A PALYNOLOGICAL STUDY RELATING TO THE TORONTO FORMATION

A PALYNOLOGICAL STUDY RELATING TO THE TORONTO FORMATION (ONTARIO) AND THE PLEISTOCENE DEPOSITS IN THE ST. LAWRENCE LOWLAND (QUEBEC)

BY

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SCOPE AND CONTENTS:

The aim of this study is to establish the age of the Toronto formation. The investigation was planned in three parts; the first dealing with field work and analytical methods, the second with fundamental pollen morphology, and the third with implications of palynological studies in related fields.

The warm climate beds of the Toronto formation were found to be of the Sangamon age.

Methods have been developed for exploring Pleistocene sediments, other than peat, for microfossils.

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General view of the Pleistocene deposits underlain by
Ordovician shale in the Don Valley Brick Yard.

I INTRODUCTION

1. Historical Note

The Toronto formation is well known to students of Pleistocene geology and paleobotany. R.F. Flint characterized it as " the most remarkable interglacial sequence yet uncovered in North America." Beds of this formation are exposed at the city of Toronto, Ontario, and have been studied for almost a century, particularly by A.P. Coleman whose investigations of them extended over fifty years. The Toronto deposits are of great interest in many respects. They contain the most complete organic record of warm interglacial conditions so far studied on this continent, but their stratigraphic position is as little known as it was when these deposits were first studied. The section is important because of its climatic implications, for the flora and fauna of the interglacial beds indicate extensive deglaciation.

Information about the Toronto formation is found scattered through the geological literature, beginning with Sir Charles Lyell's brief description of fine terraces in the backwoods of the "little city", about a hundred years ago. In a publication by the Canadian Geological Survey - Geology of Canada, 1863 - one finds a statement that freshwater shells were found in the banks of the Don, beneath a considerable thickness of sand, at about thirty feet above the level of the lake. In the same publication, Henry Youle Hind is quoted to the effect that in digging wells in Toronto, trunks and branches of trees had been found imbedded in the overlying yellow clay at depths ten to twenty feet below the surface.

However, many years passed before the real importance of the discovery of wood and shells along the Don River was recognized. About 1890 when the city undertook the task of straightening the curves of the Don River, fine sections of the drift were exposed along the river. A nature student, a printer named J. Townsend, was attracted by the fossils and started a collection of shells and bits of wood from the beds of sand and clay exposed during the work. He also collected some fragments of leaves which were sent to Sir William Dawson in Montreal for identification. This collection of leaves was finally examined by D.P. Penhallow of McGill University. Over a long period of years the Pleistocene geology of the Toronto formation was studied by A.P. Coleman who, however, was unable to establish the correct stratigraphic position of the beds. The interglacial beds of the Toronto formation have at different times been placed in the Sangamon, Yarmouth and Aftonian interglacial of the Pleistocene sequence. During recent years the Pleistocene geology of the Toronto formation and the Toronto region has been studied by A.K. Watt of the Ontario Department of Mines and by A. Dreimanis of the University of Western Ontario.

2. The Problem

Excavations for the Toronto Rapid Transit Subway exposed several sections of the Toronto formation which contained beds of sand with abundant plant debris. Samples of this material were collected and sent to Dr. N.W. Radforth of McMaster University for examination. The writer was entrusted with the task of investigating its plant fossil content. The object of this investigation was to study the fossil assemblage and to establish correlation with the sections of the Toronto formation exposed in the Don Valley Brick Yard and along the Scarborough Bluffs.

From this starting point the investigation was extended to the study of the Don beds and the Scarborough beds with a view to investigating plant fossils in these deposits, and making a detailed study of the geological sequence. This step gave rise to the problem of the age of the interglacial Don beds and the relationship of the overlying Scarborough beds and the sequence of tills and varves to the established Pleistocene stratigraphy of Eastern North America.

However, it soon became apparent that more geological and palynological information about the recent, postglacial and interglacial deposits was necessary in order to interpret the results gained by studies of the Toronto formation. For that reason the opportunity to work with the Pleistocene field parties of the Geological Survey of Canada was greatly appreciated. During the summer of 1952 the writer had an opportunity to work on the Wisconsin interstadial and interglacial deposits on Vancouver Island, B.C. and in the Vancouver district. During 1953 similar studies were carried on in the St. Lawrence Lowland and during 1954 the studies were extended to New Brunswick to establish correlation with work carried out in the New England states. These studies supplied valuable information about the different stages of the Wisconsin glaciation and particularly about the nature of the interstadial periods. During the spring and fall of these years the Toronto formation was carefully studied and sampled; the winters were used for laboratory work.

In establishing a picture of our general knowledge of the Pleistocene events in the Great Lakes area, Flint (1953) states,

> "The later history of the St. Lawrence Valley and the region north of the Great Lakes are so little understood at present that in these areas great future improvements in our knowledge can be expected."

This is, unfortunately, true not only for the region mentioned, but also for the greater part of all Canadian territory. Our knowledge of the Late Wisconsin events is inadequate, but our knowledge of the earlier Pleistocene time is even more so. In another outline Deevey (1949, p. 1353) states,

> "... but it also happens, that our knowledge of interglacial deposits is extremely meager. The wealth of information on Pleistocene climatic and other environmental conditions and on past ranges of species available to European workers is almost missing in North America. This inadequacy, part of the larger difficulty that there is no real Pleistocene stratigraphy except in a local sense, is the greatest existing obstacle to progress in Pleistocene research... ."

Further, Deevey states that,

"Information on North American interglacial fossil floras, especially of fossil pollen is astonishingly deficient" (p. 1353), and he feels that, "as most of the known sections are incomplete, microstratigraphical methods would seem almost imperative for correlation, yet they are almost never used."

A three point objective was set up as the aim of this study: first, to find an answer to the above quotations by Flint and Deevey and to make a contribution to our present knowledge of the Pleistocene events in Canada by establishing the age of the Toronto formation; second, to find methods of exploring sediments, other than peat, for microfossils and to establish the principles for utilisation of Canadian Pleistocene microfossils in this kind of study; third, to demonstrate the implications of a palynological study of this kind in related fields.

3. Definition of Palynology

The writer feels justified in discussing briefly the meaning of palynology, because palynology as a science is comparatively young and not widely understood in the broad field of research. Nevertheless, the study of pollen goes back to the seventeenth century, three papers concerning it being published before 1700. These early papers have to do mainly with pollen morphology.

In palynology, fundamental study relates chiefly to the walls of pollen grains and spores (regardless of the age of any particular pollen grain or spore) and to a less extent with their protoplasm content. This study is primarily morphological, descriptive, and developmental, and an elaborate terminology has been developed to describe it (cf. recent papers by G. Erdtman in Sweden, J. Iversen in Denmark and R.P. Wodehouse in the United States).

Palynology is divided into basic and applied. Basic palynology is related to cytology, genetics, morphology, physics, chemistry and other brances of science. To basic palynology may also be referred investigations of pollen and spore dispersal, preferably by wind and water, and of the pollen and spore content of peat and other sediments under formation. Through investigation of the latter kind are forged keys for unlocking certain problems of applied palynology, the history of plants and plant communities through the ages. Applied palynology also comprises research into phytogeography (botanical pollen analysis), geology (geological pollen analysis), climatology, glaciology, limnology, oceanography and pedology including recent research on organic terrain in the Arctic (Radforth, 1952, 1953). Similarly archaeology and zoology approach palynology in certain aspects of the dating of artifacts, skeletons ect. The importmant aerobiological aspects of palynology are subject to investigation mainly in connection with researches into hayfever and fungus spore dispersal.

Applied palynology for geological purposes has for the most part been used for stratigraphical correlation. The finding of different pollen grains and spores in beds of different age or the use of the assemblage of microfossils specific to a particular horizon, has successfully established correlation between separate sections. Microfossils are particularly useful because they are produced in great numbers and are therefore distributed much more uniformly through a layer than the megafossils. In addition, the worker can find sufficient numbers of microfossils in a small piece of rock or sediment, whereas much more extensive study is necessary to reveal enough megafossils for a satisfactory result. Microfossils can easily be obtained from samples taken from a drill core.

One other aspect deserves mention. In a particular layer of sediment one usually finds abundant megafossils of plants that grew in that particular area. Microfossils usually represent a much wider area, as many of them were distributed by wind, thereby revealing information about the vegetation of a relatively large area. It is easier to use applied palynology for more recent geological periods because pollen grains and spores can be related to the plants from which they originate and one can interpret the climatological and environmental conditions during that time. This often gives useful information when the formation of sediments is under consideration. An excellent example is the recent organic terrain studies carried on by N.W. Radforth (1952, 1953 and 1954) in the Canadian north, where an appempt is being made to utilize potential microfossils in relation to the formation of peat and modern vegetation units.

In Paleozoic strata (Ordovician, Silurian) plant megafossils become gradually very scarce, but the rocks still contain workable amounts of plant microfossils (Radforth and McGregor, 1954). Even in Mesozoic rocks where both megafossils and microfossils are relatively abundant, it is often easier to utilize the microfossil assemblages (Radforth and Rouse, 1954).

Working backwards through geological time, we gradually lose the relationship between plants and the pollen grains and spores produced by them. This is due to the relatively small amount of work that has been done so far on the problem and to the fact that the plants from which these pollen grains and spores originate are now extinct. These difficulties force a palynologist to use plant microfossils without knowing their relationship to the parent plants. Elaborate artificial classifications of fossil spores have been proposed by several workers.

Important facts about interrelations between applied palynology and plant taxonomy have been pointed out by Erdtman (1952), who wrote:

" The broad contact between applied palynology and plant taxonomy does not call for introductory comments. A cautious approach to this field may be made through investigations showing whether taxonomical amendments on a megamorphological base can be confirmed by palynological evidence or not. The evaluation of palynological criteria should be equally critical and cautious in more or less advanced investigations: the pollen grains in related genera are usually more or less of the same type, but striking exceptions occur / cf. e.g. Anthotium - Leschenaultia (p. 191) and Larix - Pinus; the pollenmorphological discrepancy between the last two genera is, however, not inexplicable in the light of recent experience/. Another reason in favour of a critical attitude is the fact that pollen grains of more or less the same type (as far as can be judged from investigations by means of an ordinary microscope) are sometimes found in plants supposedly not closely interrelated. Thus a counterpart to the queer pollen type in Limnanthes (p. 241) is met with in the Connaraceae - Jollydoroideae and the pollen grains in Adoxa are similar to those in Cynomorium.

On the other hand more than one pollen type will be found in certain genera / e.g. in Abelia (p. 97 - 99), Anemone (p. 372), Centaurea, Cneorum (p. 114), Morina (p. 152), and Symplocos (p. 424) /. In these cases the different types are usually each confined to particular sections of the genera. Several types of pollen grains may even be produced by a single species. Examples: the dimorphic pollen grains of certain plumbaginaceous plants (p. 325); further Primula farinosa (Fig. 197 B, p. 338) and P. veris (Fig. 197 D); the two pollen types in this species differ not only in size but as a rule also in shape and aperture number. Other examples of plants with several pollen types, though merging into each other, have been mentioned e.g. by Bremekamp. Thus in Thunbergia grandiflora 'spiraperturate' and 'zonaperturate' grains were found in one and the same flower (Bremekamp, 1938, Fig. 2, p. 143), whereas in another acanthaceous plant, Dicliptera javanica, eight pollen types were found in one and the same anther. These were more or less different inter se in polarity, symmetry, aperture number (2 - 6) and shape but apparently not in exine stratification and patterns (Bremekamp, 1942, Fig. 15, p. 189). "

The chance of finding microfossils has proved to be far greater than that of finding megafossils (Radforth and McGregor, 1954). If pollen and spores can be related to their parent plants, the development of those plants can be followed through geological time. The difficulty is that during the long period of evolution many plants have died out and new ones have taken their place. Pollen grains and spores are found separated from their parent plants and even if macroscopic plant remains are found the relationships are difficult to establish. A knowledge of the pollen and spore morphology of modern plants is important as a basis for paleobotanical speculations.

Nevertheless, paleobotanists have as a rule not paid much attention to fossil remains and potential fossils in Pleistocene and recent deposits. Stumps and stems of ferns and conifers - hundreds of millions of years old - have been treated with respect whereas fossils buried in Pleistocene strata for only five or fifty thousand years have frequently been neglected; paleobotanically speaking, the latter have not yet come of age. However, to make the record complete, to trace the history of plants from the present day to remote ages, botanists should first study the present, living plants, then actuopaleontology (i.e. the transformation of living substance into fossil) and finally, paleontology itself, beginning with the most recent fossils proper. Until this has been accomplished, wide gaps will remain between our knowledge of Pleistocene and recent fossils, gathered by plant geographers, Pleistocene geologists and others, and that of older fossils supplied by paleobotanists.

Referring to gaps, it should also be pointed out that our paleobotanical knowledge has so far been chiefly derived from the study of megafossils (relatively large fossils: trunks, leaves, fruits, seeds etc.). Due attention should, however, also be paid to the study of microfossils such as pollen grains and spores. Recognition of the importance of palynology as an auxiliary paleobotanical science is gradually increasing. The ideal development of paleobotany would be to secure, as far as possible a continuous record of plant microfossils as well as megafossils back through the ages.

II GENERAL GEOLOGY AND SOME BOTANICAL ASPECTS OF THE AREAS WHERE THE STUDIES WERE CARRIED OUT

1. Pleistocene Stratigraphy

As the geological and botanical background has to be closely considered when interpreting the results of pollen analysis a general description of this background relative to the areas where the studies were carried out seems to be justified.

In Eastern North America where the Pleistocene stratigraphy has been worked out most fully, the following sequence of Pleistocene events has been discovered so far.

Glaciation	Interglacial stages
Wisconsin	
	Sangamon
Illinoian	
	Yarmouth
Kansan	
	Aftonian
Nebraskan	

The most recent stage of glaciation, the Wisconsin, has been further divided into substages.

		Postglacial
	Mankato	
		Two Creeks interval
	Cary	
Wisconsin		Interval
	Tazewell	
		Interval
	Iowan	

The Pleistocene stratigraphy will be analysed in detail in the last chapter of this thesis. Here the discussion will be limited to the broader geological aspects, starting with the Toronto district.

1A. Pleistocene Deposits in Southern Ontario

The Pleistocene deposits in Southern Ontario are underlain by Paleozoic sedimentary rocks slightly dipping towards the south. In the Toronto area the bedrock consists of interbedded shale and limestone of the Upper Ordovician Dundas formation. According to L.J. Chapman and D.F. Putnam (1951) about sixteen per cent of Southern Ontario is covered by shallow overburden and the surface features are those of the underlying rock. The remaining parts of the area are covered by Wisconsin till or other sediments of the same or more recent age. The most recent till rests either on bedrock or on the residue of the unconsolidated drift left by previous ice advances. Deposits older than the most recent till are exposed at many places in the shore cliffs of the Great Lakes and in many stream banks and road cuts. Having been overridden they are often compacted and the stratified beds are usually contorted. For example, older till sheets and interbeds are well displayed in bluffs along the Lake Erie shore west of Port Dover. The valleys of Big Creek, Otter Creek, Kettle Creek and other smaller streams which dissect the adjacent plain also provide some magnificent sections. One exception to the shallow-covered bedrock of Southern Ontario constitutes a massive ridge of glacial drift extending east-west through the counties north of Lake Ontario. According to Chapman and Putnam,

> "It forms the drainage divide south of Scugog and Rice Lakes and extends from the Niagara escarpment in Caledon township to the Trent Valley. At its deepest in King township there is roughly 800 feet of overburden piled up upon the bedrock. That the bulk of it is of Pre-Wisconsin age is apparent from the discovery of older beds in gullies along the upper slopes of the ridge, and in deep road cuts. The earlier glaciers must have followed the same route as the latest one whose record is so much more complete."

At Toronto the Thickness of the drift varies from ten to fifteen feet along the lake front west of the city to more than 400 feet north of Toronto. A well drilled in 1908 passed through 650 feet of drift, the surface elevation of this boring being about 650 feet above sea level (Watt, 1953). This boring penetrated one of the numerous glacial or interglacial valleys present in the area. Although the position of these valleys is definitely located in places, parts of their courses are still unknown. They tend to underlie and perhaps partly control the present drainage system. Municipalities in the Toronto area which use ground water have wells that are invariably in these buried valleys.

The most complete succession of Pleistocene strata is exposed at Toronto, in the Don Valley Brick Yard and in the Scarborough Bluffs along Lake Ontario, constituting an excellent section through the Toronto formation.

Although considerable work has been done on the Pleistocene geology of Southern Ontario, the sequence of Pleistocene events found here has not yet been successfully correlated with the similar sequence in the adjoining States.

13. Pleistocene Deposits in the St. Lawrence Lowland

In the St. Lawrence Lowland the Pleistocene stratigraphy is not well known. During recent years important information has been disclosed by the studies of N.R. Gadd, although an account of this work has not yet been published. In the Lowland two distinct till sheets are present, with interglacial deposits between them. These interglacial deposits are exposed in excellent sections where layers of peat are found. A major moraine has been traced from Quebec City to almost the northern end of Lake Champlain. The last major ice advance was followed by a marine invasion (the Champlain Sea); at the same time a minor ice advance occurred and the end moraine has been studied and traced for some distance. The marine deposits are overlain by river sediments and the sequence of Pleistocene deposits has been subsequently eroded by the present drainage system.

The study of the interglacial deposits in the St. Lawrence Lowland has provided information about the nature and the relative length of this interval and the results have been used for establishing a more complete picture of the Late Wisconsin intervals.

Correlation between the Pleistocene stratigraphy in the St. Lawrence Lowland and that in the United States has not yet been worked out with certainty. However, these studies have been useful for the correct interpretation of the results of studies of the Toronto formation.

10. Pleistocene Deposits in the Vancouver District

On the west coast, at Seattle, the following sequence of Pleistocene events has been disclosed by the studies of W.J. Stark and D.R. Mullineaux (1950). A basal till (the Beacon till) lying on Tertiary bedrock is overlain by interglacial deposits (the Duwamish formation). These interglacial deposits are covered by another till sheet (the Klinker till) which is followed by the Lawton formation that is overlain by the most recent till (the Vashon till).

On Vancouver Island two distinct till sheets have been found, separated by interglacial deposits. The lower till has been called the Admiralty till and the upper one has been correlated with the Vashon till. Much additional information on the sequence of the Pleistocene deposits on the Vancouver Island has been obtained by John Fyles, but has not yet been published.

On the mainland at Vancouver similarly two till sheets separated by interglacial beds, have been discovered in the Point Grey formation. In the Fraser Valley several probable till sheets have been penetrated by drilling through the thick Pleistocene deposits. The general sequence of Pleistocene events in the Vancouver district is being developed by J.E. Armstrong of the Geological Survey.

2. Botanical Aspects

As the most logical starting point for a discussion of ancient vegetation and climates is the present situation, one tries to compare the plant communities of the present in a particular area with ancient plant communities of the area and so reconstruct the changes in vegetation and climate of the past. When reconstructing past changes in climate in the temperate zone, changes in forest types form the basis of decision; therefore, knowledge of present forest types in specific areas is the standard norm against which theories based on investigations of ancient forests in these same areas are to be measured.

The forest classification used in this thesis is that of W.E.D. Halliday (1937). The scientific names for the coniferous and deciduous tree species can be found in Halliday (1937) and in the Native Trees of Canada (1950).

2A. Botanical Aspects of the Ontario Region

The Toronto region is at or very close to the boundary between the Deciduous Forest Region and the Great Lakes - St. Lawrence Forest Region. The following description of these regions has been given by Halliday.

Deciduous Forest Region.

D1 Niagara Section.

The rather low-lying portion of the Ontario peninsula, enclosed by Lakes Ontario, Erie, and Huron, reaches the most southerly latitudes in Canada. This area enjoys very favourable climatic and soil conditions, which allow for the sole distribution in Canada of many Deciduous species.

The associations are predominantly composed of broad-leaved trees. A large number of these species, many of small size, find their northern limit here. Amongst these are chestnut, tulip tree, mockernut and pignut hickories, chinquapin, chestnut oak, scarlet oak, black oak and pin oak, black gum, blue ash, magnolia, pawpaw, Kentucky coffee tree, redbud, red mulberry and sassafras. In addition, within this section is the main distribution in Canada of black walnut, sycamore, swamp white oak, and shagbark hickory, together with the more widely distributed butternut, bitternut hickory, rock elm, silver maple and blue beech. All these species occur as scattered individuals or groups, either on specialized sites or within the characteristic association for the section. The association, made up of widely distributed broad-leaved trees common in part to both the Great Lakes - St. Lawrence and the Deciduous Forest Regions, consists primarily of beech and sugar maple, together with basswood, red maple, and (northern) red oak, white oak, and bur oak. The presence of the species listed above and the predominance of beech within the characteristic association, show a definite relationship to a centre of distribution indicated by the position of Ohio. Coniferous species are poorly represented; widely scattered hemlock occurrs within the characteristic association; on the lighter soils are small local areas of white pine, often with an undergrowth of black oak and scarlet oak, and there is some red juniper, generally on poor gravelly sites.

Owing to the influence of climate, vegetation and the underlying rock fertile soils have developed.

Great Lakes-St. Lawrence Forest Region. L1. Huron-Ontario Section.

This takes in the main body of the Ontario peninsula, extending from Lake Huron and the southern portion of Georgian Bay to Lake Ontario. With it is also included Manitoulin Island.

The topography is somewhat irregular, with a marked rise in altitude to the west culminating in the highlands south of Georgian Bay. The bedrock is overlain by glacial deposits and the west and east boundaries are, in part, modified by wave action and lacustrine deposits from glacial Lakes Algonquin and Iroquois and some marine deposits from the Champlain Sea.

The prevailing association is broad-leaved, but there is a reduction in number of species. Sugar maple and beech are dominant, comprising about three-quarters of the forest. With them are basswood, white elm, yellow birch, white ash, and some red maple, and (northern) red oak, white oak, and bur oak. Small groups of hemlock and balsam fir and an occasional white pine occur within the association, as well as a scattered distribution of large-toothed aspen, bitternut hickory, butternut, ironwood and black cherry; and blue beech, silver maple, slippery elm and rock elm, and black ash are found locally on specialized sites such as river bottoms and swamps. In the southern parts, there is some intrusion of black walnut, sycamore, and black oak; white and red pine stands are found on lighter soils and were formerly more common; red juniper is present on gravelly soils and eastern white cedar in swampy depressions. After fires, aspen, principally large-toothed, and white birch often form secondary associations.

The northern boundary or line of contact with the altered limestones of the Precambrian Shield is of importance ecologically as determining to a greater or less extent the northern or southern limits of many species. Jack pine, for instance, does not come south of this line, and sycamore, butternut, and bitternut hickory do not go north of it (Halliday, 1937).

2B. Botanical Aspects of the St. Lawrence Lowland and Northern Ontario.

Between the Laurentian Plateau to the north and its outlier, the Adirondacks, and the Alleghenies to the south, is a well-marked valley or lowland through which the waters of the Great Lakes system drain. This valley, of flat-lying Ordovician and local Cambrian limestones, is covered with Pleistocene deposits.

The upper part of these lowlands, extending from east of Montreal to reach some distance up the Ottawa River Valley to the west, comes under this section, which also continues south into the United States by the Champlain Valley.

Though the general character of the tree cover is broad-leaved, there is a fair representation of coniferous growth which, previous to settlement, was probably more extensive. The dominant association is made up of sugar maple, and beech, together with small quantities of yellow birch, white elm, red maple, basswood, white ash, (northern) red oak, white oak, and bur oak and large-toothed aspen, with a local occurrence of rock elm and blue beech. In the immediate river valleys there is some local distribution of butternut, cottonwood, and slippery elm, with the intrusion, up the Champlain Valley, of shellbark hickory. With the general association are patches of hemlock, white spruce, balsam fir, and some white pine; and on light soils as association of white pine and red pine, now as second growth stands, is relatively common. In poorly drained depressions small areas of either tamarack, eastern white cedar and black spruce, or black ash are found, and clumps of eastern white cedar are often characteristic of poor stony sites. After fires, second growth of aspen, mainly large-toothed, and white birch with balsam fir and white spruce are often found. Both this and the preceding section are noteworthy for the very rich vegetation, particularly of spring-flowering herbs, to be found on the forest floor.

Over most of the section, brown forest soils are present.

