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A RECONSTRUCTION OF POST-GLACIAL VEGETATION
IN THE NORTHWESTERN PORTION OF MICHIGAN'S LOWER PENINSULA

presented by

Nancy Nowak Cleland

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Major professor

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A RECONSTRUCTION OF POST-GLACIAL VEGETATION

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By

Nancy Nowak Cleland

A THESIS

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ABSTRACT

A RECONSTRUCTION OF POST-GLACIAL VEGETATION IN
THE NORTHWESTERN PORTION OF MICHIGAN'S LOWER PENINSULA

By

Nancy Nowak Cleland

A history of the post-glacial vegetation of the northwestern portion of Michigan's lower peninsula has been traced through the analysis of pollen and spores recovered from three bogs in the region.

As the glaciers retreated from the area about 11,000 years ago, it supported forests primarily dominated by spruce. This boreal forest was gradually replaced with pine forests at about 9,500 BP. The pine forest declined in dominance as hemlock migrated into the region by approximately 7,400 BP and as hardwood species became established around 6,300 BP. A xerothermic climate influenced the region's vegetation from approximately 6000 BP to 3000 BP delaying the establishment of a northern hardwood forest until about 3000 BP when climatic conditions began to approach those of the present. As Euro-American settlement of the region was initiated during the mid nineteenth century, extensive tracts of land were cleared. These have since supported seral communities of the field and forest.

To My Family

ACKNOWLEDGEMENTS

As with most endeavors of this nature, this study could not have been completed without the assistance of a number of individuals. I would like to extend my sincere appreciation to those who have given me guidance throughout my graduate career. Professor Aureal T. Cross, my Committee Chairman, has given support, advice, and assistance in many aspects of this study. Professor Ralph E. Taggart provided helpful, innovative suggestions in his appraisal of my work. Professors Stephen N. Stephenson, William B. Drew, and William B. Lovis offered valuable counsel as committee members. I would also like to express my graditude to Professor Ronald O. Kapp of Alma College for his helpful comments in the preliminary stages of this report.

I would also like to gratefully acknowledge the following: Professor Charles E. Cleland, my husband and dearest friend, for his support and encouragement through all phases of this endeavor and for his assistance in the collection of sediment samples; Professor William B. Lovis, for his help in aquiring financial support; Ms. Margaret Uland for the drafting of many of the figures which appear in this text; and Ms. Colleen Isslieb, for the construction of postsettlement vegetation maps of most portions of the study region.

To these, my family, and my friends I am greatly indebted.

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INTRODUCTION.

This study attempts to trace the post-glacial history of the northern hardwood forest in northwestern lower Michigan by means of pollen analysis. Three bogs in the region were cored to obtain a stratigraphic sequence of samples containing sufficient identifiable pollen and spores to represent the post-glacial vegetation of the region.

The bogs selected for coring are filled with peat of the Greenwood series, which is a highly acidic type (Weber et al, 1966). Initial testing of the bogs demonstrated them to be relatively dry, continuous and deep. Selecting bogs with these physical attributes enhanced the possibility of obtaining a complete chronological sequence in the pollen record. In addition to desired physical attributes, the bogs were selected on the basis of geographic location to provide the best possible coverage along the major north-south axis of the study area.

REGION OF STUDY.

Location.

The study region is located in the most northwestern section of Michigan's lower peninsula in the vicinity of 85° W longitude and 45° N latitude. It extends along the Lake Michigan coastline from the base of the Leelanau peninsula to the Straits of Mackinac (Figure 1). Portions of eight counties are included in the region: Benzie, Leelanau, Grand Traverse, Kalkaska, Antrim, Charlevoix, Emmet, and Cheboygan. Generally the region follows the shoreline of Lake Michigan, northeast to southwest, and is approximately 128 km (80 miles) in length and 29 km (18 miles) in width. The region's southeasternmost point lies approximately 112 km (70 miles) due south and 128 km (80 miles) due west of its northeasternmost extremity. The topography of the region generally varies from 182 to 234 m (600 to 800 feet) above sea level with the exception of occasional highlands with elevations up to 334 m (1100 feet) (Sommers, 1977). The region has a mean annual temperature of 6° C (42-44 F), a growing season of 125 days, and a mean annual precipitation of approximately 0.8 m (30.5 inches) (Sommers, 1977).

Bedrock Geology.

Glacial drift covers the bedrock of most of the study region with an average thickness of 60 m (200 feet) (Sommers, 1977). The bedrock was deposited during the Devonian and Mississippian Periods of the Paleozoic Era. Devonian marine limestones, siltstones, and shales are distributed in an arc from the Leelanau Peninsula to the

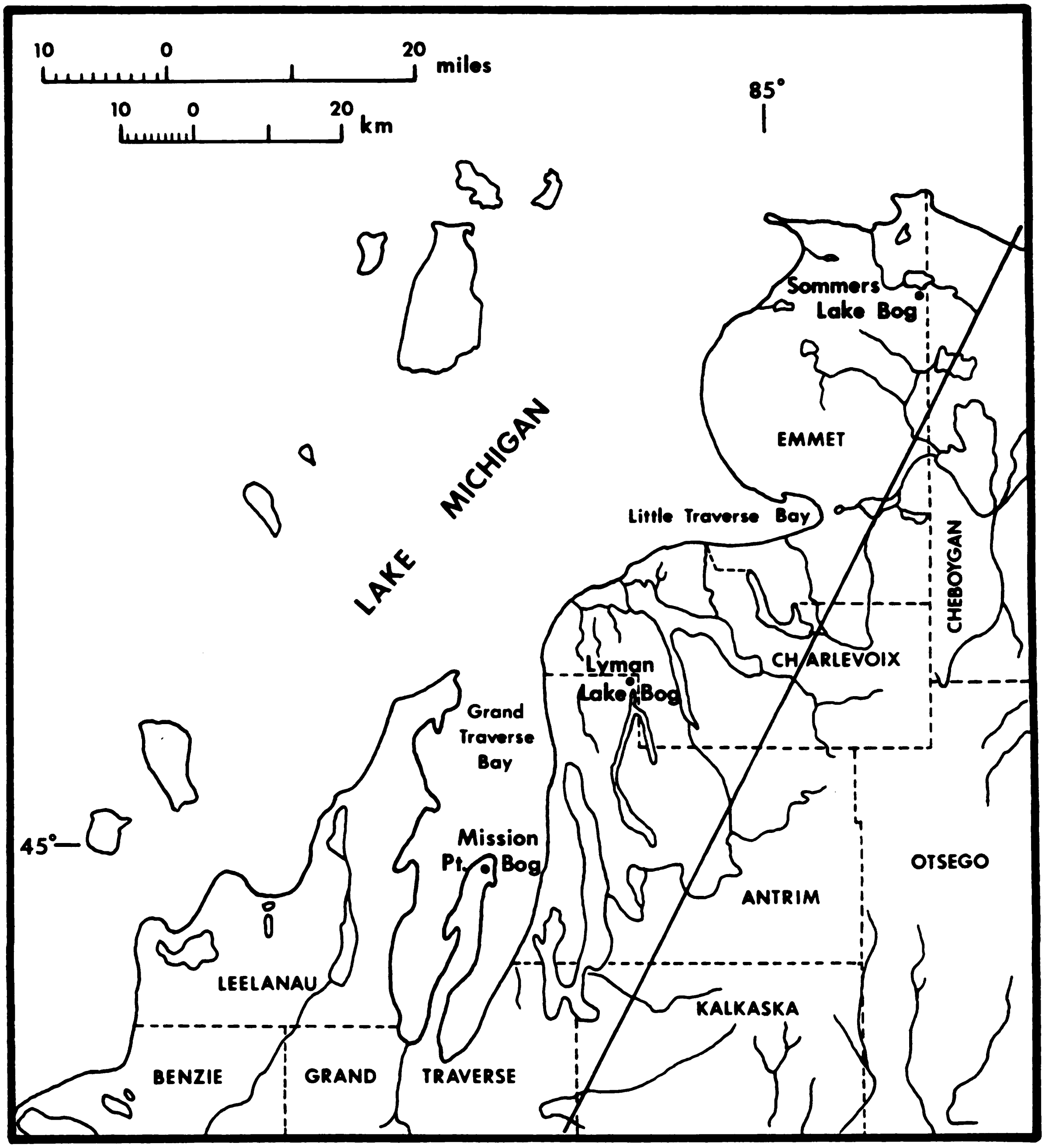


Figure 1 Sketch Map of Northwestern Lower Michigan

tip of northern lower Michigan. They surround the younger Mississippian strata of the Michigan Basin. The Devonian limestone is quarried in this region for building material, cement and road surfacing (Hudgins, 1961). The underlying bedrock in the southern portion of the study region of Mississippian age includes some salt and gypsum as well as sandstone, limestone and shale. Gas and oil are produced from various petroliferous reservoirs.

Physiography and Glacial History.

Northwestern lower Michigan is characterized by a rolling landscape, numerous inland lakes, and sandy beaches along the Lake Michigan shoreline. These features, like those of the entire Great Lakes region, were primarily determined by the activities of the Pleistocene glaciers. The final retreat of the glaciers from the Great Lakes region, which began approximately 14,800 B.P. is discussed by Kelly and Farrand, 1967 and Dorr and Eschman, 1971.

By 11,000 BP northern lower Michigan was deglaciated and partially inundated by an extensive body of water known as Lake Algonquin (Kelly and Farrand, 1967). Situated along the ice front with an elevation of 182 m (605 feet), Lake Algonquin occupied the basins, as well as adjacent lands of Lakes Michigan and Huron. Its high-level waters cut a somewhat continuous beach ridge which can be traced throughout the study region as it generally parallels the present day shorelines of Lake Michigan and the inland waterway system. Initially, Lake Algonquin was drained to the south by the Illinois River and later by the St. Clair-Detroit Rivers.

As the glaciers retreated from the Great Lakes, they formed many of the region's inland lakes as well as most of the region's hills and ridges and flat to rolling plains. Deglaciation of the land to the northeast of the Michigan-Huron basins provided a series of drainage outlets which were progressively lower in elevation than the St. Clair channel. Consequently drainage of the basins shifted to the northeast through the North Bay and Ottawa River resulting in the formation of low level lakes Chippewa and Stanley.

As the glaciers continued to retreat, however, the earth's crust, depressed from the weight of the ice masses, began to rebound. While the drainage of the basins continued through the North Bay outlet, it rose in elevation resulting in the formation of Lake Nipissing at approximately 4500 BP (Kelly and Farrand, 1967) which stood at an elevation of 182 m (605 feet) and occupied the Michigan, Huron, and Superior Lake basins and surrounding areas. Lake Nipissing, stabilized by three channels, the North Bay-Ottawa River, the St. Chair-Detroit Rivers, and the Illinois River, endured for about 1000 years. During this time its high waters cut a prominent beach which can be readily observed as it generally follows the coastline of Lake Michigan and the inland waterway system.

At approximately 3500 BP (Kelly and Farrand, 1967), rebound of the crust had resulted in a rise in elevation of the North Bay outlet beyond 182 m (605 feet) thereby shifting drainage to the southern outlets. Erosion of the St. Clair River initiated the formation of the present day Great Lakes through an alteration of lake levels and a final shift in drainage to the southeast. As the water levels of Lakes Michigan and Huron receded to their present day levels, the extensive belt of sand dunes along the coastline of western lower Michigan was formed.

Soils and Drainage.

The soils of the region, also primarily the products of glaciation, are relatively young and scrambled in occurrence. Basically, however, they are classified as spodosols, which are formed beneath a mixed hardwood-conifer forest and have accummulations of iron, aluminum and humus or partially decayed organic material in the B horizon (Sommers, 1977).

The impact of glaciation is also reflected on the region's drainage systems which are generally haphazard and immature. The coastal areas drain directly into Lake Michigan and the Straits of Mackinac. The interior areas to the northeast are part of the Cheboygan watershed which includes the Pigeon, Sturgeon, and Black Rivers (Sommers, 1977).

Cultural History.

As the glaciers retreated from northwestern lower Michigan at approximately 11,000 BP, nomadic bands of prehistoric Indians entered the region in pursuit of fish, game, and edible wild plants. From the archaeological record it is known that the region's prehistoric inhabitants established camp, village, quarry and burial sites along a transportation network of lakes and streams. The cultural evolution of these native inhabitants can be traced through the dating of artifacts recovered <u>in situ</u> from these localities. Consequently, it is known that by approximately 625 BP (1350 A.D.), Indians of this region cultivated a few domesticated crops such as corn and squash, but remained heavily reliant on the provisions of fishing, hunting, and the gathering of wild plants. As such, their subsistence and settlement patterns had little effect in altering their natural environment.

