5 | 33.2 | 16.8 | ---- | 6.1 |
| 16-6-2 | 7.8 | .4 | .9 | .9 | 3.0 | 9.0 | 2.1 | 31.9 | 23.2 | ---- | 3.4 |
| 16-6-3 | 6.4 | --- | 1.5 | .5 | 7.3 | 11.8 | 3.4 | 34.8 | 14.2 | ---- | 3.4 |
| 16-6-4 | 5.2 | --- | --- | .9 | 4.2 | 14.6 | .5 | 29.6 | 26.3 | ---- | 1.9 |
| 16-6-9 | 4.8 | --- | --- | .4 | 3.5 | 32.6 | .4 | 20.0 | 30.8 | ---- | 2.2 |
| 16-7-1 | 3.3 | ---- | .4 | .8 | 2.0 | 31.7 | .4 | 20.0 | 30.8 | ---- | 2.9 |
| 16-7-2 | 3.2 | ---- | .8 | .4 | 1.2 | 31.2 | --- | 16.2 | 29.1 | ---- | 3.7 |
| 16-7-3 | 4.3 | ---- | --- | --- | 1.9 | 28.1 | --- | 27.1 | 20.0 | ---- | 3.3 |
| 16-7-4 | 5.3 | ---- | --- | 1.0 | 2.1 | 52.2 | --- | 12.8 | 17.0 | ---- | 2.5 |
| 16-8-4 | 2.7 | ---- | --- | .4 | 3.0 | 33.9 | .4 | 20.8 | 24.8 | ---- | 2.7 |
| 16-8-8 | 1.9 | ---- | .5 | .5 | 3.4 | 63.0 | .5 | 17.8 | 4.3 | ---- | 1.9 |
| 16-9-3 | 4.3 | ---- | .4 | 1.7 | 3.8 | 45.2 | .4 | 23.4 | 10.6 | ---- | 2.1 |

POLLEN PERCENTAGES CORE #16

| FAGUS | JUGLANS | ULMUS | SALIX | TILIA | MIMOSA | NAP | CHENOPOD-TYPE | COMPOSITAE | GRAMINEAE | CYPERACEAE | TRIGLOCHIN | PLANTAGO |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .7 | --- | --- | .3 | --- | 1.3 | 80.6 | 75.6 | .5 | 4.4 | .1 | --- | --- |
| .3 | --- | --- | .7 | --- | --- | 50.2 | 35.7 | 6.1 | 6.4 | --- | 1.3 | --- |
| --- | --- | --- | .5 | --- | --- | 35.5 | 16.4 | 8.7 | 8.2 | .5 | 1.6 | --- |
| .5 | --- | --- | 1.9 | --- | --- | 32.5 | 7.7 | 14.8 | 8.1 | --- | 1.9 | --- |
| 1.2 | --- | --- | --- | --- | --- | 33.7 | 5.1 | 20.4 | 5.7 | --- | 1.2 | --- |
| --- | --- | --- | .9 | --- | --- | 30.4 | 11.9 | 7.5 | 6.8 | .5 | 1.5 | 1.5 |
| --- | --- | --- | --- | --- | --- | 36.4 | 4.9 | 20.9 | 5.8 | --- | 2.9 | 1.5 |
| --- | --- | --- | --- | --- | --- | 41.1 | 6.9 | 18.3 | 11.9 | --- | 2.5 | .5 |
| .5 | --- | --- | --- | --- | --- | 17.8 | 2.8 | 6.1 | 1.4 | --- | --- | --- |
| --- | --- | --- | --- | --- | --- | 19.3 | --- | 6.1 | .5 | --- | --- | --- |
| 1.3 | --- | --- | --- | --- | --- | 16.3 | 2.1 | 3.0 | .9 | --- | --- | --- |
| 1.0 | --- | --- | --- | --- | --- | 15.7 | 4.4 | 4.9 | 1.5 | --- | .5 | --- |
| 1.4 | --- | --- | --- | --- | --- | 15.5 | --- | .5 | 1.9 | 2.3 | .5 | --- |
| --- | --- | --- | --- | --- | --- | 5.7 | .4 | --- | .9 | .9 | --- | --- |
| --- | --- | --- | --- | --- | --- | 7.4 | --- | .4 | .4 | .4 | --- | --- |
| --- | --- | --- | --- | --- | --- | 14.2 | 2.0 | .4 | 1.2 | 2.8 | --- | --- |
| .9 | --- | --- | --- | --- | --- | 14.3 | 1.9 | 3.8 | .5 | 2.4 | --- | --- |
| .7 | --- | --- | --- | --- | --- | 6.4 | .3 | --- | .3 | --- | --- | .7 |
| .4 | --- | --- | --- | --- | --- | 10.9 | .4 | .9 | .4 | --- | --- | 1.3 |
| --- | --- | --- | --- | --- | --- | 6.3 | .5 | --- | 1.0 | --- | --- | 1.9 |
| 1.7 | --- | --- | .4 | --- | --- | 5.9 | --- | .4 | .4 | --- | --- | --- |