L3. Lower St. Lawrence Section

The eastern part of the valley described above comes under this heading. The lowlands narrow down to the east, and the boundary on the north side of the river is only a short distance below Quebec City. On the south side it continues for some distance along the river flats.

A mixed forest prevails, showing influence of the Boreal Forest Region. The principal association is made up of sugar maple, hemlock, white pine, and yellow birch, with considerable balsam fir and white birch and scattered white spruce, the latter three all being boreal species. In these are distributed some silver maple, (northern) red oak, beech, white ash, butternut, red pine, and white elm. Aspen and white birch are relatively common after disturbances; cottonwood and red maple are found on river banks, and swamps provide suitable sites for black spruce, black ash and eastern white cedar. The soil type is predominantly podsolic.

L 4. Algonquin - Laurentian Section

This quite extensive section takes in the Georgian Bay district, the Algonquin Highlands, the upper Trent Valley, the upper course of the Ottawa River and the lower slopes of the Laurentian mountains including the valleys of the St. Maurice and Gatineau Rivers.

The whole section differs fundamentally from the preceding ones in the Great Lakes - St. Lawrence Forest Region in that the bedrock is part of the Precambrian Shield consisting largely of crystalline limestone, schists and gneisses and granitic intrusives. The topography is rough and irregular. Glacial deposits cover the greater part of this section. In addition there are some lacustrine deposits from the Nipissing Great Lakes and Lake Algonquin.

In this section white pine probably reached its maximum development in Canada, but extensive lumbering and fire have removed the greater part. Red pine has also been a prominent species, especially on the Algonquin Highlands. In spite of the previous dominance of these species and the presence of intrusive conifers from the Boreal Forest Region, the general character is that of a mixed forest, and the dominant or competitive association is one of sugar maple, yellow birch, hemlock and white pine. In addition are varying amounts of basswood, white spruce, balsam fir, beech, (northern) red oak, elm, white ash, red maple, ironwood, white birch, and large-toothed aspen. Throughout the section areas of hardwood occur on ridge tops and on heavier soil. Black spruce, tamarack and eastern white cedar are found in swampy depressions.

In the eastern parts, the general mixed association grades northward to the Boreal Forest stands of the Central Transition and Northeastern Coniferous sections, with yellow birch as the surviving hardwood, which becomes more scattered and stunted in its growth.

To the west, along the shores of Georgian Bay, is a special area or "shore type" developed on the rather rocky, thin soil. Jack pine, of an open clumpy nature, is dominant, together with aspen, white birch, red oak, red maple, white spruce, black spruce and white pine and red pine, all showing poor form and size.

2C. Botanical Aspects of the Coast Forest Region

Vancouver Island and the Vancouver region on the mainland fall into the Coast Forest Region and are covered by sections C 1 and C 2. The following description has been given for these sections by Halliday (1937, p. 26).

C 1. M a d r o n a - O a k T r a n s i t i o n S e c t i o n

On the islands of the Strait of Georgia, the adjancent east coast and southernmost part of Vancouver Island, and at scattered points along the mainland shores occurs the only distribution in Canada of two species, the madrona and the Garry oak. Of these two the latter is almost entirely confined to the southeast part of Vancouver Island. The madrona occurs as a characteristic subclimax tree with associations of western red cedar, western hemlock and a much more widely distributed species, the Douglas fir. Garry oak tends to form pure associations or groves, but is also found scattered in other associations. On alluvial soil red alder is common, and broad-leaved and vine maples have a general distribution.

C 2. S o u t h e r n C o a s t S e c t i o n

The southern part of the Coast Forest, extending over most of Vancouver Island and the British Columbia mainland north to Knight Inlet, is included in this section. The eastern boundary is, for the most part, the higher elevation of the Coast Range (approximately 4500 feet), where alpine tundra, bare rock or permanent snow and ice conditions are encountered.

The main association comprises the two Coast Forest dominants, western red cedar and western hemlock, in combination with Douglas fir and scattered western white pine (report by British Columbia Lands Department, 1923). At a higher elevation amabilis fir and mountain hemlock are present, with alpine fir increasing towards the tree line. Black cottonwood, red alder, broad-leaved maple and grand fir occupy alluvial bottom land, the last species being restricted to this section. There is a small scattered representation of Sitka spruce at low coastal points.

A knowledge of the vegetation and the pollen and spore assemblage produced by plants of a given area together with the environmental requirements of individual plant species, makes it possible to establish whether a particular microfossil and megafossil composition of the same locality but of a different age is similar to or different from the present. If the composition of the vegetation in different directions from the locality under observation is known, one may be able to trace the migration of some plants and to establish the possible changes in the climate during the past.

In climatological discussions based on the study of pollen grains and spores in ancient deposits the present knowledge of major forest units or regions and ecological studies of plant communities are very important.

III FIELD WORK AND LABORATORY METHODS

1. Collection of Samples and Preservation of Material

The palynological study of sediments consists of two main aspects, the field work, during which the stratigraphy of the deposits is studied, types of sediment closely investigated and samples taken for the other aspect of the study, the laboratory work.

As a wide variety of materials, ranging from glacial till and outwash deposits to peat and lichens, has been used for this investigation, new methods for field work and laboratory treatment of samples had to be worked out. It has been the view of the writer that a great deal of reliability of the final results depends on the first step in the procedure, the field study of deposits and the sampling, as well as on the proper laboratory treatment of samples.

The first and foremost requirement for samples is that they must be free of contamination. Carelessly taken samples often prove worthless and may be a source of error if used.

Whenever possible open faces of sections have been used for collecting samples. This speeds up the sampling procedure, decreases risk of contamination, and enables one to get a much more complete interpretation of the stratigraphy of the section.

In any case the stratigraphy of the section was recorded as accurately as possible in order to help the later interpretation. In order to arrive at a correct result, geological and botanical evidence must be considered in conjunction with the pollen and spore assemblage. To obtain this evidence as much information as possible was recorded at and near the sampling locality.

The part of the section from which samples were to be collected was cleaned first by scraping or cutting horizontally, partly to reveal the fine stratification if present, and partly to prevent contamination with material from different levels. If more or less consolidated material was encountered a piece of it was chipped or cut out with a knife. When a bed or a sequence of considerable thickness was to be sampled, small samples were taken at different levels in order to study the possible change of composition of vegetation during the time that this bed was deposited. Representative channel samples have not been used for this study. Occasionally cores through the whole thickness of a layer were preserved for later detailed study. These cores were usually cut into sections and preserved in bulk ice cream cartons (Sealright cartons, round type and waxed inside). Ice cream cartons have proved very useful also when larger samples of peat or other material were taken. In this way soft material is not deformed or compressed with the result that it can be more easily studied later; delicate structures are not crushed and the tight sealing of cartons prevents moulding of material. On some occasions wax paper and canvas bags were used to preserve large samples.

A peat bed in a section at Nanoose Bay, Vancouver Island, B.C., was sampled by John Fyles in the following manner. A core was cut through the peat layer, then the core was cut into sections and each section was strapped on a piece of board on which the top and bottom of the sample were indicated. The sections of the core were wrapped in canvas and shipped in a wooden box. All samples arrived well preserved and intact.

Sampling postglacial peat bogs and lake sediments is in many ways different from sampling older Pleistocene deposits. The main difference is that these postglacial deposits in general are unconsolidated and risk of contamination during sampling is greater. This is due to the considerable water content of the material and the softness, which tends to make the work more difficult. Forceps with smooth ends were used to take samples of medium and poorly decomposed peat and a spatula or even a table knife, when highly decomposed peat and lake sediments were concerned. For this study samples were obtained by the Hiller and Davis type peat borers and from open sections. The Hiller and Davis samplers have been described in Faegri and Iversen (1950) where also the method of working with them has been discussed in detail.

From the practical working point of view the Hiller sampler is much more satisfactory than the Davis sampler. The Hiller sampler has a more durable construction and stands up better in all kinds of sediment, the Davis sampler proving useless in poorly decomposed, loose peat and compact inorganic lake sediments. If samples are to be taken at regular intervals of ten, five or one cm, the Davis sampler is unsatisfactory because of the unequal compression of the sample core. If only "foot-levels" or approximate intervals are used the Davis borer is quite adequate. The Davis sampler is, of course, not as heavy to carry as the Hiller sampler. Other types of ordinary hand-augers, used for work on Pleistocene deposits, are of little use, for one reason or another.

Most of the small samples, collected for this study, have been preserved in cellophane or polyethylene bags (size two by six inches). A numbered label was first inserted in the bag and the bottom part was folded. Then the sample was placed in the bag and the rest of the bag was folded around the label and the sample so that the number on the label could be read without unfolding. Preserved in that way, the samples dried slowly and no noticeable damage was done to the material. This method proved to be very satisfactory as the bags are convenient to carry and the labels can be put into the bags beforehand, thus saving time when taking samples.

For a few open sections of peat, glass tubes open at both ends and sealed with waxed cork stoppers were used. In this case the stoppers were removed, the tube pushed into the face of the section and one stopper replaced, the tube was thenwithdrawn and the core in it was sealed with the other stopper. This procedure avoids contamination of material but is difficult to use in poorly decomposed peat.

For a number of samples from bogs small vials (twelve by sixty mm) with cork stoppers were used with success. For this special experiment the vials were stored in fifteen mm deep holes drilled into wooden blocks, each block holding fifty vials in three rows. Twenty-four of these blocks with vials were fitted into a solid wooden box. Samples of material were inserted into vials with forceps. Numbers were written on the cork stoppers. In this way the samples were carefully preserved and appropriately organized. Continuous series of samples preserved in this way are very instructive for demonstrations and for further laboratory work, as the sediment is kept moist. This method of preserving samples is easy to use if the sampling locality is near transportation.

For some samples of undecomposed peat and lake bottom sediments, larger test tubes (35 by 120 mm) with waxed cork stoppers were used. For <u>Sphagnum</u> peat, two methods of sampling were tried. A handful of growing <u>Sphagnum</u> moss was placed in one tube and into the other tube was squeezed the water from abother handful of the same moss taken twenty cm away from the first handful. No significant diffesence was observed when these samples were examined for pollen and spores and other microfossils. However, the water residue was much easier to work with and a higher degree of concêntration of microfossils was obtained as no considerable amount of moss had to be removed.

There is some controversy among workers in this field as to whether the collected samples should be kept moist until analyses or be allowed to dry. Iversen states, (Faegri and Iversen, 1950, p. 53) that " Recent experiences have demonstrated that samples should be kept moist until analysed, as the more fragile pollen grains are easily destroyed if the sample dries out, and are therefore partly overlooked by subsequent routine analysis." Experience proves that samples that are kept moist are much easier to work with. On the other hand it is questionable whether serious damage is done if the sample is let dry. For testing this troublesome problem a sample of Spagnum peat and a sample of rather highly decomposed Carex peat were divided into two parts. One part was kept moist and the other was let dry completely. All significant microfossils were present with the same percentage in both samples after chemical treatment. No significant difference was observed between dried and moist samples. Of thinwalled pollen grains only Cyperaceae were present in these samples. The fact that there was no difference in this case between dried and moist samples does not mean that under other circumstances difference could not be present.

When samples are kept moist precautions must be taken to prevent moulding by adding a drop of formaline or some other suitable chemical. If possible, samples should be kept moist, but circumstances during field work may render the use of vials impossible, and if such is the case, not too much damage is done if the samples dry out. It is very difficult to keep large samples from drying under field conditions and then it is better to let them dry than to let them become mouldy. From the point of view of sampling and preserving the samples, working close to the laboratory is very different from working a few thousand miles away from it. For this reason the practical, rather than the ideal, possibilities have to be considered very seriously, and one has to make the best of the situation.

Choosing the best location for sampling is important. When interglacial beds are concerned one has to take samples where the bed is exposed at the time. One cannot dig away the extensive slump or overburden. When postglacial peat bogs or lakes are concerned, the possibilities of finding a suitable location for sampling are much better. Experience can help to find the best sampling point on a bog, but test borings should be made to ensure the best sequence of sediments for palynological study. Test borings are time-consuming, but the wisdom of making test borings and profiles through the sediment sequence before taking the final series of samples is proved by the results achieved in laboratory work. How to go about the test boring and profile making has been well described in Faegri and Iversen (1950, p. 54-56).

For determining the depth of lake the Bendix depth finder, a sounding device used by Potzger and Courtemanche (1954), is very useful. So also is the Grenier sampler for getting samples of the top part of soft lake sediments. Unfortunately, these devices were not available for this study.

When the suitable location for sampling has been chosen, samples must be taken at certain intervals. Earlier workers used longer intervals between samples. The so-called foot-levels, taking samples at each foot, have been popular with American workers. One reason for this is the frequent use of the Davis sampler with which distances other than foot-levels are difficult to estimate. Intervals of one foot are much too great. The practical interval of sampling is ten, five, two and a half and one cm depending on the type of sediment and estimated rate of accumulation. Across the contacts continuous core samples are desirable. Taking samples at close intervals has proved to be very profitable when later during analysis a particular part of the section shows important palynological features or proves to have accumulated very slowly.

A few problems concerning the sampling done during this study are of interest.

The writer knows of experience that sampling in rainy weather should be avoided. Rain drops into the sample and contamination is unavoidable, notebooks and paper get wet, the workers get wet, everything is miserable and every-body unhappy.

Sampling during the time of intensive pollen dispersal may also cause a certain amount of contamination of material. If the sample contains abundant pollen this kind of contamination is not important. For example, let us assume that in one unit area of a prepared slide there are 150 pollen grains. If the contamination amounts to two pollen grains on the same surface, it does not change the final picture significantly. On the other hand if in the previously mentioned area there are only five to ten pollen grains and the same amount of contamination, the story may be changed considerably.

On one occasion sampling of lake sediments was tried through ice during winter. A reasonably warm day was selected and everything worked out well except that the sampler became covered with thin ice and was slippery.

2. Chemical Treatment of Samples for Microscopical Analysis

In order to make microscopical examination of samples possible the material must be prepared in some suitable way. Different methods of treatment must be used for different kinds of deposits.

For chemical treatment it is much easier to use material that has been kept moist because it can be broken up and easily attacked by reagents. For this study, however, dried samples often had to be used. All material that was soft enough was put through a fine metal screen and chemical treatment was done on the powdered part of the sample. The interglacial peat and often the well decomposed peat dried so hard that gentler softening methods such as moistening with water, dilute acid or alcohol were useless. In this case the material was crushed down to sand grain size by using an iron plate and hammer, similar to the crushing used for lignites and coals previous to chemical treatment. Crushing was also used for hard, dry inorganic materials.

Hydrochloric Acid Treatment

Whenever the material was found to contain free lime or carbonates in excess, the sample was treated with ten per cent hydrochloric acid solution, washed, centrifuged and further treatment was done on the residue.

Potassium Hydroxide Treatment

The simplest method of chemical treatment of samples is boiling the material in ten per cent potassium hydroxide solution. This treatment disaggregates the sample into individual particles.

For the potassium hydroxide treatment one cc of material was used. The sample was put into a 100 cc Pyrex beaker and twenty to thirty cc of solution was added. The material was stirred and brought to boiling, boiled a few minutes, stirred again and the liquid decanted into a centrifuge tube leaving the coarse residue in the beaker. The coarse residue was then washed with water, the water decanted and centrifuged. In this way most of the coarse plant particles were separated from pollen and spores. Slides were made of the residue in the centrifuge tube.

When the microfossil content of the sample is high potassium hydroxide treatment is the most suitable. This treatment does not destroy any pollen grains or spores. It is quick and easy to use and does not require elaborate equipment. It is usually the only effective treatment that can be used under field conditions.

A very simple method of potassium hydroxide treatment was often used under field conditions. A few cubic millimetres of sample were placed on a slide and a few drops of ten per cent potassium hydroxide solution were added. The material was mixed with a spatula and brought to boiling over a flame of an alcohol burner. Some drops of water were added as it evaporated, and then the liquid part of the mixture was collected under the spatula which was held about two millimetres above the slide and pulled to the corner of the slide. Then the spatula was pulled away from the slide and a drop of glycerine was added and mixed into the liquid. A cover slip was placed on the material and the slide was ready for examination.

Acetolysis Treatment

This treatment was introduced by Erdtman in 1933 and has been described by him in later papers as the method was improved. The basis for this treatment and the working procedure has been described by Erdtman (1943, p. 34-36) and by Faegri and Iversen (1950). The writer used this treatment with slight modifications and the working procedure is now described.

The treatment was started on one cc of material, or less when working with residues from other previous treatments. The sample was placed in a centrifuge tube and if wet, it was first dehydrated with glacial acetic acid, about five cc of acid being used, and centrifuged. Then about six cc of the acetolysis mixture (nine parts of acetic anhydride and one part of concentrated sulphuric acid) was measured into the tube with a pipette. The acetolysis mixture deteriorates after a day or two and must therefore be mixed just before using. The next step was to heat the material slowly to 100° C in a waterbath. It is not practical to have the starting temperature higher than 70° C. The material was kept at the boiling point only a few seconds and was then centrifuged, washed with water, centrifuged again and slides made from the residue. Iversen (1950, p. 63) recommends washing with acetic acid after the tre tment with tha acetolysis mixture to avoid the precipitation of cellulose acetate. No acetic acid is used to wash the residue after acetolysis treatment at Erdtman's laboratory.

Hydrofluoric Acid Treatment

The method was introduced by two Swedish workers, Assarson and Granlund (1924); it has also been described by Erdtman (1943, p. 36) and by Faegri and Iversen (1950, p. 62). For this study the following procedure was used.

Approximately one cc of the sample was placed in a plastic crucible (capacity about 150 cc) and moistened with a few drops of ninety-five per cent alcohol. If the sample contained sand, the sand was removed by repeated decanting at the beginning of the procedure. Alcohol was added in order to keep down the foam that forms when the hydrofluoric acid is added, for a violent reaction may result owing to the high content of fine silicuous material. A small quantity (two or three cc) of hydrofluoric acid was added first and after a few seconds about twenty cc more of the acid was added. The sample was stirred thoroughly and let stand in the fume cupboard for two or three days during which period the material was stirred a few times. This procedure seems to be less drastic than boiling with hydrofluoric acid on a gas flame. After acid treatment the excess acid was decanted and the remainder transferred to a centrifuge tube and centrifuged, washed with about a ten per cent solution of hydrochloric acid in order to remove colloidal silica and silicofluorides, centrifuged, washed with water and centrifuged again.

Bromoform Treatment

The purpose of this tre tment is to separate organic particles from inorganic ones by floating them in a heavy liquid, in this case bromoform. Bromoform was diluted with some acetone to obtain the right separation and acetolysed modern pollen was used for calibration. This method was often preceded by hydrofluoric acid treatment to remove the fine clay fraction from the sample, as very fine particles of mineral matter tend to adhere to particles of organic matter. Working procedure for this treatment was as follows. Approximately one-half cc of sample was put into a centrifuge tube, washed with acetone and centrifuged. Three cc of bromoform mixture (about one part acetone and three parts bromoform of specific gravity 2.85 - 2.90) was added to the sample and stirred thoroughly, then centrifuged at low speed. The top part of the liquid, containing pollen grains, was transferred to another tube by careful decanting, about four cc of acetone w s added, and the liquid was stirred and centrifuged. The residue was washed with ninety-five per cent alcohol and then with water.

Sieving of the Sample

This procedure was used chiefly for poorly decomposed peat. In this case the sample (one cc or more) was boiled in potassium hydroxide first and then washed through a very fine screen or strainer by a jet of water from a washbottle. As also pointed out by Iversen (1950, p. 60) a good concentration of pollen is obtained by this procedure.

Oxidation of Material

This treatment is called chlorination by Erdtman and is frequently used in company with acetolysis. It has been described by Iversen (1950, p. 63) and Erdtman (1943). Iversen points out that " oxidation is very dangerous, because sporopollenins are not very resistant to oxidation." The oxidation was carried out as described by Iversen with the difference that only two to three drops (instead of five or six) of sodium chlorate and three to four drops (instead of one cc) of concentrated hydrochloric acid were used. The reagents were allowed to react upon the material a few seconds only. This difference in the treatment makes it less drastic than when larger amounts of reagents are used.

Maceration of the Sample

For hard, compressed interglacial peat Schulze's treatment and the bromine treatment were also tried. Schulze's treatment consists of using a mixture of concentrated nitric acid and potassium chlorate; the bromine treatment employs liquid bromine. Both treatments were found to be too drastic for peat.

For different sediments the treatments outlined have been used in combination to obtain best results.

Silty material containing few microfossils was first treated with hydrofluoric acid, then by acetolysis and bromoform treatment if such seemed necessary. In the case of samples that were largely inorganic, containing sand and silt and very little organic matter, the laboratory treatment was started on a rather big sample (about 100 - 200 cc). The sample was washed in a 500 cc beaker and the water centrifuged. This procedure was repeated several times. The fine residue received hydrofluoric acid treatment, followed by acetolysis.

Occasionally when coarse organic debris, incorporated in outwash deposits, was to be analysed the procedure was started by sieving the dried sample. Coarse sand was eliminated by washing and decanting. Then the free lime was eliminated by hydrochloric acid treatment and the mineral part of the sample by the hydrofluoric acid treatment followed by acetolysis and at times by bromoform treatment (see Plate I).

3. Preparation of Reference Material

For reference purposes slides of modern pollen and spores have been prepared. Material collected from herbarium specimens has been used extensively, together with material collected from plants in the field. Collecting material from herbarium specimens has been described by Erdtman (1952) and the same procedure has been followed for this study. For fresh material small vials (nine by thirty mm) were used. Wooden boxes were made for transportation of the vials, each box containing 100 vials in separate cells. Vials were half-filled with glaical acetic acid and sealed with waxed cork stoppers in the laboratory. In the field pollen and spore material was picked with forceps and put into the vials where it kept fresh until used. This method was developed by Erdtman and is used by him with success. For the material that was let dry small paper envelopes were used. It is easy to collect in this way under field conditions and pollen can later be extracted from the collected material in the same way as from herbarium specimens. For the chemical treatment of reference material the procedure used by Erdtman (1952) has been followed entirely. Dry material was put through a fine brass screen using a piece of screen on top of a funnel which led down into a centrifuge tube. The powdered material in the funnel was washed down with acetolysis mixture from a pipette (about six cc of mixture was used). Fresh material was acetolysed without putting it through the screen. After acetolysis some of the material was mounted and checked for colour. If it was too dark the rest was bleached by oxidation and some of the bleached material was mixed into the first slide so that both oxidized and acetolysed grains could be seen in the same slide. As glycerine jelly was generally used as the mounting medium the material after acetolysis or oxidation was treated with glycerine-water (one part glycerine and one part water) before embedding.

Very little glycerine was used for embedding so that it did not run out to the edge of the cover slip. Round thin cover slips were used. To make slides as permanent as possible paraffin was melted under the cover slip around the glycerine jelly. To do this the slide was heated slightly and melted paraffin was added by means of a glass rod. The glycerine jelly under the cover slip is sealed airtight by the paraffin which, moreover, is not affected by immersion oil. It must be admitted that it takes practice to achieve neat preparations.

4. Corn Syrup as an Embedding Medium

Material for analytical use was embedded in corn syrup as practised by N.W. Radforth at McMaster University. The pure corn syrup was diluted with water to facilitate the embedding process. Then the syrup was let dry to a hard film and the slide was ready for examination. In this process air bubbles sometimes form, but if the residue of the sample is washed properly before embedding and the right dilution of syrup is made, this fault can be avoided. If corn syrup is used, the microfossils can be moved about and turned for closer study by softening this spot on the slide with a tiny drop of water. When a little phenol was added to the corn syrup the slides have kept perfectly well for at least three years and would probably last much longer. The use of corn syrup is very convenient and easy under field conditions. The only drawback seems to be that fairly often the syrup will not harden sufficiantly, and in this case if the slides are not placed perfectly horizontal in storage the syrup runs to one side of the slide or even runs off it.

Using corn syrup as an embedding medium has all the advantages mentioned above. However, a few difficulties were found during the examination of the slides. The detailed study of pollen grains and spores for identification purpose requires high magnification, and oil immersion must be used to find out about minute morphological details. As cover slips are not used, immersion oil is used on the hard surface of dried syrup film. The use of immersion liquid that ordinarily can be wiped off the slide with a moistened piece of paper tissue is quite complicated when no cover slip is used, and the syrup surface cannot be treated with water for cleaning. Leaving immersion oil on the slide is not practical because it collects dust particles and seems to soften the surface of the syrup. During this study the immersion oil was wiped off carefully immediately after the slide was examined. This procedure, however, is not completely satisfactory in that some oil was left on the slide and the surface of the syrup was scratched and had to be smoothed by moistening. This tended to change the position of the microfossils and render the use of the co-ordinates of the mechanical table difficult.