Contact between Europeans and Native American populations of the region was first initiated as early as 1615. During the following one hundred and fifty years, French explorers, missionaries, and traders entering the territory encountered Algonquian speaking people residing in the northwest portion of Michigan's lower peninsula. It has been impossible to trace directly the cultural heritage of the Algonquian speaking tribes of the Ottawa, Ojibwa and Potawatomi back to their prehistoric ancestors since aboriginal traditions and artifacts were so rapidly replaced by those of European origin.

French influence in the region was superceded by British following the conclusion of the Seven Years War in 1763. Although title to the region passed to the United States following the Revolutionary War, the British delayed the surrender of Michigan's forts until 1796.

Michigan became a State in 1837 but it had been included as a Territory of the United States as of 1787. Northwestern lower Michigan originally comprised a portion of the extensive

Michilimackinac County. As the region became settled, present day county divisions were established. While the tip of the lower peninsula was among the earliest settled areas of the state, the Mission Peninsula, located in Grand Traverse Bay, and the Lake Michigan coastline directly southwest of the Straits of Mackinac were settled between 1820 and 1839. Settlement continued along the Lake Michigan shoreline until approximately 1860 at which time settlement of the interior portions of the region commenced. By 1880, settlement of northwestern lower Michigan had been firmly established.

Present-day Vegetation.

The composition and distribution of the present day vegetational communities have been determined by man's activities within the region during the past one-hundred years. During this time lumbering, post-logging fires, and agriculture cleared vast tracts of land which had long supported a mature northern hardwood forest.

Today, seral forest communities are developing throughout the region and comprise approximately 67% of the vegetation cover. These forests are mainly composed of immature stands of Acer saccharum (sugar maple), Fagus grandifolia (beech), Tsuga canadensis (hemlock), and Betula lutea (yellow birch). If allowed to continue their development, a climax forest of these northern hardwood species would most likely result.

Portions of the region which had supported conifer dominated forests, either spruce-fir or mixed pines, presently support forests dominated by Betula papyrifera, (white birch), Populus tremuloides (quaking aspen), and P. grandidentata (largetooth aspen). These early colonizing species are more prevalent in recently as well as severely disturbed areas throughout the region.

A substantial portion of the region remains cleared and supports either meadow, oldfield or crop vegetation. Approximately 26% of the region's land is utilized for agricultural purposes. Dairy farming is predominant in the northern counties and fruit farming is foremost in the southern counties (Sommers, 1977).

Bog Localities Sampled.

The Sommers Lake bog was the northernmost locality sampled. It is located in northern lower Michigan approximately 19 km (12 miles) from Lakes Michigan and Huron and the Straits of Mackinac (Figure 1). It is located approximately 3.2 km (2 miles) north of Levering and 1.6 km (1 mile) south of Carp Lake, in the NE$\frac{1}{4}$, SW$\frac{1}{4}$, Sec. 25, Carp Lake Twp., T. 38 N., R. 4 W., Emmet County, Michigan. Its geographic coordinates are 45°39'24" N and 84°44'36" W.

The bog surrounding Lyman Lake provided the central sampling locality. Lyman Lake is located in northern lower Michigan approximately 11 km (7 miles) inland from the Lake Michigan coastline approximately midway between the Straits of Mackinac and the base of Grand Traverse Bay (Figure 1). It is located approximately 3.2 km (2 miles) north of the town of Ellsworth and about 9.6 (6 miles) south of Lake Charlevoix. Lyman Lake is situated in the S$\frac{1}{2}$, SW$\frac{1}{4}$, Sec. 1 and N$\frac{1}{2}$, NW$\frac{1}{4}$, Sec. 12, Banks Twp., T. 32N., R. 8 W., Antrim

County, Michigan. Its coordinates are $45^{\circ}11'27''$ N latitude and $85^{\circ}14'12''$ W longitude.

The Mission Point Bog, the southernmost bog locality sampled for pollen, is located near the tip of the Mission Peninsula in Grand Traverse Bay (Figure 1). The Mission Point bog is located in the NE$\frac{1}{4}$, NW$\frac{1}{4}$, Sec. 26, Peninsula Twp., T. 30 N., R. 10 W., Grand Traverse County, Michigan ($44^{\circ}58'18''$ N and $85^{\circ}29'12''$ W). It is situated near the tip of the 24 km (15 mile) long peninsula. The bog is less than 1.6 km (1 mile) from the waters of Grand Traverse Bay to the west, north or east. Approximately 8 km (5 miles) of bay separate the point from eastern and western extensions of the northwestern lower Michigan mainland.

RECONSTRUCTION OF THE REGION'S VEGETATION COVER.

The Presettlement Forest: An Overview.

Previous to American settlement, which became substantially established between 1860 and 1880, the area was nearly entirely covered with a mature northern mixed hardwood-conifer forest (Figure 2). According to Küchler (1964), this forest was dominated by _Acer saccharum_ (sugar maple), _Betula lutea_ (yellow birch), _Fagus grandifolia_ (beech), and _Tsuga canadensis_ (hemlock). Other components included _Acer pennsylvanicum_ (striped maple), _A. rubrum_ (red maple), _A. spicatum_ (mountain maple), _Fraxinus americana_ (white ash), _Kalmia latifolia_ (mountain laurel), _Pinus strobus_ (white pine), _Prunus serotina_ (black cherry), _Taxus canadensis_ (american yew), _Tilia americana_ (basswood), and _Ulmus americana_ (american elm).

A conifer bog forest covered far less extensive areas within the study region (Ibid). This forest was directly inland of Little Traverse Bay as well as directly south of the Straits of Mackinac thereby covering the northernmost portion of Michigan's lower peninsula. Dominants of this forest were _Larix laricina_ (tamarack), _Picea mariana_ (black spruce), and _Thuja occidentalis_ (white cedar). Also occurring were _Acer rubrum_ (red maple), _Carex_ spp. (sedge), _Chamaedaphne caliculata_ (leatherleaf), _Ilex verticillata_ (holly), _Kalmia polifolia_ (bog kalmia), _Ledum groenlandicum_ (labrador tea), _Nemopanthus mucronata_ (holly), and _Sphagnum_ spp. (peatmoss).

Küchler (1964) also indicates isolated extensions of the Great Lakes pine forest into northern and southern interior portions of

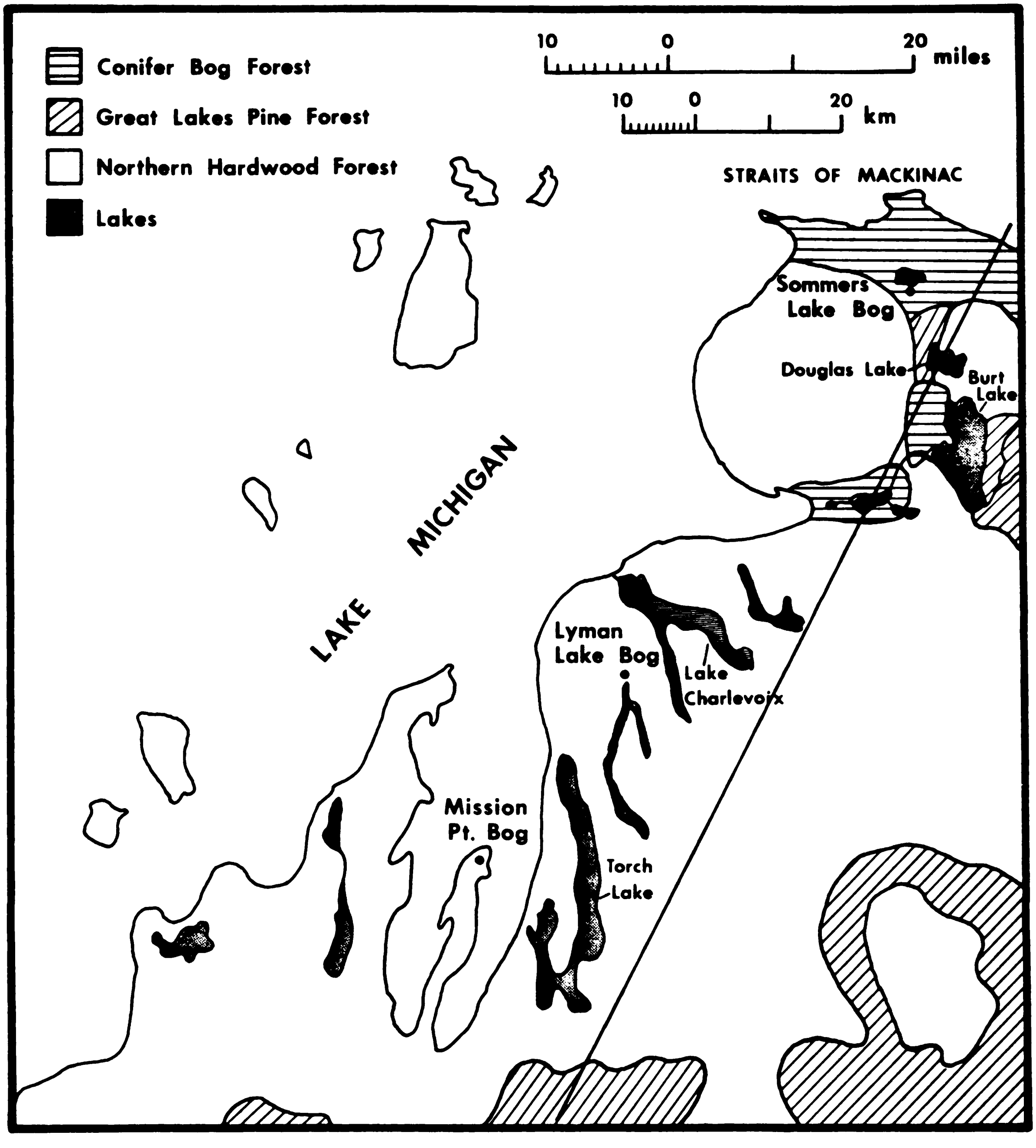


Figure 2 Natural Vegetation of Northwestern Lower Michigan (Küchter, 1964)

the study region. Three species of pine, *Pinus banksiana* (jack pine), *P. resinosa* (red pine) and *P. strobus* (white pine), were the dominant components of this forest. Species of minor importance included *Kalmia angustifolia* (sheep laurel), *Populus grandidentata* (largetooth aspen), *P. tremuloides* (quaking aspen), *Quercus coccinea* (scarlet oak), *Q. ellipsoidalis* (northern pin oak), *Q. rubra* (red oak), and *Q. velutina* (black oak).

Vegetation Analysis Based on Land Surveyor's Notes.

Although Küchler (1964) provides a generalized overview of the pre-settlement vegetation of the region, additional information on the distribution of plant communities can be gained through the construction of maps based on the records of government land surveyors who zoned the region into township units of thirty six one-mile square sections prior to American settlement. As teams of land surveyors walked the perimeters of each township section they recorded the locations of alterations in the vegetational cover. From their notes, dating from 1839-1851, on file in the Lands Division of the Michigan Department of Natural Resources, maps were constructed which plotted the documented changes in vegetation.

Reconstruction of the vegetation of northwestern lower Michigan based on land surveyors' notes was begun in 1968 by Colleen Isslieb, a graduate student working in the Anthropology Division of the Michigan State University Museum. Ms. Isslieb plotted the outlines of vegetational communities occurring in Emmet, Charlevoix, Antrim, Kalkaska, Missaukee, Leelanau and portions of Grand Traverse and

Benzie counties. The author constructed comparable maps for Cheboygan county, the Beaver Island Archipelago and South Manitou Island.

With the assistance of Dr. Peter Murphy, a plant ecologist on the staff of the Department of Botany and Plant Pathology, Michigan State University, a code was devised to denote the types of plant communities encountered by the surveyors (Figure 3). Applying this legend to a township map and following the recorded course of survey, the boundaries of these coumunities were charted along each section line of every township. The vegetational cover of the interior portions of each section was determined from correlated factors of land elevation and drainage. As the mapping of each township was completed, it was compiled into county maps which were then frequently compiled into more extensive regional portions in order to facilitate study and use (Figures 3-6). The locations of archaeological sites were also plotted and the bog localities cored in this study have been designated on these maps.

As can be seen in Figures 3-6, prior to intense American settlement, much of northwestern lower Michigan (approximately 72%) was covered by a mixed hardwood forest of Acer saccharum (sugar maple), Fagus grandifolia (beech), and Tsuga canadensis (hemlock), with Pinus strobus (white pine), Ulmus americana (american elm), Tilia americana (basswood), Betula lutea (yellow birch), Ostrya virginiana (ironwood) and Prunus serotina (cherry) (designated by number 8 on the map). Low, poorly drained areas were primarily covered by Thuja occidentalis (cedar), Larix laricina (tamarack),

Figure 3. Vegetation of Emmet, Charlevoix, and Antrim Counties as Recorded on Land Surveys 1839-1854. (Compiled by Isslieb).

