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APPENDIX I:

Geomorphic History of the Leipsic River and the Alston Branch in the Vicinity of Archaeological Site 7K-C-194A, Kent County, Delaware

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NOTE: This appendix contains its own list of references at the end of the appendix and three sub-appendices are also added to the end of Appendix I

ABSTRACT

Three sedimentary facies have been defined in deposits of the valleys of the Alston Branch and the Leipsic River in the vicinity of archaeological site 7K-C-194A: sand and muddy sand, mud, and peat. The sand and muddy sand facies was deposited in fluvial and tidal river channels, the mud facies was deposited in floodplains and in an estuary (perhaps best described as an arm of a precursor to the modern Delaware Bay), and the peat facies was deposited in palustrine fluvial and tidal wetlands, and also in oligohaline estuarine tidal wetlands.

Prior to 3000 years B.P., the valleys of the study area were alluvial environments characterized by stream channels, subaerially exposed floodplains, and backswamps. Around 3000 years ago, the Leipsic River and the mouth of the Alston Branch were drowned by an estuary. Following this event, tidal marshes filled in the estuary, and a tidal river valley was established. Around 2000 years B.P., another estuary formed, creating open water conditions in the valleys of the Leipsic River and the lower Alston Branch. The present tidal river valley environment was established about 900 years B.P.

INTRODUCTION

The goal of this study is to describe the geomorphic history of the vicinity of archaeological site 7K-C-194A during the latter part of the Holocene. The primary geomorphic event in Delaware during this period has been the drowning of fluvial valleys by the ongoing Holocene marine transgression (Kraft et al., 1976; Fletcher et al., 1990). Below we reconstruct the history of this event using stratigraphic and geochronologic methods.

THE LOCATION AND GEOLOGY OF THE STUDY AREA

Archaeologic site 7K-C-194A is located on a promontory defined by the valleys of the Leipsic River and the Alston Branch (Figure1). Because previous studies have focused on the history of the Leipsic River (Whallon, 1989; Whallon and Pizzuto, 1988; Pizzuto and Rogers, 1992), we decided to obtain our samples primarily from the valley of the Alston Branch.

The Alston Branch is located on the western coast of the Delaware Bay, in the Atlantic Coastal Plain and Continental Shelf Province. This Province is made up of a seaward thickening wedge of Cenozoic and Mesozoic sediments that are overlain mainly by fluvial sands and gravels of the Pleistocene Columbia Formation and the Miocene Calvert Formation (Kraft, 1976; Pickett, 1976; Pickett and Benson, 1983). Lowered sea levels during the Quaternary Period caused coastal plain streams to erode into the Columbia and Calvert Formations, forming deeply incised valleys (Kraft et al., 1976; Chrzastowski, 1986; Belknap and Kraft, 1977; Fletcher et al., 1990; Knebel et al., 1988). The result is a pre-Holocene surface of antecedent stream valleys of low elevation that lie between paleointerfluves of higher elevation (Kraft et al., 1979). The Holocene transgression has drowned many of the stream valleys of the coastal plain, forming a seaward thickening wedge of Holocene sediment (Richter, 1974; Pizzuto and Rogers, 1992). These transgressive Holocene estuarine and marine sediments overlie the older, pre-transgressive fluvial deposits of the coastal plain.

METHODS

In the southern part of the study area, the Alston Branch near Route 13 is a forested fluvial environment unaffected by tides. As one travels downstream, the estuarine influence of the Delaware Bay becomes progressively more pronounced. At its mouth, the Alston Branch merges with the tidal Leipsic River. Here both streams flow between estuarine tidal marshes.

The sedimentary environments of the modern Alston Branch are probably similar to those of the past, though the transition from fluvial to estuarine environments should have moved progressively upstream during the Holocene. Thus, by carefully characterizing the sediments of the modern Alston Branch, we hoped to develop criteria for recognizing similar sedimentary environments in the subsurface record of the study area.

Four transects across the Alston Branch were selected to span the range of modern environments of the study area (Figure 1 and Table 1). These transects were located at a fluvial reach of the stream

Table 1. Salinity, vegetation, and moisture characteristics of the four transects as classified by Tiner (1985) using the methods of the National Wetlands Inventory (Cowardin et al., 1979).

Transect	Classification	Explanation	Tidal[a]
AB91-1	PF01E	Palustrine, forested (broad-leaved deciduous), seasonally saturated	No
AB91-2	PF01E	Palustrine, forested (broad-leaved deciduous), seasonally saturated	Yes
AB91-3	PSS3/EM5R	Palustrine, scrub/shrub (broad-leaved evergreen) to emergent (narrow-leaved persistent), seasonally tidal	Yes
AB91-4	E2EM5N6	Estuarine, intertidal, emergent (narrow-leaved persistent), regularly flooded, oligohaline	Yes

[a] - based on field observations

the confluence with the Leipsic River (AB91-4). A few cores were also taken in the valley of the Leipsic River downstream of the mouth of the Alston Branch.

At each transect, cores were obtained using a hand-driven Eijkelkamp gouge auger. The coring equipment consists of a 1 m long, half cylinder blade with a diameter of 2.5 cm, along with 1 m long extension rods. The lithology of the various sedimentary units obtained in the cores was described in the field. The GSA Rock Color Chart (Rock Color Chart Committee, 1991) was used to estimate the color of the different lithologies. Organic-rich facies were described using nomenclature of Pizzuto and Rogers (1992). At selected sites of particular interest, cores were taken again using a coring blade with a 5 cm diameter. These cores were stored and transported back to the laboratory in split PVC pipes lined with aluminum foil and plastic wrap. A handlevel, stadia rod and tape were used to establish the relative locations of each core along a given transect.

The absolute elevations of each transect relative to the National Geodetic Vertical Datum (1929) (NGVD) were estimated in the following way. The right-of-way of the new Route 13 Relief Route passes between transects AB91-1 and AB91-2; it then follows a north-northwesterly path parallel to the existing Route 13 (Figure 1) until it intersects the Leipsic River. This right-of-way has been surveyed in detail at a scale of 1:600 with a 0.30 m contour interval. We have assumed that the elevation of the marsh at the mouth of the Alston Branch is the same as the surveyed elevation of the marsh located where the Relief Route crosses the Leipsic River. This provides two known elevations along the Alston Branch (one located between transects AB91-1 and AB91-2 and the other located at the mouth) which can be used to calculate the average slope of the stream in the study area. This average slope provides a crude basis for estimating the elevations of all four transects. The relationships between NGVD and mean high water, mean water level, and mean low water at the mouth of the Alston Branch were estimated using the procedure described by Pizzuto and Rogers (1992).

In the following text all cores are identified using a three-part number, for example, AB91-4-3. "AB91" denotes that the core is from Alston Branch and was taken in 1991. The two following numerals indicate the transect and core number, respectively. Samples taken from a given core have the core identification number followed by the depth range (in cm) from the top of the core, indicating where in the core the sample was taken from. For example, AB91-4-3-405-410 would represent a sample of the above mentioned core which was obtained from a depth of 405 - 410 cm.

Several samples were sent to outside laboratories for radiocarbon dating, diatom analyses and seed analyses. Radiocarbon analyses were obtained from Beta Analytic, Inc. Diatom identifications were provided by Dr. John Sherman of the Philadelphia Academy of Natural Sciences and Dr. Grace Brush of Johns Hopkins University identified seeds on selected samples. The diatom and seed analyses are included in Appendices II and III. Graphic core logs with a brief description of each lithologic unit are included in Appendix I.

RESULTS

Lithology

The basal unit encountered in several of the cores consists of an olive gray to light bluish gray, medium to coarse sand (Figures 2, 3, 4, and 5). This unit is typically very dense and it cannot be penetrated for more than a few centimeters. It frequently contains greenish gray, sometimes weathered granules and pebbles. This unit has been designated as pre-Holocene in age since it bears characteristics of the Miocene Calvert Formation (Pickett and Benson, 1983).

There are essentially three lithofacies which are found overlying the pre-Holocene sediments. These lithofacies are described below, beginning with the facies which is typically found in the lowest stratigraphic position, and proceeding upwards through the section.

The olive gray (5Y 4/1) to olive black (5Y 3/1) sand and muddy sand facies is typically the basal Holocene unit encountered in the cores (Figures 2, 3, 4 and 5). The sand and mud are often interbedded. Mud laminations and wood fragments are also commonly scattered throughout, as are granules and pebbles.

An olive gray (5Y 4/1) mud facies frequently overlies the sand and muddy sand facies (Figures 2, 3, 4, and 5), although it is occasionally found overlying the peat facies described below (Figure 5). The mud facies is organic-rich, containing wood fragments, small twigs, and plant fibers. It can be traced along the axis of the Alston Branch (Figure 6) from transect AB91-2, across the Leipsic River to core LR92-DC-1 (see Figure 1 for the locations of these transects and cores).

It should be noted that the mud facies in cross-section AB91-1 (Figure 2) bears different characteristics from the above mentioned muds. Although the mud is gray (probably a result of gleyzation), it contains orange mottles, which is typical of soils that are alternately saturated and oxidized (Tiner, 1985).

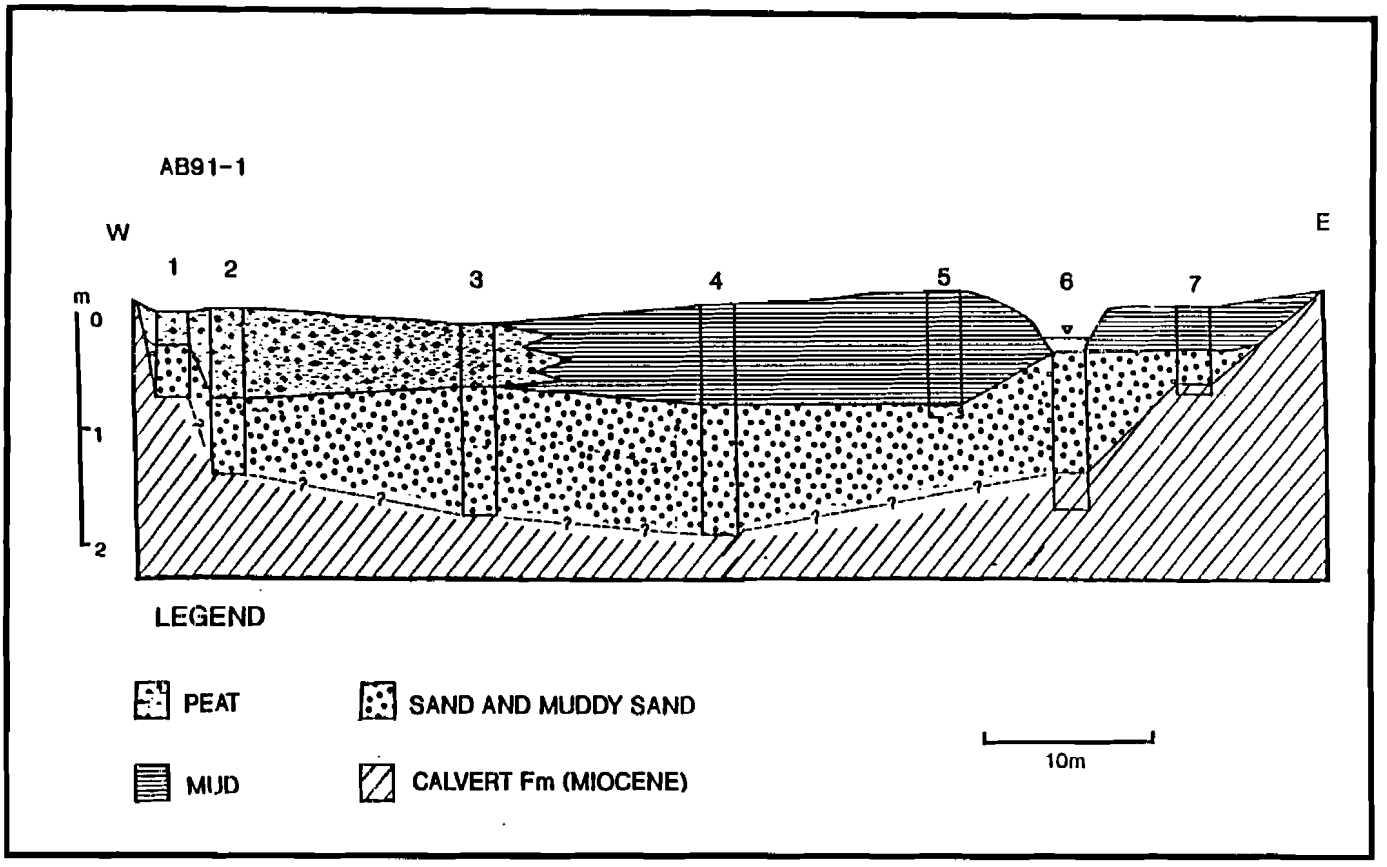


Figure 2. Cross-section along transect AB91-1.

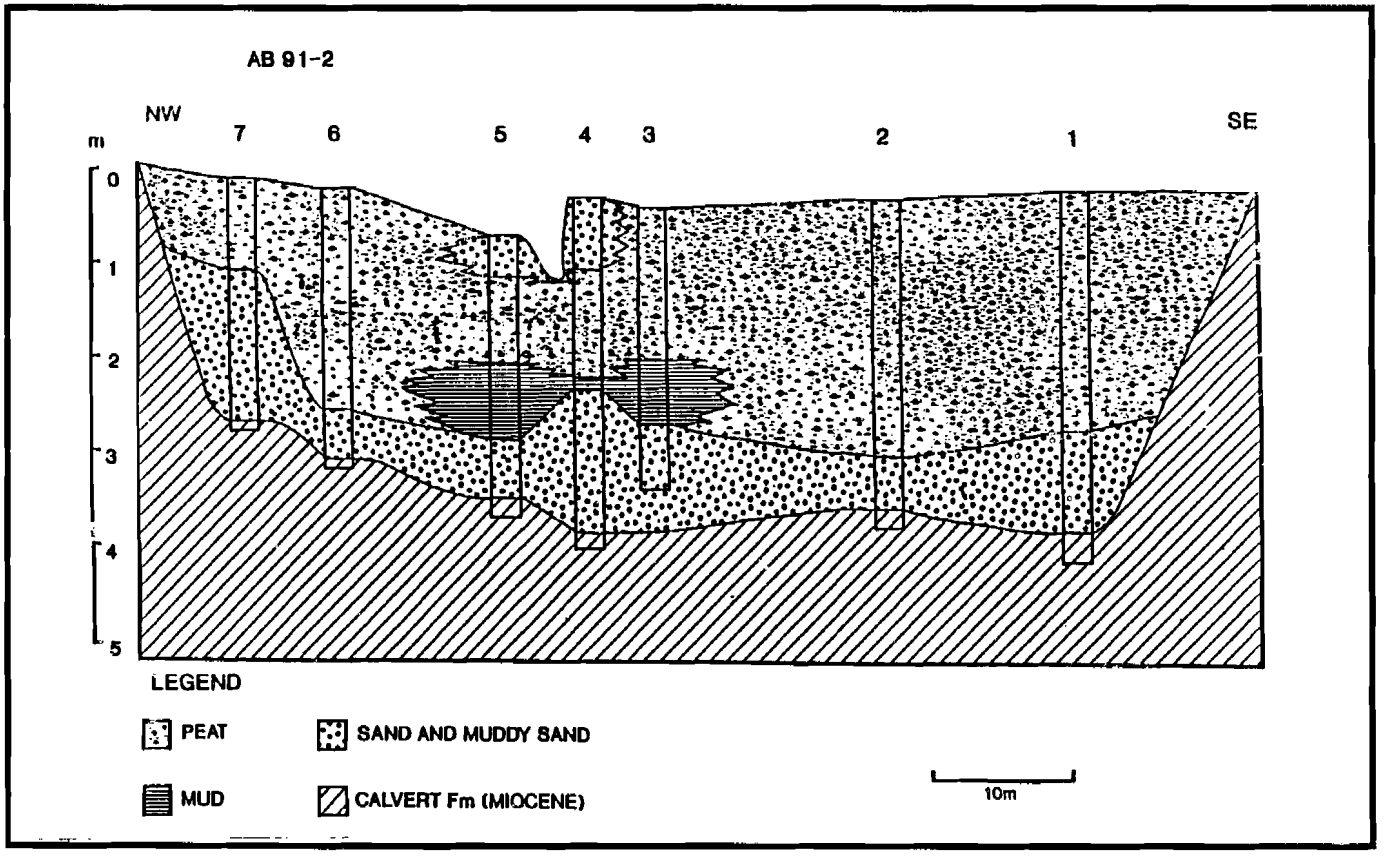


Figure 3. Cross-section along transect AB91-2.