Another difficulty is present when the cover slip is omitted. It could be observed that fine details were somewhat blurred when a high dry objective was used. To master this difficulty oil immersion was used perhaps more frequently than was absolutely necessary. As this difficulty did not appear when a cover slip was used, specialists at the W.A.

Carveth Ltd. (E. Leitz representative) in Toronto were consulted. They explained the cause of this difficulty. As artificial embedding materials are generally used, a smooth interfacial boundary must be obtained between this medium and the air. This interfacial boundary is obtained by using a cover slip. This fact again disturbs the optical system, requiring another compensation. Knowing that cover slips are used, in most cases manufacturers of microscope objectives grind in their lenses a correction for a cover slip of ordinary thickness. All objectives except the immersion lenses carry the correction and therefore if the cover slip is omitted this correction for it in the lens becomes a distortion. For this reason a proper embedding material and a cover slip of ordinary thickness are as much a part of the optical system as the lenses themselves. With low magnification the visual defect arising from the omission of the cover slip or proper embedding material is not serious, but with high magnification the resolving power of the lenses is so much reduced that such things as texture of pollen grains and even sometimes their finer sculpturing cannot be discerned.

Under Dr. Erdtman's supervision at the Palynological Laboratory in Stockholm the thickness of cover slips was seriously considered and lenses with adjustable correction, the "correction collar", were used if necessary to compensate for the variation in thickness of cover slips. For pollen morphology and for identification purpose the best binocular microscopes (such as Leitz' Ortholux and Dialux) with built-in illuminating system and variable transformer were used to obtain maximum results and to interpret minute details correctly.

Unfortunately, such elaborate equipment has not been available for this study and an ordinary, good monocular microscope has been used throughout this investigation. This is one reason why more detailed study of pollen and spore morphology was not planned, as up to date morphological investigations, in sensu Erdtman, could not have been carried out. Also, to achieve the objective here, working at this level of detail would have been somewhat superfluous and therefore questionable in value.

5. Staining of Prepared Material

Modern pollen material for reference slides was not stained as all samples were treated by the acetolysis treatment and if the pollen grains were too dark some of the pollen material of the same sample was oxidized and mixed in the same slide.

Fossil pollen grains, however, if treated only with the potassium hydroxide, hydrofluoric acid, or bromoform treatments, often were left too light in colour and might for that reason have been easily overlooked. In that case staining was carried out on the slide. Faegri and Iversen

(1950) state that, "preparations should always be stained, otherwise small or thinwalled pollen grains are frequently overlooked." The writer has found that if the acetolysis treatment is used for the samples, in general no difficulties should appear with regard to the 'shadow' pollen.

When staining was found necessary, safranin, methylene blue and fuchsin have been used. A mixture of methylene blue and fuchsine proved satisfactory.

6. Photography

For photography a monocular microscope, manufactured by Cooke, Troughton & Simms Ltd., York, England, was used. The photomicrographs were taken with the help of the Leitz' Ibso-attachment and a Leica camera using an eyepiece 10 x.

Two types of Kodak film have been used; Plus-X and the Microfile. Microfile gives a high contrast on negatives and was found useful when dealing with clear-cut microfossil details; however, the writer is inclined to think that the Plus-X type is more suitable for microfossils because it gives the gradation between dark and light parts of the fossil and for this reason more detail can be seen on the final print. Microfile was used for taking photographs of tables with success (this type is also designed for copying by Kodak). The plates were photographed with the Plus-X type film.

The effect of various filters was not tried; a blue filter used in photomicrography seemed to improve the results. In some cases infra-red photography and the use of colour film may prove very useful. However, the results have to be evaluated against the increase in expense due to more elaborate equipment and more costly materials.

For taking photographs of plates much larger negatives (about five by seven inches) than the customary thirty-five mm film which was used for this investigation, would considerably improve the detail on final plates. This again would require more elaborate equipment. The use of large-size negative material would also enable the worker to use fine-grained film (not available in thirty-five mm size). For example, the Panatomic-X type of Kodak films would give more clear-cut and sharp detail on the final print.

7. Reliability of Methods Used

During microscopical examination of samples and the later interpretation of diagrams several problems arose relating to the reliability of the obtained results. Among these were the following questions. (1) Was the number of pollen grains and spores counted in each slide sufficient to give reliable percentages? (2) Did the chemical treatment change the original composition of the pollen and spore flora in a sample? (3) Was the pollen and spore flora identified in a sample characteristic of the surrounding vegetation at the time when this layer of sediment was deposited? (4) Did the pollen diagram, i.e. the changes in the relative percentages of different pollen and spore types, reflect the actual changes in the vegetation? (5) Would two pollen diagrams from different parts of the same bog or lake be identical or significantly different? (6) Over how great a distance can palynological correlation be established between two sediment sequences?

A certain minimum number of microfossils must be counted in every sample in order to explore the true composition of the microfossil flora, or fauna. An obstacle is found often in the paucity of microfossils in some samples. Therefore the writer desired to know the lowest possible numbers of pollen grains and spores to be counted in a sample in order to achieve adequate results, that is, to represent the true pollen and spore flora in the sample.

Barkley (1934, p. 288) states that, "there is little significant shifting of relative percentages beyond the 200 count." The results of Bowman's investigation (1931) indicate that after 800 - 1000 grains have been counted, the percentages are fairly constant. According to Booberg's work in Sweden (1930, p. 225-230) the main AP (arboreal pollen) diagram curves are comparatively safe if about 150 AP are counted. The following example is taken from his work (p. 230).

Species of AP	Number of pollen grains counted										
	25	50	100	200	300	400	500	600	700	800	1000
Picea (%)	0	0	0	0	0	0	x	x	x	x	x
Pinus (%)	28	34	42	42	40	38	37	37	40	40	41
Betula (%)	68	56	51	50	51	52	53	53	50	50	49
Alnus (%)	4	10	7	8	8	10	10	10	10	10	10
Ulmus (%)	0	0	0	0	0	0	0	0	0	0	x
Salix (%)	0	0	0	0	1	x	x	x	x	x	x
Total 100%											

Several trends are apparent from this example. If the pollen flora consists of few species the overall picture is clear after a count of fifty pollen grains. The difference between counting 100 - 200 and about 1000 pollen grains is practically nonexistent. However, the time required to count 100 pollen grains and that to count 1000 pollen grains are very different. This conclusion of course concerns the major components of the pollen flora. It has been proved, and it is illustrated by the above table, that if components of the pollen flora, present in very low percentages, are significant and must be included in the diagram the number of pollen grains counted must accordingly be much higher. For this reason the writer has often used the following procedure.

First, about 200 pollen grains were counted and percentages calculated on this material. Further, more material was examined to find which pollen types occurred besides the ones included in the 200 count. These pollen and spore types were included in the description accompanying the diagram, followed by the symbol P meaning present. This procedure was employed because one purpose of this investigation has been to make palynological investigations usable for geological correlation as a routine analysis where the time element has to be considered.

As to the chemical treatment of samples, the use of hydrofluoric acid treatment, potassium hydroxide treatment and acetolysis treatment does not essentially change the pollen and spore flora present in the original sample (see page 59). The main differential destruction of pollen grains and spores takes place during the fossilisation as some pollen grains are less resistant than others.

Whether or not a sample represents the surrounding vegetation depends on several factors. Pollen and spore flora in lake sediments and peat usually give a good representation of the surrounding vegetation. Erosion of sediment and re-deposition; lack of sediment accumulation during a certain time may cause serious errors in interpretation. If the pollen production of the local vegetation is high the small amount of pollen derived from other sources is negligible. The latter, however, may become significant when the pollen production from local vegetation is low as in treeless areas. For example, when lichens from northern Canada (latitude 65 degrees north and longitude 92 degrees west) were analysed a fair amount of pine and spruce pollen was present in the samples. No pine or spruce grow at or near this locality and the pollen must therefore have been wind-transported. The difference in the pollen production of different species may distort the actual picture. For these reasons sound knowledge of the geological background of the sediment investigated is necessary, as well as knowledge of different vegetation types and plant ecology. Botanical and geological judgement should be combined with common sense in order to interpret findings correctly. Statistical treatment of material is a useful and necessary approach, but a worker must not rely entirely on it and forget his reasoning power.

The above discussion, of whether or not a pollen flora in a given sample represents the surrounding vegetation at a given time, has a direct bearing on the problem of relative percentage curves in a pollen diagram. Do changes in these curves actually represent corresponding changes in the surrounding vegetation? If the errors, some of which have been mentioned above, can eliminated, they do. At the present time one has to rely on his knowledge of the relationship between the plant community and the pollen spectrum produced by it, and this necessity requires that samples of recent sediment should be carefully studied in relation to the surrounding vegetation. It may be questioned whether the samples taken from different parts of the bog surface or on a lake bottom would give the same results. Granlund (1931, p.15) gives one example. He collected samples from a bog surface, spaced thirty feet from each other along a straight line, the distance between sample number five and sample number nine being about seventy-five feet.

Species of AP	Number of sample						Average %
	4	5	9	10	11	14	
Picea	26	29	26	26	29	27	27
Pinus	65	59	63	65	62	65	63
Betula	7	10	9	8	7	7	8
Alnus	2	2	2	1	2	1	2

This example shows a striking correspondance between samples taken at different places on a bog surface. This has been corroborated by investigations by Woodhead and Hodgson (1935). If the samples area has a considerable relief resulting in variable vegetation in a small area the parts of the bog may receive different pollen rain (*cf.* Lüdi, 1947).

Two pollen diagrams, made up from the same sequence of sediment and spaced not far apart usually resemble each other closely. Different pollen analytical zones may be compressed or expanded owing to the rate of sedimentation. A good example of this is given by Granlund (1931, p. 11-12).

The distance between two pollen diagrams from two different localities that can safely be correlated is variable. It may be a few tens of miles or it may extend to a few hundred miles. Sometimes correlation between diagrams from bogs spaced only a few miles apart is hard to establish. If an area has been well investigated from the palynological point of view, correlation may be established over longer distances.

During the course of the present investigation the writer felt that different preparations from the same sample might show significant differences. For testing this, seven separate preparations were made of the same piece of material (peat, that was easily split along horizontal planes) spaced about one inch from each other. A total of 1024 AP pollen grains were counted and average percentages were calculated on that total.

Species of AP	Number of sample							Average %
	1	2	3	4	5	6	7	
<u>Pinus</u>	76	89	84	89	94	90	91	87
<u>Picea</u>	8	3	5	2	2	3	4	4
<u>Betula</u>	9	4	5	6	2	5	2	5
<u>Alnus</u>	4	3	4	2	2	1	2	2.5
NAP	4	6	10	6	4	4	4	5.5

Within this total fifteen pollen grains of other AP (<u>Abies</u>, <u>Quercus</u>, <u>Carya</u>, <u>Ulmus</u>, <u>Tsuga</u>, <u>Larix</u>, <u>Tilia</u> and <u>Juglans</u>) were found, an average of 1.5 %. One to three pollen grains of these AP were found in each sample. The correlation between samples was good.

Two slides were prepared of the same residue in the centrifuge tube in two cases to see if correlation between counts existed.

Sample	Pinus	Picea	Betula	Alnus	Abies	Quercus
1	80 80	11 10	6 8	1 1	1 1	1 -
						Other AP
2	77 73	7 8	7 13	4 1.5	2 1.5	4 3

Also in this case correlation was good.

Cain and Slater (1948, p. 493) state that " in certain instances each of the authors independantly prepared duplicate spectra as checks. In other cases second spectra were prepared to verify certain abrupt changes in the representation of c rtain pollen types. Five sets of these data show a remarkable uniformity of results. In no case are the differences sufficient to alter any interpretation of the data."

Depth below surface in feet	Ab	Pc	Pi	Q	Ca	Be	Fa	Ac	Ti	Ts	Ny	Ul	Ju	Cpd	Und	Total count
15.5	0.3 –	0.3 –	5.0 6.7	71.2 67.2	4.0 6.7	0.7 1.3	2.3 5.9	1.7 1.7	1.7 3.8	1.7 –	– 0.4	6.3 5.1	1.3 –	2.0 0.8	2.0 0.4	302 238
16.5	– –	0.5 –	4.1 5.8	70.5 71.3	1.4 2.9	– 0.4	3.2 3.4	2.3 2.5	0.5 2.9	0.5 –	0.5 0.4	10.6 4.2	1.4 –	– 2.9	– 2.6	217 234
20.0	– –	P 0.4	4.8 5.9	74.6 77.5	1.8 3.4	2.2 2.9	– 2.1	4.4 3.7	0.4 0.4	– –	– –	6.1 1.8	– –	2.2 2.1	3.1 2.1	228 241
21.5	0.5 0.4	– 0.9	55.9 55.2	25.7 33.5	1.5 0.9	4.4 3.5	0.5 1.3	4.0 1.7	– 0.4	– –	– –	4.9 0.4	– –	1.5 –	1.0 1.7	202 230
22.5	0.8 –	1.3 P	41.5 43.5	33.1 34.9	1.7 3.0	3.9 3.4	– 0.4	0.4 1.2	– –	– –	– –	3.7 2.0	– –	11.7 6.9	1.3 3.4	239 252

Ab - Abies
Pc - Picea
Pi - Pinus
Q - Quercus
Ca - Carya

Be - Betula
Fa - Fagus
Ac - Acer
Ti - Tilia
Ts - Tsuga

Ny - Nyssa
Ul - Ulmus
Ju - Juglans
Cpd - Carpinoid
Und - Undetermined

Figure 1. Table showing difference between separate counts on five samples. (From Cain and Slater, 1948).

7A. Resistance of Different Pollen Types to Various Chemical Treatments

To test the resistance of a variety of pollen types, modern pollen was treated by different chemical methods and combination of methods. Pollen grains of the following species were tested:

Pinus laricio	*Populus deltoides*
Picea excelsa	*Typha angustifolia*
Quercus rubra	*Scirpus rubritinctus*
Gramineae	*Juncus* sp.

Pollen grains of the above species were treated in the following ways.

Potassium hydroxide treatment - This treatment did not cause any damage to the tested types. When reference material is prepared in this way the interior of modern pollen is not cleared and the morphological details of the sporoderm are difficult to study. Potassium hydroxide treatment usually leaves fossil pollen grains and spores too light in colour so that they have to be stained.

Acetolysis treatment - This treatment did not damage the tested types of pollen, except perhaps *Juncus*, which is slightly attacked. There are, however, pollen grains of some tropical plants that are destroyed by acetolysis (Erdtman, 1952). Both modern and fossil pollen grains generally are left conveniently brown-coloured and no staining is necessary.

Pollen grains of certain plants (Geraniaceae, Malvaceae, Campanulaceae, some Compositae and Umbelliferae) become too dark when treated by acetolysis and have to be bleached.

Potassium hydroxide treatment followed by acetolysis - The effect of this combination is the same as that of acetolysis alone.

Acetolysis followed by oxidation - Pollen grains of Juncus are definitely attacked and corrosion of exine can be observed. Pollen grains of Scirpus are left undamaged. Pollen grains of Populus are not destroyed. The slight swelling effect of pollen hrains is obvious. Thin-walled pollen grains generally become too light in colour for examination and must be stained.

Hydrifluoric acid treatment - This treatment does not cause damage to any of the tested pollen grains. Pollen grains are left rather light in colour after this treatment.

Hydrofluobic acid treatment followdd by acetolysis - This combination does not damage the tested pollen types, except Juncus which is slightly corroded. Damage on pollen grains of Populus is questionable. This combination of treatments leaves fossil pollen grains and spores light-brown in colour and staining is not necessary.

Schulze's treatment - This treatment is decidedly too drastic for fossil Pleistocene pollen and spore material. The pollen material is broken up into small rod-like particles and some of the exine is left as an amorphous mass.

Acetolysis followed by Schulze's treatment - This combination destroys all fossil (Pleistocene) and modern pollen.

Bromine treatment - The effect of this treatment is very similar to that of Schulze's treatment.

The resistance tests of various types of pollen suggest that the methods of chemical treatment of samples for this investigation did not damage or essentially change the plant microfossil assemblages originally present in the samples.

IV POLLEN AND SPORE MORPHOLOGICAL INVESTIGATIONS

It was realized by the writer and has also been pointed out by Faegri (1945, p. 74) and by Faegri and Iversen (1950, p. 82) that the pollen diagram as such has no direct bearing on anything other that the vegetation of the locality in question. Only after translating the diagram into terms of vegetation may one attempt to find reasons for the observed vegetational changes. To reconstruct ancient plant communities one must try to identify as many plany microfossils as well as megafossils as possible. For this reason a study of the pollen and spores of modern plants is most important for the correct interpretation of the fossil material. The better the knowlegde of the pollen and spore types, the better are the chances of detecting causes that changed the composition of the vegetation during ancient times.

From the ideal point of view one should know all pollen types of the modern plants before attempting the analysis of fossil material; that is, one should work out the basic palynology before starting on applications. However, the palynologist often has to work on the basic pollen morphology at the same time as the investigation progresses and as new problems appear. For this reason the pollen and spore morphological studies have been carried out when necessary in relation to this study.

At an early stage of this study differences in fossil pollen grains of both *Betula* and *Alnus* were observed and to investigate this problem and similar problems concerning other pollen grains, morphological studies were carried out on modern pollen of these genera.

It was thought, that if pollen morphological studies could be extended down to species, and different species of, for example, pine, spruce, alder and birch could be distinguished from each other by pollen morphological characters, a much more complete picture would be obtained of the ancient vegetation which has a direct bearing on ecological conditions and climates.

1. Pollen morphological Terminology and Methods.

When describing pollen grains and spores the terminology outlined by Erdtman (1952) has been followed, partly because the writer is familiar with it. The terminology outlined by Iversen and Troels-Smith (1950) and used by Faegri and Iversen (1950) has also been considered seriously but it seems to the writer that this terminology in numerous details is more artificial than strictly morphological and descriptive. About his own terminology Erdtman (p.22) states that,

> "Several suggestions in the above terminology are more or less tentative and preliminary and have to be replaced by better terms when a greater number of plants have been investigated and when methods making it possible to penetrate beyond the limits of ordinary microscopy have been applied."

The truth of the previous statement has been proved by electrone microscopical studies of exine structure (Erdtman, 1954, p. 155-161) where important details of the exine construction have become apparent, as for example, the lamellar structure of the outer layer of exine of Lycopodium spores and the granular structure of the inner exine layer of the same spore.

For the sake of simplicity the writer has favoured the use of widely understood terms, instead of complicated specific ones, in the description of the various morphological details. Terminology that is too complicated, involves many difficulties. It is hard to assimilate and interpret correctly and as new discoveries are made in the palynological field some terms have to be replaced, thus increasing the confusion.

The way to calculate the shape of pollen grains and spores has been adapted from Erdtman (1952, p. 16).

Shape classes	$\frac{P}{E}\cdot 100$
Peroblate	< 50
Oblate	50 - 75
Suboblate	75 - 88
Oblate-spheroidal	88 -100
Prolate-spheroidal	100 -114
Subprolate	114 -133
Prolate	133 -200
Perprolate	> 200

The polar axis (P in the above table) is defined as a line passing through the centre of the pollen grains coming from the middle of the pollen-tetrad. Equatorial diameter (E in the above table) is measured at a right angle to the polar axis through a point in the centre of the pollen grain at equal distance from both poles. It is admitted that there are cases when the above definitions are difficult to apply, for example, in a case of triangular and egg-shaped pollen grains. For these anomalous cases the writer refers to Erdtman's textbook (1952).

Terms for describing sporoderm stratification have also been adapted from Erdtman (1952, p. 18-19).

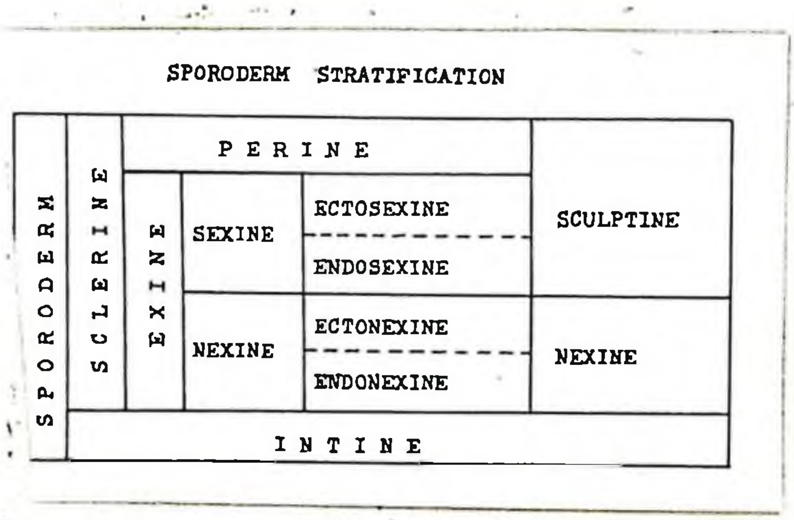

Figure 2. Diagram showing the possible stratification of a complex wall of a pollen grain.

The meaning of the above terms is as follows:

Sporoderm - the wall of a spore (pollen).

Sclerine - sporoderm except for intine.

Intine - the inner, usually not very resistant sporoderm layer.

Exine - the main, usually resistant layer of a sporoderm.

Perine - the outermost, extra-exinous sporoderm layer in some spores (in certain mosses, ferns, etc.). It seems to be due to the activity of a periplasmodium.

Sexine - the outer, sculptured part of exine.

Nexine - the inner, non-sculptured part of exine.

Sculptine - sclerine except for nexine.

For further explanation of these terms I quote Erdtman (1952, p. 18).

"Sclerine is usually synonymous with exine. In the spores of certain plants (certain mosses, ferns etc.), however, it also comprises an outer layer, perine. The presence of this layer seems to be due to the activity of a periplasmodium with perinogeneous properties. The physico-chemical qualities of the perine differ more or less from those of the exine. It is, however, still impossible, particularly when dealing with pollen grains, to decide - without undertaking cytological investigations - whether a certain sporoderm layer or sporoderm element is exinous or more or less perinous. As long as this cannot definitely be proved 'perine' can be classified under the same noncommittal heading - 'sculptine' - as the outer, sculptured part of exine. This has, however, not been observed in the present book in order to reduce the terminology: 'sclerine' is decribed as 'exine' even if it should happen to be more or less perinous. Likewise 'sculptine' is always replaced by 'sexine'."

For the study of the sporoderm details the LO-analysis has proved very profitable (cf. also Terasmae, 1951). LO is derived from L - lux and O - obscuritas, meaning light and darkness respectively. The idea of this analysis is rather simple.

By lowering and elevating the focus of the microscope the depressions and elevations appear correspondingly as light and dark shades on the sporoderm surface. A spine, protruding from the surface of the sporoderm vertically upward, shows as a light-coloured spot against the darker sporoderm surface when the focussing is adjusted to the level of the top of the spine. On a gradual lowering of the focus the spine turns towards darker shades, whereas the smooth sporoderm surface, first appearing dark turns towards a lighter shade (Plate II, figure 21 and 25). On the other hand if there is a hole in the exine, focussing on the exine surface shows the hole as a dark spot against the light-coloured exine. Lowering the focus shows the hole changing to a lighter shade and the surrounding exine appears dark. Keeping these phenomena in mind, one can gradually work out the pattern of exine sculpture and the structure of different sporoderm layers. Erdtman (1952, p. 22) states that, "the method of penetrating the sexine and describing the patterns in the way just mentioned is often difficult and hazardous." The writer admits that a certain amount of experience is necessary for efficient LO-analysis.

As a help for identification, descriptions and illustrations of pollen grains, scattered through the palynological literature, were used together with data from more comprehensive papers as published by Erdtman (1943, 1952), Faegri and Iversen (1950), Iversen and Troels-Smith (1950) and Wodehouse (1935, 1942, 1945).

From the geological point of view the descriptions of pollen grains given in the following may not seem pertinent to the problem of the investigation. However, as this study is both geological and botanical and knowledge of pollen grains and spores actually provides the foundation on which the results of this investigation are ultimately based, the writer feels justified in treating the pollen morphological data as an important part of this study. In general the pollen grains of plants have been discussed in the sequence outlined by Engler and Prantl in their "Natürliche Pflanzenfamilien."