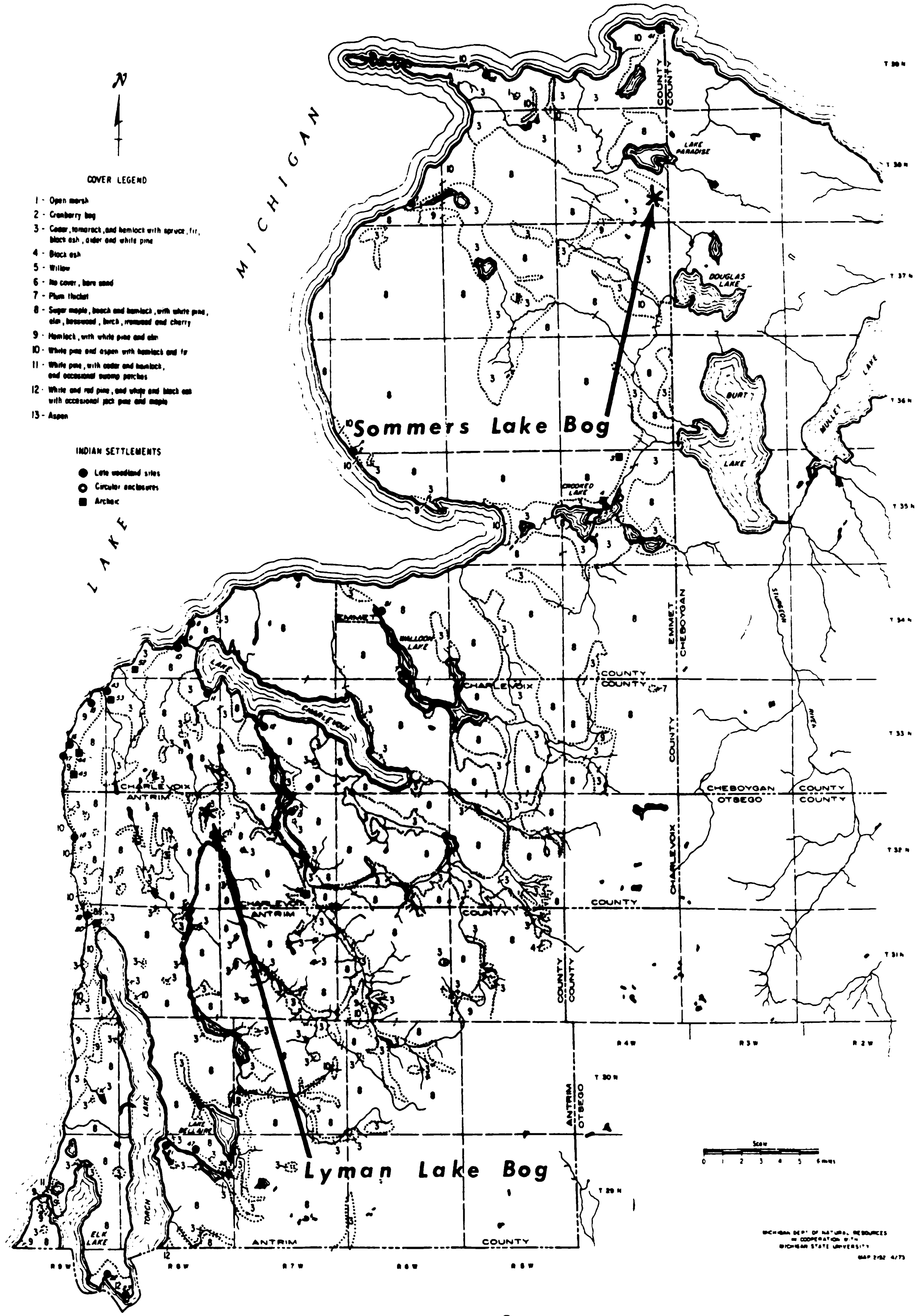

N
COVER LEGEND
1 - Open marsh
2 - Cranberry bog
3 - Cedar, tamarack, and hemlock with spruce, fir, black ash, alder and white pine
4 - Black ash
5 - Willow
6 - No cover, bare sand
7 - Plum thicket
8 - Sugar maple, beech and hemlock, with white pine, elm, basswood, birch, ironwood and cherry
9 - Hemlock, with white pine and elm
10 - White pine and aspen with hemlock and fir
11 - White pine, with cedar and hemlock, and occasional swamp patches
12 - White and red pine, and white and black oak with occasional jack pine and maple
13 - Aspen
INDIAN SETTLEMENTS
Late woodland sites
Circular enclosures
Archaic
LAKE MICHIGAN
Sommers Lake Bog
Lyman Lake Bog
LAKE PARADISE
DOUGLAS LAKE
BURT LAKE
MULLET LAKE
CROOKED LAKE
WALLOON LAKE
LAKE CHARLEVOIX
LAKE BELLAIRE
TORCH LAKE
ELK LAKE
EMMET COUNTY
CHEBOYGAN COUNTY
CHARLEVOIX COUNTY
ANTRIM COUNTY
OTSEGO COUNTY
Scale
0 1 2 3 4 5 6 miles

Figure 3

Figure 4. Vegetation of Cheboygan County as Recorded on Land Surveys 1839-1854. (Compiled by Cleland).

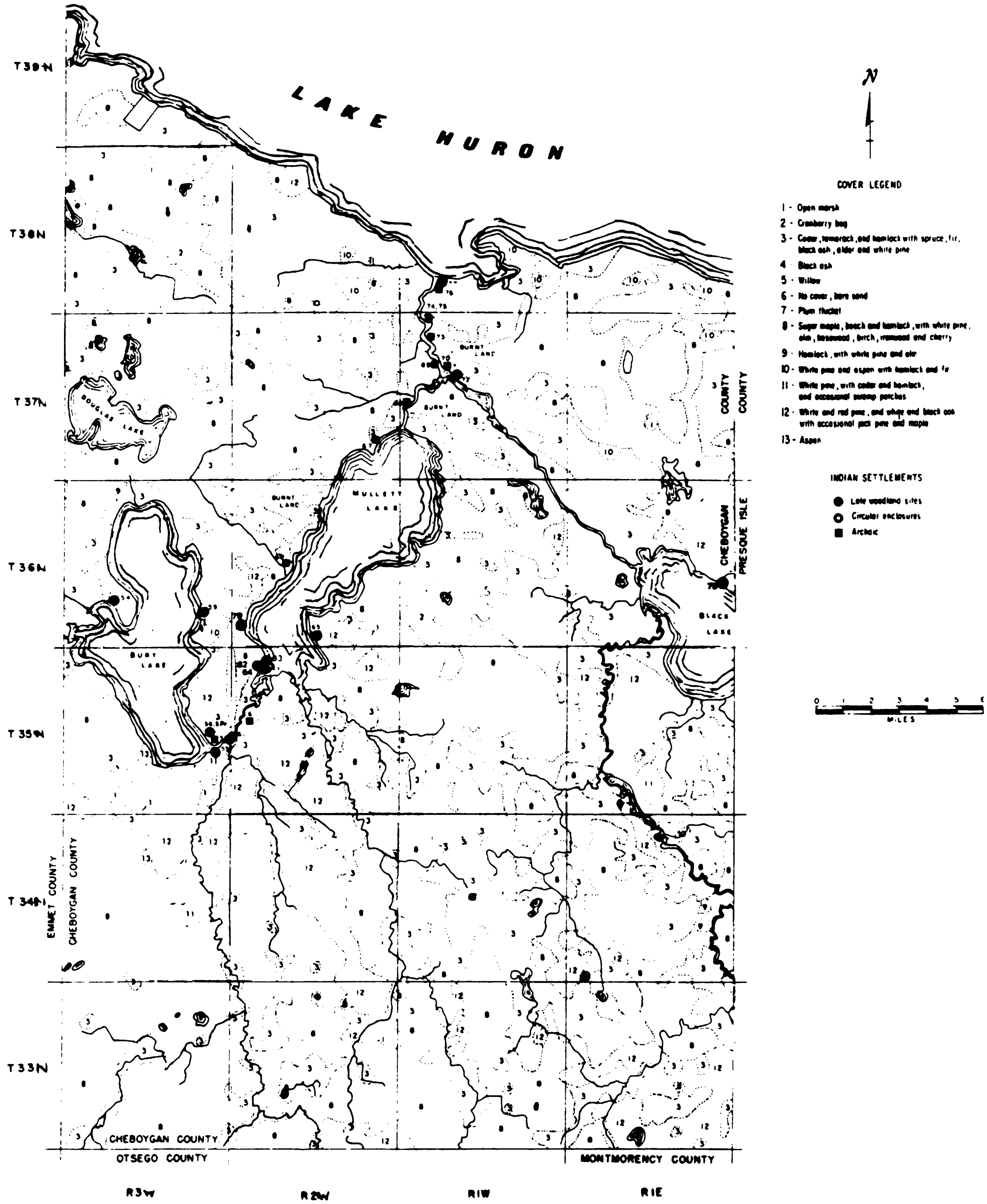
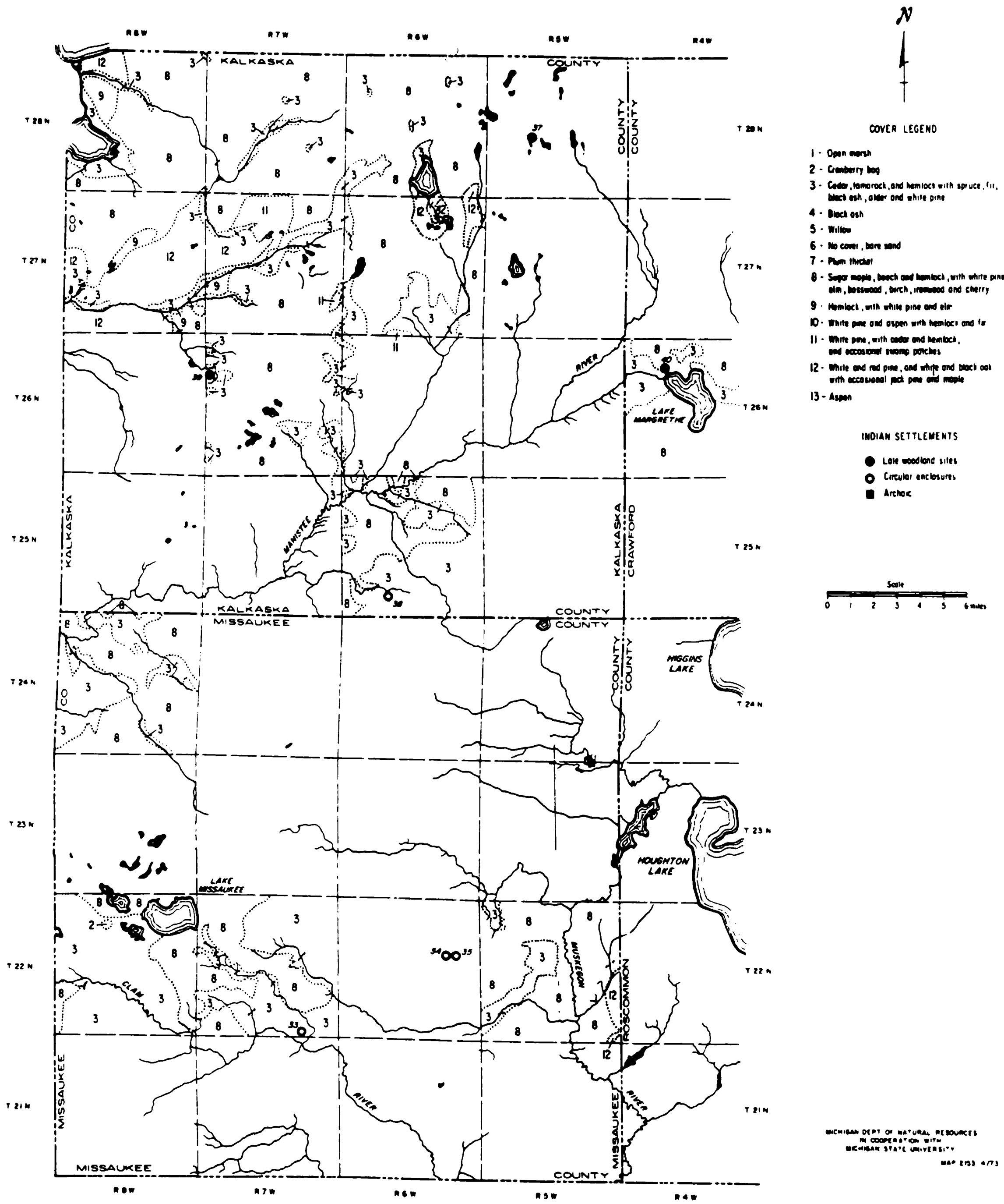

LAKE HURON
N
COVER LEGEND
1 - Open marsh
2 - Cranberry bog
3 - Cedar, tamarack, and hemlock with spruce, fir, black ash, alder and white pine
4 - Black ash
5 - Willow
6 - No cover, bare sand
7 - Plum thicket
8 - Sugar maple, beech and hemlock, with white pine, elm, basswood, birch, ironwood and cherry
9 - Hemlock, with white pine and elm
10 - White pine and aspen with hemlock and fir
11 - White pine, with cedar and hemlock, and occasional swamp patches
12 - White and red pine, and white and black oak with occasional jack pine and maple
13 - Aspen
INDIAN SETTLEMENTS
Late woodland sites
Circular enclosures
Archaic
MILES
T39N
T38N
T37N
T36N
T35N
T34N
T33N
R3W
R2W
R1W
R1E
DOUGLAS LAKE
BURT LAKE
MULLETT LAKE
BLACK LAKE
EMMET COUNTY
CHEBOYGAN COUNTY
CHEBOYGAN COUNTY
OTSEGO COUNTY
MONTMORENCY COUNTY
PRESQUE ISLE COUNTY

Figure 4

Figure 5. Vegetation of Kalkaska and Missaukee Counties as Recorded on Land Surveys 1839-1854. (Compiled by Isslieb).


