Environmental History of Piermont Marsh, Hudson River, NY

A Final Report of the Tibor T. Polgar Fellowship Program

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ABSTRACT

Although Hudson River wetlands have long attracted the interest of naturalists and scientists, Piermont Marsh has not been studied as extensively as others along the Hudson estuary. The purpose of this study is to provide a broad overview of the paleoecology of Piermont Marsh, particularly changes in vegetation and fluctuations in sea level over time. An 11.15 m core was retrieved from the site and sampled for macrofossils, loss-on-ignition, and pollen grains. The lithology of the core is comprised of peats and clays that vary in color and texture. Several short reversals between peat and clay sediments were found at about the 6 m and 7 m depths. AMS carbon -14 analyses revealed that the marsh is approximately 4190 years old and the rate of deposition in the marsh is 0.26 cm/yr. Loss-on-ignition carbon combustion indicated the marsh has undergone a change in carbon accumulation not exclusively due to sediment oxidation. Percent carbon content ranged from 10% to 41%. Plant macrofossils indicate the core site included sedges throughout much of the history of the marsh. Uppermost sediments are devoid of plant diversity caused by the influx of grass species, which suggests human influence in the marsh. Foraminifera macrofossils revealed marine transgression at the core site. The core stratigraphy revealed shifts between low marsh environments and high marsh environments. The absence of foraminifera specimens at certain depths is a possible indicator of stream influence, a high rate of deposition, or salt pannes. Charcoal particles peaked at 3 m, 7 m, and 11 m depth in the core, which is evidence for a change in fire frequency due to climatic change or from anthropogenic influence.

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INTRODUCTION

This study seeks to answer several specific questions about the paleo environmental conditions of Piermont Marsh, one of the four wetland sites protected by the Hudson River National Estuarine Research Reserve (HRNERR). The questions addressed are as follows:

(1) How old is Piermont Marsh?

(2) Can a study of macrofossils in the sediment and radiocarbon dating demonstrate a chronicled history of sea level change?

(3) How has vegetation changed in Piermont Marsh over time?

- Are these changes indicative of anthropogenic influences?
- When did Phragmites become dominant?

(4) What climatic changes are documented in the pollen grain record of the region?

(5) What is the history of carbon accumulation in the marsh sediment?

Piermont Marsh (40° 00' N, 73 ° 55' W) is situated along the Hudson River approximately 40 kilometers north of the southern tip of Manhattan. It is bordered on the western side by Tallman State Park and Piermont pier forms the Marsh's northern border. It is the nearest of the four designated HRNERR sites to the mouth of the Hudson River. Two meandering creeks, the Crumkill and the Sparkill, run through the approximately two mile long marsh. The average annual temperature for the area is 28.6°C and the average annual precipitation is 108 cm. Like other inland areas adjacent to the coast in the North Atlantic region, the climate at Piermont is subject to continental as well as maritime influences. The mean tidal range for the marsh is 0.98 meters (Winogrond 1997). With a mean salinity of 6 ppt (Winogrond 1997), Piermont is classified as a brackish marsh, but supports salt and freshwater species.

Plant species recorded in a 1967 field study at Piermont, either in the marsh itself or on the pier, include *Spartina alterniflora, Spartina patens, Spartina cynosuroides, Pluchea purpurascens, Iva frutescens, Chenopodium glaucum, Polygonum erectum, Potamogeton perfoliatus, Scirpus robustus, Scirpus americanus*, *Typha glauca* and *Typha angustifolia* (Lehr 1967). The predominant plant species noted in the study was *Typha.* Presently, *Phragmites* constitutes 76% of the marsh vegetation; 4% are *Spartina patens*, *Distichlis* and Saltmarsh grass. The remainder of the plant species consist of *Typha*, *Scirpus americanus*, and Marshmallow (Blair and Nieder 1993).

Piermont Marsh has not been as well-studied as other Hudson River wetland sites further north. The provenance of the Marsh is a particular point of controversy. A video distributed by the Audubon Society entitled <u>Birds of Rockland County</u> suggests the marsh formed as the result of silting after construction of Piermont Pier in the 1850's. However, a map of the Marsh and its surrounding area (Haagensen 1986) was made in 1745 (see Fig. 1) and clearly shows the marsh existed before the pier was built. The only study to contain radiocarbon dates of the marsh located thus far began in 1967 and was