All measurements have been made on acetolysed material mounted in glycerine jelly. For mean values measurements on ten different grains were made using mostly oil immersion. For checking purpose similar measurements were also made with a high dry objective (about 600 x magnification) and no significant differences were recorded for medium and large pollen. Whenever pollen of different species had to be distinguished the morphological features have been employed in the first place and after that the size of pollen grains and spores has been considered. This is chiefly due to strong criticism from different workers concerning the variation in size of pollen as the result of different chemical treatment of material. The writer knows of experience that if the pollen material is properly treated, size range is also useful (cf. also Cain, 1940, ,948, and Cain and Cain, 1948).

2. *Gymnosperms*

C o n i f e r a e

Abietineae

On the basis of pollen morphology Abietineae may be divided into two groups; one without and the other with air-sacs (bladders) - sacci *in sensu* Erdtman; vesiculae *in sensu* Iversen; wings *in sensu* Wodehouse. The writer agrees with Cain (1940, p. 301) that,

"Usually it is not difficult to distinguish the three common genera of conifers with winged pollen grains: *Abies*, *Picea* and *Pinus*. According to Wodehouse (1935), who studied several species from each genus, *Abies* grains range from 78 - 111 u in their longest dimension and are usually over 90 µ; *Picea* grains range from 68 - 91 µ, mostly less than 85 µ; *Pinus* grains range from 45.5 - 65 µ. Fortunately, the pollen grains of *Picea* are distinguished from either the larger *Abies* or the smaller *Pinus* by the absence of a marginal ridge where the dorsal exine cap meets the insertion of the wings. Furthermore, the wings of *Picea* are characteristically broadest at the base, giving them an ovoid-conical form. The curves of the cap and the outer wall of the wings make a continuous, essentially unbroken line. In both *Pinus* and *Abies* the wings are broadest above the base and are spheroid in form. The somewhat narrower wingbase results in a re-entrant angle between the wings and the dorsal portion of the grain so that the two do not form a continuous curve."

On the more or less round angiosperm pollen grains it is easy to define and measure the polar and equatorial axis and to use these measurements as reference. The winged conifer pollen grains, however, present a difficult case in this respect. Here the winged conifer pollen grains have been measured in the following manner (cf. also Cain, 1940).

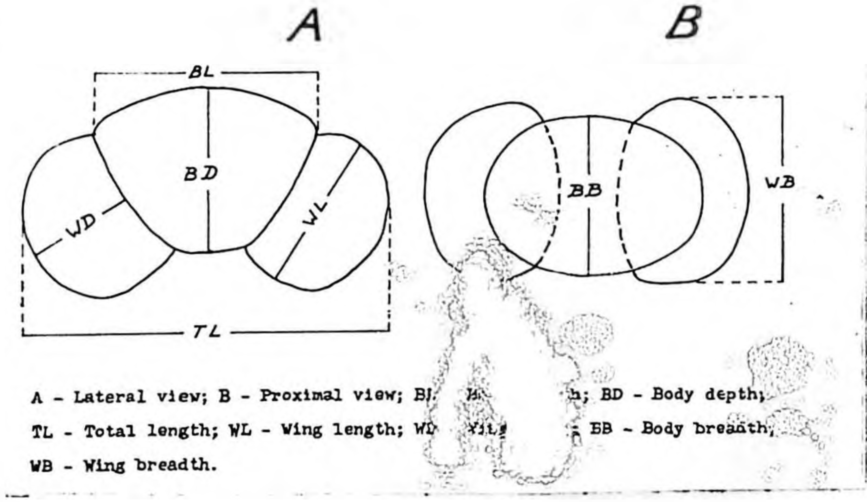

Figure 3. Diagram showing axes of measurement on winged conifer pollen grains.

A complicated way of measuring in detail winged conifer pollen has been presented by Erdtman (1954, p. 1-14) where photographs have been neatly combined with schematical drawings into a palynogram. It was felt, however, that for the sake of balance of the different parts of this investigation a simpler method of morphological study was adequate.

Morphology of winged pollen grains (cf. Wodehouse, 1935, and Erdtman, 1943). Winged pollen grains consist of a body and varying numbers of air-sacs (e.g. Tsuga mertensiana). The body is more or less spheroidal or slightly flattened (suboblate or oblate). The exine is particularly thick in the proximal part of the body - the cap. It consists of ektexine (sexine), endexine (nexine), and between these, rod-like mesexinous elements in a compact arrangement which gives the exine a complicated, somewhat dotted texture. A distinct boundary frequently occurs between the thick exine of the cap and the thin exine of the distal part of the body. The latter part is mainly occupied by air-sacs. These are separated from the interior of the grain by the nexine; their outer wall consists of sexine with attached mesexinous elements which protrude into the lumen of the air-sacs. The mesexinous elements are more widely spaced than those of the body and are much more irregular. Branched or unbranched, single or combined in different ways, they tend to produce an array of different patterns, generally more or less reticular.

Near the proximal root of the air-sacs there are frequently slight sexinous ridges or frill-like projections (marginal ridges), varying in appearance in different species and within one species.

At the distal root of the air-sacs, where they merge into the distal surface of the body of the pollen grain, the characteristic texture of the air-sacs fades out. The space between the air-sacs is, morphologically speaking, the furrow which in <u>Pinus</u> extends from end to end of the grain vertical to the plain which passes through the two air-sacs. The 'furrow' is covered by an exceedingly thin and flexible membrane, smooth and often devoid of any markings.

PINUS - nine species studied for this investigation. All pollen grains of P. silvestris type (Erdtman, 1943, p. 136). Total length (TL) of grains ranging from 66 u in P. banksiana to ca 100 u in P. ponderosa.

Pinus banksiana Lamb - McMaster Herbarium # 180. TL - 66 u; BL - 46 u. Pattern on cap coarse, distinct. Cap relatively thick ca 1.7 u. Reticulation on air-sacs coarse delicate and broken. Marginal crests generally present. Air-sacs often rather small in relation to body. Grains generally not crumpled.

BL - 41 u (Deevey, 1939; grains from Quebec); BL - 40.7 - 47.58 u (Cain and Cain, 1948). Plate X, figure 6 - 11.

Pinus resinosa Ait. - National Herbarium, Ottawa; New Liskeard, Ont., June 12, 1952, W.K.W. Baldwin and A.J. Breitung, No 2496. TL - 83 u; BL - 58 u. Pattern on cap dense, distinct, rather coarse. Thickness of cap 2 - 2.5 u. Surface of body uneven. Air-sacs bigger in relation to body than in P. banksiana. Grains fairly often crumpled. General appearance more thin-walled than in P. banksiana. BL - 58.3 u (Cain, 1940); BL - 43.93 - 49.21 u (Cain and Cain, 1948). Plate II, figure 9 - 14.

Pinus strobus L. - National Herbarium, Ottawa; Big Island, Georgian Bay, Ont., June 9, 1903, R.T. Anderson (Can. No. 6508). TL - 89 u; BL-62 u. Pattern on body coarse and uneven. General appearance much like that of

P. resinosa. Thickness of cap *ca* 2.5 u. Pollen grains often crumpled, particularly in fossil material. BL - 59.1 u (Cain, 1940); BL - 47.16 - 53.95 u (Cain and Cain, 1948). Plate II, figure 15 and Plate I, figure 1 - 5.

Pinus monticola Dougl. - Herbarium of Univ. of B.C. # 5527, Vancouver; Willow Point, Kootenay Lake, B.C., June 10, 1938. J.W. Eastham # 173. TL - 76 u; BL - 58 u. Pattern on body well defined. Marginal crests present. Reticulum on air-sacs rather dense. Plate IX, figure 6.

Pinus ponderosa Dougl. - Herbarium of Univ. of B.C., Vancouver, # 5550; Penticton, B.C., J.W. Eastham # 172, June 5, 1938. TL - 93 - 104 u; BL - 64 -75 u. Reticulation on air-sacs coarse, delicate, broken. Pattern on cap coarse, distinct. Plate IX, figure 3 and 4.

Pinus contorta Dougl. - Herbarium of Univ. of B.C., Vancouver, # 5482. Sproat Lake, Vancouver Island, B.C. T.M.C. Taylor # 1197, August 11, 1941. TL - 66 u; BL - 49 u. General appearance much like that of *P. banksiana*.

Pinus contorta Dougl. var. *latifolia* Engelm. - National Herbarium, Ottawa. Peace River Valley, Hudson Hope, B.C. June 25, 1932. Raup and Abbe No 3683. TL -82 u; BL - 56 u. General appearance of pollen grains like that of *P. contorta*.

Pinus murrayana Balf. - National Herbarium, Ottawa. Bankhead, Banff, Alta. July 3 or 31, 1906. Stewardson Brown No 795. TL - 86 u; BL - 58 u. General appearance like that of _Pinus strobus_.

Pinus albicaulis Engelm. - Herbarium of Univ. of B.C., Vancouver, # 21909. Sage Pass, B.C. Lat. 49 deg., long. 114 deg., August 10, 1951. T.M.C. Taylor # 8898. Altitude 7500 feet. TL - 86 u; BL - 61 u. Reticulum on air-sacs dense, distinct. Surface uneven.

During the present investigation it was most desirable to distinguish between different species of pine in the fossil pollen flora. An attempt was made to use morphological features only for identification. Because of the variation in the morphological characters within one species and the overlap of range of variation between different species, the writer concludes that morphological features only are not distinct enough to make an accurate identification of fossil pine pollen of different species possible. When the size of pollen grains is considered together with the morphological differences and known environmental requirements of modern species, reasonably sure results may be obtained. In the St. Lawrence Lowland, for example, the pine pollen in the bottom part of the post glacial sequence belongs mostly to jack pine whereas the pine pollen towards more recent time consists mostly of white pine and red pine. Distinguishing different pine species by means of the statistical size range frequency calculations requires abundant and well preserved fossil material and is no doubt time-consuming. The usefulness of this method has been convincingly described by Cain (1940, 1948).

"Such hope as there is for identification of species by size-frequency histograms lies in matching position of modes of the fossil arrays with those of the known species, coupled with cautious reasoning about the probable presence of one or another species for ecological and phytosociological reasons," (Cain and Cain, 1948, p. 584).

In fossil material from western Canada and United States, Hansen has distinguished between many species of pine using size measurements. Cain (1940) states that,

"In correspondence concerning the identification of conifer species, February,1940 Hansen wrote: ' my method of identification by measurement and discard of those that overlap is in effect about the same as your new method, only I do not use graphs for comparison of modern with fossil pollens'."

PICEA - five species investigated, General description see p. 71, 72-73.

Picea sitchensis Carr. - National Herbarium, Ottawa; Haines Rd., Klehini R., B.C. July 23, 1944. C.H.D. Clarke No. 372. BL - 93 u; TL - 130-140 u. Pattern on the cap coarse, dense, distinct. Reticulation on air-sacs similar to that of other *Picea* species. General appearance rather thickly-walled and firm.

Picea engelmanni Engelm. - Pollen supplied by Professor B. Brink of the Agronomy Dept. of Univ. of B.C. MY 49, Lytton, Boothanie. BL - 93-96 u; TL - 122 u. Pollen grains of this species are similar to those of *Picea sitchensis*.

Picea mariana (Will) BSP. - National Herbarium, Ottawa. Eskimo Island,Mingan Islands, Quebec. June 28, 1915. Harold St. John # 90071. TL - 80-90 u; BL - 67 u (according to Cain, 1948). Reticulation of bladders dense, distinct. Appearance firm. Grains generally not crumpled. Plate V.

Picea glauca (Moench) Voss - National Herbarium, Ottawa. Long Island, east coast of Hudson Bay. July 25-28, 1949. W.K.W. Baldwin # 1769. TL - 100-120 u; BL - 77 u according to Cain (1948). Appearance of the pollen grains rather thin-walled, often crumpled. Pattern on cap finer and more delicate than e.g. that of Picea sitchensis. Relatively large air-sacs with coarser and more delicate reticulation than in Picea mariana. Plate V.

Picea rubens Sarg. - National Herbarium, Ottawa. Covey Hill, Potsdam Huntington Co., Quebec. June 4, 1950. Raymond, Kucyniak and Churchill # 874. TL - 115 u; BL - 80-83 u (83 u according to Cain, 1948). Pollen grains of the same type as those of Picea glauca.

No attempt has been made continuously to differentiate Picea species in the course of this investigation. In material from eastern Canada the black spruce and white spruce can be kept separate in fossil material. It also seems that in more recent post glacial sediments pollen grains of spruce of larger size than those of ordinary Picea glauca are present. The size matches those of Picea rubra. These large grains are definitely not present in early post glacial sediments, studied for this investigation.

ABIES - four species have been investigated. For a general description see p. 71-73.

Abies grandis Linl. - Herbarium of Univ. of B.C., Vancouver. # 5340. Cloverdale, B.C. C.E. Somerville, May 2, 1920. TL - 124-141 μ; BL - 87 -91 μ. In optical section the sexine of the cap is well separated from the outer surface of exine by prominent bacula. The surface of the cap is rather uneven. Air-sacs are well separated from the body. Plate X, figure 12, 13, 14 and 17.

Abies lasiocarpa (Hook.) Nutt. - Herbarium of Univ. of B.C. Vancouver, # 5359. Smithers, B.C. Lat. 54 deg., long. 127 deg. F.R. Sanderson # 62. June 1, 1949. TL - 115 - 119 μ; BL - 75 - 83 μ.

Abies balsamea (L.) Mill. - Fresh material from campus of McMaster University, Hamilton, Ont. TL - 124-132 μ; BL - 87 -95 μ.

Abies amabilis Forbes. - National Herbarium, Ottawa. Mt. Benson, Vancouver Island, B.C. June 8, 1887. Macoun # 24880. Pollen grains in this slide were poorly developed and irregularities in air-sac development were interesting to observe as occasional grains resembled those of *Tsuga mertensiana* on casual observation. Plate X, figure 15, 16; Plate XI, figure 1-5.

TSUGA - three species investigated.

Tsuga canadensis (L.) Carr. - National Herbarium, Ottawa. Argyle, Yarmouth Co., N.B. August 4, 1920. Long & Linder # 50. Diameter in polar view ca 76 μ (68 -

85 u, Wodehouse, 1945). Pollen grains of T. *canadensis* have no air-sacs and seem not to be subsaccate (i.e. have a tendency to form bladderlike structures). In polar view the grains are circular and in lateral view flat or cup-shaped, the centre of the distal part of the grain being frequently depressed. Sporoderm stratigraphy of a rather complicated nature.

Tsuga heterophylla (Raf.) Sarg. - Herbarium of Univ. of B.C. Vancouver # 5600. West Lake Trail, Hollyburn, Vancouver, B.C. J.W. Eastham # 10,746. May 15, 1943. Altitude 1500 feet. Diameter in polar view *ca* 70 u, (50-55 u, Wodehouse, 1945). Pollen grains of T. *heterophylla* have no air-sacs but show a tendency to form a bladder-like frill around the grain, that is, to be subsaccate. Pollen grains of T. *heterophylla* are very similar to those of T. *canadensis*. Plate VII, figure 1 - 4.

Tsuga mertensiana (Bong.) Sarg. - Herbarium of Univ. of B.C. Vancouver # 5614. West Lake Ski Club, Hollyburn, Vancouver, B.C. J.W. Eastham # 10, 894. July 17, 1943. BL - 55 u; BB - *ca* 46 u; BD - *ca* 37 u. Pollen grains of T. *mertensiana* are supplied generally with two well developed air-sacs, sometimes with a variable number of subsaccate structures or encircled by a loose frill. Air-sacs are usually well defined like those of *Pinus*. The pattern on the air-sacs appears to be of a granular, reticular nature, being distinctly different from that in *Pinus*. Plate VII, figure 5 - 8.

Pseudotsuga taxifolia (Poir.)Britt. - Herbarium of Univ. of B.C. Vancouver # 5585. Cloverdale, B.C. C.E. Domerville, March 2, 1920. Diameter of pollen grains *ca* 90 u. Thickness of exine *ca* 2.5 u. Sexine thicker than nexine. Surface of sexine psilate, with no visible pattern. No apertures.

Pseudotsuga mucronata (Raf.) Sarg. - National Herbarium, Ottawa. Sidney, Vancouver Island, B.C. May 2,1913. John Macoun # 88305. Diameter of pollen grains *ca* 97 u. Thickness of exine *ca* 1.5 u. Sexine thicker than nexine. Surface of sexine psilate. No visible pattern. No apertures (cf. Plate IV, figure 17).

Chamaecyparis nootkatensis (Lamb.) Spach. - National Herbarium, Ottawa. Victoria, Vancouver Island, B.C. March 13, 1915. John Macoun # 94487. Diameter of pollen grains *ca* 29.6 u. Grains thin-walled. Nexine as thick as sexine. Surface of exine flecked with granules (pila). No visible apertures. Diameter 27 u according to Erdtman (1943). Plate VI, figure 1.

Taxus brevifolia Nutt. - Herbarium of Univ. of B.C. Vancouver. # 5625. Caulfields, West Vancouver, B.C. K. Auden, April 21, 1923. Diameter of pollen grains *ca* 21 u; 24 - 27 u according to Erdtman (1943). Pollen grains thin-walled. Surface of exine densely set with small rods (pila) of unequal length. No distinct aperture;

possibly a thin spot in the exine (tenuitas) may be the equivalent to an aperture. Plate VI, figure 3.

Thuja occidentalis L. - National Herbarium, Ottawa. Lake Duc-harme, L. Chibougamau, P.Q. July 8, 1948. I. Hustich # 50. Diameter of pollen grains *ca* 26 u. Grains thin-walled. Surface of exine with scattered pila or granules. Grains often crumpled. Plate VI, figure 8 and 9.

Thuja plicata Donn. - Herbarium of Univ, of B.C. Vancouver. # 5901. Roic Creek, B.C. D.C. Buckland, March 10, 1939. Diameter of pollen grains *ca* 27 u. In appearance similar to those of *T. occidentalis*. No apertures. Plate VI, figure 10.

Larix laricina (Du Roi) Koch. - National Herbarium, Ottawa. Akimiski Island, James Bay. June 27-29, 1929. A.E. Porsild, # 4509. Diameter of pollen grains *ca* 65 u. Thickness of exine 2-3 u. Thickness of sexine variable. Sexine does not seem to be very resistant. Surface has a faint, indistinct pattern. Plate VII, figure 16 and 17.

3. *Angiosperms*

D i c o t y l e d o n s

Salicaceae

SALIX - No attempt has been made in this study to distinguish between pollen grains of different *Salix* species, although the writer knows that this is possible to a certain extent (cf. Terasmae, 1951 and Straka, 1952).

POPULUS - three species investigated.

Populus balsamifera L. (*P. tacamahacca* Mill.) - National Herbarium, Ottawa. Near head of Chitina River, S.E. Alaska, H.M. Laing # 49, May 26, 1926. Diameter of pollen grains *ca* 28 u. Grains spheroidal, nonaperturate. Sexine thicker than nexine. Sexine seemingly consisting of densely spaced pila which gives the surface of exine a coarse granular and very distinct pattern. Thickness of exine *ca* 2 u.

Populus trichocarpa Torr and Grey - Herbarium of Univ. of B.C. Vancouver, # 32062. Smithers, B.C. P.R. Sanderson # 2 A, May 8, 1949. Altitude 1600 feet. Diameter of pollen grains *ca* 23 u. Grains spheroidal, nonaperturate. Thickness of exine 0.6 - 1 u. Exine stratification seems to be the same as in *P. balsamifera*, but is confused and not distinct. Pattern finely granular.

Populus tremuloides Michx. - National Herbarium, Ottawa. Campbellton, N.B. May 27, 1876. R. Chalmers (Can. No. 40449). Pollen grains spheroidal, nonaperturate, diameter *ca* 31 u. Thickness of exine *ca* 1.5 u. Exine stratification the same as in other *Populus* species. Pattern granular, very distinct.

Betulaceae

BETULA - eight species investigated.

<u>Betula</u> <u>lenta</u> L. - National Herbarium, Ottawa. Boston, Mass. May 14, 1883. C.W. Swan # 45573. Pollen grains sub-oblate (20.5 x 25 u). Pattern rather distinct, coarse. Poroid apertures (aspides) well developed.

<u>Betula</u> <u>lutea</u> Michx. - National Herbarium, Ottawa. (Ottawa # 27). Granby, P.Q. May 17, 1946. F. Fabius # 57. Pollen grains suboblate (25 x 29 u). Pattern coarse, distinct. Grains occasionally 4-aperturate. Thickness of exine <u>ca</u> 2 - 1.7 u. Sexine twice as thick as nexine . Aspides well developed. Plate VIII, Figure 5.

<u>Betula</u> <u>populifolia</u> Marsh. - National Herbarium, Ottawa. (Ottawa # 71). Canton, New York. May 16, 1914. Orra Parker Phelps # 369. Pollen grains suboblate (19 x 24 u). Pattern coarse, distinct. General appearance rather thick-walled. Sexine thicker than nexine; thickness of exine <u>ca</u> 1.5 u. Plate VIII, Figure 22.

<u>Betula</u> <u>minor</u> (Tuck.) Fern. - National Herbarium, Ottawa. (Ottawa # 70). Bradore Bay, Saguenay County, P.Q. June 30, 1927. Harrison F. Lewis # 151859. Pollen grains suboblate (18 x 22 u). Appearance rather thin-walled, thickness of exine <u>ca</u> 1.2 u, and round. Apertures not pouting. Pattern distinct, rather fine. Sexine thicker than nexine.

<u>Betula</u> <u>papyrifera</u> Marsh. - National Herbarium, Ottawa. (Ottawa # 42). Canol Rd., mile 132. Lower Lapie R. Crossing, elev. 2750 feet. Yukon Territory. June 16, 1944. A.E. Porsild and A.J. Breitung # 9530. Pollen grains suboblate (21.5 x 27 u). Apertures well defined. In polar view grains appear triangular. Pattern fine, distinct. Thickness of ex <u>ca</u> 2 µ. Sexine to nexine as 3 to 1.

<u>Betula</u> <u>papyrifera</u> Marsh. - National Herbarium, Ottawa. (Ottawa # 44). Revelstoke, B.C. May 5, 1890. (John) Macoun # 23631. Distributed as <u>B</u>. <u>papyrifera</u> Mx. having note in M.F. Fernald's handwriting "<u>B</u>. <u>alba</u> L. ." Pollen grains suboblate (25 x 31 u). Numerous 4-aperturate grains present in this material, some grains 5-aperturate. Aspides well developed. Pattern medium distinct. Thickness of exine <u>ca</u> 2 µ. Sexine to nexine as two to one. Plate VII. figure 19, Plate VIII, figure 1 and 3.

<u>Betula</u> <u>papyrifera</u> Marsh. - National Herbarium, Ottawa. (Ottawa # 43). McQuesten area, Lat. 63-64 deg. N and long. 136-138 deg W. McQuesten Rd. Hay Creek Camp, Yukon Territory, July 22, 1948. John D. Campbell # 537, determined by A.E. Porsild. Pollen grains suboblate (18.7 x 23.5 µ). Aspides well developed. Shape in polar view rather triangular. Thickness of exine <u>ca</u> 2 u. Sexine to nexine as 3 to 1.

<u>Betula</u> <u>papyrifera</u> Marsh. var. <u>neoalaskana</u> (Sarg.) Raup. - National Herbarium, Ottawa. (Ottawa # 41). Canol Rd.

mile 132, Lower Lapie R. Crossing, elev. 2750 feet. Yukon Territory. June 16, 1944. A.E. Porsild and A. J. Breitung # 9539. Pollen grains suboblate (20 x 26.5u) Pattern very distinct. Thickness of exine 1.5 - 1.7 µ. Sexine to nexine as 2 to 1. On one pollen grain in this material there was observed a tri-radiate mark, (tetrad scar). Plate VII, figure 18, 20.

Betula papyrifera Marsh. var. neoalaskana (Sarg.) Raup. - National Herbarium, Ottawa. (Ottawa # 39). Tisdale, Sask. May 14, 1939. A.J. Breitung # 52. Distributed as B. papyrifera, revised 1946 by Breitung to B. papyrifera v. humilis (Regel) Fern. and Raup. = B. papyrifera v. neoalaskana (Sarg.) Raup. Pollen grains suboblate (20 x 26 u). Pattern coarse, rather distinct. Thickness of exine ca 1.7 u. Sexine to nexine as 2 to 1.