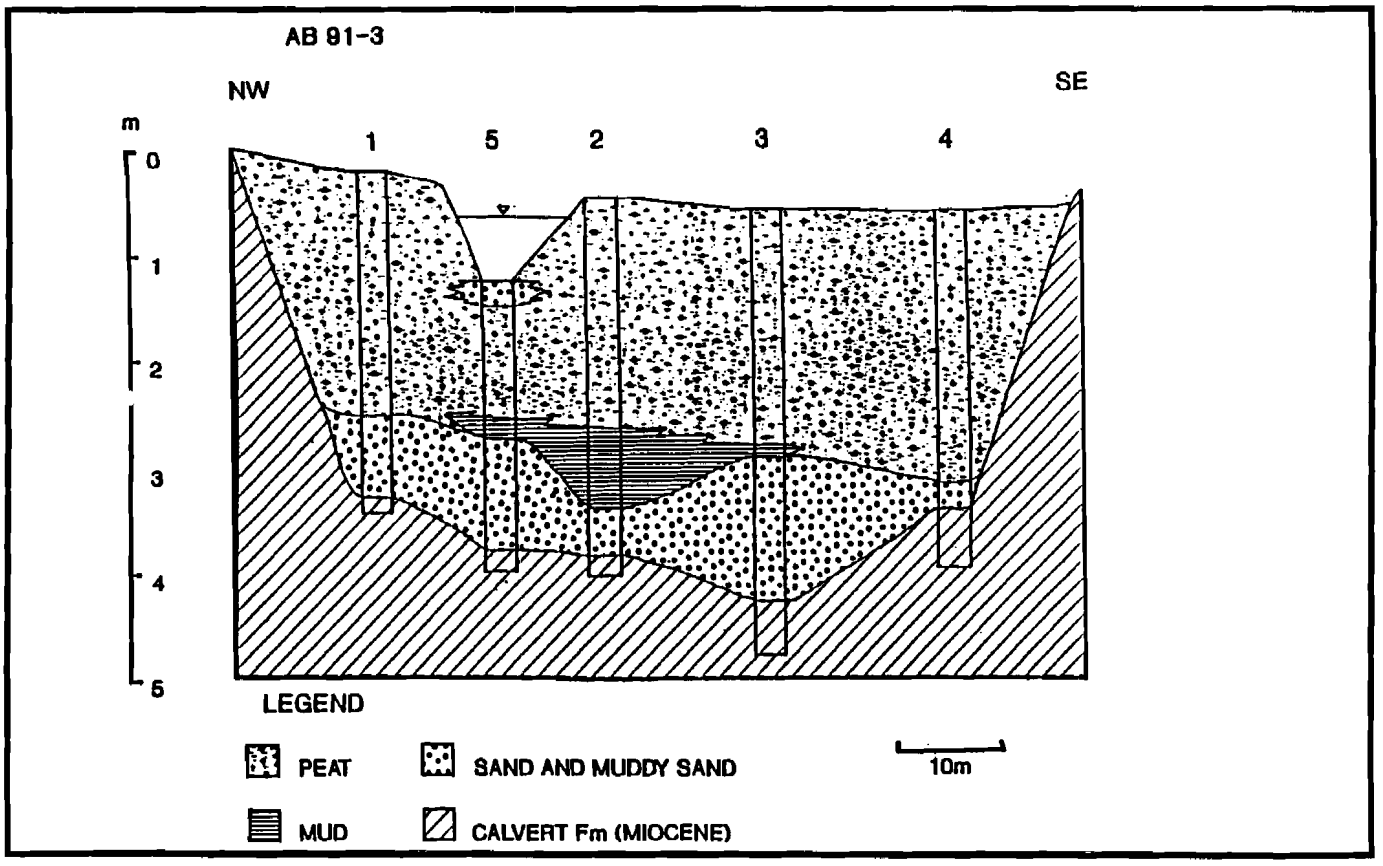


Figure 4. Cross-section along transect AB91-3.

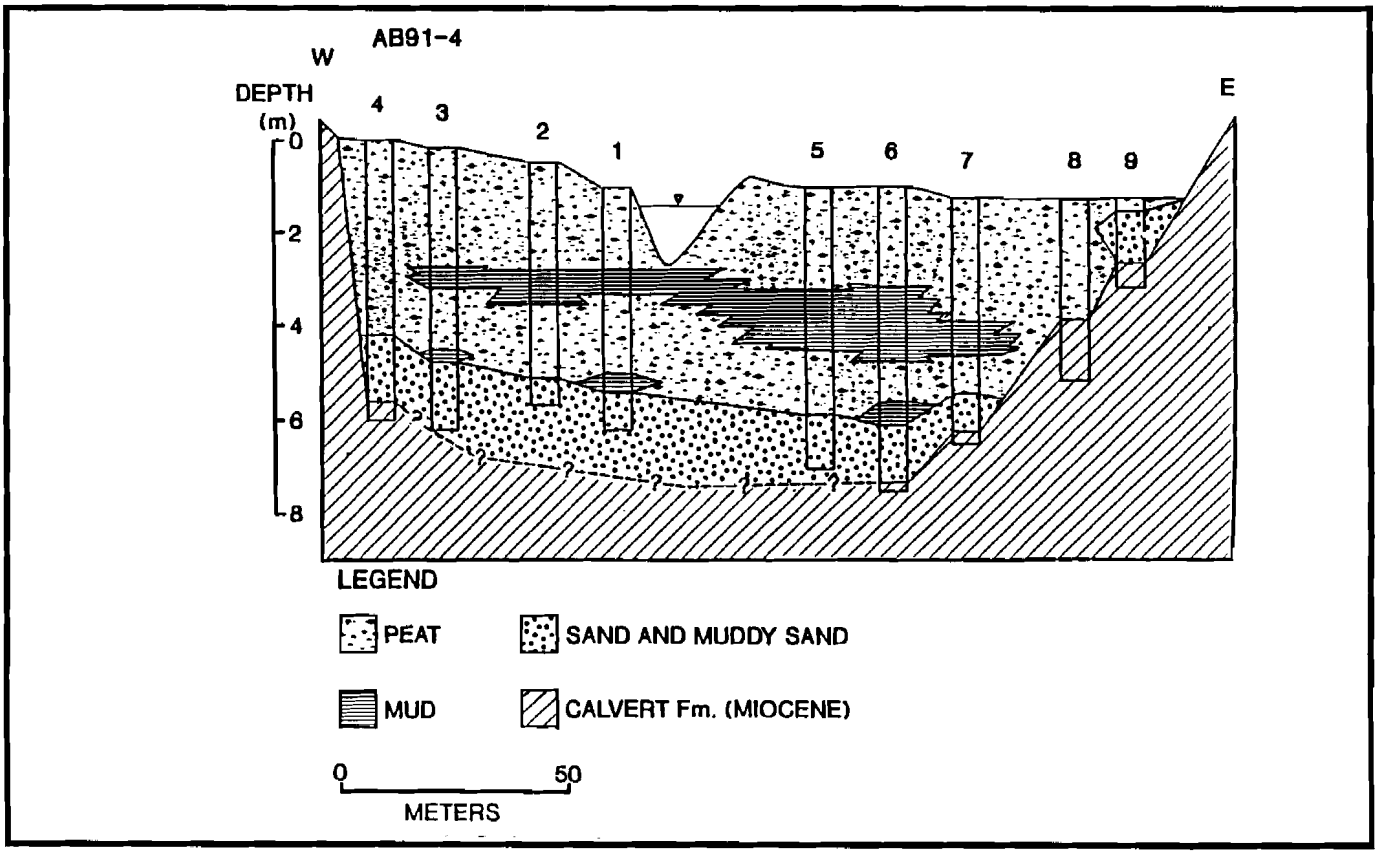


Figure 5. Cross-section along transect AB91-4.

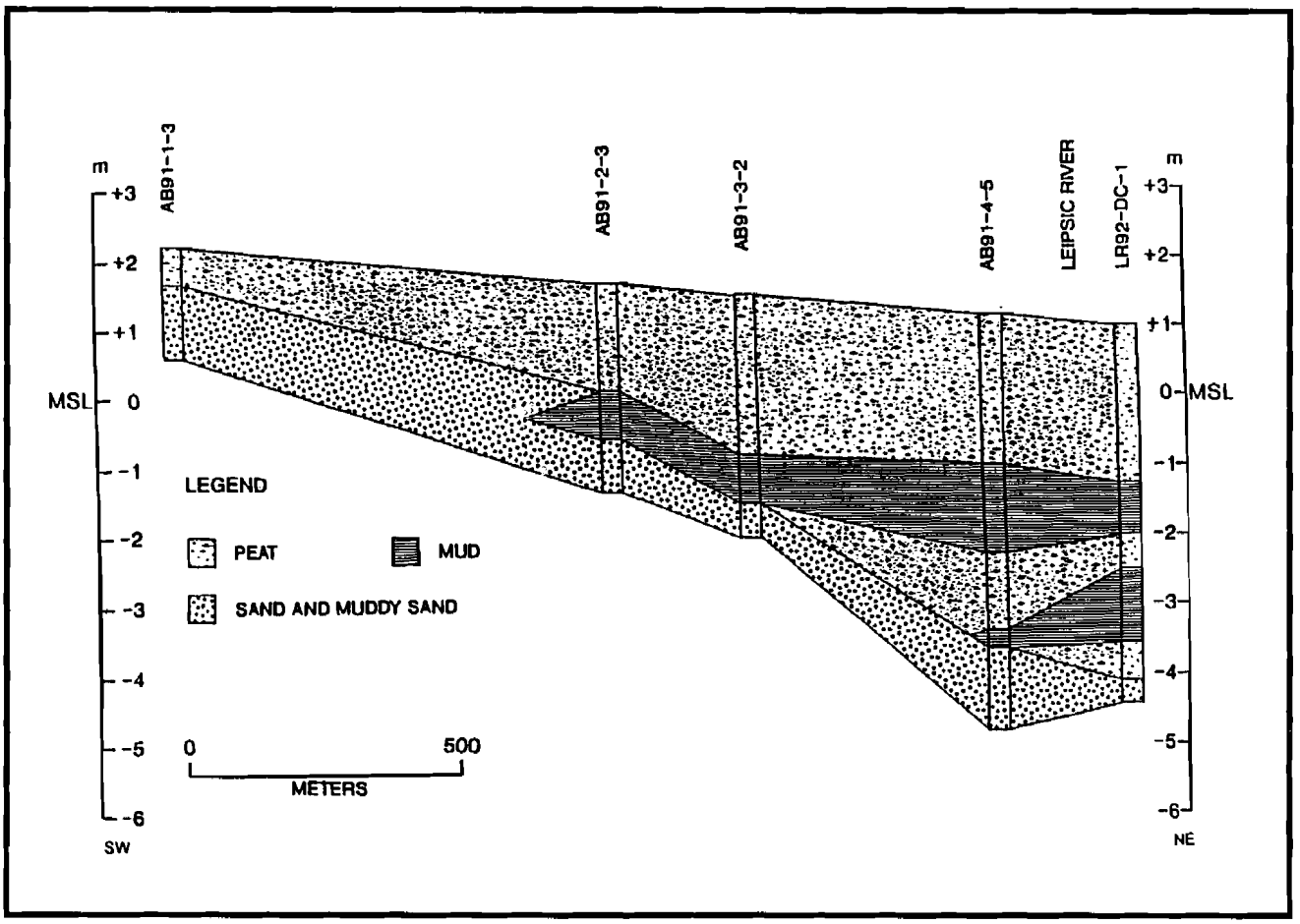


Figure 6. Cross-section along the axis of the Alston Branch into the valley of the Leipsic River

A peat facies is also abundant in the study area, where it typically overlies the sand and muddy sand and the mud facies (Figures 2, 3, 4, and 5). It consists of a mixture of partly decomposed roots, stems, leaves, and wood fragments along with variable amounts of inorganic sediment. Colors range from dusky yellowish brown (10 YR 2/2) to dark yellowish brown (10 YR 4/2).

Diatoms

Diatom assemblages were identified in eighteen samples (Appendix II). Many species of diatoms inhabit water with specific salinity conditions (Table 2). Thus, identification of the diatom population within a sample will indicate whether the depositional environment was freshwater or brackish. The spatial distribution of freshwater and brackish assemblages is illustrated in Figure 7.

Seeds

Seeds were identified to a species level when possible, and are presented as a total count of emergent and woody species within each sample (Appendix III). The ratio of emergent to woody species (Table 3) is used as a proxy for moisture content in the wetland system. Data from core AB91-

Table 2. Typical diatom genera identified in the cores and their salinity preference.	
Brackish Species	**Freshwater Species**
Coscindiscus sp.	Fragilaria sp.
Rhopododia sp.	Gomphonema sp.
Melosira sp.	Eunotia sp.
Achnathes sp.	Amphora sp.
	Cyclotella sp.
	Epithemia sp.

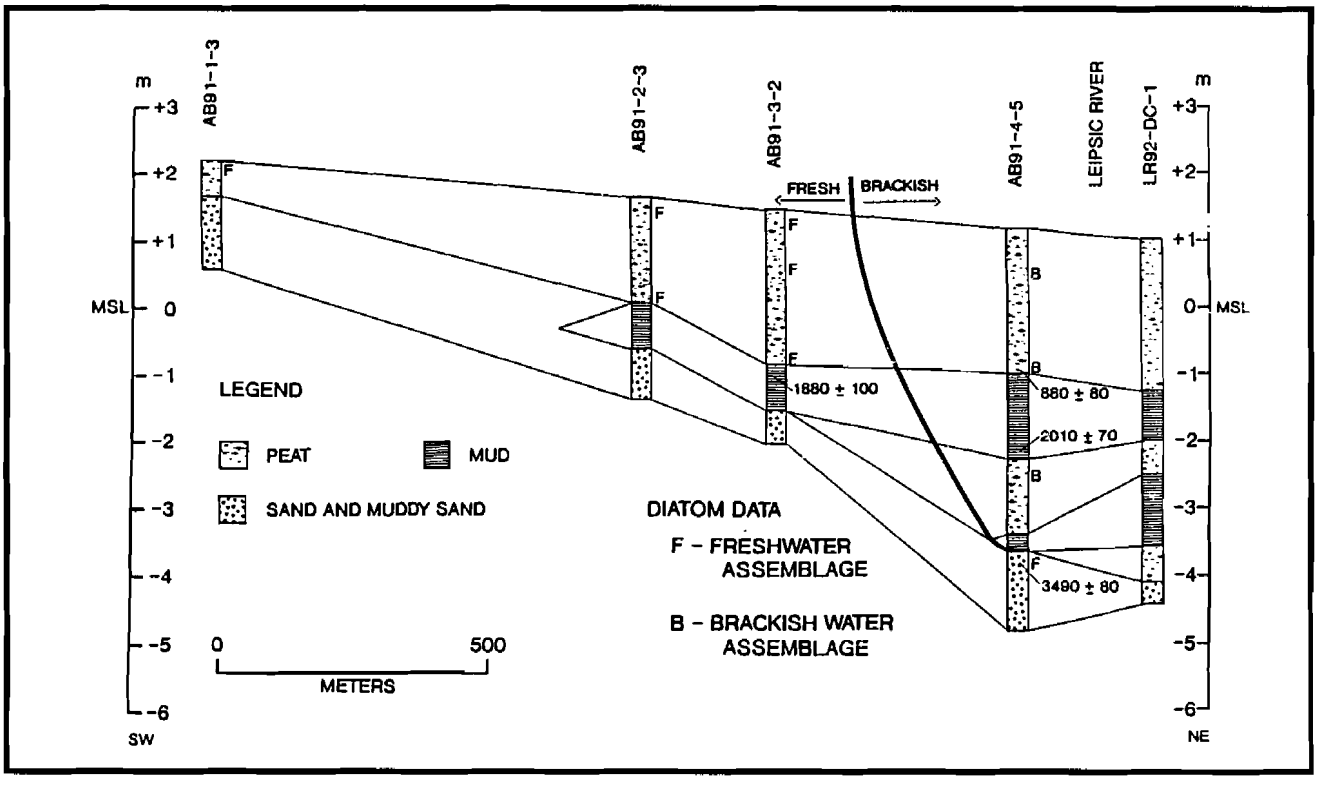


Figure 7. Spatial distribution of the freshwater and brackish water diatom assemblages. The locations and ages of several samples dated by radiocarbon methods are also indicated.

Table 3. Percentages of seeds of emergent and woody species identified by Brush in selected samples.		
SAMPLE NO.	% EMERGENT SPECIES	% WOODY SPECIES
AB91-1-2-10-15	75	25
AB91-1-2-55-60	38	60
AB91-1-4-20-25	100	0
AB91-2-3-15-20	50	50
AB91-3-2-15-20	100	0
AB91-3-2-150-155	55	44
AB91-3-2-260-265	33	66
AB91-4-3-30-35	47	53
AB91-4-3-190-195	80	20
AB91-4-3-250-255	25	75
AB91-4-3-380-385	77	23
AB91-4-3-450-455	95	5

3-2 show an increasing trend in the percent emergents with decreasing depth (Figure 8), indicating the progressive drowning of woody species as sea level rises.

Radiocarbon Dates

A total of nine radiocarbon dates (Table 4) were obtained from organic-rich horizons of the cores. These dates were used to establish the chronostratigraphy of the wetland system. The samples for radiocarbon dates were selected to yield the age ranges for the three lithologic units. The spatial distributions of several dated horizons is illustrated in Figure 7.

DISCUSSION

Environmental Interpretation of Sedimentary Facies

Sand and Muddy Sand Facies

The relatively coarse grain size and stratigraphic position of the sand and muddy sand provide useful clues in interpreting its depositional environment. At transect AB91-1 (Figure 2), the sand and muddy sand facies directly overlies the pre-Holocene Calvert Formation, and it is clearly currently being deposited in the river channel by modern fluvial activity. Thus, the sand and muddy sand facies is a fluvial channel deposit where it is found in stratigraphic positions analogous to that illustrated in Figure 2.

