

ABSTRACT

Brenda Joyce Smith. PALEOECOSYSTEMATICS OF THE DISMAL SWAMP VIRGINIA-NORTH CAROLINA. (Under the Direction of Dr. Lee J. Otte) Department of Biology, East Carolina University, Greenville, North Carolina.

Peat deposits of the Virginia portion of the Dismal Swamp were mapped and 13 cores were analyzed for plant macrofossils and sediments. Plant macrofossils from the peat deposit indicate a successional pattern of two extensive, stable wetland ecosystems separated by a relatively short transitional period.

The earliest stages of wetland development in the Dismal Swamp occurred eight to ten thousand years before present . A relatively deep, ponded environment, probably created by a blocked drainage system, supported a highly productive marsh dominated by sedges (Cyperaceae) and deep-water aquatics. The presence of floating-leaved, submergent and emergent marsh vegetation suggests that a mosaic of deeper open water and shallower water environments was present.

Following an initial deposition of fluvial clays, mineral sediment influx into the marsh decreased markedly as the vegetation became dense enough to trap incoming sediments and as the source area for sediments became inundated with peat. Dissolved nutrients present in runoff from surrounding uplands were the primary nutrient source for the marsh, since the vegetation root mat was quickly out of reach of the underlying mineral sediments in the permanently saturated peat-forming environment. This freshwater, highly productive marsh ecosystem remained stable, with an

to 3,500 years before present.

Once peat accumulation exceeded the upper water level of the blocked drainages, the marsh would have been an unsuitable environment for the accumulation of organic material. Decomposition of peats, now exposed above the water level, concentrated the more resistant organic sediments and released abundant humic compounds into the water. Under these conditions of a lower local water table and an exposed peat surface, the marsh would have provided an environment conducive to fire and to the establishment of acidophilous terrestrial vegetation.

Chamaecyparis thyoides, which was present over the peaty sands and peats of adjacent interfluvies, invaded the exposed marsh peat deposits. C. thyoides needs open areas, with high organic and water saturated soils, such as those of the marsh to become established and to thrive. The high lignin and cellulose content of C. thyoides leaf litter, in addition to the existing acidic edaphic conditions associated with decomposition of the surface peats, probably contributed to renewed organic accumulation. The enormous water-retaining capacity of this organic material would have contributed to the build up of peat beyond the upper levels of the blocked drainages and to its spread across the interfluvies.

As the C. thyoides forests matured to a closed canopy stage, ground cover probably became sparse, with little vegetation for trapping any influx of mineral material. A corresponding increase in terrigenous sediments is present in the upper horizons of forest peats. Allochthonous dissolved materials were probably the primary source of nutrients for the forest, as they were for the marsh. The acidic, brown water Chamaecyparis thyoides-dominated forest ecosystem was present from approximately 3,500 to 200 years before present.

Extensive logging and drainage efforts began in the Dismal Swamp about 200 years ago. C. thyoides seedlings were unable to survive beneath the dense tangles of slash left at the timbering sites and, as a result, very little C. thyoides forest remains in the Dismal Swamp. With continued logging, and the addition of over 190 km of ditches, edaphic conditions in the swamp became more suitable for mesic species such as Acer rubrum and Liriodendron tulipifera. A. rubrum is now the most common canopy species in the Dismal Swamp.

PALEOECOSYSTEMATICS OF THE DISMAL SWAMP,
VIRGINIA-NORTH CAROLINA

A Thesis

Presented to
the Faculty of the Department of Biology
East Carolina University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science in Biology

by

Brenda Joyce Smith

August, 1985

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PALEOECOSYSTEMATICS OF THE DISMAL SWAMP,
VIRGINIA-NORTH CAROLINA

by
BRENDA J. SMITH

APPROVED BY:

SUPERVISOR OF THESIS Lee J. Otte
Lee J. Otte, Ph.D.

THESIS COMMITTEE Mark M. Brinson
Mark M. Brinson, Ph.D.

Vincent J. Bellis
Vincent J. Bellis, Ph.D.

Albert E. Radford
Albert E. Radford, Ph.D.

CHAIRMAN OF THE DEPARTMENT OF BIOLOGY

Charles E. Bland
Charles E. Bland, Ph.D.

DEAN OF THE GRADUATE SCHOOL

Joseph G. Boyette
Joseph G. Boyette, Ph.D.

ACKNOWLEDGEMENTS

I sincerely thank each member of my thesis committee for their interest, encouragement and support throughout this project, and express my appreciation to my thesis chairman, Dr. Lee J. Otte, for his contribution. Special recognition goes to Dr. A.E. Radford who permanently instilled the concepts and principles of ecosystematics into my everyday life as well as my academics.

Others who deserve acknowledgement for contributing to this work are Charles Saunders and Dave Mallinson for assistance with field work, and Tim Charles for direction of the SEM work and photographic plates.

The greatest possible thanks, gratitude and respect go to my husband, Ronald C. Davis, for his constant friendship, support and understanding throughout this endeavor. The completion of this thesis would have been an even more difficult task without his steady and often self-sacrificing contribution.

Financial support was provided by the Sigma Xi Scientific Society, the United States Geological Survey - Water Resources Division, and the Department of Biology, East Carolina University, Greenville, N.C.

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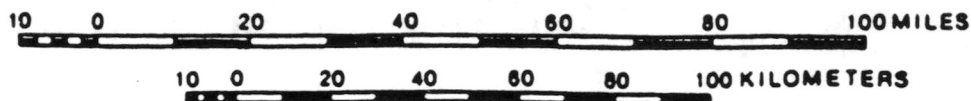
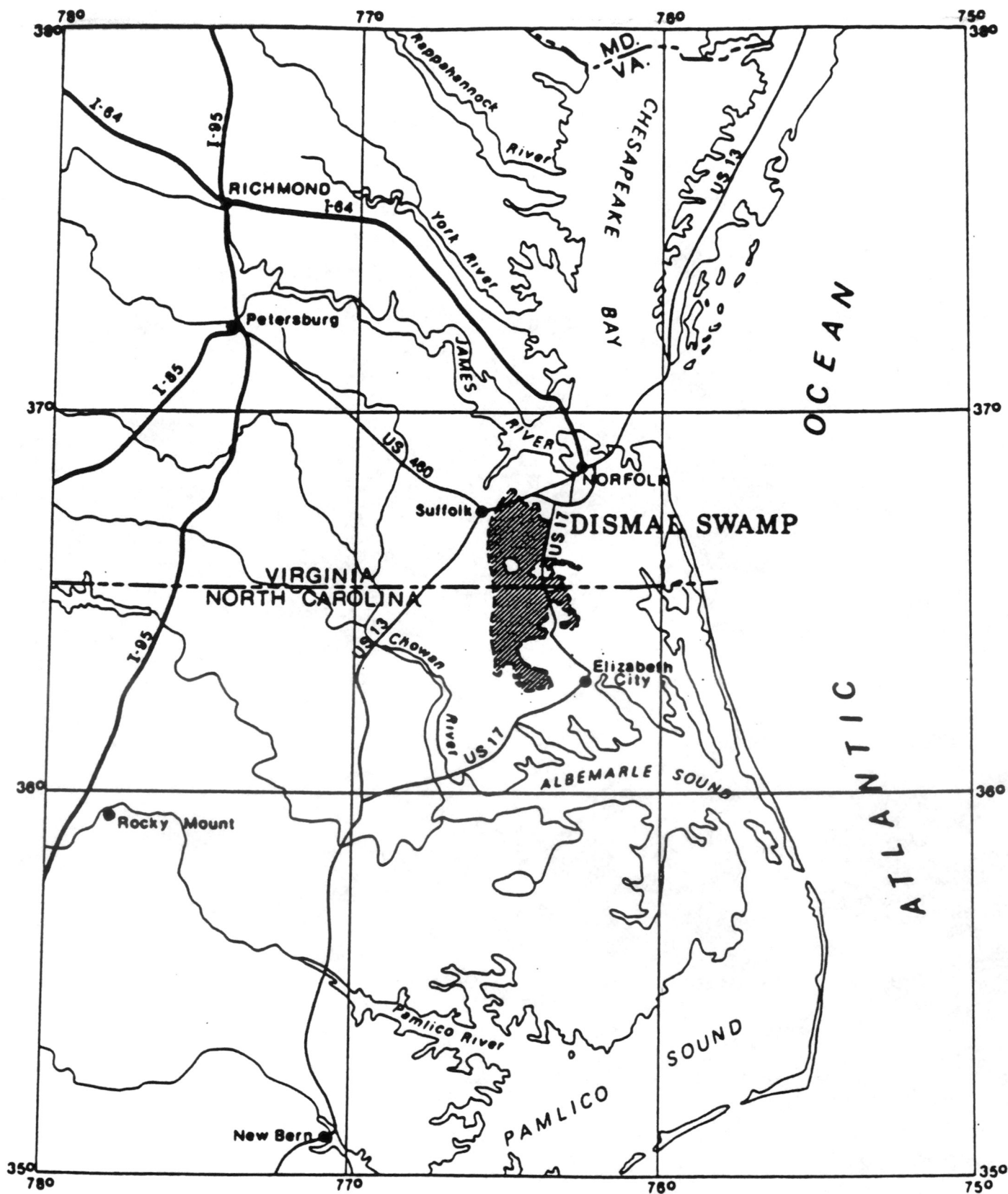
INTRODUCTION

The Great Dismal Swamp, a 210,000 acre palustrine wetland, is located in the lower Coastal Plain of northeastern North Carolina and southeastern Virginia (Figure 1). Wetlands are , in general terms, lands where the dominant factor controlling the pedologic conditions and vegetational communities is saturation of the soil. The boundary between terrestrial and wetland communities roughly corresponds to the boundary between hydrophytic vegetation and mesophytic or xerophytic vegetation (U.S. Fish and Wildlife, 1979).

Very little, if any, of the swamp has remained undisturbed over the last 200 years. Almost all of the original Chamaecyparis thyoides (Atlantic White Cedar) and Taxodium distichum (Cypress) forests had been logged by the late 1800's (Reid, 1952). Over 190 km of roads and ditches, constructed for logging operations, have severely altered the natural hydrologic regime of the swamp. With increased water loss through the ditches and oxidation of the water-retaining organic soils, the swamp has, in many respects, lost the original character for which it was so appropriately named. The United States Fish and Wildlife Service presently manages 30,760 ha. (76,000 acres) of the swamp as the Great Dismal Swamp National Wildlife Refuge.

The extensive peat deposits which underlie the swamp have not been so severely disturbed, and can be used to reconstruct the developmental stages of the Dismal Swamp. Peat accumulation originated in the Dismal Swamp 10,000 to 12,000 years ago in a series of blocked drainage systems. By approximately 3,500 years before present, peat had completely filled in

Figure 1: Location of the Dismal Swamp



the deeper channels , spread across the interfluves, and coalesced into one major wetland (Whitehead, 1972). The change from an active fluvial system to a blocked drainage system marks the time when the swamp changed from an erosional to a depositional system.

Initial swamp sediments consist of bed load coarse sands and suspended silts and clays that were deposited as the channel water lost velocity due to the blockage. The water-saturated, predominantly anaerobic conditions necessary for preservation of organic material were created when water backed up behind the blockage and eventually led to the accumulation of peat. Beginning with the initial stream sediments deposited in the channel bottoms, these deposits provide a nearly continuous record of wetland development in the Dismal Swamp.

Vegetative debris and terrigenous sediment are the major components of this record. Each provides specific information about the development of the Dismal Swamp. The distribution of terrigenous sediments within peat horizons reflects the movement of sediment (and thus nutrient) bearing waters through the swamp during peat formation. Plant material preserved in peat, primarily pollen and macrofossils, indicates the vegetational succession of the swamp throughout its development.

Pollen analyses from the Dismal Swamp have been used to help determine the regional climatic and vegetational patterns associated with the Dismal Swamp over the past ten to twelve thousand years (Whitehead, 1972). Pollen is produced in excess and efficiently wind dispersed. The total pollen that settles on a surface over time constitutes the 'pollen rain' of that area. It is assumed, by palynologists, that pollen is randomly mixed and that even a small sample is representative of the regional vegetation. 'Seed rain', in contrast, is produced in limited amounts, has

a relatively limited dispersal distance, and is considered to be representative of local vegetation (Watts, 1980).

The purpose of this study is to focus on the succession of wetland communities, specifically those associated with the peat deposits, by (1) detailed mapping of the peat channels, (2) macrofossil ('seed rain') analyses from numerous cores throughout the peat channels, and (3) determination of the terrigenous sediment component (ash content) of the peat. The information obtained from this study - in conjunction with existing geological, hydrological, palynological, archaeological, and vegetational data for the Dismal Swamp - will be used to determine the development of peat deposits in the Dismal Swamp.

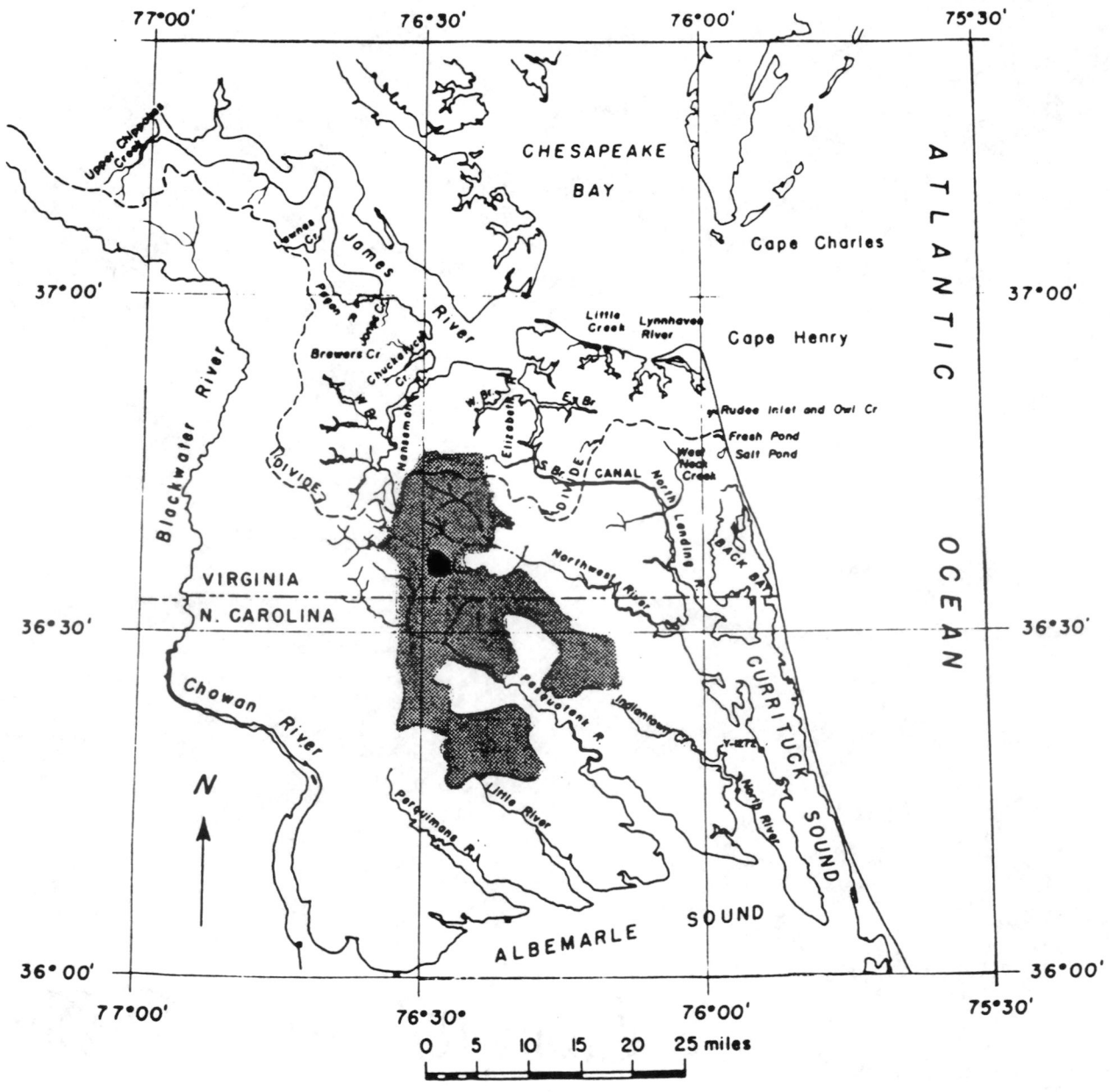
PREVIOUS STUDIES

The Dismal Swamp has been an area of interest since the late 1700's when George Washington supervised the digging of Washington Ditch to reach Lake Drummond at the center of the swamp. Since that time, foresters, geologists, biologists, botanists, archaeologists, naturalists, and historians have studied the swamp. Only in the last 30 years, however, have the origin, development, and maintenance of the swamp begun to be understood (Kirk, 1979).

ORIGIN AND DEVELOPMENT

Some of the most commonly argued points about the Dismal Swamp concern its origin and development. Early hypotheses related initial peat formation to sea level rise during the last 18,000 years (Lewis and Cocke, 1929; Lewis and Patrick, 1934). It was proposed that as sea level rose, water ponded in the upper reaches of the coastal rivers, and produced conditions suitable for peat development in these areas. Sea level influence was proposed before the extent and rates of sea level rise were determined for the Atlantic Coast. This idea may have been supported by (1) the presence of fibrous basal peats with a strong odor of hydrogen sulfide, characteristic of brackish water peats, and (2) the fact that the Dismal Swamp's peat deposits form in the headwaters of five coastal rivers: the Northwest River, Little River, North River, Perquimmons River, and Pasquotank River (Figure 2).

Figure 2: Drainages associated with the Dismal Swamp.
Shaded area delineates the swamp. After Oaks and
Whitehead, (1979).

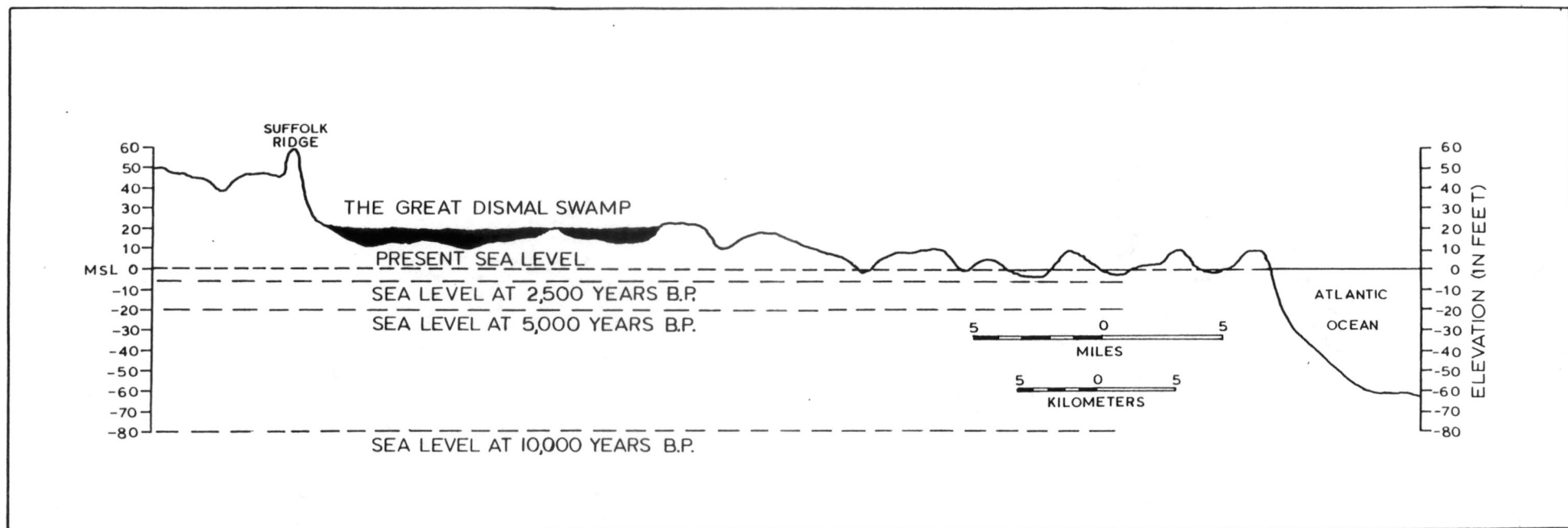


Modern sea level curves, however, indicate that sea level was not a factor in initial peat formation in the Dismal Swamp (Lichtler and Walker, 1974). These sea level curves (Dillon and Oldale, 1978; Blackwelder et al., 1979) show that at the time of initial peat formation in the swamp, approximately 10,000 years ago, sea level was 26 m (80 ft) lower, and 160 km (100 mi) east of its present position (Figure 3). Thus, sea level was too far away from the drainages in which peat initially formed to have had a direct influence on peat formation in the swamp.