Betula pumila L. - National Herbarium, Ottawa. (Ottawa # 68). Rocky Bay, Saguenay County, P.Q. June 24, 1927. Harrison F. Lewis # 131871. Pollen grains suboblate (19 x 25 u). Pattern fine distinct. Sexine thicker than nexine. Some grains in this material are 2-aperturate. Plate VII, figure 21.

Betula Michauxii Spach. - National Herbarium, Ottawa. (Ottawa # 69). Kegashka River, Saguenay County, P.Q. June 25, 1928. Harrison F. Lewis # 131861. Pollen grains suboblate (17 x 22 u). Some pollen grains in this material are 4-aperturate. Pattern fine, distinct.

Sexine thicker than nexine.

Betula glandulosa Michx. - Herb. Royal Bot. Gardens, Hamilton, Ont. # C 551. Churchill, Man. June 22, 1948. H.S. Webb. Pollen grains suboblate (21 x 26 u). Pattern rather coarse, indistinct. Thickness of exine *ca* 1.2 u. Arci present as in all other *Betula* species. General appearance of pollen grains round and thin-walled. Aspides not pouting. The pollen grains of *B. glandulosa* closely resemble those of *Betula nana* (cf. Terasmae, 1951). Plate VIII, figure 2,4,6.

The pollen morphology of *Betula* was studied in greater detail because of the variability observed in the fossil material. The aim of this separate study was to find out whether different species of *Betula* or different groups of species could be distinguished on the basis of their pollen morphology.

The following grouping of *Betula* is given in Fernald's Gray's Manual of Botany.

Betula L.	Measurements in μ		$\frac{P}{E} \cdot 100$
Series C o s t a t a e Regel			
B. lenta L.	20.5	x 26	80
B. lutea Michx.	24	x 28.5	81.5
Series A l b a e Regel			
B. populifolia Marsh.	19	x 24	79
B. minor (Tuckerm.) Fern.	18	x 22	79
B. papyrifera Marsh.	22	x 27	80

Series H u m i l e s D.J. Koch	Measurements	
B. *pumila* L.	19 x 25 u	76
B. *glandulosa* Michx.	21 x 26 u	81
B. *Michauxii* Spach.	17 x 22 u	77

Applying the data obtained by pollen morphological studies on fossil *Betula* pollen, the following conclusions can be reached.

The fossil *Betula* pollen in early post glacial sediments consists mostly of *Betula papyrifera* type (pollen grains rather triangular in polar view, relatively thick-walled, aspides well developed, pattern distinct, size approximately 22 x 26 u) while a small part matches the *Betula glandulosa* type (pollen grains rather round in polar view, relatively thin-walled, apertures not pouting, pattern fine, obscure, size approximately 20 x 25 u).

Fossil pollen in more recent sediments in the St. Lawrence Lowland often contains a considerable part of *Betula* pollen grains that match closely those of *Betula lutea*.

The fossil pollen studied in the St. Pierre interval samples, contains the *Betula papyrifera* type and *Betula glandulosa* type.

On the basis of pollen morphology the material of *Betula papyrifera* seems to be rather heterogeneous. This view is also supported by A.E. Porsild's experience (personal communication), *Betula papyrifera* is not a clean-cut species.

Another interesting problem appears in connection with N. Polunin's (1940) investigations in the Canadian Eastern Arctic. Concerning Betula glandulosa and Betula nana Polunin (1940, p. 173 and 174), says:

"Betula glandulosa Michx. This is a bad typus polymorphus, varying, especially around Churchill and other regions slightly to the south of our area, enormously in size and habit, in the glandulosity of the twigs and in the size and shape of the leaves (cf. Raup 1936 b, p. 242). The material from strictly within our area is, however, more uniform, being of low espalier habit and having small, rounded leaves and densely glandular twigs. This, even if it is merely a reduced northern form that can occur farther south in exposed or otherwise unfavourable places, certainly occupies alone all the northernmost stations of the species, and so seems to deserve maintenance as var. sibirica (Ledeb.) S.F. Blake in Rhodora XVII, p. 87 (1915), of Betula rotundifolia. This occurs not only in the mainland parts of our area but also in Baffin northwards to Cumberland Gulf, and moreover on Southampton Island. Thus to the range given for the species by Sargent (1896, p. 47) we have considerably northern extensions to record; we must also note it as new to the Arctic Archipelago. General distribution. The whole species extending from southern Greenland across subarctic and alpine regions of North America to Northern Asia. Northernmost station appears to be Demarcation Point 69 deg. 41 ' N in eastern Alaska (Johansen ex Macoun and Holm, 1921). Eastern Arctic distribution. Widespread in the extreme south, including the southernmost parts of the Arctic Archipelago, and in Baffin extending northwards to near the Arctic Circle. Occurrence. Rather local, but sometimes abundant to dominant on well drained and sunny sheltered slopes. Here it grows generally as an ascending shrub 30 - 60 cm high and often more than a metre in diameter, flat-topped as a result of being unable to persist above the usual level of the snow in the winter. On the other hand in exposed places it remains pressed against the surface of the soil creeping laterally to form a mat of gnarled, thick-barked axes and glandular twigs.

Betula nana L. This seems to be the first confirmed record (fide Fernald) of B. nana in North America between Greenland and western Alaska, previous reports being based (in most cases certainly and in all others at least possibly) on the much more common B. glandulosa or the closely related B. Michauxii Spach. This last, however, seems to be restricted to the regions around the Gulf of St. Lawrence, with one station on the coast of Labrador somewhat farther north. There is also a specimen in the National Herbarium of Canada labelled "No. 23826, thickets (swamps) W. Coast of Hudson's Bay (?) R. Bell 1882" which probably belongs to B. nana, and, if confirmed, would help greatly in bridgeing the last big gap in what previously appeared to be a strangely broken distribution. It seems probable that closer investigation in the future may show this to be one of the few (perhaps the only ?) fully circumpolar or circumboreal amentiferous shrubs. General distribution. ? circumpolar (see above), chiefly arctic and alpine. Northernmost record Green Harbour, 78 deg. N in Spitsbergen (Resvoll - Holmsen, 1927, p. 35, and cf. Polunin 1933, field notes). Eastern Arctic distribution. Known only from Cumberland Gulf in central Baffin, where it has been found in two small side-fjords near the Arctic Circle. Occurrence. Rare. My one collection of this species from within our area was growing in the manner of its southern representative B. Michauxii, as a very low shrub in a deep sphagnous bog above whose surface the thin whippy branches rose only 15 - 20 cm - in spite of the fact that the area was beautifully sheltered and probably drifted over with deep snow from early in the winter."

Further detailed studies of modern pollen of Betula nana and B. glandulosa, combined with studies of fossil Betula pollen in Pleistocene sediments should give some very interesting information about the problems of the migration of these species during the past.

ALNUS - six species and four varieties investigated.

Alnus crispa (Ait.) Pursh. - Origin of specimen uncertain.

Pollen grains oblate (16 x 22 µ). Pattern fine indistinct. Apertures flattened, number of apertures five, four and six. Grains often crumpled. Thickness of exine 1.5 µ. Sexine slightly thicker than nexine.

Alnus crispa (Ait.) Pursh. - National Herbarium, Ottawa. (Ottawa # 51). Nueltin Lake, mouth of Windy R., Northwest Territories. July 4, 1947. Francis Harper # 2257. A.E. Porsild det. Pollen grains oblate

(17.8 x 24 u). Pattern fine indistinct. In polar view grains often irregular in outline. Arci poorly defined. Sexine thicker than nexine. Diameter of aspides ca 5 u. Plate VIII, figure 9.

Alnus crispa (Ait.) Pursh. - National Herbarium, Ottawa. (Ottawa # 49). Dawson Creek, B.C. June 10, 1932. Hugh M. Raup and Ernst C. Abbe # 3541. Pollen grains oblate (16.4 x 25 u). In polar view of the pollen grains the arci seem to run around the periphery of the grains. Apertures rather flat. Plate II, figure 1.

Alnus crispa (Ait.) Pursh. var. mollis (?) - National Herbarium, Ottawa. Ottawa # 48. Kegaska R. Saguenay County, P.Q. June 10, 1927. Harrison F. Lewis # 131879. Pollen grains oblate (16.6 x 25 µ). Pollen grains have often the same appearance as those of Alnus rugosa var. americana (see in the following). However, the grains are more thin-walled and often crumpled. Number of apertures five, six and four.

Alnus crispa var. mollis Fern. - Labrador. Pollen grains suboblate (15 x 18 u). Pattern fine, indistinct. Arci poorly defined if present. Thickness of exine 0.8 - 1 u. Sexine as thick as or thicker than nexine. Apertures flat, diameter ca 5 µ.

Alnus crispa (Ait.) Pursh. var. sinuata (Regel) Rydb. - National Herbarium, Ottawa. Ottawa # 46. NOTE: Western. Lake Louise, Alta. June 25, 1951. A.E. Porsild No. 17967. Pollen grains oblate (17 x 26 u). Coarse, distinct pattern. Apertures flattened. Arci indistinct. Thickness of exine *ca* 1.2 u. Sexine thicker than nexine. In polar view the grains are rather regular in outline.

Alnus rugosa (DuRoi) Spreng. var. *americana* (Regel) Fern. - National Herbarium, Ottawa. Ottawa # 47. Ste. Anne Des Monts, Gaspe P.Q. June 10, 1885. Porter (Can. No. 41135). Distributed as *A. incana* Ait. Pollen grains oblate (15.4 x 22 u). Arcî strong, swinging in. Thickness of exine *ca* 1.5 u. Apertures rather flat. Sexine thicker than nexine. Diameter of apertures *ca* 6.5 u.

Alnus rugosa var. *americana* (Regel) Fern. - Herbarium of McMaster University # 640 (193). Pollen grains oblate (17 x 26 u). Apertures well defined, pouting. Arci distinct, swinging in towards the centre (in polar view). Pattern fine, indistinct. Number of apertures five, six and four. Thickness of exine 1.5 - 2 u. Sexine thicker than nexine. Plate IX, fig. 2.

Alnus incana (L.) Moench. - National Herbarium, Ottawa. Ottawa # 45. NOTE: Western. Dawson, Yukon Territory. April 29,1914. Alice Eastwood (Can. # 41339). Pollen grains oblate (20.5 x 30 u). Arci well defined. Thickness of exine *ca* 2 u. Sexine to nexine as 3 to 1. Pattern fine, granular, distinct. A number of grains have four apertures. Plate VIII, figure 11.

Alnus tenuifolia Nutt. - Herbarium of Univ. of B.C. Vancouver # 6421. Armstrong, Okanagan Valley, B.C. E. Wilson. April 4, 1944. Pollen grains oblate (16 x 23 u). Arci well present. Apertures well defined, pouting, number generally five but some grains are 4-aperturate. Thickness of exine 1 - 1.5 u. Sexine thicker than nexine. Pattern fine, indistinct.

Alnus oregona (Bong.) / *A. rubra*/ - Herbarium of Univ. of B.C. Vancouver, # 6337. West Point Gray, Vancouver, B.C. J.W. Eastham # 1991. March 13, 1937. Pollen grains oblate (18 x 26 u). Arci quite well defined. Pattern fine, indistinct. Thickness of exine ca 1.5 u. Sexine thicker than nexine. Apertures flattened, number chiefly five.

Alnus sinuata (Regel) Rydb. - Herbarium of Univ. of B.C. Vancouver, # 6403. South of Fort St. James, B.C., J.W. Eastham # 11816. July 3, 1944. Pollen grains oblate (15.4 x 22 u). Arci poorly defined, running around the periphery (in polar view). Pattern fine, indistinct. Apertures poorly defined.

The aim in studying the alder pollen was to investigate the possibility that the pollen of the more northerly *Alnus crispa* might be different in morphological character from that of *Alnus rugosa* which has a more southerly distribution. Fernald gives the following grouping of *Alnus* in Gray's Manual of Botany.

ALNUS B. Ehrh.

Subgenus A l n a s t e r Endl.

Alnus crispa (Ait.) Pursh.

Alnus crispa var. *mollis* Fern.

Subgenus A l n u s Endl.

Alnus rugosa (DuRoi) Spreng.

Alnus rugosa var. *americana* (Regel). Fern

Alnus serrulata (Ait.) Willd.

It seems to be supported by the pollen morphological studies that the subgenera mentioned above have slightly different pollen. *Alnus crispa* pollen appears as more thin-walled, often crumpled in fossil material, with arci poorly defined or absent, whereas pollen of *Alnus rugosa* seems to have well defined arci, a thicker exine and in fossil material appears to be of a more regular shape (not crumpled). Apertures in *Alnus rugosa* are often larger and more distinct than those in *Alnus crispa*.

The fossil *Alnus* pollen in the material from the St. Pierre interval and in early post glacial sediments in the St. Lawrence Lowland matches that of *Alnus crispa* whereas towards the present time pollen of *Alnus rugosa* type becomes dominant.

Juglandaceae

<u>Carya ovata</u> (Mill.) K.Koch - Herbarium of McMaster University, Hamilton, Ont. # 196. Pollen grains oblate (29 x 48 u). Apertures generally three, sometimes four, close to the equator on one hemisphere. Pattern fine in polar view, coarser and distinct towards and around the apertures. Thickness of exine <u>ca</u> 2.5 u. Sexine much thicker than nexine.

<u>Carya cordiformis</u> (Wangh.) K.Köch - Herbarium of McMaster University, Hamilton, Ont. # 17. Pollen grains oblate (28 x 42 u). General appearance much like that of <u>Carya ovata</u> but apertures definitely closer to the equator.

Aceraceae

ACER - five species investigated.

<u>Acer saccharum</u> Marsh. - (<u>A. saccharinum</u> Wangh. not L.) - National Herbarium, Ottawa. Niagara escarpment, Lincoln County, Ont. May 4, 1897. W.C. McCalla # 4 (Can. No. 79900). Pollen grains subprolate (38 x 30 u). 3-colpate. Sexine thicker than nexine. Bacula distinct. Pattern dense, distinct, finely reticular (?). No striation.

<u>Acer saccharinum</u> L. - Material from the collection of modern pollen at the Muskeg Research Laboratory at McMaster University, Hamilton, Ont. # 257 B. Pollen grains prolate (40 x 27 u). 3-colpate. Sexine thicker than

nexine, bacula distinct. Surface of exine markedly uneven. Exine thinning out towards colpi. Otherwise distinct pattern is somewhat obscured by the uneven surface of the exine. Pattern becomes indistinct towards the margins of the colpi. Striation present.

Acer negundo L. - Material from the collection of modern pollen at the Muskeg Research Laboratory, McMaster Univ., Hamilton, Ont. Pollen grains subprolate (33 x 26 u). 3-colpate, sexine thicker than nexine. Pattern dense, finely reticular, not as distinct as in A. saccharum. Bacula indistinctly visible. No striation. Exine surface undulating this being very prominent on some poorly developed or young pollen grains .

Acer macrophyllum Pursh. - Herbarium of Univ, of B.C. Vancouver # 5739. West Point Gray, Vancouver, B.C. C.B.W. Rogers # 12. April 27, 1948. Pollen grains subprolate (43 x 37 u), 3-colpate. Sexine thicker than nexine. Striation quite distinct. Pattern fine, bacula indistinctly visible. When striation is very distinct then the surface of exine seems to be undulating. Plate IV, figure 13, 14.

Acer circinatum Pursh. - Herbarium of Univ. of B.C. Vancouver, # 5690. Haney, B.C. T.M.C. Taylor # 1008. May 3, 1947. Pollen grains subprolate (28 x 23 u), 3-colporate or 3-colporoidate. Pattern coarse, distinct. Striation present. Bacula distinct. Sexine slightly thicker than nexine.

Oleaceae

Fraxinus pennsylvanica Marsh. - Material from the collection of modern pollen at the Muskeg Research Laboratory, McMaster Univ., Hamilton, Ont. Pollen grains mostly expanded and round, diameter ca 22 u, occasionally ca 22 x 19 u (subprolate). 4- 3- and 5-colpate. Margins of the colpi rugged, thinning out. Reticulation coarse, very distinct. Plate IV, figure 16.

Fraxinus excelsior L. - Material from the collection of modern pollen at the Muskeg Research Laboratory, McMaster Univ., Hamilton, Ont. Pollen grains expended, round, diameter ca 23 u. Reticulation slightly coarser than that of F. pennsylvanica and also very distinct. Pollen grains mostly 3-colpate. Plate IV, figure 15.

Arbutus Menziesii Pursh. - National Herbarium, Ottawa. Victoria, B.C. May 1885. J. Fletcher (Can. No. 89096). Diameter of tetrads 50 u. Tetrads rounded, with strongly marked, long, narrow apertures. Pattern fine, granular.

The above descriptive study of pollen grains suggests several aspects that contribute to the objective of this study.

The fundamental study of modern pollen enables the palynologist to recognize more species of plants among the fossil pollen and spore assemblages. This improves the chances for a correct interpretation of the data.

Also, this kind of study is important from the taxonomical point of view. For example, in the study of *Betula* and *Alnus* pollen different taxonomical units may be described by their pollen.

The recognition of species by their pollen morphology opens up new aspects in phytogeography (tracing the migration of plants during the past) and also in ecological and climatological interpretation.

V PALEOBOTANICAL, GEOLOGICAL AND PHYTOGEOGRAPHICAL APPLICATIONS

1. Interpretation of Microfossil and Megafossil Content of the Studied Deposits

If in a certain layer of deposit an assemblage of micro- and megafossils is found the worker is immediately faced with the problem of what this assemblage of fossils means in terms of vegetation, and further still, what this composition of fossils will tell him about the contemporary climate and environmental conditions at the time that the deposit in question was laid down.

It is well known that there exist close inter-relations between geological, biological and meteorological factors and these relationships have been illustrated below.

Geology ⟷ Climate

Relief and soil

↑ ↓

Vegetation

↑ ↓

Animal life

If a certain type of vegetation has been established by a study of the microfossils in ancient deposits, and if the relationships of this particular type of vegetation to its environmental requirements are known one can draw definite conclusions as to the contemporary environmental conditions.

The importance of geological and ecological considerations becomes rather obvious when interpreting the pollen diagram. O. Beenhouwer (1953) in collaboration with P. Sears has studied the inter-relations between the Thornthwaite climatic classification and palynology and he finds that,

> "From the species and genera present at a particular level in a pollen profile, from the fact of their presence alone, a summation of the climatic characteristics of the individual species and genera can be read off as the series of possible climates for that level." And further that, " It can be said that the climate at the given level must have been between the extremes of the series of possible moisture and thermal conditions; it definitely cannot be said what the actual climate was at the given level (time) in the specific locale from which the profile came merely from a list of the species and genera present."

One must carefully consider the autecology and synecology of the species in the profile together with a precentual amount of each pollen type to establish the actual climate. The influence of the geological background in palynological studies has been made evident by the studies on relations of soils and forest growth by Wilde, Whitford and Youngberg (1948) where they found that,

> "Limestone ridges support clumps of bur oak and red cedar. Sandy terraces are covered by jack pine or scrub oaks. Poorly drained soils are occupied by sedges or lowland hardwoods, viz. elm, black ash, swamp white oak, river birch, silver maple, cottonwood and willows. Tamarack is found on moss peat formed in relic oxbows. This forest cover, common to the prairie-forest zone of Wisconsin, in this particular area is supplemented by the unusual occurrence of red pine, white pine, hemlock, and yellow birch growing on outcrops of sandstone."

The above quotation illustrates rather well the fact that Pleistocene geology may yield very useful information for palynological considerations.

Ecological studies have proved that vegetation on a sand area is different from that on a clay area and it is certain that former types of vegetation were just as different during the past. Pollen diagrams from these areas are also different, but if, for example, a climatic change takes place in the district covering both areas it will show in both diagrams but likely in a different manner. An experienced botanist with some knowledge of geology would probably be able to distinguish between edaphic and climatic influence in the pollen diagram.

From the above it is clear, and the writer wants to point out particularly, that the pollen diagrams and the relative percentage curves of various pollen types should never be considered as independent phenomena and discussed as such. One should remember that the pollen percentages in a diagram are only registrations of vegetation.

Another factor influencing the interpretation of pollen diagrams is the pollen production of various plant species and the formation of the pollen rain that is reflected by the pollen diagram. H.A. Hyde (1950) has discovered that at different stations where the atmospheric pollen was investigated, the pollen picture was mainly influenced by the sources of pollen close to the station. An extensive, homogeneous pollen cloud will be formed only when the species under consideration is growing over a wide area. The problem of long-distance transport of pollen grains and the relative importance of this factor on the pollen diagram has been discussed and studied by a number of authors and it seems to have significance in cases when the local pollen production is, for some reason, low.

The factor of pollen production and the dispersal of pollen of various plants must also be carefully taken into account. For example, pine produces tremendous amounts of pollen and the pollen grains are well dispersed by wind. The genus Calluna (Ericaceae) produces a great amount of pollen but the dispersal is poor.

Plants could be grouped according to their pollen production. One group could include plants that produce great quantities of pollen: Pinus, Betula, Alnus, Corylus. One group could include poor pollen producers: Picea, Tilia, Fraxinus, Fagus. Another group might include plants that have a scattered distribution and are poor pollen producers as well: Ilex, Viscum, Vitis, Lonicera. The last group might include species that as climatological indicators are of great value but that have a scattered appearance in the pollen diagram, and must be considered in a special way.

On the basis of the pollen production and dispersal of different plants several workers (cf. Faegri and Iversen, 1950) have calculated corrections for final diagrams. I have taken the following example from Faegri and Iversen (1950, p. 88), to illustrate the principle.

	Number of pollen grains	Percentage	Number after reduction	Percentage after reduction
Pinus	120	60	30	30
Betula	24	12	6	6
Querc. mixt.	32	16	32	32
Fagus	24	12	24	24
	200	100		
Corylus	32	16	8	8
			100	100

In this case the *Quercetum mixtum* includes the Scandinavian broad-leaved tree species, and *Corylus* is in the first case calculated outside the AP total and included in the AP in the reduced diagram. It has been common practice among pollen analysts (at least in Europe) to sum up all tree pollen (AP - arboreal pollen) as 100 per cent and on this total calculate the percentages of pollen grains of herbaceous plants and scrubs (*Corylus* in the above case), constituting the NAP - non-arboreal pollen. The percentage of spores is usually calculated on the AP total.

This procedure seems arbitrary to the writer because it is logical to think that the pollen and spore flora should be treated as a whole in a sample. However, the writer appreciates fully the difficulties in treating the AP, NAP and spores together, as the NAP and spores in general are not uniformly dispersed over a large area and are of local origin in most cases.

Whether a reduction should be supplied in all cases seems debatable to the writer, chiefly because not enough is known yet about the inter-relations between pollen spectra and the vegetation to justify the corrections. For these reasons the customary procedure of making the diagrams and calculating the percentages has been followed during this investigation.

Another factor influencing the interpretation of a pollen diagram is the problem of "secondary pollen" in sediments with a high content of inorganic matter; geological and limnological judgement has to be used in these cases, and possible sources from which the secondary pollen could have been derived must be considered.

Establishing the position of the timber-line in the early post glacial time, that is, determining which pollen spectrum indicates a forested area and which represents the tundra conditions, has caused much controversy among pollen analysts. The general opinion is that the ratio AP/NAP is useful and that the AP is dominant in the forested area and close to the timber-line, whereas in the treeless tundra the NAP becomes dominant. However, going farther away from the timber-line the AP starts to increase again owing to the very low local pollen production and the relative importance of the far-transported pollen grains and spores. Botanical judgement together with common sense have to be used to resolve these difficulties.

Experience has shown that lake sediments are the best source of samples for palynological investigations. Peat samples must be considered as subject to greater local influence, that is, from plants growing at the spot of sampling. The composition of NAP especially seems to be affected by the plants growing at the sampling point or very close to it. A lake bottom sediment seems to receive a rather well-mixed assemblage of pollen grains and spores representing the surrounding vegetation in a wider area. Moreover, if the bog surface is of soft, spongy *Sphagnum* moss the undecomposed top part of peat is unsuitable for pollen analysis. In many cases, however, peat is the only usable source of material.

Complicated statistical methods to cover the sampling errors and to evaluate the final results have been worked out, for example, by Faegri and Ottestad (1948). The writer believes that these methods are useful when one keeps in mind the nature of the material and does not forget his botanical, geological and palynological judgement and common sense.