| MIMOSA | NAP | CHENOPOD-TYPE | COMPOSITAE | GRAMINEAE | CYPERACEAE | TRIGLOCHIN | PLANTAGO | CARDAMINE | TYPHA | ERICACEAE | SPORES |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.3 | 80.6 | 75.6 | .5 | 4.4 | .1 | --- | --- | --- | --- | --- | 3.5 |
| --- | 50.2 | 35.7 | 6.1 | 6.4 | --- | 1.3 | --- | .3 | .3 | --- | 9.1 |
| --- | 35.5 | 16.4 | 8.7 | 8.2 | .5 | 1.6 | --- | --- | --- | --- | 18.2 |
| --- | 32.5 | 7.7 | 14.8 | 8.1 | --- | 1.9 | --- | --- | --- | --- | 22.0 |
| --- | 33.7 | 5.1 | 20.4 | 5.7 | --- | 1.2 | --- | --- | 1.2 | --- | 23.4 |
| --- | 30.4 | 11.9 | 7.5 | 6.8 | .5 | 1.5 | 1.5 | --- | --- | --- | 23.1 |
| --- | 36.4 | 4.9 | 20.9 | 5.8 | --- | 2.9 | 1.5 | --- | --- | .5 | 24.3 |
| --- | 41.1 | 6.9 | 18.3 | 11.9 | --- | 2.5 | .5 | --- | --- | 1.0 | 23.5 |
| --- | 17.8 | 2.8 | 6.1 | 1.4 | --- | --- | --- | --- | .5 | 7.1 | 14.1 |
| --- | 19.3 | ---- | 6.1 | .5 | --- | --- | --- | --- | .5 | 12.1 | 5.7 |
| --- | 16.3 | 2.1 | 3.0 | .9 | --- | --- | --- | --- | --- | 9.9 | 4.9 |
| --- | 15.7 | 4.4 | 4.9 | 1.5 | --- | .5 | --- | --- | --- | 4.4 | 9.8 |
| --- | 15.5 | --- | .5 | 1.9 | 2.3 | .5 | --- | --- | --- | 10.3 | 5.8 |
| --- | 5.7 | .4 | --- | .9 | .9 | --- | --- | --- | --- | 3.5 | 2.1 |
| --- | 7.4 | --- | .4 | .4 | .4 | --- | --- | --- | --- | 6.2 | 4.0 |
| --- | 14.2 | 2.0 | .4 | 1.2 | 2.8 | --- | --- | --- | --- | 7.7 | 3.9 |
| --- | 14.3 | 1.9 | 3.8 | .5 | 2.4 | --- | --- | --- | --- | 5.7 | 8.3 |
| --- | 6.4 | .3 | --- | .3 | --- | --- | .7 | --- | --- | 5.0 | 3.4 |
| --- | 10.9 | .4 | .9 | .4 | --- | --- | 1.3 | --- | --- | 7.8 | 2.9 |
| --- | 6.3 | .5 | --- | 1.0 | --- | --- | 1.9 | --- | --- | 4.3 | 6.2 |
| --- | 5.9 | --- | .4 | .4 | --- | --- | --- | --- | --- | 5.1 | 11.3 |