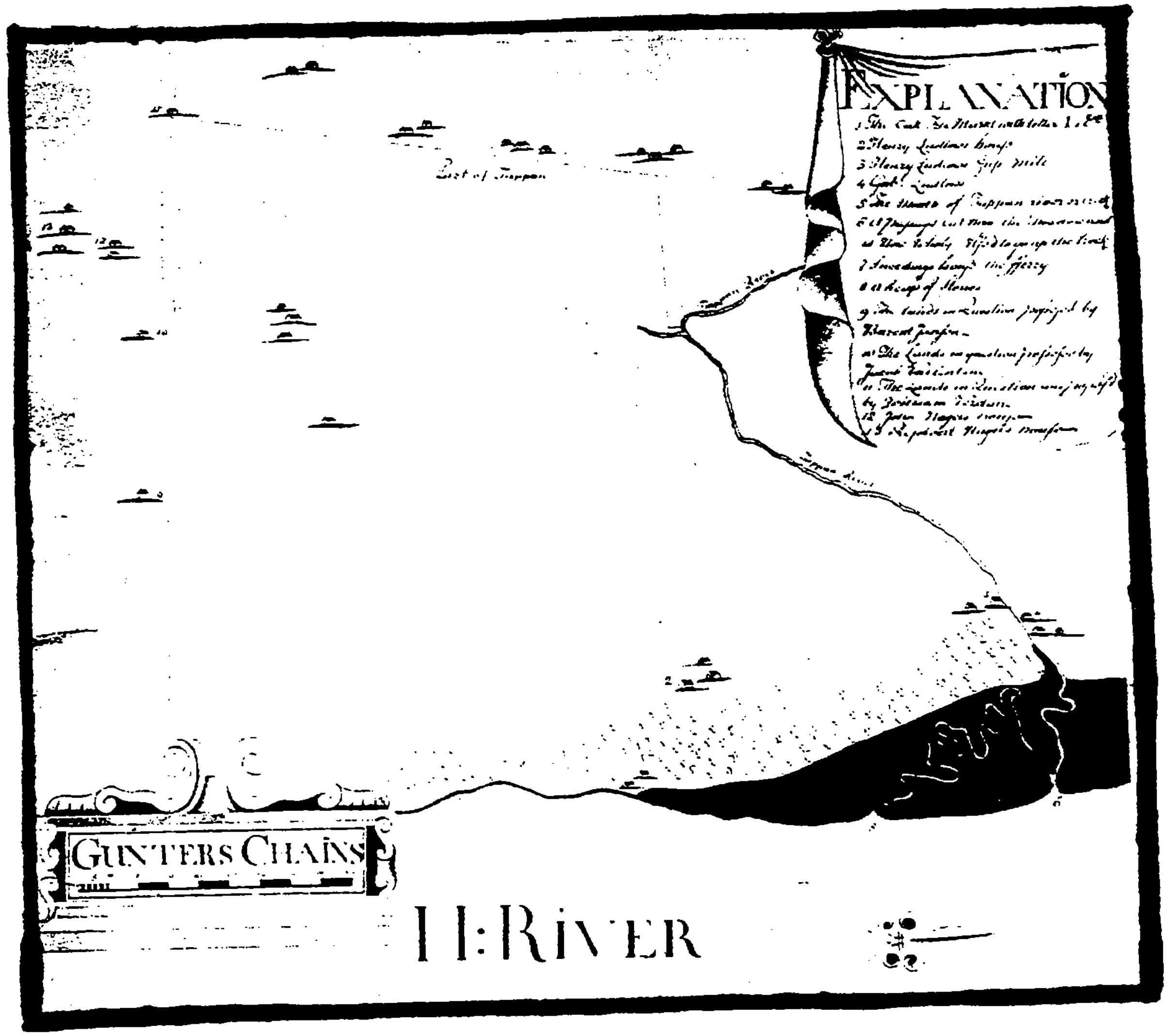
Fascimile of Verplanck Map, 1745
Made by James S. Haring, 1876

Figure 1. Verplanck map of 1745

published in 1987 by Walter S. Newman. The nineteen dates taken at an unnamed location in the marsh indicate that the marsh has been in existence for approximately 6800 years (Newman et al. 1987). A modified 2.54-cm U.S. Geological Survey Davis peat and marl sampler and a 4.5-cm "Dutch" gouge augur were used. Because three or four 20-cm-long sediment samples were pooled in order to obtain enough carbon for dating, the dates probably do not accurately represent the correct ages of stratified layers of marsh sediment.

Our goal was to retrieve a sediment core with a modified 5-cm Livingston piston corer to provide a stratigraphy of the marsh and a chronicled record of its paleoecology. Changes in representative species of flora and fauna deposited in the marsh are used to determine which geological and climatic factors have changed over time. Marsh sediment is typically anoxic and macrofossils, such as foraminifera and seeds, as well as microscopic particles, like pollen grains, are well-preserved in the subsurface.

Plant macrofossils and pollen grains have successfully been used to document local and regional climatic events, geomorphology and human influence. Plant macrofossils may include identifiable plant species representative of high marsh or low marsh environmental conditions. In cores taken from Fresh Pond Marsh and Deep Pond in Long Island, New York, Clark and Patterson (1985) found variations of peat containing *Spartina alterniflora* and *Spartina patens* rhizomes, indicating a change in the level of inundation. A shift in vegetation may also indicate brackish or freshwater conditions (Rue and Traverse 1997). Identifiable plant macrofossils--seeds, wood, needles and stems--are evidence for the local presence of plant species. They are critical for determining vegetative succession because, unlike pollen grains, they are not airborne

and therefore are more reliable for establishing the local presence of species. Furthermore, macrofossils can be classified to the species level whereas pollen often cannot. Carbon from plant macrofossils is also used for Accelerated Mass Spectrometry (AMS) radiocarbon dating.