N
KALKASKA
COUNTY
KALKASKA COUNTY
CRAWFORD COUNTY
MISSAUKEE
LAKE MARGRETHE
MANISTEE
HIGGINS LAKE
HOUGHTON LAKE
LAKE MISSAUKEE
CLAM
MUSKEGON
ROSCOMMON
RIVER
COVER LEGEND
1 - Open marsh
2 - Cranberry bog
3 - Cedar, tamarack, and hemlock with spruce, fir, black ash, alder and white pine
4 - Black ash
5 - Willow
6 - No cover, bare sand
7 - Plum thicket
8 - Sugar maple, beech and hemlock, with white pine, elm, basswood, birch, ironwood and cherry
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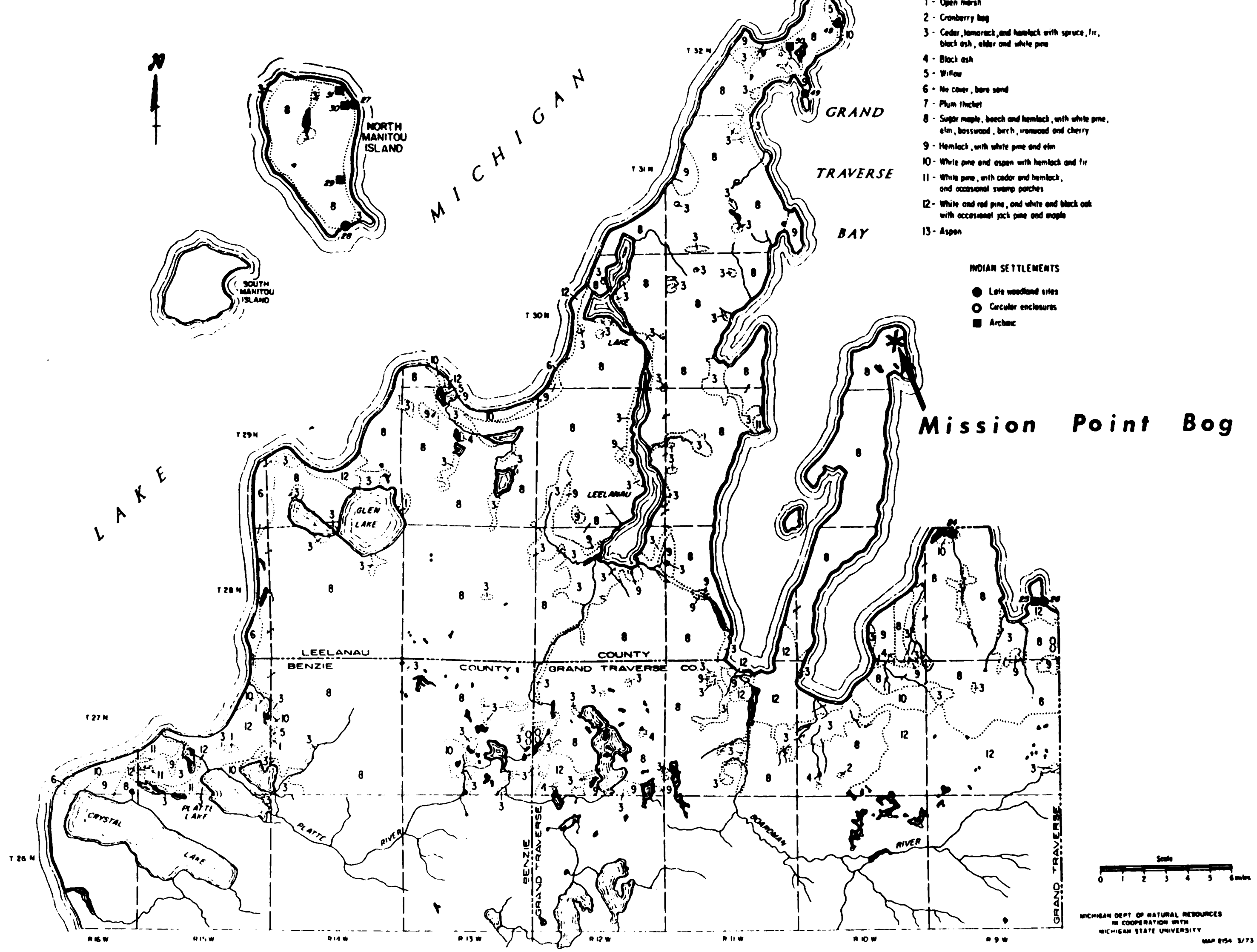
12 - White and red pine, and white and black oak with occasional jack pine and maple
13 - Aspen
INDIAN SETTLEMENTS
Late woodland sites
Circular enclosures
Archaic
Scale

Figure 5

Figure 6. Vegetation of Portions of Grand Traverse, Benzie, and Leelanau Counties as Recorded on Land Surveys 1839-1854. (Compiled by Isslieb).

FIGURE 6


COVER LEGEND
1 - Open marsh
2 - Cranberry bog
3 - Cedar, tamarack, and hemlock with spruce, fir, black ash, alder and white pine
4 - Black ash
5 - Willow
6 - No cover, bare sand
7 - Plum thicket
8 - Sugar maple, beech and hemlock, with white pine, elm, basswood, birch, ironwood and cherry
9 - Hemlock, with white pine and elm
10 - White pine and aspen with hemlock and fir
11 - White pine, with cedar and hemlock, and occasional swamp patches
12 - White and red pine, and white and black oak with occasional jack pine and maple
13 - Aspen
INDIAN SETTLEMENTS
Late woodland sites
Circular enclosures
Archaic
Mission Point Bog
LAKE MICHIGAN
GRAND TRAVERSE BAY
NORTH MANITOU ISLAND
SOUTH MANITOU ISLAND
GLEN LAKE
LEELANAU
CRYSTAL LAKE
PLATTE LAKE
PLATTE RIVER
BOARDMAN RIVER
LEELANAU COUNTY
BENZIE COUNTY
GRAND TRAVERSE CO.
Scale
0 1 2 3 4 5 6 miles
MICHIGAN DEPT OF NATURAL RESOURCES IN COOPERATION WITH MICHIGAN STATE UNIVERSITY
T 32 N
T 31 N
T 30 N
T 29 N
T 28 N
T 27 N
T 26 N
R 16 W
R 15 W
R 14 W
R 13 W
R 12 W
R 11 W
R 10 W
R 9 W

and Tsuga canadensis (hemlock) in association with Picea mariana (black spruce), Abies balsamea (fir), Fraxinus nigra (black ash), Alnus rugosa (alder) and Pinus strobus (white pine). This conifer dominated forest community covered approximately 20% of the area (designated by number 3 on the map). The third most common type of forest community to occur in the region, representing 4-5% of the study area (designated by number 12), was dominated by Pinus strobus (white pine), P. resinosa (red pine), and Quercus alba (white oak) and Q. nigra (black oak) with occasional Pinus banksiana (jack pine) and Acer spp. (maple).

Correlation of Modern Forest Composition and Pollen Assemblages.

Webb (1974) made a quantitative analysis of the geographic distribution or abundance of modern forest genera of lower Michigan and the frequency of occurrence of their pollen in the top two cm of surface sediments. Two maps were constructed for each genus: one illustrated the relative abundance of a particular genus in the vegetation; the other demonstrated its relative abundance in the pollen record (Table 1).

Table 1 shows the relative abundance of genera in the vegetation and pollen record of northwestern lower Michigan. Fagus and Ulmus are equally represented in the vegetation and pollen record. Representation between the two variables fluctuates slightly for Picea, Abies, Fraxinus, and Quercus. The frequencies of representation of pollen of Tilia, Acer, Populus, and Thuja, however, are considerably less than their frequencies of cccurrence in the

Table 1. Relative percent occurrence of genera in the vegetation and pollen record of northwestern lower Michigan. (From data by Webb, 1974).

GENERA	VEGETATION RELATIVE % OCCURRENCE	POLLEN RELATIVE % OCCURRENCE
Fagus	5 - 10	5 - 10
Ulmus	5 - 10	5 - 10
Picea	0 - 5	0 - 2
Abies	0 - 5	0 - 1
Fraxinus	5	0 - 5
Quercus	0 - 10	10
Tilia	5 - 10	0 - 1
Acer	30 - 40	5 - 10
Populus	10	0 - 3
Thuja	10	1 - 3
Tsuga	0 - 5	10 - 15
Betula	5	15 - 20
Pinus	0 - 10	20 - 30

vegetation. The pollen frequency of Tilia is only about one-seventh of its relative abundance in the plant cover. Acer, Populus, and Thuja are underrepresented by approximately one-fifth of their occurrences. Relative frequencies of representation of pollen of Tsuga, Betula, and Pinus greatly exceed their relative percentage occurrences in the vegetation. While the frequencies of occurrence of Tsuga and Betula pollen exceed their vegetational representation approximately three-fold, the frequency of occurrence of Pinus pollen is five times that of its occurrence in the vegetation.

An understanding of the relationship which exists between the relative percent of occurrence of each genus in the pollen record and the plant cover should aid in the reconstruction of past environments based on the analysis of relative pollen frequencies.

METHODOLOGY.

Field Techniques.

Peat samples were collected from the three bog locations using a Hiller sampler (Borros, Solna, Sweden). This instrument has a 50 cm chamber which fills along the side or length of the barrel. A sleeve fits over the opening to prevent loss and contamination of material. The Hiller sampler is a particularly good collecting instrument in fibrous peat of variable compactness since, by the nature of its design, there is minimal stratigraphic distortion from compaction of the peat by the instrument. A boring tool, however, is mounted at the head of the sampling chamber. As a 50 cm core interval is being obtained, therefore, the top of the next 50 cm interval of the core is being disturbed. Consequently, in order to obtain an undisturbed sample at all levels, it is necessary to collect alternate samples from two adjacent core holes.

The location for the coring site at each bog was determined by preliminarily probing with the rods of the sampler to determine the area which contained the thickest peat deposit. Alternate 5 cm intervals of the peat were collected from each core. The sampling chamber of the Hiller sampler is marked at intervals of 5 cm so that alternate sampling was easily accomplished. Before and after each sample was taken, the sampler tube was thoroughly cleaned with water sprayed from a hand-pumped, portable sprayer

(Hudson Mfg. Co.) and dried with paper toweling. When the sampler was pulled from the hole, with the recovery of each 50 cm core interval, the outside of the barrel of the tool was cleaned with paper toweling to prevent contamination of the sample in the chamber when it was opened. Each 5 cm sample was then removed individually with a clean knife, wrapped separately in aluminum foil and labelled according to stratigraphic depth and location. The samples were stored in a cooler of dry ice until they could be transferred to a freezer for more permanent storage. Freezing the samples until their maceration in the laboratory insured that the stratigraphy of the core would not be altered during handling or transport.

Laboratory techniques.

The removal of larger organic and extraneous inorganic material from soil and peat samples concentrates the pollen and spores for easier examination and identification. All samples were macerated as follows according to a procedure adapted from Erdtman (Faegri and Iversen, 1975):

1. Weigh out 3 gms of wet peat in a 40 ml test tube.

2. Cover sample with 7% potassium hydroxide and boil in steam bath for 5 min. Centrifuge at 1600 rpm for 2 min. and decant.

3. Sieve sample through 250 um and 177 um mesh sieves with distilled water into 250 ml beaker. Transfer to 40 ml tubes.

4. Centrifuge sample at 1600 rpm for 2 min. or longer, until sample is concentrated at the bottom of the tube. Decant.

5. Wash in glacial acetic acid three times. Centrifuge at 1600 rpm for 2 min. and decant each time.

6. Boil in acetolysis solution for 3.5 min (9% acetic anhydride and 1% sulfuric acid). Centrifuge for 2 min. at 1600 rpm and decant.