| SAMPLE NO. | PINUS | PICEA | TSUGA | CARYA | BETULA-TYPE | ALNUS | CASTANEA | QUERCUS | ILEX | FRAXINUS | ACER |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 16-9-8 | 5.2 | ---- | 1.9 | 1.4 | 2.9 | 51.9 | ---- | 21.4 | 2.9 | .5 | .5 |
| 16-10-1 | 1.7 | ---- | 1.3 | .4 | 3.9 | 33.3 | ---- | 29.1 | 21.2 | --- | 2.6 |
| 16-10-2 | 5.9 | .4 | .4 | .4 | 4.7 | 35.8 | 2.1 | 20.4 | 18.3 | --- | 1.3 |
| 16-10-3 | 4.3 | ---- | 7.2 | 1.9 | 1.9 | 25.2 | 1.0 | 30.1 | 11.1 | 1.0 | 1.0 |
| 16-10-8 | 4.7 | .5 | 4.7 | 2.4 | 4.7 | 25.5 | .5 | 36.8 | 2.8 | 1.4 | 1.9 |
| 16-11-3 | 5.0 | ---- | 3.0 | 2.0 | 3.0 | 21.5 | 1.0 | 37.0 | 8.0 | .5 | 4.0 |
| 16-11-8 | 4.7 | ---- | .4 | .4 | 3.9 | 30.5 | .4 | 37.8 | .9 | 3.4 | 5.6 |
| 16-12-2 | 3.4 | ---- | .8 | .4 | 1.7 | 36.1 | ---- | 25.2 | 17.7 | 2.1 | 2.5 |
| 16-12-5 | 5.0 | ---- | .9 | .9 | 1.8 | 33.6 | ---- | 36.4 | 4.1 | 3.6 | 3.2 |
| 16-12-6 | 3.6 | ---- | --- | .9 | .9 | 33.6 | ---- | 43.5 | ---- | 3.6 | 3.6 |
| 16-12-8 | 4.7 | ---- | .9 | .5 | 1.4 | 35.7 | .5 | 37.5 | 1.4 | .9 | 6.6 |

POLLEN PERCENTAGES CORE #16 (CONT.)

| FAGUS | JUGLANS | ULMUS | SALIX | TILIA | MIMOSA | NAP | CHENOPOD-TYPE | COMPOSITAE | GRAMINEAE | CYPERACEAE | TRIGLOCHIN | PLANTAGO |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.4 | --- | --- | --- | --- | --- | 10.0 | --- | .9 | .9 | .5 | --- | .9 |
| 2.2 | --- | --- | .4 | --- | --- | 6.5 | .4 | .4 | .4 | --- | .4 | .4 |
| 1.7 | --- | --- | --- | --- | --- | 8.5 | 1.7 | 1.3 | --- | --- | .4 | .4 |
| 1.0 | --- | --- | --- | --- | --- | 13.5 | 1.4 | 1.9 | --- | .5 | --- | 1.0 |
| 2.4 | --- | --- | .5 | --- | --- | 11.4 | 1.0 | 2.4 | 1.4 | 2.4 | --- | 3.3 |
| 1.0 | --- | --- | .5 | --- | --- | 13.5 | 1.0 | --- | 3.5 | 5.5 | --- | 2.0 |
| 1.9 | --- | --- | 1.9 | --- | --- | 8.6 | --- | 1.9 | .4 | .9 | --- | 2.1 |
| 1.3 | --- | --- | .8 | --- | --- | 8.0 | .4 | .4 | .8 | --- | --- | 1.3 |
| 2.7 | --- | --- | .5 | --- | --- | 6.3 | --- | .5 | .5 | --- | --- | 2.7 |
| .9 | --- | --- | --- | --- | --- | 9.4 | --- | 3.1 | --- | --- | --- | 2.7 |
| .9 | --- | --- | --- | --- | --- | 8.9 | --- | 1.9 | --- | --- | --- | .9 |

(CONT.)