Another macrofossil indicator of human activity and climate change is charcoal. In addition to pollen and macrofossil evidence, Holocene warming in two cores from Spruce Pond and Sutherland Pond in the Hudson Highlands is supported by charcoal influx (Maenza-Gmelch 1997). Conversely, there were fewer charcoal counts during the period of Younger Dryas cooling. Fires were important in the development of forest flora. For instance, present-day *Quercus* dominance in the Hudson Highland region may be attributed to fires (Clark and Robinson 1993). Charcoal particles may also be indicators of human-induced fires by Native Americans or Europeans.

Unlike macrofossils, pollen grains are assumed to either remain on the marsh surface after deposition or are washed in by incoming tides. Pollen grains therefore represent marsh and upland vegetation from a larger regional area. Regional records of vegetational change in the Northeastern region of the United States have been well established through various palynological studies. For example, significant vegetational changes interpreted from plant macrofossils and pollen grains have been used to document climatic events such as the Younger-Dryas Oscillation (Peteet 1993). One site used for this vegetational history, Alpine Swamp (Peteet 1990), is situated atop the Palisades in Alpine, NJ, not far from Piermont Marsh. The pollen record from Alpine Swamp as well as Sutherland Pond, NY (Maenza-Gmelch 1997) will provide the background upland regional pollen record history from which we can compare the pollen stratigraphy from Piermont Marsh. The pollen grain of weed species, such as *Ambrosia,* are evidence of human activity. They are found in agricultural fields and along roadsides (Niering 1988). A study of pollen and macrofossils in a sediment core taken from the Hackensack Marsh showed an increase in *Ambrosia* pollen frequency to almost 20% in the past 800 years (Carmichael 1980). Decreases in the pollen percentages of certain trees genera, such as *Quercus, Tsuga* and *Pinus,* in the younger sediment of cores obtained from Spruce Pond and Sutherland Pond, both in southeastern New York, are related to their usage in industry (Maenza-Gmelch 1997).

Dating control of post-glacial paleoecological changes is best served by radiocarbon or carbon-14 dating (Bradley 1985). Radiocarbon dating is capable of delineating a time-frame that ranges from paleolithic times to the early historical past. Radioactive carbon is produced in the atmosphere by neutron bombardment of nitrogen caused by cosmic radiation. The carbon-14 atoms descend into the lower atmosphere where they are then incorporated into carbon dioxide and subsequently taken up by plants and animals through photosynthesis and respiration, thereby making them radioactive. After an organism dies the carbon-14 is no longer at equilibrium with the atmosphere and radioactive decay to nitrogen begins. It decays at a negative exponential rate with a half-life of 5730 years. Recent technological developments in mass spectrometry allow for small samples of carbon to be measured. Dating *in situ* stems and seeds provides more accurate dates and control over which detailed parts of the core section is dated.

Changes in the lithology of the marsh stratigraphy indicate the origin of the particles comprising the sediment, and the processes responsible for their deposition. For example, the presence of varved clay under peat in a core retrieved from the Hackensack

marsh in New Jersey suggests a freshwater lake existed prior to the formation of the marsh (Carmichael 1980).

Relative sea level rise is an important aspect of paleoecology addressed in this study. The provenance and extension of coastal salt marshes have been attributed to the rise in global sea level over the past ten thousand years (Redfield and Rubin 1962). Marsh deposition is at equilibrium with relative sea level rise (Varekamp and Thomas 1998). Accelerated sea level rise is counteracted by increased rates of marsh deposition resulting in low marsh environments. Consequently, when marsh accretion exceeds relative sea level rise, a high marsh environment results (Varekamp and Thomas 1998). Marsh submergences and emergences can be recognized from paleoenvironmental analyses of sediment using agglutinated foraminifera as indicators of fluctuations in relative sea level rise.