The sand and muddy sand facies is not always associated with fluvial channels, however. At transects AB91-2 and AB91-3 (Figures 3 and 4), the sand and muddy sand facies is found around the perimeter of the modern tidal channel. In both cases, the sand and muddy sand facies overlies peat deposits. Thus, in these stratigraphic settings, the sand and muddy sand facies is associated with tidal

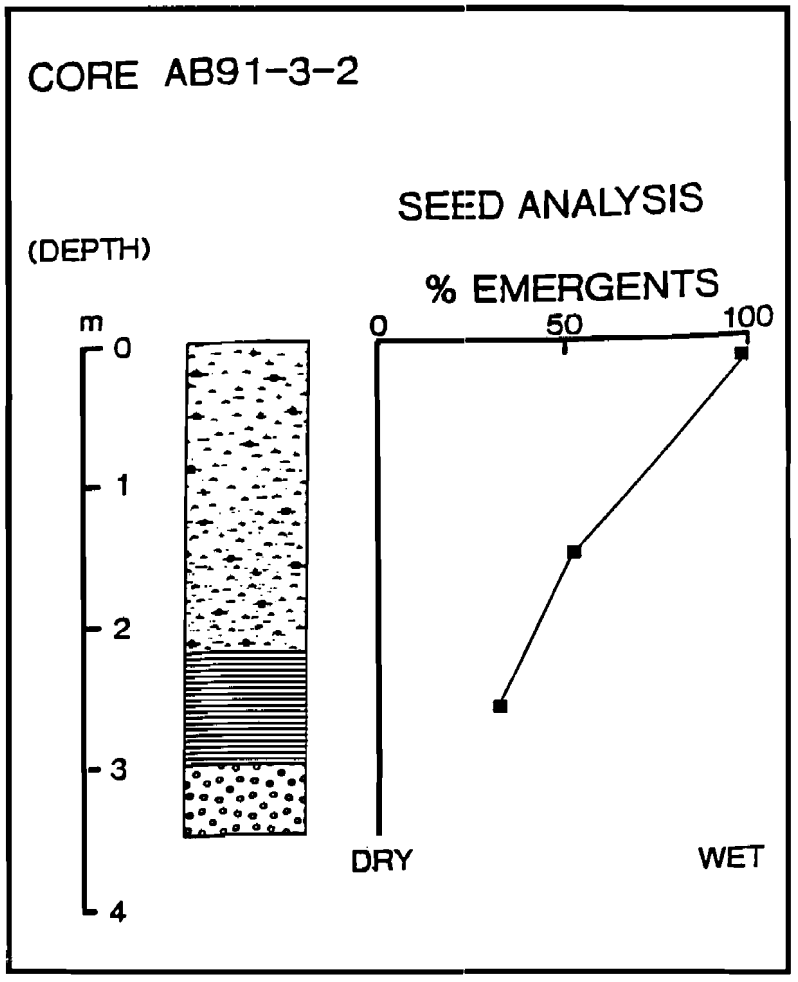


Figure 8. The percentage of emergent seeds as a function of depth for core AB91-3-2.

river channels. Sedimentary structures were not observed in any of the cores, so unambiguous lithologic criteria for distinguishing between fluvial and tidal channels could not be developed.

The sand and muddy sand facies is also present in another stratigraphic setting in transect AB91-4-9, where it appears to be isolated from other tidal or fluvial channel deposits (Figure 5). Because the sand and muddy sand facies here is close to the steep valley wall, it is likely that these deposits are colluvial rather than being associated with either fluvial or tidal river channels.

Mud Facies

Like the sand and muddy sand facies, the mud facies represents several depositional environments. At transect AB91-1 (Figure 2), the mud facies directly overlies the fluvial channel facies and it contains orange mottles which indicate periodic saturated and unsaturated conditions. These characteristics provide unambiguous evidence that, at least at transect AB91-1, the mud facies is an overbank deposit associated with the floodplain of the Alston Branch (see Walker and Cant (1984) for an illustration of the stratigraphic setting of typical overbank deposits).

At transect AB91-4, a continuous deposit of the mud facies overlies the peat facies (Figure 5). This deposit extends across most of the valley of the Alston Branch, and it can be traced downstream into the valley of the Leipsic River (Figure 6). Peat deposits which bracket this mud deposit contain brackish diatoms (Figure 7), suggesting that the mud itself was deposited in brackish water.

The data summarized above suggest that the continuous mud facies at transect AB91-4 could have been deposited in either 1) a migrating, relatively narrow tidal stream, or 2) a broad, open water estuarine environment which would have represented an extension of the Delaware Bay into the valley of the Leipsic River. It is difficult to distinguish between these two alternatives with the data available; however, a migrating, relatively narrow tidal stream would deposit mud over a basal erosion surface. The base of the mud facies at AB91-4 appears to be conformable; vertical roots and plants are preserved in growth position. Thus, we interpret the mud facies at AB91-4 as an estuarine deposit. It is noteworthy that this deposit extends downstream into the valley of the Leipsic River, suggesting the existence of an estuarine environment of considerable spatial extent (Figure 6). Furthermore, two mud units, both overlying peat facies, are present in core LR92-DC-1, suggesting that two open water estuarine environments have developed during the Late Holocene in this area.

The mud facies is also found immediately overlying the sand and muddy sand facies at transects AB91-2, 3, and 4. These deposits are similar in lithology to the continuous mud deposit which overlies the peat facies at transect AB91-4. Furthermore, these deposits are all spatially correlative with the estuarine mud facies described above. Thus, we provisionally interpret all of these deposits as representing estuarine open water depositional environments, and correlate them as is indicated in Figure 7.

Peat Facies

Because modern peat deposits are found at the surface at all of the transects, modern analogues can be used to interpret the peat facies mapped in the subsurface. All of the modern peat-forming environments are wetlands, and therefore the ancient peat-forming environments were also wetlands.

Modern wetlands from the study area are quite diverse, however (Table 1). They range from forested, seasonally inundated palustrine wetlands at transect AB91-1 to emergent, regularly flooded, intertidal oligohaline wetlands at transect AB91-4. These different wetland types cannot be readily distinguished using purely lithologic criteria. However, the diatom analyses indicate that all of the peat deposits at transect AB91-4 are associated with estuarine brackish marshes. Furthermore, all of the peat deposits at transects AB91-1, AB91-2, and AB91-3 are associated with freshwater marshes. We cannot, however, distinguish freshwater tidal wetlands from freshwater fluvial wetlands. However, the lower part of many peat units contains large wood fragments which probably mark the transition from palustrine forested fluvial wetlands to palustrine emergent tidal wetlands. We have not, however, mapped this transition in detail.

Geomorphic History of the Study Area

Geomorphic Environments

The modern environments and sedimentary facies of the study area suggest that three characteristic geomorphic environments dominated the Holocene history of the study area (Table 5). These are the alluvial valley, the tidal river valley, and the estuary.

The alluvial valley consists of a river channel and its subaerially exposed floodplain and associated backswamp. These environments and landforms are clearly illustrated by those of the modern Alston Branch at transect AB91-1. Conditions at the modern Alston Branch indicate that the backswamps of the alluvial valley are palustrine forested wetlands.

The tidal river valley consists of a tidal river channel and associated tidal wetlands. Wetlands of the tidal river valley range from seasonally tidal palustrine forested wetlands to oligohaline, regularly flooded, intertidal emergent wetlands (Table 1). Modern examples of these environments and landforms may be found at transects AB91-2, AB91-3, AB91-4.

The estuary consists of a relatively wide, brackish openwater environment fringed by emergent tidal wetlands. This environment is not presently found in the study area. However, the drowned

Table 5. Holocene geomorphic environments of the study area.

Geomorphic Environment	Landforms within the Geomorphic Environment	Representative Sedimentary Facies	Salinity
alluvial valley	channel, subaerial floodplain, forested backswamp	sand & muddy sand, mud, peat	fresh
tidal river valley	tidal river channel, emergent tidal marsh complex	sand and muddy sand, peat	fresh/ oligohaline
estuary	estuary, marginal emergent tidal marshes	mud, peat	oligohaline

tributaries of Indian River and Rehoboth Bays, including Pepper Creek, Vines Creek, Indian River, White Creek, Live Creek, and Herring Creek may provide suitable modern analogues (these features may be found on the U.S. Geological Survey 1:24000 scale Bethany Beach, Fairmount, and Frankfurt Quadrangles of Southern Delaware). Similar estuarine deposits are common in other valley fills of tributaries of the Delaware Bay (Belknap and Kraft, 1977; Stedman, 1990; Fletcher et al., 1990, 1991, in press (a); Meyerson, 1972; Chase, 1974; Yi et al., 1991), so comparable deposits are abundant in the stratigraphic record of the region.

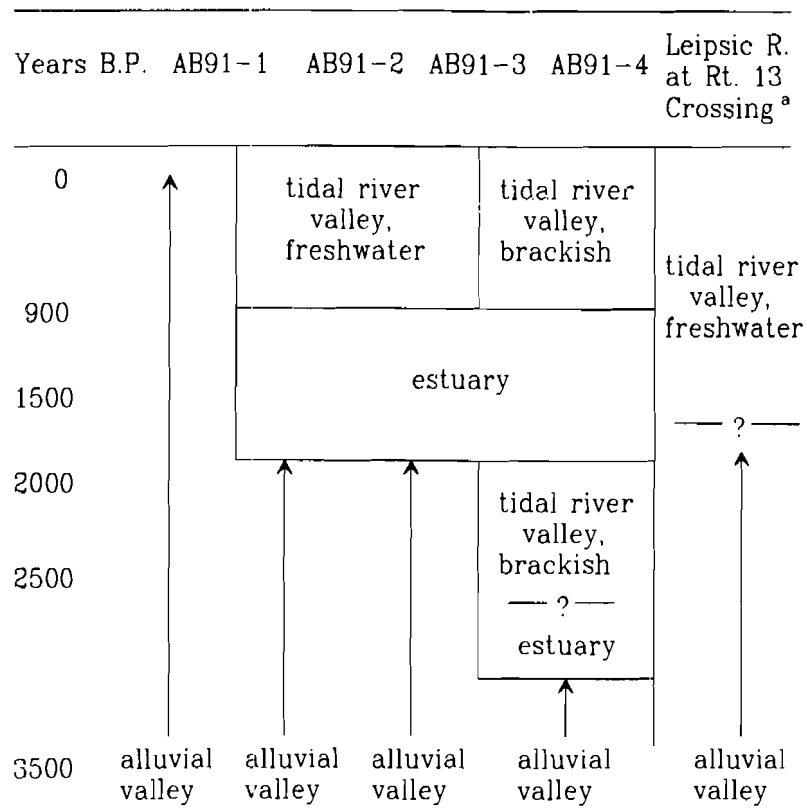
The spatial extent of the estuarine deposits of the study area could not be determined based on the limited coring program of the present study. However, three arguments suggest that these openwater environments once extended all the way to the Delaware Bay. First, all the modern analogues described above continue as open water areas into Delaware's Inland Bays. Second, the comparable deposits cited above in other Delaware Bay tributaries valleys are extensive, and many continue abated seaward of the present shore of Delaware Bay. Finally, Fletcher et al. 1992, Fletcher et al., in press (b), and John et al. 1993, suggest that several estuarine deposits from widely separated tributary valleys are temporally correlative. Regional drowning of the tributary valleys of the Delaware Bay could not have occurred unless drowning was forced by the Bay itself, and such drowning would probably create embayments which were continuously open from the Bay up into the tributary valleys. Thus, the open water estuarine environments of the study area were probably small arms of the Delaware Bay, similar to the many modern drowned valleys of Delaware's Inland Bays.

Geochronology

Table 6 presents a chronology of the geomorphic environments of the study area based on the radiocarbon dates presented in Table 4. Results obtained by Pizzuto and Rogers (1992) for the Leipsic River Valley at the crossing of the Route 13 Relief Route are also indicated. The chronology of the facies of transect AB91-4 also is illustrated schematically in Figure 9.

Before 3000 years B.P., alluvial valleys characterized the study area. Around 3000 years B.P., an estuary drowned the mouth of the Alston Branch and the Leipsic River. This short-lived event may have occurred throughout tributary valleys of the Delaware Bay, because it has also been observed in Wolfe Glade (near the modern Cape Henlopen) by Fletcher et al (in press (a) and (b).

Table 6. Chronology of geomorphic environments of the study area.

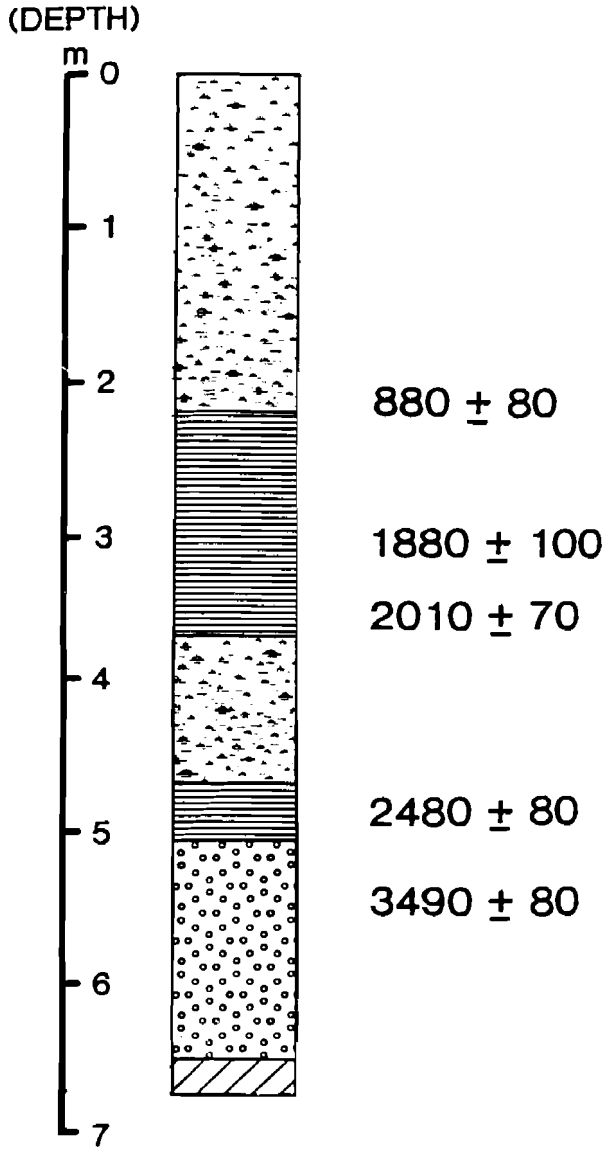


[a] from Pizzuto and Rogers (1992)

Sometime between 2000 and 3000 years B.P. a tidal river valley replaced the estuary at the mouth of the Alston Branch. By 2000 years B.P., a major transgressive event had occurred, leading to the development of an estuary at transects AB91-2, AB91-3, and AB91-4. Apparently, the estuary did not extend up the Leipsic River Valley to the present crossing of the Route 13 Relief Route (Pizzuto and Rogers, 1992). As noted by Fletcher et al. (1992, in press (b)), the development of the estuary represents a major regional event which has been observed at Wolfe Glade in southern Delaware and also at the Dennis Creek Marsh in New Jersey (Meyerson, 1972).

Around 900 years B.P., the estuary was replaced by a tidal river valley. Conditions were brackish at transect AB91-4 and freshwater at transects AB91-2 and AB91-3. A freshwater brackish tidal river valley also formed where the Route 13 Relief Route crosses the Leipsic River (Pizzuto and Rogers, 1992). An alluvial valley continued to characterize transect AB91-1. All of these geomorphic environments have persisted until the present.

COMPOSITE CORE SHOWING C-14 DATES



CONCLUSIONS

Three sedimentary facies have been defined in deposits of the valleys of the Alston Branch and the Leipsic River in the vicinity of archaeological site 7K-C-194A: sand and muddy sand, mud, and peat. The sand and muddy sand facies was deposited in fluvial and tidal river channels, the mud facies was deposited in floodplains and in an estuary (perhaps best described as an arm of a precursor to the modern Delaware Bay), and the peat facies was deposited in palustrine fluvial and tidal wetlands, and also in oligohaline estuarine tidal wetlands.

Prior to 3000 years B.P., the valleys of the study area were alluvial environments characterized by stream channels, subaerially exposed floodplains, and backswamps. Around 3000 years ago, the Leipsic River and the mouth of the Alston Branch were drowned by an estuary. Following this event, tidal marshes filled in the estuary, and a tidal river valley was established. Around 2000 years B.P., another estuary formed, creating open water conditions in the valleys of the Leipsic River and the lower Alston Branch. The present tidal river valley environment was established about 900 years B.P.

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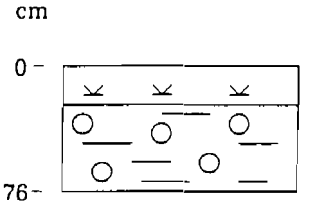
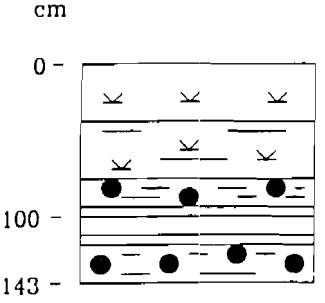
SUB-APPENDIX I. GRAPHIC CORE LOGS

AB 91-1-1



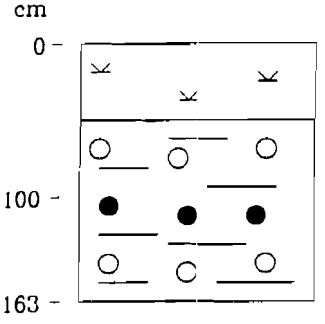
0-10 cm NR. 10 yr 2/2 peat. No sand
Grades into mud/peat with pebbles..
Plant fragments abundant.
Sandy mud, 10 yr 4/2. Pebbles and granules.
Below 76 cm -light olive gray 5 y 6/1. silty clay. Calvert Fm??

AB 91-1-2



Peat, dusky yellowish brown 10 yr 2/2
Abundant organic material
Grades into grayish brown mud/peat 5 yr 3/2.
Dark yellowish brown muddy sand 10 yr 2/2. Some pebbles.
Mud (same color) Wood, granules and plant fibres. Grades into peat (115-128 cm)
Muddy sand. Brownish black 5 yr 2/1.
NR below (sand/gravel??)