| MIMOSA | NAP | CHENOPOD-TYPE | COMPOSITAE | GRAMINEAE | CYPERACEAE | TRIGLOCHIN | PLANTAGO | CARDAMINE | TYPHA | ERICACEAE | SPORES |
|---|---|---|---|---|---|---|---|---|---|---|---|
| --- | 10.0 | --- | .9 | .9 | .5 | --- | .9 | --- | --- | 6.7 | 13.3 |
| --- | 6.5 | .4 | .4 | .4 | --- | .4 | .4 | --- | --- | 4.3 | 10.5 |
| --- | 8.5 | 1.7 | 1.3 | --- | --- | .4 | .4 | --- | --- | 4.7 | 11.3 |
| --- | 13.5 | 1.4 | 1.9 | --- | .5 | --- | 1.0 | --- | --- | 8.7 | 14.9 |
| --- | 11.4 | 1.0 | 2.4 | 1.4 | 2.4 | --- | 3.3 | --- | --- | .9 | 25.6 |
| --- | 13.5 | 1.0 | --- | 3.5 | 5.5 | --- | 2.0 | --- | --- | 1.5 | 26.4 |
| --- | 8.6 | --- | 1.9 | .4 | .9 | --- | 2.1 | --- | --- | 3.4 | 14.6 |
| --- | 8.0 | .4 | .4 | .8 | --- | --- | 1.3 | --- | --- | 5.1 | 11.9 |
| --- | 6.3 | --- | .5 | .5 | --- | --- | 2.7 | --- | --- | 2.7 | 15.7 |
| --- | 9.4 | --- | 3.1 | --- | --- | --- | 2.7 | --- | .4 | 3.1 | 14.9 |
| --- | 8.9 | --- | 1.9 | --- | --- | --- | .9 | --- | --- | 6.1 | 10.2 |

# APPENDIX C

## SEDIMENTARY PHOSPHATE METHOD PALEOSALINITY VALUES

SEDIMENTARY PHOSPHATE METHOD PALEOSALINITY CORE #6

| Sample No. | Fe-phosphate micromole/gram | Ca-phosphate micromole/gram | $\frac{Ca}{Fe+Ca}$ | Salinity °/oo |
|---|---|---|---|---|
| 6-1-1 | 17.78 | 9.88 | .36 | 10.3 |
|  | 15.83 | 9.64 | .37 | 10.8 |
| 6-2-3 | 3.08 | 5.57 | .64 | 21.1 |
|  | ---- | ---- | --- | ---- |
| 6-3-2 | 3.58 | 6.65 | .65 | 21.5 |
|  | ---- | ---- | --- | ---- |
| 6-4-2 | 2.86 | 5.62 | .66 | 21.9 |
|  | 2.80 | 6.35 | .69 | 23.0 |
| 6-5-2 | 2.02 | 6.74 | .77 | 26.2 |
|  | 1.94 | 5.87 | .75 | 25.4 |
| 6-6-2 | 2.03 | 5.80 | .74 | 25.0 |
|  | 1.65 | 5.73 | .78 | 26.5 |
| 6-7-2 | 1.87 | 6.80 | .78 | 26.5 |
|  | 1.61 | 8.07 | .83 | 28.4 |
| 6-8-2 | 1.57 | 6.12 | .80 | 27.3 |
|  | 2.32 | 5.82 | .72 | 24.2 |
| 6-9-2 | 2.23 | 4.93 | .69 | 23.0 |
|  | 2.72 | 6.20 | .70 | 23.4 |
| 6-10-2 | 1.62 | 6.44 | .80 | 27.3 |
|  | 1.61 | 6.28 | .80 | 27.3 |
| 6-11-2 | 1.36 | 6.27 | .82 | 28.1 |
|  | 1.40 | 6.42 | .82 | 28.1 |
| 6-12-2 | 2.23 | 6.21 | .74 | 25.0 |
|  | 2.25 | 5.78 | .72 | 24.2 |
| 6-13-3 | 4.60 | 5.68 | .55 | 17.7 |
|  | 4.11 | 4.98 | .55 | 17.7 |
| 6-14-2 | 2.89 | 3.61 | .55 | 17.7 |
|  | 3.66 | 2.62 | .42 | 12.6 |
| 6-15-2 | 2.40 | 4.80 | .67 | 22.3 |
|  | 2.95 | 5.37 | .65 | 21.5 |
| 6-16-2 | 1.26 | 6.83 | .84 | 28.8 |
|  | 0.97 | 7.23 | .88 | 30.4 |