7. Wash in glacial acetic acid twice (centrifuge at 1600 rpm for 2 min. and decant each time).

8. Wash in distilled water three times (centrifuge at 1600 rpm for 2 min. and decant each time).

9. Transfer to small storage vials, centrifuge and decant. Store in HEC (hydroethyl cellulose).

Four to six slides were made of each sample. A drop or two of the residue dispersed in HEC (Hydroethyl cellulose) was pipetted onto a glass cover slip, smeared evenly with a toothpick and allowed to dry on a slide warming table at about 42° C (108° F). A drop or two of HSR (Harleco synthetic resin, Hartman-Ledden Co., Philedelphia, item 7885) was then pipetted onto the cover slip and dispersed by gently and evenly dropping the slide onto the cover slip. The slide and cover slip were then allowed to dry in an upright position on the slide table or in an oven (ca 30° C). The meceration number of each sample was inscribed into each slide along one of the short edges with a diamond pencil. Each slide was then labelled with location, depth, date, preparation and preparator information marked on a paper label attached to the left side of the slide.

As mentioned previously, while making the slides, an attempt was made to distribute the palymorphs evenly on the cover slip. It has been demonstrated that if the spores and pollen grains are distributed on the slide by flow currents or gravity from one central point, there is some sorting which results in a strong correlation between the size and weight and hydrodynamic characteristics of a grain and the distance travelled (Taggart, personal communication). The failure to systematically and equally view all sections of the slide could result in a distortion of the relative frequencies of occurrence of pollen which are calculated from the counts made. A few simple precautions were taken, consequently, to avoid obvious sources of error. Portions of at least three slides per sample were viewed under the microscope. Equidistant traverses were made across the slide using a mechanical stage so that representative sections of each slide were examined equally.

Generally, pollen and spores were viewed, identified and counted on a Zeiss microscope at a magnification of 320 X. Occasionally, identification of palymorphs required additional magnification to 800 X with an oil immersion lens. At least 250 grains were counted in nearly all samples. The sum of the number of grains of arboreal pollen (AP) and non-arboreal pollen (NAP) (excluding aquatics) comprised the percentage base from which relative pollen frequencies were calculated for each sample. A variable number of grains were counted for each sample but generally more than 250 grains were counted.

Standard pollen and spore identification manuals (McAndrews, et al, 1973; and Kapp, 1969) as well as a convenient collection of reference slides of frequently encountered pollen and spore types greatly facilitated the task of identification. Those grains which were either partially destroyed or obscured were classified as unidentifiable.

RESULTS.

Sommers Lake Bog.

Sommers Lake covers an area of approximately 3.6 hectares (9 acres) (Figure 7). The bog surrounding the lake increases the acreage to approximately 11.2 hectares (28 acres). The bog encompasses the lake irregularly with its greatest extension to the northwest. It is in this portion of the bog that a core sample was taken.

Present Vegetation.

The density and diversity of vegetation supported by the *Sphagnum* spp. mat increases with distance from the lake. The bog immediately surrounding the lake supports low herbs and shrubs such as *Sarracenia purpurea*, *Chamaedaphne calyculata*, *Vaccinium* spp., *Alnus* spp., and *Salix* spp. With the establishment of a tree canopy a few yards from the lake, the shrubs and herbs are replaced by taller bog species such as *Thuja occidentalis*, *Larix laricina*, and *Picea mariana*. These species dominate the vegetation surrounding the area that was selected for sampling.

Beyond the bog in all directions, the land rises approximately 3 m (10 feet) to an elevation of 225 m (750 feet). To the north it supports a mixed northern hardwood forest dominated by *Fagus grandifolia*, *Acer saccharum*, and *Populus tremuloides*. Oldfield vegetation covers the outlying areas to the east and south.

Figure 7. Aerial View of the Sommers Lake Bog.

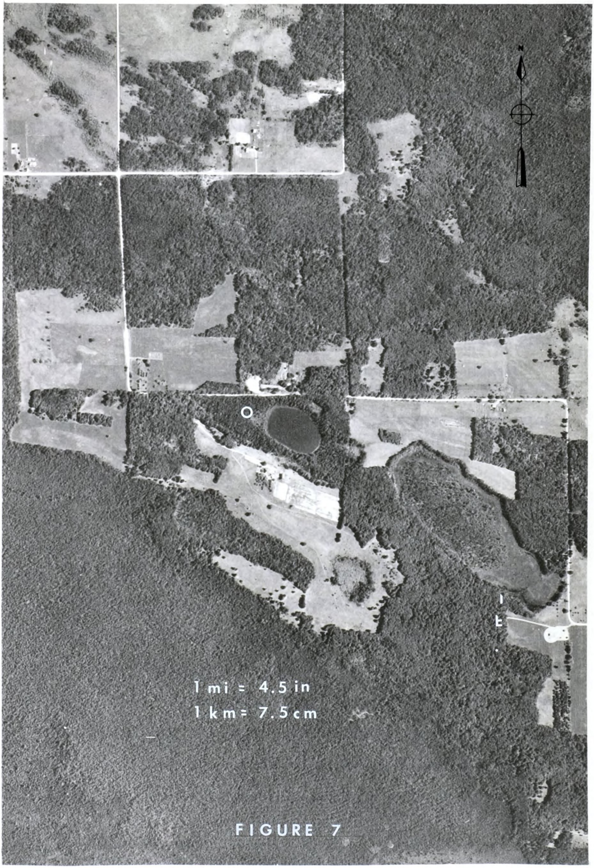


FIGURE 7

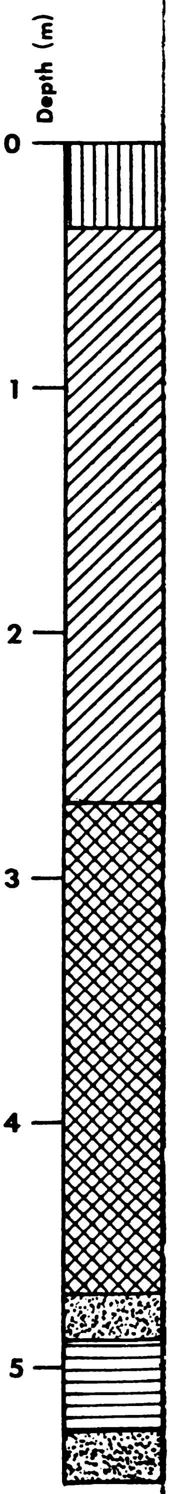
Bog Sediments.

The Sommers Lake bog was cored to a depth of nearly 5.5 meters (18 feet). The stratigraphy encountered varies as follows:

Top	
0.00 - 0.35 m	sediment dry; with coarse plant debris; reddish brown
0.35 - 2.70 m	peat; with *Sphagnum* and variable plant debris; coarse near top and becoming finer with depth; deep brown
2.70 - 4.70 m	gyttja; soft and somewhat gelatinous; deep brown
4.70 - 4.90 m	silty clay; somewhat gelatinous; bluish gray
4.90 - 5.30 m	mottled gyttja with silty clay; somewhat gelatinous; variable deep-brown to bluish gray
5.30 - 5.50 m	silty clay; somewhat gelatinous but becoming coarse with gravel downward; gray-beige. Penetration impossible beyond this depth.
Bottom	

Pollen Stratigraphy.

The pollen stratigraphy of the Sommers Lake bog is illustrated in Figure 8. Strata of the lower third of the column are dominated by pollen of coniferous genera. *Picea* pollen dominates the lowermost strata. It declines in frequency in subsequent strata as *Pinus* increases as the dominant taxa. Approximately midway up the column *Tsuga*, *Acer*, and *Fagus* pollen increase in their occurrences. Strata of the upper half of the column are dominated by pollen of a mixture of hardwood and softwood genera.


Depth (m)
0
1
2
3
4
5

Lyman Lake Bog.

Lyman Lake covers an area of approximately 8 hectares (20 acres) (Figure 9). Together, the lake and surrounding bog encompass an area of 28 hectares (71 acres). The bog was sampled where it is most extensive, to the west of the lake.

Present Vegetation.

Tall trees and shrubs are supported by the bog's Sphagnum spp. mat to the lake's edge. The species which dominant the vegetation of the bog are consistantly mature specimens of Larix laricina, Picea mariana, and Thuja occidentalis. Outward from the bog and lake there are occasional depressions which support Typha latifolia, and Ulmus americana. Beyond this, the land rises approximately 6 m (20 feet) in elevation through a series of ridges or terraces which support a northern hardwood forest dominated by Fagus grandifolia, Acer saccharum, Tsuga canadensis, Populus tremuloides, and Betula lutea. Beyond this, the land rises an additional 6 m (20 feet) to an elevation of 227 m (760 feet) and remains relatively level for miles. The land at this elevation is occupied by cultivated fields to the west of the bog and a northern hardwood forest to the north, east and south.

Bog Sediments.

The Lyman Lake bog was cored to a depth of 3 meters (10 feet). The following stratigraphy was encountered:

Figure 9. Aerial View of the Lyman Lake Bog.


1 mi = 4.5 in
1 km = 7.5 cm
N
FIGURE 9

Top	
0.00 - 0.10 m	peat; humified; deep reddish-brown
0.10 - 2.00 m	peat; with Sphagnum and variable plant debris; coarse near surface but becoming increasingly fine downward; deep reddish-brown
2.00 - 2.95 m	gyttja; soft and somewhat gelatinous; deep-brown
2.95 - 3.00 m	clay; silty with gravel; gray-beige. The sediment could not be penetrated further with equipment used.
Bottom	

Pollen Stratigraphy.

Figure 10 illustrates the pollen stratigraphy encountered in the sediments of the Lyman Lake bog. Observation of the diagram shows fluctuations in representation of pollen or arboreal and non-arboreal genera. Pollen of arboreal taxa, both coniferous and deciduous, dominate nearly the entire column. The uppermost strata of the column are dominated by non-arboreal taxa, namely Compositae.

Mission Point Bog.

The Mission Point bog covers an area of approximately 13 hectares (32 acres) (Figure 11). Although there are some small, shallow ponds within the bog, it does not presently encompass a lake *per se*.

Present Vegetation.

These, and other wet areas of the bog support stands of *Typha latifolia*. The *Sphagnum* spp. mat of the bog premarily supports herb and shrub vegetation dominated by *Chamaedaphne calyculata* and

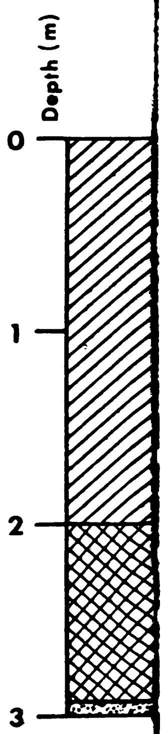


Figure 10.

Figure 11. Aerial View of the Mission Point Bog.


N
1 mi = 4.5 in
1 km = 7.5 cm
O
FIGURE 11

Vaccinium spp. There are small, scattered stands of Picea mariana and Pinus spp. An area surrounded primarily by Chamaedaphne calyculata was selected for coring.

The bog is immediately surrounded by a northern hardwood forest which stands at an elevation of approximately 182 m (620 feet) and is dominated by Fagus grandifolia, Acer saccharum, Tsuga canadensis, Populus tremuloides and Betula lutea. Beyond the immediate vicinity of the bog, there are fruit tree orchards to the north and west and open fields to the south and east.

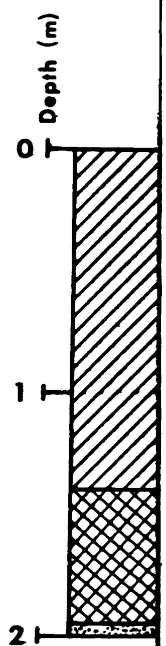
Bog Sediments.

A core was driven through the bog to a depth of two meters (7 feet). The stratigraphy was as follows:

Top	
0.00 - 0.08 m	peat; humified; deep reddish-brown
0.08 - 1.40 m	peat; with Sphagnum and coarse plant debris; deep reddish-brown
1.40 - 1.95 m	gyttja; fine somewhat gelatinous; deep reddish-brown
1.95 - 2.00 m	clay; dense with gravel near bottom; gray. Further penetration impossible.
Bottom	

Pollen Stratigraphy.

The pollen stratigraphy encountered at the Mission Point bog is illustrated in Figure 12. Most of the column is dominated by arboreal pollen of both coniferous and deciduous genera. A notable fluctuation is a consistantly lower representation of Tsuga pollen in the lower strata of the column followed by higher occurrences


Depth (m)
0
1
2

within the upper strata. The uppermost strata are dominated by pollen of non-arboreal taxa, notably Compositae.

ZONATION OF POLLEN STRATIGRAPHY.

Zonal Criteria.