A possible explanation for initial peat development in the Dismal Swamp, without sea level influence, is blockage of the drainage systems in which peat originated. The narrow outlets of the Northwest and Pasquotank Rivers through the Fentress Rise would have been likely areas of blockage by beaver dams or by an accumulation of fallen trees (Oaks and Whitehead, 1979). The location of the deepest and best-preserved peats in proximity to the narrow channels cutting through the Fentress Rise support this theory of initial ponding in the Dismal Swamp. No attempts, that I am aware of, have been made to locate any of these proposed blockages.

Initiation of peat formation in the Dismal Swamp has also been attributed to upward seepage of water along the stream that eroded through the confining layer (Sandbridge Formation) over the underlying aquifer (Norfolk Formation). According to Lichtler and Walker (1974), this seepage, in combination with naturally sluggish surface drainage, may have led to conditions suitable for peat formation in these streams. The precise role of the Norfolk aquifer in the hydrology of the swamp is not known.

Figure 3: Cross section from the Suffolk Scarp to the Atlantic Ocean. Dotted lines indicate sea level at various intervals since the initiation of peat accumulation in the swamp. (Lee J. Otte, unpublished figure)



VEGETATIONAL SUCCESSION

Previous studies of the succession of vegetation in the Dismal Swamp are primarily based on pollen analyses (Lewis and Cocke 1929; Cocke et al., 1934 and Whitehead, 1972). The majority of this work was done by Whitehead, who identified an eleven to twelve thousand year succession of vegetation in the swamp (Table 1). Whereas most of Whitehead's data considers the arboreal pollen from the surrounding uplands, there is palynological evidence for the existence of extensive freshwater marshes along streams during the early stages of swamp development.

No studies have analyzed the macrofossils from the Dismal Swamp peat deposits. Studies of plant macrofossils from marsh and lake deposits in Pennsylvania (Watts, 1979) and Minnesota (Watts and Winter, 1966) have been used to determine vegetational succession patterns, and to add detailed information to pollen analyses from the same sediments. For example, a study of the macrofossils from Crider's Pond, N.J., determined the presence of Pinus rigida and Betula populifolia. Neither of these species was documented in pollen analyses from the area (Watts, 1979).

Table 1: Vegetation zones based on peat pollen assemblages in the Dismal Swamp (Whitehead, 1972).

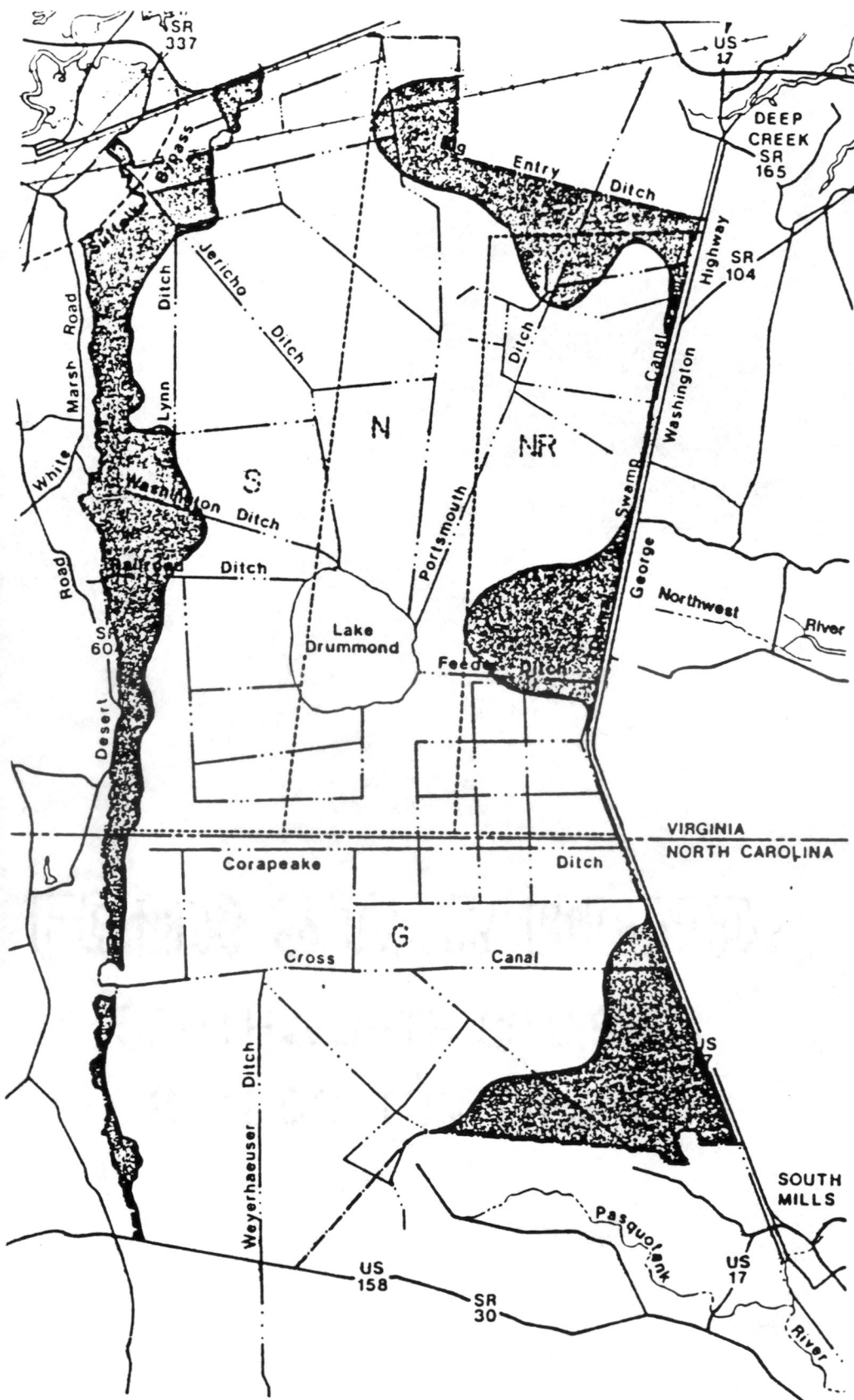
ZONE	SEDIMENT	AGE (years b.p.)
cypress-gum	coarse forest peat	0 - 3,500
oak-hickory	finer-grained peats	3,500 - 8,200
beech-hemlock-birch	organic clays	8,200 - 9,500
pine-spruce	inorganic horizons	9,500 - 12,700

SOILS

The soils of the Dismal Swamp are predominantly organic (Histosols), with mineral soil deposits primarily limited to the base of the Suffolk Scarp and the remaining swamp perimeter (Presnell-Kidd Associates, 1979) (Figure 4). Organic soils of the Dismal Swamp have been classified as Typic and Terric Medisaprists. Typic medisaprists are soils that have thick, continuous sapric materials from the surface to a depth of 130 cm or more. Terric Medisaprists are soils that have greater than 40 cm but less than 130 cm of continuous sapric materials (USDA, 1975).

Drainage, fire and agricultural clearing have reduced the extent and depth of organic soils in the Dismal Swamp. Soils that would have formerly been classified as Typic Medisaprists have been reduced in thickness, by oxidation, and are now classified as Terric Medisaprists. Many Terric Medisaprists have likewise decreased in depth and are now classified as Histic Humaquepts (organic layers between 20 cm and 40 cm thick) (Presnell-Kidd Associates, 1979). It has been estimated that as much as one-third of the original volume of deep organic soils may be lost to oxidation if the soils remain dehydrated over an extended period of time (Dolman and Buol, 1967).

Figure 4: Soil map of the Dismal Swamp. After Presnell-Kidd Associates (1979).



LEGEND



MINERAL SOILS - Soils with Organic Layers less than 16" thick.



ORGANIC SOILS - Includes Terric Medisaprists (Organic Layers more than 16" thick but less than 51") and Typic Medisaprists (Organic Layers more than 51" thick).

SOIL SURVEYS

S

"Soil Survey, Suffolk, Va." Unpublished field survey Jerry S. Quesenberry, Soil Scientist, U.S. Department of Agriculture, Soil Conservation Service, 1977.

N

"Soil Survey, Norfolk County, Virginia," 1953 U.S. Department of Agriculture, Soil Conservation Service

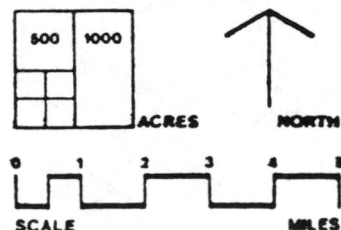
NR

"Soil Survey, Norfolk County, Virginia," 1953, with partial revisions, principally to organic soils, from an "in-progress" revision of this Survey by Jerry S. Quesenberry, Soil Scientist, U.S. Department of Agriculture, Soil Conservation Service, 1977.

G

"Great Dismal Swamp and Dismal Swamp Canal Study: Report on Ascertainment of Soil Types and Agricultural Information," February, 1974. U.S. Department of Agriculture, Soil Conservation Service

Soils Classification



**Great Dismal Swamp
National Wildlife Refuge**

PEAT

The North Carolina portion of the Dismal Swamp peat deposits were mapped by the North Carolina Peat Inventory Project (Ingram and Otte, 1981) (Figure 5). As used by the Peat Inventory Project for North Carolina, peat has a very specific definition based on percent organic matter at dry weight (Table 2). According to this definition (a maximum of 25% ash at 0% moisture), all peats contain enough organic material to be classified as Histosols (organic soils) since the maximum ash content for organic soils ranges from 70 - 80 % at 0% moisture. It should be noted that, by these standards, not all Histosols contain sufficient organics to be considered peats.

Table 2: Sediment classification for Peat, as used by the North Carolina Peat Inventory Project.

SEDIMENT	% ORGANICS	% MINERAL *
MINERAL SEDIMENT	0 - 25	75 - 100
PEATY MINERAL SEDIMENT	25 - 50	50 - 75
VERY PEATY MINERAL SEDIMENT	50 - 75	25 - 50
PEAT	75 - 100	0 - 25

* Percentages are at 0% moisture.

Ingram and Otte's data show a trend of higher ash peats in the Dismal Swamp and other forested wetlands, than in peat deposits with less forested and/or more shrubby vegetation. This difference is related to the proximity of the developing wetland to a source for mineral sediment influx, and to the ability of the vegetation to trap incoming sediments. Incoming sediments mix with organic material being deposited, and result in higher ash content peats. The Suffolk scarp to the west and the Fentress Rise to the east provide a steady source of influxing sediments for the Dismal Swamp.

Figure 5: Peat Isopach map for the North Carolina portion of the Dismal Swamp (Ingram and Otte, 1981). Triangles and circle indicate sites sampled for statistical analyses of ash content of the sediments.

STUDY AREA

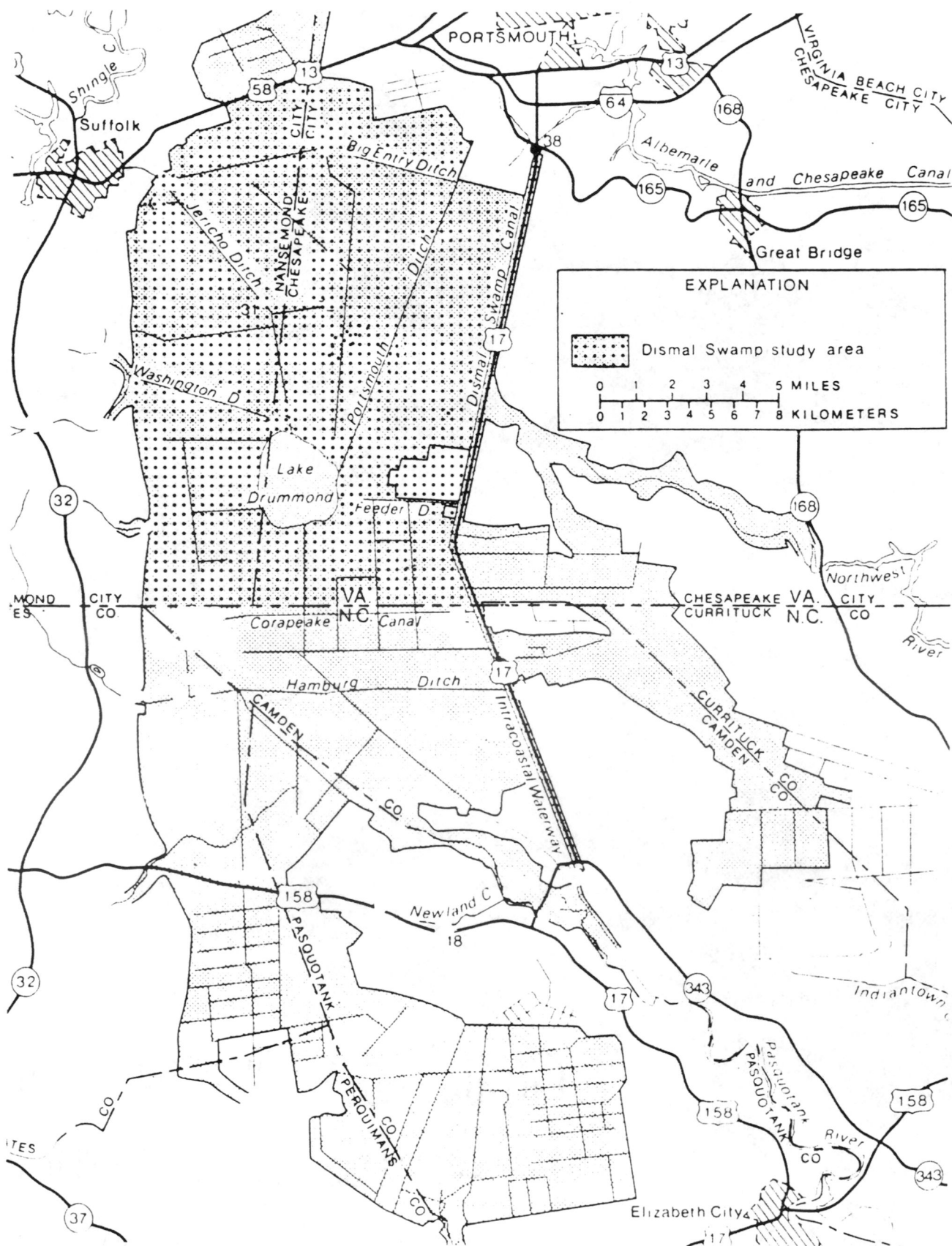
LOCATION

Field work for this study was carried out in the Virginia portion of the Dismal Swamp (Figure 6). The peat channel mapped and sampled originates in the northwestern section of the swamp and extends southeast until it passes through a narrow breach in the Fentress Rise. The area where the peat channel cuts through the Fentress Rise is considered to be the boundary between the study area and the headwaters of the Northwest River. This boundary is paralleled by US Highway 17 and the Dismal Swamp Canal along the eastern edge of the swamp.

CLIMATE

The Dismal Swamp has a mesothermal, temperate climate with very hot and moderately wet summers, moderately cold and moderately wet winters, with an average to long freeze-free period. The average annual rainfall at the Wallaceton-Lake Drummond station at the control structure on the Feeder Ditch is 127 cm. Annual loss of water to evapotranspiration is estimated at 102 cm. Precipitation is relatively uniform throughout the year, with a slight increase from June through September and a corresponding decrease from October through December (U.S. Department of the Interior, 1979).

Figure 6: Location of Study Area. Modified from
Lichtler and Walker(1974).



HYDROLOGY

The major sources of water for the Dismal Swamp are precipitation, sheet flow from the surrounding uplands and stream flow from tributaries that cut through the Suffolk Scarp. The swamp receives approximately 12 million m³ (31 billion gallons) of inflow per year from a drainage basin covering about 293 km² (113 square miles) of upland area (Figure 8). Ground water flow into the swamp is primarily from the west through the Norfolk Aquifer (U.S. Department of the Interior, 1979). The exact role of this aquifer in the hydrology of the swamp has not been determined (Lichtler and Walker, 1974).

Natural water flow patterns in the swamp have been obliterated by ditches and dike roads, most of which were constructed since 1925. Surface drainage was sluggish through poorly defined streams prior to ditching, with the primary outflow through the Northwest River, Pasquotank River, Elizabeth River and Shingle Creek (Figure 7).

Present drainage out of the swamp is primarily through Lake Drummond, the Dismal Swamp Canal and the complex of ditches in the southern portion of the swamp. Lake Drummond receives approximately 70 % of the inflow into the swamp. The principal outflow of the lake is eastward into the Dismal Swamp Canal through Feeder Ditch. Outflow through Feeder Ditch is controlled by the Fish and Wildlife Service (U.S. Department of the Interior, 1979).

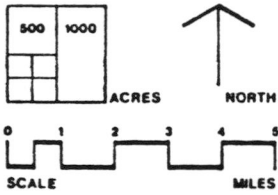
The Dismal Swamp contains approximately 190 km of ditches. Most of the ditches in the northern part of the swamp empty into Lake Drummond. The majority of ditches in the southern portion of the swamp have no water control structures, and water from the swamp readily passes through them

Figure 7: Hydrology - Drainage of the Dismal Swamp (Modified from U.S. Department of the Interior, 1979).

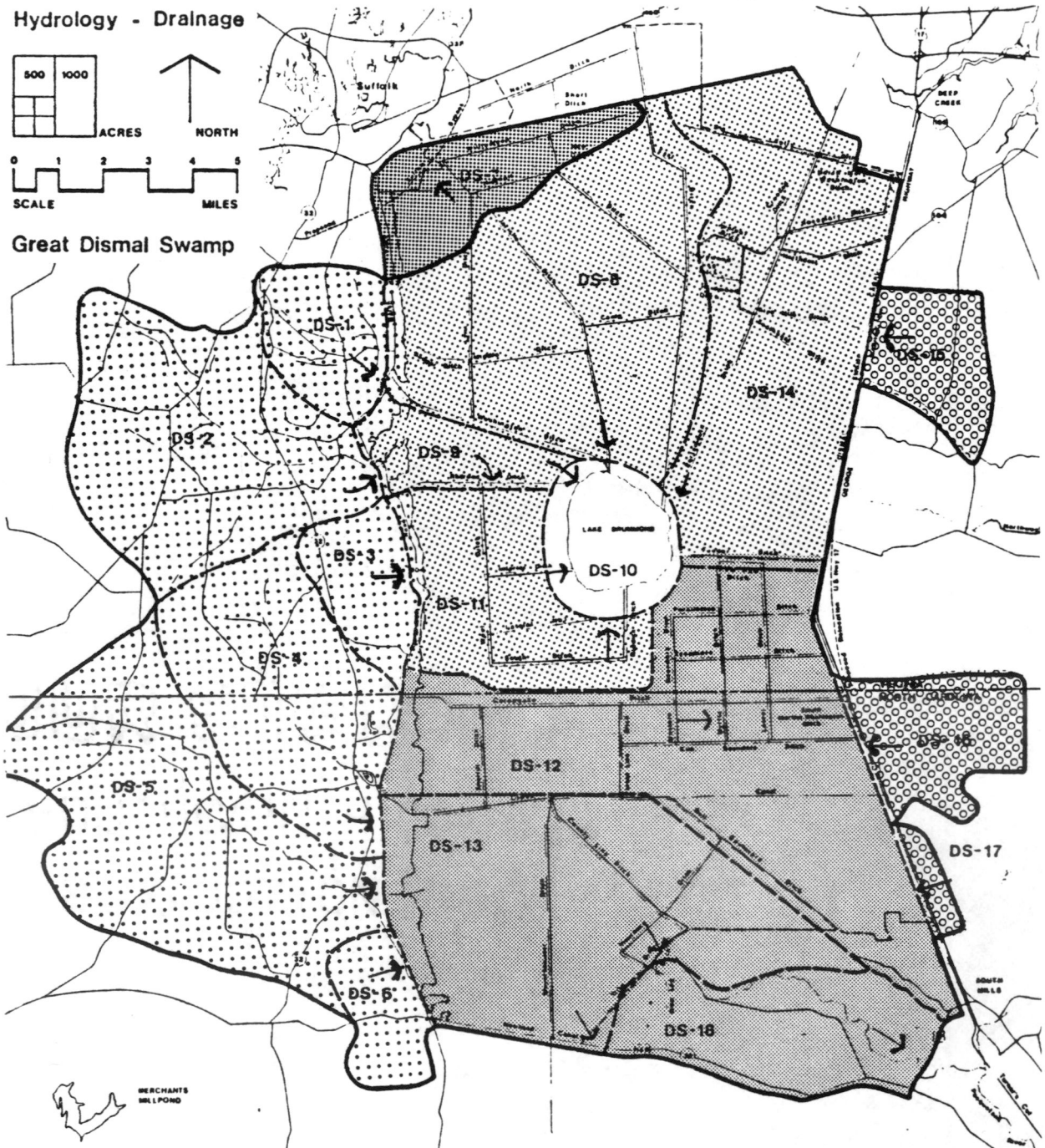
Legend

-  Drainage Basin Boundary
-  Sub-drainage Basin Boundary
-  Direction of Surface Water Flow
-  Drainage Basin of the Dismal Swamp
-  Drainage into Lake Drummond
-  Drainage to Shingle Creek (North)
-  Drainage to Dismal Swamp Canal,
-  Pasquotank and Perquimmons Rivers (South)

Hydrology - Drainage



Great Dismal Swamp



to the Pasquotank River. Very little of the water that enters the swamp is stored for any period of time before it exits through either Lake Drummond or the southern canals (U.S. Department of the Interior, 1979).

