PALYNOLOGICAL STUDIES OF HOLOCENE DEPOSITS IN PARRY SOUND

PALYNOLOGICAL STUDIES OF POST-GLACIAL DEPOSITS

WITH DIFFERENT WATER RELATIONS

AND MUSKEG ENVIRONMENTS

by

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SCOPE AND CONTENTS:

This investigation is intended to explore and trace the trend in the development of muskeg (organic terrain), of which water is an essential factor. The work proceeded as follows: field work and laboratory pollen macerations, identification of pollen and spores and pollen counting; and finally the analysis of the results obtained.

The results do not favour the establishment of a strong relationship between water in muskeg and vegetation *in situ*. However, this needs further test. On the other hand, there are relationships found between pollen species, and also interesting natural grouping was observed to exist in the bogs studied, due to unknown factors.

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INTRODUCTION

Organic terrain is a term that Radforth introduced in 1952, which is used to designate muskeg, and is described as "the physical condition of which is governed by the structure of the peat it contains, and its related mineral sub-layer, considered in relation to topographic features and the surface vegetation with which the peat co-exists" (Radforth, 1953). There is confined and unconfined organic terrain or muskeg, depending upon the presence or absence of surrounding geomorphic features at relatively higher elevation. The former is also the equivalent of peat bog, which is a term used very often in the present work.

The occurrence of organic terrain is wide-spread in many countries, particularly in Canada and U. S. S. R. Leahey in 1951 estimated that the extent of such terrain in Canada is roughly 435,000 sq. miles or 11.8 per cent of the entire country. This is a rather conservative estimate, and lower than Radforth's estimate of 500,000 sq. miles (1957), which is also considered to be low. In Canada, most of this terrain occurs in the far northern part and becomes a hindrance when transportation and development are attempted.

It is known that water is an essential component in organic terrain formation. The source of water may be different, but all organic terrains originally arise when there is stagnated water present (Radforth, 1962, Ratcliffe, 1964). In the stagnated water, vegetation grows and is finally stratified and fossilized together with pollen and spores (from both nearby and afar) into peat, because of the suitable anaerobic environment the stagnated water supplies (Terasmae, 1958). The further development of the organic terrain is easily continued, especially if Sphagnum mosses have become established (Vaino Auer, 1928, Radforth, 1962). This is because Sphagnum spreads fast and can adsorb many times its weight in water: the water exists in a fashion simulating that in a sponge. The Sphagnum grows upon its own fossil remains and brings the water table with it. When the deposit becomes several feet deep, the main water table may separate and a perched water table exists at the top. When the deposit is very deep, there may be little free water at the base of the peat, only at the top (Radforth, 1962).

Vaino Auer (1927) in his investigation on peat bogs present in south-eastern Canada, suggested that the formation of peat bogs usually occurs in three ways. They are lakes filling up into peat bog, flooded lands turning into peat bog, or dry land turning into bog. However, the last formation must be accompanied by the paludification process. That is to say, dry land must be first turned into wet land by one means or another in order to become a suitable place for peat formation. He also suggested the first two developments are examples for progressive development, and the third one an example for regressive development (1928).

Often the water is seen in the muskeg with a certain combination of vegetation communities, and one wonders if vegetation appears in muskeg by a process of either progressive development or regressive development as many scientists believed, or whether it follows a biotic trend and thus represents specification in ecosystem. Ecosystem includes both the living entities and their associated non-living factors. All factors interact to constitute a single unit. Within the system there is interassociation of materials and energy (Woodbury, 1954, Knight, 1965). In order to ascertain this, among the purposes of the present investigation is the finding of pollen composition from the surface to 18 inches under the surface, and the discovery of simultaneous occurrence of different genera or families of plants. Emphasis is placed on finding whether there is a relationship between water concentration in the muskeg and pollen composition in the top 5 inches (approximately) of the peat. If there is a relationship one may reasonably hypothesize that it will reveal itself in comparisons of water concentration and pollen distribution with the culminating levels. It must be assumed that shift in pollen composition is a function of change in water content or behaviour. One can then interpret how pollen distribution varied when past vegetation was deposited to form the peat.

To use fossil pollen to explore for ecological relationship and subsequently interpret distribution of vegetation is more convenient and reasonable than to use macro-remains, for example seeds, fruits, leaves, wood or charcoals. It was well explained by Terasmae (1958) that microfossils are generally produced in great numbers, are spread over wide areas by wind, and are much more uniformly distributed through the layers of sediments than macrofossils. Also, one can demonstrate biological relationships with pollen by using very small samples. The samples used in the present work are from recent post-glacial deposition. This can be determined by the abundance of <u>Picea</u>, <u>Pinus</u> and non-arboreal pollen (NAP)(Godwin, 1956, Flint, 1966), and it is known that pollen analysis gives the most comprehensive record of the more recent past vegetation. Supporting this claim, Nair (1965) mentioned "It is in Quaternary Geology that pollen is more depended upon, evidently due to the close resemblance of the plants of that period with those of the present, thus facilitating easy recognition of the pollen fossils and interpretation of depositional environment".

There are, on the other hand, drawbacks in pollen analysis. According to Martti Salmi (1962) and earlier authors, plants produce pollen in extremely varying quantity. For example, anemophilous plants produce many times more than the amount from entomophilous ones. Also pollen grains are not as evenly distributed as they are disseminated. The distribution of anemophilous grains is mainly affected by specific gravity of the grain; the lighter ones are scattered farther. The size of the grain and the size of the plant is important; pollen from smaller plants stands a lesser chance of wide distribution than that from larger plants. It is known that pollen of plants from species of Picea, Pinus, Corylus and Quercus are generally more abundant about 400 meters away from the plants, while Betula pollen decreases rapidly with distance. Grass pollen has marked local influence, because of the lightness of the grain, and usually small output. Also, some pollen grains are preserved better than others. Sometimes, depending upon method of application and utilization of results, interpretation of pollen frequency diagrams requires corrective consideration.

Toive Aartolahti (1965) suggested that besides using pollen as indicators of water conditions, one can use Sphagnum species, tissues of plants, and fungus spores as indicators. In 1960, Rauno Ruuhijärvi in his work on northern Finland bogs, listed plants which will grow on peat ridges, and hence have a dry habitat as follows:

> *Picea abies*, *Pinus silvestris*, *Calluna vulgaris*, *Chamaedaphne calyculata*, *Empetrum hermaphroditum*, *E. nigrum*, *Ledum palustre*, *Vaccinium microcarpum*, *V. myrtillus*, *V. uliginosum*, *V. Vitis-Idaea*, *Carex globularis*, *Eriophorum vaginatum*, *Rubus chamaemorus*, *Sphagnum fuscum*, *S. magellanicum*, *S. nemoreum*, *S. parvifolium*, *S. robustum*, *Aulacomnium palustre*, *Dicranum Bergeri*, *Hylocomium splendens*, *Pleurozium Schreberi*, *Polytrichum commune*, *P. strictum*, *Mylia anomala*, *Mehrere flechten*.

Plants which grow on a flat surface, with a medium water content are as follows:

> *Andromeda polifolia*, *Vaccinium Oxycoccos*, *Molinia coerulea*, *Carex lasiocarpa*, *C. pauciflora*, *C. dioeca*, *Eriophorum alpinum*, *Trichophorum caespitosum*, *Sphagnum balticum*, *S. compactum*, *S. magellanicum*, *S. papillosum*, *S. parvifolium*, *S. rubellum*, *S. warnstorfianum*, *Romentypnum nitens*.

Plants which grow in depressions between ridges, and hence with moist habitat, can be divided into two groups, one of which is rich with mosses including:

> *Vaccinium Oxycoccos*, *Carex lasiocarpa*, *C. chorodorrhiza*, *C. limosa*, *C. magellanics*, *C. rostrata*, *C. rotundata*, *Eriophorum angustifolium*, *E. russeolum*, *Rhynchospora alba*, *Menyanthes trifoliata*, *Scheuchzeria palustris*, *Sphagnum apiculatum*, *S. balticum*, *S. cuspidatum*, *S. Dusenii*,

S. Jensenii, *S. Lindbergii*, *S. riparium*, *Calliergon stramineum*, *Drepanocladum exannulatus*, *D. fluitans*, *D. procerus*, *Scorpidium scorpioides*.

The second group which is poor in mosses includes:

Carex chordorrhiza, *C. limosa*, *C. livida*, *Eriophorum angustifolium*, *Juncus stygius*, *Rhynchospora alba*, *Drosera anglica*, *Equisetum fluviatile*, *Menyanthes trifoliata*, *Sphagnum platyphyllum*, *Scorpidium scorpioides*.

When *Sphagnum* sp. is used as indicator, 100 *Sphagnum* leaf fragments are counted, and the ratio of more moist ones to the dryer ones is calculated. This ratio can show the water condition in which the mosses grow. In practice, it was realized that the identification of *Sphagnum* sp. is very difficult because of the close resemblance of leaf structure between species. When fungus is used as an indicator, fungus spores are counted along with 100 arboreal pollen (AP) grains. The abundance of fungus is usually an indication of a wet condition.

When the problem of past climate fluctuation is studied in a certain big area, over-representation of local pollen is usually a problem and one should try to avoid it. In other words one would expect that what the pollen diagram represents is not only those pollen grains produced by plants growing *in situ* where the sample was taken, but also pollen grains from the larger area as a whole. Therefore, for interpretive purposes, non-arboreal pollen is not depended on so much as arboreal pollen, because NAP usually has short transport distance, and likely gives an indication of conditions in the vicinity of the sample location rather than of a wider region (Durno, 1956). Generally speaking, a peat bog is not a good site to study the climate fluctuation problem, because local over-representation is very likely dangerously prevalent due to the fact that in peat, the pollen producer is part of the parent formation (Iversen and Faegri, 1950). For a part of the work at hand, when water problem is concerned, the assumption is made that the water condition in a given bog is not appropriately expressed by vegetation that is a long way from the bog, that is by AP, a misleading proportion of which probably comes from afar. Therefore, non-arboreal pollen analysis is appropriately emphasized as being more reliable.

DESCRIPTION OF THE STUDY AREAS - FIVE PEAT BOGS IN PARRY SOUND DISTRICT

All samples were taken from five sites in different areas north of the town of Parry Sound, Ontario. Parry Sound is adjacent to Georgian Bay, at latitude 45°15' N and longitude 80°0' W (Fig. 1). The district named after the town lies wholly within the granite rocks of the Precambrian shield. Rock ridges enclosing small lakes are therefore characteristic of the entire area (District Report No. 31 of the Ontario Soil Survey, 1962). The most important forest trees in this area are sugar maple (*Acer saccharum*), beech (*Fagus grandifolia*), basswood (*Tilia americana*), yellow birch (*Betula lutea*), hemlock (*Tsuga canadensis*), white pine (*Pinus strobus*), red maple (*Acer rubrum*), white ash (*Fraxinus americana*), white spruce (*Picea glauca*), jack pine (*Pinus banksiana*), aspen (*Populus tremuloides*), red oak (*Quercus rubra*), white birch (*Betula papyrifera*), black spruce (*Picea mariana*), black ash (*Fraxinus nigra*), eastern cedar (*Thuja occidentalis*), and balsam fir (*Abies balsamea*) (Roe, 1959).

There are several hundred peat bogs in the district of Parry Sound, some of which have been studied by Radforth and his colleagues. The bogs that have been studied are mainly designated by number, for example, Area 1, 2, 3, according to the sequence of study. There are also sub numbers, for example Area 10A, Area 10G, just to designate one of the several subordinate bogs that are near or connect to a larger one.

Fig. 1 Outline map showing the location of study area - Parry Sound, Ontario.

A few of the bogs are designated according to local or convenient expression, for example Thousand Acre Bog, and the others are named according to their surroundings, for example Woods Area Bog.

The five sites sampled were Thousand Acre Bog, Area 7, Area 10A, Area 10G and Woods Area Bog. Figure 2 shows the locations of these five peat bogs, their vegetal covers and water level. Vegetal covers are expressed as combination of vegetal coverage classes EI and FI, which are based on the Radforth classification system (Radforth, 1952, 1953).

The classification system was established after the investigation on the muskeg land of a coastal area east of Churchill, where the following plants are predominant. Those plants are classified into A, B, C to I vegetal coverage classes according to their height and texture.