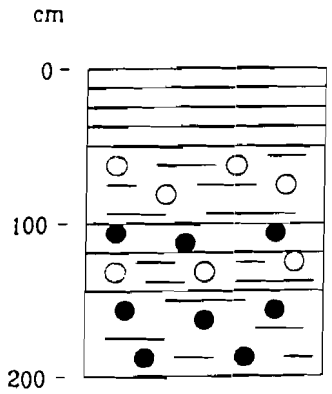
AB 91-1-3



Peat, dark yellowish brown 10 yr4/2
Abundant plant material.

Interbedded sandy mud and muddy sand. Dusky yellowish brown 10 yr 2/2
Wood fragments are present. At 125-126 there is an olive gray 5 y 3/2 layer of fine to med muddy sand.
!26-136 Olive black 5 y 2/1
Nr below 163 cm (sand/gravel??)

AB 91-1-4



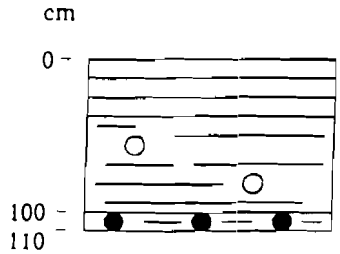
Mud, olive gray 5 y 4/1, with scattered orange mottles. Low organic content. Grades into a dark greenish gray mud 6 y 4/1

Sandy mud, olive gray 5 y 4/1. Few wood fragments. Becomes olive black 5 y 2/1.

Muddy fine sand, olive black 5 y 2/1

Sandy mud, brownish black,5 yr 2/1 Few granules and pebbles. Increase in organics towards the bottom. Color changes to olive gray 5 y 4/1. Wood fragments and pebbles. At 172-182 olive black mud layer.

AB 91-1-5

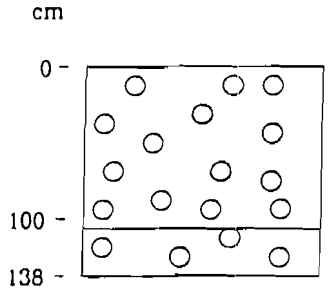


Mud, dark yellowish brown 10 yr 4/2 rootlets and orange mottles

Mud, olive gray 5 y 4/1, with scattered fine sand. At 61-100 cm the color changes to dusky yellowish brown 10 yr 2/2

Muddy sand. (Bottoms in sand?)

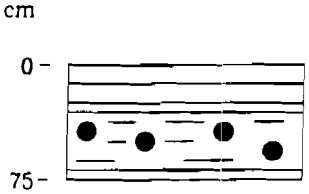
AB 91-1-6



Medium to coarse channel sand
Some pebbles

Sand, light bluish gray 5 b 7/1 (Calvert Fm??)

AB 91-1-7

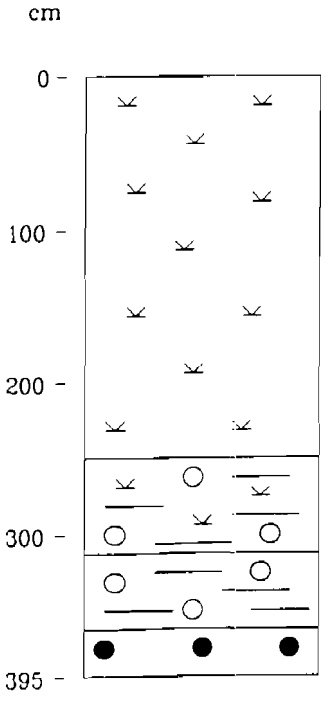


Mud, dark yellowish brown 10 yr 4/2, with orange mottles

Muddy sand with gravel at the bottom

Below 71 cm is a light olive gray clay 5 y 6/1. (Calvert Fm??)

AB 91-2-1



Peat ranging to peat/mud. Dark yellowish brown. 10 y 4/2. Rootlets, fibres and scattered sand grains.
Becomes true peat at 37 cm

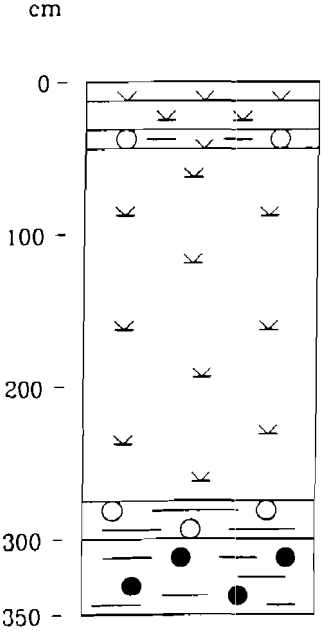
NR 87-100 cm

Color change to dark/dusky yellowish browm 10 yr 3/2.
Several wood chunks.

Sandy mud/peat. Dusky yellowish brown 10 yr 2/2.
Wood chunks towards the bottom

Interbedded sandy mud and muddy sand.
Color changes to brownish black 5 yr 2/1
Some granules and pebbles. Fibres and small w. are present.
Muddy sand and gravel, olive gray 5 y 4/1 (Calvert Fm??)

AB 91-2-2



Watery peat, dusky-dark yellowish brown 10 yr 3/2. Scattered sand. Changes to olive gray mud/peat 5 y 4/1. Many rootlets. Changes to 10 yr 4/2 sandy mud/peat.

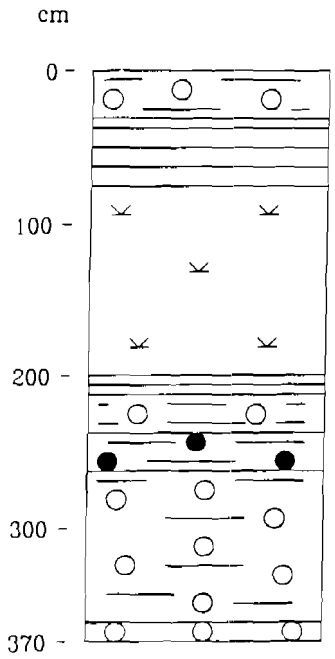
Peat, 10 yr 3/2. Dense, made up of small fibres.
Abundant small pieces of wood

Changes to peat/mud towards the bottom.. scattered sand

Sandy mud, dusky yellowish brown 10 yr 2/2

Muddy sand and gravel (few pebbles and granules and twigs) Olive black to olive gra 5 y 2/1 -5 y 4/1

AB 91-2-4



Sandy mud, dark yellowish brown 5 yr 4/2.
Orange mottles, few twigs.
Olive gray mud with very little sand and organics

Peat with abundant wood chunks (size and frequency increase towards the bottom)

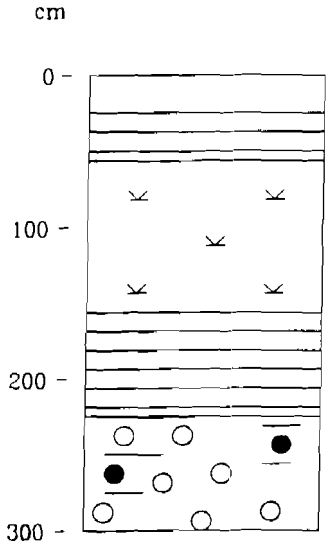
Dusky yellowish brown mud, 10 yr 2/2
Scattered pieces of wood
Laminated sand and organic rich mud
Olive gray to olive black muddy sand.

Sandy mud, 10 yr 3/2
Finely disseminated organic matter

Appears to be laminated.

Light olive gray 5 y 6/1, med.-coarse sand (Pre-Holocene??)

AB 91-2-3



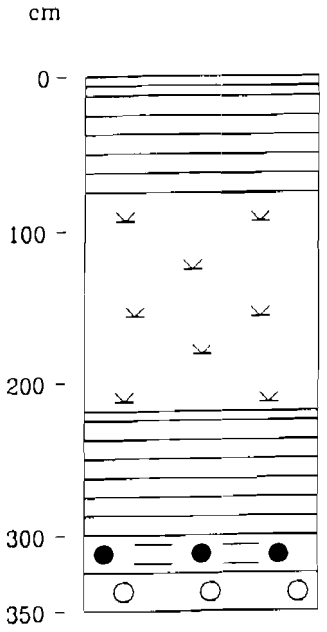
NR
Mud, dark yellowish brown 10 yr 4/2
Very little sand, Abundant roots and fibres

Peat, dusky yellowish brown 10 yr 3/2
Becomes very watery towards the bottom
Wood chunks are present at the bottom

Dense mud, olive black 5 y 2/1
Very little organic matter. Abrupt (erosive) upper contact

Fine to med. sand, slightly muddy with small wood fragments. Sand is olive gray 5 y 4/1

AB 91-3-2



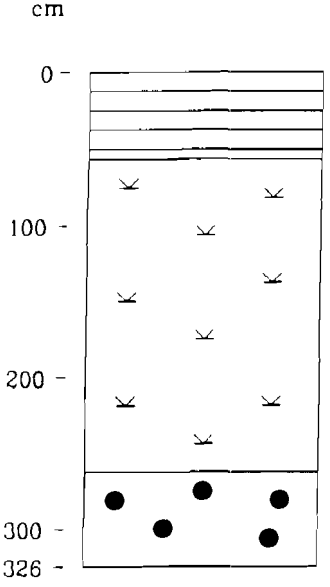
0-5 cm Loose mud with roots. Olive gray 5y 3/2 At 5-6 cm oxidised shell and mud layer. Olive gray (estuarine) mud 5 y 4/1. Roots and other plant fragments

Dark yellowish brown peat 10 yr 4/2 (freshwater)

Olive gray to olive black mud with some fine sand

Sharp upper contact, looks rooted.
Mud with roots. Olive black to dusky yellowish brown
Med. dark gray muddy fine sand, N4
Fine to med. sand, gets coarser towards the bottom

AB 91-3-1



Mud with roots and plant fragments
Dark yellowish brown 10 yr 4/2

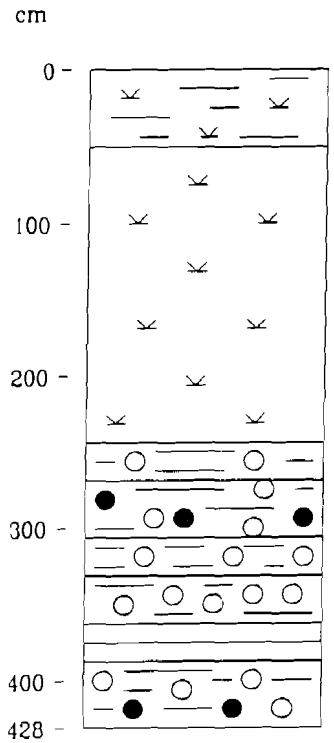
Peat 10 yr 3/2 (freshwater)
Abundant plant fragments and wood chunks

206-208 Layer of clean yellowish gray sand 5 y 8/1
Diffused sand and mud in the peat below this

272-276 olive gray med. sand with weathered Pre-Holocene grains 5 y 5/1

Muddy sand with abundant wood fragments. Color ranges from olive gray 5 y 4/1 to olive black 5 y 2/1. Abundant granules. and plant fibres.

AB 91-3-3



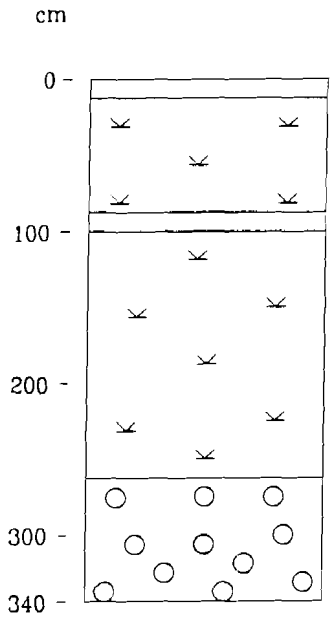
Mud/peat, dark yellowish brown 10 yr 4/2

Peat. Dusky to dark yellowish brown
10 yr 3/2. Mostly small fibres and
few wood fragments

Wood content increases

Fine sand and some mud towards the
bottom
Med. olive gray to dark gray (N3) sand and
mud.
Grades into olive black 5 y 3/1 and brownish
black 5 yr 2/1 sandy mud and muddy sand.
Dark gray sandy mud, N3.
Olive black fine to med. sand. 5 y 2/1. Wood
and organic rich mud.
Olive gray/black5 y 3/1 mud. Dark green
mottles and fine scattered sand.
Olive black/gray sandy mud and muddy sand
Few granules.

AB 91-3-4



NR

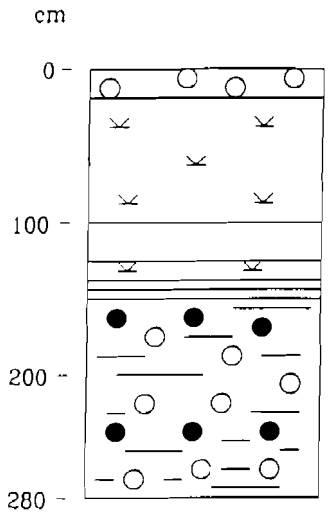
Peat. 10 yr 3/2

NR

Peat, 10 yr 3/2. Abundant wood chunks

264-269 olive gray med. to coarse sand
Below that is sand with some mud and gravel
Color ranges from brownish black to greenish
black 5 gy 2/1 to black N7 (glauconite rich?)
323-340 light bluish gray fine sand
5 b 7/1

AB 91-3-5



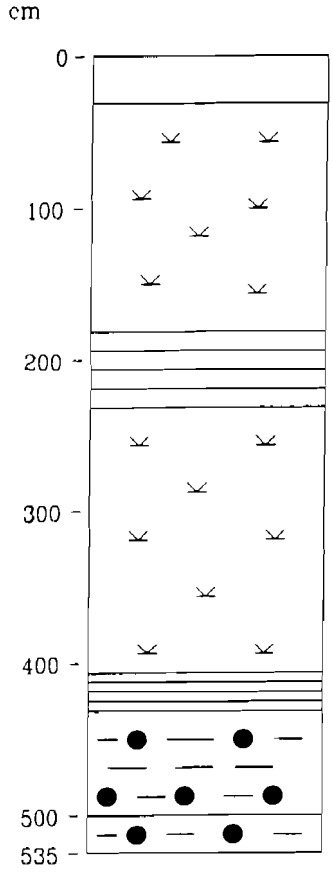
Med. to coarse sand with few granules
Olive gray/black 5 y 3/1

Peat 10 yr 3/2

NR
Peat
Brownish black to olive gray/black mud

Interbedded sandy mud, sand and muddysand
Color varies from olive gray/black to dark gray
dusky yellowish brown. Several pieces of wood
Scattered pebbles and granules
Few mud lenses.

AB 91-4-1



NR

Peat. very watery, abundant twigs, leaves and rhizomes.
10 yr 3/2

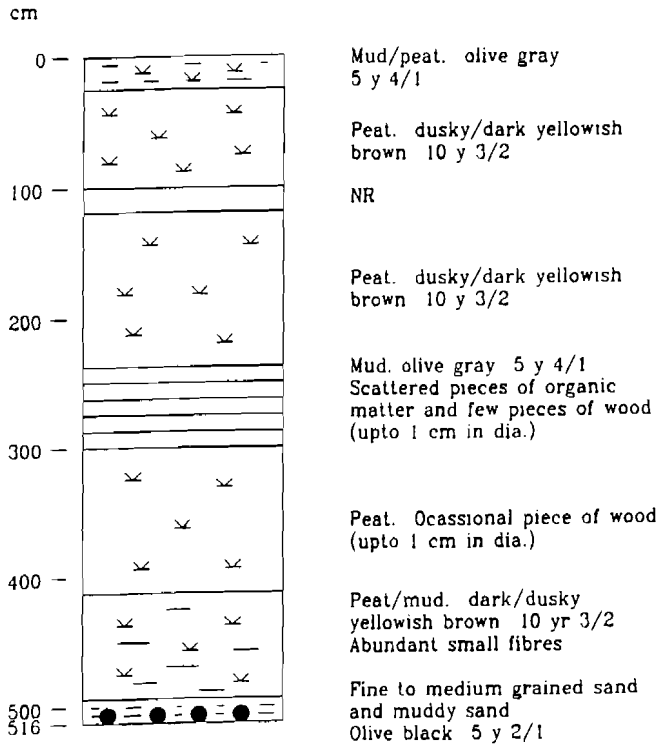
Organic rich mud. Small twigs and fibres Olive gray 5 y 4/1

Peat.