SEDIMENTARY PHOSPHATE METHOD PALEOSALINITY CORE #6 (CON'T)

| Sample No. | Fe-phosphate micromole/gram | Ca-phosphate micromole/gram | Ca/Fe+Ca | Salinity °/oo |
|---|---|---|---|---|
| 6-17-2 | 1.20 | 7.31 | .86 | 29.6 |
|  | 1.29 | 7.47 | .85 | 29.2 |
| 6-18-2 | 0.66 | 14.17 | .95 | 33.1 |
|  | 1.12 | 9.12 | .89 | 30.8 |
| 6-19-2 | 0.98 | 6.60 | .87 | 30.0 |
|  | 0.36 | 6.42 | .94 | 32.7 |
| 6-20-2 | 0.84 | 3.26 | .79 | 26.9 |
|  | 1.18 | 3.08 | .72 | 24.2 |
| 6-21-2 | 1.49 | 0.57 | .27 | 6.9 |
|  | 0.80 | 1.98 | .71 | 23.8 |
| 6-22-3 | 0.19 | 0.27 | .59 | 19.2 |
|  | ---- | ---- | --- | ---- |
| 6-23-2 | 0.49 | 0.37 | .43 | 13.1 |
|  | ---- | ---- | --- | ---- |
| 6-24-2 | 0.56 | 0.80 | .59 | 19.2 |
|  | 0.37 | 1.82 | .83 | 28.5 |
| 6-25-2 | 0.19 | 0.75 | .80 | 27.3 |
|  | 1.67 | 1.62 | .49 | 15.3 |
| 6-26-2 | 0.94 | 1.81 | .66 | 21.9 |
|  | 0.61 | 3.04 | .83 | 28.5 |
| 6-27-2 | 1.34 | 3.65 | .73 | 24.6 |
|  | 1.24 | 3.75 | .75 | 25.4 |
| 6-28-2 | 0.94 | 2.44 | .72 | 24.2 |
|  | ---- | ---- | --- | ---- |
| 6-29-2 | 1.31 | 3.67 | .74 | 25.0 |
|  | ---- | ---- | --- | ---- |
| 6-30-3 | 0.93 | 2.09 | .69 | 23.0 |
|  | 1.18 | 3.41 | .74 | 25.0 |
| 6-31-3 | 1.27 | 3.13 | .71 | 23.8 |
|  | ---- | ---- | --- | ---- |
| 6-32-2 | 1.28 | 2.97 | .70 | 23.4 |
|  | 1.32 | 3.31 | .71 | 23.8 |

SEDIMENTARY PHOSPHATE METHOD PALEOSALINITY CORE #6 (CON'T)

| Sample No. | Fe-phosphate micromole/gram | Ca-phosphate micromole/gram | $\frac{Ca}{Fe+Ca}$ | Salinity $^o/oo$ |
|---|---|---|---|---|
| 6-33-3 | 0.63 | 1.45 | .70 | 23.4 |
|  | 0.82 | 1.65 | .67 | 22.3 |
| 6-34-2 | 1.14 | 5.08 | .82 | 28.1 |
|  | 1.16 | 4.68 | .80 | 27.3 |
| 6-35-2 | 1.63 | '3.93 | .71 | 23.8 |
|  | ---- | ---- | --- | ---- |
| 6-36-2 | 0.86 | 3.26 | .79 | 26.9 |
|  | 0.89 | 2.87 | .76 | 25.8 |
| 6-37-2 | 2.42 | 0.98 | .29 | 7.6 |
|  | 2.75 | 1.09 | .28 | 7.3 |