Larix laricina (Du Roi) Koch., Picea glauca (Moench.) Voss., Picea mariana (Mill.) B. S. P., Betula glandulosa Michx., Salix spp. (The above plants are representatives of coverage classes either A or B or D, depending on the size of the plant: A-plants 15 ft. or over, B-plants 5 to 15 ft., D-plants 2 to 5 ft.) Andromeda polifolia L., Arctostaphylos rubra (Fern.) Rhed. and Wils., Arctostaphylos Uva-ursi (L.) Spreng., Dryas integrifolia M. Vahl., Empetrum nigrum L., Kalmia polifolia Wang., Ledum decumbens (Ait.) Lodd., Ledum groenlandicum Oeder, Rhododendron lapponicum (L.) Wahlenb., Rubus arcticus L., Rubus chamaemorus L., Vaccinium uliginosum L., Vaccinium vitis-Idaea L. (The above plants are mainly representatives of coverage class E.) Calamagrostis canadensis (Michx.) Beauv. (This plant belongs to coverage class C, which is non-woody, 2-5 ft. tall.) Carex spp., Eriophorum angustifolium Roth., Eriophorum scheuchzeri Hoppe, sensu lato, Juncus albescens (Lge.) Fern. (Above

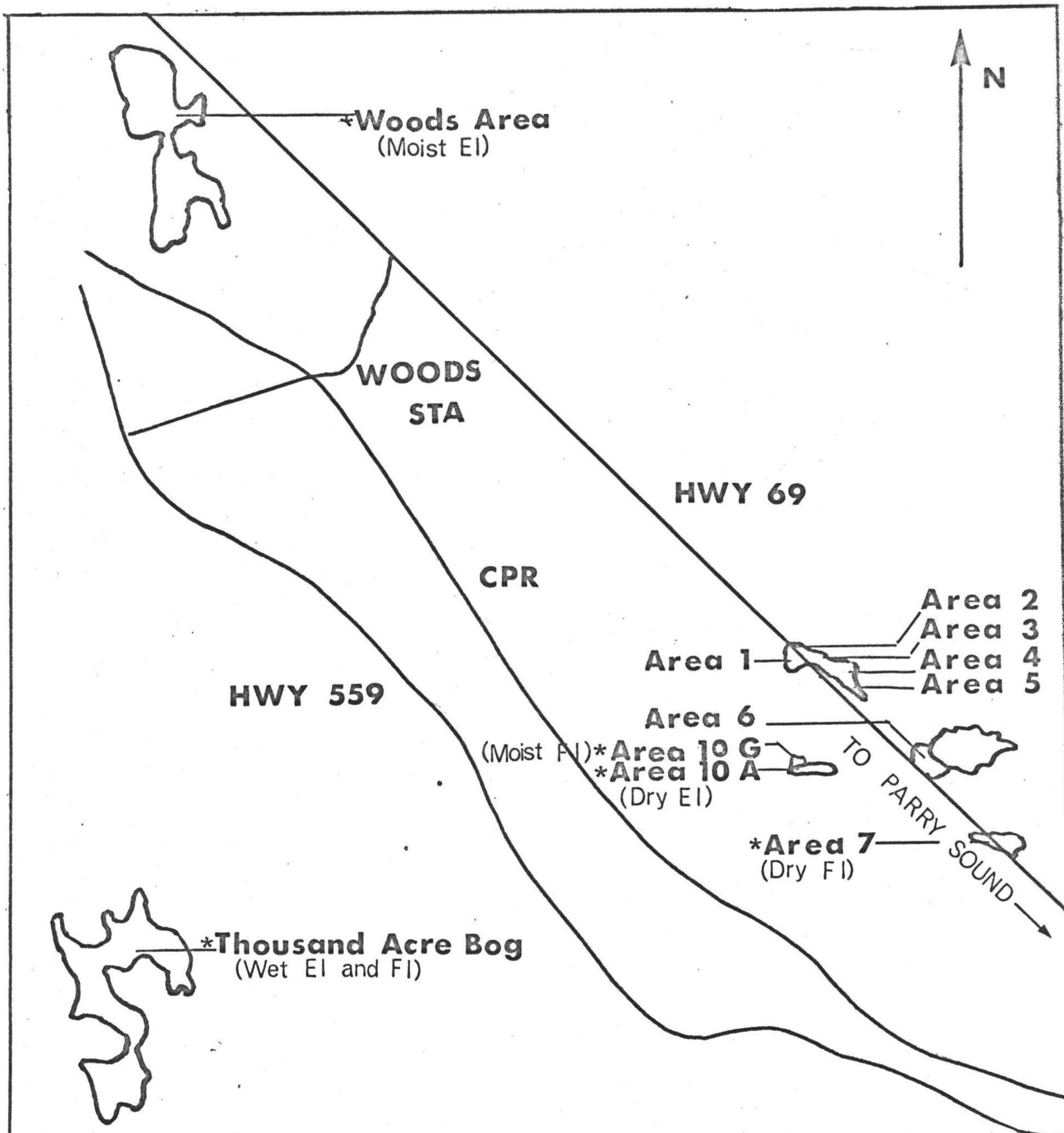


Fig. 2 Outline map showing the location of the peat bogs near Parry Sound, Ontario.

plants are mainly representatives of coverage class F.) <u>Epilobium</u> spp. e.g., <u>E</u>. <u>angustifolium</u> L., <u>Pedicularis</u> spp. e.g., <u>P</u>. <u>labradorica</u> L., <u>Petasites</u> <u>palmata</u> (Ait.) Gray, <u>Petasites</u> <u>sagittata</u> Pursh., <u>Senecio</u> spp. e.g., <u>S</u>. <u>palustris</u> (L.) Hook. (The above plants are representatives of coverage G, which are non-woody, 0 to 2 ft.) Hypnaceae spp., Sphagnaceae spp. (These two families are representatives of coverage class I.) <u>Cladonia</u> spp. e.g., <u>C</u>. <u>coccifera</u> (L.) Willd., <u>C</u>. <u>fimbriata</u> (L.) Fr., <u>C</u>. <u>gradilis</u> (L.) Willd., and <u>C</u>. <u>rangiferina</u> (L.) Web. (The above plants are representatives of coverage class H, which are non-woody, 0 to 4 inches tall.)

The vegetal coverage classification system can be well applied to the vegetal cover in Parry Sound bogs. However, plants that exist in these two areas (Churchill and Parry Sound) are a little different. The plants listed below are those not likely present in Parry Sound bogs. They are: <u>Arctostaphylos</u> <u>rubra</u> (Fern.), <u>Empetrum</u> <u>nigrum</u> L., <u>Ledum</u> <u>decumbens</u> (Ait.) Lodd., <u>Rhododendron</u> <u>lapponicum</u> (L.) Whlenb., <u>Rubus</u> <u>arcticus</u> L., <u>Rubus</u> <u>chamaemorus</u> L., <u>Eriophorum</u> <u>scheuchzeri</u> Hoppe, <u>sensu</u> <u>late</u>, <u>Epilobium</u> spp. e.g., <u>E</u>. <u>angustifolium</u> L., Pedicularis spp. e.g., <u>P</u>. labra-<u>dorica</u> L., <u>Petasites</u> <u>palmata</u> (Ait.) Gray, <u>Petasites</u> <u>sagittata</u> Pursh., Senecio spp. e.g., <u>S</u>. <u>palustris</u> Hook., Hypnaceae spp., <u>Cladonia</u> spp. e.g., <u>C</u>. <u>coccifera</u> (L.) Willd., <u>C</u>. <u>fimbriata</u> (L.) Fr., <u>C</u>. <u>gradilis</u> (L.) Willd., and <u>C</u>. <u>rangiferina</u> (L.) Web.

On the other hand, there are plants that grow in Parry Sound District bogs which may not be present in the Churchill area. For example, <u>Chamaedaphne</u> <u>calyculata</u> (L.) Moench, <u>Sarracenia</u> <u>purpurea</u> L., <u>Typha</u>

latifolia L., Artemisia spp., Ambrosia spp., Ilex spp., Chenopodium spp. etc.

In Parry Sound area bogs, both EI and FI covers are abundant, and EI means woody vegetation up to 2 feet high with non-woody vegetation up to 4 inches. For example, Chamaedaphne calyculata (L.) Moench together with Sphagnum spp. FI means non-woody vegetation up to 2 feet high together with non-woody vegetation up to 4 inches. For example, Carex spp. together with Sphagnum spp.

The water regime in these five peat bogs investigated is expressed qualitatively as high, medium and low water regime. When the bog has much free water on the surface (about 2 to 4 ft. deep), the water regime can be classified as high. When the surface of a peat bog is moist, but the free water is less than about one foot deep, the water regime can be classified as medium. When the surface of the bog has hardly any free water, water regime can be classified as low.

Thousand Acre Bog is characterized by EI and FI covers, and has a high water regime, Area 7 has FI vegetal cover and low water regime, Area 10A is of EI cover and has a medium water regime, Area 10G has FI vegetal cover and medium water regime, and Woods Area is covered with EI and has a low water regime. These five peat bogs were selected because they represent good examples for EI and FI vegetal covers; also they contain a varying degree of water conditions for studies.

FIELD ANALYSIS OF SAMPLES

A Hvorslev piston sampler which is 6 inches long was used for sampling in the field. The samples are taken usually 20 feet to 30 feet from the edge of the bog, and under typical EI or FI vegetal covers. The field samples obtained were cylindrical with a diameter of 2 inches, and the length of the cylinder was 18 inches (from surface of peat deposit to 18 inches under the surface, this is the depth the sampler usually can go except in 10G bog) which divides into three 6-inch long sections. All field samples were wrapped with plastic bags to prevent contamination of pollen and spores in the atmosphere, and also to prevent the loss of moisture of samples. Samples have to be handled with care to maintain their original shape. By so doing, the samples were well preserved even after storage for one year, and this facilitated the re-maceration and re-investigation of the field samples when necessary.

In Area 7, Area 10A, Area 10G and Woods Area bogs, only one type of vegetation, either EI or FI, is mainly presented and one cylindrical field sample was taken from each bog. In Thousand Acre Bog, both EI and FI are represented. Therefore, there was one field sample from the EI area, and one from the FI area.

The field sample from Thousand Acre FI area had a top part (0-6 inches) with much free water in evidence and was medium brown, which associates with only moderate humification, and there were plant bodies interwoven distinctly into it. Applying the von Post degree of humification scale (Scottish Peat Surveys 1965), the degree of humification from the surface to a depth of 6 inches transformed steadily from H2 to H3 then to H4. One maceration was made from this part (maceration No. 1), and material was taken at about 3 inches under the surface. The depth interval 6-12 inches yielded a dark-brown sample, with less water than the first, and with a degree of humification H4. Two macerations were made from this part (maceration No. 2 and No. 3, from 8 and 10 inches under the surface respectively). The sample from 12-18 inches was dark and solid, and the degree of humification was H7 to H8. Two macerations (No. 4 and No. 5) were made from 14 and 16 inches under the surface level.

In the Thousand Acre EI area, the water content and color of samples from 0-18 inches were about the same as in the FI area. Degree of humification was as follows: 0-6 inches, H3 to H4; 6-12 inches, H4 to H5; 12-18 inches, upper part H5; lower part suddenly transforming into H7. Macerations No. 6, No. 7, No. 8, No. 9 and No. 10 were made from 3, 8, 10, 14, 16 inch depths under the surface respectively.

In Area 10A, the sample from 0-6 inches was dark brown, very moist. Degree of humification: H4 to H5. From 6-18 inches, sample turned to be black-colored, degree of humification: H8. Macerations No. 11, No. 12, No. 13, No. 14, No. 15 were made from 3, 8, 10, 14, 16 inches level under surface.

In Area 10G, samples were taken from surface to 16 inches under surface. All were black-colored solid samples consisting of very fine particles, and the top part was moist. Degree of humification was as follows: 0-2 inches, H4; 2-4 inches, H6; 4-9 inches, H7; 9-12 inches, H8; 12-16 inches, H9. Macerations No. 16, No. 17, No. 18, No. 19, No. 20, No. 21 were made from 2, 4, 8, 10, 14, 16 inches under the surface respectively.

In Woods Area, from the surface to a depth of 18 inches the sample was entirely dark-colored peat, but the top was more moist, and lower part had finer particles. Degree of humification: 0-1 inch, H3; 1-4 inches, H5; 4-6 inches, H6; 6-12 inches, H7; 12-18 inches, H7 to H8. Macerations No. 22, No. 23, No. 24, No. 25, No. 26 and No. 27 were made from 2, 4, 8, 10, 14, 16 inches level under surface.

In Area 7, from 0-6 inches, the sample was black with the degree of humification transforming steadily from H4 to H5 then to H6. From 6-12 inches, the sample was black and very solid, particles were very fine, and the degree of humification changed gradually from H8 to H9. From 12-18 inches, the sample started with grey peaty detritus ooze or organic clay, and then turned into light-grey sand. This part was very solid and heavy. Macerations No. 28, No. 29, No. 30, No. 31, No. 32, and No. 33 were made from 2, 4, 8, 10, 14, 16 inches level under surface. Peat profile is in Fig. 3, page 29.