Sea level changes over time have occurred in response to deglaciation of the polar ice sheets due to higher average global temperatures. Eustatic sea level rise is believed to be the cause of the submergence of the eastern Atlantic coast over the past 7000 years. The average rate of sea level rise in the northeastern United States is 3 mm/yr between 3000 years ago and today (Scott and Medioli 1986, 1987; Gayes et al. 1992). Weiss (1974) found salt water foraminifera in the sediment at Iona Island, another Hudson wetland further north, and hypothesized they were derived from tidal activity. Marsh foraminifera and radiocarbon dates are commonly used to determine the relative rate of sea level rise because their surface distributions are dependent on elevation and salinity (Scott and Leckie 1990). Foraminiferal assemblages in the marsh are sensitive to elevation changes and can be used to locate former sea levels +/- 10 cm (Scott and

Medioli 1986). The high marsh zone from mean high water to highest high water on the landward edge is characterized by the dominance of *Trochammina macrescens.* The relative abundance of *T. macrescens* is inversely proportional to the frequency of flooding (Varekamp et al. 1992; Lomax 1994). The relative abundance of "other species," using *T. macrescens* as the high marsh parameter, is indicative of the frequency of inundation and coastal transgression (Varekamp et al. 1992). More recently, sea level rise has been attributed to human-induced global warming. Our ability to understand the future and present response of marshes to sea level rise is through paleoecological research.

Another facet of marsh paleoecology of great interest is the relative rate that marshes accumulate carbon in their sediment. Preservation of marshes has been prompted in part because of global warming. We know wetlands function as carbon sinks and accumulate significant amounts of carbon. Wetland responses to increases in emitted carbon due to human activity would be beneficial in our understanding of how this complex ecosystem may cope with carbon emissions in the future.

METHODS

Field and Laboratory Methods:

A sediment core was retrieved in Piermont Marsh during the summer of 1998. The core site was in the north central area of the marsh directly south of an unnamed

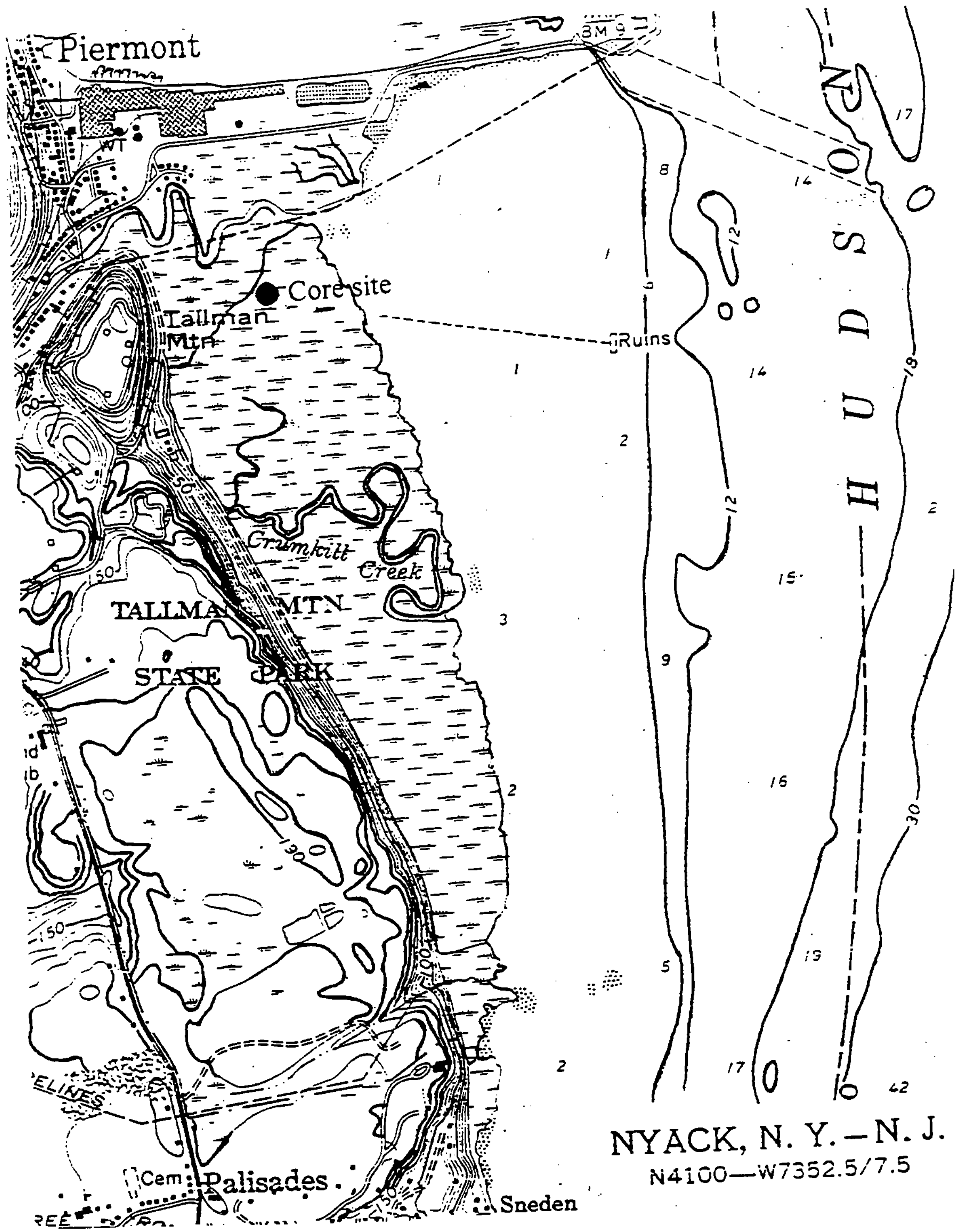

Figure 2. Core site at Piermont Marsh, Hudson River, New York

stream, directly south of Sparkill Creek, and characterized by *Spartina patens* grass (Fig. 2). This site was chosen because we hypothesized that the oldest and deepest part of the marsh was located in the center of the marsh. Because of the ubiquity of *Phragmites* grass in Piermont, which made access to the central part of the marsh difficult, this location was the most readily accessible through use of a boat.