Studying the pollen spectra in different forest regions along a north-south transect one finds that these spectra differ according to the specific forest regions. The same kind of change in pollen assemblages is found in a sediment series from a lake located close to, or within the border of, the last glaciation. Evidence of a tundra type of vegetation is found at the bottom of the sequence and then gradually working upward we pass through changing pollen assemblages which indicate a migration of forest types. This is the principle on which the discussions on the climatological changes during the past are based. Now, as the climatological changes were contemporaneous over extensive areas, even if the changes show in a different manner in different areas, it is possible to correlate pollen diagrams from one locality with those from another and, besides climatological data, the migrations of vegetational units can be traced. Further, if absolute dates for certain horizons in the diagrams can be established, for example, by means of radiocarbon dating, the age of specific horizons in other diagrams some distance from the first can be estimated. In this way, if an area has been extensively studied palynologically, it is possible to work out fossil forest maps for particular time intervals in the past. This has actually been done for Denmakr and for Southern Sweden (Faegri and Iversen, 1950). In Germany, Firbas (1949) has worked out, using all available pollen diagrams of the area, the migrations of different forest tree species during the post-glacial time.

2. Age of the Interglacial Beds of the Toronto Formation

It seems to be a curious coincidence that in three separate areas the interglacial deposits better known and climatologically more significant than any others elsewhere (the Toronto formation, the Hötting deposits in northern Alps and the Eem deposits in the southern Baltic region) are similar in their stratigraphy, i.e. they are overlain by drift of a recent ice advance and are underlain by drift of unknown age.

All attempts so far have failed to yield a satisfactory answer to the problem of the position of these beds in the Pleistocene stratigraphy. As the geological evidence and megafossils have not given conclusive results the writer has attempted to utilize microfossils (both the qualitative and quantitative assemblage) for exploring new ways to solve the problem.

During recent years the Pleistocene geology of the Toronto region has been intensively studied by A.K. Watt of the Ontario Department of Mines and by A. Dreimanis of the University of Western Ontario.

As a result of A.P. Coleman's studies the following composite Pleistocene section including the Toronto formation could be constructed (see Flint, 1949, p. 286).

Lake Iroquois features (wave-cut cliffs, gravel bars, and finer sediments with fossils).

Upper till (sandy till with swell-and-swale topography, veneering the older deposits).

Interglacial sand, possibly marine.

Middle complex consisting of tills, interbedded with varved fine sediments.

	<u>Scarborough beds</u>. Stratified clay-silt and sand, with peat. Include 14 species of trees and 72 species of beetles of which 70 are extinct. Both trees and beetles indicate a cli ate cooler than now, though
Toronto formation (interglacial)	by no means subarctic.
	- probable conformity -
	<u>Don beds</u>. Lacustrine caly, sand and gravel, and peat with 32 species of trees, including pawpaw, red cedar, and osage orange; pelecypods and gastropods; vertebrates including woodchuck, deer, bison, bear, and giant beaver, indicating a mean temperature higher than now by 2 deg. to 3 deg.C.

Lower till, 2 to 3 feet thick; fresh, no weathering of upper surface.

A close examination yielded the following sequence of Pleistocene deposits in the Don Valley Brick Yard (see figure 4).

On the Ordovician shale is a thin layer of till, about two to four feet in thickness. This till is bluish-grey in color and appears to be fresh with no signs of weathering of upper surface. It is compact and harder than the younger tills and it contains numerous small pebbles together with some cobbles and a few boulders in a sandy matrix. Most of the pebbles and cobbles are of local bedrock. However, there are pebbles and boulders of more ancient rocks, granite, gneiss and dark, fine-grained volcanics. Many stones in the till have striae on their faceted surfaces.

Overlying the fresh till are the Don beds with a total thickness of twenty-seven feet. The basal portion of the Don beds is clayey, with a layer of blue, stoneless clay overlying the till; thin layers of sand occur in this clayey part of the section (Plate XX, figure B and C). About four feet up from the surface of the till the sequence changes to medium-grained to coarse sand with thin beds of clay. Lenses of fine gravel may occur in this sand at a level approximately ten feet from the top of till (Plate XX, figure D). Overlying this sandy sequence is a layer of stratified silt and clay with thin sand partings. Numerous thin streaks of organic debris occur in this layer (from twelve to fifteen feet from the top of till) and fossil wood is plentiful in this part of the section (cf. Plate XIX, figure C and D). Overlying the stratified silt and clay are two to three feet of sand with layers of clay. At eighteen to twenty feet from the bcrock there is a layer of yellow-coloured coarse sand overlain by four feet of str tified silty clay which is again overlain by yellow medium-grained to coarse sand which is considered to be the top of the Don beds.

Overlying the rusty yellow sand of the Don beds are about eighteen feet of stratified silt and clay (the Scarborough beds). The upper surface of this stratified silt

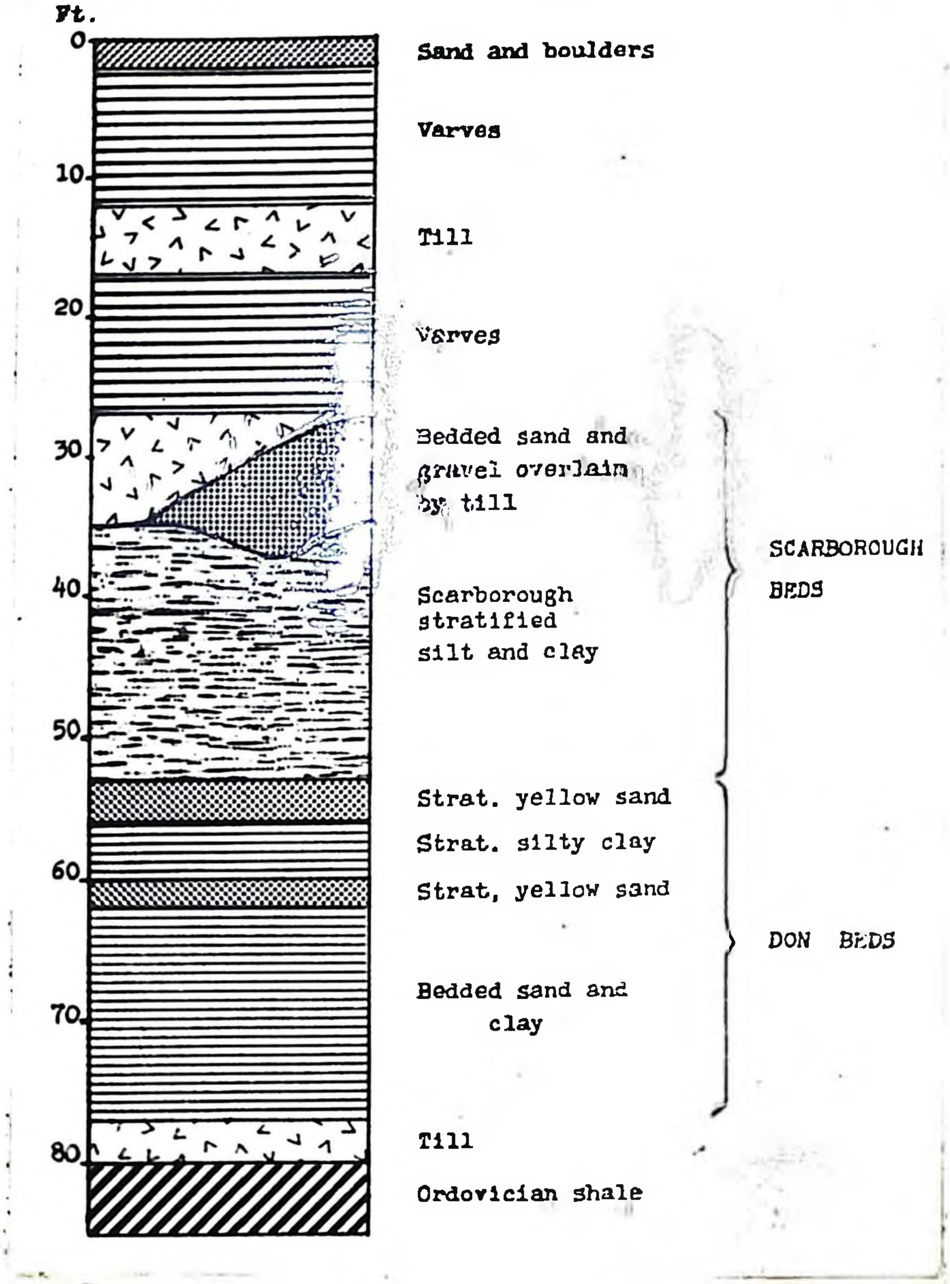

Figure 4. Section through the Pleistocene deposits in the Don Valley Brick Yard.

and clay has been subject to erosion by water and this process is clearly evident in the valley-cutting by streams. One of these valleys has been studied closely and there gravel with boulders is found on the bottom of the old valley, mixed with and overlain by crossbedded sand containing chunks of clay, sometimes with preserved stratification. According to Coleman, the valleys may sometimes be cut down right to the basal till so that the till which overlies the valley deposits is resting on the older till. The thickness of the valley deposits and the till is generally ten feet, but may be more in some places and less in others. The contact between the stratified clay and silt and the valley deposits and the overlying till is an erosional one and therefore sharp (Plate XXII).

This till is overlain by varves and the contact is a gradual change from till to varves without a distinct break. In the lower part of the varves there are abundant pebbles and a few cobbles.

This sequence of varves is again overlain by another sheet of till and the contact here is also a gradual one towards the overlying varves.

The section in the Don Valley Brick Yard is topped by sand and boulders. At Leaside, a short distance (about a mile) north of the section in the Brick Yard, Coleman reports the following sequence. About fifteen feet of stratified sand that lies on varved clay is overlain by thirty feet of sandy till, which may be blue-coloured and fine-textured in places.

The till and the sand were exposed by digging by the writer but a detailed study was impossible because of extensive slump.

The following sequence of Pleistocene deposits (see figure 5) has been disclosed by studies of the excellent sections along the shore of Lake Ontario at the Scarborough Bluffs.

From the lake level up, there are about forty feet of stratified silt and sand with thin layers and lenses of organic debris (fragments of plants between the layers, cf. Plate XXIV, figure D). Then follows a massive layer (ten feet) of silt and fine sand containing finely disseminated organic matter. This bed is overlain by a layer of stratified silt (one foot), then by a one foot layer of massive silt, which is overlain by ten feet of stratified silt and sand. Then follows another layer of massive silt (about one and a half feet) and this is overlain by twelve feet of stratified silt and sand. This bed is overlain by a massive layer of bedded silt, followed by five feet of stratified fine sand and silt with 'peaty' partings between layers. The stratified beds previously mentioned also have partings of organic debris between some of the layers. Then follows a thirty to fifty foot bed of crossbedded and stratified sand which may occasionally contain chips of wood and other coarse plant debris in the crossbedding (Plate XXII, figure B). This sand contains a few silty 'peaty' layers of organic debris in the

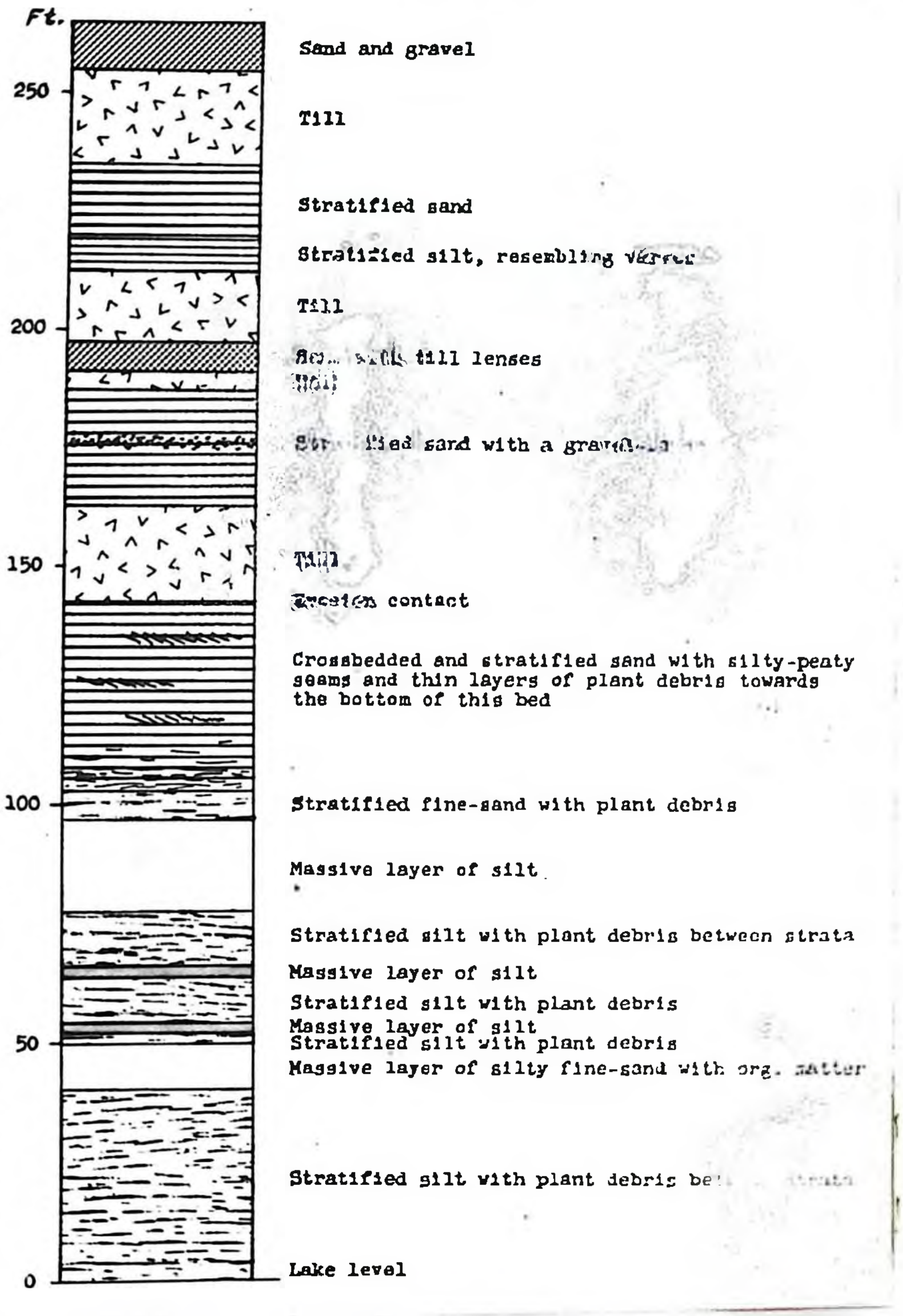

Figure 5. The Seminary section at Scarborough Bluffs, showing the Scarborough beds and the overlying till-complex. This section was measured in a large ravine about 1000 feet northeast from the end of Underhill Drive.

basal part of the sand. The medium-grained or coarse sand is overlain by fifteen to twenty feet of till and the contact is a markedly sharp one (Plate XXII, figure A). Apparently a period of erosion preceded the deposition of the till. Above the till is a twenty-five foot layer of stratified medium-grained to coarse sand with a layer of gravel in the middle. The sand is followed by four feet of till and then by four to five feet of sand which contains some lenses of till-like material. Then follow about fifteen feet of till, overlain by five to eight feet of poorly varved silt and fifteen to twenty feet of stratified sand. The sand is overlain by twenty feet of till and the section is topped by ten feet of sand and gravel.

At the lake level opposite the bluffs where the above section was measured, i.e. in a large ravine about 1000 feet northeast from the end of Underhill Drive, close to the Seminaty, Coleman (1933) reports as the result of drilling,

"Beneath a few feet (five feet) of clay like that above water, a set of sandy beds (thirty-five feet) charged with shells and bits of wood, evidently representing the warm climate beds of the Don Valley."

This supports the idea that the entire section exposed at the Scarborough Bluffs correlates with the upper part of the section exposed in the Don Valley Brick Yard.

There is strong evidence of a period of erosion following the deposition of the Scarborough beds (the stratified silt, clay and sand in the Seminary section up to the first till bed). About half a mile southwest from the Seminary

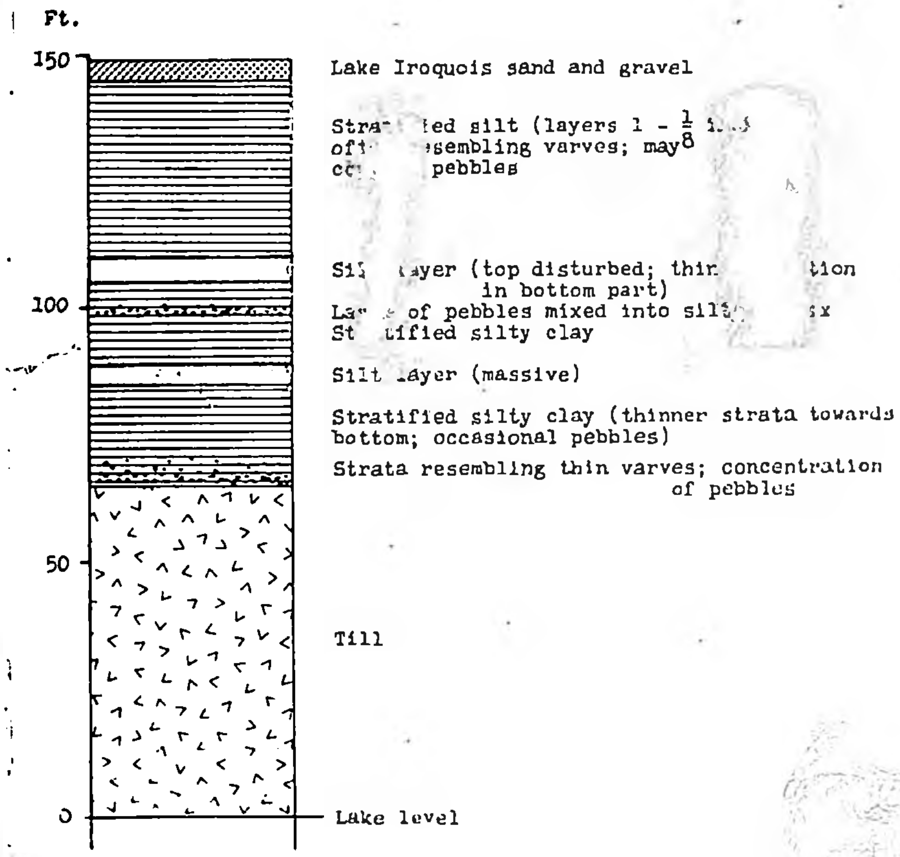

Figure 6. The Dutch Church section at Scarborough Bluffs, showing thick till and overlying lacustrine deposits filling an eroded valley in the Scarborough beds.

section a valley has been cut deep into the Scarborough clays and silts and is now filled with till overlain by stratified silt and clay. The till forms the cliff right down to the level of lake at this part of the bluffs, which is called the "Dutch Church". A section of the cliff at this point has been illustrated in figure 6. Coleman thought that the valley was eroded during a period of deglaciation, when the lake level dropped after deposition of the Scarborough beds. A.K. Watt (1953) has suggested that the valley was eroded by the advancing ice which gouged large troughs out of the inter-glacial beds. The writer is inclined to think that the valley at Scarborough Bluffs and also the valleys at the Don Valley Brick Yard were eroded by water perhaps shortly before the area was over-ridden by the ice. There are boulders and stratified gravel and sand deposited along these valleys, including chunks of stratified Scarborough silt and clay. It seems that for some reason the lake in which the Scarborough beds were deposited was drained and sand deposited over the earlier silt and clay. The sand was eroded by the advancing ice and the material in the valleys was partly removed. Depositon of crossbedded sand in front of the advancing glacier is evident also in the upper sequence of varves and till (cf. Plate XXIII, figure A and B).

The following sequence of events can be interpreted from the geological section of the Toronto formation.

Above the Upper Ordovician shale and limestone deposited possibly three hundred million years ago, there is no evidence of deposition during the Upper Paleozoic, Mesozoic and Cenozoic eras except in the most recent Pleistocene time. It is likely that some deposition has occurred during so extensive a period of time, but all traces of it have been removed by subsequent erosion.

It is probable that deposition occurred during the Pleistocene time previous to the glaciation represented by the basal till. But these deposits also were removed by the advancing ice sheets or by water during periods of deglaciation. Why the most recent glaciation in the Toronto region did not remove all traces of the previous deposits is an unanswered question and lies beyond the scope of this investigation.

After deposition of the basal till the interglacial Don beds were laid down. There is possibly an unconformity between the till and the Don beds. This point of view, however, is open to question as the till surface does not show evidence of the erosion or weathering which logically would have occurred if the till surface were exposed for any length of time. It is also possible that the cold period, immediately following the ice recession is represented by very little deposition (clay is deposited on the till) and fossil evidence is lacking.

It seems reasonable to suppose that some deposition occurred during the late glacial time but that these deposits may have been partly eroded before the deposition of the warm-climate Don beds. Sudden changes must have taken place during the deposition of the lower part of the Don beds, as layers of sand, clay and gravel closely follow one another (Plate XX). At the middle of the interglacial sequence of deposits a bed of stratified silt occurs with lenses of gravel and sand. The silt strata contain abundant, finely disseminated plant fragments and occasionally trunks of trees are found here.

The upper part of the Don beds is rather sandy and ends with a bed of coarse sand and fine gravel towards the overlying Scarborough beds which consist of stratified silt and clay. There likely is conformity between the Don beds and the Scarborough beds, although the latter represent an assemblage of fossils that indicate a boreal to subarctic climate. It is probable that a lake was dammed up in front of the advancing ice, and such a condition would explain the change from sand to silt and clay in deposition. The Scarborough silt and clay is overlain by a sequence of sand that shows erosion previous to the overriding by ice. This contact has been discussed on pages 110-112. Overlying the Scarborough sands is a sequence of tills and varved clays with some sand. The members of this sequence are so closely associated that it seems logical to assume that the sequence was deposited by one glaciation with rather small fluctuations of the ice margin.

This sequence of tills interbedded with varved and stratified fine sediments is overlain by sand which apparently originated from a period of deglaciation previous to the most recent glaciation depositing till in the Toronto region.

Now the question arises - can the age of the interglacial beds of the Toronto formation be determined from the geological evidence alone ? The answer is obviously no.

The next step is to find some suitable way of measuring the age of the deposit. Here also, one runs into difficulties. The methods for dating older Cenozoic, Mesozoic amd Paleozoic deposits cannot be used because of the wide margin of error. The methods for dating post glacial and Late Wisconsin events cannot be used either because the range of these methods, for example, the radiocarbon method, does not extend beyond 25,000 - 40,000 years from the recent (Libby, 1952;Suess 1954). Wood from the interglacial Don beds has been reported by R.F. Flint (personal communication) to lie beyond the present dating methods.

Rubin and Suess (1955) report the age of a sample (W-121) as older than 30,000 years. A.K. Watt collected this sample from stratified sands under the upper till which were exposed near St. Clair Avenue by the Toronto Rapid Transit Subway excavation. The writer has suggested a correlation between these sands and the Upper Scarborough beds. The interglacial Don beds must be considerably older. In this connection Suess (in Rubin and Suess, 1955) states that,

"No absolute dates are given for samples found to be older than 32,000 years. Although the carbon-14 determinations as such are sufficiently accurate to measure radiocarbon from samples as old as 45,000 years, we feel that further work is necessary to substantiate the validity of radiocarbon dates in that range."

As the geological evidence and the dating methods do not yield conclusive results one is left with another possibility, and that is to study the fossil evidence in these deposits.

The fossils in the Pleistocene deposits can in most cases be related to the plants and animals that are living at the present time, and with a knowledge of the environmental requirements of these modern organisms it is possible to reconstruct the climatic situation and environmental conditions that produced a certain assemblage of fossils. The careful piecing together of geological and fossil evidence leads to results that permit at least tentative conclusions about the age of certain deposits.

The numerous shells in the Don beds were collected by A.P. Coleman and a list was prepared by W.H. Dall of Washington. Unfortunately a study of these fossils and changes of the assemblage through the section vertically was not made, nor was the relative abundance of types of these fossils considered in different beds of the sequence. Therefore the long list of fossils has to be discussed as a unit and interpretations must be based on the assemblage as a whole. The following Pelecypoda and Gastropoda have been identified by Dall (in Coleman, 1933). This list has been revised according to "The Fresh Water Mollusca of Wisconsin" by F.C. Baker, Bull. # 70, Wisconsin Geol. and Natural History Survey, 1928, the original list being the work of W.H. Dall of Washington. Older names have been put in parentheses.