MICROFOSSIL ANALYSIS

CHEMICAL TREATMENT

(1) KOH treatment

In the laboratory, with well-humified peat (according to von Post humification scale, H5 or above), the quantity of pollen in absolute terms is high. For chemical maceration, about 1 c.c. of the field sample was boiled in about 10 c.c. of 10% KOH solution in a test tube for approximately 3 minutes, until the mixtures became uniformly dark-brown. The mixture was then removed to a centrifuge tube, and centrifuged for 4 or 5 minutes (International Clinical Model, speed 1500-2000 RPM). The supernatent fluid was decanted, and to the sediment distilled water was added to remove the remaining KOH. Washing was repeated and then the sample was ready for staining and mounting.

With slightly humified peat (H4 or under) in which Sphagnum plants were separated and distinct, about 10 c.c. of the field sample were boiled in 10% KOH. The quantity of field sample should be increased somewhat when dealing with less humified peat, the quantity of KOH solution should be enough to cover the loose mass of field sample, and the boiling is usually done in a beaker. After 3 minutes, the mixture was sieved, and coarse materials discarded, and the liquid part then was centrifuged and processed exactly as for well-humified peat.

This KOH treatment gives satisfactory results for most field samples investigated, and is also simple and time-saving. The KOH solution relieves pollen and spores from the matrix that adheres to them, and also extracts some of the matrix, and gives more transparency to the pollen and spores. This makes the microscope examination easy to do. The KOH solution does little or no harm to the plant fragments. Therefore, when microfossil fragments are required, this treatment serves the purpose best. However, too much accumulation of plant fragments may cover the pollen and spores under them, and influence the result obtained. This is especially serious when the absolute quantity of pollen and spores is low (Wodehouse, 1935, Faegri and Iversen, 1950).

(2) Acetolysis treatment

With samples having a low absolute quantity of pollen and spores, for example, those from Thousand Acre Bog, both EI and FI areas, surface to 6 inches under surface, one may use the acetolysis treatment after the KOH maceration. This is an approach which breaks away and removes the gross organic matrix from the pollen and spores, and pollen and spore content is therefore concentrated. However, the size of pollen and spores increases somewhat as a result of this treatment, which is therefore not suitable for use whenever judgment of size is concerned. The acetolysis treatment used in this work was based on that adopted by Knut Faegri and Johs. Iversen (1950) as follows:

1. KOH treatment.
2. Dehydrate with glacial acetic acid. Centrifuge.
3. Treat with a fresh mixture of 9 parts anhydric acetic acid and one part H_2SO_4 conc. Heat gently in a water bath to the boiling point. Centrifuge.

4. Wash with glacial acetic acid. Centrifuge. (Direct transfer to water causes the cellulose acetate to precipitate again.)
5. Wash with water. Centrifuge.
6. Boil (15 seconds) with KOH to permit staining. Centrifuge.
7. Wash with water. Centrifuge.

(3) HF treatment

From area 7, the lower part of the cylindrical sample contained lots of minerals besides plant residues, and in order to eliminate these minerals after KOH treatment, the washed sediment was processed further as follows (based on that adopted by Norem, 1953, Funkhouser, 1959 and Brown, 1960):

1. In a copper or nickel container, boil the sample with 40% HF solution for 1 to 2 hours (depending upon the amount of mineral). The HF solution container should be kept about one-third full.
2. Wash the sample free of excess HF solution with diluted HCl solution (1 part of conc. HCl solution to 3 parts of water).
3. Wash the mixture with hot HCl (concentration as before) from 1 to 5 times. Each time centrifuge and decant the liquid fraction. When the sediment swirls up upon giving the tube a gentle shake, the treatment is complete.
4. If the pollen and spores are very dark, oxidize the mixture with HNO_3.
5. Boil the sample with 10% KOH, if a basic dye is to be applied.

When the acetolysis treatment is necessary, apply it after using the HF treatment.

STAINING AND MOUNTING PROCESS

After the field samples have been properly macerated one way or another, temporary and permanent slides can be made after staining. The mounting process of temporary slides was as follows:

Mix one part of glycerol with one part of Safranin dye; place one drop of this mixture on a clean slide, and mix with the prepared maceration. After applying the cover clip to the slide, the slide is good for temporary examination.

When mounting to make permanent slides for long term observation, the prepared maceration is first stained with 2-5 drops of Safranin dye, the amount of dye applied depending on the amount of macerated sediment. During mounting, one drop of melted glycerin jelly is put on a clean slide, and a small bit of stained maceration is also applied on the slide and mixed with the glycerin jelly. Glycerin jelly is used as mounting medium with the advantage that individual specimens may be rotated to change their orientation, especially for studying Recent and Pleistocene microfossils. Most older fossil microfloras, however, contained flattened specimens, so that changes in the orientation are less advantageous (Jeffords and Jones, 1959).

The preparation of glycerin jelly is as follows (based on that adopted by Courteville, 1937):

1. Soak 7 grams of solid gelatin and .5 gram of phenol crystal in 42 c.c. of distilled water for an hour.
2. Add 50 grams of glycerin and filter the mixture through glass wool; use a vacuum system to accelerate this process.

At room temperature, glycerin jelly is solid. Before using it for mounting, it should be warmed up with gentle heat, which is done by putting the glassware containing glycerin jelly into a heated water bath until it becomes fluid.

In mounting of both temporary and permanent slides, the right amount of macerated sediment taken should be such that relative areas covered by fossil specimens and by mounting medium on slides give discrete particles that are neither crowded nor too widely scattered, and the amount of mounting medium and maceration mixture should be such that no excess mixture skips out from the margin of the cover slip when applying one. If a large amount of jelly escapes from under the slip, no appreciable difference exists between counts made within or beyond the edge of the coverslip. This is probably because the depth of jelly at the edge is sufficient to allow free passage of all the different sized grains in the mixture. If a small amount of jelly oozes, small-sized pollen which is likely to accumulate on the margin of the slip will not remain under the slip, and thus only the pollen of bigger size will be left for examination. This would cause a considerable amount of error (Pollen et Spores Vol. IX- No. 3, Dec. 1967).

The applying of a cover slip is done by using a tweezer to hold one narrow end of the slip, and touching the opposite end on the slide. The slip is slowly lowered, care being taken not to let air bubbles form under it. Usually after a few hours' exposure at room temperature, the glycerin jelly solidified and the cover slip adheres fast to the slide. However, the pollen and spores as seen under a microscope are usually not on the same level, and continual refocusing is found to be necessary in this case. In order to avoid this, right after mounting, the slide is put upside-down on a rack by supporting the two narrow ends of the slide without touching the cover slip. Pollen and spores are then likely to accumulate to a single focal plane near the slip. The slide is then left at room temperature for a few hours to assure the complete adherence of the slide. The four sides of the cover slip should be sealed with turpentine, which prevents excess evaporation and keeps the slide in good condition for more than a year.

In all those laboratory procedures described above, care must always be taken to keep the field samples or macerations from the open air, because the pollen and spores that are suspended in the atmosphere may contaminate and distort the results. This is especially serious for the field samples. Pollen and spores which have been treated with chemicals look more transparent than those direct from field samples due to extraction of cell content residue by chemicals, and appear quite different from those that come from atmosphere which often contain protoplasm. All glassware must be cleaned, and distilled water is used to avoid the chance of contamination from tap water.

IDENTIFICATION OF POLLEN AND SPORES

Identification of pollen and spores had to be learned before pollen counting. In the process of learning, a ready-made pollen herbarium in the Muskeg Laboratory, McMaster University was found useful. Also many good pictures and drawings of microfossils from others' work were always of great help. Among many others, the plates from Grana Palynologica (Erdtman, 1954, 1961, 1964, 1965) were favoured because the pollen pictures are taken from different levels and angles, and were found easy to interpret. Plates from Erdtman's "An introduction to pollen analysis" (1954), Hyde and Adams' "An atlas of airborne pollen grains" (1958), and Suguitan's "Palynological evolution of five muskeg landscape patterns" (1963) have been referred to often. Other information of pollen and spore morphology came from Erdtman's "Pollen morphology and plant taxonomy" (1965), and "Pollen et Spores" published by Museum National D'Histoire Naturelle. A great deal of information on morphology (drawings) of Pteridophyta and Sphagnum spores came from "Spores of N. Z. Pteridophyta" (Harris, 1957) and "Atlas of plant residues found in peat" (Dombrowskaja, Korenewa, and Tjuremnow, 1959). In general, drawings of pollen and spores are usually difficult to compare with pollen and spores under a microscope, while photographs serve the purpose better.

The microscope used for identification of pollen and spores has to have high magnification (at least 1000 x) in order to examine the detail of the grain, which is usually minute.

POLLEN COUNTING AND MAKING OF POLLEN DIAGRAMS

Slides are examined from left end to right end in successive rows; about 150 pollen grains of forest trees are counted at each level, and pollen of each genus or family is recorded as percentage of the total. Identification of species by means of pollen grains is seldom practicable because of the resemblance in morphology between species. While completing the one hundred and fifty count, at the same time, non-arboreal pollen, Sphagnum spores, and other microfossils were also counted and recorded as a percentage of the total arboreal pollen. For slides containing a low amount of pollen, several slides which from the same maceration were counted continuously to complete the 150 count.

In order to magnify the result on the part of non-arboreal pollen (NAP), NAP alone has been counted once by recording 150 pollen grains, and the quantity of pollen from each genus or family was calculated as a percentage of the total NAP, and also fungal elements and the amount of *Sphagnum* spores were recorded.

From the results obtained through pollen counting, pollen diagrams are made for easy examination as shown in the next section: Results expressed in pollen diagrams.

STATISTICAL ANALYSIS OF THE DATA OBTAINED

This is done by simple correlation or principal component analyses of raw data of pollen and spores through computer programming. The conclusions and discussions of these analyses are in the Discussion section.

ANALYTICAL PRESENTATION

Fig. 4 Pollen diagrams of both AP and NAP

Diagram I - is the diagram of all the EI bog deposits (Thousand Acre, Area 10A, Woods Area).

Diagram II - is the diagram of all the FI bog deposits. (Thousand Acre, Area 10G, Area 7)

DIAGRAM I:

ALL NUMERICAL SCALES PERTAIN TO % OF TOTAL AP

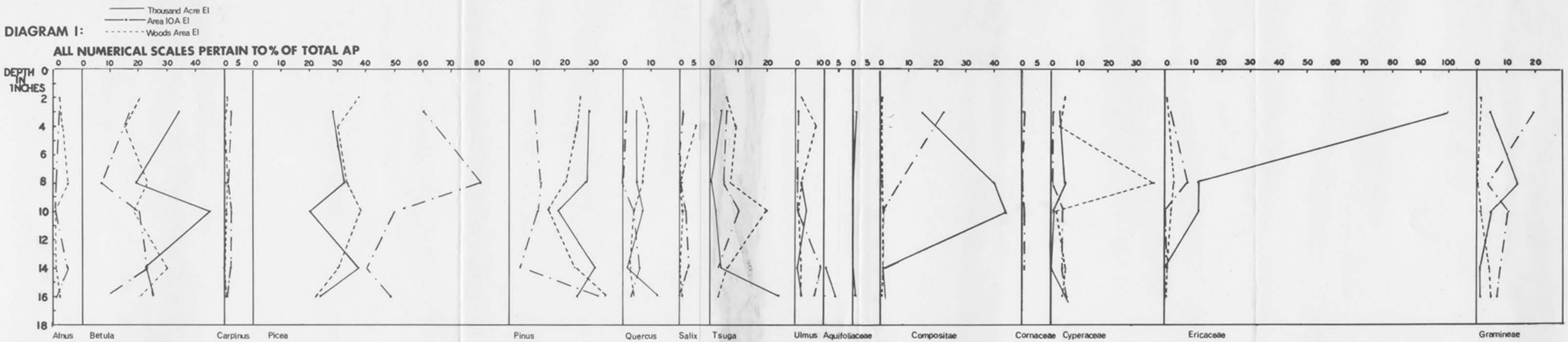


DIAGRAM II:

ALL NUMERICAL SCALES PERTAIN TO % OF TOTAL AP

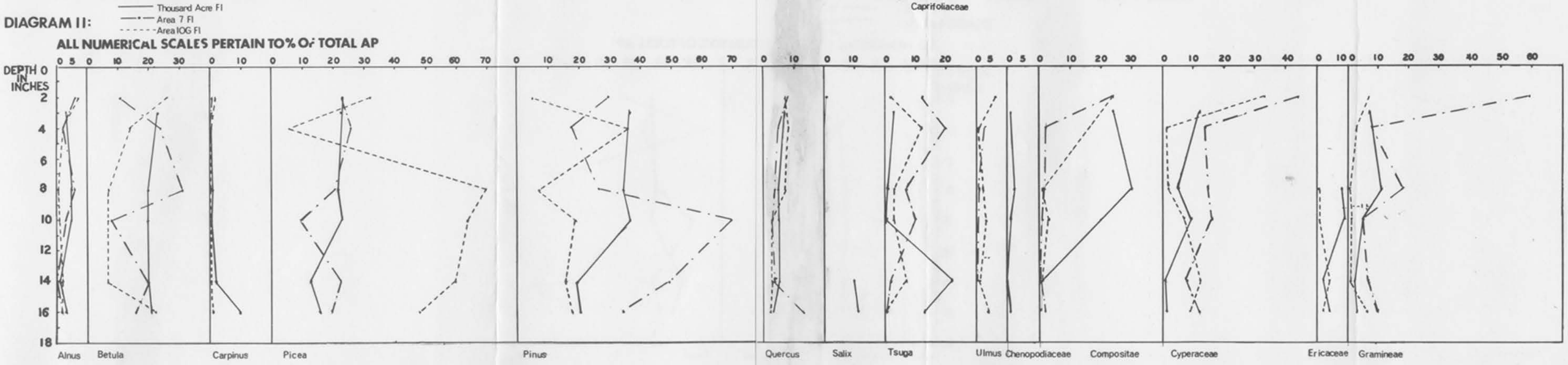


Fig. 5 Pollen diagrams of only NAP

Diagram III - shows NAP deposits in all the EI bogs (Thousand Acre, Area 10A, Woods Area).