The core was obtained on two separate days. The first 7.00 meters were obtained in mid-June and the remaining 4.15 meters were obtained in mid-July. A rowboat was used to access the core site and this limited our time there because favorable tidal conditions were needed to exit the unnamed stream. The sediment became more compact and harder to penetrate with depth, resulting in a slower retrieval process than expected. A total of 11.15 meters of sediment was retrieved at the core site. However, gravel or bedrock was not retrieved in our last attempt suggesting that we did not reach basal sediment. We thus believe the bottom of the marsh is deeper than 11.15 meters.

Sampling:

The core sections were obtained with a modified 5-cm Livingston piston corer (Wright et al. 1984). The sediment is condensed and compacted by the piston corer and as a result, some core sections are shorter than one meter. Core sections were wrapped in plastic wrap and aluminum foil, and stored in a refrigerator at Lamont Doherty Earth Observatory. The lithology was generated by describing the color and texture along the length of the core. Visual observations and the Munsell Soil Chart were used to determine color and sediment composition. Tactile observations were used to determine sediment grain size. Samples were taken at the end of each one-meter drive and at the

surface of the marsh for a total of twelve samples. Each sample was approximately 20 cubic centimeters (cc) in volume. One cubic centimeter sub-samples were obtained for pollen processing and loss-on-ignition carbon combustion. The remaining 20 cc sample was used for foraminifera, charcoal and plant macrofossil sampling.

Macrofossils:

Samples were soaked for one night in a bath of 10% KOH and water to break up the sediment. The samples were then washed with water through 500 micron and 150 micron mesh screens. Macrofossils—seeds, twigs, stems, foraminifera and charcoal, were examined, sorted, and counted with a (50x) dissection microscope.

Seeds

Seeds were identified according to the reference collection at Lamont Doherty Earth Observatory. Descriptions and illustrations in Gray's Manual of Botany and various seed and fruit identification books were used as well (Berggren 1981; Britton and Brown 1970; Fassett 1957; Fernald 1970; Hotchkiss 1970; Katz et al. 1965; Knobel 1980; Martin and Barkley 1961; Montgomery 1977; Roberts 1971).

Foraminifera

Foraminifera were identified using a National Ocean and Atmospheric Administration guide (Todd and Low 1981) and plates from Scott and Medioli (1980). The number of *T. macrescens* specimens were counted and the percentage of this foraminifera species in relation to the total number of foraminifera specimens in each sample was calculated. The relative abundance of "other species," which is an indicator of low marsh, is the difference between the percentage of *T. macrescens* and 100%.

$$\frac{\text{Total number of } T.\ macrescens}{\text{Total number of foraminifera species}} = \%\text{ of } T.\ macrescens$$

100% - % of *T. macrescens* = RELATIVE ABUNDANCE OF "OTHER SPECIES"

Charcoal

Charcoal particles greater than 500 microns were counted. Charcoal in the 63-125 micron size range convey the same information as do particles of larger sizes (Long et al. 1998).

Radiocarbon Dating

Plant macrofossils, primarily twigs and stems, from 3 m, 5 m, 7 m, 9 m, and 11 m, were selected for AMS carbon-14 dating. These five samples were sent to the AMS C^{14} Laboratory/ITP ETH in Zurich, Switzerland for analysis. Selection of macrofossils for dating was done with extreme prudence as to avoid contamination by younger and/or older organic material either during coring or sampling. Only *in situ* macrofossils were chosen when possible taking care not to use plant roots, which would make the sample appear younger in age.

Pollen Grains

Subsamples for pollen processing were subject to a series of chemical treatments in order to isolate pollen grains in the sediment. Subsamples were boiled in 10% KOH and a tablet containing approximately 12,000 non-native *Lycopodium* pollen grains were added to determine absolute pollen influx. Samples were then sieved through 150 micron and 7-10 micron mesh screens to remove sediments of inappropriate size. Subsequently, a solution of 10% solution of HCl was added to remove carbonates; HF was added to remove silica; and an acetolysis mixture of acetic anhydride and sulfuric acid was added to remove any remaining organic material. The samples were then treated with ethanol and butanol to dehydrate the pollen grains and then mounted on slides with methyl silicone oil.