To facilitate discussion of the post-glacial pollen stratigraphies produced from the bogs of this study, zones have been established. These zones are characterized by distinctive fluctuations in the percentages of certain pollen types and they represent particular floras. The divisions employed in this study correspond to zones identified in late and post-glacial sediments throughout northeastern North America. Although standardization exists in zone identification, sub-divisions of the zones are not yet uniform. This is primarily due to the fact that zonal sub-divisions are not uniformily represented throughout the region. Generally, zonal sub-divisions are established to identify less pervasive floral communities influenced chiefly by micro-climatic conditions.

The nomenclature employed in zone description has not been standardized. Miller (1973) and others employ an alphabetical system of zonal nomenclature developed by Deevey (1939). Davis, et al (1975), Kapp, et al, (1969) as well as others, follow a system by which the zones are designated by Roman numerals. In a system of nomenclature developed by Cushing (1967) the zones are named after the primary dominant generic components which comprise it. The zonal nomenclature which appears in this study most closely resembles that employed by Kapp, et al (1969) and Deevey, et al (1975) since the zones are designated by Roman numerals, I,

II, III, and IV. Only Zone III has been sub-divided with letter designations A, B, and C.

Zonal Characteristics.

Pollen Zone I is the lowermost zone identified from the pollen stratigraphy of the bogs of this study. It is characterized by high percentages of spruce and pine pollen. Pollen Zone I is comparable to Deevey's (1939) Zone A and Cushing's (1967) *Picea-Pinus* zone. Of the three bogs sampled, this zone is represented solely at the Sommers Lake bog.

Pollen Zone II comprises the subsequent interval of pollen stratigraphy produced by the bogs of this study. This zone is distniguished by an overwhelming dominance of pine pollen. Pollen Zone II is equivalent to Deevey's (1939) Zone B and Cushing's (1967) *Pinus*-*Betula*-*Alnus* zone. It is represented only in the stratigraphy of the Sommers Lake bog of the localities sampled in this study.

Pollen Zone III is dominated by a fluctuating mixture of arboreal pollen of both hard and softwood genera. It has been further divided into three sub-zones: A, B, and C. These sub-divisions most closely resemble Deevey's (1939) sub-divisions of Zone C: 1, 2, and 3a. Sub-Zone IIIA is characterized by the initial significant influx of the pollen of hardwood genera as well as *Tsuga* and a corresponding decrease in the pollen of softwoods, particularly pine. This zone is represented in the pollen stratigraphies of the Sommers Lake and Mission Point bogs. Sub-Zone IIIB is characterized by a significant decrease in the representation of Tsuga pollen. The zone continues to be dominated by the pollen of arboreal genera, both coniferous and deciduous. Zone IIIB is represented in the stratigraphies of the Sommers Lake, Lyman Lake and Mission Point bogs. Sub-Zone IIIC is characterized by a shift in the pollen frequencies of arboreal taxa, hard and softwood genera included, to accommodate a substantial increase in Tsuga. This zone is represented in the stratigraphies of all three bogs of the study.

Pollen Zone IV is characterized by a substantial increase in pollen of non-arboreal taxa and a corresponding decrease in arboreal pollen. It is comparable to Deevey's (1939) Zone C-3b. Pollen Zone IV is represented in the stratigraphies of the Lyman Lake and Mission Point localities.

Zones Represented at the Sommers Lake Bog (Figure 8).

Pollen Zone I. The most abundant pollen type represented, Picea, ranges in relative frequency from 34 to 62% with an average representation of 50%. Pinus pollen, the second most common type, represents 10 to 18% of the relative frequency with an average value of 13%. Of the hardwoods, Quercus is the sole genus showing a significant representation in this zone. It ranges in frequency from 5-12% with an average representation of 8%.

Pollen of other arboreal genera, both hardwood and softwoods included, are represented in very low frequencies. Softwood genera, Abies, Tsuga, and Larix are represented by values of 1 to 6%, 1 to 2%, and 2 to 4% respectively. The pollen of hardwoods, Acer, Fagus,

Ostrya, *Ulmus*, and *Populus* do not exceed values of 3% in this zone. *Betula* pollen, however, with a relatively high initial value of 7%, decreases to 1%, thereby averaging 3% in occurrence. *Castanea* and *Thuja* each comprise 1% or less of the pollen represented in this zone.

Non-arboreal pollen occurs in low frequency in pollen Zone I and comprises approximately 2% of the total. *Salix* and *Corylus* pollen each represent roughly 1% of the total count. Pollen of members of the Compositae and Gramineae show minimal representation as do the spores of *Sphagnum* and members of the Polypodiaceae.

Pollen Zone II. *Pinus* pollen clearly dominates this zone as it ranges from 33 to 42%. This average signifies nearly a three-fold increase in *Pinus* over its previous representation in Zone I and constitutes the maximum average value this genus achieves in the vegetational history of this bog. *Picea* pollen is also well represented in this zone although its frequency has significantly decreased to roughly 40% of its previous average occurrence in Zone I. *Picea* represents 10-30% of the pollen (average 19%). During Zone II *Betula* pollen increases in frequency to nearly three times its average occurrence in Zone I. *Betula* fluctuates in frequency of occurrence from 4-13% (average 9%). *Quercus* continues to represent 4 to 12% of the total as in Zone I.

The remaining hardwood and softwood genera which occur in Zone II are scantily represented. *Abies*, *Tsuga*, and *Thuja* each range between 0-2% in relative percentage of the pollen flora. *Larix*, however, represents a maximum of 4% of the total pollen (average 3%). Pollen of *Acer* ranges in values from 2-5% of the total. Pollen of Fagus, Ostrya, Ulmus, Populus, Carya, and Tilia each represent a mere 1-2% of the total.

Non-arboreal pollen comprises approximately 6% of the total. Of this, Corylus represents approximately 3%, while members of the Compositae and Gramineae comprise 2% and 1% respectively. The pollen of Salix and Alnus have only trace occurrences as do the spores of Sphagnum, Lycopodiaceae and Polypodiaceae.

Pollen Zone III. In Zone IIIA, Picea and Pinus each represent an average of 18% of the total pollen count. While this percentage represents a slight decrease from previous values for Picea, it represents a substantial decrease, approximately 50% for Pinus. As a result of this decrease, Pinus is reduced to a frequency of occurrence comparable to that of Zone I. Zone IIIA shows the first significant influx of Tsuga pollen. In this zone, Tsuga reaches a maximum representation of 25% of the total count (average 16%).

Increases in relative percentages of Acer and Fagus pollen in Zone IIIA indicate their growing establishment into the region's flora. On the average, Acer represents 10% of the total while Fagus represents 4%. Betula pollen decreases in occurrence to 6%, or approximately two-thirds of its representation in Zone II, Quercus remains unchanged at about 7%,

Most of the remaining arboreal species which occur in this zone continue to occur in low frequencies as in Zone II. Ulmus pollen represents approximately 2% of the total; Populus, Tilia, and Abies each comprise 1%. Larix and Ostrya each comprise about 2%. Trace occurrences of Carya and Castanea are noted.

Non-arboreal pollen comprises roughly 2% of the total with

Corylus and members of the Compositae at about 1% each. *Salix*, *Alnus*, and *Ilex* have minimal representation in this zone.

Spores of Lycopodiaceae and Polypodiaceae together show a frequency of 3%. Pollen of the Nymphaeaceae and Alismaceae families comprise about 1% of the total.

In Pollen Zone IIIB *Tsuga* pollen decreases significantly to a minimal level of representation. *Picea* and *Pinus* although continuing as dominant genera, decrease somewhat in their representation to 13% and 12% averages respectively. *Fagus* pollen increases in representation to values ranging from 7-15% (average 10%). Other important hardwood genera, *Quercus*, *Acer*, and *Betula*, show minimal fluctuations in representation. *Quercus* and *Acer* pollen each comprise approximately 8-9% of the total; *Betula* remains at an average value of 5%.

Softwood genera of *Abies* and *Thuja* continue to represent less than 1% of the total. *Larix* pollen increases to an average of 4%. Of the minor hardwood genera, only *Populus* increases to 4% of the total pollen flora. In this zone *Ostrya* shows little fluctuation in values (averages 2%). *Ulmus*, *Carya*, *Tilia*, and *Celtis* each are present in percentages of about 1%. *Juglans* and *Castanea* show only a trace in Zone IIIb.

Non-arboreal pollen occurs in the sediment at an average value of 10%. Of this, only *Salix* and Gramineae show substantial increases in representation, comprising 4% and 3% respectively. *Alnus*, *Corylus*, and members of the Compositae continue to each represent approximately 1% of the total. Pollen of *Ilex*, *Typha*, and members of the Ericaceae continue to occur in traces. Spores from the

Lycopodiaceae and Polypodiaceae occur in a frequency of about 2% of the total. Sphagnum is present as a trace.

In Pollen Zone IIIC an increase in occurrence of Tsuga pollen to an average of 8% is accompanied by an increased frequency of Pinus and Larix, which average respectively 16% and 7%. The frequencies of occurrence of Picea and Acer pollen decrease in this zone to 8% and 6%, respectively. The pollen frequencies of Quercus and Fagus remain unchanged from Zone IIIA as does Betula, which continues to represent approximately 6% of the count.

Of the minor arboreal components occurring in Zone IIIC, Populus represents roughly 2% of the total pollen count while Ostrya and Ulmus each comprise an average of 1%. Carya, Tilia, Castanea, and Thuja show scant occurrences in this zone.

Non-arboreal pollen comprises approximately 7% of the total count in pollen Zone IIIC. Of this, members of the Gramineae represent 3% while Salix represents 2%. Each representing an average of 1% of the total count are members of the Compositae and Cyperaceae. Alnus, Corylus, Ilex, Polygonaceae, and Typha have only trace occurrences in this zone.

Spores of the Lycopodiaceae and Polypodiaceae families occur in a frequency equivalent to 3% of the total count. Sphagnum continues to occur only in traces as does the pollen of the Nymphaeaceae and Alismaceae.

Pollen Zone IV. Since satisfactory pollen samples could not be retrieved from the uppermost 20 cms (0.66 ft) of the core obtained from the Sommers Lake bog, this zone is not represented at this locality.

Zones Represented at the Lyman Lake Bog (Figure 10).

Pollen Zone III. In Pollen Zone IIIB the pollen of Acer and Fagus occur most frequently at the Lyman Lake bog. While Acer comprises an average of 15% of the total count, Fagus accounts for an average of 12%. Occurring at considerably lower frequencies but still amply represented are Quercus, Betula, and Pinus. Quercus pollen represents an average of 8% of the count in this zone and Betula and Pinus pollen each represent 7% of the total. Tsuga and Picea pollen fluctuate in percent of representation from 0 to 11%. Tsuga pollen averages 6%, however, and Picea shows an average value of 5%.

The pollen of a number of hard and softwood genera occur in low frequencies in this zone. Each representing an average of 4% of the total count are Ostrya and Ulmus. Carya averages 3% and Populus 2% Trace occurrences of Abies, Larix, Thuja, Tilia, Castanea, Celtis, and Morus are identified.

Non-arboreal pollen comprises approximately 12% of the total count in Zone IIIB at the Lyman Lake bog. Salix has the highest frequency averaging 4%. The Compositae and Gramineae each represent 2% of the total and Alnus, Corylus, Ilex, and Typha each account for 1%. The Ericaceae and Polygonaceae are rare. Spores of Lycopodiaceae, Polypodiaceae, and Sphagnum together occur in a frequency equivalent to 2%. Aquatic pollen occurs only in traces.

In Pollen Zone IIIC Tsuga pollen increases three-fold from earlier Zone IIIB values to an average representation of 9%. Pollen of dominant hardwood genera continue to occur at approximately the same percentages of representation. Acer represents 13% and Fagus pollen 11%. Quercus and Betula each average 7% of the count and Picea and Ulmus 5%.

Ostrya, Populus, and Carya occur in low frequencies. Ostrya pollen represents 3% of the total, Populus 2%, and Carya 1%. Arboreal genera of Larix, Thuja, Tilia, Juglans, Fraxinus, Castanea, Celtis, and Morus each represent averages of less than 1% of the total count.

Non-arboreal pollen makes up approximately 9% of the total count in this zone. Salix averages 3% and Corylus 2%. Each representing averages of 1% of the total count are Alnus, Typha, and members of the Compositae and Gramineae. Trace frequencies of Ilex and members of the Ericaceae, Cruciferae, Polygonaceae, Nymphaeaceae, Alismaceae, Sphagnum, Lycopodiaceae, Polypodiaceae, Selaginellaceae, and Osmundaceae occur.

Pollen Zone IV. In this zone, the pollen of non-arboreal genera collectively average 42% of the total pollen count. More than half of the non-arboreal genera belong to the Compositae which comprises an average of 26% of the total count. Pollen of the Gramineae account for approximately 6%. This increase in relative percent of representation occurs primarily at the expense of the formerly dominating genera of Zone IIIC, Fagus, Acer and Tsuga which each average 5 or 6%.