Diagram IV - shows NAP deposits in all the FI bogs (Thousand Acre, Area 10G, Area 7).

DIAGRAM III

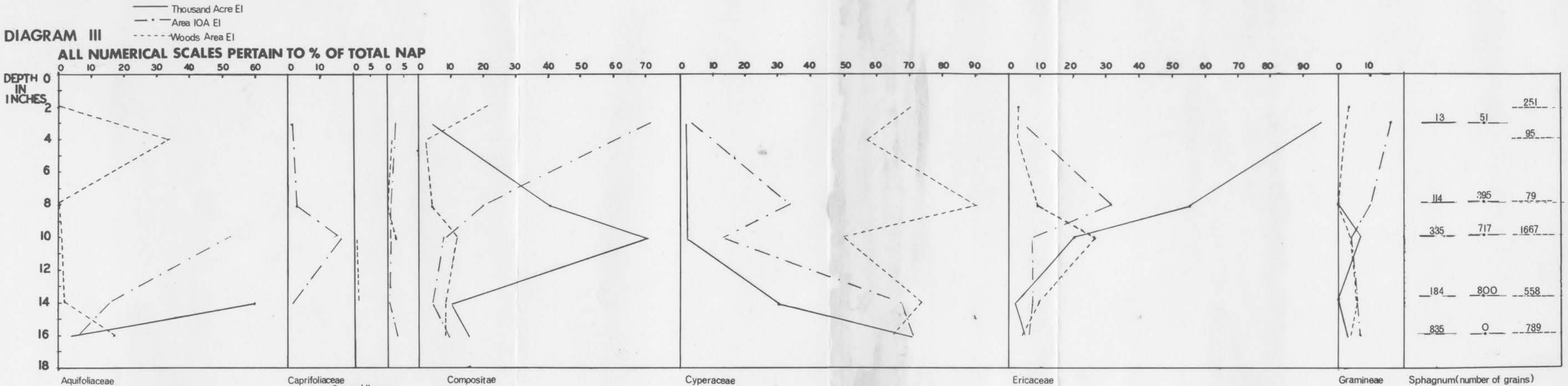
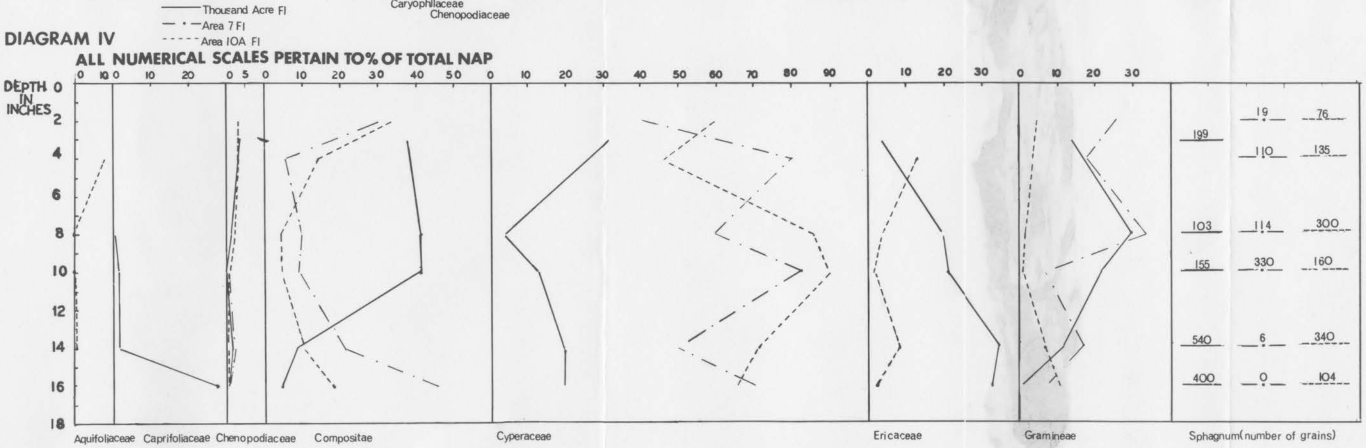


DIAGRAM IV



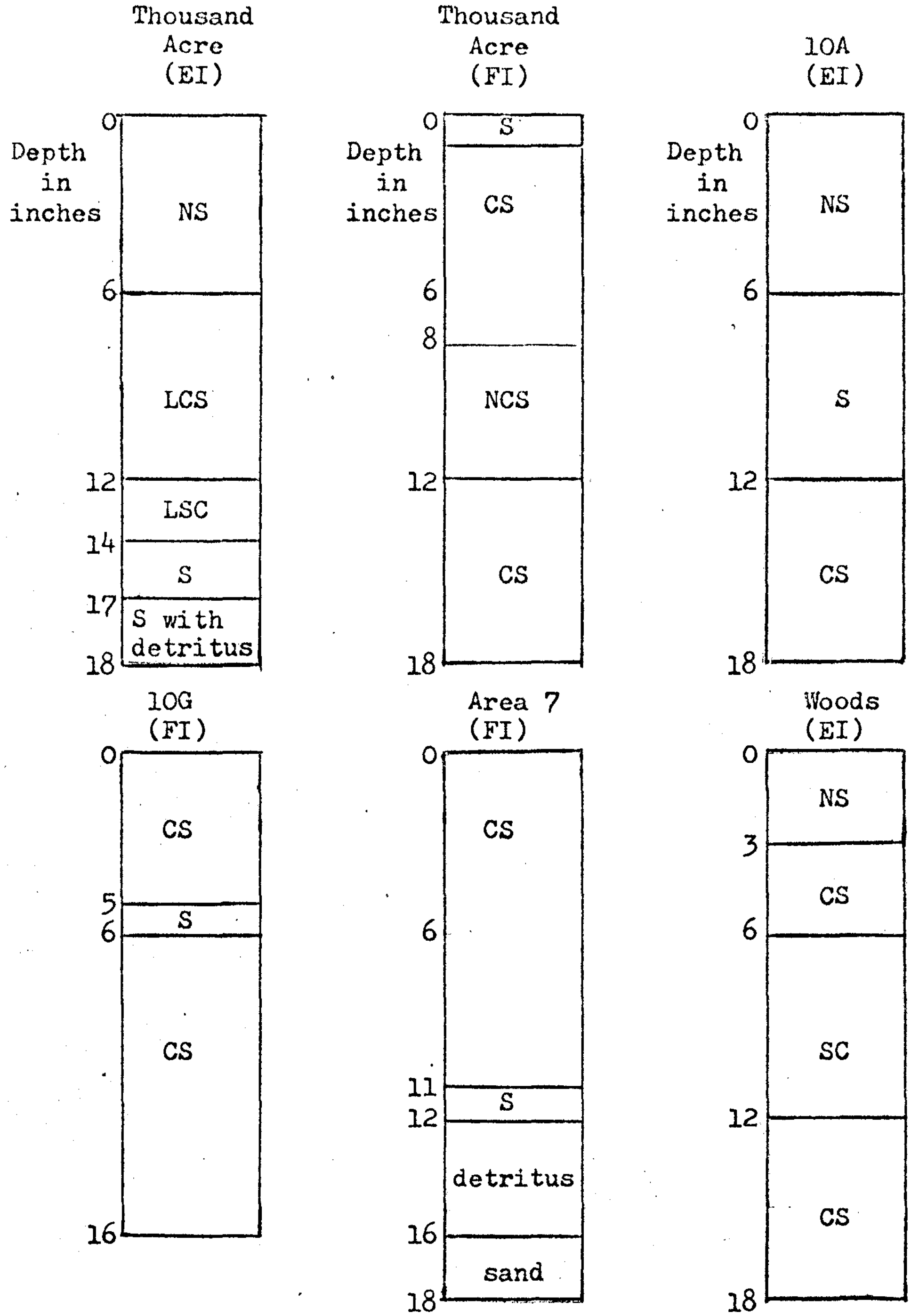


Fig. 3 Peat profiles of the field samples

S = Sphagnum peat
C = Carex peat
CS = Carex-Sphagnum peat
SC = Sphagnum-Carex peat
N = Nanolignid peat
NS = Nanolignid Sphagnum peat
LCS = Lignid-Carex-Sphagnum peat
LSC = Lignid-Sphagnum-Carex peat

COMPARISON OF POLLEN DIAGRAMS

COMPARISON OF ARBOREAL POLLEN DIAGRAMS - based on diagrame I and II

Thousand Acre EI bog:

Betula is very abundant (34%) on the surface, and rises and falls all the way through the peat between the range 19%-45%.

Picea is abundant (28%) on the surface, rises and falls all the way through the peat, but not so sharply as Betula.

The curve representing Pinus is more or less the same shape as the one for Picea, but indicates a less abundant amount of pollen.

Quercus appears all the way through the peat, but in amounts around 5%, and becomes more important at the 16 inch level.

Tsuga is always present, but only becomes important at the 16 inch level.

Ulmus does not appear until the 8 inch level, and from 8 inches to the 16 inch level, it occurs but in small amounts.

Thousand Acre FI bog:

Alnus and Quercus appear only in small amounts (around 5%) all the way through the peat.

Betula is quite important on the surface (23%), and only changes very little in quantity with depth.

Carpinus is scarce even 14 inches under the surface, but becomes important at the 16 inch level (10%).

Picea is present on the surface in the amount of 23%, remains in the same amount until the 10 inch level, then decreases to 13% at the 14 inch level.

Pinus is of great abundance throughout the peat, but decreases sharply from 37% to 20% at the 10-14 inch level. The curve representing Picea is more or less the same as the one for Pinus.

Salix only appears in an important amount (10%) from the 14 inch to 16 inch level.

Tsuga is important only at the 14 inch level, the amount is 22%, but then, it decreases again.

In this area, apparently the 8 inch level seems to be the turning point at which the percentage of all the pollen deposits change prominently.

Area 7 bog:

Alnus appears all the way through the peat, but the amount is small.

Betula is present on the surface in the amount of 11%, increases to 31% at the 8 inch level, decreases sharply from 31% to 8% at the 8 to 10 inch level.

Carpinus is unimportant through the peat.

Picea is abundant, but is more prominent at the 10 inch level.

Pinus becomes most abundant at the 8 to 10 inch level (70%), but decreases afterwards.

The curve representing Picea is just opposite to the one for Pinus; this is different from the observation in the Thousand Acre EI and FI bogs.

Quercus is always present, but seems only important at the 16 inch level.

Salix is so scarce as to be almost negligible.

Tsuga is more abundant on the surface, but decreases to a very unimportant amount with the depth.

Ulmus is of small amount, but present all through the peat.

The 8 and 10 inch levels seem to be the two turning points.

Area 10A bog:

Alnus occurs through the peat in small amounts.

Betula is abundant but rises and falls between a range of 7-23%.

Carpinus is present all the way through the peat, but only in small amounts.

Picea is the most predominant type. It is present in great amounts all through the peat but has the tendency to decrease in the peat (80%) below the 8 inch level.

Pinus is not so important until it comes to the 14 inch level and increases to 31%.

Salix is unimportant on the surface, but increases a little from the 10 inch level on.

Quercus is about the same as Carpinus.

Tsuga is in the amount between 6-10%, but from 10 inch level on, it keeps decreasing.

Ulmus is similar to Salix.

The 8 inch and 14 inch levels seem to be the turning points for all the pollen deposits.

Area 10G bog:

Alnus appears all the way through the peat, but is not important.

Betula is abundant (26%), decreases to 7% at the 8 inch level, maintains this until the 14 inch level, and increases again.

Carpinus is scarce all the way through the peat.