Vegetation in the swamp, particularly the deciduous forest, has a tremendous effect on water levels in the swamp. Evapotranspiration exceeds rainfall during the growing season and causes a major drawdown of water levels in the swamp. Drawdown reaches a maximum at the end of the growing season in September. The dormant state of the deciduous forest, from October through December, is characterized by rising water levels in the swamp. Water accumulates as a result of decreases in evapotranspiration, due to lower average temperatures and loss of foliage (U.S. Department of the Interior, 1979).

The period of drawdown further affects the hydrology of the swamp by drying out the organic soils. These soils, the peats in particular, have a low hydraulic conductivity as long as they remain saturated. Once peats become dehydrated, they irreversibly lose much of their water-retaining ability and can no longer function as barriers to water loss from the swamp (Dolman and Buol, 1967). Dehydrated peats, that I have observed in the Dismal Swamp, are very granular and porous and allow subsurface water movement through the dehydrated horizons.

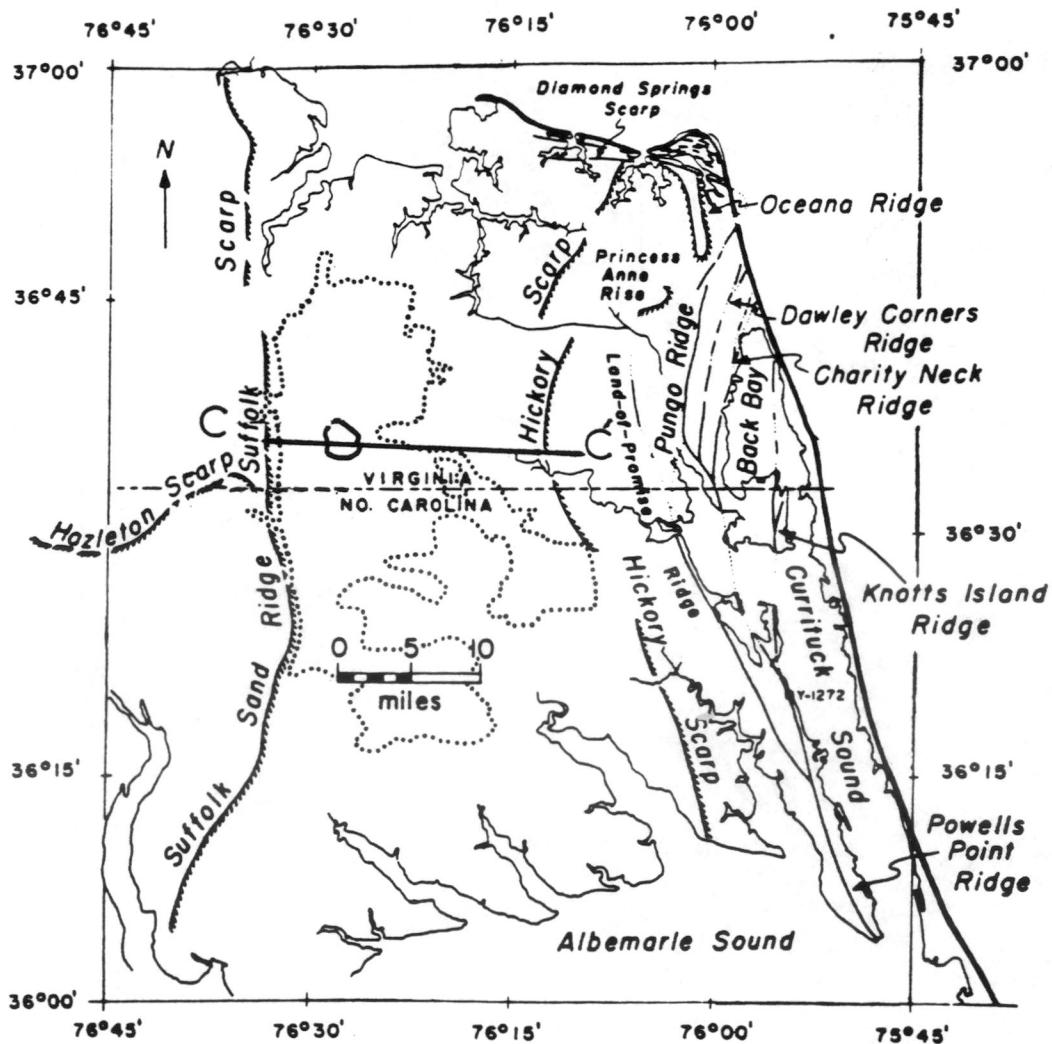
TOPOGRAPHY AND GEOLOGY

The Suffolk Scarp, a Pleistocene shoreline that sharply defines the western boundary of the swamp, has an elevation of 12 to 15 m MSL (mean sea level). The Fentress Rise, which defines the eastern border of the swamp, is a less distinct Pleistocene barrier island complex with an elevation of approximately 4.6 m MSL. The surface of the swamp is relatively flat, sloping eastward at about 0.2 m per km from an elevation of 6 m MSL at the base of the Suffolk Scarp to an elevation of 4.6 m MSL at the Fentress Rise (U.S. Department of the Interior, 1979) (Figures 3 and 9).

The swamp extends north along topographic lows towards the James River and Chesapeake Bay. Two major lobes of the swamp, consisting of two separate peat channels, extend southward towards Elizabeth City, N.C. One of these channels connects with the headwaters of the Pasquotank River, and the other with the Perquimmons River. Peat depth reaches 3.3 m in the centers of channels, ranges from 1.2 to 1.8 m across the interfluves and thins to 0.3 to 0.6 m along the outer boundaries of the swamp (Figure 4) (Ingram and Otte, 1981).

Deeper peat channels in the swamp are underlain by thin horizons of freshwater clays with coarse fluvial sands. These sediments, referred to as underclays in this paper because of their similarity to typical underclays of coal deposits (Grim and Allen, 1938; O'Brien, 1963), represent the earliest deposition in the peat forming environment of the Dismal Swamp. A series of lagoonal facies of the Pleistocene Sandbridge and Londonbridge Formations immediately underlie the peat deposits and asso-

Figure 8: Major morphologic subdivisions of the Dismal Swamp region.
After Oaks and Coch (1973). Cross-section C-C' shown in
Figure 9.



ciated fresh water underclays of the Dismal Swamp. The Sandbridge and Londonbridge formations overlie near shore marine sediments of the Norfolk Formation (Figure 9). The Norfolk Formation (also Pleistocene) was deposited on the erosional surface of the Yorktown Formation, a Miocene near-shore marine sediment. Lenses of the lagoonal clay facies of the Great Bridge Formation, deposited over the Yorktown formation but subsequently severely eroded, are occasionally found separating the Norfolk and Yorktown formations (Oaks and Coch, 1963).

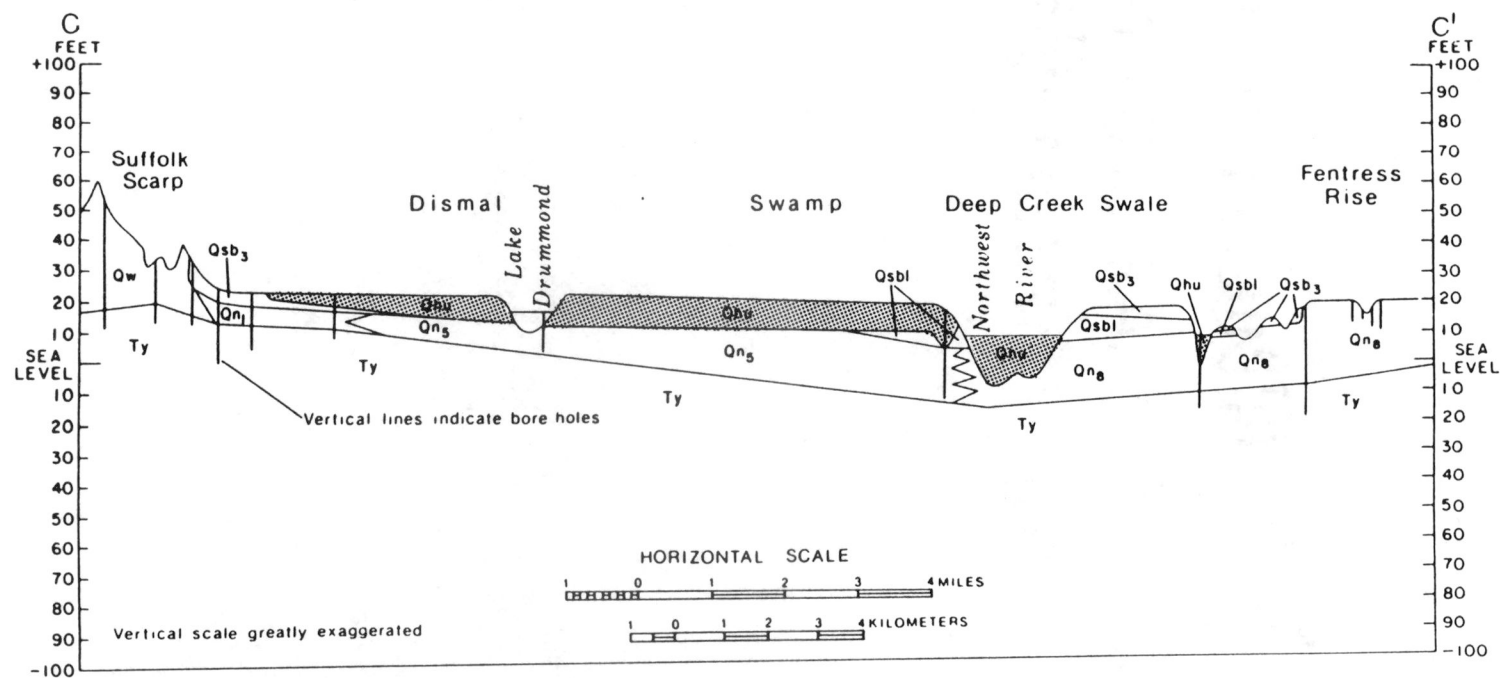
Each of these formations, described in Table 3, represents a separate transgression during fluctuating interglacial transgressive and regressive cycles. These cycles, resulting from sea level changes due to glacial fluctuations, are responsible for the complex depositional history of the pre-swamp sediments of the Dismal Swamp (Oaks and Coch, 1963).

VEGETATION

Lumbering, construction of canals, and encroaching agriculture have severely altered the natural vegetation of the Dismal Swamp. The earliest complete survey of the Dismal Swamp vegetation (Kearney, 1901) was performed after extensive disturbance had already occurred. Many of the earliest reports on the swamp's vegetation used few scientific names, leaving some confusion concerning the meanings of some of the common names (U.S. Department of the Interior, 1979).

Logging records, made available by the Union Camp Corporation, show that prior to timbering most of the Dismal Swamp was dominated by Chaemacyperus thyoides (Atlantic White Cedar) forests (Figure 10).

Figure 9: Geologic cross-section showing the Miocene and Pleistocene formations underlying the Dismal Swamp (Lichtler and Walker, 1974). Trace of cross-section shown on Figure 8. Qhu unit (shaded) corresponds to organic sediments.



EXPLANATION

Qhu - Undivided sediments

Qsb - Sand Bridge Formation

Qsb₁ - Lower member

Qn - Norfolk Formation

Qgb - Great Bridge Formation

Qw - Windsor Formation

Ty - Yorktown Formation

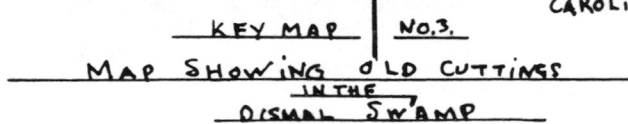
Table 3: Description of Geologic Units Underlying the Dismal Swamp
(Lichtler and Walker, 1974).

Holocene	<u>Qhu-Undivided sediments</u> Beach, marsh, swamp, and stream sediments.
Pleistocene	<u>Qsb-Sand Bridge Formation</u> Upper member: (facies designated by numbers in geologic sections) (1) Estuarine and tidal-channel: clayey-sand facies. (2) Fluvial and lagoon: silty-sand facies. (3) Marsh and tidal-flat: silty-clay facies. (4) Barrier: sand-ridge and mud-flat complex. Lower member: Coastal sand, silty sand, and clayey sand (exposed only as narrow bands along streams; combined with upper member on map, but shown separately in cross sections as Qsbl).
	<u>Ql-Londonbridge Formation</u> Beach and dune sand and gravel in Oceana Ridge; lagoon clayey silt westward nearly to Suffolk Scarp.
	<u>Qn-Norfolk Formation</u> Upper member: (facies designated by numbers in geologic sections) (1) Beach and dune: coarse-sand facies. (3) Marsh and lagoon: silty-clay facies. (4) Brackish-marine: silty-sand facies. (5) Shoreface: medium-sand facies. (6) Shelf: silt facies. (7) Shelf: sand facies. (8) Shelf: fine-sand facies. Lower member: Beach sand and gravel (combined with upper member).
	<u>Qgb-Great Bridge Formation</u> Upper member: (facies designated by numbers in geologic sections) (1) Beach sand and gravel near present coast. (2) Lagoon silty clay in west. Lower member: Fluvial sand, gravel, and freshwater peat along channels in top of Yorktown Formation.
Pliocene and/or Pleistocene	<u>Qw-Windsor Formation</u> Upper member: Lagoon silty sand Lower member: Beach-and nearshore-marine sand and gravel.
	<u>Qts-Sedley Formation</u> Marine and estuarine clay, silt, and fine sand.
Miocene and Pliocene	<u>Ty-Yorktown Formation</u> Fossiliferous marine clay, silt, sand, and coquina.

Figure 10: Logging map of the Dismal Swamp. Redrawn from Reid (1952).

Legend

-  Chamaecyparis thyoides
-  Pinus taeda
-  Taxodium sp.



MAP SHOWING OLD CUTTINGS
IN THE
DISMAL SWAMP

Through several centuries of intensive cutting and drainage, these communities have been replaced by a mosaic of deciduous broadleaf canopy species. Acer rubrum (Red Maple), Nyssa sylvatica (Black Gum) and Liquidambar styraciflua (Sweet Gum) are strongly represented in the present forest communities of the swamp (Walker, 1974).

Acer rubrum is now the dominant canopy species in the Dismal Swamp. Stands that are not dominated by A. rubrum probably are succeeding to an A. rubrum dominace, as evidenced by a increasing amount of A. rubrum in the understory. The once-dominant communities of Chamaecyparis thyoides are being replaced primarily by A. rubrum and L. styraciflua (Walker, 1974).

METHODS

MAPPING

The study area was mapped by the same methods used by the North Carolina Peat Inventory Project (Ingram and Otte, 1981). 200 sites were sampled in the field area, for a total of 978 individual samples.

Field Methods

Samples were taken at 0.4 km intervals along roads or transects when peat thickness was 1.2 m or less, and the interval closed as necessary to locate the central portion of channels greater than 1.2 m in depth (Figure 11). Peat samples were obtained with a McCauley peat sampler (200 cm³ volume), at 0.3 m vertical intervals from the surface down until the underlying mineral sediments were reached. At least 0.3 m of the underlying mineral sediments were also collected. Samples were stored in heavy-duty zip-lock plastic bags.

Laboratory Methods

Moisture content of peat and underclays was determined by heating approximately 10 g from each sample in a 17 ml flat-bottomed crucible at 105° C until dry (approximately 16 hr). Ash content at 0% moisture was then determined, by heating the dried sample at 550° C until all organic material was burned (approximately 1 hr).

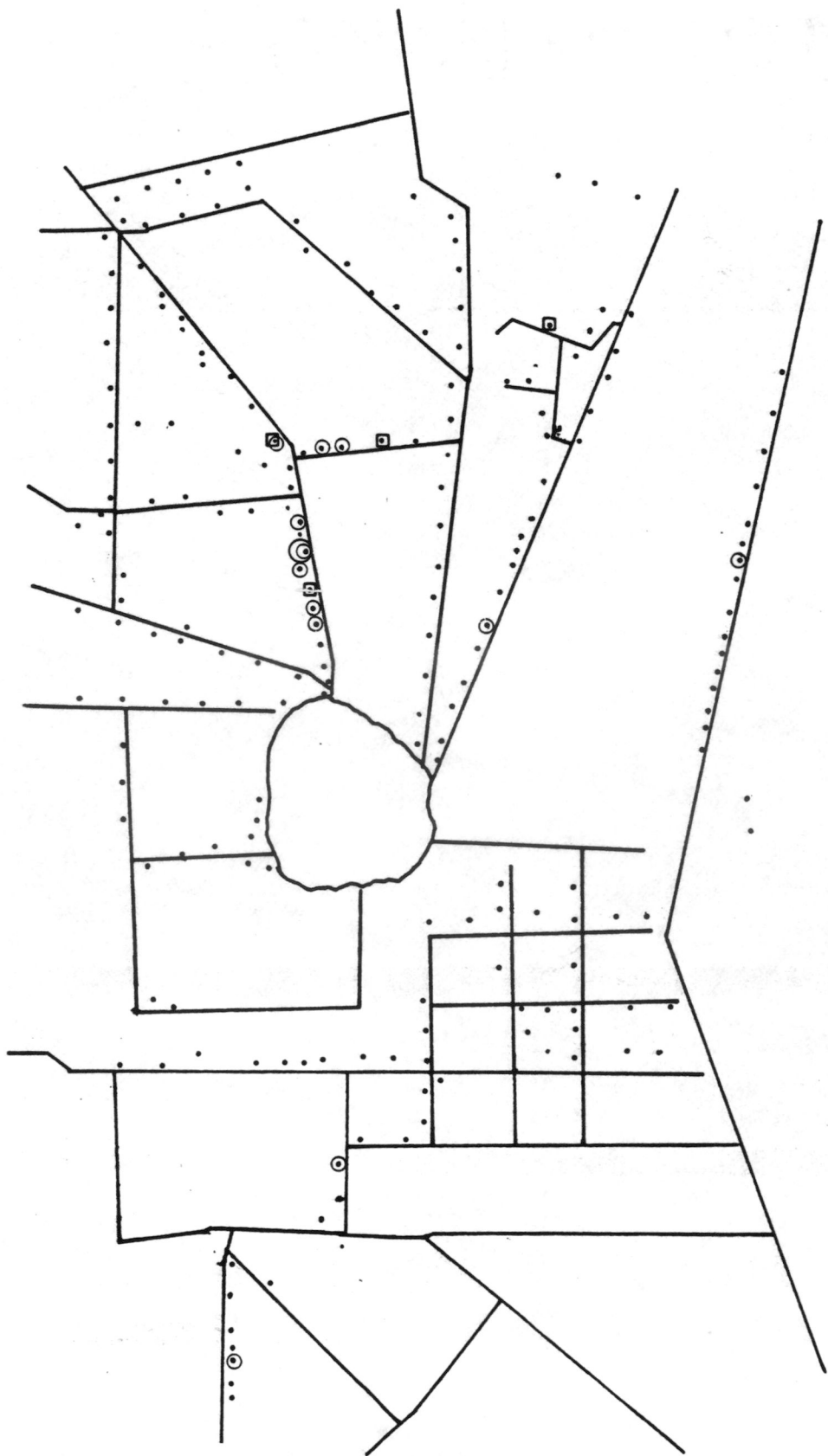
Figure 11: Location of sampling sites.