Of the remaining dominant genera represented in this zone. the pollen of Betula and Picea increase in occurrence while Pinus and Quercus show little fluctuation. Betula pollen represents 12% of the total, Picea and Pinus each average 8%, and Quercus comprises 7% of the count.

Arboreal genera exhibiting low frequencies of occurrences include Ostrya, Ulmus, Populus, and Tilia. With the exception of Ostrya pollen which accounts for 2% of the total, pollen of the remaining genera each represent 1% of the count.

Of the remaining non-arboreal taxa, Alnus, Corylus, and members of the Chenopodiaceae and Polygonaceae families each comprise an average of 2% of the total. Salix represents 1% of the count.

Spores occur in low frequencies: Sphagnum, 2%, the Lycopodiaceae, 1%. Pollen of aquatic plants, the Nymphaeaceae and Alismaceae, average 1% of the total.

Zones Represented at the Mission Point Bog.(Figure 12).

Pollen Zone III. In Pollen Zone IIIA Quercus pollen is the most abundant type representing an average of 18% of the total. Acer and Pinus each account for 13% of the total. Tsuga pollen comprises 8% of the total and Betula 5%. Fagus and Populus each represent 4% of the pollen in this zone.

Softwood genera with low percentages of representation are Picea and Larix, each at 2% and Thuja, at 1%. Ulmus, Carya, and Tilia pollen each represent 2% of the total count and Ostrya, Fraxinus, Castanea, and Celtis each comprise 1%.

Non-arboreal pollen represents 13% of the total in pollen Zone IIIA. Of this, the shrubs represent 5% of the total; Salix, comprising 3% and Corylus, 2%. Members of the Compositae and Polygonaceae each represent 2%. Ilex, Typha and members of the Graminaeae and Chenopodiaceae families each make up 1% of the total.

Spores of Sphagnum as well as members of the Polypodiaceae, together occur in a frequency equivalent to 3% of the total count. Aquatic plants of the Nymphaeaceae and Alismaceae show minimal occurrences.

In Pollen Zone IIIb, Fagus pollen increases substantially in occurrence ultimately establishing itself as the dominant genus. Fagus ranges between 12 and 27% in frequency for an average of 21%. Quercus pollen attains 12% relative frequency, the second highest in this zone. This represents a considerable decrease from Zone IIIA values. Acer and Picea each represent an average of 9% of the total pollen count in Zone IIIB. This average indicates a slight decrease in occurrence of Acer but represents a considerable increase in the frequency of Picea pollen.

Arboreal genera of minor importances are Pinus, Tsuga, and Betula. Pinus represents an average of 7% and Tsuga and Betula each have an average value of 6%.

In pollen Zone IIIB, Ostrya pollen comprises 3% of the total; Ulmus and Populus each comprise 2%, and Carya, 1%. Arboreal genera with trace occurrences include Abies, Larix, Tilia, Fraxinus, and Castanea.

Approximately 6% of the total pollen count is represented by non-arboreal taxa. Of these, Corylus and members of the Ericaceae each represent 2%; Salix and members of the Compositae each comprise 1%. Genera having only scant representation are Ilex, Typha, and members of the Cruciferae, Chenopodiaceae, Polygonaceae, and Gramineae families. Pollen of aquatic plants and spores are scarse in this zone.

In Pollen Zone IIIC Tsuga pollen increases in frequency two-fold averaging 12% of the total. Acer pollen, which also increases to 12%, represents a small gain from earlier values. Fagus pollen, however, still continues to be the dominant type, fluctuating between 16-26%, for an average representation of 20%. Quercus and Picea pollen decrease slightly to average values of 10% and 7% respectively. Pinus and Betula continue to represent 7% and 5% of the total respectively.

Arboreal taxa with low pollen frequencies include Ulmus, Ostrya, Populus, and Carya. Ulmus pollen represents 4% of the total, Ostrya, 3%, and Populus and Carya each 2%. Abies, Larix, Tilia, Fraxinus, and Castanea are present in trace occurrences only.

Six percent of the total pollen are non-arboreal genera. Of these, Corylus and members of the Compositae each comrpise 2%, and Salix and members of the Ericaceae, Polygonaceae, and Gramineae, occur minimally. Spores show trace representation while aquatic plant pollen are absent in this zone.

Pollen Zone IV. In this zone non-arboreal pollen comprises approximately 42% of the total count. Members of the Compositae show the highest frequency of occurrence as they represent an average value of 19% of the total count or nearly half of the pollen from non-arboreal genera. Betula and Quercus each represent 10% of the total. Quercus pollen occurs in the same relative frequency as in the previous zone, but there is a considerable increase in Betula pollen in the bog in Zone IV. Fagus and Gramineae each comprise 6% of the total in this zone. This represents an important decrease for Fagus to two-thirds of its previous average occurrence, but it also represents a substantial increase in Gramineae pollen. Acer pollen also decreases substantially to an average value of 5%.

Pollen of Pinus, Tsuga, and Picea decrease substantially to average values of 3% or less. Conversely, pollen of Populus, Ostrya, and Ulmus, show little fluctuation and continue each to represent about 2-3% of the total.

Minor non-arboreal taxa include Salix, 3%, Corylus, 2%, and members of the Polygonaceae, 2%. Spores of Sphagnum increase considerably in this zone to about 10% of the count.

INTERPRETATION OF REGION'S POST-GLACIAL VEGETATION HISTORY.

As the glaciers retreated northward at the close of the Pleistocene, vegetation began to become re-established in communities along the glacial front. The components of these communities as well as their pattern of succession can be determined through the analysis of pollen and spores deposited and preserved in bog and lake sediments during post-glacial times. When radiocarbon dates are known and associated with pollen spectra, the time of occurrence as well as the length of duration of these communities may often be determined. Although radiocarbon dates were not obtained from the bogs cored in this study, the relative time of establishment and duration of forest communities can be extrapolated from the radiocarbon dated pollen spectra of nearby sites.

Zone I.

The region's earliest post-glacial vegetation is represented at the Sommers Lake bog in pollen Zone I. Consistantly high percentages of *Picea* pollen (50%) indicate that a northern boreal forest became established in northwestern lower Michigan as the glaciers and associated inundating waters of Lake Algonquin retreated from the region. A spruce-fir forest covering a broad region south of the glacial front extended nearly continuously across northeastern North America (Bernabo and Webb, 1977). By approximately 11,000 BP this forest had migrated northward to include the Upper Great Lakes region (Kelly and Farrand, 1967). During this time the climate would have been colder and wetter than that of the present day (Dorr and Eschman, 1971).

Since low percentages of pine, oak, and birch pollen are initially represented in the lower strata of this zone, it is believed that the spruce-fir forest must have initially been open and dominated by Picea glauca, white spruce, before becoming a closed stand of both Picea glauca and P. mariana, black spruce (Kapp, 1977). Unlike the bottom strata of a number of other Michigan localities (Kapp, et al, 1969; Miller and Benninghoff, 1969) and throughout the Great Lakes region (Bernabo and Webb, 1977), non-arboreal, mostly herb, pollen of tundra components is very poorly represented at the Sommers Lake bog. Since the lower strata of the Cheboygan Bryophyte bed (Miller and Benninghoff, 1969) has been dated between 13,300 and 12,500 BP, it may be that late glacial as well as early post-glacial vegetation of the region is not recorded at the Sommers Lake bog.

Zone II.

The spruce-fir forest continued to dominate the region landscape until approximately 9,500 BP (Bernabo and Webb, 1977). By this time, with a gradual warming trend, the boreal forest migrated northward and was gradually replaced by forests dominated by species of pine. Pinus rose to dominance in Zone II (37%). Again, as in Zone I, Zone II is represented only at the Sommers

Lake bog of the three bogs analyzed in this study.

As species of Picea declined, Pinus banksiana, jack pine and P. resinosa, red pine were the initial species to migrate westward to northwestern lower Michigan (Bernabo and Webb, 1977). Their establishment was followed by the arrival of Pinus strobus, white pine.

Since the frequency of occurrence of Pinus pollen in the bog sediments greatly exceeds its frequency of occurrence in the vegetation (Table 1), it has long been debated whether the high relative percentages of representation of Pinus pollen in this zone accurately reflected a dominance of this genus in the vegetation. Davis (1967) demonstrated that pine was actually an important component of the forest during this period by determining the absolute pollen frequencies of genera occurring in this zone.

Although the occurrence of Picea had diminished during this time, it continued to be a well-represented component of the vegetation. Also during this time, populations of hardwood genera of oak and birch became permanent components of the community.

Zone III.

Pine forests dominated the landscape of northwestern lower Michigan for approximately 2000 years until roughly 7500 to 7000 BP (Bernabo and Webb, 1977). Zone III, which begins at approximately this time, traces the initial establishment and continued development of the northern hardwood forest. This zone is further divided into three sub-zones: A, B, and C. The lowermost, Zone IIIA, is represented at the Sommers Lake and the Mission Point bogs.

Zone IIIA.

The appearance of Tsuga in the region indicates the lower boundary of Zone IIIA. Tsuga is believed to have entered the state from the east, having migrated across southern Ontario and the eastern Great Lakes. It appears to have arrived in central lower Michigan at approximately 7900 to 7500 BP (Kapp, 1977). From this central locality it migrated in both northward and southward directions so that by approximately 7200 BP (Kapp, et al, 1969) it had established itself in the Beaver Island group. Therefore, it most likely had arrived in northwestern lower Michigan by roughly 7400 BP and rapidly increased in abundance. This is reflected in the pollen record despite its over-representation in the pollen flora. Tsuga declined in abundance as rapidly as it had increased. This decline most likely reflects not only a deterioration of optimum climatic conditions for Tsuga, but also increased competition for sites with the influx of hardwood species.

Acer became established in the region just prior to the migration of Tsuga. Unlike Tsuga, however, once becoming established, Acer increased in its abundance gradually and steadily, never deviating significantly in its population. This phenomena is reflected in the pollen record from Sommers Lake. The prevalence of maple in the flora may not be readily apparent from its pollen profile, however, because it is inferred that Acer is underrepresented in the pollen spectra.

Other hardwood genera migrated into and became established in the region during Zone IIIA. Following the arrival of Tsuga, Ostrya entered the region and became established in the vegetation. Just prior to the close of Zone IIIA Fagus migrated into the region and began to increase in its abundance. Like Tsuga, Fagus is believed to have entered Michigan from the east as it migrated through southern Ontario and the lower Great Lakes. It has been suggested, however, that Fagus may have migrated into the upper and lower peninsulas of Michigan independently from the vicinities of the northern and southern extremities of Lake Huron. In the north, near Sault Ste. Marie, Ontario, Fagus may have been present as early as 6700 BP (Kapp, 1977).

Radiocarbon dates from central lower Michigan show that Fagus had established itself in that area by 7,900 to 7,100 BP (Kapp, 1977). Like Tsuga, Fagus migrated to the north and south from this area. By approximately 6000 BP (Kapp, et al, 1969) Fagus had established itself as a component in the vegetation of the Beaver Islands. Consequently, having migrated from either northern or southern Michigan, Fagus most likely was present in northwestern lower Michigan by approximately 6300 BP.

These trends can readily be seen in the pollen diagram from Sommers Lake bog. Little distortion occurs in the pollen profile of Fagus since it closely reflects its frequency of occurrence in the vegetation.

Zone IIIB.

Zone IIIB, which is represented at the Sommers Lake, Lyman Lake and Mission Point bogs begins at approximately 6000 BP, shortly after the arrival of _Fagus_ to the region. While the forests present during this time continue to be dominated by a mixture of hard and softwood species, the occurrence of _Tsuga_ is significantly and consistantly lower in its representation than its occurrences in previous and subsequent phases of Zone III.

The region's record of forest history encompassed within Zone IIIB is believed to reflect a time during which climatic conditions were warmer and drier than that of the present. These xerothermic conditions which began to develop at approximately 6000 BP reached their optimum in the Great Lakes region at approximately 4000 BP (Dorr and Eschman, 1971; Kapp and Kneller, 1962). Then, according to Hushen and Benninghoff (Miller, 1973) by roughly 3200 BP or 2500 BP (Dorr and Eschman, 1971) the climate had once again altered to approximate conditions of the present day.

A warmer and drier climate during this period is evidenced by the development and establishment of plant communities which favor these conditions as well as the absence of others intolerant of it. A forest component intolerant of prolonged warm and dry conditions is _Tsuga_. Not only does _Tsuga_ prefer an environment which is wet and cool but it also requires these conditions to sustain its shallow root system. Studies have shown that _Tsuga_ root tips die rapidly during periods of drought (Miller, 1973).

This gradually results in the deterioration of the root system and the eventual attack of the organism by parasites.

As previously noted, Tsuga which was a dominant component of the landscape in this region during Zone IIIA is present in extremely low frequencies during Zone IIIB. Tsuga pollen, which exceeds the frequency of the whole plant in nature by roughly three-fold (Table 1), is present in an average value of 1% of the pollen in the Sommers Lake bog and 6% in the Lyman Lake and Mission Point bogs during this period. Tsuga appears to have been virtually eliminated as a component of the region's forests during this time.