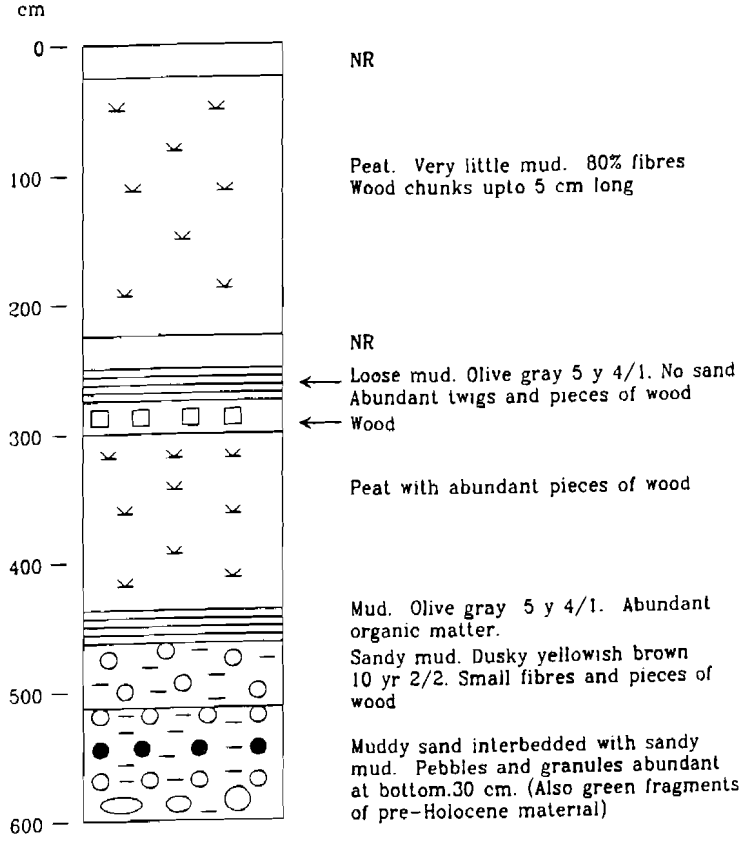
Mud with scattered fine sand. Organics decrease toward bottom. Olive gray 5 y 4/1

Muddy fine to medium sand. Olive gray/black 5 y 3/1. Scattered wood pieces. Sand gets coarser towards bottom. 5 cm thick unit of laminated sand and mud near bottom.

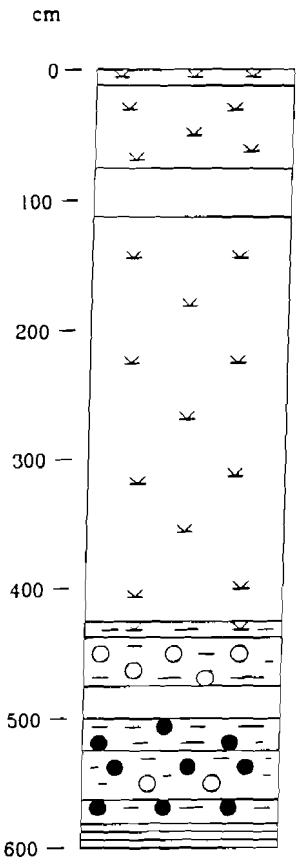
AB 91-4-2



AB 91-4-3



AB 91-4-4



Peat. Dark yellowish brown 10 yr 4/2

Peat. Very loose fibres 10 yr 3/2

NR

Peat. Very loose and watery. Lots of fibres and wood chunks (upto 3 cm in diameter)

Mud/peat. dusky yellowish brown 10 yr 2/2

Sandy mud. Olive gray/black 5 y 3/1 loose and has abundant organics

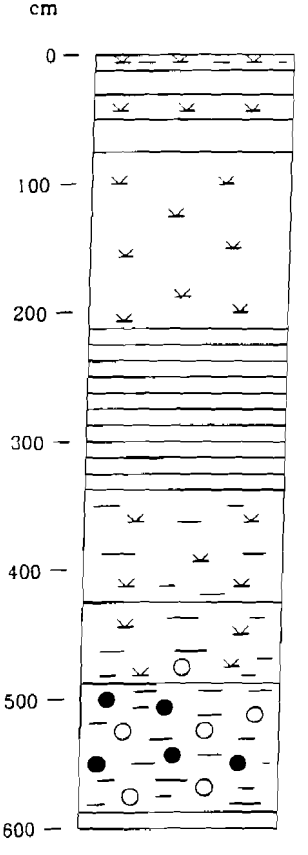
NR

Loose muddy sand. brownish black 5 yr 2/1 Abundant plant fragments

Muddy sand to sand (med - coarse) olive black 5 y 2/1

Interbedded muddy fine sand and mud. Light bluish gray 5 B 7/1 (Pre-Holocene)

AB 91-4-5



Mud/peat. Olive gray 5 y 4/1. Fibres

NR

Peat. Olive gray 5 y 4/1

NR

Peat. 10 yr 3/2 Abundant fibres

Mud with scattered organics. Olive gray 5 y 4/1 Higher organic content at the top

Mud/peat. Dark/dusky yellowish brown 10 yr 3/2.. Small wood fragments and fibres.

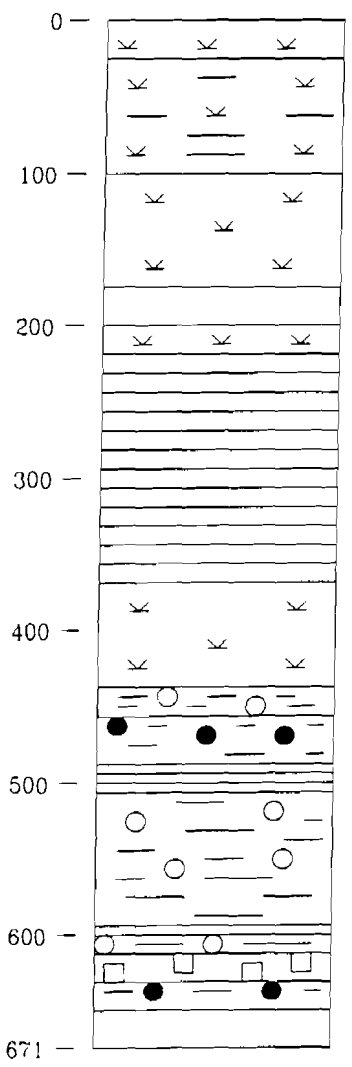
Same as above but with scattered sand grains. increasing towards base

Sandy mud/ muddy sand. Olive gray/ black 5 y 3/1 Bedding. Wood fragments

NR Sand?

AB 91-4-6

cm



Fibrous peat, dark yellowish brown 10 yr 4/2

Organic rich mud, olive gray/black 5 y 3/1. Fibrous, vertical roots. Ranges to peat./mud

Peat with abundant wood chunks. 10 yr 4/2.

NR

Peat, same as above

Organic rich mud, olive gray, 5 y 4/1 Fibrous, vertical roots and wood fragments.

Peat ranging to peat/mud, 10 yr 3/2 Few pieces of wood.

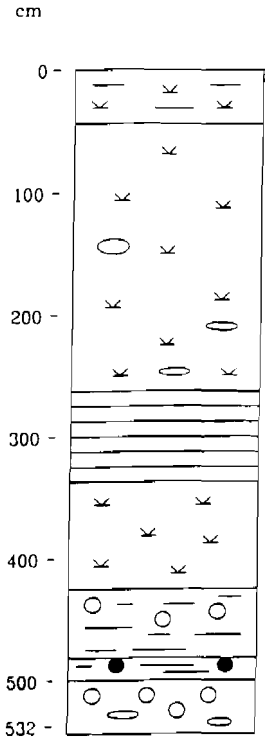
Mud with fine scattered sand, N 4
Light gray muddy sand, N 6

Dark gray mud, N 4

Dusky yellowish sandy mud, 10 yr 2/2 interbedded with fine to med. clean sand,(1 cm)

NR
Olive gray sandy mud, 5 y 4/1
Wood chunks
Olive gray sand with little mud
NR

AB 91-4-7



Olive gray peat ranging to muddy peat 5 y 4/1 Abundant plant fragments

Peat 10 yr 3/2, with scattered pebbles. Atleast 4 sand layers (1 cm) Wood chunks.

Olive gray mud. 5 y 4/1. Scattered organic matter.

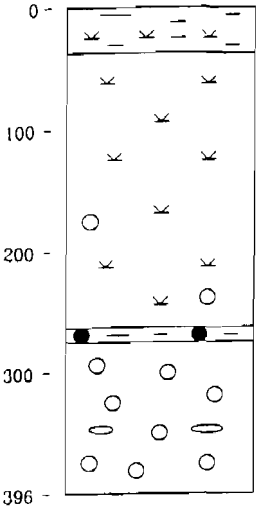
Peat with abundant wood. 10 yr 3/2

Gray mud with scattered sand, N 7 yellow mottling

Olive gray muddy sand 5 y 4/1.

Coarse sand with granules and pebbles

AB 91-4-8



Mud/peat ranging to organic rich mud, olive gray 5 y 4/1. Abundant roots

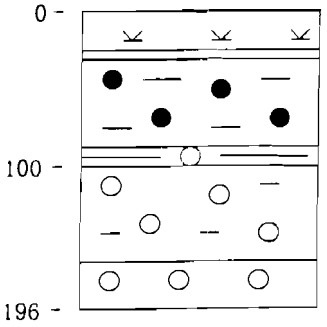
Dark yellowish brown peat 10 yr 4/2 Scattered sand and pebbles. Some sand and abundant wood chunks.

Dusky brown muddy sand 10 yr 2/2

Light bluish gray sand 5 B 7/1, with scattered pebbles. Yellow stains and mottles. Staining becomes orange towards the bottom

AB 91-4-9

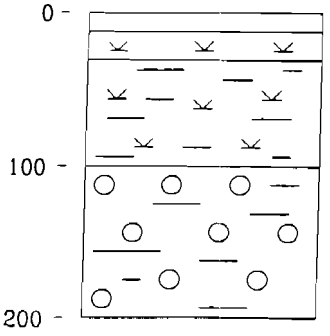
cm



Dark yellowish brown peat, 10 yr 4/2
NR
Med to coarse sand with little mud
Color ranges from 10 yr 4/2 to light olive gray.
Sandy mud with abundant organics
Fine to med sand with little mud.
Light olive gray 5 y 6/1. Scattered pebbles
Yellowish gray sand 5 y 8/1, pebbles

LR 91-L-1

cm



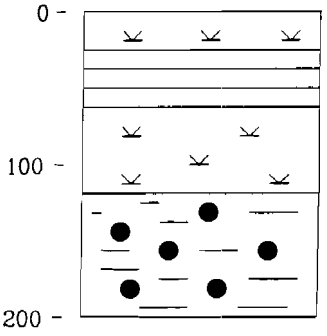
NR
Dark gray peat, N3. Roots and fibres

Mud/peat, color ranges from dark yellowish brown 10 yr 4/2 to olive gray/black 5 y 3/1

Sandy mud 10 yr 3/2
Looks like pre-Holocene material at 118 cm

LR 91-L-2

cm



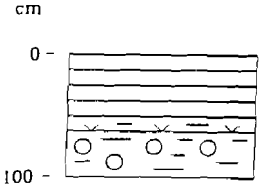
Peat (root mat) olive black 5 y 2/1

Mud with abundant plant fragments 5 y 3/1

Peat, 10 yr 4/2, fibrous. Sand grains towards bottom

Muddy med. to coarse sand. Pale/dark yellowish brown 10 yr 5/2.
Pre-Holocene ?

LR 91-L-3

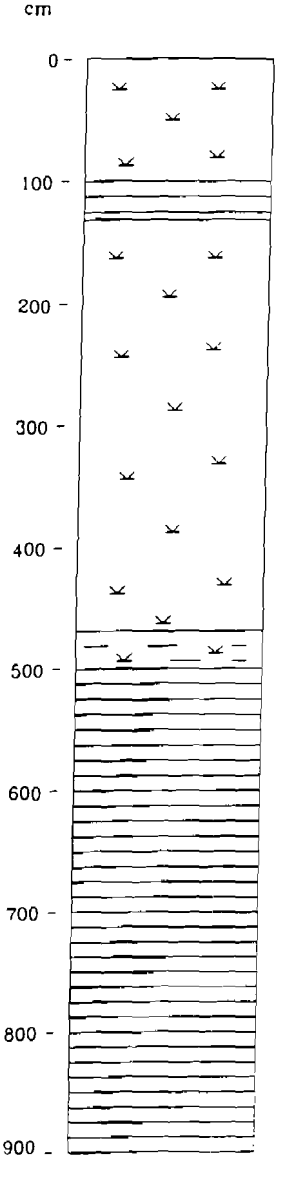


Mud with abundant plant fibres, rhizomes. Olive gray 5 y 3/1

Mud/peat, abundent fibres 10 yr 3/2

Sandy mud, low organics, 10 yr 3/2, becomes dense at bottom (pre-Holocene ?)

LR 91-L-4



Dark gray peat N 3 , becomes peat/ mud at bottom.
Living roots and rhizomes

Mud with scattered organic matter. Olive gray/black 5 y 3/1. Fibres increase toward bottom

Fibrous peat, almost no mud and no wood fragments. 10 yr 2/2..

Some mud down at about 300 cm.

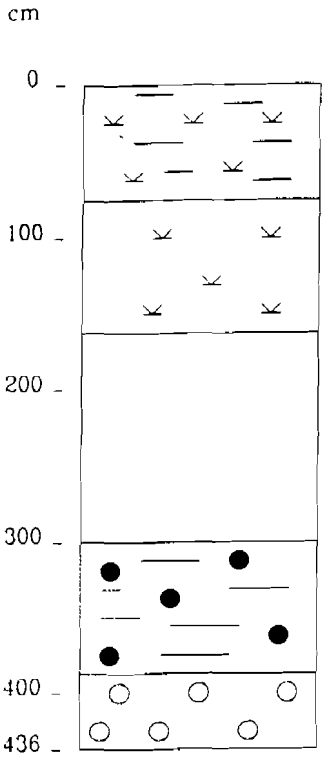
Becomes an olive gray mud/peat in some places

NR between 157-174 cm
194-200 cm
288-300 cm

Mud/peat, olive gray 5 y 2/1, patchy organic distribution

Mud (clay) with isolated plant fragments.. Olive gray 5 y 4/1. Occasional patches of fine scattered sand.
Some fine laminae towards the bottom

LR 91-L-5



Estuarine mud/peat, dark gray N3
Living roots

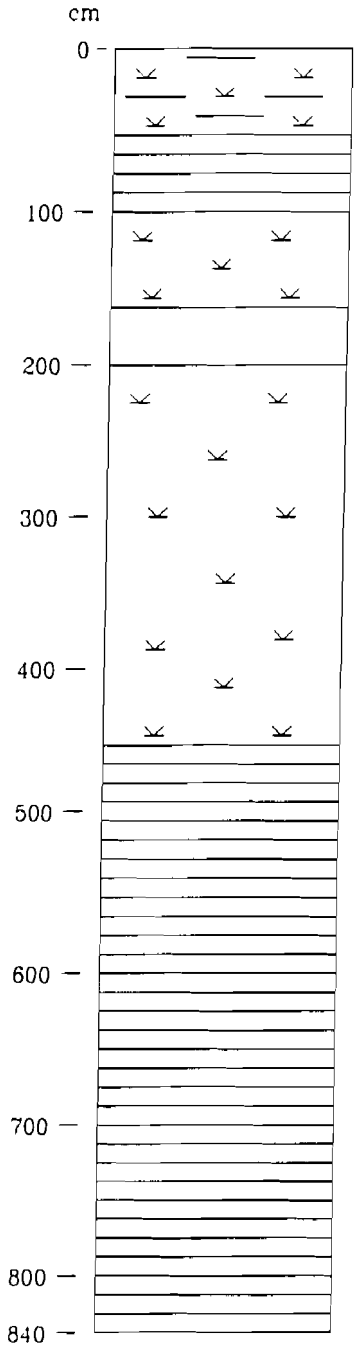
Dark yellowish brown peat, 10 yr 4/2
Fibres, rhizomes, and plant fragments abundant. Scattered sand

NR (loose peat??)

Muddy sand with plant fragments.
Appears estuarine.

Med to coarse sand, olive gray 5y 4/1
Pre-Holocene?

LR 91-L-6



Estuarine mud/peat, dark gray N3
Living roots and rhizomes

Mud, olive gray 5 y 4/1. Abundant fibres.

Peat. Abundant fibres and vertical stalks.

NR

Peat (same as the above unit) Seems to be more mud.

Appears to be a fresh water peat.

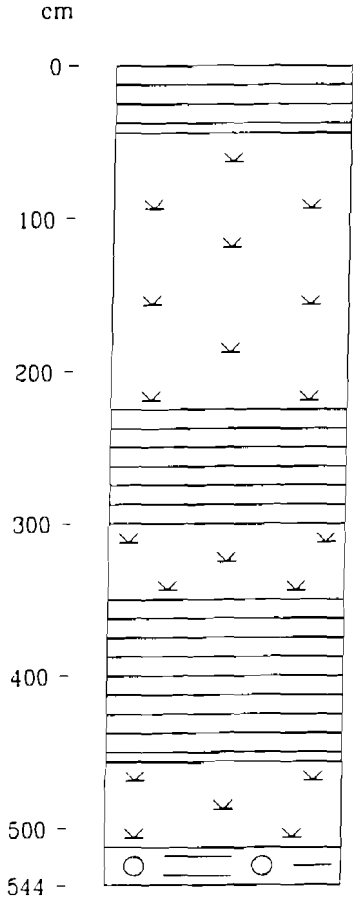
Mud, medium gray, N5. Appears estuarine. Scattered plant fragments.

Scattered sand encountered at 500-600 cm.

More compact from 600-815 and less plant remains.

Mud with scattered plant fibres and sand. Dark yellowish brown 10 yr 4/2. Appears to be more organics than in the above unit. (815-840)

LR92-DC-1



Estuarine mud. Dark greenish gray 5GY 4/1. Living roots and rhizomes

Peat (appears to be freshwater) Few pieces of wood

dusky brown 5yr 2/2

Mud with abundant organics. Mainly fibres. Olive gray 5y 4/1. The upper contact is gradational. Increase in organic matter in the bottom 20 cm

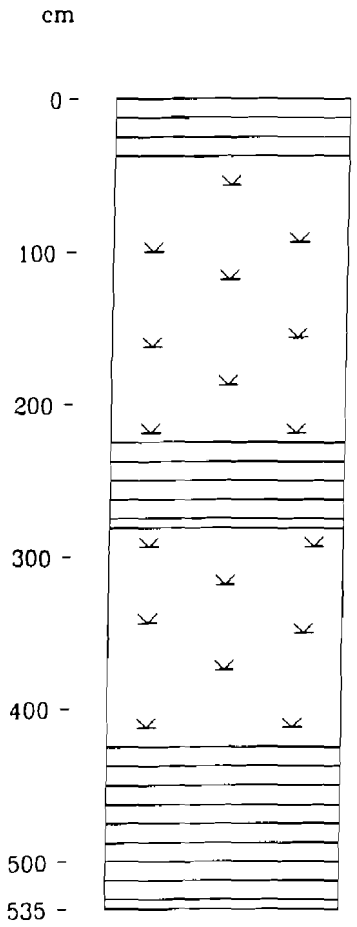
Fibrous peat.. Dusky brown 5yr 2/2

Organic rich mud. black N1 Scattered rhizome or stem fragments near the top of unit. Mud is dense with scattered sand.