• Peat

□ Underclay

○ Whitehead (1972) pollen core

○ Macrofossil



A peat isopach map was prepared for the study area based on peat depths as determined by laboratory analyses of ash content. Orthophotomaps and low altitude infrared photographs provided additional information about the location of peat channels in areas between sampling sites.

STATISTICAL ANALYSES OF ASH CONTENT

Statistical analyses of average ash contents from two groups of sample sites from the peat deposits in the North Carolina portion of the Dismal Swamp (Figure 5) were provided by Dr. Kevin O'Brien of the Biostatistics Department at East Carolina University, Greenville, NC. The two groups included 1) comparisons between the ash content of peat samples located in the center of a deep channel, 0.03 km (0.5 mi) away from the center and 0.6 km (1 mi) away from the center, and 2) comparisons between a subgroup of samples from the centers of various deep peat channels and a subgroup of samples from the surrounding interstream divides.

A SAS (SAS Institute, 1979) program, using the following procedures was used:

- 1) Pearson product-moment correlations with covariances,
- 2) Pearson product-moment correlations with covariances, by area.
- 3) Analysis-of-variance.
- 4) Simple univariate descriptive statistics for area and depth.
- 5) Sidak T Tests for ash by area and by depth.
- 6) Scheffe's test for ash by area and by depth.

UNDERCLAYS

Five underclay samples from the study area were analyzed by X-ray diffraction to determine the clay minerals present. Analyses were performed on a General Electric XRD-5 by standard procedures (Ingram, 1967).

PLANT MACROFOSSILS

Separation of Macrofossils

Thirteen sediment cores were analyzed for plant macrofossils. Nine cores were located in the study area and 4 were from the North Carolina portion of the Dismal Swamp (Figure 11). Macrofossils used in this project were wood, leaves and seeds.

Macrofossils were obtained by wet sieving peat and underclay samples. Sieve samples contained approximately 200 cm^3 (minus about 10 g used for moisture and ash analyses). Samples were first dispersed in approximately two l of water, making a peat 'soup' that could be poured through the sieves with minimal damage to the macrofossils. Material was sieved through 4, 2, 1, and 0.5 mm opening screens to facilitate separation of various size macrofossils from surrounding plant material.

Woody material was picked out of the plant debris while still wet, and preserved by replacing the interstitial water with 70% ethanol (by immersing for 15 min in solutions of 10%, 35%, 50%, and 70% ethanol) (Kay, 1967). Samples were stored in 70 % ethanol prior to preparation for Scanning Electron Microscopy (SEM).

The remaining plant debris was allowed to air dry at room temperature and examined under a dissecting microscope to recover macrofossils. Plant debris that had compacted with drying was very gently crumbled to loosen any fossils from the rest of the material. Fossils were then picked out with the moistened tip of a pair of needle-nosed forceps. Macrofossils were stored dry, to be suitable for SEM, until all of the cores had been examined and representative specimens from each taxa present had been selected. All macrofossils found in this study have been deposited at the herbarium of the University of North Carolina at Chapel Hill, Dr. Jimmy R. Massey, Curator.

Scanning Electron Microscopy

Seed and leaf material was used in its dry condition for SEM. Representative specimens from each taxa were mounted on stubs, sputter coated and photographed by standard SEM methods (Kay, 1967).

Wood sections of 3 to 4 cm were hand cut with a single edge razor blade and mounted on stubs. These sections were then critical point dried to prevent shrinkage of their cellular structure, sputter coated and photographed. An ISI 40 SEM was used for all SEM photography.

Identifications

Macrofossils were identified primarily by comparison with photographs, drawings and descriptions found in various texts (Fasset, 1940; Muenscher, 1944; Martin and Barkley, 1961; Radford et al., 1968; Correll and Correll, 1972; Beal, 1977; Godfrey and Wooten, 1979) and with pressed specimens from the herbarium at the University of North Carolina at Chapel Hill. Dr. A.E. Radford, of the Department of Biology at the University of North Carolina at Chapel Hill was consulted for identification of species about which I was uncertain, and to confirm my own identifications. SEM photographs of macrofossils were used extensively to aid identifications, rather than repeated examinations of the macrofossils.

Identification of woody material was based on cellular structure (Brown et al., 1949). SEM photographs of wood sections from known species were used as references for identifying macrofossil woody material. Tracheid size, ray size, intertracheid pitting and resin canals were the most commonly used diagnostic characteristics .

RESULTS

PEAT

Peat channels in the Virginia portion of the Dismal Swamp were continuous with the peat deposits in the North Carolina portion of the swamp. Peat fills a dendritic drainage system in the study area. Three tributary channels connect with a deeper main channel which passes through the Fentress Rise to become the headwater region of the Northwest River (Figure 12). Peat depth in the study area reached a maximum of 2.4 m in the center of the main channel, was from 1 to 1.5 m across the interfluves and thinned to 0.3 or 0.6 m toward the swamp perimeter (Figure 13).

Peat Types

Two general types of peat, based on texture, were present in the study area. A well-preserved fibrous peat was found in the lower 1 to 1.5m of channels, and was usually present at the base of interfluves. Fibrous peat had a dark brown to reddish brown color and a spongy consistency. Plant material sieved from fibrous peat was composed of abundant stringy fibers and was typically dominated by marsh vegetation. Well-preserved seed macrofossils were common throughout fibrous peat, as were relatively small amounts of charcoal.

The transition between fibrous peat and the overlying sapricpeat was gradual. This transition was usually represented by a 0.3 to 0.6 meter zone of highly decomposed marsh peats, but occasionally contained both marsh and woody material.

Figure 12: Peat deposits of the Dismal Swamp, Va.- N.C. North Carolina isopach from Ingram and Otte (1981). 1.2 meter (4 foot) isopach interval. Isopach intervals shown in feet in order to maintain continuity between Virginia and North Carolina data. Base map from Lichtler and Walker (1974).

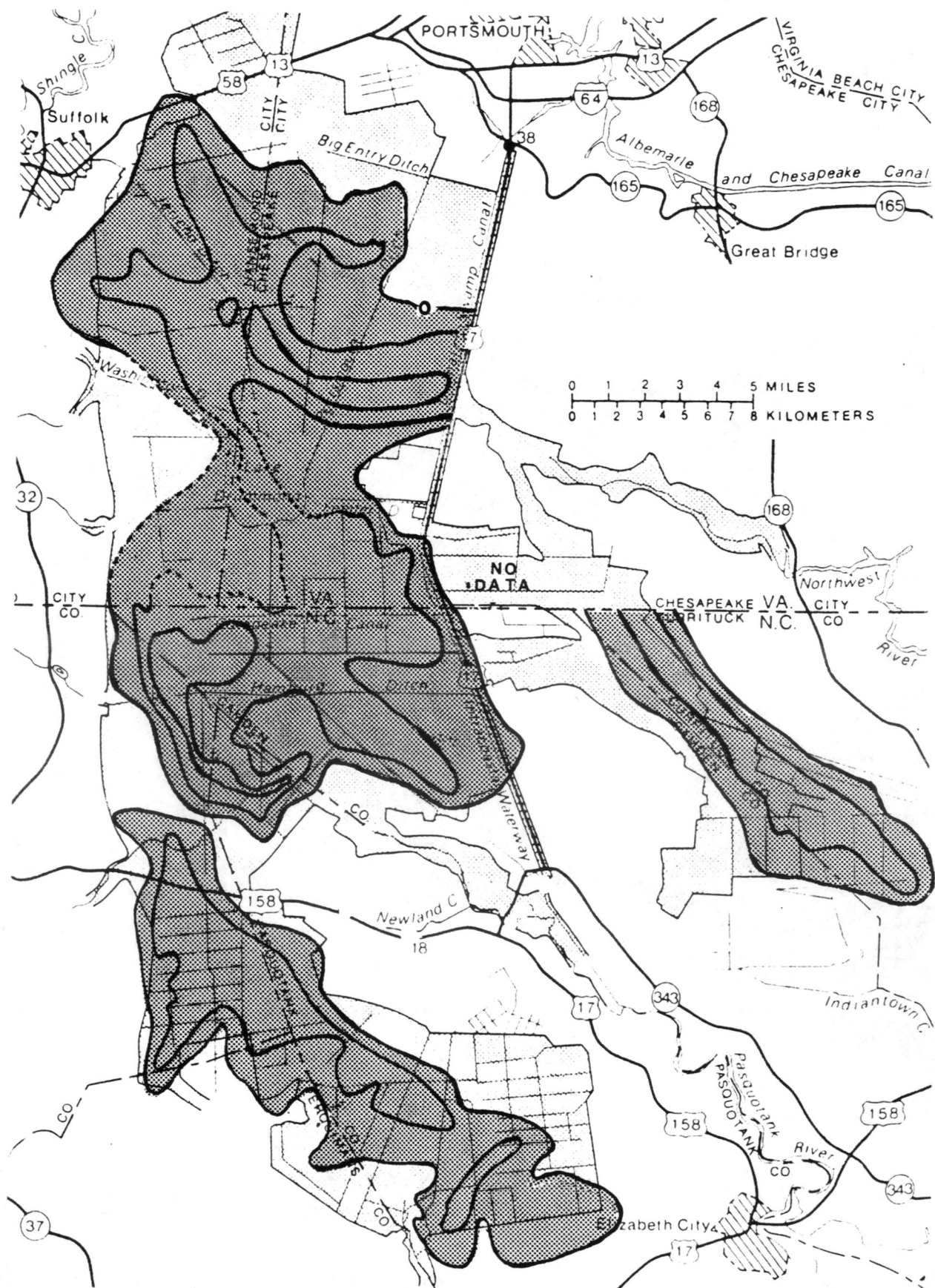
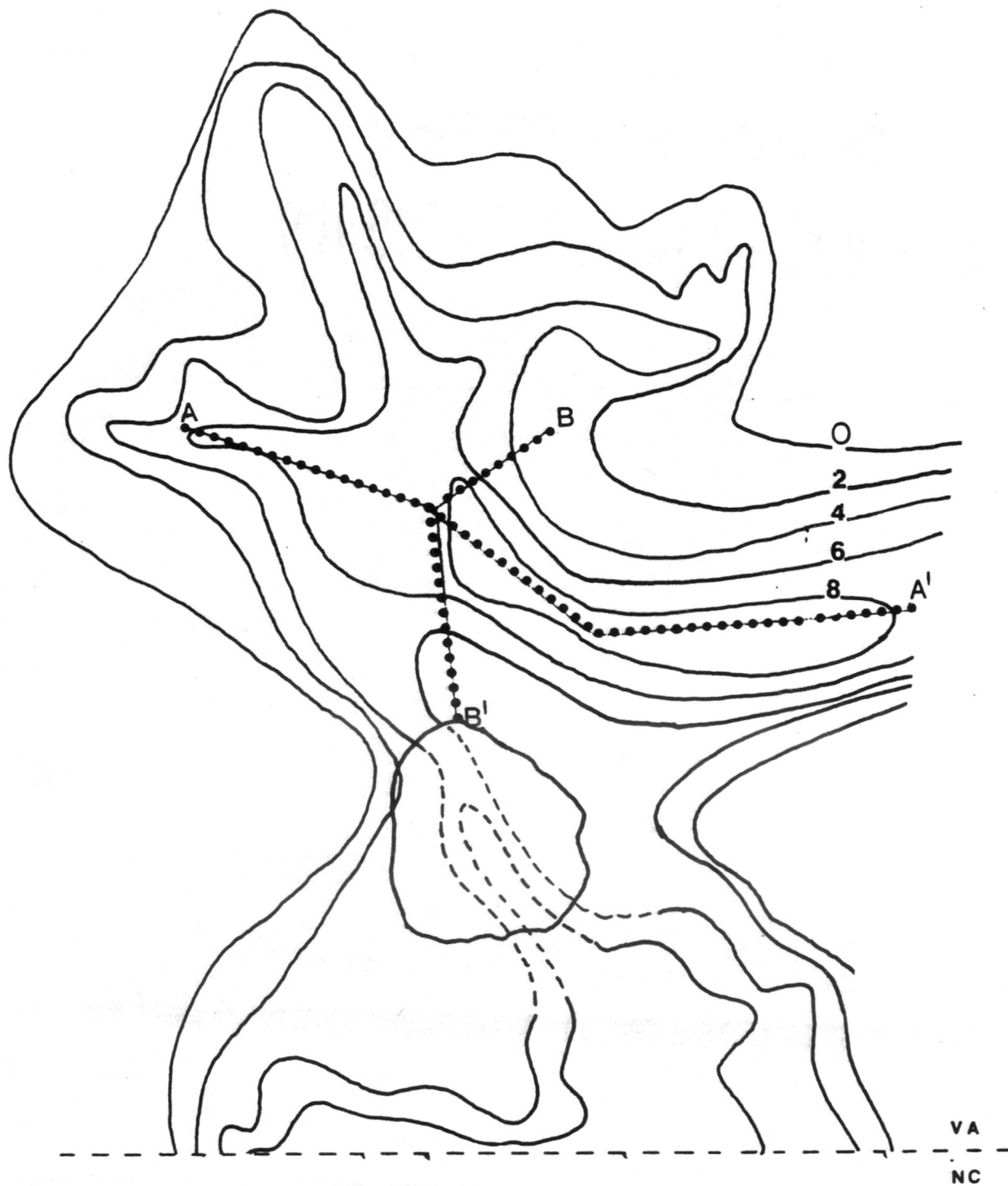


Figure 13: Detail of Study Area, showing peat isopach map and the location of cross sections A - A' and B - B' (Figures 14 and 15) through the peat deposit. 2 ft. contour interval.



A less well-preserved, brownish-black sapric peat was found along the outer edges of the main peat channels, interfluves and the top 0.9 to 1.2 m of deep channels. Most of the top 0.6 m of sapric peat had undergone some dehydration and generally had the appearance of coffee grounds, even when saturated. In contrast, deeper sapric peats that had experienced little or no dehydration had the consistency of thick axle grease. Plant material sieved from sapric peat was typically granular to chunky and was generally dominated by charcoal and wood.

The correlation of sapric peat with woody material and fibrous peat with marsh material was not continuous across the swamp; in the lowest elevations, found in the easternmost areas of the swamp, the fibrous horizon extended through the woody peat and came within 0.3 to 0.6 m of ground surface. This fibrous woody peat retained the chunky texture found in sapric woody peats and was very distinctive from fibrous marsh peat.

Ash Content

Ash content of peat varied throughout the peat deposit. Natural breaks in ash content (at 0% moisture) seem to occur at around 5 and 15 % and show distinctive distributional patterns which can be traced through cross-sections of the peat deposit (Figures 14 and 15) Highest ash peats were found in areas with the greatest influx of terrigenous sediments, such as adjacent to upland areas and inflowing streams, while lowest ash peats were found in areas receiving minimal terrigenous sediment input, such as the interior portions of the swamp that were beyond the reach of sediments brought in by sheet flow from uplands and/or stream flow.

Figure 14: Cross-section of peat channels in the Dismal Swamp, oriented perpedicularly to the direction of flow, showing peat type and ash content. Location of cross section is shown in Figure 13. Major source of sediments in the upper horizons was from sheet flow off the Suffolk Scarp to the west and the Churchland Flat to the north. Mineral sediment input in the lowest portions of peat channels was from erosion of immediately adjacent interfluves as well as the Suffolk Scarp to the west and the Churchland Flat to the north.

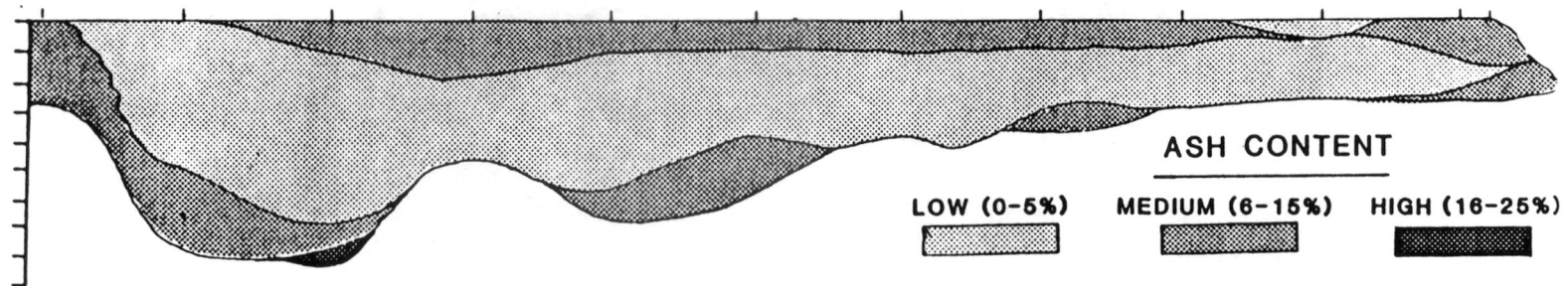
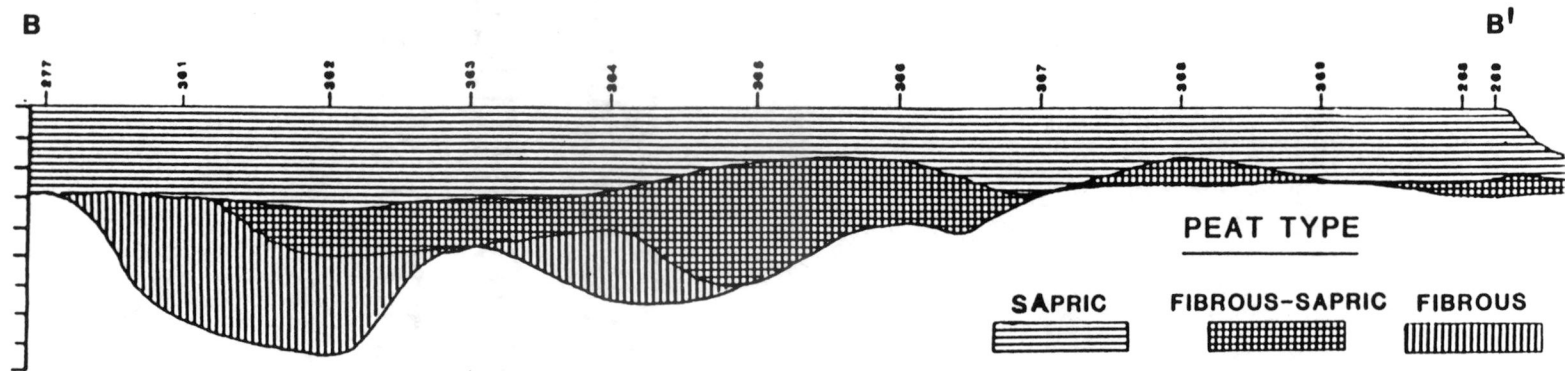
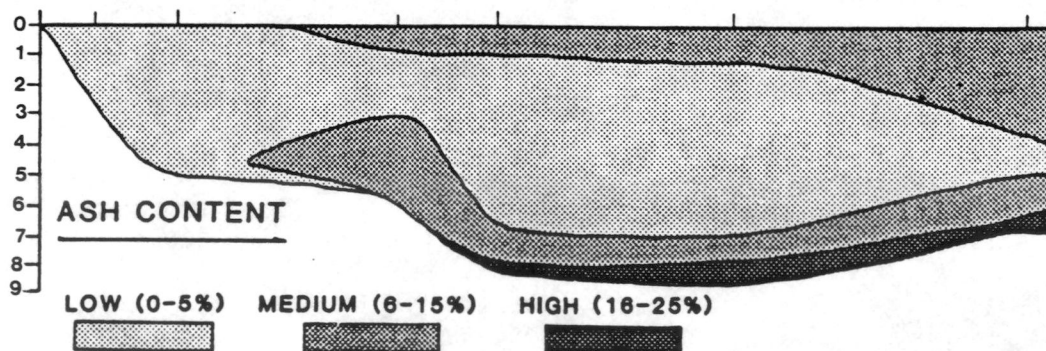
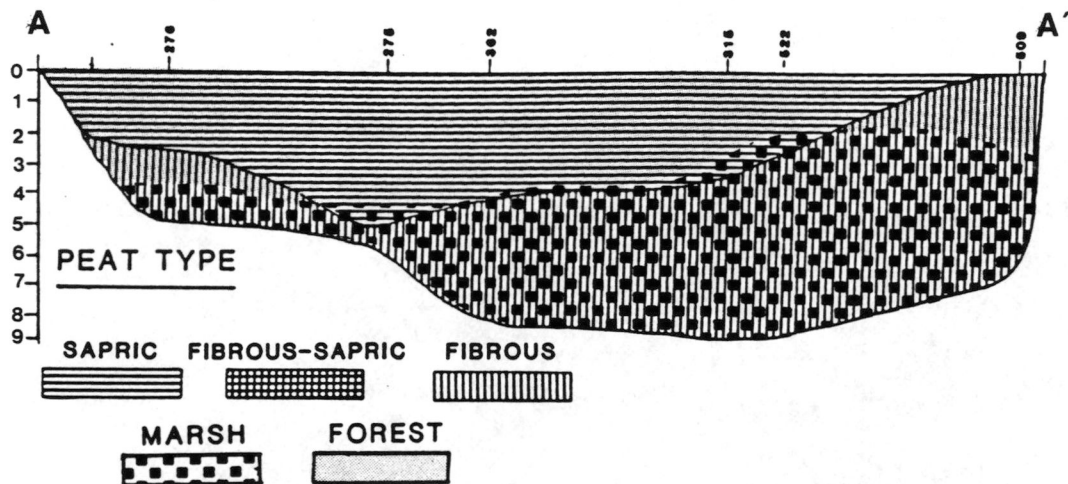


Figure 15: Cross-section through the center of a deep peat channel in the Dismal Swamp, oriented parallel to the direction of flow. Location of cross section is shown in Figure 13. The source of mineral sediments in the upper horizons was from the higher ground to the east. Sheet flow from the Suffolk Scarp to the west does not reach this far east.