Picea is abundant on the surface, decreases to an unimportant amount (5%) at the 4 inch level, but increases very sharply (70%) at the 8 inch level, decreases mildly again.

Pinus is generally not so abundant as Picea, and the curve representing it is just about opposite to the one for Picea.

Quercus appears all the way through the peat, but the quantity is much greater on the top than at the base.

Tsuga is present in a small amount on the surface (2%), but rises and falls in a range between 3% to 12% between the 2 to 14 inch levels, and almost disappears at the 16 inch level.

Ulmus is scarce through the peat (0.7-6%) as usual.

The 4 inch level seems a turning point for all these pollen deposits.

Woods Area bog:

Alnus appears all the way through the peat but in small quantities.

Betula appears throughout the peat, falls and rises all the way, and the amount remains from 15% to 30%.

Carpinus is very scarce, almost negligible.

Picea is of great abundance on the surface (37%) and rises and falls, but never sharply.

Pinus is a little less abundant than Picea. However, the curve representing it is more or less opposite to the one for Picea.

Quercus occurs all through the peat, but only in small amounts.

The quantity of Salix at the 4 inch level is 6%, but keeps decreasing with depth.

Tsuga remains below 10% except at the 10 inch level, at which it has a peak of 20%.

The 10 inch level seems to be a turning point for all the pollen deposits.

<u>COMPARISON OF NON-ARBOREAL POLLEN DIAGRAMS</u> - based on diagrams III and IV

Thousand Acre EI bog:

Aquifoliaceae appears in great quantities at 14 inches under the surface and decreases quickly when it reaches 16 inches.

Compositae is scarce on the surface, increases with depth, and reaches a maximum at a level 10 inches under the surface. Below this point, it decreases in abundance again.

Cyperaceae is very rare from the surface to 10 inches under the surface, and increases prominently when it reaches a depth of 16 inches.

Ericaceae is the most important non-arboreal plant in the surface, but decreases continuously with depth.

Gramineae has the same kind of rise and fall as Compositae except its quantity is little all through the peat and the curve is not so sharp as the latter.

<u>Sphagnum</u> occurs in small amounts on the surface, increases 30 times in amount when it reaches the 10 inch level, decreases at the 14 inch level, and increases sharply at the 16 inch level.

In all diagrams above, except Ericaceae and Aquifoliaceae, it can be seen clearly that 10 inches and 16 inches under the surface are two prominent turning points, and there could be two great environmental changes during these two periods.

Thousand Acre FI bog:

The quantity of Caprifoliaceae is unimportant at the 8, 10 and 14 inch levels, but greatly increases to 28% at the 16 inch level.

Chenopodiaceae appears all through the peat, but only in small amounts.

The amount of Compositae is important and remains around 40% from depth of 3 to 10 inches, but decreases to 9% at 14 inches and decreases more to the 16 inch level.

Ericaceae appears all through the peat, but is in small amounts at the 3 inch level, around 20% at the 8 and 10 inch levels, and about 35% at 14 and 16 inches.

Cyperaceae occurs in important numbers (31%) at the 3 inch level, decreases at 8 inches, increases again slowly and maintains a constant level of 20% at 14 and 16 inches.

Gramineae represents 14% of the population at the 3 inch level, increases to 30% at 8 inches, decreases with depth, and reaches 1% at 16 inches. The curve representing Gramineae is just opposite to the one for Cyperaceae.

Area 7 bog:

Chenopodiaceae appears only insignificantly between 10 and 16 inches.

Compositae is 30% of the total NAP on the surface, decreases between 4 and 10 inches, and increases again from 10 to 16 inches to 46%.

Cyperaceae is of great abundance throughout the peat, but rises and falls continually.

Ericaceae only appears very insignificantly on the surface and at the 14 inch level.

Gramineae appears throughout the peat, falls and rises all the way, but is more abundant from 2-10 inches.

Sphagnum increases with depth, but decreases to a very small amount at 14 inches, and disappears at 16 inches.

Area 10 bog:

Aquifoliaceae is present only from 10 to 16 inches; it is abundant at 10 inches (52%), and decreases greatly to 7% when it reaches 16 inches.

Carifoliaceae appears at 3, 8, 10 and 14 inches under the surface, but attains an important amount of 16% only at the 10 inch level.

Chenopodiaceae appears all through the peat but always in small amounts.

Compositae is important in the surface sample, reaching 71% of the total NAP, but decreases greatly while extending to 10 inches under the surface level, and remains under 10% between 10 and 18 inches.

Cyperaceae is scarce in the surface sample, increases to 33% at 8 inches, decreases at the 10 inch level, but increases greatly at 14 and 16 inches to about 70% of total NAP.

Ericaceae is present at the surface in the amount of 4%, increases to 31% at 8 inches, and decreases to 7% at 10 inches, remaining at this value at 14 and 16 inches.

The fluctuations of Gramineae are comparable to those of Compositae and opposite to Cyperaceae.

Area 10G bog:

Aquifoliaceae appears at 4 inches and 14 inches, the latter being of little importance.

Chenopodiaceae appears all the way through the peat but in small quantities.

Compositae is 34% on the surface, it decreases to about 5% between 8-10 inches and increases again from 10 to 16 inches.

Cyperaceae is of important abundance through the peat, most abundant between 8-10 inch levels.

Ericaceae appears at 4 inches as 13% of the total NAP, decreases with depth to the 10 inch level, then increases at 14 inches and decreases again.

Gramineae appears all the way through the peat, but first decreases then increases.

Woods Area bog:

Aquifoliaceae appears at the 4 inch level with an important ratio (34% of the total NAP), and decreases to an insignificant amount through the peat and rises again at the 16 inch level under the surface.

Caryophyllaceae appears in unimportant amounts at 10 inches and 14 inches.

Cyperaceae occurs in great quantities through the peat, and although it falls and rises continually, it is most abundant at the level 8 inches under the surface, and amounts to 90% of the total NAP.

Ericaceae appears through the peat, but is not important at 2-4 inches, increases to 26% at 10 inches, then decreases quickly.

Gramineae appears throughout the peat but in small quantities.

The amount of Sphagnum varies greatly through the peat, there being prominent peaks. One is between 2-4 inches, another is between 8 to 10 inches, and this seemingly has nothing to do with the rise and fall of pollen diagrams.

DISCUSSION

GENERAL DISCUSSION

Before discussing the statistical analysis of raw data of pollen and spores through computer programming and the condition of climate as interpreted by pollen diagrams, the following problems that most likely arise during the investigation should be considered.

1. Number of pollen and spores that should be counted in each maceration -

For this investigation, 150 arboreal grains or 150 non-arboreal grains (in the case when only non-arboreal pollen is involved) were counted for each maceration. This amount is generally agreed by many (von Post, 1918, Wodehouse, 1935, Erdtman, 1954, Faegri and Iversen, 1950, Flint, 1965) to be sufficient. Wodehouse (1935) believed that trustworthy percentages are obtained by counting about 150 pollen grains. He indicated that in northern Canada where only a few tree species of which pollen is preserved in bogs, fairly reliable percentages can be obtained by counting 100 or even fewer pollen grains. Only when the sample consists of a great number of tree species is it necessary to count more than 150 grains.

2. The down wash of pollen through profiles by water -

If pollen can be washed down through peat profiles, then the established pollen counts obtained will be subject to further interpretation, because the pollen normally pertinent to an upper profile may sink down to the lower profile. Fortunately, this has been proven not to be true by several people. According to Erdtman (1921), down wash of pollen is not a problem. He proved that the pollen spectra of living Sphagnum is practically identical with those obtained from nearby cushions of Grimmia and other mosses growing on rocks and other places, such as old tree stumps, where down wash of pollen is impossible. C. Mälmstrom's experiment (1923) proved that pollen grains are carried down by water only within the unconsolidated debris or litter which forms a layer from about 1 inch to 2 feet thick on the surface of certain types of bogs, and that pollen does not penetrate into the true peat. Salmi (1962) indicated that among the pollen grains of the same year's crop, those of Betula and Alnus and other pollen of comparable size and shape sink lower down in the moss when washed by rain water than does the Pinus and Picea pollen in which the grains have air sacs. But since the same process is repeated year after year, this need not cause disturbances in the pollen statistics of the peat as does the sorting performed by the water in the bog pools.

3. The preservation of pollen in peat bogs -

It is known that preservation of pollen is determined by the chemical nature of the exine and the biochemical nature of the grain's environment, and that some pollen species are preserved better than others. Sangster and Dale (1964) in their experiment found that several Pinus species (P. strobus, P. banksiana, P. resinosa), also Quercus alba, Ulmus americana, Typha latifolia do not show deterioration in bog surface peat, while Betula, Fraxinus, Corylus, Salix, Alnus and Acer show deterioration in different degree, and Populus is either poorly preserved or not fossilized at all.

DISCUSSION ON THE POLLEN DIAGRAMS AND THEIR IMPLICATIONS IN CLIMATE

From the study of pollen diagrams I and II, which contain both AP and NAP, the general impression obtained is the usual predominance of *Picea* and *Pinus*. This probably is not only because of the amount of pollen that was originally deposited, but also because of durability of these pollen grains. The abundant amount of *Betula* in all the deposit indicates the abundance of this plant near the bog area, according to the earlier statement that *Betula* does not disseminate very far, and that its pollen deteriorates easily. *Quercus* can endure as well and disseminate as far as *Picea* and *Pinus*, but is still present in very small amounts in all the deposits. Therefore, the conclusion can be drawn that *Quercus* is present only insignificantly. *Salix* is scarce and *Populus* is not present or only present in negligible amounts, probably due to both poor preservation and the originally small amount of dissemination.

There are some turning points in the pollen curves in all the diagrams (pollen diagrams I, II, III and IV), at which the percentage of different pollen changes drastically. This may suggest a change in the environment, such as a climatic change in humidity and temperature.

According to diagrams I and II, the NAP has a tendency to increase towards the upper part of the peat deposit. This may suggest the greater abundance of non-arboreal plants present in the bog more recently than in the past, and subsequently suggests a better growing substratum now compared with earlier times.

Diagrams III and IV are the magnification of the NAP diagram shown in diagrams I and II. There are more varieties of NAP in the former. The pollen curves are comparable between the former and the latter, with some minor differences that were probably caused by some uneven distribution of the pollen and spores in the maceration. These magnified data of NAP were used in computer programming when the problem of finding the relationship between surface deposit and water concentration is concerned.

It is known that Picea and Pinus are likely to be over represented, but even so the abundance of the two genera over Quercus and Alnus in the entire deposit apparently suggests that all the samples from the surface to the 18 inch depth are from the Holocene period which started within 6000 years ago (Dunbar, 1960), and belong to the most recent pollen stratigraphic zone- C3b (Flint, 1966, p. 351, Table 20-C). The abundance of Picea and Pinus also suggests a rather cooler climate (Potzger and Tharp, 1947).

The occurrence and significant amount of Tsuga pollen may suggest a rather damp climate as portrayed throughout the deposits in the entire area investigated (Auer, 1927). The occurrence of Ericaceae often is an indication of dry climate (Salmi, 1962). However, it is not present in all the deposit in significant amounts, except in the Thousand Acre EI area. The dominant number of this family on the surface of this deposit may very well be because of errors, for example local over-representation. Because of the observation of clumps of Ericaceae pollen in the maceration, they cannot be taken as an indication of climate.

The abundance of non-arboreal pollen and spores and the infrequent occurrence of Sphagnum spores are mainly indications of the local vegetation changes of the bog surface during the formation of peat, and cannot be taken as indicators of the climate as a whole.

THE KNOWLEDGE CONCERNING BIOTIC AND ENVIRONMENTAL DEVELOPMENT

Judging the results by examining pollen diagrams gives some of the information wanted. However, for more accurate examinations and evaluation, the computer programming was employed and the following topics are discussed: (1) The relationship between recent pollen deposition (approximately top 5 inches or less) and water prevalence. (2) The possibility of statistical relationship among pollen species. (3) Grouping of areas according to the resemblance of pollen composition, and evaluation of whether these groupings indicate biotic organization.

1. The relationship between recent pollen deposition and water prevalence -

In order to examine for possible relationship the data for NAP and spores from nine macerations (Macerations Nos. 1, 6, 11, 16, 17, 22, 23, 28 and 29) were analyzed as associated with present water conditions by using simple correlation coefficients. The result is listed as Fig. 6. The simple correlation coefficients between water and the different families of pollen and spores are the six figures on the bottom line. For example, the simple correlation coefficient between water and Ericaceae is 0.556 (positively related), while between water and Gramineae is -0.636 (negatively related). These figures were compared with a table that contains values of the correlation coefficient for different levels of significance, and it was found that all the simple correlation coefficients are too small to consider for the establishment of validity. In other words, there is no significant relationship between water and these five families.