Loss on Ignition

Subsamples were taken and the organic content combusted to determine percent carbon content. Samples were weighed immediately after sampling to record the wet weight of each sample. They were dehydrated at 100°C for 24 hours and weighed again to record dry weight. Carbon combustion was then performed in an oven at 600°C for one hour and samples were weighed afterwards to determine carbon loss. Carbon content is represented as a percentage of each sample's dry weight.

Weight in grams

WET WEIGHT – DRY WEIGHT = WATER CONTENT

DRY WEIGHT – WEIGHT AFTER CARBON COMBUSTION = CARBON CONTENT

$$\frac{\text{CARBON CONTENT}}{\text{DRY WEIGHT}} = \%\text{ CARBON CONTENT}$$

RESULTS

Figure 3 presents our results of lithology, % LOI, and macrofossils from twelve samples from the Piermont Marsh core. Although this stratigraphy is presented as a framework only, we do find patterns emerging over the last 4,000 years. Radiocarbon dates, plant macrofossils selected for dating, sample depth, and the designated reference number for the sample by ETH/ITP Laboratory in Zurich, Switzerland are presented in Table 1.

The core stratigraphy was divided into four zones according to changes in "other species" of foraminifera relative abundance data, and the abundance of plant macrofossils.

Zone P1 (1115 cm-898 cm; 4190 yr BP - greater than 3000 yr BP):

The foraminifera species present in this section of the core indicate the core site was frequently inundated by the tide and may be characterized as low marsh. The total number of foraminifera specimens were relatively few and within those specimens almost all were "other species." Charcoal was very high in the bottom sample and decreased in the younger sediment in Zone P1. *Chara/Nitella* oogonia were found in this zone as well. The presence of this species of algae would support the case for a low marsh environment. Carbon accumulation decreased from 14% to 7%. The sediment undergoes a series of reversals from a very hard and dense greenish-gray peaty clay layer to a 29 cm layer of gray organic clay. Deposited above the organic clay is a 21 cm layer of greenish-gray peaty clay and subsequently, a 58 cm dark gray layer of clayey peat. Contamination of the AMS sample taken at 9 m resulted in an anomalous radiocarbon