Statistics

Results from statistical analyses of average ash contents for five different areas in the Dismal Swamp are summarized in Table 4. Procedures(1) and (2) were used to look for any correlations between ash content and depth; procedure (3) to determine if the average ash content was different at each site ; and procedures (4), (5) and (6) to determine at which sites the differences in average ash content, if any, occurred. The different areas analyzed for ash content, shown in Figure 5, are: Group 1 - Area 0, center of channel; Area 1, 0.03 km away from center; Area 2, 0.06 km away from center; Group 2 - Area 3, centers of various channels; and Area 4, surrounding interfluves.

The Analysis of Variance procedure provided the most useful information concerning the average ash contents of peat samples from different locations. No significant differences in overall average ash contents were found for the areas. Variation in average ash contents for sites within areas and among depths within sites suggests that the conditions immediately adjacent to a site were the primary factors in ash distribution within the peat deposit. Local conditions, such as depth of the channel in which peat was forming; proximity to a source of mineral sediments; and vegetation cover type need to be considered for each depth at individual sites before the controlling factors in the distribution of ash content within peat deposits can be determined. Other statistical procedures employed produced inconclusive results(Table 4).

Table 4: Results from statistical analyses of average ash contents for five areas in the Dismal Swamp. Areas shown in Figure 5.

PROCEDURE	RESULTS
1. Pearson product-moment correlations with covariances	1. Basic correlation structure for ash content across depth was a decrease in correlation with increasing vertical distance between depths. Variances were heteroscedastic with respect to depth.
2. Pearson product-moment correlations with covariances, by depth	2. Areas 0,3 and 4 were similar in variance and covariance structure - variances decrease with depth, down to 1.2 m, and then stabilize. Areas 1 and 2 show no pattern in variance-covariance structure.
3. Analysis of Variance	3. There was no significant difference among areas regarding overall ash content ($F=2.08$ {4,43} $p=0.1002$). There was significant variation in average ash content among sites within areas, and among depths within sites ($F=3.16$ {42,207} $p=0.0001$; $F=36.75$ {6,207} $p=0.0001$). There was no significant interaction regarding depth and area ($F=0.78$ {23,207} $p=0.76$).
4. Sidak T Tests (by Area)	4. Site 0 had a significantly different average ash content ($p=0.05$) than sites 1,2 and 4. There was no significant difference in average ash contents for sites 1,2,3 and 4, and for sites 0 and 3.
5. Sidak T Test (by Depth)	5. Depths 1,5,7 and 8 had significantly different average ash contents ($p=0.05$). Depths 2,3,4 and 6 had no significantly different average ash contents
6. Scheffe's Test	6. Same as for Sidak T Tests.

UNDERCLAYS

X-ray diffraction analyses of underclays from five sites located in the study area (Figure 11) were performed. Kaolinite, illite and vermiculite were found to be the clay minerals present (Table 5). These sediments contained abundant plant material and when sieved produced stringy fibrous material similar to that found in the overlying fibrous peats. Well-preserved seeds of marsh plants were common in the underlying mineral sediments. In general, these sediments contained plant material that was less well-preserved and had a slightly higher charcoal content than fibrous peats.

Table 5: Clay minerals of Dismal Swamp underclays. K = Kaolinite, V = Vermiculite and I = Illite. *X = present, 0 = absent.

Sample	DEPTH (meters)	LOCATION (closest ditch)	CLAY MINERALS*		
			K	V	I
310-8-B	3.0	Camp	X	X	X
360-7	2.5	Jerico/Camp	X	X	X
361-11	3.5	Jerico (south)	X	X	0
373-3	1.2	Juniper/Hardwood	X	X	0

MACROFOSSILS

Plant macrofossils of 37 taxa were found in this study (Table 6). The number of macrofossils and the number of taxa increase with depth below ground surface (Figure 16). Two macrofossil zones , marsh and forest, were found in each of the 13 sediment cores analyzed for macrofossils.

Marsh Zone

The marsh zone was characterized by a nearly even mixture of aquatic and emergent marsh species, and was usually associated with fibrous peats and their underlying mineral sediments (underclays) Macrofossils of 12 species of aquatic plants were present in the marsh zone (Table 6). Floating-leaved (Nymphaea, Brasenia), submerged-floating (Myriophyllum, Ceratophyllum, Proserpinica, Potamogeton), emerged (Polygonum) and shrubby (Decodon) aquatic species were represented. Aquatic species were evenly mixed with emergent species throughout the peat deposit. Nymphaea odorata, Nymphoides aquatica and Myriophyllum were the most abundant and most commonly occurring aquatic species present. Representative aquatic species are pictured in Plate 1.

Over 90% of emergent taxa from the marsh zone belong to the Cyperaceae (sedge) family. Cyperaceae genera represented in the marsh zone were Fuirena, Eleocharis, Carex, Scirpus, Rhynchospora, Scleria, Cyperus, Eriophorum and Dulichium. Eriocaulon of the Eriocaulaceae family was also present (Table 6). Fuirena , Eleocharis equisetoides type and Scirpus etuberculatus type were the most abundant and most commonly occurring emergent species present. Representative examples of emergent macrofossils are pictured in Plates 2 and 3.

Table 6: Macrofossils identified from Dismal Swamp peat deposits.

FOREST

Pinaceae

Pinus taeda L.

Cupressaceae

Chamaecyparis thyiodes (L.) BSP

MARSH

Potamogetonaceae

Potamogeton sp.

Cyperaceae

Cyperus compressus L. type

Cyperus virens Michaux type

Cyperus sp.

Dulichium arundinaceum (L.) Britton

Eleocharis sp.

Eleocharis equisetoides (Ell.) Torrey type

Eleocharis parvula Link

Eleocharis interstincta type

Scirpus sp.

Scirpus etuberculatus (Steudel) Kuntze type

Scirpus smithii (Fernald) type

Scirpus americanus Persoon type

Fuirena sp.

Eriophorum virginicum L.

Rhyncospora sp.

Rhyncospora chalarocephala Feernald and Gale type

Scleria type

Carex sp.

Carex scoparia Schkuhr type

Carex comosa Boott type

Juncaceae

Juncus sp.

Juncus effusus L. type

Eriocaulaceae

Eriocaulon lineare Small type

Polygonaceae

Polygonum amphibium type

Table 6: Plant macrofossils from Dismal Swamp peat deposits (Continued).

Ceratophyllaceae

Ceratophyllum sp.

Nymphaeaceae

Nuphar luteum (L.) Sibthorp and Smith

Nymphaea odorata Aiton

Nymphaea tuberosa

Cabombaceae

Brasenia schreberi Gmelin

Lythraceae

Decodon verticillatus (L.) Ell.type

Haloragaceae

Proserpinaca sp.

Myriophyllum sp.

Apiaceae

Hydrocotyle sp.

Gentianaceae

Nymphoides aquatica (Walter ex. J.F. Gmelin) Kuntze

The designation 'type' following a species name (sensua Watts, 1980) indicates that the identification to genus was certain, but the species determination was not absolute. The designation 'type' following a genus name indicates that the macrofossil(s) were more similar to that genera than any other, but there may be some question concerning the identification.

Figure 16: Number of macrofossil seeds and macrofossil taxa by distance above underlying mineral sediments. Data includes all macrofossil samples analyzed in this study.

MACROFOSSILS BY DISTANCE ABOVE UNDERLYING MINERAL SEDIMENTS
DISMAL SWAMP PEAT DEPOSITS

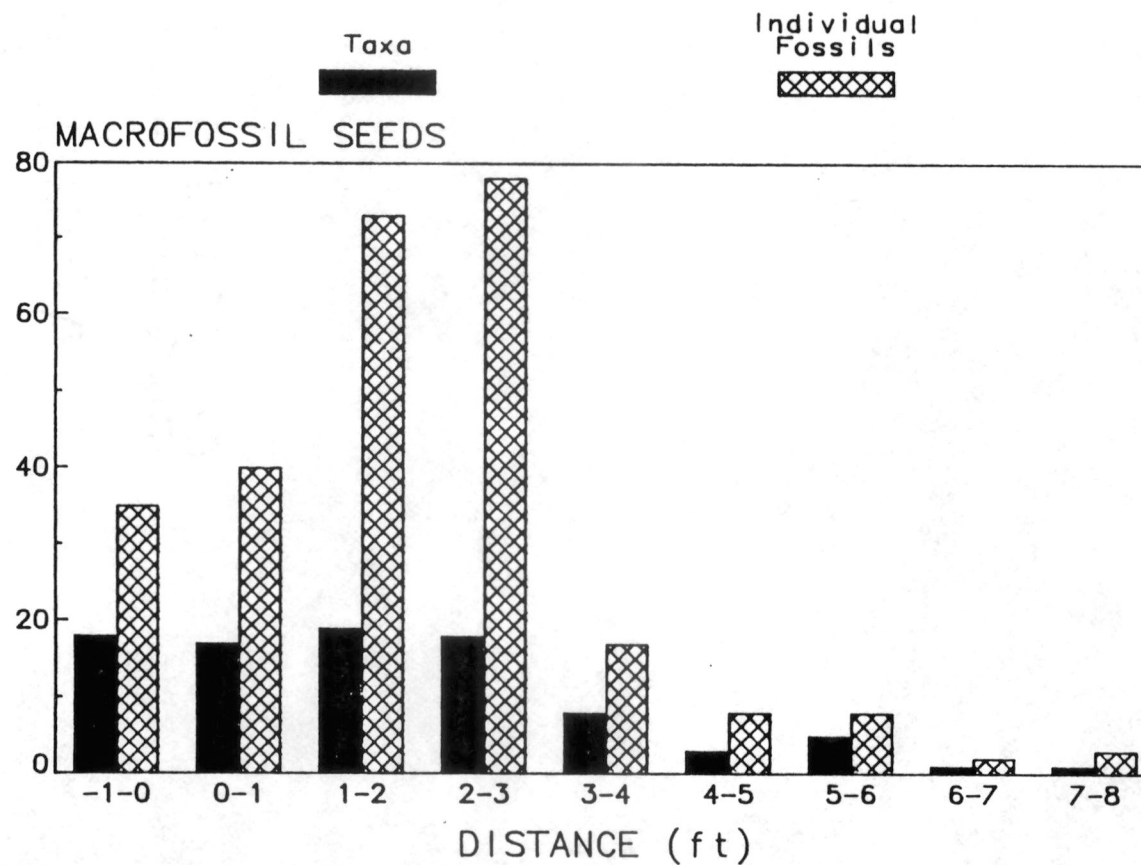
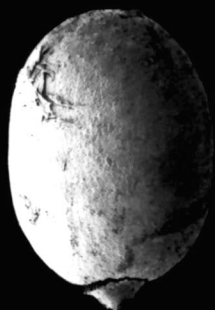


Plate 1: Macrofossils of aquatic marsh species from Dismal Swamp, VA-NC
peat deposits. Scale bar = 0.4 mm.

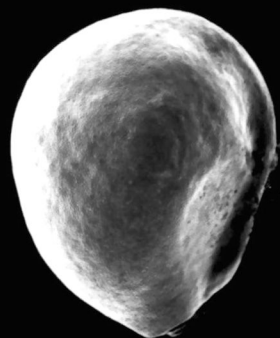
1. Ceratophyllum sp.
2. Brasenia schreberi
3. Nuphar luteum
4. Hydrocotyle sp.
5. Potamogeton sp.
6. Proserpinica sp.
7. Nymphaea odorata
8. Myriophyllum sp.
9. Nymphoides aquatica



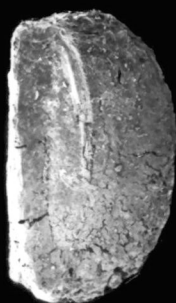
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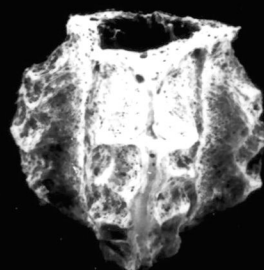
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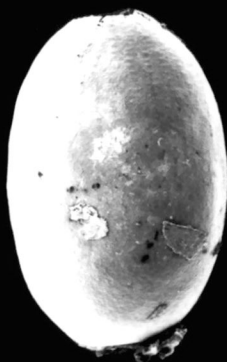
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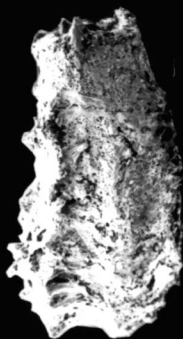
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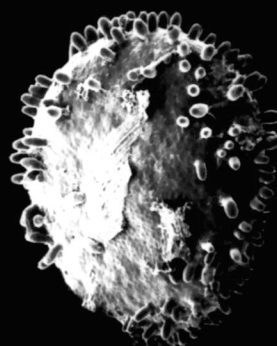
6 —



7 —



8 —



9 —

Plate 2: Macrofossils of emergent marsh species from Dismal Swamp VA-NC, peat deposits. Scale bar = 0.4 mm.

1. Eriophorum virginicum
2. Carex comosa type
3. Dulichium arundinaceum
4. Scleria type
5. Scirpus etuberculatus type
6. Eleocharis sp.
7. Decodon verticillatus
8. Eriocaulon lineare type
9. Polygonum amphibium type

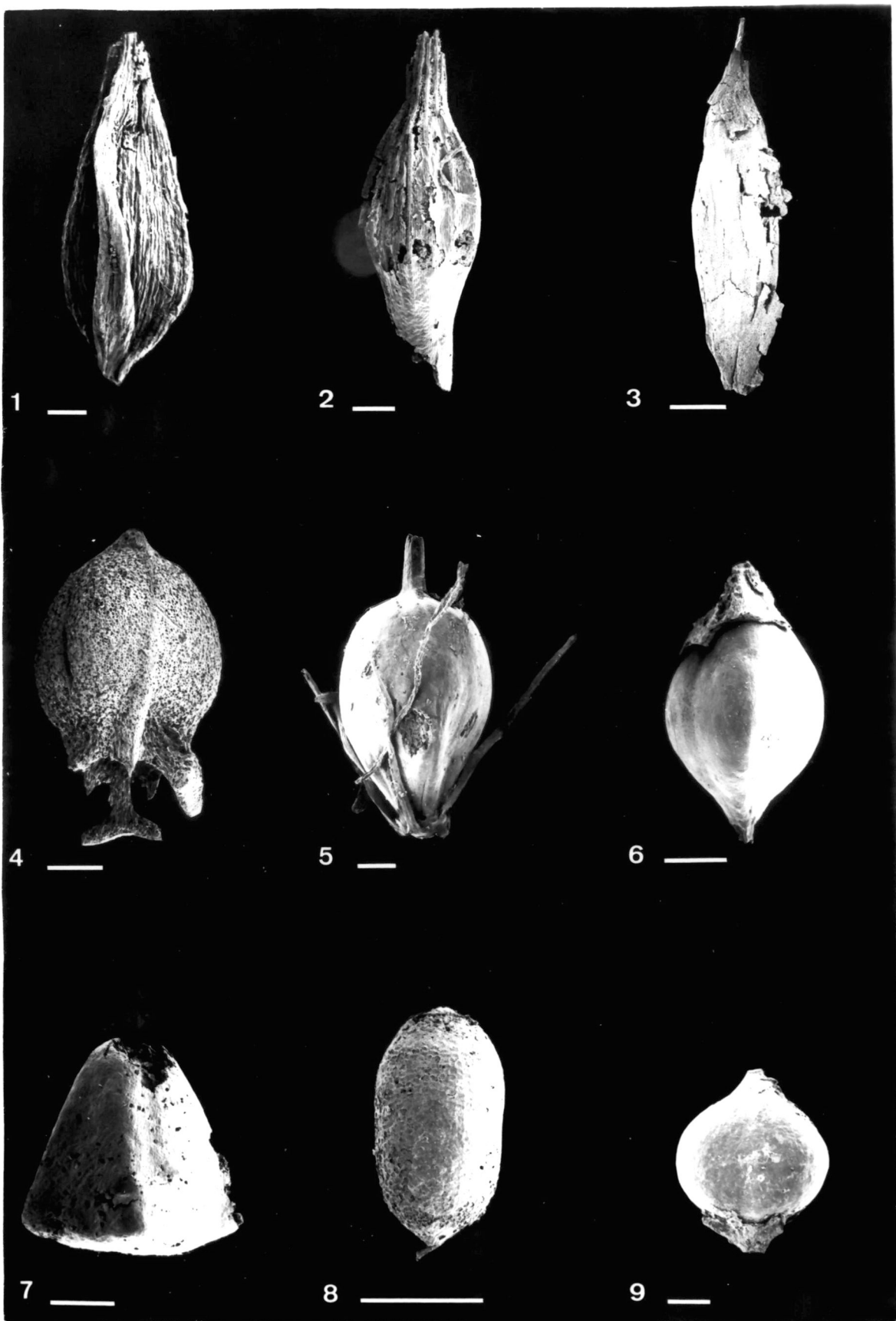
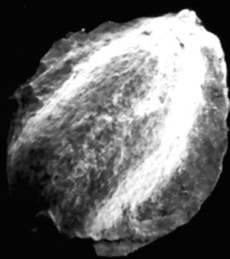


Plate 3: Macrofossils of emergent marsh species and of
Chamaecyparis thyoides (Atlantic White Cedar)
from Dismal Swamp, VA-NC peat deposits.
Scale bar = 0.4mm.

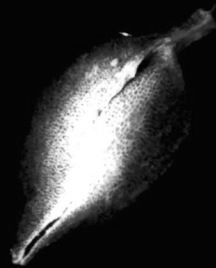
1. Chamaecyparis thyoides seed
2. Rhyncospora chalarocephala type
3. Carex (trigonous)
4. Chamaecyparis thyoides scale-like leaves
5. Rhyncospora sp.
6. Carex (flat)
7. Chamaecyparis thyoides flattened branch tip
8. Rhyncospora sp.
9. Carex trigonous
10. Chamaecyparis thyoides individual leaf
11. Rhyncospora sp.
12. Fuirena sp.
13. Juncus effusus type



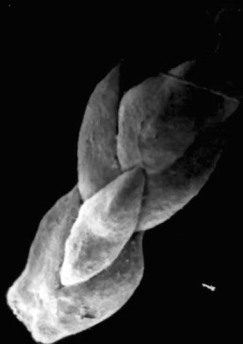
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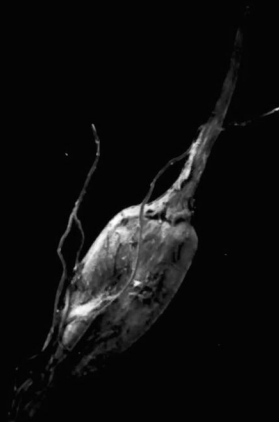
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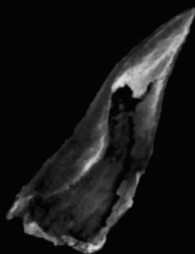
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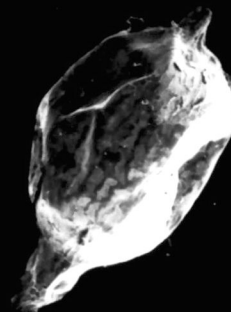
9 —



10 —



11 —



12 —

Forest Zone

The forest zone was dominated by Chamaecyperus thyiodes wood, leaves, and/or seeds in 11 of the 13 macrofossil cores. C. thyiodes seeds and leaves, pictured in Figures 1,4,7 and 10 of Plate 3, were the most commonly occurring and easily recognized macrofossils in the forest zone. Two cores (D-509 and D-522, Figure 15) contained wood and/or needles from a southern pine, probably Pinus taeda or P. serotina (Plate 4).