## SEDIMENTARY PHOSPHATE METHOD PALEOSALINITY CORE #8

| Sample No. | Fe-phosphate micromole/gram | Ca-phosphate micromole/gram | $\frac{Ca}{Fe+Ca}$ | Salinity °/oo |
|---|---|---|---|---|
| 8-1-2 | 18.42 | 11.61 | .39 | 11.5 |
|  | 19.26 | 11.40 | .37 | 10.8 |
| 8-1-4 | 6.52 | 6.45 | .49 | 15.3 |
|  | 6.84 | 6.84 | .50 | 15.8 |
| 8-2-3 | 1.76 | 7.13 | .80 | 27.3 |
|  | 2.12 | 5.65 | .73 | 24.6 |
| 8-3-2 | 2.00 | 6.42 | .76 | 25.8 |
|  | 2.07 | 2.95 | .59 | 19.2 |
| 8-3-7 | 2.22 | 4.68 | .68 | 22.7 |
|  | 2.86 | 4.51 | .61 | 20.0 |
| 8-4-3 | 1.45 | 4.60 | .76 | 25.8 |
|  | 1.27 | 4.45 | .78 | 26.5 |
| 8-5-2 | 1.93 | 3.42 | .64 | 21.2 |
|  | 1.62 | 4.13 | .72 | 24.2 |
| 8-5-7 | 1.21 | 2.90 | .71 | 23.8 |
|  | .94 | 4.45 | .82 | 28.1 |
| 8-6-2 | 1.27 | 5.08 | .80 | 27.3 |
|  | 1.39 | 5.08 | .79 | 26.9 |
| 8-6-7 | 1.61 | 5.87 | .78 | 26.5 |
|  | 1.48 | 5.84 | .80 | 27.3 |
| 8-7-2 | 1.34 | 5.64 | .81 | 27.7 |
|  | 1.61 | 5.36 | .77 | 26.2 |
| 8-7-8 | 1.37 | 6.07 | .82 | 28.1 |
|  | 1.29 | 6.03 | .82 | 28.1 |
| 8-8-2 | 1.20 | 5.87 | .83 | 28.4 |
|  | 2.31 | 5.42 | .70 | 23.4 |
| 8-8-7 | 1.50 | 5.68 | .79 | 26.9 |
|  | 1.48 | 5.39 | .78 | 26.5 |
| 8-9-2 | 1.53 | 6.19 | .80 | 27.3 |
|  | 1.53 | 5.45 | .78 | 26.5 |
| 8-9-8 | 1.57 | 6.07 | .79 | 26.9 |
|  | 1.74 | 6.03 | .78 | 26.5 |

SEDIMENTARY PHOSPHATE METHOD PALEOSALINITY CORE #8 (CON'T.)

| Sample No. | Fe-phosphate micromole/gram | Ce-phosphate micromole/gram | Ca / Fe+Ca | Salinity °/oo |
|---|---|---|---|---|
| 8-10-2 | 1.83 | 6.10 | .77 | 26.2 |
|        | 1.67 | 5.84 | .78 | 26.5 |
| 8-10-5 | 3.74 | 6.71 | .64 | 21.2 |
|        | 4.48 | 7.48 | .63 | 20.8 |
| 8-11-2 | 1.06 | 3.39 | .76 | 25.8 |
|        | ---- | ---- | --- | ---- |
| 8-11-7 | 0.69 | 1.04 | .60 | 19.6 |
|        | ---- | ---- | --- | ---- |
| 8-12-2 | 1.08 | 1.20 | .52 | 16.5 |
|        | 0.13 | 0.90 | .87 | 30.0 |
| 8-12-8 | 0.34 | 2.12 | .86 | 29.6 |
|        | 0.40 | 2.24 | .85 | 29.2 |
| 8-13-4 | 0.14 | 0.36 | .72 | 24.2 |
|        | ---- | ---- | --- | ---- |
| 8-14-2 | 0.12 | 0.59 | .83 | 28.4 |
|        | ---- | ---- | --- | ---- |
| 8-14-7 | 0.81 | 0.39 | .33 | 9.2 |
|        | ---- | ---- | --- | ---- |
| 8-15-2 | 0.98 | 0.48 | .33 | 9.2 |
|        | ---- | ---- | --- | ---- |
| 8-15-7 | 0.88 | 0.23 | .21 | 4.6 |
|        | ---- | ---- | --- | ---- |
| 8-16-2 | 1.28 | 0.64 | .33 | 9.2 |
|        | ---- | ---- | --- | ---- |
| 8-16-7 | 0.71 | 0.32 | .31 | 8.4 |
|        | ---- | ---- | --- | ---- |
| 8-17-2 | 1.14 | 0.84 | .42 | 12.6 |
|        | ---- | ---- | --- | ---- |
| 8-17-7 | 0.81 | 1.00 | .55 | 17.7 |
|        | 0.85 | 1.26 | .60 | 19.6 |
| 8-18-2 | 1.18 | 3.82 | .76 | 25.3 |
|        | ---- | ---- | --- | ---- |
| 8-18-7 | 2.24 | 2.96 | .57 | 18.5 |
|        | 3.55 | 2.33 | .40 | 11.8 |
| 8-19-2 | 1.90 | 1.94 | .50 | 15.7 |
|        | ---- | ---- | --- | ---- |

SEDIMENTARY PHOSPHATE METHOD PALEOSALINITY CORE #8 (CON'T.)