Fig. 6 Simple correlation coefficients among non-arboreal pollen spores and water

	Compositae	Cyperaceae	Ericaceae	Gramineae	Lycopodiaceae	Water
Compositae	1.000					
Cyperaceae	-0.448	1.000				
Ericaceae	-0.351	-0.592	1.000			
Gramineae	0.426	-0.032	-0.421	1.000		
Lycopodiaceae	-0.289	0.366	-0.315	-0.325	1.000	
Water	-0.288	-0.274	0.556	-0.636	0.139	1.000

However, from the knowledge that Ericaceae is a kind of plant that grows mainly in dry conditions (Salmi, 1962), while Cyperaceae, Gramineae, or *Lycopodium* tends to appear in rather wet conditions, it could be suggested that a definite relationship should exist.

To reconcile this situation, several possible explanations might be considered.

There is a possibility that the sample size may be too small, and the result obtained from nine macerations may not be adequate to represent the whole population.

There is a possibility that the water conditions existing in the bogs are not pertinent for the vegetation even at the top 5 inches. That is to state that during quite recent peat deposition, the water condition has changed from that of the preceding years.

There is a possibility that there is some relationship between water and some of the plants *in situ* but this relationship is not distinct and is too diffused to signify a pattern.

It is thought that this part of the analysis, because of design of the approach, does not reveal the answer to complete enough understanding of recent succession. For the future, increase of surface sample size, and the utilization of Fungus spores and *Sphagnum* plant residues might provide a more thorough approach.

2. The possibility of statistical relationship among pollen species -

In order to investigate statistical relationships among pollen, a sample of size 33 (Macerations No. 1 - No. 33, data of both AP and NAP) was subjected to a principal component analysis (Seal, 1964, p. 101-122). The calculation was carried out at the McMaster Computer Centre following the design of an appropriate program (Lee, 1967). Since there are 17 different families or genera of pollen and spores included, there should be 17 independent columns of principal components. However, the figures in the last four columns are small and negligible, and only the first 13 of them are listed in Fig. 7. A general principle to interpret the coefficients of Fig. 7 is that if several kinds of pollen have high coefficients in the same principal component column, this suggests that those pollen are highly correlated.

The figures shows that pollen of *Salix*, Caprifoliaceae and *Carpinus* are highly positively correlated, and they therefore increase or decrease together. Cyperaceae and Ericaceae, Compositae and Cyperaceae, and also *Picea* and *Pinus* are negatively correlated, so that when one increases, the other decreases. The remaining pollen and spores are independent, and are not correlated with each other.

3. The grouping of areas according to the resemblance of pollen compositions, and evaluation of whether these groupings indicate biotic organiza-

Fig. 7 Coefficients of 13 principal components for pollen and spores (both AP and NAP)

Pollen & spores	Principal components 1	2	3	4	5	6	7	8	9	10	11	12	13
Salix	-0.70	-0.08	-0.10	-0.05	0.06	-0.25	-0.13	0.21	0.02	0.02	-0.12	0.00	-0.07
Caprifoliaceae	-0.94	-0.07	0.15	0.09	0.04	-0.06	-0.06	0.01	0.14	0.01	0.08	0.04	0.06
Carpinus	-0.96	0.09	-0.02	0.06	0.05	-0.02	-0.10	-0.11	-0.02	0.06	-0.04	0.05	-0.12
Compositae	0.05	0.90	0.04	-0.08	-0.15	0.21	-0.03	-0.13	-0.15	0.12	-0.24	0.00	-0.09
Cyperaceae	0.28	-0.53	-0.14	-0.11	0.23	-0.03	0.65	-0.13	0.03	-0.17	0.11	0.03	-0.01
Lycopodium	-0.11	-0.12	-0.18	0.03	0.05	0.07	0.11	0.02	0.94	-0.14	-0.06	0.07	0.08
Picea	0.14	-0.02	-0.03	0.34	0.09	0.24	0.06	-0.04	0.12	-0.39	0.03	0.74	0.19
Alnus	-0.09	0.08	-0.16	-0.12	-0.25	0.12	0.11	-0.09	-0.09	0.04	0.07	-0.08	-0.91
Ulmus	0.10	-0.07	-0.86	-0.05	0.08	0.16	0.13	0.14	0.24	0.09	-0.13	0.23	-0.19
Betula	-0.05	0.12	-0.07	-0.08	-0.03	0.00	-0.16	0.01	-0.12	0.96	-0.03	-0.00	-0.03
Aquifoliaceae	0.03	-0.08	-0.10	0.01	0.13	0.03	0.08	0.97	0.02	0.01	0.08	-0.04	0.07
Ericaceae	-0.09	-0.03	0.06	0.05	0.14	0.01	-0.95	-0.13	-0.11	0.12	0.08	-0.00	0.11
Gramineae	0.12	0.18	0.08	0.09	-0.90	-0.02	0.08	-0.16	-0.06	0.04	0.03	-0.14	-0.26
Pinus	0.15	-0.00	0.17	0.03	-0.09	-0.13	0.02	0.03	-0.02	-0.12	0.02	-0.95	0.03
Quercus	0.11	0.05	-0.04	-0.96	0.07	-0.11	0.08	-0.02	-0.02	0.09	-0.07	-0.08	-0.09
Tsuga	-0.12	-0.17	0.12	-0.12	-0.02	-0.95	0.02	-0.04	-0.07	0.01	0.03	0.03	0.10
Chenopodiaceae	-0.01	0.20	-0.10	-0.07	0.03	0.02	0.05	-0.08	0.06	0.03	-0.96	0.00	0.06

tion -

The same 33 macerations as used above were subjected to principal component analysis (Seal, 1964, p. 101-122), in order to see the similarity of pollen composition among macerations. The coefficients for the first two components are listed in Fig. 8, and are also used as coordinates, drawn in Fig. 9. According to Fig. 9, the 33 macerations can be roughly divided into two groups due to their pollen and spore composition. These two groups were tested again by using discriminatory analysis through the principle of canonical correlation analysis (Seal, 1964, p. 123-152), computer programmed by Lee (1968), to determine if these two groups are really different.

The result shows that these two groups are statistically different at the 1 per cent level. That is, the occurrence of these two groups is 99 per cent not due to chance, but caused by certain existing factors. The result also suggests that Quercus, Salix, Chenopodiaceae, Ulmus and Alnus pollen are most important for differentiating these two groups (Fig. 10).

In Fig. 9, Group I consists of almost all the macerations from Area 10A (dry EI), Area 10G (moist FI), and Thousand Acre Bog (wet EI). Group II consists of almost all the macerations from Woods Area (mostly EI), Area 7 (dry FI), and Thousand Acre Area (wet FI). Group I is a very compact group, and this shows that pollen composition in the macerations involved is similar. Group II is rather dispersed, and apparently can be divided further into subgroups.

In order to find possible explanations for the true cause of this natural grouping, the following points are considered:

Fig. 8 Coefficients of two principal components for 33 macerations

No. of macerations	1	2
27	-0.55	0.32
24	-0.59	0.78
32	-0.66	0.43
18	-0.76	0.56
22	-0.78	0.48
15	-0.83	0.18
21	-0.84	0.18
10	-0.84	0.12
8	-0.84	0.02
7	-0.84	0.30
23	-0.84	0.50
6	-0.85	0.36
11	-0.87	0.26
9	-0.88	0.05
5	-0.88	0.17
4	-0.91	0.01
20	-0.92	0.22
12	-0.92	0.28
33	-0.93	0.11
13	-0.93	0.07
17	-0.94	0.18
16	-0.95	0.14
19	-0.96	0.01
14	-0.98	0.02
25	-0.14	0.96
26	-0.11	0.96
30	-0.12	0.94
31	-0.06	0.92
1	-0.07	0.82
29	-0.19	0.51
3	-0.27	0.30
2	-0.45	0.33
28	-0.36	0.14

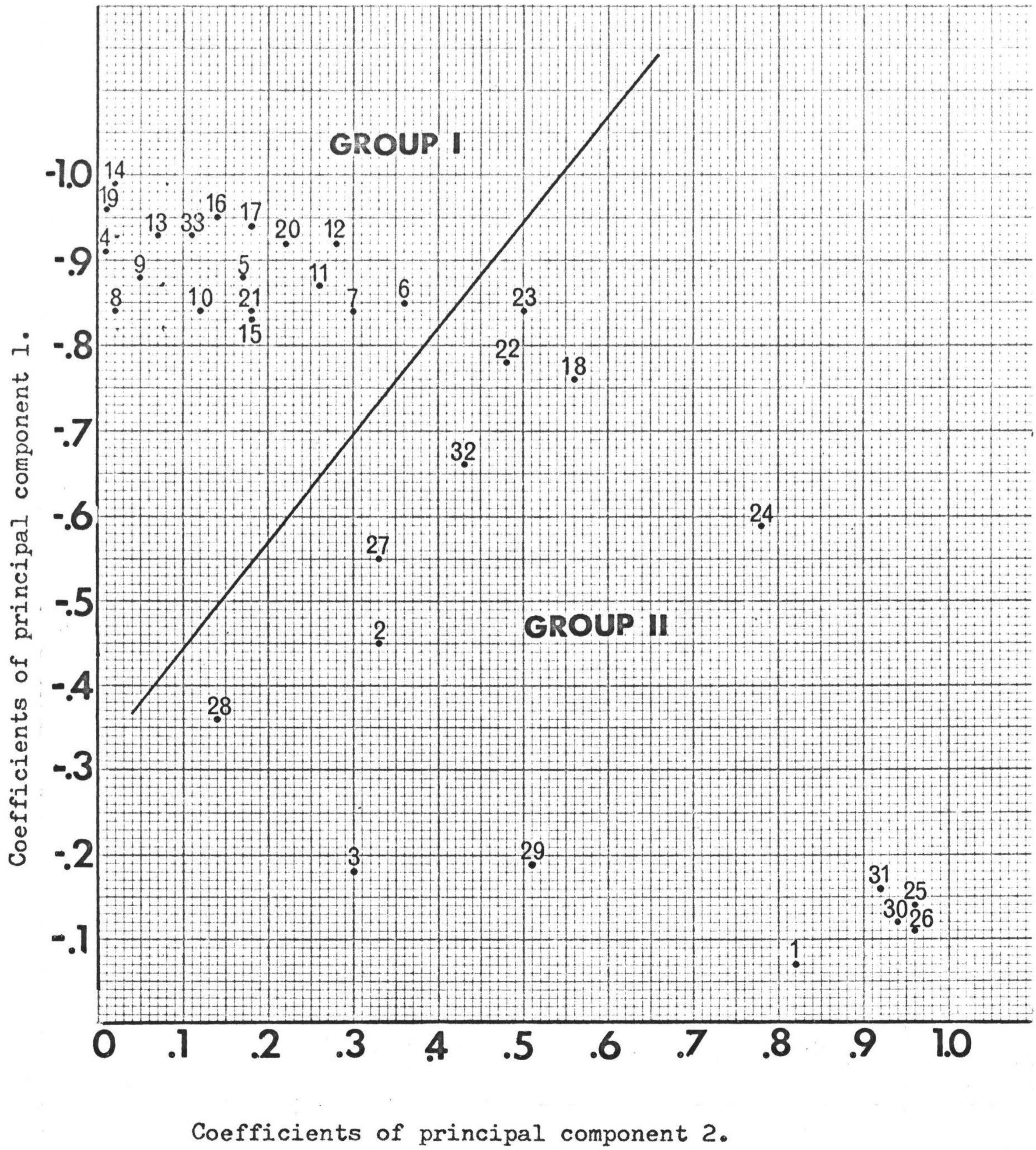


Fig. 9 The natural grouping is shown in this figure. Numbers designating the maceration number. The macerations made from Thousand Acre FI area has the maceration No. 1-5. Thousand Acre EI area No. 6-10. Area 10A No. 11-15. Area 10G No. 16-21. Woods Area No. 22-27. Area 7, No. 28-33. The line dividing these two groups is an arbitrary one.

Fig. 10 Coefficients of canonical transformation for 33 macerations (both AP and NAP)

Canonical axis		
Picea		-0.1417
Pinus		-0.1378
Tsuga		0.0563
Betula		-0.0880
Carpinus		-0.0984
Alnus	*	0.2770
Quercus	*	-0.5235
Ulmus	*	-0.3836
Salix	*	-0.4797
Caprifoliaceae		-0.0728
Chenopodiaceae	*	0.4334
Compositae		-0.0444
Cyperaceae		0.0809
Ericaceae		-0.0061
Gramineae		-0.1019
Lycopodium		-0.0054
Aquifoliaceae		-0.0143

Note: The bigger the figure, the more important the pollen in differentiating the two groups. The most important ones are designated by *.