The forest zone was found in the upper sections of the peat deposit and was typically associated with sapric peats. Interfluvial areas had up to 1.5 m of forest peat, while deeper channels generally had 1 to 1.3 m of sapric forest peat overlying fibrous peat (Figures 14 and 15).

Correlations with Ash Content

The ash content of peat and the underlying sediments varied throughout the peat deposit, and was different for the marsh and forest zones (Table 7). Marsh peats had a higher average ash content (6.91%) than forest peats (4.76%). If the underlying mineral sediments that contained marsh macrofossils are included in the ash data, marsh sediments had almost five times the average ash content of forest peats (23.6% for the marsh compared to 4.8% for the forest).

Within the marsh zone, sediments in which emergent species occurred had higher average ash contents than the sediments in which aquatic species occurred. The average ash content of the sediments in which a species occurs was greatest for Scleria sp. (55.4%) and least for Nymphoides aquatica (16.4%).

Plate 4: Cellular structure of three wetland trees. Southern Pine, indistinguishable between P. taeda, P. serotina and P. palustris by cellular structure, and Chamaecyparis thyoides (Atlantic White Cedar) were found in peat samples from the Dismal Swamp, Va-NC. Taxodium sp. (Cypress), pictured for comparison, was not found in Dismal Swamp peat deposits. Cross sections are at approximately 85 X and Tangential sections are at approximately 650 X.

1. Southern Pine.

- A. Cross (x) section. Tracheids intermediate (35-45 μ).
- B. Tangential (t) section. Uniseriate, bordered intertracheid pits; transverse resin canal.

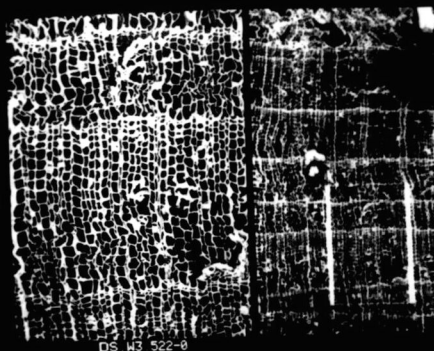
2. Chamaecyparis thyoides.

- A. Cross (x) section. Tracheids fine (25-30 μ).
- B. Tangential (t) section. Uniseriate, bordered intertracheid pits; resin canals lacking.

3. Taxodium sp.

- A. Cross (x) section. Tracheids coarse (45-60 μ).
- B. Tangential (t) section. Triseriate, bordered intertracheid pits. Resin canals lacking.

A



1



2



3

B

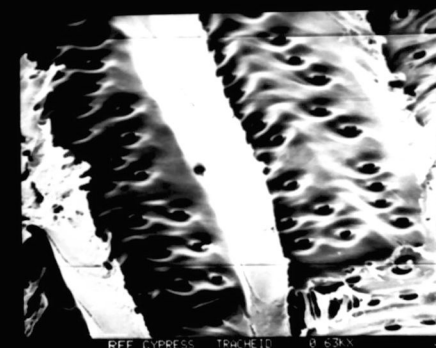
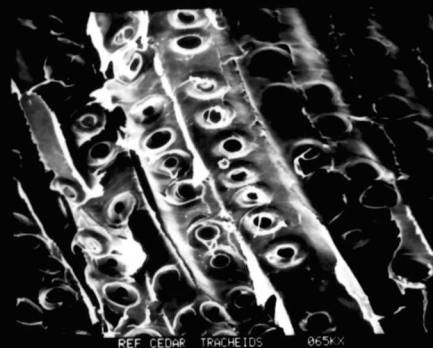
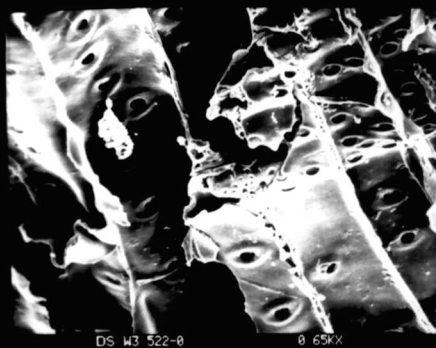


Table 7: Average ash contents for peat samples in which macrofossil species were found.

VEGETATION		PEAT	PEAT & UNDERCLAYS
ZONE	n	ave. % ash	ave. % ash
Marsh	37	6.91	23.57
Forest	68	4.76	na *
SPECIES			
<u>Myriophyllum</u>	22	13.74	31.81
<u>Nymphoides</u>	7	6.37	16.36
<u>Nymphaea</u>	8	9.13	16.92
<u>Eleocharis</u>	19	7.58	26.64
<u>Fuirena</u>	9	4.32	23.62
<u>Scleria</u>	5	10.55	55.42
<u>Scirpus</u>	7	5.16	20.96

* No forest macrofossils were found in the underclay samples.

DISCUSSION

The Holocene macrofossil flora of the Dismal Swamp is characterized by two zones: a lower marsh zone dominated by aquatics and sedges, and an upper forest zone dominated by Chamaecyparis thyoides (Figure 17). The vertical distribution of macrofossils within the peat deposit shows that the swamp began as a marsh community and then succeeded to a forest community when peat accumulation reached about 1.5 m above the base level of peat accumulation in the swamp (Figure 18).

The elevation of the deepest contact between mineral sediments and the overlying peats in the study area can be considered as a baseline above which peat accumulated in the swamp. This baseline represents a nearly horizontal plane that parallels the water table, and is the reference point by which the vertical location of macrofossils at any site in the study area can be correlated. This base level, rather than ground surface, is used for comparison and characterization of macrofossil assemblages because the base level follows the pattern of development from the bottom upward, and not from the top downward. The contact between the peat and underclays is not always a reliable reference point, particularly when making comparisons across broad areas of varying peat thicknesses: the 'bottom' of a three m thick peat channel was certainly a much different environment than the 'bottom' at one m of interfluvial peat. Macrofossil data indicate that the base of the channel was most likely a ponded marsh environment, while the interfluvial was probably drier and supported a forest community.

Figure 17: Macrofossil Diagram for the Dismal Swamp. Data are from three cores in the study area, shown in Figure 11, and do not include all of the macrofossils found in the study area.

MACROFOSSIL DIAGRAM FROM THE DISMAL SWAMP

DEPTH ABOVE MINERAL SEDIMENTS

SEDIMENT

% ASH(at 0% moisture)

POLLEN ZONE®

AQUATIC

EMERGENT

FOREST

SUMMARY

NUPHAR

NYMPHAEA

NYMPHOIDES

MYRIOPHYLLUM

PROSERPINACA

HYDROGOTYLE

RHYNCHOSPORA

ELEOCHARIS

JUNCUS

SCIRPUS

CAREX

CYPERUS

SCLERIA

FUIRENA

ERIOCAULON

DECODON

ATLANTIC WHITE CEDAR

UNKNOWN

TOTAL MACROFOSSIL SEEDS (% macrofossils)

FOREST

MARSH

FOREST-DOMINATED

ATLANTIC WHITE CEDAR

TRANSITIONAL^o

ZONE OF POOR PRESERVATION

fluctuating water table at marsh surface

MARSH-DOMINATED

MIXTURE OF AQUATICS AND EMERGENTS

AQUATIC^Δ

EMERGENT[◻]

SAPRIC PEAT

FIBROUS PEAT

SANDY CLAY

OTRANSITION DATED 3,180 BY WHITEHEAD

●BASAL CLAYS DATED 7,670 BY WHITEHEAD

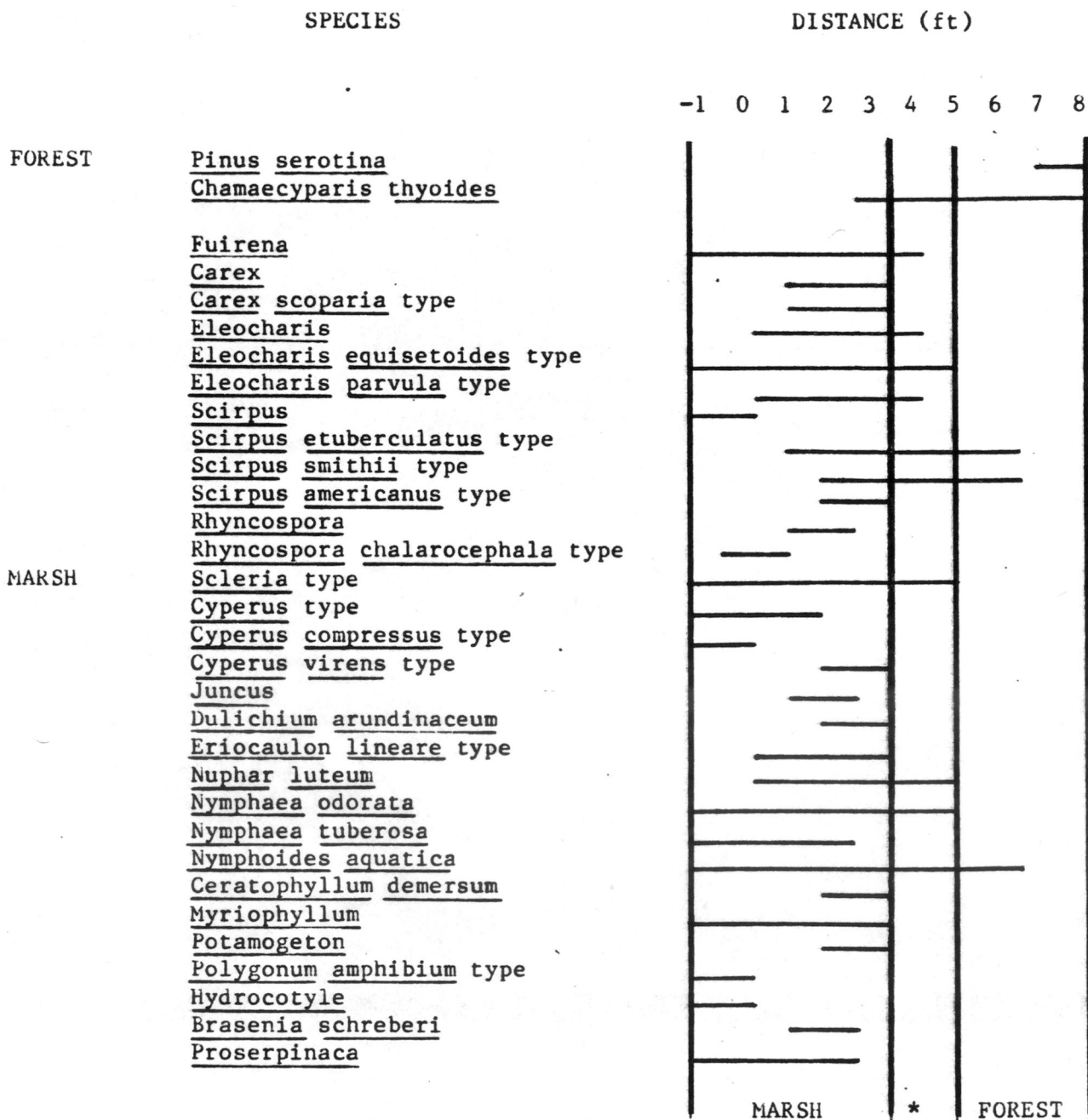
®WHITEHEAD, 1972. CORE D-49

▲ LEAVES AND WOOD DOMINANT MACROFOSSILS

■ PERCENTAGES REFLECT ABUNDANT WOOD AND LEAVES

B. SMITH '85

Figure 18: Macrofossil species distribution above the base level of initial peat accumulation in the Dismal Swamp. Includes data from all of the macrofossil cores in the study area (Virginia).



* Denotes transition zone from marsh to forest.

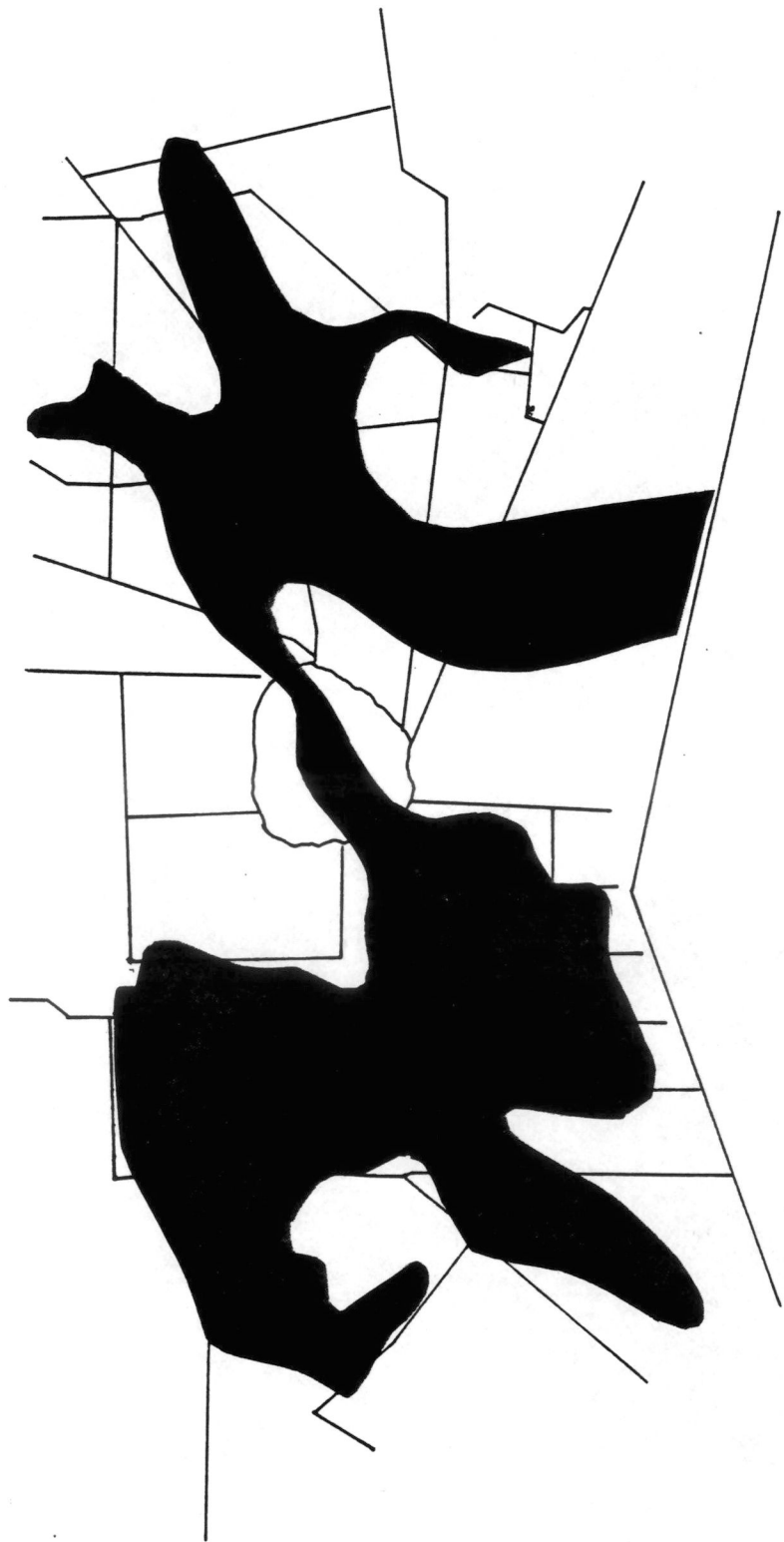
Macrofossil data, which represent locally occurring species, are the primary source of information concerning vegetational succession within the confines of the wetland system. Pollen data, which are representative of regional vegetation patterns, lend support to macrofossil evidence, and provide information about the overall regional vegetational systems within which the Dismal Swamp is located.

MARSH PALEOECOSYSTEM

Origin and Development

Marsh development is known to have begun in topographic lows along water courses - probably blocked drainage systems- between 9,000 and 10,000 years ago (Oaks and Whitehead, 1979). The presence of floating-leaved and submersed aquatic species (Nuphar luteum, Nymphaeae odorata, Ceratophyllum and Myriophyllum), in conjunction with the deposition of fresh water clays, indicates that peat deposition began in a relatively deep, quiet, ponded (as opposed to fluvial) marsh environment. This marsh may have covered as much as 24 or 26,000 ha.(60 or 70,000 a.), an area equivalent to at least one-third of the present swamp area (Figure 19). An abundance of bola stones, dating from 4,000 to 9,000 years b.p., has been found along high grounds adjacent to the swamp. These bola stones, commonly used by Indians to hunt wading birds in marshes, further indicate the existence an expansive marsh during the development of the Dismal Swamp (Bottoms and Painter, 1979).

Figure 19: Area covered by marshes during the development of the Dismal Swamp. Based on depth of marsh zone in Dismal Swamp peat deposits.



Hydrologic Characteristics

The diverse species composition found in the marsh zone suggests a mosaic of subenvironments within the marsh. The presence of floating-leaved and submerged aquatics suggest that areas of open water were always present, while emergent shore and marsh plants suggest shallower depths with water level fluctuations. The vertical distribution of marsh species, shown in the macrofossil diagram (Figure 17) indicates that no one species or type of species dominated the marsh at any time. The shift from more abundant aquatic species at the base of the peat deposit, to more abundant emergent species towards the top of the deposit, reported in pollen data (Whitehead, 1972), is not seen in the macrofossil data.

Occasional poorly preserved horizons and charcoal-rich horizons within the marsh zone suggest water level fluctuations during which the marsh surface was exposed to oxidation or fire. Such fluctuations were probably of short duration and of limited occurrence, since the poorly preserved horizons are infrequent and show no correlation among cores. In addition, these fluctuations could not have been extreme or the diverse aquatics could not have survived throughout the marsh (Harris and Marshall, 1963).

The presence of a diverse marsh flora, represented by macrofossils in the peat cores, suggests that the early Dismal Swamp marshes may have been similar to the present marshes of the Okeefenokee Swamp of Florida and Georgia. Many of the marsh species found as macrofossils in the Dismal - Nuphar luteum, Nymphoides aquatica, Nymphaea odorata, and Eriocaulon - are present in the Okeefenokee (Spackman et. al., 1976). Both the Okeefenokee and the Dismal are formed in some type of restricted

drainage system and have extensive thicknesses of basal marsh peats (Spackman et al., 1976). The Dismal Swamp may be considered to be in a more advanced successional stage than the Okeefenokee, since the original drainage system of the Dismal Swamp has been infilled with peat and the marsh has been replaced by a forest. The Okeefenokee, in contrast, still has many active fluvial channels with relatively strong surface water movement (Spackman et. al., 1976).

Mineral Sediment Influx

Sands, silts and clays washed into the ponded area, and were incorporated into the organic sediments produced by the marsh vegetation, during the early stages of marsh development. The immediate source area for influxing mineral sediments gradually decreased as the marsh surface rose with continued peat accumulation. Marsh development progressed laterally as well as vertically and increased the area of vegetation which served as a sediment trap for incoming sediments. The amount of mineral sediment incorporated into the peat decreased as marsh development proceeded, and little mineral sediment input reached the marsh following initial deposition of basal inorganic clays.