Peat, appears to be freshwater Moderate brown 5yr 3/4

Laminated sandy mud and sand. Olive black to dark gray N4

LR92-DC-2



Estuarine mud. Dark greenish gray 5 gy 4/1. Abundant rhizomes and rootlets

Peat, appears freshwater. Dusky brown 5yr 2/2
Scattered wood fragments

Gradational lower contact

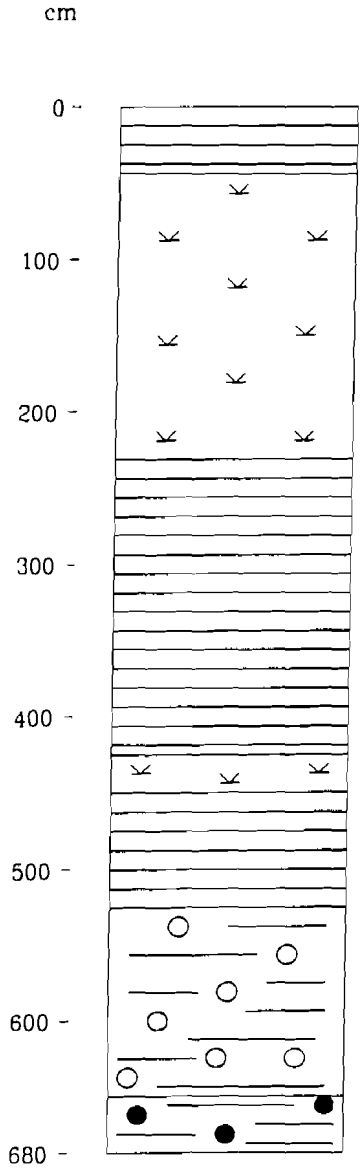
Mud with abundant organics (mainly fibres) Olive gray 5y 4/1

Peat. Olive black 5y 2/1
Wood fragments

Mud with fine scattered sand. Olive gray (5y 4/1) to black (N1).
Scattered wood and plant fragments.

Few sand laminae around 500 cm
Bottom 15 cm ranges from sandy mud to muddy sand. Scattered (vertical?) roots

LR92-DC-3



Estuarine mud. Dark greenish gray 5gy 4/1. Abundant roots and rhizomes

Peat. (appears to be freshwater) Dusky brown 5yr 2/2 Scattered wood fragments

Mud, dusky brown 5yr 2/2. Scattered sand grains. Sand content increases towards the bottom

Peat, olive gray 5y 3/1 Abrupt upper contact

Mud. Dark greenish gray 5 gy 4/1 Organic content varies from abundant to scattered. Few grains of sand. Sharp lower contact

Sandy mud. Olive black 5y 2/1 Vertical(?) rootlets . Scattered wood fragments and leaves.

Muddy fine sand Olive black 5y 2/1

SUB-APPENDIX II. DIATOM ANALYSIS

THE ACADEMY OF NATURAL SCIENCES

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PATRICK CENTER FOR ENVIRONMENTAL RESEARCH

May 3, 1992

Dr. James Pizzuto
Geology Department
University of Delaware
Newark, DE 19711

Dear Jim:

Enclosed are the Academy's final qualitative findings on the 24 sediment samples you sent us for diatom analysis. Apart from a few editorial corrections, there are no changes in our findings from the draft I prepared for you several weeks ago.

Each raw sample (approximately 0.5 cc) was prepared by boiling in concentrated nitric acid to rid the sample of organic detritus and to reveal the fine structures of the siliceous diatom frustules. Each sample was then rinsed and decanted several times using deionized water until the water\diatom suspension was near neutrality. Samples were then permanently mounted on glass microscope slides using Hyrax mounting medium. Dr. Charles Reimer then examined each interval first under low magnification (450 X) and then under high magnification (1100 X oil immersion lens). Dr. Reimer first estimated the percentage of diatom material present, and then recorded the taxa present in the order encountered on the slide. As this was a qualitative assessment, taxa were identified to species and/or varieties where immediate identification was possible, and to genus where additional taxonomic work would be required for species identification. In most cases, even if a positive species identification has not been made, the taxon could be characterized as to its salt requirements (i.e., brackish vs. freshwater taxon).

The comments on the environment that follow each taxa listing are based on the relative numbers of the various taxa present and reflect Dr. Reimer's considerable experience with diatom communities and assemblages throughout the world.

THE ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA · 19TH & THE PARKWAY, LOGAN SQUARE · PHILADELPHIA, PA 19103

If you have any questions concerning the enclosed findings, please do not hesitate to call me (302 366-8884). A copy of this report will be archived in the Editorial Section of the Division of Environmental Research.

I hope the information contained within this report will be useful in your attempts to reconstruct the history of your study area. Please consider us if you require these kinds of analyses in the future.

Sincerely,

John W. Sherman
Senior Scientist

cc: R. Davis, Editorial
C. Reimer

AB 91-1-2-26-30

~40% diatom material, no distinct dominant, good preservation. *Fragilaria virescens* common, *Eunotia* spp., several *Pinnularia* spp. (large, coarsely striated forms), *Meridion circulare*, *Neidium bisulcatum*, minor numbers of *Nitzschia* fragments.

Environment: Freshwater. Periphytic forms dominate. Very minor planktonic element, stream or freshwater tidal influence, relatively shallow.

AB 91-2-2-7-9

~20% diatom material, no distinct dominant, high diversity, sample heavy with inorganic sediment. *Stauroneis smithii*, *Meridion circulare*, *Nitzschia* cf. *obscura*, *Nitzschia* cf. *vitrea*, freshwater *Diploneis*, *Navicula* spp., fragments of large *Nitzschia* and *Surirella* spp., *Bacillaria paradoxa*, *Stauroneis* sp., *Amphora* cf. *ovalis*, *Pinnularia* spp., *Cymbella* sp., *Gomphonema* sp., *Navicula placenta*.

Environment: Freshwater. Shallow. Periphytic forms dominate, large benthic forms relatively common.

AB 91-2-2-208-212

~5% diatom material, frustules very sparse amid medium to coarse silt particles, poor preservation. *Rhopolodia* sp., *Cocconeis* sp., *Fragilaria brevistriata*, *Diploneis oblongella*, freshwater centric, *Melosira* sp., *Eunotia* sp., *Navicula confervacea*, *Achnanthes* sp., portion of brackish water *Diploneis* sp.

Environment: depositional environment of higher energy than previous samples. Sediments appear to be reworked. Fundamentally a freshwater assemblage with very minor brackish water components.

AB 91-2-3-185-190

~5% diatom material, inorganic particles somewhat smaller than above sample. Material less reworked, diatom frustules not as broken up. Freshwater sponge spicuole, *Achnanthes* sp.,

Navicula placenta, *Stauroneis smithii*, *Navicula contenta*, *Eunotia* sp., freshwater *Melosira* sp., *Achnanthes* spp., *Navicula* spp., *Meridion circulare*, *Amphora* sp.

Environment: Distinctly freshwater assemblage, large proportion of periphytic forms, fairly shallow water.

AB 91-2-6-50-54

~40% diatom material, very rich, diverse sample. *Epithemia* sp., *Navicula* spp., *Gomphonema* spp., large *Eunotia* (*monodon* group), *Rhopolodia* sp., *Navicula* cf. *anglica*, *Nitzschia parvula* v. *terricola*, *Achnanthes* spp., *Tabellaria* sp., *Navicula contenta*, *Navicula pseudoscutiformis*.

Environment: Freshwater, suggestion of being rather shallow, pond-like. *Navicula* cf. *anglica* and *Nitzschia parvula* v. *terricola* are forms often found in moist soils.

AB 91-3-2-48-50

~15% intact diatom frustules, high diversity. *Gomphonema acuminatum*, *Frustulia* sp., small *Eunotia* spp., *Melosira* sp., *Navicula confervacea*, *Meridion circulare*, *Fragilaria brevistriata*, *Cymbella* sp., *Pinnularia* sp.

Environment: strictly freshwater, no brackish water influence.

AB 91-3-2-148-150

~15% diatom material. *Stauroneis* sp., *Eunotia formica*, *Achnanthes peragalli*, freshwater *Cyclotella* sp., *Navicula* spp., *Cocconeis* spp., *Achnanthes* spp., *Cocconeis placentula*, *Caloneis lewisii*, *Opephora* sp., *Navicula bryophila*.

Environment: Similar to shallower sample above. Strictly freshwater. Periphytic forms predominate.

AB 91-3-2-212-215

~30% intact diatom frustules. Large *Pinnularia* sp., *Navicula contenta*, *Achnanthes peragalli*, poorly preserved *Cyclotella* frustules, *Opephora* sp., *Amphora* sp., small *Pinnularia* sp., *Navicula mutica* type, *Frustulia* sp., *Gomphonema* sp., *Eunotia* sp., *Cocconeis* sp.

Environment: Fresh, shallow water. Possible lake influence

(*Cyclotella* frustules).

AB 91-3-3-148-152

~30% diatom frustules. *Stauroneis phoenicenteron*, *Epithemia argus*, *Navicula* spp., *Capartogramma crucicula*, *Navicula radiosa*, *Synedra ulna*, *Cocconeis placentula* v. *euglypta*, *Pinnularia* spp., *Cocconeis* spp., *Melosira ambigua/italica* group.

Environment: Strictly freshwater.

AB 91-4-1-206-210

~30% diatom frustules. *Navicula circumsuta* type, *Surirella* spp., *Navicula americana* var. *moesta* (pond form), *Caloneis* sp., several *Pinnularia* spp., *Rhopolodia* sp., *Stauroneis* sp., *Navicula pusilla*, *Gomphonema grovei*, *Cymbella aspera*, *Cyclotella striata*, *Surirella pisonis*, *Neidium iridis* v. *ampliata*, *Gyrosigma* sp., *Rhaphoneis* sp. (slightly brackish water).

Environment: Lake-like environment (?), large, benthic forms present. The assemblage of this interval has brackish water components, sediments deposited in brackish water environment possibly washed in to the predominantly freshwater sediments. The brackish and freshwater diatom components do not suggest a transitional environment, rather post-depositional mixing.

AB 91-4-1-412-417

~40% diatom material. *Gyrosigma scalproides*, *Cyclotella striata*, *Fragilaria harrisonii*, *Rhopolodia gibba*, large *Opephora* sp., *Caloneis hyalina*, *Achnanthes* spp., freshwater *Pinnularia*, *Eunotia lunata*, *Coscinodiscus* sp., *Navicula confervacea*, *Capartogramma crucicula*, *Meridion circulare*, *Melosira sulcata*, *Actinoptychus* sp.

Environment: Real mixture of fresh and brackish water forms. This assemblage characterizes a transitional environment with freshwater and brackish water forms well represented, however, freshwater forms predominate.

AB 91-4-3-167-170

~10% diatom material, diatoms highly fragmented. *Bacillaria paradoxa*, *Epithemia* sp., large *Eunotia* spp., *Achnanthes*

coarctata, *Nitzschia parvula*, *Eunotia lunaris*, *Diploneis* sp., *Amphora ovalis*, *Melosira italica/ambigua* group, *Stauroneis salina*.

Environment: Fresh and brackish water forms are mixed with the assemblage on a whole suggesting higher conductivity water than sample AB 91-4-1-412-417. *Achnanthes coarctata* is a fairly brackish water form.

AB 91-4-3-410-414

~50% diatom material. Dominant diatom taxa are *Fragilaria construens* and varieties. Other taxa include *Melosira ambigua*, *Gomphonema acuminatum* and varieties, *Hantzschia amphioxus*, *Eunotia formica*, *Fragilaria brevistriata*, *Gomphonema parvulum*, *Navicula confervacea*, *Meridion circulare*, *Epithemia* sp., *Cocconeis placentula* v. *lineata*, *Achnanthes lanceolata*.

Environment: Freshwater. Shallow water, slow-moving stream or shallow lake.

AB 91-4-6-291-296

~20% diatom material. *Achnanthes hungarica*, *Cyclotella striata*, *Coscinodiscus* sp., *Fragilaria brevistriata*, *Nitzschia* sp., *Achnanthes lanceolata*, *Rhopolodia gibba* v. *vanheurckii*, *Fragilaria harrisonii*, large *Eunotia* sp., *Amphora* sp., *Achnanthes hungarica*, *Gomphonema acuminatum*.

Environment: Predominantly a freshwater assemblage with a very minor brackish water component. Large number of epiphytic forms suggests abundant growth of aquatic plants.

AB 91-4-6-501-504

~5% diatom material. *Amphora perpusilla*, *Eunotia ambigua*, *Opephora martyii*, *Achnanthes peragali*, *Fragilaria virescens*, *Meridion* sp., *Opephora* sp., *Gomphonema acuminatum*, *Gomphonema grovei*, *Caloneis hyalina*.

Environment: Same as above sample. Predominantly a freshwater assemblage with a very minor brackish water component.

LR 91-L-6-78-85

~10% diatom material. *Nitzschia parvula*, *Nitzschia hungarica*, *Amphora* sp., *Cyclotella striata*, *Coscinodiscus* sp.,

Nitzschia cf. *fasciculata*, *Nitzschia tryblionella*, *Rhaphoneis* sp., *Amphora* cf. *acutiuscula*, *Bacillaria paradoxa*, *Nitzschia pygmea*, *Navicula salinarum*, *Nitzschia sigma*, *Nitzschia parvula*, *Eunotia* sp.

Environment: Mostly brackish water forms with few freshwater varieties mixed in. Possibly the in-land portion of a salt marsh.

LR 91-L-6-347-351

~10% diatom material. *Navicula hungarica*, *Caloneis hyalina*, *Eunotia* sp., *Cyclotella striata*, *Nitzschia* cf. *parvula*, *Diploneis puella*, *Navicula punctata*, *Bacillaria paradoxa*, *Achnanthes hauckiana*.

Environment: Lightly brackish water, relatively stable with minor freshwater influence.

LR 91-L-6-650-655

~10% diatom material. *Navicula* cf. *circumtexta*, *Gyrosigma scalproides*, *Gyrosigma* sp., *Navicula hungarica*, *Denticula elegans*, *Cymbella* sp., *Navicula lyrata* type, *Caloneis* sp., *Nitzschia punctata*, *Gyrosigma attenuatum*, *Coscinodiscus* sp., *Rhopolodia gibberula*, *Achnanthes parvula*, *Rhaponeis* sp.

Environment: Slightly brackish water with very little freshwater influence.

SJ 91-1-147-150

~10% diatom material. *Navicula* cf. *placenta*, *Melosira sulcata*, *Coscinodiscus* sp., *Stauroneis* spp., *Frustulia vulgaris*, *Rhopolodia gibberula* type, *Navicula mutica* v. *stigma*, *Eunotia formica*, *Eunotia lunaris* type, *Meridion circulare*, *Fragilaria marginistriata*, *Eunotia* sp., freshwater *Melosira*, *Eunotia pectinalis*.

Environment: predominantly freshwater assemblage with few brackish water forms admixed.

SJ 91-1-247-253

~15% diatom material. Freshwater sponge spicuole, *Eunotia formica* group, *Neidium* sp., *Neidium iridis* v. *subundulatum*, *Eunotia pectinalis*, *Gomphonema* sp., *Cyclotella striata*, *Fragilaria marginestriata*, *Navicula dicephala*, *Pinnularia* sp., *Rhopolodia gibba* type, *Gomphonema* sp., *Actinoptychus* sp.

Environment: Predominantly freshwater assemblage (*Actinoptychus* considered an incidental occurrence).

SJ 91-1-447-450

~5% diatom material. *Navicula mutica*, *Cyclotella striata*, *Pinnularia* sp., *Denticula* sp., *Pinnularia acrospheria*, *Gomphonema turris*, *Cyclotella meneghiniana*, *Navicula bacillum*, *Meridion circulare*, siliceous plant parts belonging to the grasses.

Environment: freshwater, shallow environment, possibly an intermittent pond.

SJ 91-3-47-52

~50% diatom material. Dominance of *Fragilaria construens* in all fields along with a large number of *Melosira* cf. *distans*. *Gomphonema turris*, *Tabellaria* sp., *Stauroneis* sp., *Eunotia* sp., *Fragilaria harrisonii*, *Achnanthes marginulata*, *Neidium* sp., *Anomoeneis* sp.

Environment: Freshwater, shallow lake-like environment, circum-neutral to slightly acid with no brackish water influence.

SJ 91-3-213-215

~40% diatom material. *Navicula halophila*, *Melosira sulcata*, *Pinnularia obscura*, *Rhaphoneis* sp., *Coscinodiscus* sp., *Pinnularia viridis*, *Diploneis* cf. *bombus*, *Stauroneis* sp., *Navicula* pygmea group, *Eunotia* spp., *Eunotia formica*, *Navicula bacillum*, *Cyclotella striata*, *Capartogramma* sp.