| Sample No. | Fe-phosphate micromole/gram | Ca-phosphate micromole/gram | Ca/Fe+Ca | Salinity °/oo |
|---|---|---|---|---|
| 8-19-7 | 1.18 | 3.35 | .74 | 25.0 |
|        | 1.15 | 3.48 | .75 | 25.4 |
| 8-20-2 | 0.84 | 2.48 | .75 | 25.4 |
|        | 0.98 | 2.72 | .75 | 25.4 |
| 8-20-7 | 1.52 | 3.94 | .72 | 24.2 |
|        | 1.34 | 3.94 | .75 | 25.4 |
| 8-21-2 | 0.97 | 4.10 | .81 | 27.6 |
|        | 1.37 | 4.42 | .76 | 25.8 |
| 8-21-7 | 0.82 | 3.84 | .82 | 28.0 |
|        | 0.75 | 4.03 | .84 | 28.8 |
| 8-22-2 | 0.87 | 3.82 | .81 | 27.6 |
|        | ---- | ---- | --- | ---- |
| 8-22-7 | 0.73 | 6.45 | .90 | 31.2 |
|        | 0.48 | 6.42 | .93 | 32.4 |
| 8-23-2 | 1.30 | 4.82 | .79 | 26.9 |
|        | 1.39 | 4.91 | .78 | 26.5 |
| 8-23-7 | 0.64 | 6.43 | .91 | 31.6 |
|        | 0.62 | 6.11 | .91 | 31.6 |
| 8-24-2 | 0.91 | 6.04 | .87 | 30.0 |
|        | 0.61 | 6.57 | .92 | 32.0 |
| 8-24-7 | 0.85 | 4.80 | .85 | 29.2 |
|        | 1.12 | 4.45 | .80 | 27.3 |
| 8-25-2 | 0.74 | 5.36 | .88 | 30.4 |
|        | 1.01 | 5.75 | .85 | 29.2 |
| 8-25-7 | 0.98 | 4.12 | .81 | 27.6 |
|        | 1.23 | 4.53 | .79 | 26.9 |
| 8-26-2 | 1.18 | 5.19 | .81 | 27.6 |
|        | ---- | ---- | --- | ---- |
| 8-26-7 | 1.01 | 3.70 | .78 | 26.5 |
|        | 1.17 | 4.08 | .78 | 26.5 |
| 8-27-2 | 0.89 | 4.91 | .85 | 29.2 |
|        | 0.80 | 4.34 | .84 | 28.8 |
| 8-27-6 | 0.84 | 1.51 | .64 | 21.2 |
|        | ---- | ---- | --- | ---- |

SEDIMENTARY PHOSPHATE METHOD PALEOSALINITY CORE #8 (CON'T.)

| Sample No. | Fe-phosphate micromole/gram | Ca-phosphate micromole/gram | $\frac{Ca}{Fe+Ca}$ | Salinity $^o/oo$ |
|---|---|---|---|---|
| 8-28-2 | 0.16 | 2.56 | .69 | 23.0 |
|  | 0.69 | 2.68 | .79 | 26.9 |
| 8-28-7 | 0.84 | 2.13 | .72 | 24.2 |
|  | 1.47 | 2.19 | .60 | 19.6 |
| 8-29-2 | 0.56 | 1.26 | 0.69 | 23.0 |
|  | 0.63 | 1.01 | 0.62 | 20.3 |
| 8-29-6 | 0.70 | 0.57 | .45 | 13.8 |
|  | 1.42 | 0.18 | .11 | 0.8 |
| 8-30-2 | 0.92 | 2.00 | .68 | 22.7 |
|  | 0.75 | 1.61 | .68 | 22.7 |
| 8-30-7 | 0.83 | 0.21 | .20 | 4.2 |
|  | 1.17 | 0.54 | .32 | 8.8 |
| 8-31-2 | 1.46 | 3.73 | .72 | 24.2 |
|  | ---- | ---- | --- | ---- |
| 8-31-7 | 1.00 | 1.80 | .64 | 21.2 |
|  | 1.04 | 1.87 | .64 | 21.2 |
| 8-32-2 | 0.96 | 2.69 | .74 | 25.0 |
|  | 0.97 | 2.80 | .74 | 25.0 |
| 8-32-7 | 0.77 | 2.28 | .75 | 25.4 |
|  | 0.91 | 2.27 | .71 | 23.8 |
| 8-33-4 | 1.92 | 4.24 | .69 | 23.0 |
|  | 1.05 | 3.59 | .77 | 26.2 |
| 8-34-2 | 1.68 | 3.94 | .70 | 23.4 |
|  | 1.62 | 3.80 | .70 | 23.4 |
| 8-34-7 | 0.85 | 4.47 | .84 | 28.8 |
|  | 0.70 | 3.97 | .85 | 29.2 |
| 8-34-9 | 0.67 | 4.44 | .87 | 30.0 |
|  | 0.75 | 4.50 | .86 | 29.6 |