The decrease in mineral sediment content as the marsh developed is seen in the patterns of ash content shown in cross-sections of the peat deposit (Figures 14 and 15). Ash content is higher in the base of the peat channel and decreases toward the top of the marsh zone. It should be noted that even though basal peats are designated as having high ash contents, they consist primarily of water with relatively minor amounts of organic and mineral material. The relative abundance of these components can be illustrated by calculating the amount of each component that is present in

one peat sample (0.3 m vertical core). For illustrative purposes, an approximate breakdown of the individual components (not adjusted to volume or for differences in bulk densities of organics, ash and water) is used. A 0.3 m vertical peat core which is 90 % moisture at field conditions and has 25% ash at zero percent moisture contains approximately 27 cm water, 2.9 cm of organic material and 0.8 centimeters mineral material. Based on an accumulation of 2.2 m in about 4,500 years (Whitehead, 1972), this corresponds to an influx of approximately .02 cm of mineral sediment per year. Mineral sediment influx rates for medium and low ash peats are even lower (Table 8).

Table 8: Influx rates of terrigenous sediments and organic material for medium, low and high ash peats in the Dismal Swamp.

% ASH (0% MOISTURE)	% MOISTURE (FIELD)	DEPTH (METER)	CM PER 1 M CORE			ACCUMULATION/YEAR	
			W	O	M	O	M
HIGH (25%)	89.0	2.4	26.7	0.8	2.9	0.2	0.06
MED (15%)	89.0	2.0	26.7	1.0	2.3	0.2	0.03
LOW (5%)	89.0	1.8	26.7	1.1	2.2	0.2	0.01

W = water, O = organics, M = mineral. Accumulation is in centimeters per year. Based on an overall accumulation of 2.2 meters in 4,490 years (Whitehead, 1972).

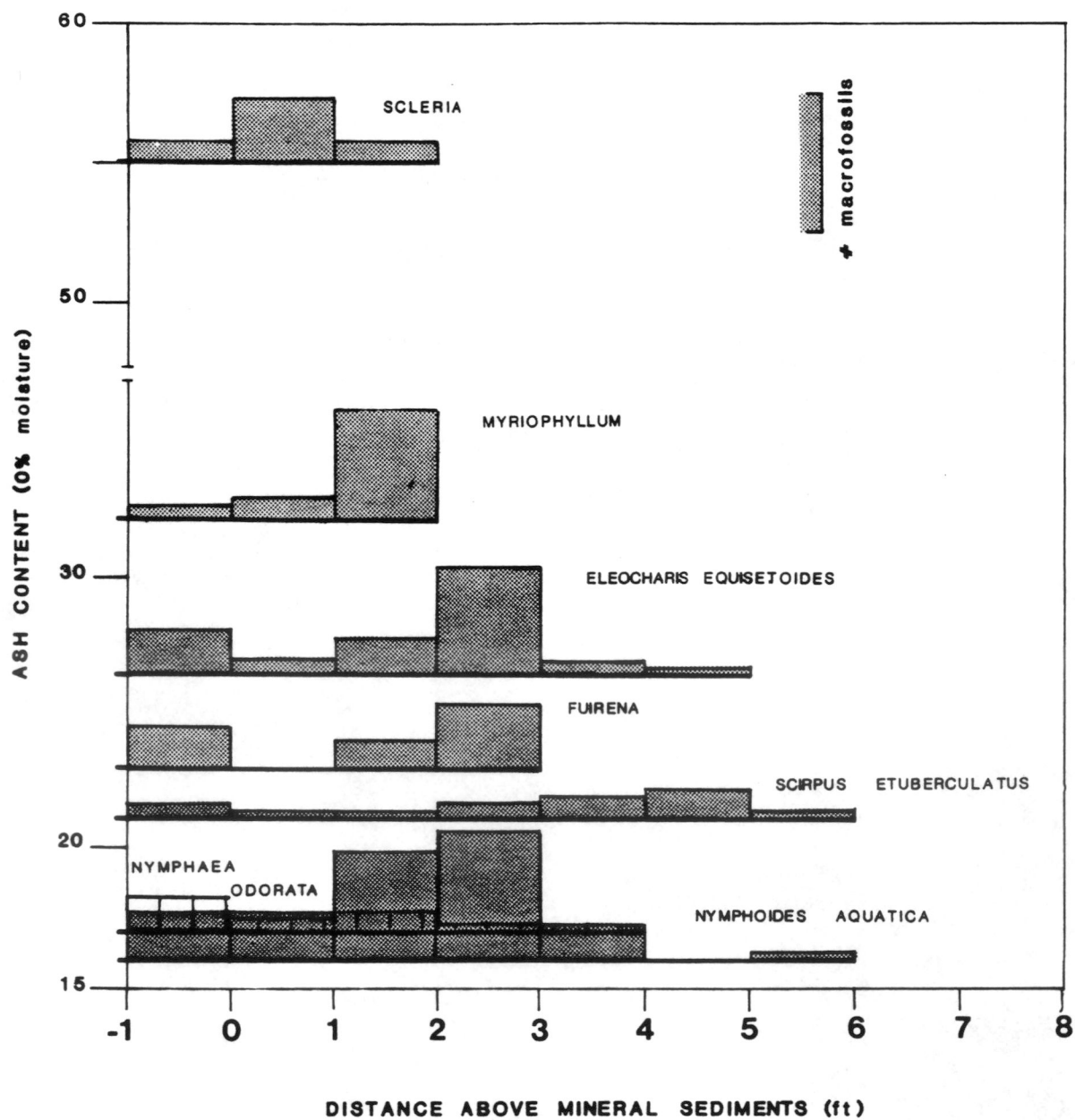
Nutrient Levels

Dissolved nutrients and influxing mineral sediments must have provided nutrients at a level capable of supporting the highly productive and diverse marsh vegetation that was present in the Dismal Swamp. Runoff from the surrounding uplands was probably enriched in nutrients leached from rich forest soil and leaf litter, and was capable of supporting the marsh vegetation even after the root zone could no longer reach the underlying mineral sediments and high ash peats. Maximum marsh development, indicated by a maximum in macrofossils, occurred between 2 and 3 feet above the underlying mineral sediments (Figure 18). It is doubtful that at this point marsh vegetation was deriving substantial nutrients from basal mineral sediments: roots of plants in water-saturated conditions typically form thick mats that are horizontal and parallel to the water table (Whitlow and Harris, 1979).

Proximity to underlying mineral sediments does not appear to have been a limiting factor for nutrient levels in the marsh. However, there does seem to be some relationship between the distance above the basal mineral sediments and the vertical distribution of emergent marsh species. Some species are associated with high ash peats at the base of the peat deposit (Scleria), while others are more common in the upper marsh horizons which are dominated by low ash peats (Scirpus etuberculatus, Fuirena and Eleocharis equisetoides) (Figure 20). If these distributions are an indication of varying substrate and nutrient preferences of different species, then Scleria requires the highest amount of mineral sediments (55% ash at 0% moisture) and Scirpus and Fuirena the least (21% and 23% ash at 0% moisture). A similar pattern is not seen for aquatic species.

Interpretation of quantitative data based on abundances of macrofossils should be viewed within the following limitations of such information: 1.) preferential preservation - species with durable seeds (Scirpus, Eleocharis, Brasenia) may be over represented compared to species with less durable seeds (Gramineae, Juncus); 2.) abundant seed producers (Myriophyllum) may be over represented compared to species that produce few seeds (Ceratophyllum) and 3.) statistically small sample size (limited number of macrofossils).

Figure 20: Distribution of the most abundant macrofossils, with respect to ash content and distance above underlying mineral sediments. Shaded bars represent abundance of macrofossil or taxon. Vertical position on graph indicates the average ash content of the peat and/or mineral sediments in which a species was found. For example, the average ash content of sediment samples in which Scleria occurred was 55; Scleria occurred from -1 to 2 ft. above the base level of mineral sediments, but was most abundant from 0 to 1 ft.



FOREST PALEOECOSYSTEM

Transition from Marsh

A major change in the physical and chemical characteristics of the developing wetland occurred when peat accumulation exceeded the level of the local water table. This change is represented in the macrofossil profile by a zone of poor preservation that occurs from 1 to 1.5 m above the base level of peat accumulation in the swamp. Decomposition of the surface peat became intense with subaerial exposure, since air contains more available oxygen for oxidation than water (209,500 ppm for the atmosphere compared to about 9 ppm for fresh water, at equilibrium with the atmosphere) (Stoker and Seager, 1972). Fluctuations of the water level below the peat surface would have increased the release of dissolved organic matter from the peat and increased the proportion of the more resistant humic compounds (Wetzel, 1975). Thus, the marsh had changed from an environment of peat accumulation to an environment of decomposition, with concentration of the most decay-resistant organic material.

The absence of a concentrated charcoal layer associated with the transitional zone suggests that the forest was not established as a result of a severe fire over the marsh. I have seen layers, up to 30 cm (1 ft.) thick and composed almost exclusively of charcoal, at two sites in the swamp. One of these layers contained a concentration of Ilex seeds, indicating a transition from a marsh to a shrub community, associated with the fire and an undoubtedly severe drought. Neither of these layers was associated with the transition from marsh to forest, as far as could be determined in the field. An extended period of drought, which allowed the C. thyoides seedlings to become established before water levels returned to normal, but not severe enough to prevent germination of the seeds or to

permit a deep burn into the marsh peat, was probably a major factor in the establishment of the forest over the marsh surface. A gradual loss of standing water, over a long period of time, would probably be represented by an absence of deep water aquatics, with a dominance of less hydric graminoids and shrubs in the transitional zone. The presence of floating-leaved and submerged aquatics, and the absence of any shrub macrofossils, near the top of the marsh profile suggest that an unusual period of drought, rather than a gradual drying-out or severe burn, occurred in the marsh.

With the subaerial exposure of peat, the marsh would have provided an ideal environment for the establishment of Chamaecyparis thyoides (Atlantic White Cedar). Warm, open situations such as clearings and recent burns in peat-filled swamps provide the best conditions for the establishment of Atlantic White Cedar stands (Korstian and Brush, 1931). Macrofossils of C. thyoides dominate interfluvial peats, and indicate the presence of a seed source for the establishment of C. thyoides. Atlantic White Cedar seed produced by the adjacent forests would have easily reached the marsh, since they are well adapted for wind dispersal because of their small size compared to their relatively large wings (U.S. Department of Agriculture, 1974).

A change from the decompositional stage associated with subaerial exposure of the marsh surface, to a new system of peat accumulation, occurred with the establishment of a C. thyoides forest over the marsh peats. Many factors were responsible for this change, and probably include (1.) the production of leaf litter which has a high lignin and cellulose content and is thus resistant to decay (Wetzel, 1975), (2) closing of the forest canopy, which allowed less light penetration to the forest floor

and resulted in lower temperatures that inhibited the breakdown of organic material (MacLean and Wein, 1978), (3) the extreme water-holding capacity of organic material that could raise the water above the original level of the exposed marsh surface, in the presence of sufficient water which would have occurred with (4) return to more normal hydrologic conditions, if the C. thyoides forest was established during a drought. Thus, through a combination of physical and chemical interactions, peat accumulation was resumed in the Dismal Swamp.

Chamaecyparis thyoides Forest

Soil and soil moisture are the primary factors limiting the occurrence of Atlantic White Cedar within its range (Korstian and Brush, 1931). The availability of light becomes another primary factor during the seedling stage . While Atlantic White seedlings frequently germinate in shaded areas, they seldom become established under these conditions. There is no macrofossil evidence of the establishment of a shrub or forest community on the marsh surface that might have prevented or hindered Atlantic White Cedar establishment.

Deep peats that are highly acidic and contain little silt or clay provide a substrate on which Atlantic White Cedar outcompetes most other swamp canopy species. The proportion of swamp hardwoods and Taxodium (Cypress) decreases as the amount of silt and clay in the underlying soil decreases (Korstian and Brush, 1931). By the time an Atlantic White Cedar stand is 10 to 15 years old, any Cypress trees growing there will be overtopped by the Atlantic White Cedar and eventually shaded out. Pinus serotina (Pond Pine) and Pinus taeda (Loblolly Pine) generally overtop

Atlantic White Cedar, but are seldom more than a minor component in Atlantic White Cedar (Korstian and Brush, 1931).

Mineral Sediment Influx

Forest peats have little mineral sediment content, although there is an increase from low to medium ash content associated with the establishment of the forest on the marsh surface (Figures 13 and 14). This increase probably represents the change from sediment-baffling marsh vegetation to a scarce ground cover beneath a closed canopy. Sediments borne by sheet flow could travel much farther into the swamp in the absence of ground cover, particularly during the non-growing season when the water may have been as much as a meter (3 ft) deep, than with abundant herbaceous marsh vegetation. I have seen silts and sands carried over a half a mile into the swamp via sheetflow during periods of high water ($> 0.6\text{m}$). No macrofossil evidence of an extensive shrub layer, which might have acted as a sediment trap, was found in this study

No major changes in the sediment sources or precipitation (and thus runoff) for the Dismal Swamp area are known to have occurred contemporaneously with the transition from marsh to forest, and are not considered as likely explanations for the slight increase in ash content that occurs in the upper horizons of forest peats, relative to the ash content of upper marsh peats (Figures 14 and 15). The source of sediments had decreased, if anything, as more of the interfluvial areas were covered with peat. Such a decrease may explain the lower average ash content for forest peats (4.8%) than for marsh peats (6.9%).

Fire

Fire plays a major role in the longevity of the Atlantic White Cedar community. An abundance of fires throughout the history of Atlantic White Cedar in the Dismal Swamp is indicated by an abundance of charcoal throughout the forest zone. Fire can act to either maintain the community by removing competitors or to lead to the replacement of Atlantic White Cedar by destruction of its trees and seeds stored in the leaf litter.

Fires that occur in winter and spring when water levels are high generally serve to restock cedar communities. High water levels prevent destruction of seeds stored in surface sediments and limit damage to mature trees, while destroying competitive species that would shade out any cedar seedlings. This gives the fast growing cedar seedlings a chance to become established before any of the damaged vegetation recovers from the fire.

Fires that occur during a dry season generally result in a change in the composition of the succeeding forest (Korstian, 1924). Such fires are likely to destroy Atlantic White Cedar seeds stored in the 0.3 to 0.6 m of peat, as well as the mature trees. In these cases, Pinus serotina or Pinus taeda will usually succeed the Atlantic White Cedar. The survival of Pines is due to their thick bark which is much more fire resistant than the relatively thin bark of Atlantic White Cedar. Instances in which fire destroys not only the cedar but the Pines as well, with a large amount of peat loss, usually result in stands of swamp hardwoods (Korstian and Brush, 1931).

Pinus sp. Forest

Macrofossil profiles from two sites (D-509 and D-520, Figure 14) in the Dismal Swamp show a succession from Atlantic White Cedar to a southern pine, *Pinus serotina* or *P. taeda*. There is no extensive charcoal layer associated with the transition from Atlantic White Cedar to Pine. The lack of such a charcoal layer does not rule out a possible relationship between fire and the establishment of Pine at these sites; in a young forest, even a light fire might be capable of killing Atlantic White Cedar trees and damaging their seed stored in the upper peat layers (Korstian and Brush, 1931). It is always possible that a catastrophe other than fire, such as a severe wind storm, could explain the loss of the cedar community. Atlantic White Cedar has an extremely shallow root system with limited stability in the underlying peat, and is extremely vulnerable to windthrow. Trees not directly affected by the wind may be knocked down by other trees, with the damage spreading into the interior of the stand.

The sites at which Pine occur are located in the narrowest portion of the central peat channel and are adjacent to sandy uplands rather than peat covered interfluves. Loblolly Pine, which presently dominates the sandy upland areas around the swamp, would have been a likely source for restocking a burned or otherwise severely damaged Atlantic White Cedar forest.

Atlantic White Cedar needs some type of disturbance to perpetuate itself. If Atlantic White Cedar stands remain undisturbed, they eventually begin to thin out from old age and disease. The gradual increase in sunlight reaching the forest floor is insufficient to support new Atlantic White Cedar seedlings and the site is usually taken over by more shade

tolerant species such as Acer rubrum (Red Maple) or Nyssa sylvatica (Black Gum) (U.S. Department of the Interior, 1979).

Macrofossils from the Dismal Swamp indicate that conditions suitable for perpetuation of Atlantic White Cedar communities existed in the swamp for most of the past 3,500 years. These favorable conditions , sufficient water levels and limited competition with species such as A. rubrum, no longer exist due to extensive logging and drainage in the swamp over the last 200 years.

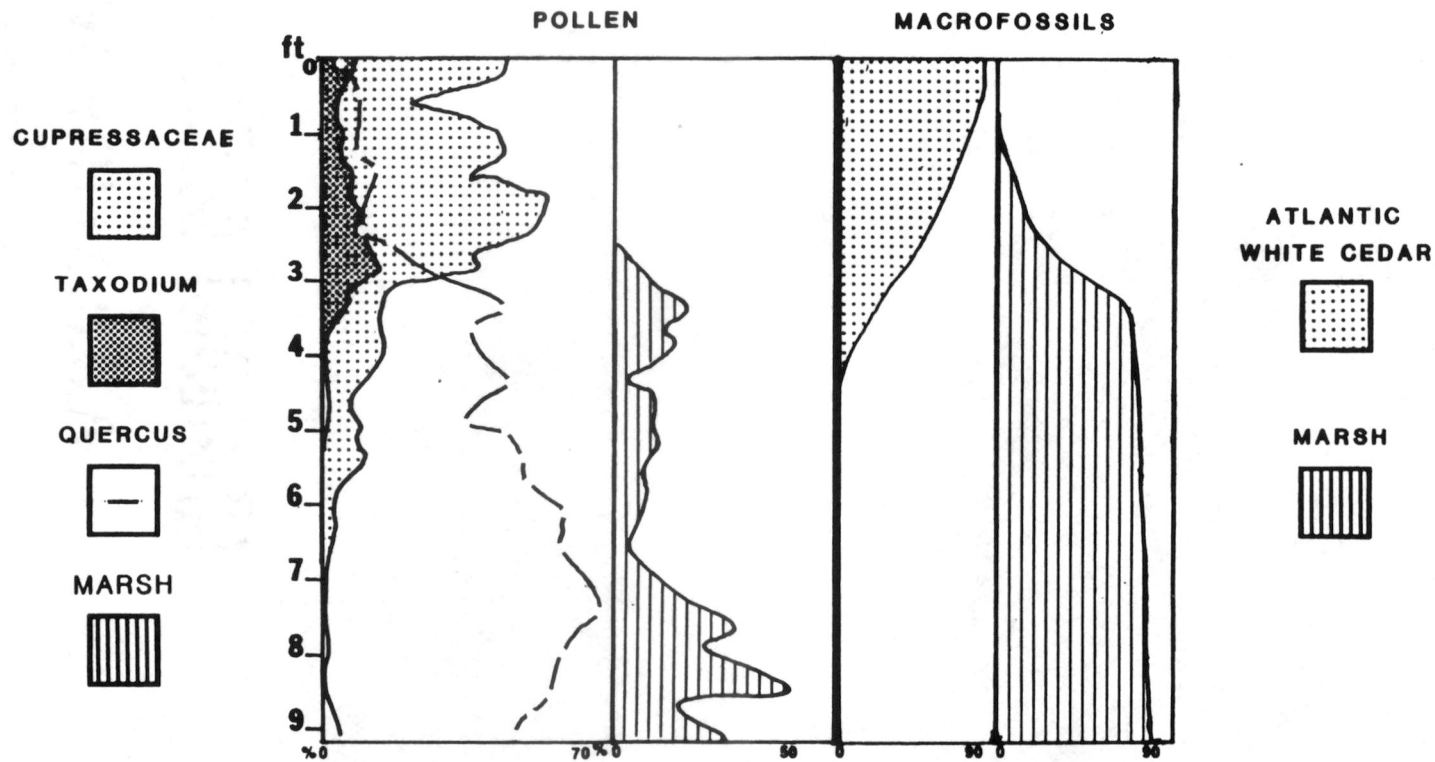
COMPARISONS BETWEEN MACROFOSSIL AND POLLEN DATA FOR THE DISMAL SWAMP

MARSH PALEOECOSYSTEM

Although Whitehead (1972) concentrated on arboreal pollen from the surrounding uplands, abundant pollen of marsh species was found in his Oak-Hickory pollen zone (Figure 21) and led to his conclusion that extensive freshwater marshes were present in the swamp from approximately 8,000 to 3,500 years before present. Whitehead's marsh pollen profiles correlate with the macrofossil profiles of this study, with both showing the transition from marsh to forest occurring at about the same time (Figure 21). Most of the marsh species represented in the pollen (Myriophyllum, Polygonum, Nuphar, Nymphaea and Cyperaceae) are also represented in the macrofossils.