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a. Water content -

Water content shows no relationship with this grouping, because both groups contain all the water regimes - high, medium and low. Therefore, this natural grouping is not due to the differentiation of wetness or dryness.

b. The location of the bog -

There is a possibility that bogs closely associated geographically have more chance to show similar deposition of pollen and spores. The compact Group I seems to support this statement, because the three areas involved are located quite close to each other, especially Area 10A and Area 10G which are two connected bogs. However, the Thousand Acre EI and Thousand Acre FI areas lie side by side, but the macerations from them are grouped into separate groups, and this proves that location alone can not be the reason. The fact that the EI and FI areas in Thousand Acre separate into two groups may also suggest that EI and FI are biotically distant.

c. Climatic influence -

Climate should not be the reason for grouping, because the biggest distance between bogs is about 5 miles. Therefore climatic changes should have been about the same during the past.

d. The vegetation on the bog or surround the bog -

The Parry Sound bogs with trees surrounding them and occasionally having trees growing in the bog may very well influence the pollen count. This point is also supported by Vaino Auer (1927).

e. Bog surface vegetation coverage - EI and FI -

Since in both groups there are both EI and FI vegetation coverages present, EI and FI cover classes probably do not correspond with differentiation into two groups, especially when the most important pollen differentiating the grouping are Quercus, Salix, Ulmus, Chenopodiaceae and Alnus. They are mostly trees or shrubs except Chenopodiaceae, and EI and FI which represent mainly very small shrubs or grasses. However, the statement cannot be proved to be true until further tests involving only data of in situ pollen and spores are compared through statistical analysis.

SUMMARY AND CONCLUSION

Cylindrical field core samples were taken from bogs with either EI or FI vegetal cover, and the water regime in the bog was recorded. Macerations were made from the field samples every 2 to 4 inches apart, and the data of AP and NAP percentage were recorded and presented in pollen diagrams.

The data of surface NAP percentage together with the water concentration in the bog were analyzed through computer programming to find out if there is any relationship between the NAP which is most likely from *in situ* plants and abundance of environmental free water. The analysis as designed does not favour specific relationship between water and surface NAP. However, this should not be considered to be a final statement until some adjustment in the experimental approach has been done. For example, the surface sample size could be increased.

The data of both AP and NAP percentages in all macerations were also subjected to computer programming to find out the relationship among pollen genera or families, and also the relationship among macerations. The results of the analyses show that there are pollen genera or families which always increase or decrease their amount the same way (simultaneous occurrence), and there are pollen genera or families which increase or decrease their amount in the opposite way. The analysis on macerations shows that according to the pollen composition, macerations can be roughly divided into two groups. The natural factors causing the grouping are to be explored, but assumption is made that the vegetation around or in the bog probably is the reason for the grouping.

The pollen diagrams show the predominance of Picea and Pinus pollen, the abundance of Betula and Tsuga pollen, and the existence of Alnus, Carpinus, Quercus, Salix, Ulmus but in insignificant amount. The AP diagram suggests a cool and moist climate, and also indicate the age of all the samples to be in recent Holocene.

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PLATE I

Fig. 1 One side of the Thousand Acre bog, with EI vegetal cover. The front part of the picture shows the high water regime clearly.

Fig. 2 Another side of the Thousand Acre bog, with FI vegetal cover and high water regime. This area lies beside the EI area shown in Fig. 1.

PLATE I

PLATE II

Fig. 1 Area 10A bog, with EI vegetal cover and low water regime. There is a patch of FI vegetal cover in the front part of the picture, but this exists in less than 25% of the total vegetal cover and is negligible according to the Radforth Classification System.

Fig. 2 Area 10G bog, with FI vegetal cover and medium water regime.

PLATE II

1

PLATE III

Fig. 1 Area 7 bog, with FI vegetal cover. This picture shows clearly the low water regime (with no free water in evidence).

Fig. 2 Woods Area bog, with EI vegetal cover and medium water regime. The field sampling is also shown here.

PLATE III

1

2

PLATE IV

Fig. 1 Aerial photograph of Thousand Acre bog. The lighter part is the FI vegetal cover, and the darker part the EI vegetal cover.

Fig. 2 Aerial photograph shows the Area 10A bog. Area 10G bog lies on the side of this one (not shown here).

PLATE IV

PLATE V

Fig. 1 Aerial photograph shows the Area 7 bog.

Fig. 2 Aerial photograph shows the Woods Area bog.

PLATE V

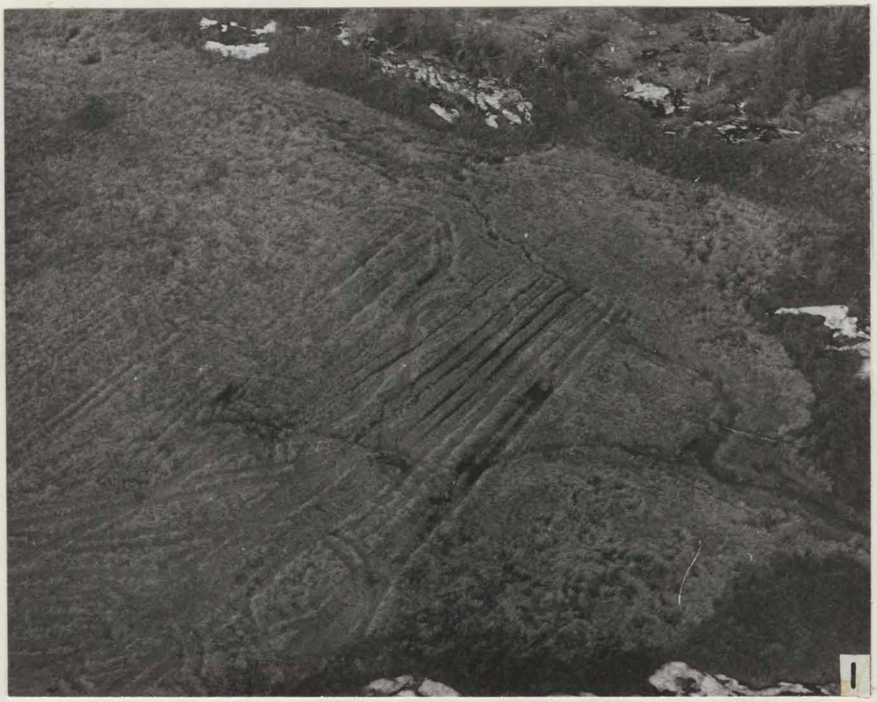

PLATE VI

Arboreal pollen found in Parry Sound bog (Mag. 1500X)

Fig. 1, 2	*Alnus* sp. about 25 μ
Fig. 3	*Betula* sp. 29 μ
Fig. 4	*Carpinus* sp. 30 μ
Fig. 5	*Corylus* sp. 37 μ
Fig. 6, 7	*Fraxinus americana*
Fig. 8	*Acer* sp. 30 μ x 15 μ
Fig. 9a, 9b	*Ulmus* sp. 33 μ
Fig. 10, 11	*Quercus* sp. 23 μ x 18 μ
Fig. 12	*Quercus* sp.
Fig. 13	*Quercus* sp. 31 μ x 30 μ
Fig. 14a, 14b	*Salix* sp.
Fig. 15, 16	*Nyssa* sp. 33 μ x 32 μ
Fig. 17a, 17b	*Tilia americana* 45 μ

PLATE VI

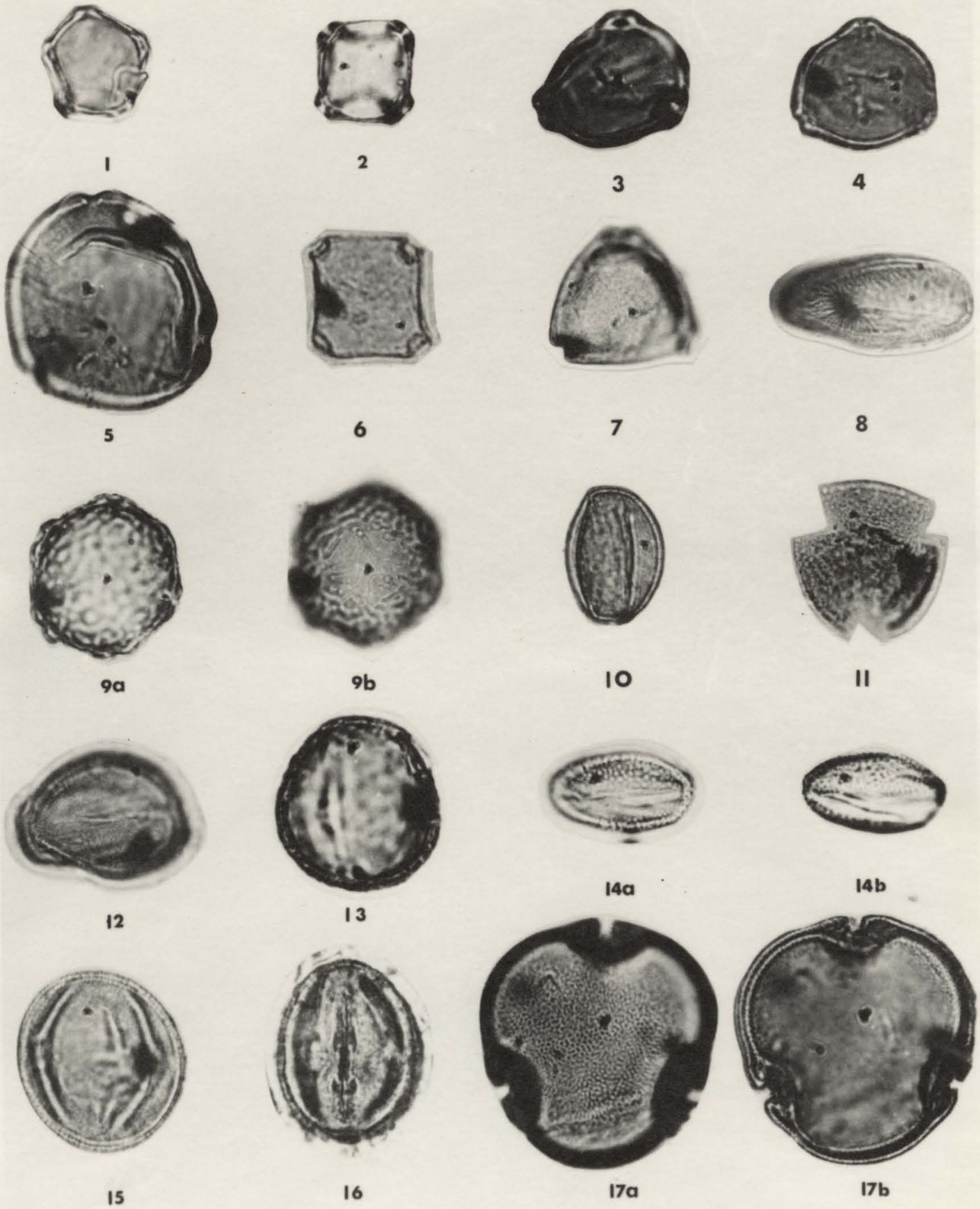

PLATE VII

Arboreal and non-arboreal pollen found in Parry Sound bog

(Fig. 1-3 and Fig. 5-15: Mag. 600X.,Fig. 4 Mag. 800X, Fig. 16-18 Mag. 1500X)

Fig. 1	*Tsuga* sp. 90 μ
Fig. 2	*Tsuga* sp. 60 μ
Fig. 3	*Tsuga* sp. 30 μ
Fig. 4	*Picea mariana*
Fig. 5	*Juniperus* sp.
Fig. 6	*Larix* sp.
Fig. 7	*Thuja* sp.
Fig. 8	*Juniperus* sp.
Fig. 9	*Podocarpus* sp. Distal end, about 80 μ
Fig. 10	*Picea glauca*
Fig. 11	*Pinus monticola*
Fig. 12, 13	*Pinus banksiana*
Fig. 14	*Pinus silvestris*
Fig. 15	*Pinus strobus*
Fig. 16a, 16b	Aquifoliaceae 42μ x 30μ
Fig. 17a, 17b	Caprifoliaceae 27μ x 23μ
Fig. 18	Caryophyllaceae 40μ

PLATE VII

PLATE VIII

Non-arboreal pollen found in Parry Sound bog (Mag. 1500X)

Fig. 1a, 1b, 3	Chenopodiaceae 20 μ
Fig. 2	Chenopodiaceae 23 μ
Fig. 4, 6	Compositae, Ambrosia sp. 20 μ
Fig. 5	Compositae, Achillea sp. 27 μ x 26 μ
Fig. 7a, 7b	Compositae, Artemisia sp. 20 μ
Fig. 8, 9	Aster sp. 27 μ x 20 μ
Fig. 10	Compositae 20 μ
Fig. 11	Cyperaceae
Fig. 12-14	Ericaceae
Fig. 15-17	Gramineae
Fig. 18	Rosaceae 20 μ x 17 μ
Fig. 19	Rosaceae 40 μ x 28 μ
Fig. 20	Scheuchzeriaceae 45 μ x 30 μ
Fig. 21a, 21b	Typhaceae, Typha latifolia