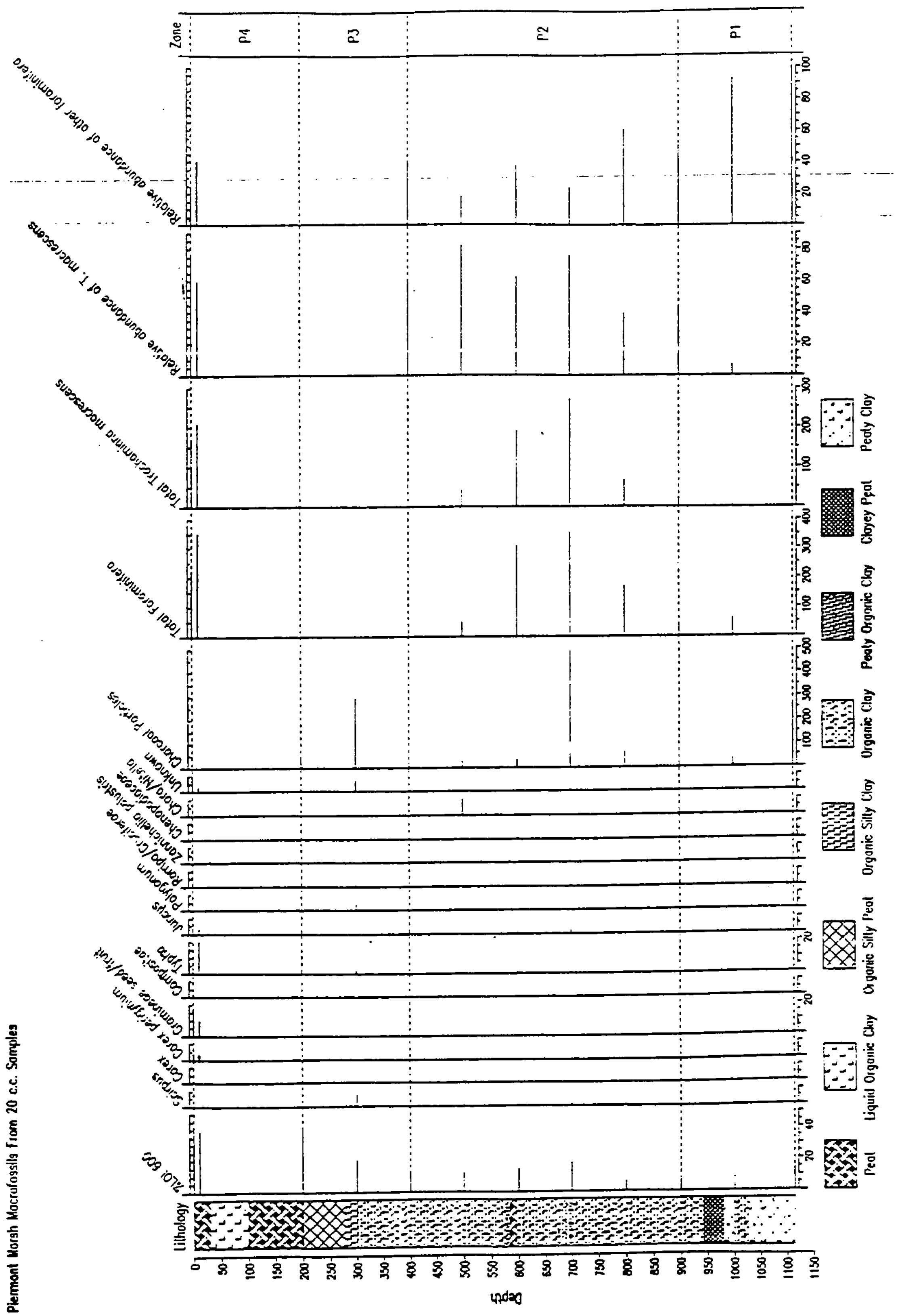

Figure 3. Diagram of Results

Piermont Marsh Macrofossils from 20 c.c. Samples date (see Table 1). Contamination by younger organic material may have occurred during retrieval of the core, or during selection of macrofossils for dating. The organic material at 9 m was exceptionally sparse. Alternatively, faulty methods at ITP/ETH in Zurich, Switzerland may have caused the errant radiocarbon date.

Zone P2 (898cm-398cm; greater than 3100 yr BP – approximately 1900 yr BP):

Foraminifera data reveals that the core site experienced a transition from low marsh to high marsh conditions, as evidenced by the high relative abundances of *T. macrescens*. Relative abundance of "other species" from 5 m reaches the lowest value of 18%. Charcoal counts peak at 489 particles at 7 m, the largest value of charcoal throughout the core. *Scirpus spp.* seeds were found consistently from all the samples taken in Zone P2. *Typha* and *Juncus* seeds were found as well. At a depth of 5 m, ten *Chara/Nitella* oogonia were found. The high number of algae species contradicts the conditions typical of a high marsh environment as indicated by the foraminifera data. In Zone P2, carbon accumulation climaxed at 7 m at 20% and thereafter decreased to 10%. Generally, sediment in this zone was smooth, uniform, light gray, organic clay, but in the organic clay were visible dark, isolated points of organic inter-fingering. Included in the organic clay were a series of reversals approximately 2 cm in length of peat or peaty organic clay. These peaty reversals were darker color in color and had an irregular texture.

Table 1. AMS Carbon-14 Dates for Piermont Marsh, Hudson River, New York

ITP/ETH Reference Number	Sample Depth (cm)	Plant Macrofossils	AMS C^{14} Age (yr. BP)
19034	300	Stems; woody organic matter; twig; stem node	1430 ± 50
19035	500	Stems; woody organic matter; stem epidermis	2325 ± 60
19036	700	Stems; twig; woody organic matter	3100 ± 70
19037	900	Stem epidermis; stem node; woody organic matter	1680 ± 55*
19038	1115	Stems	4190 ± 65

*Contaminated sample

Zone P3 (398 cm-198 cm; approximately 1900 yr BP – less than 1430 yr BP):

This third zone is typified by few or no foraminifera specimens, thus making it difficult to accurately assess whether low or high marsh conditions existed. Samples from 3 m and 2 m contained one and zero specimens, respectively. In Zone P3, 293 charcoal particles were counted at 3 m, representing a peak in the charcoal data. An abundance of *Scirpus* seeds were found in the sample at 3 m. Four *Rorripa* or *Cruciferae* seeds, and *a Zannichellia palustris* seed, an aquatic species, were found at 3 m also. The plant macrofossils found at 3 m comprised much of the relatively high organic content, which is reflected in the loss on ignition data. Percent carbon accumulation at 3 m is 20%. There is an increasing pattern of carbon accumulation in Zone P3 from 10% to 20% to 41%. The sediment in Zone P3 changes from organic clay to an organic grainy deposit, organic silty clay. The organic content increases to form a layer of organic silty peat. The sediment changes again to form a pure peat at the top of the zone.

Zone P4 (198cm-0cm; greater than 1430 yr BP – to the present):

This zone, containing the surface of the marsh, is characterized by an increase in "other species" of foraminifera and an increase in the total number of foraminifera specimens. Marsh species found at the core site are representative of a high marsh environment. There were no charcoal particles found in Zone P4. This portion of the core contained a greater number of grass seeds. Seeds and fruits of an unidentified grass not previously seen in the rest of the core were found in abundance from the two samples taken in the first meter of sediment. There were no *Scirpus* seeds found and aside from several *Carex* perigynia, the number of sedge seeds found were relatively few in comparison to samples obtained from the older sediments of the core. The percent carbon content in the first meter is 39% from the sample taken at 30 cm and 40% for the sample taken at 0 cm. Relatively high carbon content is expected for these samples because they have not been oxidized over time as much as samples lower in the core stratigraphy. The sediment in the first meter consisted of dark fibrous peat. The core section retrieved for the first meter is actually only 30 cm in length, as approximately 70 cm of sediment appeared to be a soupy organic clay. Because of its liquid consistency, the piston corer did not retain this portion of the sediment in the barrel of the corer.