A pattern of abundant aquatics at the base of the swamp changing to abundant emergents towards the top of the marsh zone, reported by Whitehead, (1972) is not seen in the macrofossils. Ericaceous species are likewise lacking in the macrofossil material, but present in pollen assemblages for the Dismal Swamp.

Figure 21: Comparison of macrofossil and pollen zones
for the Dismal Swamp.



COMPARISON OF MACROFOSSIL AND POLLEN ZONES

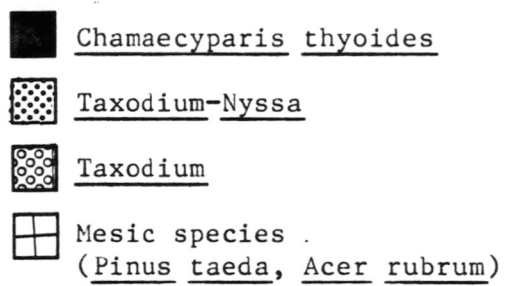
FROM A PEAT CHANNEL IN THE DISMAL SWAMP

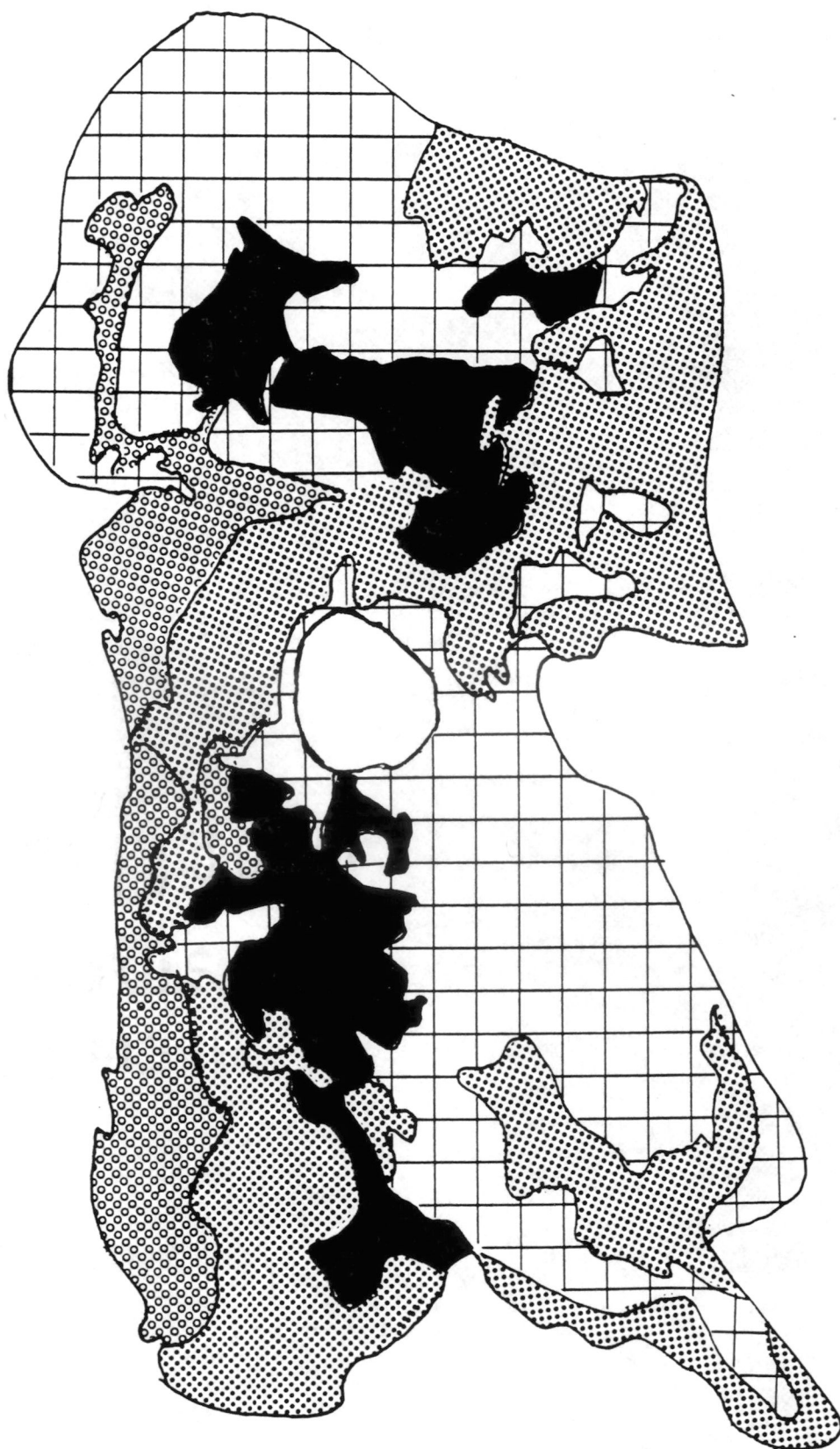
FOREST PALEOECOSYSTEM

A major difference between the pollen and macrofossil profiles exists in the interpretation of the dominant forest species. Macrofossils show that Chamaecyparis thyoides (Atlantic White Cedar) was the dominant canopy species in the Dismal Swamp. Dominance of the forest by Atlantic White Cedar is further indicated by logging records which show that most of the swamp was Atlantic White Cedar forest prior to logging (Reid, 1952) (Figure 10). Whitehead interpreted his pollen data, which shows a large influx of Cupressaceae pollen, as extensive Taxodium-Nyssa (Cypress-Gum) forests. Although Cypress and Atlantic White Cedar pollen are distinguishable from each other, they are both fragile in terms of preservation and usually are found as fragments in the fossil record. It is these fragments that are indistinguishable between Cypress and Atlantic White Cedar (Paul D. Delcourt, personal communication 1985) and are collectively designated as Cupressaceae by palynologists.

Pollen data indicate that a Taxodium-Nyssa community was present in the swamp. This community probably occurred in localized subenvironments where there was a significant influx of silts and clays, since both gum and cypress are typically found on fine textured mineral-dominated soils (Fowells, 1965). Taxodium and Nyssa are presently found over clayey sediments along the base of the Suffolk Scarp and are associated with tributaries cutting through the scarp. The few remaining Atlantic White Cedar communities are generally found over the deeper peat channels in the interior of the swamp (Figure 22). The present distribution of these species is probably very similar to the distributions that occurred throughout the development of wetland forests in the Dismal Swamp.

Figure 22: Vegetation cover map for the Dismal Swamp.
 Modified from Carter and Gammon (1976).





REGIONAL PERSPECTIVE

HOLOCENE VEGETATIONAL SUCCESSIONAL PATTERNS IN EASTERN NORTH AMERICA

The general Holocene vegetational succession pattern (Pine-Spruce ---Beech-Hemlock-Birch---Oak-Hickory) recorded in Dismal Swamp pollen assemblages (Whitehead, 1972) is found throughout the southeastern United States (Watts, 1980). Much emphasis has been placed on regional responses of vegetation to full through early post glacial environmental changes, with little attention paid to the effects of such changes within specific ecosystems. The development of wetlands - the sedimentary environment from which most palynological and macrofossil evidence is gathered - has largely been ignored. With the emphasis on regional patterns, the general rule seems be the exclusion of locally occurring species from pollen analyses except when a species is of regional significance.

Species compositions of wetlands, gathered from macrofossil data associated with pollen cores, provide clues to the successional patterns that occurred at various locations in eastern North America (Figure 23). During the period of amelioration, regional climate was probably the major control on wetland successional patterns under which localized controls operated. These localized controls, such as topography, soil, and precipitation, are reflected in the diversity of species present in similar ecosystems at different locations (Table 9). For example, the forest stage in wetland development is represented by different community types based on both overall climate and localized conditions. Wetland successional forests are represented by Spruce-tamarak in Minnesota; Atlantic White Cedar in coastal plain sites in New Jersey and Virginia-North Carolina;

Figure 23: Wetland vegetational succession patterns associated with climatic amelioration in eastern North America.

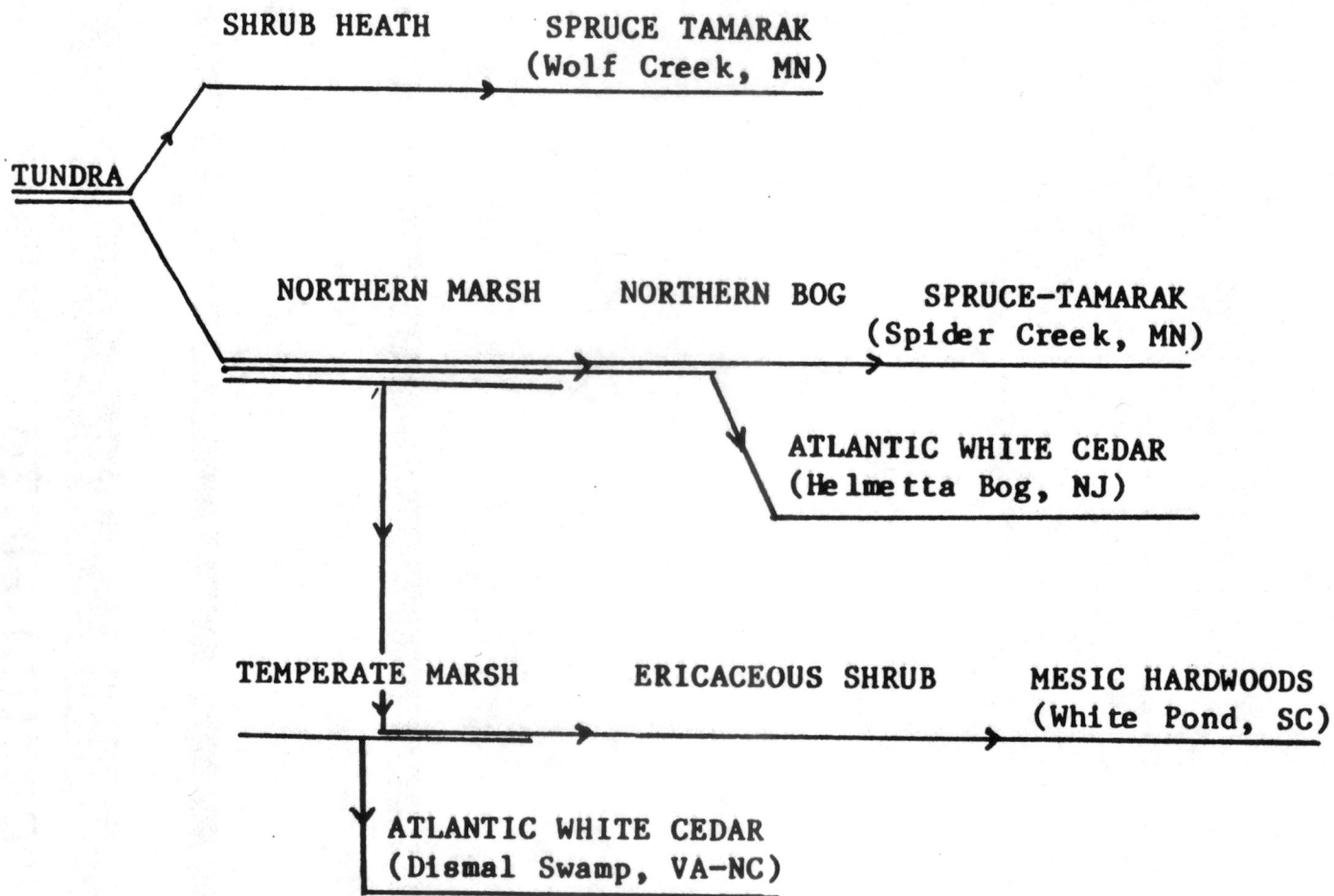


Table 9: Macrofossil indicator species for various wetland successional stages that occurred with climatic amelioration in eastern North America.

ENVIRONMENTAL CONDITIONS	REPRESENTATIVE MACROFOSSIL SPECIES	MACROFOSSIL LOCATIONS
TUNDRA	<u>Dryas integrifolia</u> <u>Juncus balticus</u> <u>Rhododendron lapponicum</u>	Spider Ck., MN (Baker, 1962)
NORTHERN MARSH	<u>Myriophyllum humile</u> <u>Cladium mariscoides</u> <u>Juncus balticus</u>	Spider Ck., MN (Baker, 1962) Wolf Ck. MN (Birks, 1976)
BOG	<u>Eleocharis palustris</u> <u>Scirpus cyperinus</u> <u>Carex lasiocarpa</u> <u>Carex aquatilis</u> <u>Vaccinium oxycoccus</u> <u>Lysmachia</u> <u>Betula pumila</u>	Helmetta Bog, N.J. (Watts, 1979) Wolf Ck., MN (Birks, 1976)
TEMPERATE MARSH	<u>Nymphoides aquatica</u> <u>Nuphar luteum</u> <u>Decodon verticillatus</u> <u>Scirpus etuberculatus</u> <u>Proserpinaca</u> <u>Nymphaea</u>	Dismal Swamp, VA-NC
SWAMP FOREST	<u>Chamaecyparis thyoides</u>	Dismal Swamp, VA-NC Helmetta Bog, NJ (Watts, 1979)

and mesic hardwoods in the South Carolina coastal plain. The presence of Spruce-Tamarak forests is probably limited by the regional colder climate; the presence of Atlantic White Cedar by available peaty soils in conjunction with the precipitation and humidity provided by its proximity to the Atlantic Ocean; and the presence of mesic hardwoods by their predominantly mineral soil.

SYNTHESIS OF THE DEVELOPMENT OF THE DISMAL SWAMP

The Dismal Swamp is located in a transitional zone between major and minor vegetational response to the full-glacial conditions of 18,000 years before present (Watts, 1980). In the Dismal Swamp, Va.- N.C.; Rockyhock Bay, northern coastal plain of Virginia; and the Shenandoah Valley of Virginia, higher percentages of Spruce pollen occur than are found farther south (Watts, 1980). Environmental conditions were very different from the present when wetland development began in the Dismal Swamp (Table 10). At the time marsh development began in the swamp, the climate had warmed somewhat from full glacial times (18,000 years b.p.), but was similar to present boreal conditions, evidenced by spruce and jack-pine forests in the interfluves.

Northern marsh species are not more abundant at the base of the peat deposit, as might be expected with the colder climatic conditions and the boreal interfluve vegetation that existed during the early stages of marsh development. Present geographic ranges of all of the marsh macrofossils identified to species include the Dismal Swamp area. Many of the marsh species, such as Fuirena, Decodon verticillatus and Nymphoides aquatica, have predominantly southern ranges and are near their northern limit in the swamp. Other species' ranges, such as Eriophorum virginicum, Dulichium

arundinaceum and Nymphaea extend into Maine and Canada. Southern species probably appeared in the marsh prior to upland forests because aquatic species respond more quickly to small increases in average annual temperature and growing season than do terrestrial plants (Watts, 1979).

As the climate continued to become warmer and wetter, marshes expanded and the interfluvial forests progressed from boreal, to northeastern forests (Beech - Hemlock - Birch), and then to southeastern forests (mixed Oak - Hickory and Pine). Between 6,000 and 8,200 years b.p., regional climate stabilized similar to the present; forest succession from southern hardwoods to Atlantic White Cedar probably reflected a change from regional climatic control to local edaphic control over swamp vegetation .

Vegetation in the swamp remained stable until the last 200 years when man's influence became responsible for vegetational changes in response to changes in local edaphic conditions. Extensive logging and drainage of the swamp have essentially created a reversal in wetland development, with extensive oxidation of the peats, and succession to a mesic forest community. Acer rubrum is now the most abundant canopy species in the Dismal Swamp: approximately 7,000 acres are all that remain of the Chamaecyparis thyoides forests (Department of the Interior, 1979).

**Table 10: Brief synthesis of the development of the
Dismal Swamp.**

Years Before Present	EPOCH	BRIEF SYNTHESIS OF THE DEVELOPMENT OF THE DISMAL SWAMP		
		GEOLOGY	CLIMATE	VEGETATION
0	HOLOCENE	OXIDATION OF PEAT DEPOSITS-AS MUCH AS A METER OR MORE LOST	TEMPERATE CLIMATE. CHARACTERIZED BY LONG, HUMID SUMMERS AND MILD WINTERS.	LOSS OF ATLANTIC WHITE CEDAR-DOMINATED FOREST DUE TO LOGGING AND DRAINAGE-REPLACED BY MORE MESIC RED MAPLE.
300		.....	.....	.....
		DEPOSITION OF FOREST PEAT OVER MOST OF SWAMP.	SIMILAR TO PRESENT.	ATLANTIC WHITE CEDAR-DOMINATED FOREST EXPANSION FROM INTERFLUVES ONTO MARSH SURFACE. FOREST RELATIVELY STABLE.
3,500		.....	.....	.....
		DEPOSITION OF MARSH PEATS SPREADING TO INTERFLUVES.	SIMILAR TO PRESENT.	EXPANSION OF FRESH-WATER MARSHES ONTO INTERFLUVES. GRADUAL REPLACEMENT OF S.E. HARDWOOD FORESTS WITH ATLANTIC WHITE CEDAR ² .
6,000		.....	.....	.....
		CONTINUING ORGANIC SEDIMENT DEPOSITION IN DEEPER PORTION OF CHANNELS.	STABILIZING-BECOMING SIMILAR TO PRESENT. TOO WARM AND DRY FOR MESIC FORESTS.	FRESH-WATER MARSH DEVELOPMENT, IN CHANNELS, WITH EXPANSION TOWARDS THE SUFFOLK SCARP. INTERFLUVE FORESTS SIMILAR TO PRESENT S.E. HARDWOOD FORESTS - MIXED OAK, HICKORY AND PINE.
8,200		.....	.....	.....
		DEPOSITION OF ORGANIC AND INORGANIC FRESH-WATER CLAYS IN DEEPEST PORTIONS OF CHANNELS.	COOLER THAN PRESENT, BUT WITH INCREASING ANNUAL TEMPERATURE. ABUNDANT AVAILABLE MOISTURE.	MARSH DEVELOPMENT CONFINED TO DEEPER CHANNELS IN EASTERN AREA OF SWAMP. INTERFLUVE FORESTS SIMILAR TO N.E. HARDWOOD FORESTS - OAK, HICKORY, BEECH, HEMLOCK AND BIRCH.
10,000		.....	.....	.....
	PLEISTOCENE	INORGANIC CLAY DEPOSITION IN DEEPEST PORTIONS OF CHANNELS	CONSIDERABLY COLDER THAN PRESENT - SIMILAR TO PRESENT BOREAL.	BEGINNING MARSH DEVELOPMENT IN DEEPEST AREA OF CHANNELS ALONG EASTERN EDGE OF SWAMP. INTERFLUVE VEGETATION BOREAL - SPRUCE AND JACK-PINE.
13,000		.....	.....	.....
		PERIOD OF EROSION. DEVELOPMENT OF DENDRITIC PATTERN ON PLEISTOCENE SURFACE.	EXTREMELY WINDY, COLD AND DRY CONDITIONS.	JACK-PINE, SPRUCE AND "NORTHERN" HERBS.
22,000		.....	.....	.....

*Summarized from Watts (1980), Whitehead (1972) and ²macrofossil evidence from this study.

RECOMMENDATIONS FOR FURTHER STUDY

This project was undertaken as a preliminary study to determine what type of macrofossils are preserved in peat from the Dismal Swamp, with hopes that they could be used to identify general vegetation successional stages during peat development. Results of this study have far exceeded the original goals, but only begin to utilize a small portion of the macrofossil material preserved in the peat deposits.

Much more work needs to be done in the Dismal Swamp, and other peat deposits, in order to better understand their developmental histories. Major areas of of research that need to be addressed are:

- (1). Closer sampling interval along study transects, with more transects.
- (2.) Utilization of different types of macrofossil material, such as
 - (a.) characteristics of vegetative material such as stomate arrangement of pine needles and cellular structures of grass blades;
 - (b.) silica phytoliths and diatoms, which are concentrated with burning of the peat and
 - (c.) rhizome and root material.
- (3.) Correlation with pollen analyses from the same sediments used for macrofossil analyses, with C-14 dating.
- (4.) Macrofossil studies in more different peat deposits.
- (5.) Begin major macrofossil reference collection for peat deposits.

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