Environment: Both fresh and brackish water influences with predominance of freshwater forms; freshwater periphyton with brackish water plankton varieties suggests a shallow freshwater pool intermittently inundated by brackish water.

SJ 91-3-405-407

~30% diatom material. *Nitzschia lorenziana*, *Cyclotella striata*, *Cymatosira belgiqua*, *Nitzschia punctata*, *Navicula lirata* group, *Stauroneis* sp.

Environment: Strong preponderance of medium conductivity forms with very few true freshwater varieties suggests a relatively stable, slightly brackish water enviroment.

SUB-APPENDIX III. SEED IDENTIFICATIONS

NOTES ON SEED IDENTIFICATIONS

Seeds were assigned to a species when identification was virtually certain. A seed which is reasonably identifiable to a taxon is listed as "cf", usually because the seed is either fragmentary or because comparative material is lacking. A seed that closely resembles a particular taxon but which may belong to a closely related species with a similar seed morphology is listed as "type".

Carex lurida type: seeds resemble this species in general shape but are smaller and lack the extended, curled style of this species. The style in the seeds recovered from these sediments is short and straight or slightly curled.

Polygonum cf. punctatum: Seeds of *Polygonum* in these samples are both trigonal and flattened like *P. punctatum*. Other species with a similar seed morphology are *P. sagittatum* and *P. hydropiperoides*. One seed in particular is unmistakably *P. punctatum* because it had preserved the sheath with glandular dots, a feature that is characteristic of the species. *P. punctatum* is a common species in regularly flooded locations within freshwater tidal marshes.

Eleocharis ambigens type: Seeds in these samples most closely resemble this species, but without complete comparative material of all species in the genus, the identification is tentative.

Eupatorium/Mikania: Fossils, which are black, closely resemble *Eupatorium perfoliatum* in color and size but lack glandular dots and the ends of the fossil seeds are not as tapered as those of extant seeds. The fossil seeds also resemble closely *Mikania scandens* in shape and size, but lack glandular dots and the brown color of *Mikania*. The fossils do not resemble any other taxa within the Compositae.

DELAWARE SEDIMENT SAMPLES
ALSTON BRANCH
AB 91- 1 -2

	A (10-15 cm)	B (55-60 cm)
EMERGENTS	# seeds 100 cm^{-3}	# seeds 100 cm^{-3}
Carex sp.	9.0	0
Carex lurida	0	14.4
Carex lurida type	0	9.6
Carex sp. *B*	4.5	4.8
Carex sp. *C*	0	67.2
Polygonum arifolium	4.5	9.6
P. punctatum	0	9.6
Gramineae sp.	4.5	0
Panicum sp.	0	9.6
Bidens laevis	0	4.8
Eupatorium/Mikania	4.5	14.4
UPLAND HERBACEOUS		
Phytolacca americana	0	4.8
WOODY SPECIES		
Almus serrulata	0	201.6
Sambucus canadensis	4.5	0
Liriodendron tulipifera	0	14.4
Other species	4.5	9.6
TOTAL SEEDS	**36.0**	**374.4**
CHARCOAL	0	4.8

Sample A is a peat mud with abundant leaf fragments.
Sample B is a peat mud with fewer leaf fragments than in A and also with woody stems

DELAWARE SEDIMENT SAMPLES
ALSTON BRANCH
AB 91 - 4 - 3

	A 30-35 cm # seeds 100 cm^{-3}	B 190-195 cm # seeds 100 cm^{-3}	C 250-255 cm # seeds 100 cm^{-3}	D 450-455 cm # seeds 100 cm^{-3}	E 450-455 cm # seeds 100 cm^{-3}
SUBMERGED AQUATICS	0	0	0	0	0
EMERGENTS					
Cyperaceae sp.	0	7.1	0	9.1	0
Carex lurida type	6.3	14.2	0	45.5	5.9
Carex lupulina type	0	0	7.1	0	0
Carex sp. *B*	0	0	0	0	0
Dulichium sp.	0	0	0	0	23.6
Polygonum cf. *punctatum*	6.3	7.1	0	27.3	11.8
Polygonum sp.	0	0	0	9.1	0
Acnida cannabina	0	7.1	0	0	0
Bidens laevis	0	0	0	0	23.6
Viola papillionacea	18.9	0	0	0	0
Impatiens capensis	0	0	0	0	5.9
Other emergents	12.6	21.3	0	0	35.4
WOODY SPECIES					
Alnus serrulata	18.9	14.2	14.2	9.1	5.9
cf. Cornus ammomum	6.3	0	0	9.1	0
Viburmum dentatum	6.3	0	7.1	0	0
Other woody species	18.9	0	0	9.1	0
TOTAL WOODY SPECIES	**50.4**	**14.2**	**21.3**	**27.3**	**5.9**
CHARCOAL	18.9	7.1	0	0	0

Samples A, B and C are peat mud with scattered woody plant fragments; D is a herbaceous peat with some woody fragments; E is a mud with herbaceous fragments; F is a peat with herbaceous rhizomes, not much wood and some sand.

DELAWARE SEDIMENT SAMPLES
ALSTON BRANCH
AB 91 - 3 - 2

	A 15-20 cm # seeds 100 cm^{-3}	B 150-155 cm # seeds 100 cm^{-3}	C 260-265 cm # seeds 100 cm^{-3}
SUBMERGED AQUATICS	0	10.6	0
EMERGENTS			
Cyperaceae sp.	18.9	0	0
Carex lurida type	0	5.3	0
Polygonum cf. punctatum	25.2	0	0
Acnida canabina	44.1	0	0
Bidens laevis	0	26.5	0
Eupatorium/Mikania	0	15.9	5.6
Other emergents	6.3	5.3	11.2
WOODY SPECIES			
Alnus serrulata	0	26.5	0
cf. Lyonia ligustina	0	15.9	0
Sambucus canadensis	0	0	11.2
cf. Pinus rigida	0	0	5.6
Other woody species	0	0	16.8
TOTAL WOODY SPECIES	0	42.4	33.6

There is no charcoal in these samples.
Sample A is mud with herbaceous peat; B is woody peat with abundant leaf fragments; C is mud with herbaceous and woody fragments.

DELAWARE SEDIMENT SAMPLES
ALSTON BRANCH
AB 91 - 1 - 4

	A 20-25 cm # seeds 100 cm^{-3}	B 115-120 cm # seeds 100 cm^{-3}
SUBMERGED AQUATICS	0	0
EMERGENTS		
Acnida cannabina	7.1	0
Other herbaceous species	21.3	0
WOODY SPECIES	0	0

There are very few seeds in these samples and no charcoal. Sample A is a light gray mud with herbaceous peat and includes woody rootlets. B is mud with sand containing sparse plant fragments.

AB 91 - 2 - 3

	A 15-20 cm # seeds 100 cm^{-3}	B 145-150 cm # seeds 100 cm^{-3}	C 205-210 cm # seeds 100 cm^{-3}
SUBMERGED AQUATICS	0	0	0
EMERGENTS			
Viola papillionacea	12.0	0	0
WOODY SPECIES			
Liriodendron tulipifera	8.0	0	0
Prunus serotina	4.0	0	0
CHARCOAL	4 pieces	13.5 pieces	43.8 pieces

These samples contained very few seeds. Sample A is a light grey mud with rootlets; B is mud with rootlets and bark fragments; C is dark mud and sand with scattered plant fragments.

DELAWARE SEDIMENT SAMPLES
LEIPSIC RIVER
LR 91 - L - 6

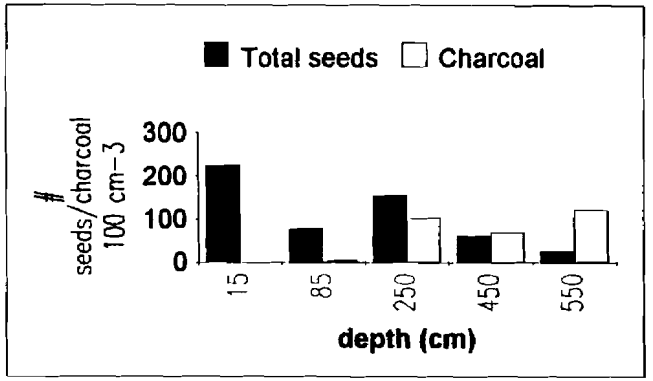
	A 15-20 cm # seeds100 cm^{-3}	B 85-90 cm # seeds 100 cm^{-3}	C 250-255 cm # seeds 100 cm^{-3}	D 450-455 cm # seeds 100 cm^{-3}	E 550-555 cm # seeds 100 cm^{-3}
SUBMERGED AQUATICS	0	0	0	0	0
EMERGENT HERBACEOUS					
Carex sp.	0	0	0	15.4	0
Carex lurida type	0	0	0	7.7	0
Eleocharis ambigens type	0	11.2	117.0	23.1	0
Scirpus validus/acutus	0	5.6			
Polygonum cf. punctatum	0	5.6	3.0	0	3.8
Gramineae sp.	0	0	0	0	19.0
Acnida cannabina	226.8	11.2	0	0	0
Eupatorium/Mikania	0	11.2	30.0	7.7	0
Pontederia cordata	0	0	22.4	0	0
Sagittaria latifolia	0	0	11.2	0	0
Umbelliferae species A	0	0	6.0	0	3.8
Other herbaceous species	0	0	0	7.7	0
WOODY SPECIES	0	0	0	0	0
CHARCOAL	0	5.6 pieces	102 pieces	69.3 pieces	121.6 pieces

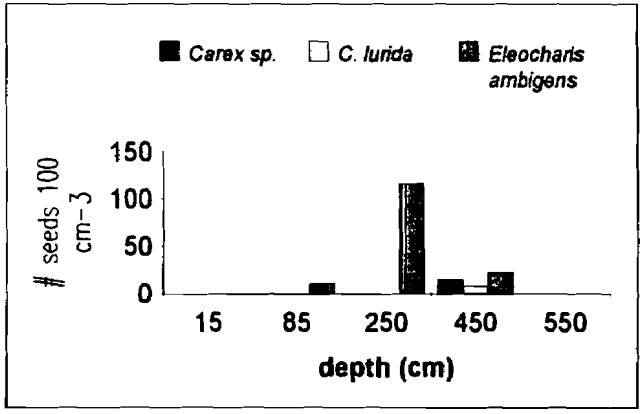
Samples A and B are light gray muds and herbaceous peat; C is a thick herbaceous peat with excellent preservation; D is a black mud with herbaceous peat; E is a light gray mud with herbaceous fragments.