DISCUSSION

AMS radiocarbon data indicates that the age of the marsh at 11.15 meters is approximately 4190 years old. Evidence of contamination is apparent for the radiocarbon date of macrofossils taken at 9 m. Nevertheless, the dates indicate a high sedimentation rate in the marsh (0.26 cm/yr). This was also apparent from the bulk carbon dates taken in 1967 (Newman et al. 1987). This rate of sea level rise of about 26 cm/century is higher than the sea level curve of 15 cm/century from several sites in New Jersey (Carmichael 1980). Basal sediment for the marsh is believed to be approximately 12 meters depth (Newman et al. 1987). Future coring of the site is necessary to accurately determine the age of Piermont marsh.

The presence of foraminifera throughout most of the core stratigraphy is indicative that Piermont Marsh was tidal throughout much of its history. The relative abundance of "other species" of foraminifera demonstrates variability in inundation and marine transgression at the core site. Several hypotheses are proposed for the absence or scarcity of foraminifera in some samples. The hydrodynamics of streams within the marsh may wash out material deposited in the sediment. The lack of foraminifera may also denote a period of time when conditions in the marsh were similar to those which exist in fresh marshes. Environmental conditions at the core site may have also become unfavorable for marsh foraminifera because the site may have been a salt panne at one time. These basins of high salinity are isolated from the tide and have been known to shift locations in the marsh. A fourth hypothesis for the disparity in total number of foraminifera specimens within the twelve samples may be related to the rate of marsh accretion. A problem with the usage of foraminifera was experienced in a study of northern Maine, USA. The rate of post-glacial sedimentation was very high and the foraminifera were diluted such that there were only one or two specimens per sample (Scott and Medioli 1986). Interestingly, the type of sediment does not appear to influence the deposition of marsh foraminifera which were found in both clay and peat layers of the core.

The core stratigraphy attests to the consistent presence of sedge throughout most of Piermont Marsh's history. *Scirpus* seeds or *Carex* perigynia were found in all but three of the twelve samples. The samples that were taken from the first meter of the core contain species of grass seeds and fruits which were not found elsewhere in the core stratigraphy. The influx of grass seeds in the younger sediment is probably related to human activity which has favored the spread of grass species and depleted the marsh of species diversity. The rapid invasion of *Phragmites* over the past thirty years is a reflection of this decrease in marsh plant diversity. We were surprised to find a lack of charcoal in the most recent sediments, but this may reflect more recent forest regrowth in the northeastern US in contrast to earlier deforestation and burning in the eighteenth century. Three hypotheses are offered to explain high charcoal counts at 3 m, 7 m, and 11 m depth in the core. Intentional burning in the marsh or the surrounding upland by Native Americans may have caused the deposition of charcoal. Charcoal particles may have been favored by a warmer drier climate at these times. Lightning may also have been the incendiary for local fire, caused by increased storminess.

Pollen grains were processed and remain to be counted. Pollen data will help explain other data presented in this study by providing the vegetational history. Pollen

percentages showing an increase in grass species in the uppermost sediments would support the plant macrofossil data. Pollen percentages that are similar to the regional pollen record will suggest that high charcoal counts are attributed to local environmental changes and not to climatic variations.

The variable amount of carbon stored in the sediment of Piermont Marsh is not exclusively due to oxidation. Generally, carbon stored in sediment will gradually decrease as the sediment is exposed to oxygen over time. Instead, the data demonstrate changes in carbon storage caused by something other than oxidation and the lithology indicates that the sediment varies as to its origin. Variations in percent organic content are a reflection of differences in organic productivity of the marsh as well as changes in stream deposition at the site and sea level fluctuations.

There are three ways in which we hope to enhance the findings of this study. Retrieval of another sediment core at a different site in the marsh would help explain whether lithological changes seen in the core stratigraphy are related to local conditions at the core site, marsh ecology or regional climatic changes. Marsh foraminifera are particularly sensitive to changes in the environment. The puzzling absence of foraminifera in some samples may be resolved by obtaining a modern foraminifera analog study along a horizontal transect. Finally, the conclusions reached in this study are preliminary until more detailed examination of the core can be performed. Refined sampling along the core would give a more comprehensive understanding of marsh paleoecology. Because of the high rate of deposition in Piermont Marsh, detailed evidence of climatic changes in the Northeastern, U.S.A. during the late Holocene will be will be well-preserved in the stratigraphy column.

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