SEDIMENTARY PHOSPHATE METHOD PALEOSALINITY CORE #16

| Sample No. | Fe-phosphate micromole/gram | Ca-phosphate micromole/gram | $\frac{Ca}{Fe+Ca}$ | Salinity °/oo |
|---|---|---|---|---|
| 16-2-2 | 2.28 | 4.36 | .66 | 21.9 |
|  | 2.41 | 3.24 | .57 | 18.5 |
| 16-2-5 | 1.88 | 3.97 | .68 | 22.6 |
|  | 1.97 | 2.88 | .59 | 19.2 |
| 16-3-2 | 1.91 | 3.97 | .68 | 22.6 |
|  | 1.86 | 4.03 | .68 | 22.6 |
| 16-3-5 | 2.28 | 4.07 | .64 | 21.1 |
|  | 1.36 | .92 | .40 | 11.9 |
| 16-5-2 | 2.63 | .54 | .17 | 3.1 |
|  | 2.44 | .43 | .15 | 2.3 |
| 16-5-5 | 1.88 | 1.34 | .42 | 12.6 |
|  | 2.20 | .89 | .29 | 7.6 |
| 16-6-1 | 2.24 | .23 | .09 | 0 |
|  | ---- | ---- | --- | ---- |
| 16-6-8 | 2.15 | .21 | .09 | 0 |
|  | 1.22 | .61 | .33 | 9.2 |
| 16-7-5 | 1.29 | .10 | .07 | 0 |
|  | ---- | ---- | --- | ---- |
| 16-8-3 | 2.49 | 1.11 | .31 | 8.4 |
|  | ---- | ---- | --- | ---- |
| 16-8-7 | .96 | .08 | .08 | 0 |
|  | ---- | ---- | --- | ---- |
| 16-9-2 | 1.54 | .74 | .32 | 8.8 |
|  | ---- | ---- | --- | ---- |
| 16-9-7 | .70 | .26 | .27 | 6.9 |
|  | ---- | ---- | --- | ---- |
| 16-10-4 | .80 | .19 | .19 | 3.9 |
|  | ---- | ---- | --- | ---- |
| 16-10-7 | .59 | .30 | .34 | 9.6 |
|  | ---- | ---- | --- | ---- |
| 16-11-2 | 1.29 | .80 | .38 | 11.1 |
|  | ---- | ---- | --- | ---- |

SEDIMENTARY PHOSPHATE METHOD PALEOSALINITY CORE #16 (CON'T.)

| Sample No. | Fe-phosphate micromole/gram | Ca-phosphate micromole/gram | Ca / Fe+Ca | Salinity °/oo |
|---|---|---|---|---|
| 16-11-7 | .65 | 1.04 | .62 | 20.3 |
|  | .77 | .13 | .14 | 1.9 |
| 16-12-3 | 1.10 | .32 | .22 | 5.0 |
|  | .95 | .53 | .36 | 10.3 |
| 16-12-7 | .61 | .12 | .16 | 2.7 |
|  | .69 | .20 | .22 | 5.0 |

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# VITA

Arthur Lee Meyerson, son of Hilda and Samuel Meyerson, was born June 30, 1938 in East Orange, New Jersey. He attended grade school in Stanhope, New Jersey, and was graduated in 1955 from Netcong (N.J.) High School. His undergraduate studies were completed at the University of Pennsylvania, Philadelphia, Pennsylvania, where he received an A.B. degree in geology in June, 1959.

Mr. Meyerson entered the Department of Geology at Lehigh University, Bethlehem, Pennsylvania as a graduate student in September, 1959 and received an M.S. degree in geology in June, 1961. While at Lehigh University Mr. Meyerson served as a teaching assistant.

In February, 1964, Mr. Meyerson entered the Department of Geology at New York University and continued study there until June, 1968.

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