According to Bernabo and Webb (1977) prairie vegetation migrated to its maximum eastward post-glacial advance as compared with its present position during the period from 9,000 to 7,000 BP. From roughly 7,000 to 2,000 BP, however, it again slowly retreated to its present day position. Although a warmer and drier climate particularly affected the vegetation of the region south and west of the Great Lakes with an influx of prairie species, its influence was, nonetheless, recorded in the vegetational history of Michigan and the Great Lakes area. Wilson and Webster (1942) postulated that in all likelihood during this period the oak-hickory forests extended approximately 90 miles (144 km) north of their current limit in Wisconsin. While the present study notes no increases in occurrence of Quercus in northwestern lower Michigan during this period, increases in the frequencies of occurrence of Carya are observed at the Sommers Lake and Lyman Lake localities. Meanwhile, in southern portions of the state, Zumberge and Potzger (1956) noted an increase in prairie components in southwestern Michigan while Kapp and Kneller (1962) have documented an increase in the abundance of Carya, Juglans, and Platanus in southeastern Michigan.

Further, according to Bernabo and Webb (1977) an additional effect of the climate of this period on the vegetation of the Great Lakes region was the delayed dominance of a northern hardwood forest. Whereas this forest type became established in New England immediately following the arrival of its primary components, namely Betula, Acer, Fagus, and Tsuga, it did not achieve its potential prevalence in the Great Lakes region for 2,000 to 5,000 years after its initial arrival. Specifically in northwestern lower Michigan, the northern hardwood forest became firmly established at approximately 3,000 BP. Bernabo and Webb (1977) attribute the delayed establishment of the northern hardwood forest in the Great Lakes region to the influence of drier climatic conditions associated with the migrating border of the prairie tension zone. Until it had retreated sufficiently westward at roughly 3,000 BP to approximate its present day position, components of the northern hardwood forest had to compete for sites with previously established prairie taxa. The final establishment of a northern hardwood forest in this region is indicative of a climatic shift to wetter conditions.

Differences in the extensiveness of the northern hardwood forest during this time are noted in northwestern lower Michigan. While the pollen of the dominant components of the northern hardwood forest together comprise an average value of only 21% at the

Sommers Lake bog, they comprise averages of 40% and 42% respectively at the Lyman Lake and Mission Point bogs. Further examination of pollen histograms produced from the sites indicates that the region surrounding the Sommers Lake bog, the most northerly and most interior locality sampled, supported a greater number of conifers than did the areas to the south. In all instances, however, the percentages of representation of northern hardwood components represent approximately 9% less than their respective average values in Zone IIIC.

A shift to drier conditions during this period may be observed locally at the Sommers Lake bog. The influx of herbs and shrubs such as Populus, Salix, and members of the Gramineae, Lycopodiaceae, and Polypodiaceae may be indicative of the colonization of newly exposed areas surrounding a dessicated lake. Then, as the climate becomes colder and wetter, these taxa decrease in abundance.

Zone IIIC.

This zone is represented in the stratigraphy of all three bog localities of this study. A gap in the record, however, occurs within this subdivision at the Sommers Lake bog. As the previous subdivisions of Zone III, C is dominated by a mixed assemblage of coniferous and deciduous genera. Its lower boundary is identified by the re-establishment of Tsuga in the region which persists abundantly throughout this zone.

Zone IIIC began approximately 3000 BP. It is characterized by the development of the northern hardwood forest which may have been long delayed but which has dominated the region's landscape until its destruction approximately 100 BP. It is believed that cooling of the climate and an increase in moisture quite similar to that of the present made possible the return of Tsuga and the establishment of the northern hardwood forest.

This forest type was prevalent throughout the region. Some similarities and differences are indicated in its extent and composition based on records obtained from the bogs studied. At the Sommers Lake bog the pollen of the dominant components of the northern hardwood forest together comprise only 30% of the total. Arboreal pollen which are characteristic of other forest types account for 43%. In contrast, the pollen of northern hardwood genera comprise 48% and 49% of the totals of the Lyman Lake and Mission Point bogs, respectively. At these sites pollen of other arboreal taxa are reduced to approximately 22%. Clearly, the pollen stratigraphy produced from the Sommers Lake area shows the influence of more than one forest type.

In order to gain a better understanding of the forest composition of the region during this period the average relative percent of representation of the pollen of each genus has been converted to its corresponding relative average percent of representation in the forest. This conversion has been made for all dominant arboreal components through the employment of the data incorporated in Table 1. The results of this conversion are presented in Table 2.

The area of the study region encompassing the Sommers Lake bog chiefly supported a northern hardwood forest dominated primarily

Table 2. Relative percent of dominant arboreal genera in the pollen record and forest history composition of Zone IIIc.

GENERA	SOMMERS LAKE BOG Pollen Relative % Occurrence	SOMMERS LAKE BOG Vegetation Relative % Occurrence	LYMAN LAKE BOG Pollen Relative % Occurrence	LYMAN LAKE BOG Vegetation Relative % Occurrence	MISSION POINT BOG Pollen Relative % Occurrence	MISSION POINT BOG Vegetation Relative % Occurrence
Pinus	16	3	9	2	7	1
Quercus	10	10	7	7	10	10
Fagus	10	10	11	11	20	20
Picea	8	8	5	5	7	7
Tsuga	8	3	17	6	12	4
Larix	7	7	-	-	-	-
Acer	6	30	13	65	12	60
Betula	6	1-2	7	1-2	5	1
Ulmus	-	-	5	5	-	-

by species of Acer and secondarily by _Fagus_. Other components of this forest such as _Tsuga_, _Pinus_, and _Betula_ also occurred in the association but to a much lesser extent. Another forest type, dominated by species of _Quercus_ and _Pinus_ was common throughout this portion of northwestern lower Michigan. Either of these forest communities would have found the area's well-drained uplands to be suitable for habitation.

The relatively high percent of representation of _Picea_ may be indicative of sizable portions of the area having supported swamp and/or bog vegetation. This is plausible since this most northern portion of the study region is characterized by many extensive areas whcch are poorly drained. The presence of _Larix_, however, while comparable to _Picea_ in representation, may only be interpreted as indicative of the bog's local environment at this time.

The portion of the study region located in proximity to the Lyman Lake bog also primarily supported a northern hardwood forest. Species of _Acer_ clearly dominated this forest while less abundant components included _Fagus_, _Tsuga_, _Ulmus_, _Pinus_, and _Betula_. During this time _Acer_, _Tsuga_, and _Ulmus_ probably occurred at least twice as frequently within the vicinity of Lyman Lake as were present near the Sommers Lake bog. Clearly, a major portion of this vicinity's landscape was covered by a northern hardwood forest.

Forests dominated by species of _Quercus_ and _Pinus_ also were present, but were not nearly as prevalent in this area as they were in the vicinities of the Sommers Lake and Mission Point bogs.

The area surrounding the Mission Point bog also chiefly supported a northern mixed hardwood-conifer forest. As in the vicinity of Lyman Lake, this forest was outstandingly dominated by species of _Acer_, although _Fagus_ also occurred to a considerable extent as well. Its presence here was probably twice its occurrences in the Sommers Lake and Lyman Lake areas. Less frequently occurring components of this forest also included _Tsuga_, _Ulmus_, _Pinus_, and _Betula_. _Pinus_ and _Betula_ were represented in the forest at approximately the same frequencies as they occurred within the Sommers Lake and Lyman Lake areas. While _Tsuga_'s representation in the landscape, however, was similar to its occurrence in the Sommers Lake vicinity, _Ulmus_ occurred at approximately the same frequency as it did within the Lyman Lake area. Despite regional differences in species composition, however, the area predominantly supported a northern hardwood forest.

Forest communities dominated by species of _Quercus_ and _Pinus_ as well as those dominated by _Picea_ also occurred within this portion of the study region. Given the converted percentages of representation of _Quercus_ and _Picea_ in the area's landscape, it could be interpreted that their prevalence was comparable to that of the Sommers Lake vicinity. The frequency of occurrence of _Picea_, may, however, represent local as well as regional forest composition.

A comparison among the forest histories produced by the three locations of this study shows that there are variations in the composition and extensiveness of the northern hardwood forest in northwestern lower Michigan. At the Sommers Lake bog there is considerable influence of genera not intrinsic to the northern hardwood forest. This is most likely due to its northernmost, interior location in close proximity to extensive low and poorly drained areas. Conversely, the Lyman Lake and Mission Point bogs record an almost ubiquitous distribution of the northern hardwood forest. At both sites the most dominant genus, *Acer*, is significantly more abundant than its occurrence in the Sommers Lake vicinity. Further, in the area of the southernmost site, Mission Point, *Fagus*, the second most important genus, is twice as common as it is in the Sommers and Lyman Lake areas. The increased representation of the northern hardwood forest at the Lyman Lake and Mission Point bogs is most likely due to the bogs' more southerly locations within predominatly well drained rolling uplands.

Zone IV.

Zone IV is represented in the stratigraphy of the Lyman Lake and Mission Point bogs. This zone is characterized by a radical influx on pollen of non-arboreal species and represents the youngest unit recognized in this study.

The lowermost boundary of Zone IV dates to approximately 100 BP. Since this time vast tracts of land in northwestern lower Michigan were cleared by agricultural and/or lumbering activities. The clearing of the land resulted in an increased abundance and diversity of non-arboreal taxa characteristic of fields and meadows.

During Zone IV, pollen of non-arboreal taxa represent 58% of the total at both the Lyman Lake and Mission Point bogs. Members of the Compositae represent the highest average freqeuncy of occurrence, 26% at Lyman Lake and 19% at Mission Point. Members of the Graminaae account for 6% of the total at both localities.

Pollen of arboreal taxa represents 42% of the total at each bog site. Of the arboreal genera, Betula occurs at the highest average frequency of representation accounting for approximately 11% of the total at each site. Arboreal genera which represented lesser, but significant percentages of the vegetation at Lyman Lake during this period included Pinus, Picea, Quercus, Fagus, Acer, and Tsuga. At the Mission Point bog, Quercus, Fagus, and Acer are locally important.

Although Zone IV is not represented in the stratigraphy of the Sommers Lake bog, it is found at the Inverness Mud Lake Bog, located in close proximity to Sommers Lake in nearby Cheboygan County (Benninghoff, 1960). A pollen profile was obtained from each phytographic community of this bog, including one dominated by Thuja which was similar in composition to the area cored at the Sommers Lake locality. As the upper strata of the Lyman Lake and Mission Point bogs, the most recent zone of the Inverness Mus Lake bog was also dominated by the pollen of non-arboreal taxa. Pollen of Alnus and members of the Compositae each comprised 23% of the total while that of Betula, Thuja, and members of the Gramineae each represented approximately 15%.

While the major portion of the landscape of northwestern lower Michigan has supported field vegetation during the past one hundred years, a substantial area has remained forested. The Zone IV forests, however, differ somewhat in composition as compared to those dominating the landscape during Zone IIIC. While forest composition during Zone IIIC is indicative of the prevalence of a climax forest of northern hardwood and conifer species throughout northwestern lower Michigan, the composition of the forests of the region during Zone IV suggests sucessional forest communities as the result of extensive regional disturbance.

SUMMARY AND CONCLUSIONS.

The history of the vegetation of portions of northwestern lower Michigan since the close of the Pleistocene has been traced through the analysis of the pollen preserved in the sediments of three bogs.

As the glaciers retreated from northwestern lower Michigan approximately 11,000 BP, the region supported forests dominated primarily by spruce and fir. As the climate became more equitable at about 9,500 BP, however, the boreal forest was gradually replaced with forests dominated by species of pine (Pinus strobus, white pine, P. resinosa, red pine, and P. bankisana, jack pine).

The pine forest declined in dominance initially with the migration of hemlock into the region at approximately 7,400 BP and secondarily with the arrival and establishment of mixed hardwood species at roughly 6300 BP.

The influence of a xerothermic climate throughout the Great Lakes region from approximately 6000 BP to 3000 BP delayed the extensive establishment of a northern hardwood forest dominated by species of maple, beech, hemlock and birch. This forest community, which prevailed throughout the region, became established at roughly 3000 BP as climatic conditions approximated those of the present. While the composition and abundance of components of this forest were generally similar throughout northwestern lower Michigan, differences have also been noted.

As Euro-American settlement of the region was initiated approximately 100 BP, extensive tracts of land were cleared and the vegetation of the region was drastically altered. Areas which had supported a climax forest dominated by *Acer*, *Fagus*, *Tsuga*, and *Betula* were shifted to dominance by seral communities of colonizing taxa.

The cliseral progression of the establishment, development, and replacement of vegetational communities both natural and artificial of northwestern lower Michigan has been traced for nearly 11,000 years.

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