Fossil Pelecypoda and Gastropoda identified from the interglacial Don beds.

Pelecypoda:	Habitat
Amblema costata (*Quadrula undulata*)	Small rivers and tributaries of large rivers; chiefly in sand but sometimes in mud
Elliptio dilatatus (*Elliptio gibbosus*)	Rivers and lakes; in mud and sand
Fusconaia undata (*Quadrula undata*)	Large rivers; deep water; mud bottom
Lampsilis siliquoidea (*L. luteola*)	Quiet water; mud bottom
Lampsilis ventricosa	Large rivers; sand and gravel bottom; rarely mud
Ligumia recta (*Eurynia recta*)	Rivers, lakes; stony, gravelly and sandy bottom
Pleurobema clava	Small streams or creeks; in sand or gravel
Pleurobema coccineum (*Quadrula coccineum*)	Small streams or creeks; in sand or gravel
P. coccineum solida (*P. solidum*)	Medium sized rivers; sand, gravel or mud
P. pyramidatum (*Quadrula pyramidatum*)	Medium sized rivers; sand, gravel or mud
Pisidium adamsi	Quiet water; small lakes and slow streams
Pisidium compressum	Creeks, rivers; mud bottom
Pisidium noveboracense (?)	Spring brooks
Sphaerium rhomboideum	Rivers, lakes; mud bottom
Sphaerium simile	Rivers; gravel and sand
Sphaerium simile var. (*Sphaerium sulcatum*)	Rivers; gravel and sand
Sphaerium solidulum	Clear, shallow water; gravel and sand bottom

Sphaerium striatinum	Rivers, lakes; sand and gravel bottom

Gastropoda:

Acella haldemane (*Goniobasis haldemane*)	Sheltered bays in larger lakes
Amnicola ancillaria (?)	
Amnicola limosa	Rivers, streams and quiet bodies of water
Amnicola porata	Lakes
Biasolla subglobosa (*Somatogyrus subglobosus*)	Lakes
Cincinnatia emarginata lacustris (*Amnicola emarginata*)	Lakes
Goniobasis livescens (*depygis*)	Rivers
Pleurocera acuta	Shores of great lakes where wave action is strong
Pleurocera acuta tracta (*Pleurocera elevatum*)	Various habitats
Pomatiopsis cincinnatiensis	On wet earth and roots at margins of small streams
Valvata lewisii (?)	In lakes for the most part
Valvata sincera	Same as above
Valvata tricarinata	Same as above
Gyraulus parvus (*Planorbis parvus*)	Small bodies of water; associated with vegetation
Lioplax subcarinata (*Limnaea bicarinatus*)	Same as above
Physella heterostropha (*Physa heterostropha*)	Mud flats and sewage
Stagnicola palustris elodes (*Limnaea elodes*)	Both clear and stagnant water but prefers water not in motion

Stagnicola desidiosa
(*Limnaea desidiosa*)

Succinea avara Terrestrial

Most of the fossils listed above indicate conditions close to the present in the Toronto region but some are thought to represent a warmer climate and to have a distributin slightly south of Lake Ontario (cf. Coleman, 1933).

On the basis of leaf fossils the following plants were identified from the Don beds by D.P. Penhallow.

	Common name
Acer saccharum	Sugar, hard or rock maple
Acer saccharinum	Silver or white maple
Acer spicatum	Mountain maple
Acer pleistocenicum	
Acer torontoniensis	
Asimina triloba *	Pawpaw
Carya ovata	Shell-bark hickory
Chamaecyparis thyoides *	Southern white cedar
Clethra alnifolia	White alder
Fraxinus quadrangulata *	Blue ash
Fraxinus nigra	Black or swamp ash
Fraxinus americana	White ash
Gleditsia donensis	(Honey locust)
Juniperus virginiana	Red cedar
Maclura pomifera *	Osage oragne
Ostrya virginiana	Hop hornbeam

Pinus strobus	White pine
Platanus occidentalis	Sycamore
Populus balsamifera	Balsam poplar
Prunus sp.	Cherry or plum
Quercus stellata *	Post oak, iron oak
Quercus alba	White oak
Quercus rubra	Red oak
Quercus velutina	Black oak
Quercus macrocarpa	Bur oak
Quercus muhlenbergii *	Chestnut oak
Populus grandidentata	Large-toothed aspen
Robinia pseudacacia *	Black locust
Salix sp.	Willow
Taxus canadensis	Yew
Ulmus sp.	Elm
Thuja occidentalis	Eastern white cedar

Trees followed by * are of southerly distribution.

The above list was revised by A. Hollick and J.H. White and A. Hollick supplied the following additional species.

Acer carolinianum (?) Walt.	*Ilex* sp.
Alnus serrulata Willd.	*Tilia* sp.
Castanea dentata Marsh.	*Vitis* sp.

Furthermore the following plants were identified by D.P. Penhallow from the Don beds.

Cyperaceae	*Eriocaulon* sp.
Festuca sp.	*Hippuris vulgaris*

Vaccinium uliginosum	*Chara* sp.
Drepanocladus capillifolius	*Hypnum* sp.

The seeds were examined by W.A. McAtee and he identified *Naias* sp., *Scirpus* sp. and *Sicyos angulatus* from this assemblage.

The following animal fossils have been identified from the Don beds.

Arctomis monax	- ground-hog
Castoroides ohioensis	- giant beaver
Two species of deer	(antlers)
Bones of bison	
Bones of bear	- (grizzly ?)

The identified tree assemblage in the Don beds consists of a total of 38 species of which four are coniferous and 34 are deciduous. Seven species are thought to be of a southerly distribution; and two species of maple, to be extinct. According to Coleman the botanists and foresters agreed that this interglacial forest indicates a climate about four to five degrees warmer that the present, resembling that of Ohio and Pennsylvania at the present time.

The presence of extinct species was considered as proof that the interglacial Don beds were of great age. However, as the identification of these species was based on fossil leaves, considerable criticism has been directed towards the validity of this conclusion. R.W. Brown (1942) has investigated this problem and he found that, "It would not be surprising to find maples among such an assemblage, but the illustrations given by Penhallow, and repeated by Coleman, of the type specimens of the supposed extinct maples are not those of maples but of variant leaves of the plane-tree or sycamore, Platanus occidentalis, a species already listed as being present in the Don Valley collections. That these maples are in fact sycamores is corroborated by Penhallow's description of Acer torontoniensis. Of these leaves he says: 'Two principal veins extend from the base of the midrib to the corresponding lobes, and two subordinate veins of varying prominence extend diagonally downward from near the same point into the two minor and variable lobes which form the base of the leaf blade.' The last clause gives the clue to the distinction between full-formed, typical maple and sycamore leaves. In palmately veined maple leaves all the strong primary veins and an occasional pair of lesser veins radiate from the same point at the top of the petiole. In sycamores, however, only two primary lateral veins arise from the top of the petiole, a strong secondary vein branches into the lower lobe of the leaf.

An inspection of Coleman's upper illustration on page 188, which is a reproduction of one from Penhallow, shows the strong secondaries branching from the primaries at about a half inch from the top of the petiole. The basal sinus of this leaf also is platanoid, with the margin concave inward, rather than convex outward, as it would be in maples. The marginal teeth on the fossil are not well preserved and could perhaps be duplicated in some living maples. They can be mathhed readily in Platanus. In view of the misidentification to which attention is called here, and in order to avoid further perpetuation of this error, the names of the two supposed extinct maples should be stricken from fossil plant lists."

For further information a palynological study of the Don beds was made. As the clay and coarse sand did not yield satisfactory material for pollen and spore studies, eight samples were collected across the middle of the section of stratified silt (Plate XIX, IX and XXI). The microfossil content in each sample will be discussed individually in the following tables.

1. A sample of sand with abundant plant debris. The following assemblage of plants was identified from this sample.

Pinus cf. *strobus*	Gramineae
Pinus banksiana	Cyperaceae
Picea glauca	Compositae
cf. *Taxus*	*Ambrosia*
Tsuga canadensis	Chenopodiaceae
Abies balsamea	Caryophyllaceae
Betula	*Polygonum* sp.
Alnus	Unidentified NAP
Ulmus	Polypodiaceae
Tilia	Fungus spores and hyphae
Quercus	
Carya	
Acer	
Fagus	
Corylus	
Salix	

The most prominent pollen types were *Quercus*, *Pinus*, *Tilia* and *Fagus*.

2. A sample (marked, Don beds 54-0) of silt and fine sand with abundant fragments of plants.

	Number of pollen grains counted		Number of pollen grains counted
Pinus	24	Unidentified NAP	39
Picea glauca	11	Cyperaceae	4
Picea mariana	6	Chenopodiaceae	1

Abies	3	*Ambrosia*	2
Carya	7	Compositae	1
Fagus	1	Caryophyllaceae	1
Tilia	21	*Polypodium* spores	4
Betula	6	Fungus spores and hyphae	
Quercus	8		
Acer	1		
cf. *Cornus*	1		

The total number of coniferous tree pollen grains is 33 and that of deciduous trees is 44. The ratio coniferous/deciduous is 33/44. It seems reasonable to suggest that the ratio between pollen grains of coniferous and deciduous trees has some value as a measure of climate. In a boreal forest zone the percentage of coniferous pollen of AP total is high (up to 90 per cent or more), whereas towards the south the pollen of deciduous trees (especially other than *Betula* and *Alnus*) becomes more prominent. The NAP total is in this sample 48, excluding *Polypodium* spores. Pollen grains of *Fraxinus* are quite abundant in this sample, but they are poorly developed (immature) and a cluster of pollen was present indicating local over representation of *Fraxinus* pollen in this sample.

3. A sample (marked, Don beds 54-1) of silt.

	Number of pollen grains counted		Number of pollen grains counted
Pinus	32	Unidentified NAP	21
Picea	22	Compositae	1
Abies	Present	*Ambrosia*	1

Tilia	3	*Polypodium* spores	2
Quercus	15	Fungus hyphae	
Fraxinus	3		
Betula	4		
Tsuga canadensis	1		
Carya	4		

Furthermore, fragments of woody tissue were observed. A number of possibly poorly developed pollen grains of *Quercus* were present in this slide, and one pollen grain of cf. *Cornus*. The ratio coniferous / deciduous in this sample was 55/28. Most of the *Picea* pollen belongs to *Picea mariana*.

4. A sample (marked, Don beds 54-2) of silt and fine sand.

	Number of pollen grains counted		Number of pollen grains counted
Pinus	30	Unidentified NAP	29
Picea	14	Compositae	3
Abies	1	*Ambrosia*	1
Alnus	2	Caryophyllaceae	2
Tilia	30	Chenopodiaceae	2
Quercus	22	Cyperaceae	2
Carya	18	Gramineae	2
Betula	8	*Polypodium* spores	12
Ulmus	13	Fungus spores and hyphae	

Pollen in this sample was not well preserved. A four-pored pollen grains of *Tilia* was found. Some poorly developed *Fraxinus* pollen was observed. The ratio coniferous / deciduous in this sample was 45/93.

5. A sample of silt (marked, Don beds 54-4).

	Number of pollen grains counted		Number of pollen grains counted
Pinus	21	Unidentified NAP	20
Picea	6	Compositae	2
Tsuga	1	*Ambrosia*	2
Tilia	5	Chenopodiaceae	1
Quercus	14	Cyperaceae	6
Carya	15	*Polypodium* spores	7
Fraxinus	3	*Lycopodium* spore	1
Ulmus		Fungus hyphae	
Betula			
Alnus			
Juglans			
cf. *Cornus*			

Numerous small fragments of charcoal were observed in this sample. A number of poorly dveloped quercoid pollen grains were present. The ratio coniferous/ deciduous in this sample is 28/51.

6. A sample (marked, Don beds 54-5) of silt.

	Number of pollen grains counted		Number of pollen grains counted
Pinus	10	Unidentified NAP	11
Picea	5	Compositae	1
Tilia	7	*Ambrosia*	2
Carya	6	Caryophyllaceae	3

Quercus	14	Chenopodiaceae	1
Betula	5	*Artemisia*	1
Ulmus	3	Cyperaceae	1
cf. *Fraxinus*	1	*Polypodium* spores	3
Alnus	2	Fungus hyphae	

Pollen grains in this sample were poorly preserved. A part of an annulus from a Polypod-sporangium was found in one slide. The ratio coniferous / deciduous in this sample was 15/38.

7. A sample (marked, Don beds 54-6) of silt.

	Number of pollen grains counted		Number of pollen grains counted
Pinus	11	Unidentified NAP	11
Picea	3	Compositae	1
Abies	Present	*Ambrosia*	1
Acer	1	Caryophyllaceae	3
Tilia	21	Chenopodiaceae	2
Quercus	15	*Polypodium* spores	8
Carya	3	Fungus hyphae	
Betula	4		
Ulmus	2		
Fagus	2		
Tsuga	2		

Pollen grains not well preserved. Fine plant debris and fungus remains were plentiful. The ratio coniferous/ deciduous in this sample was 16/48.

The sample, marked Don beds 54-3, contained very poorly preserved pollen grains and was not taken into consideration.

Two samples of silt from the middle section of the Don beds were studied for the diatoms, and the following assemblages were isolated from this material.

Sample No. 1. Middle section of stratified silt from the Don beds.

Stephanodiscus astraea (Ehrenb.) Grun.

Stephanodiscus astraea var. minutus (Kütz.) Grun.

Campylodiscus hibernicus Ehernb.

Cocconeis disculus (Schum.) Cleve

Cocconeis placentula Ehrenb.

Epithemia turgida (Ehrenb.) Kütz.

Epithemia Muelleri Fricke

Tabellaria fenestrata (Lyngb.) Kütz.

Fragilaria lapponica Grun.

Diploneis elliptica (Kütz.) Cleve

Gyrosigma attenuatum (Kütz.) Cleve

Pinnularia sp.

Cymbella sp.

Surirella cf. ovata Kütz. (fragment)

Sponge needles

Sample No. 2. Middle section of stratified silt from the Don beds. Marked x on the slides.

Stephanodiscus astraea (Ehrenb.) Grun.

Stephanodiscus astraea var. minutus (Kütz.) Grun.

Cocconeis placentula Ehrenb.

Melosira granulata (Ehrenb.) Ralfs.

Diploneis cf. elliptica (Kütz.) Cleve

Epithemia turgida (Ehrenb.) Kütz.

Epithemia Hyndmanni W. Smith

Navicula scutelloides W. Smith

Tabellaria fenestrata (Lyngb.) Kütz.

Tabellaria flocculosa (Roth.) Kütz.

Gyrosigma attenuatum (Kütz.) Cleve

Synedra capitata Ehrenb.

Opephora Martyi Heribaud.

Fragilaria lapponica Grun.

Cymbella sp.

Pinnularia sp. (fragments)

Sponge needles

According to C.S. Boyer (1927) and M.H. Hohn (1951) these assemblages indicate fresh water environments covering a variety of habitats (streams, springs, ditches, small rivers and big ones, ponds, lakes, cedar swamps and bogs). Most of these environments can be interpreted from the geological evidence as having been present during deposition of the Don beds. All these species have been found by Hohn to be living south of and in Lake Ontario, indicating conditions rather similar to those of the present. It is possible, judging by the diatom assemblage, that the climate was slightly warmer at the time of deposition of the Don beds than it is now in the Toronto region. The most abundant species of diatoms in these samples were; *Stephanodiscus astraea*, *Stephanodiscus astraea* var. *minutus*, *Epithemia turgida*, *Tabellaria fenestrata* and *Pinnularia*.

Quite a different assemblage of fossils has been identified from the Scarborough beds. According to Coleman (1933) John Macoun found in the plant debris between the silt layers evidence of the following plants.

Salix sp.	*Carex utriculata*
Alnus sp.	*Equisetum*
Picea sp.	*Vaccinium oxycoccus*
Carex aquatilis	*Vaccinium uliginosum*

Seeds of the following plants were identified in the same material by W.L. McAtee.

Scirpus fluviatilis	*Prunus* (*pennsylvanica* ?)
Potamogeton sp.	*Polygonum* sp.
Chenopodium sp.	*Ceratophyllum demersum*
Brasenia purpurea	

Furthermore Penhallow has identified wood of *Larix americana* and *Abies balsamea* from the Scarborough beds.

The palyonological study of the Scarborough beds yielded the following results.

Sample # 1. Fine sand and plant debris from the stratified silt.

	Number of pollen grains counted		Number of pollen grains counted
Pinus	24	Unidentified NAP	6
Picea	25	Ericaceae	2

Betula	4	Cyperaceae	1
Tilia	1	Gramineae	1
Corylus	1	*Nymphaea*	1
		Lycopodium	1
		Polypodium spores	1
		Sphagnum spores	Present

Small fragments of charcoal were found in this sample and the pollen grains were generally poorly preserved.

Sample #2. From the middle of one of the massive silt and fine sand layers with finely disseminated plant debris, overlying the sequence of stratified silts.

	Number of pollen grains counted	Identified as present
Pinus	37	Cyperaceae
Picea	35	Gramineae
Betula	Present	Compositae
Abies	"	Ericaceae
Carya	"	*Lycopodium*
Carpinus	"	Polypodiaceae
Quercus	"	*Osmunda* sp.
		Sphagnum spores
		Fungus hyphae

Leaf fragments of brown mosses were found in this sample and also small pieces of charcoal. Pollen was not well preserved.

During the construction of the Toronto Rapid Transit Subway some material was collected from the exposed sections, consisting of course sand and plant debris. This sample, correlating with the Upper Scarborough sands according to the microfossil assemblage, gave the following results.

	Number of pollen grains counted		Number of pollen grains counted
Pinus cf. *strobus*	25	Unidentified NAP	2
Pinus cf. *banksiana*	36	Ericaceae	13
Picea mariana	6	Compositae	2
Picea glauca	17	Caryophyllaceae	1
Abies balsamea	3	Gramineae	13
Alnus	2	Cyperaceae	3
Carya	1	*Equisetum*	4
Tilia	1	Polypodiaceae	6
Populus	6	*Sphagnum* spores	Present
cf. *Juniperus*	2	Moss spores	Present
cf. *Thuja*	1	Fungus spores	Present
Larix (?)	5		

Great numbers of pollen grains of *Betula* were identified from this sample. However, as clusters of pollen grains were present the abundance appears to be due to local over representation. The ratio coniferous / deciduous in this sample was 95/10.

One sample from the Scarborough silt (one of the massive beds above the stratified silts) and one sample of the varves from the middle till complex were studied for diatoms, but the result was negative, no diatoms were encountered.

The palynological study of the Scarborough beds supports the idea of a change of climate from warm (or temperate) during the deposition of the Don beds to boreal and gradually arctic during the deposition of the Scarborough beds. The pollen assemblage from the Scarborough beds suggests a boreal type of coniferous forest, essentially spruce and pine with some tamarack and fir. The scattered appearance of basswood and hickory suggests that remnants of the previous deciduous association still have survived to some extent. This is indicative of the closing of a deglacial interval previous to an advancing glaciation.

Thanks to the authorities of the Ontario Agricultural College, Guelph, the writer was able to have a soil test on several samples collected from the Toronto formation. Soil extract was prepared from the samples and the availability test was run on this extract giving results in parts per million. The results have been summarized in figure 7.

Figure 7. Availability test in parts per million on soil extract of samples from the Toronto formation.

Sample	pH	N	P	K	Ca	Mg	Sul-phates	Chlo-rides	Mn	Total salts
Basal till on bedrock	7.6	-	-	-	200	T	-	-		15
Don sand, 10' above the till	7.6	T	-	-	200	2	-	-		12
Top of Don beds (fine sand)	7.6	-	-	-	200	5	-	-		9
Bottom of Scarborough stratified silt	7.6	-	-	-	200	6	-	-		17
Massive silt layer in Scarborough beds	7.6	9	-	15	200	7	-	-	1	39
Top of Scarborough silt	7.6	-	-	-	200	6	-	-		15
Valley sand	7.6	-	-	-	200	3	T	T		5
Till	7.6	-	-	-	200	5	150	-		65
Varves	7.6	T	-	-	200	5	-	-		19
Till	7.6	-	-	-	200	6	T	-		15
Varves	7.6	-	-	-	200	7	-	-		13

To make the meaning of the p.p.m. values more comprehensible the soil nutrient levels for horticultural crops in p.p.m. (used at the Ontario Agricultural College) are given in the following table.

	Summer Excess	Winter Excess	Normal	Summer Deficient	Winter Deficient
Nitrogen	> 12 +	6 +	3-5	0-2	-
Phosphorus	30 +	20 +	8-12	< 4	< 4
Potash	50 +	50 +	20-30	< 15	< 15
Calcium	200 +	200 +	150	40	40
Magnesium	-	-	7 +	5	5
Sulphates	300 +	150 +	0-50	-	-
Chlorides	150 +	20 +	0-20	-	-
Total salts	> 75	30-50	40-50	20	< 20

A feature common to all the previously described deposits is the slightly alkaline pH and the high calcium content. Otherwise there is not enough difference between, for example, the till sheets to allow sure identification. The valley sand (figure 7) and the till overlying the interglacial deposits are slightly richer in sulphates, chlorides and total salts respectively, and the massive silt in the Scarborough sequence has a slightly higher content of available elements than the rest of the samples.

To be able to compare the results of the palynological studies, made on the Don and Scarborough beds, with the present conditions a few subrecent pollen spectra will be presented in the following.

Four samples were collected from an uncultivated part of the bog at Bradford Marsh, just south of Lake Simcoe. Number one was taken at four inches below the surface, number two at ten inches, number three at sixteen inches and number four at twenty-two inches below the surface of the bog. All samples were of poorly decomposed peat. The microfossil assemblage in these samples was as follows.

Sample No. 1.

	Number of pollen grains counted		Number of pollen grains counted
Pinus	39	Unidentified NAP	10
Picea	4	Cyperaceae	3
Fagus	6	Gramineae	1
Quercus	13	Compositae	1
Betula	12	*Artemisia*	1
Tilia	2	Polypodiaceae	1
Tsuga	9		
Carpinus	1		
Acer	5		
Ulmus	10		
Corylus	1		
Fraxinus	1		

Sample No. 2.

	Number of pollen grains counted		Number of pollen grains counted
Pinus	38	Unidentified NAP	13
Picea	7	Cyperaceae	5
Fagus	12	Gramineae	1
Quercus	9	*Artemisia*	1
Betula	7	*Ambrosia*	2

Tilia	1	Fragments of *Carex* roots
Tsuga	24	
Acer	10	
Ulmus	8	
Corylus	1	
cf. *Larix*	1	

Sample No. 3.

	Number of pollen grains counted		Number of pollen grains counted
Pinus	25	Unidentified NAP	9
Picea	8	Cyperaceae	8
Abies	1	Compositae	1
Fagus	4	*Sphagnum* spores	Present
Quercus	7	Fungus remains	
Betula	7		
Tilia	1		
Tsuga	14		
Acer	4		
Ulmus	3		
Corylus	2		
cf. *Larix*	2		
Carya	3		
Alnus	2		
Salix	1		

Sample No. 4.

	Number of pollen grains counted		Number of pollen grains counted
Pinus	31	Unidentified NAP	25
Picea	5	Cyperaceae	4
Abies	1	*Ambrosia*	1
Fagus	31	Polypodiaceae	1
Quercus	14		
Betula	15		
Tilia	3		
Tsuga	6		
Acer	7		
Ulmus	10		
Corylus	4		
Carya	1		
Alnus	1		

The coniferous/deciduous ratios for these samples are: number one - 52/51; number twp - 70/48; number three - 50/34; number four - 43/36. The NAP percentage is relatively low in all samples.

A sample from the Parry Sound district in which lichens were used for the spectrum shows the following assemblage.

	Number of pollen grains counted		Number of pollen grains counted
Pinus	36	Unidentified NAP	31
Picea	8	Cyperaceae	5
Abies	Present	Gramineae	8
Fagus	1	Chenopodiaceae	5

	Number of pollen grains counted		Number of pollen grains counted
Quercus	6	Compositae	2
Betula	26	*Ambrosia*	25
Tilia	4	cf. *Plantago*	1
Tsuga	2	Gramineae (cultivated)	1
Acer	3		
Ulmus	1	Sphagnum spores present	
Corylus	4		
Carya	1		
Alnus	5		
Populus	3		
Carpinus	Present		

The following spectrum was identified in the subrecent bottom sediments of the Dundas Marsh at Hamilton, Ontario.