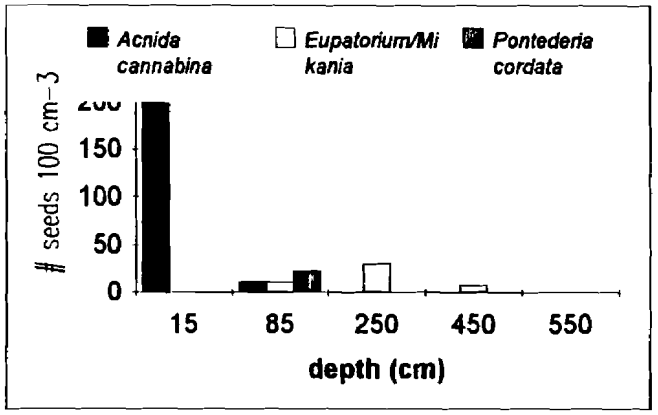
LEIPSIC RIVER

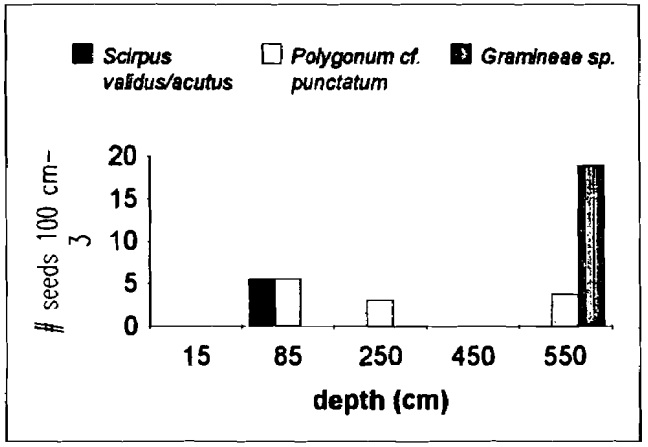
LR 91 - L - 6

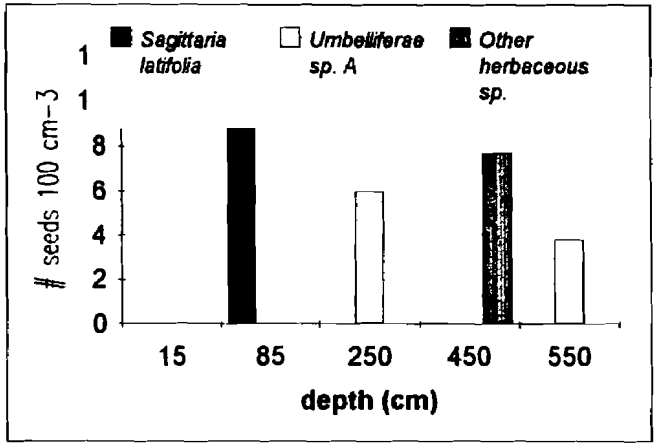
Seed analysis of sediment

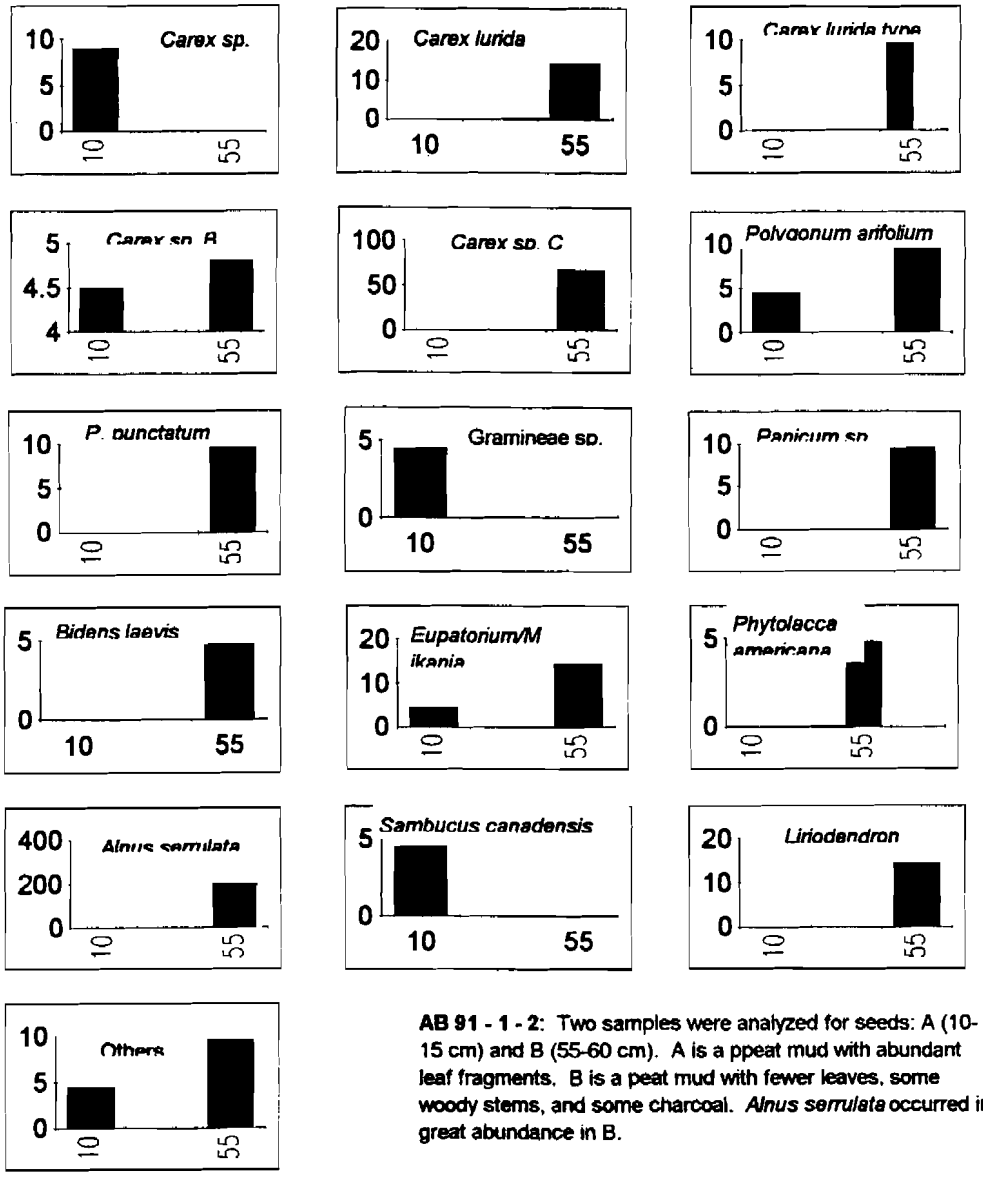




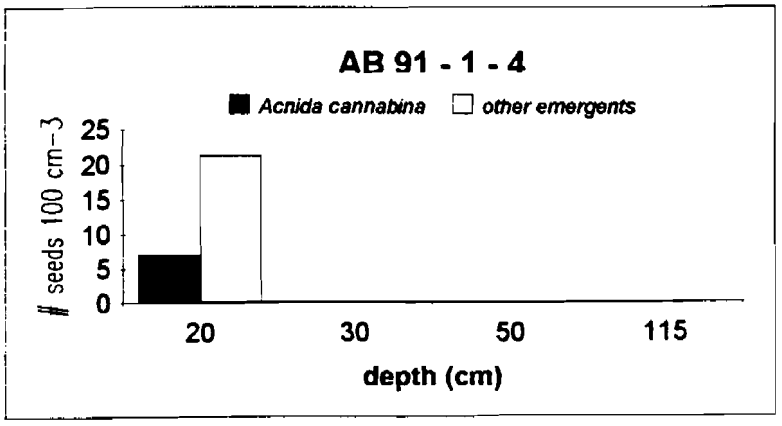




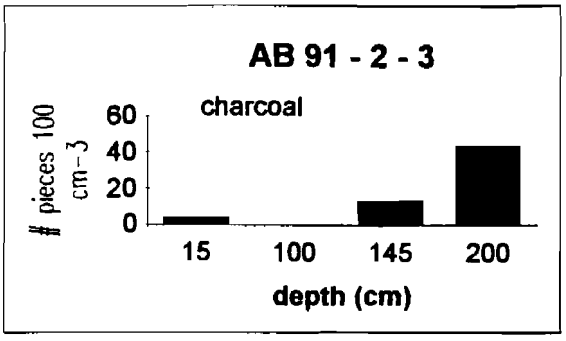


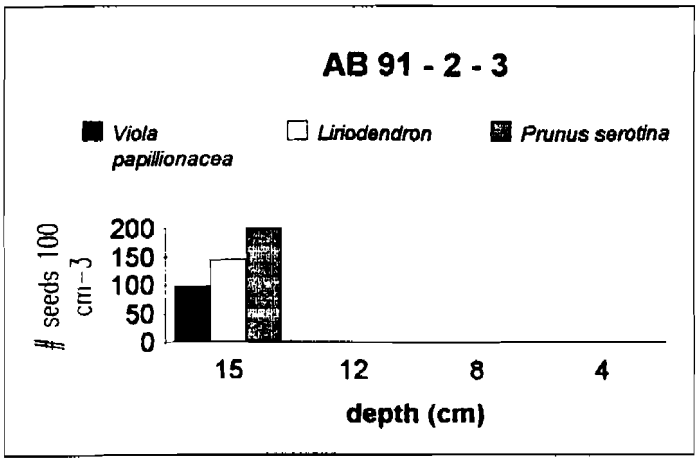


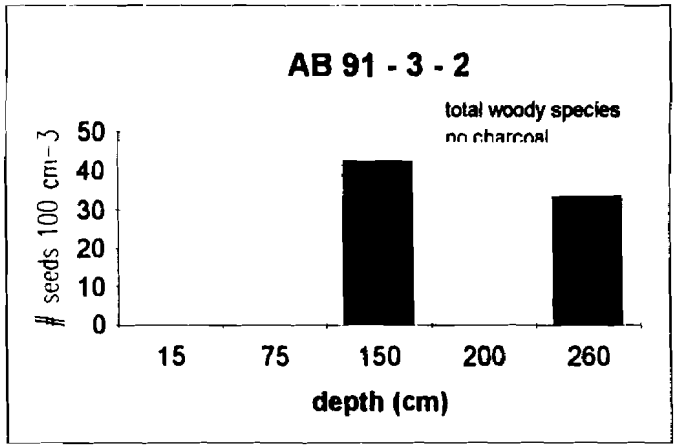
AB 91 - 1 - 2: Two samples were analyzed for seeds: A (10-15 cm) and B (55-60 cm). A is a ppeat mud with abundant leaf fragments. B is a peat mud with fewer leaves, some woody stems, and some charcoal. *Alnus serrulata* occurred in great abundance in B.

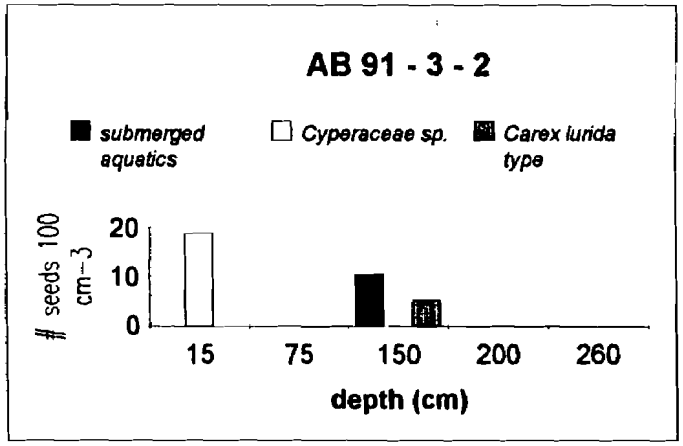


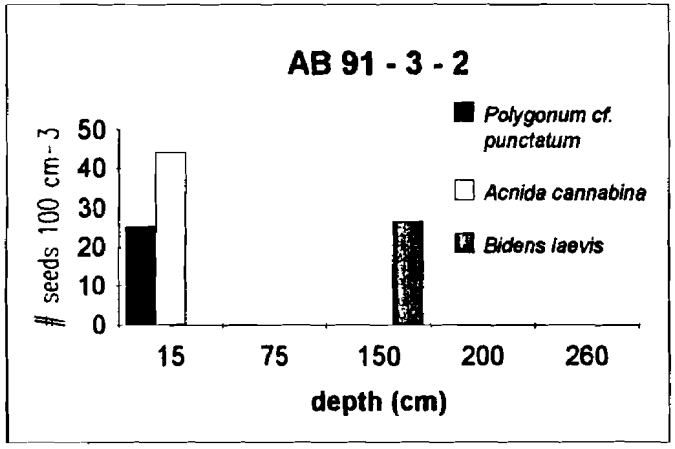
There are very few seeds in these samples

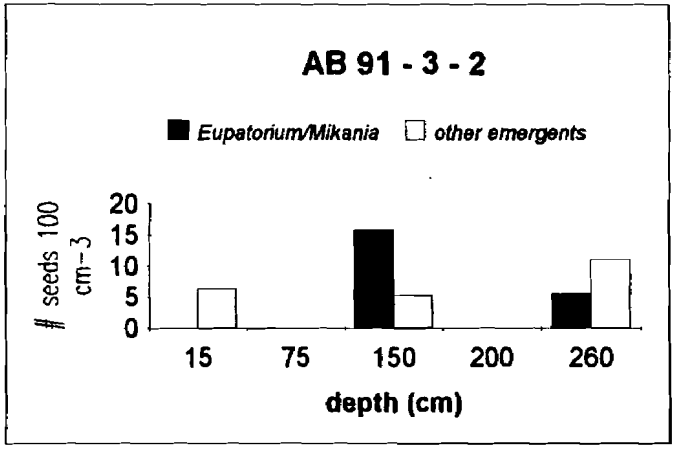


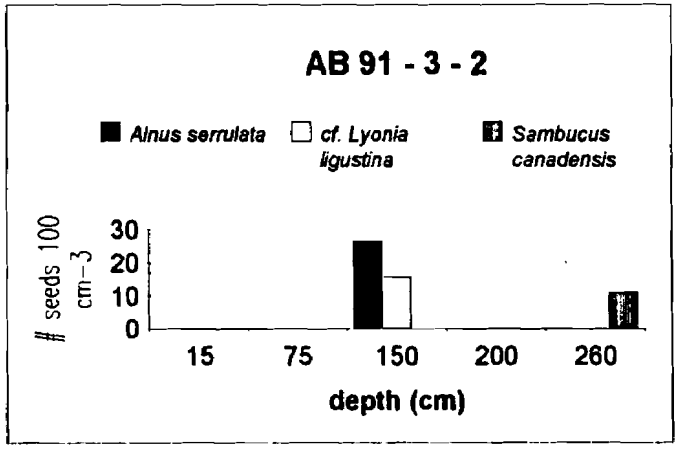


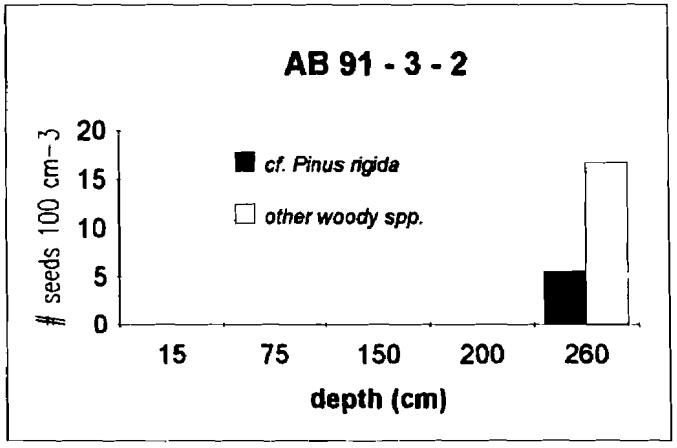

AB 91 - 3 - 2
total woody species
no charcoal
seeds 100 cm-3
50
40
30
20
10
0
15
75
150
200
260
depth (cm)

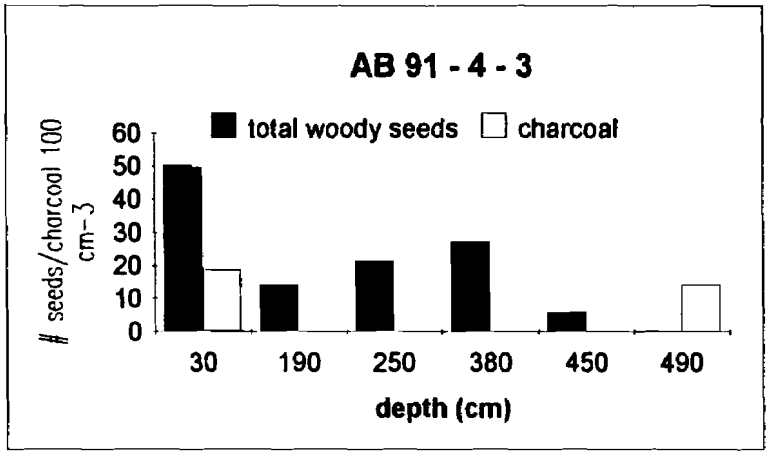

AB 91 - 3 - 2
submerged aquatics
Cyperaceae sp.
Carex lurida type
seeds 100 cm-3
20
10
0
15
75
150
200
260
depth (cm)

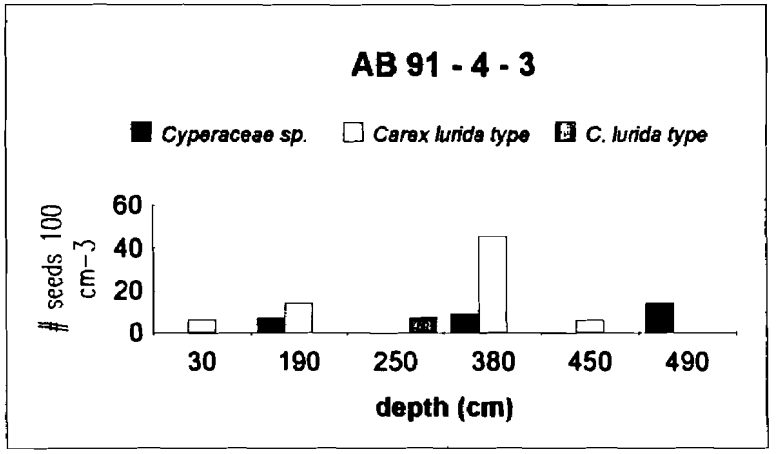

AB 91 - 3 - 2
Polygonum cf. punctatum
Acnida cannabina
Bidens laevis
seeds 100 cm-3
50
40
30
20
10
0
15
75
150
200
260
depth (cm)

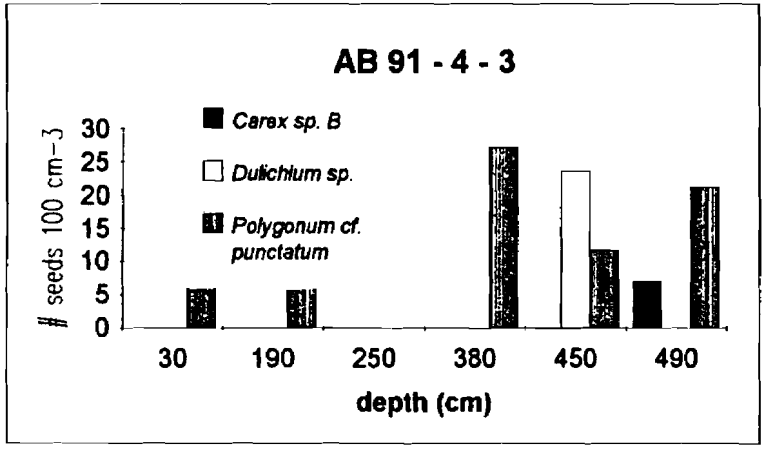

AB 91 - 3 - 2
Eupatorium/Mikania
other emergents
seeds 100 cm-3
20
15
10
5
0
15
75
150
200
260
depth (cm)

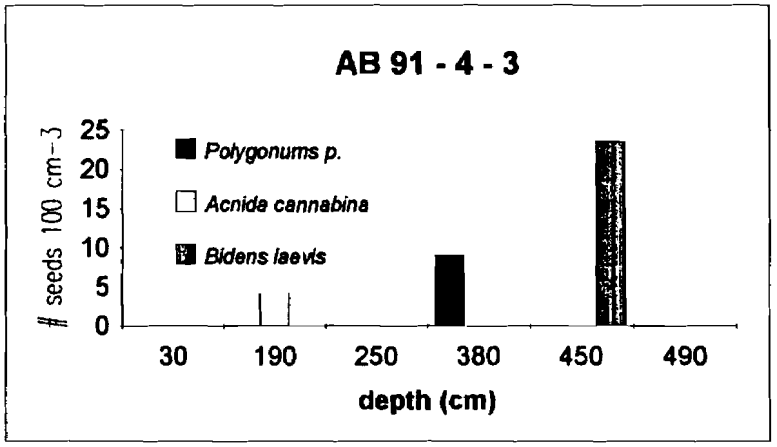

AB 91 - 3 - 2
Alnus serrulata
cf. Lyonia ligustina
Sambucus canadensis
seeds 100 cm-3
30
20
10
0
15
75
150
200
260
depth (cm)

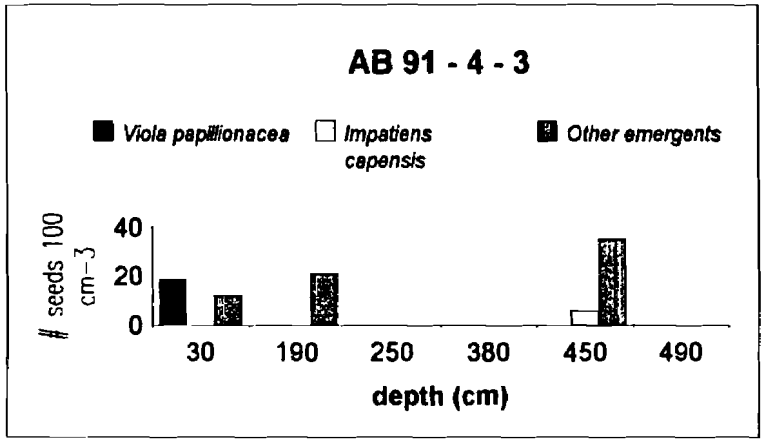

AB 91 - 3 - 2
cf. Pinus rigida
other woody spp.
seeds 100 cm-3
20
15
10
5
0
15
75
150
200
260
depth (cm)

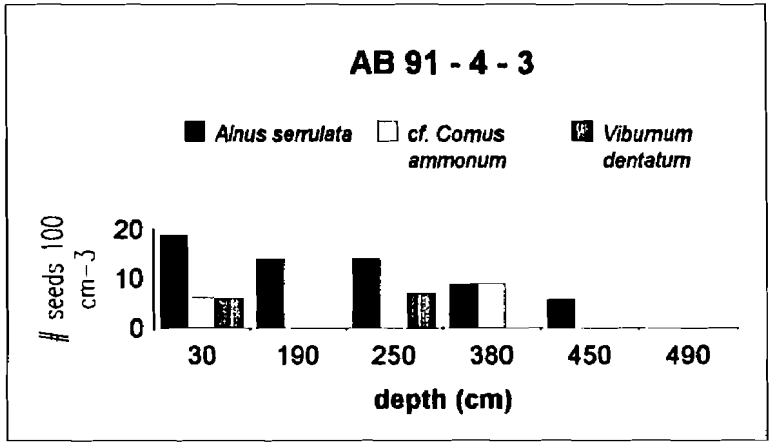

AB 91 - 4 - 3
total woody seeds
charcoal
seeds/charcoal 100 cm-3
60
50
40
30
20
10
0
30
190
250
380
450
490
depth (cm)


AB 91 - 4 - 3
Cyperaceae sp.
Carex lurida type
C. lurida type
seeds 100 cm-3
60
40
20
0
30
190
250
380
450
490
depth (cm)


AB 91 - 4 - 3
Carex sp. B
Dulichium sp.
Polygonum cf. punctatum
seeds 100 cm-3
30
25
20
15
10
5
0
30
190
250
380
450
490
depth (cm)


AB 91 - 4 - 3
Polygonums p.
Acnida cannabina
Bidens laevis
seeds 100 cm-3
25
20
15
10
5
0
30
190
250
380
450
490
depth (cm)


AB 91 - 4 - 3
Viola papillionacea
Impatiens capensis
Other emergents
seeds 100 cm-3
40
20
0
30
190
250
380
450
490
depth (cm)


AB 91 - 4 - 3
Alnus serrulata
cf. Cornus ammonum
Viburnum dentatum
seeds 100 cm-3
20
10
0
30
190
250
380
450
490
depth (cm)