PLATE VIII

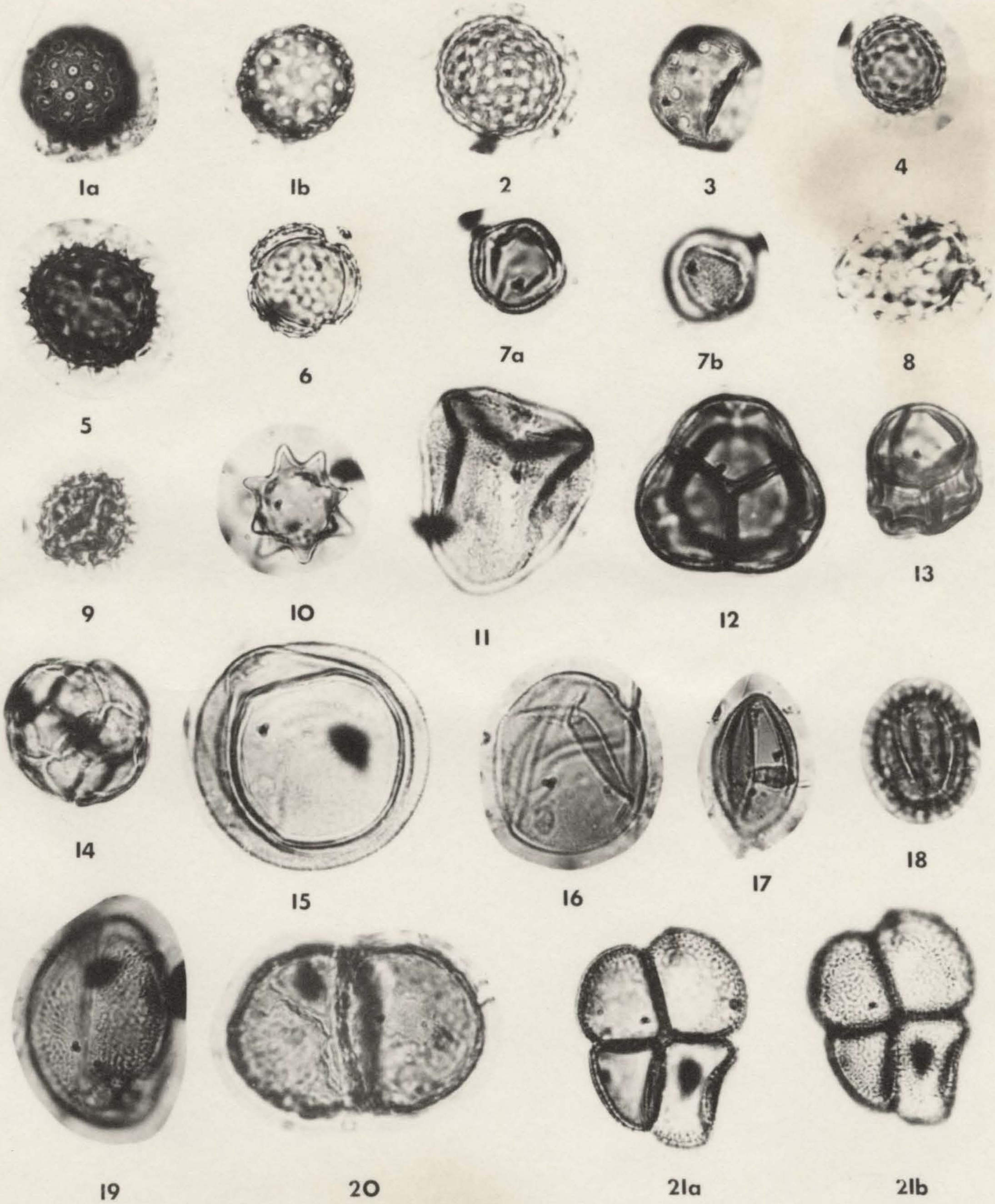

PLATE IX

Spores found in Parry Sound bog (Mag. 1500X)

Fig. 1	*Osmunda* sp. 30μ
Fig. 2	*Osmunda* sp. 60μ
Fig. 3	*Equisetum* sp.
Fig. 4	*Athyrium* sp. $45\mu \times 35\mu$
Fig. 5	*Asplenium* sp. $48\mu \times 30\mu$
Fig. 6	Trilete spore 23μ
Fig. 7a, 7b	*Lycopodium* sp. 45μ
Fig. 8a, 8b	*Lycopodium inundatum*
Fig. 9	*Drosera* sp. Distal end about 45μ
Fig. 10-13	*Sphagnum* sp.

PLATE IX

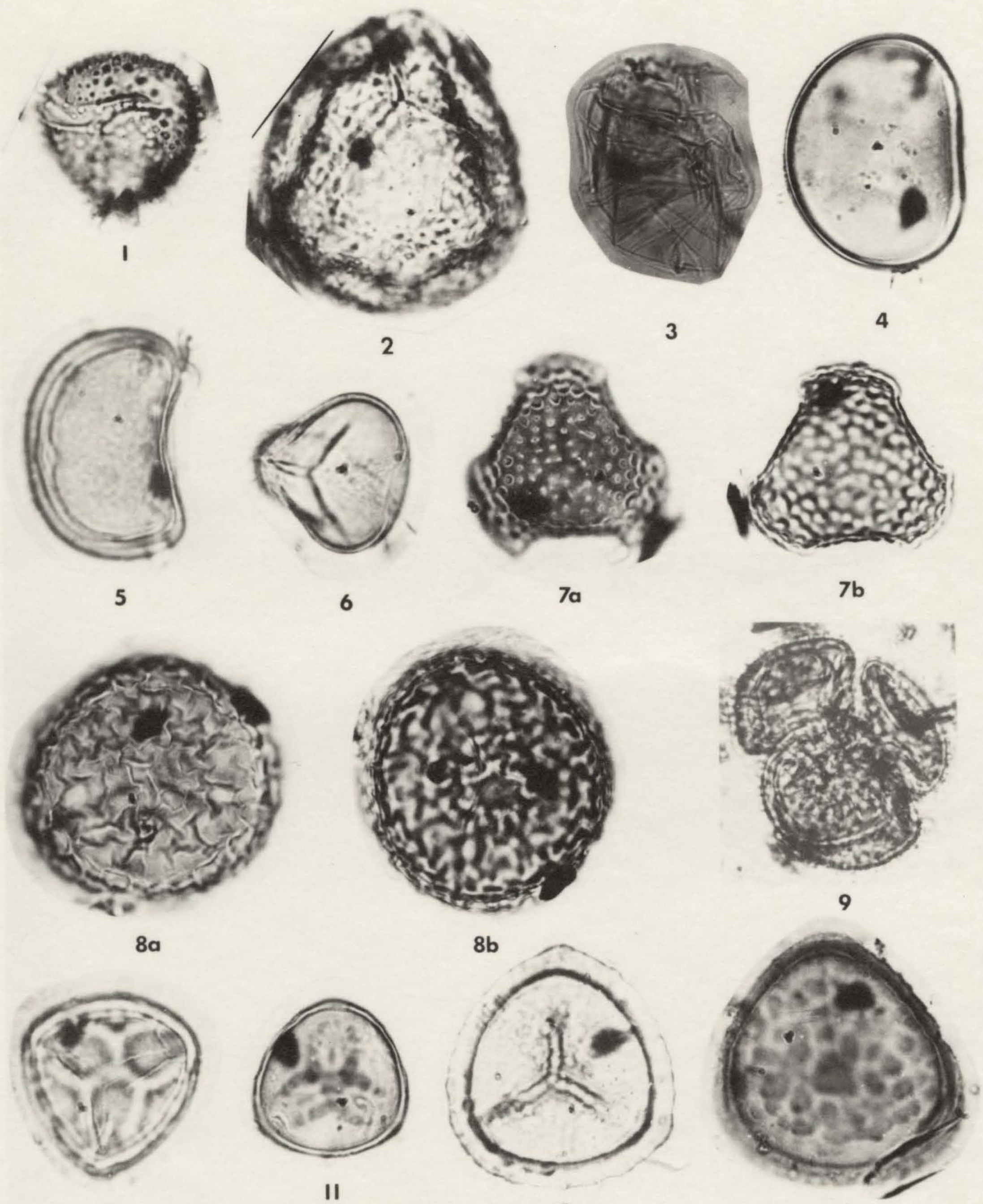

PLATE X

Spores and miscellaneous findings

Fig. 1-6	*Sphagnum* sp.
Fig. 7a, 7b	*Lycopodium clavatum*
Fig. 8, 9	Fungal spores
Fig. 10-16	Unidentified findings

PLATE X

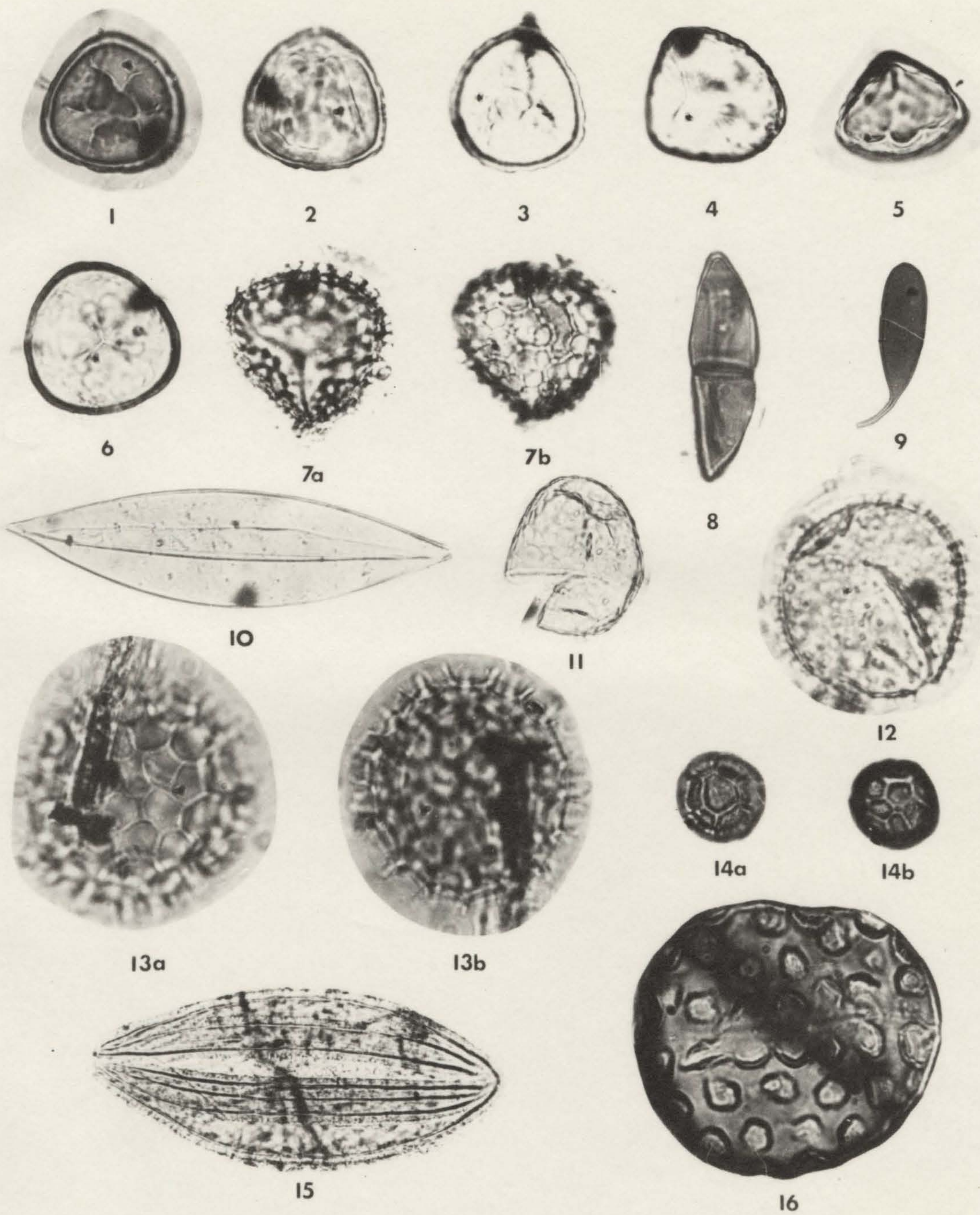

PLATE XI

Miscellaneous unidentified findings

Fig. 1, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17. Mag. 1500X

Fig. 2, 3, 4, 18. Mag. 600X

Fig. 5, 6, 11. Mag. 800X

PLATE XI