	Number of pollen grains counted		Number of pollen grains counted
Picea	1	Unidentified NAP	17
Pinus	5	Gramineae	3
Betula	8	*Ambrosia*	41
Alnus	1	Compositae	14
Quercus	9	Cyperaceae	8
Ulmus	7	*Typha*	3
Acer	2	*Potamogeton*	2
Corylus	1	*Sparganium*	5
Juglans	2	Chenopodiaceae	4
Carpinus	1	Umbelliferae	1

Carya	2	*Myriophyllum*	1
Tsuga	1	*Menyanthes* (cf.)	1
Fagus	1	Polypodiaceae	1
Tilia	1	*Equisetum*	15
Salix	1		

The percentage of NAP in this sample is extremely high due to the dense settlement of the area. The ratio coniferous/deciduous is 7/37.

For a general, rough comparison of the palynological data the ratios between pollen grains of coniferous and deciduous trees have been used together with percentage of the total NAP plus spores of ferns and lycopods and *Equisetum*. The fungus remains (spores etc.) and the *Sphagnum* spores have been left out of consideration.

No. of sample	Per cent coniferous	Per cent deciduous	NAP total plus spores (%)
Don beds			
# 2	43	57 ?(plus *Fraxinus*)	62
# 3	66	34 ?(plus *Quercus*)	30
# 4	33	67	38
# 5	35	65	49
# 6	35	65	54
# 7	25	75	41
Scarborough			
# 1	89	11	24
# 2	95	5	19

No. of sample	Per cent coniferous	Per cent deciduous	NAP total plus spores (?)
Subway sample			
	90	10	42
Dundas Marsh			
	16	84	263
Bradford Marsh			
# 1	50	50	16
# 2	59	41	19
# 3	60	40	21
# 4	33	67	24
Parry Sound			
	46	54	78

When the palynological data of the Don beds are compared with those from Bradford Marsh and Dundas Marsh, certain similarities can be detected. In all cases the percentage of pollen of deciduous trees is high. In four samples from the Don beds the percentage of deciduous tree pollen is over sixty per cent. When it ks also noted that in samples from the Don beds the major part of the conifer pollen belongs to Pinus, a tree that produces tremendous amounts of pollen, it is suggested that, at the time when the Don beds were deposited, deciduous forest covered the Toronto region and that Tilia, Quercus, Carya, Fraxinus and Ulmus were the major components of the association. One more fact deserves mention; some tree species of southerly distribution (found as leaf fossils in the Don beds) produce little pollen and, besides that, the pollen grains of these species have not yet been distinguished from those of the northern species of the same genera. Therefore their absence from the pollen assemblage does not necessarily mean that the trees were not growing in Toronto region during the interglacial time. Considering all fossil evidence, the writer suggests that at the time when the Don beds were deposited, the climate in Toronto region was slightly warmer (about two to five deg. F) than the present. The annual mean temperature is taken as basis for the above suggestion.

The Scarborough beds present a different palynological picture. The assemblage of pollen grains suggests a boreal type of coniferous forest, where scattered remnants of a deciduous forest still survive. As suggested on page 133, there seems to be a gradual change from the warm climate, during the deposition of Don beds, towards a boreal climate during deposition of Scarborough beds. An advancing glaciation is also indicated by the geological evidence.

The sequence of till sheets and varves does not yield any usable amount of pollen and spores in this case.

The next deposit that might yield microfossils in sufficient amounts for analysis is the interstadial (interglacial ?) sand, underlying the surface till at Leaside, north of the Don Valley Brick Yard. This sand, however, was not examined because of the extensive slump and weathering which prevented collecting of uncontaminated samples.

Chunks of compressed peat have been found associated with the most recent till sheet in the Toronto region. Samples of one of these peat "boulders" were turned over to the writer by A. Dreimanis of the University of Western Ontario, who had discovered the peat in gravel at Markham (north of Toronto). The microscopical analysis gave the following results.

	Number of pollen grains counted		Number of pollen grains counted
Pinus	26	Unidentified NAP	1
Picea	33	Cyperaceae	2
Betula	1	Chenopodiaceae	1
Salix	1	Compositae	1
Carya	1	*Lycopodium*	Present
		Sphagnum spores	"

Pollen in this sample was not well preserved. Small pieces of plant tissue were plentiful and fragments of woody tissue were found. Among macroscopic remains twigs of coniferous trees and leaves of grass and sedge were noticed. This microfossil assemblage is typical of northern forest regions and also is found in late glacial deposits.

The peat was also radiocarbon dated as older than 34,000 years (Rubin and Suess, 1955). This radiocarbon date was obtained from Dr. Suess' laboratory at the United States Geological Survey.

The surface till in the Toronto region has been supposed to be of Mankato age (the latest major ice advance in Wisconsin) and the underlying sand logically should be Mankato-Cary. This interval, however, has been definitely dated (Flint and Deevey, 1951) to approximately 11,000 years. Suess (1954 b) states that,

"Two determinations on wood from the type locality of the "Two Creeks" Forest Bed were carried out. Five previous determinations on wood from this locality by Libby (C-308, 365, 366, 536, and 537) gave an average of 11,404 ± 350 years. W-42: weathered appearance, identical with Y-141 - 11,350 ± 120 years. W-83: well preserved appearance, identical with Y-227 11,410 ± 180 years."

As the presence of a deglacial interval of Two Creeks age in the Toronto region is problematical, the results of palynological and geological studies made on the west coast and in the St. Lawrence Lowland were taken into consideration.

On Vancouver Island, several sections, where interglacial deposits are exposed, were examined for pollen and spores. The silty peat in these sections contained very poorly preserved pollen grains and spores and did not yield reliable material for analysis. It is likely that the influence of the tidal change of the sea level prevented good preservation of plant microfossils. However, a sample of peat was collected for radiocarbon analysis from a section on Vancouver Island at Dashwood, two miles west of Qualicum Beach, approximately at west boundary of Lot 73.

Lithology	Feet
Beach gravel	1
Till	65
Sand	63
Silt containing wood	1

Lithology	Feet
Peat (sample taken for C-14 analysis)	3½
Pebble gravel	34
Stony, gritty clay (glaciomarine?)	5
Covered to beach	20
Till ?	

The age of the radiocarbon dated sample turned out to be more than 30,000 years (this radiocarbon date was obtained through the Geological Survey of Canada).

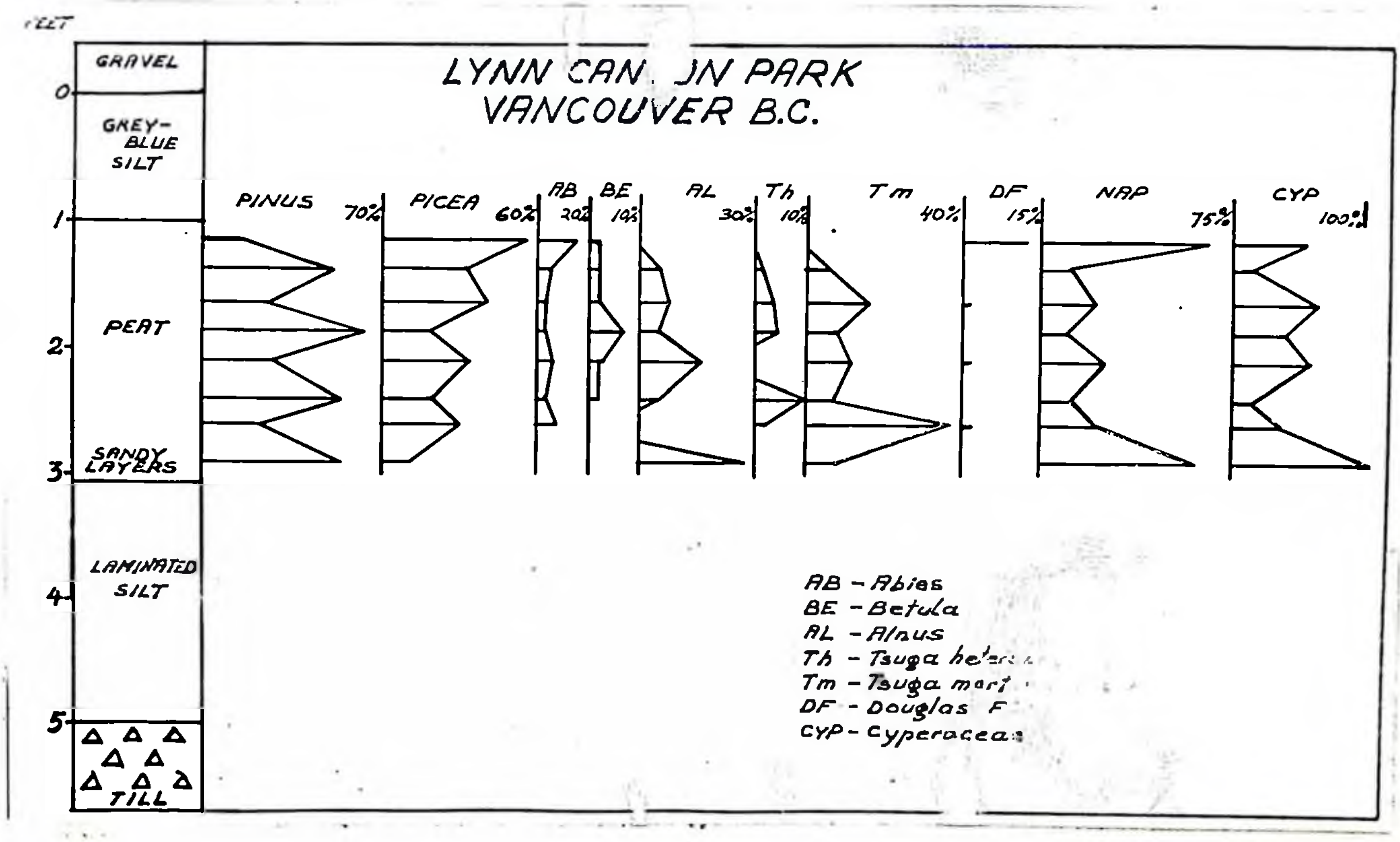

Figure 8. Pollen diagram from the Lynn Canyon Park section, Vancouver, B.C.

At Lynn Canyon Park, just north of Vancouver, B.C., two tills are present in a section through Pleistocene deposits. The interglacial sequence includes three feet of peat, which yielded well preserved plant microfossils. A pollen diagram from this section has been prepared (see figure 8).

This pollen diagram seems to cover most of that particular interglacial period, because the microfossil assemblage indicates cold climate at the bottom of the diagram, then a slightly warmer period during the deposition of the middle part of the peat, and a colder climate again towards the top of the diagram. The first initial cold period is indicated by high percentage of Pinus, Tsuga mertensiana and NAP; the low NAP percentage during the middle section indicates increasing forest coverage and the high spruce and NAP at the top of the section seem to indicate the closing period of that interglacial period. In general, this interval did not reach a thermal maximum as warm as the present.

Cyperaceae have been excluded from the other NAP because of their high percentage and the NAP consists of pollen grains of following plants. Artemisia, Ericaceae, Chenopodiaceae, Gramineae, Umbelliferae, Compositae, Caryophyllaceae, Oenotheraceae, Nymphaea (in bottom part of peat). Spores of Polypodiaceae were present in all samples and spores of Lycopodium and Sphagnum were present in most samples. Scattered pollen grains of Salix were present in some samples and Carex root tissue fragments were found in the bottom samples.

In the St. Lawrence Lowland excellent sections were discovered during the mapping of Pleistocene deposits. Interglacial deposits, including peat, are exposed in several of these sections, two of which, the St. Pierre section and the Les Vieilles Forges section, will be discussed below.

The St. Pierre section is approximately 110 miles downstream from Montreal on the south shore of the St. Lawrence River. It is about one mile southwest along No. 3 Highway from the village of St. Pierre-les-Becquets and about one-quarter of a mile up a creek from the highway. The layers of peat are exposed in the face of a ten-foot waterfall.

The sequence of peat layers and silt is overlain by ca. seventy feet of varves, which are overlain by till in a section near by. A few hundred yards downstream from the waterfall, a reddish till is exposed in the creek bed.

The best exposure of the peaty sequence is described below in more detail. From the top, starting at the base of the varves, the sequence is as follows:

Lithology	Inches
Topmost peat layer at base of varved section	0 - 2
Blue-grey silty clay; stratified.	2 - 8
Brownish-green sandy silt	8 - 24
Hard, well decomposed *Carex* peat (compressed) with a few twigs	24 - 30
A layer of brown-moss peat; numerous remains of *Drepanocladus* sp.	30 - 35
Hard, compressed, well decomposed *Sphagnum* peat with wood in lower	

	Inches
part and twigs scattered throughout. At one horizon charcoal specks were found in this layer. Occasional *Menyanthes* fruits and wing covers of beetles have been found here. Wood for C-14 analysis was collected from this layer	35 - 46
Coarse sand, coloured by humic matter from the overlying peat	46 - 62
Grey silty clay with lenses of sand	62 - 74
Brown, peaty silt grading into peaty sand in lower half of this layer	74 - 92
Grey silty clay	92 - 122
Brown-moss peat; abundant *Drepanocladus* remains	122 - 124
Hard, well decomposed peat grading into peaty silt in lower half of the layer	124 - 134
Blue-grey silt and silty sand	134 -

A pollen diagram (figure 9) from this sequence shows an assemblage of pollen grains and spores characteristic of subarctic climate and only a slight amelioration of climate seems to have taken place during the deposition of the middle part of the sequence.

The first radiocarbon date on a sample of the St. Pierre peat gave an average of 11,050 ± 400 years (this C-14 dating was obtained through the Geological Survey of Canada; the C-14 determination was made by the Lamont Laboratory). Later checking of another collection of the same material for C-14 at Yale and the United States Geological Survey laboratories suggested an age of more than 23,000 and 40,000 years (Flint and Rubin, 1955) respectively, the one just at; the other beyond the range of the dating method. This difference in determinations is surely appreciable and the writer will try to offer an explanation of it in connection with discussion of the Wisconsin stratigraphy.

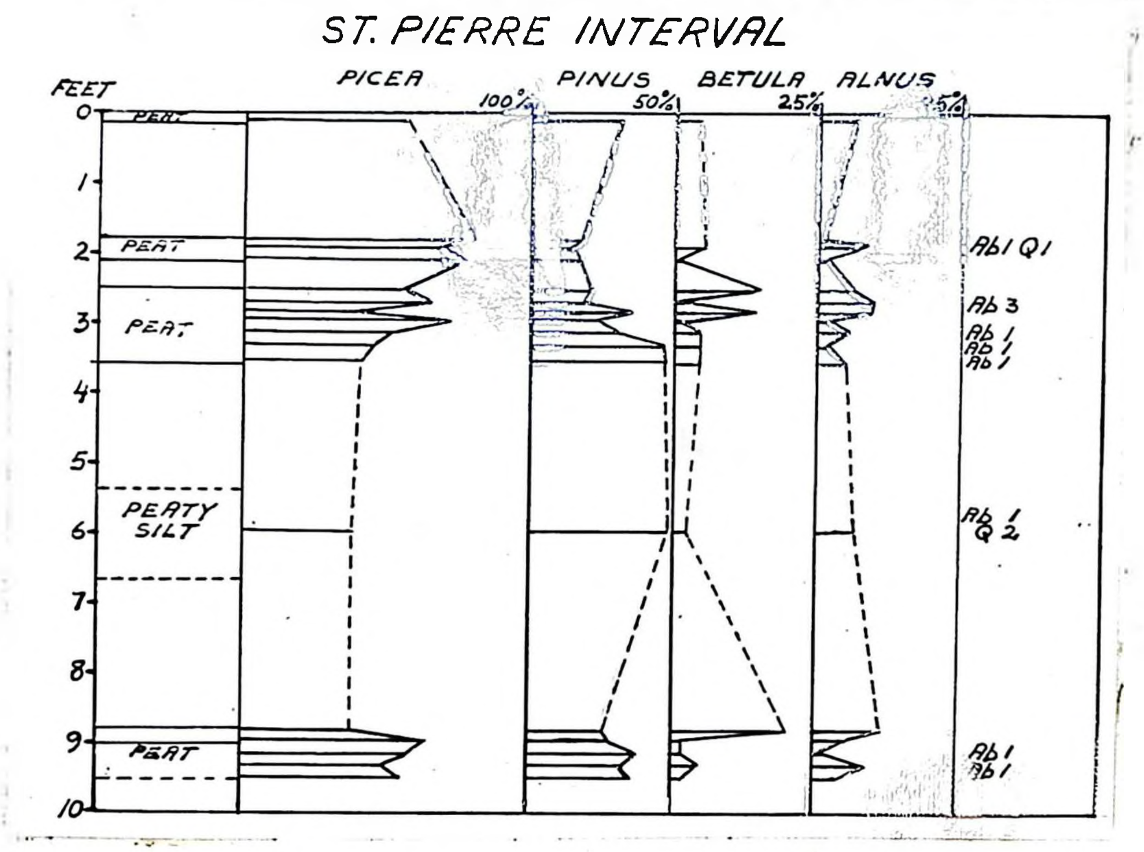

Figure 9. Pollen diagram from St. Pierre interval.

The Les Vieilles Forges section is on the west bank of St. Maurice River, one-quarter mile downstream from the highway near Les Vieilles Forges village. The section measuring from top downward id as follows:

Lithology		Thickness (feet)
Medium-grained to coarse stratified sands, probably sands of the Three Rivers delta		83.0
Medium gravel		0.3
Stratified silt and clay, thin sand partings, probably slack-water alluvial or lacustrine		1.5
Sandy gray till with dominantly granitic components, marked boulder pavement at upper surface		12.0
Fine sand with lenses of silty sand		2.0
Medium to fine sand		0.5
Medium to coarse sand		0.7
Silt and fine sand, thin-bedded, horizontal strata		1.0
Coarse sand with some cross-bedding (southward dips) some bands of medium- to fine-grained sand		32.0
Compact fine sand		2.0
Brownish-grey medium-grained sand		20.6
Blue-grey fine to medium sand		21.0
Stratified silt and fine sand with regular stratification and general appearance of varves, but materials generally coarser than normal for varves, possibly as a result of proximity to source; gradational contact upwards into overlying fine sand	*	20.0
Coarse sand with thin beds of silty clay		2.0
Stratified clay with sand between layers		0.5
Coarse sand		0.1
Peaty silt	*	1.2
Peat with some wood (both much compressed)		0.7
Blue-grey silty fine sand with disseminated organic matter		2.0

Lithology	Thickness (feet)
Brown organic silt with some fragments of plants *	1.0
Peat and wood (much compressed). A three-foot * length of black spruce stump with roots attached was excavated from the base of this layer. * Samples for C-14 dating were collected from this layer *	1.2
Blue-grey silty sand with a few plant remains	4.5
River level	-------
By borings:	
Blue-grey silty sand, compact	15.0
Gravel (?)	?

To illustrate the plant microfossil content of this sequence, eight samples were selected at most characteristic levels; these levels have been marked by * in the description of the section.

1. Sample No. 54-523, from just below the first peat layer. *Picea* 53%; *Pinus* 36%; *Abies* 2%; *Betula* 3%; *Alnus* 7%. NAP 12%, consisting of unidentified NAP, Cyperaceae, Caryophyllaceae, cf. *Myriophyllum*. *Polypodium* spores were present together with those of *Lycopodium* and fungus.

2. Sample No. 54-524, from bottom of the first peat layer. *Picea* 36%; *Pinus* 50%; *Abies* 6.5%; *Betula* 5%; *Alnus* 3%. NAP 12%, consisting of unidentified NAP, Compositae, Gramineae, *Polypodium* spores, *Lycopodium* spores, *Sphagnum* spores and fungus remains are present. Also fragments of bark and woody tissue were found in this sample. Polypodiaceae spores are rather plentiful.

3. Sample No. 54-526, from silt within the first layer of peat. *Picea* 27%; *Pinus* 22%; *Abies* 11%; *Betula* 15%; *Alnus* 24%. NAP 29% consisting of unidentified NAP, *Typha latifolia*, cf. *Ambrosia*, Ericaceae, *Artemisia*, Compositae, Umbelliferae, *Myriophyllum*, Spores of *Equisetum* and Polypodiaceae are present in this sample. Also one pollen grain of *Tilia* was found.

4. Sample No. 54-529 from a silty band within the first peat layer. *Picea* 40%; *Pinus* 53%; *Abies* 2%; *Betula* 1%; *Alnus* (local over representation); *Salix* 2%. *Carya* and *Tilia* present; NAP 47% including Cyperaceae (26%), unidentified NAP, Gramineae, Chenopodiaceae, Compositae, Umbelliferae, *Artemisia*. Polypodiaceae spores are plentiful. *Lycopodium* spores, *Sphagnum* spores and *Equisetum* spores are present. Also *Typha latifolia* was found in this sample.

5. Sample No. 54-532, from the peaty silt above the first peat layer. *Picea* 13%; *Pinus* 36%; *Abies* 8%; *Betula* 6%; *Alnus* 37%; *Salix* 1%; *Corylus* and *Tilia* present. NAP 20%, including unidentified NAP, Umbelliferae, Cyperaceae, *Typha latifolia*, Gramineae, Compositae, Caryophyllaceae, cf. *Sparganium*, cf. *Rubus chamaemorus*, *Artemisia*, Chenopodiaceae. Spores of Polypodiaceae, *Lycopodium*, *Sphagnum* and fungus are present. Pollen grains of cf. *Myrica* were also found.

6. Sample No. 54-544, from peaty silt overlying the second peat layer. *Picea* 50%; *Pinus* 25%; *Abies* 5%; *Betula* 9%; *Alnus* 11%; *Carya* 1%. NAP 19% including unidentified NAP,

Cyperaceae, Gramineae, Compositae, Ericaceae, Caryophyllaceae, cf. *Rubus chamaemorus*. Spores of Polypodiaceae, *Lycopodium*, *Sphagnum* are present together with fungus remains.

7, Sample No. 54-546, from the top of the peaty silt. *Picea* 43%; *Pinus* 36%; *Betula* 8%; *Alnus* 12%; *Salix* 1%. NAP 27% including unidentified NAP, Cyperaceae, *Typha latifolia*, Compositae, Chenopodiaceae. Spores of Polypodiaceae and *Lycopodium* are present.

8. Sample No. 54-555, from the middle of the stratified silt and fine sand. *Picea* 57%; *Pinus* 27%; *Abies* 4%; *Betula* 5%; *Alnus* 6%; *Tilia* 1%; *Quercus* 1%; *Ulmus* present. NAP 10%, including Compositae, Caryophyllaceae, *Nuphar* sp. Spores of Polypodiaceae, *Lycopodium* and *Sphagnum*.

This Les Vieilles Forges section, which from the geological point of view correlates definitely with the St. Pierre section, exhibits, moreover, a sequence of plant microfossils that indicate a cold climate at the beginning of the peat accumulation, then a slight amelioration of climate and later again the return of a cold climate. High spruce values are interpreted as an indicator of a cold climate and the increasing *Pinus* values together with the scattered occurrence of the pollen of broad-leaved trees would indicate the warmer period. During this interval of deglaciation the climate stayed considerably colder than the present in the same locality. A sample from this section was found to be older than 40,000 years, according to information from Dr. Flint (personal communication).

To illustrate the post glacial sequence of events, two pollen diagrams have been reproduced below from the St. Lawrence Lowland.

1. The Wilson's Pond bog is about four and one-quarter miles south-southeast from South Durham in the Richmond map area. This bog lies in a bedrock-dominated area and higher than the lowland marine deposits.

2. The St. Albert bog is about one and one-half miles north-northeast of St Albert village in the Aston map area. This bog lies within the limit of the marine deposits in the lowland and the surface deposits around the bog are dominated by sand.

Both these bogs have formed over ancient lakes and are at present raised bogs with a central open area where the spongy Sphagnum carpet and ericaceous shrubs are dominant. A small lake still remains unfilled in the marginal area of the Wilson's Pond bog.

In both diagrams the early post glacial period is characterized by a high percentage of spruce and low percentage of pine, whereas the broad-leaved trees are hardly present at all. The very early stages of deglaciation may not be represented because the area was invaded by the Champlain Sea. However, the pollen diagrams from the interglacial deposits can be matched with the lower part of the post glacial diagrams and therefore it seems logical to assume that the climate during the St. Pierre deglacial interval remained boreal.

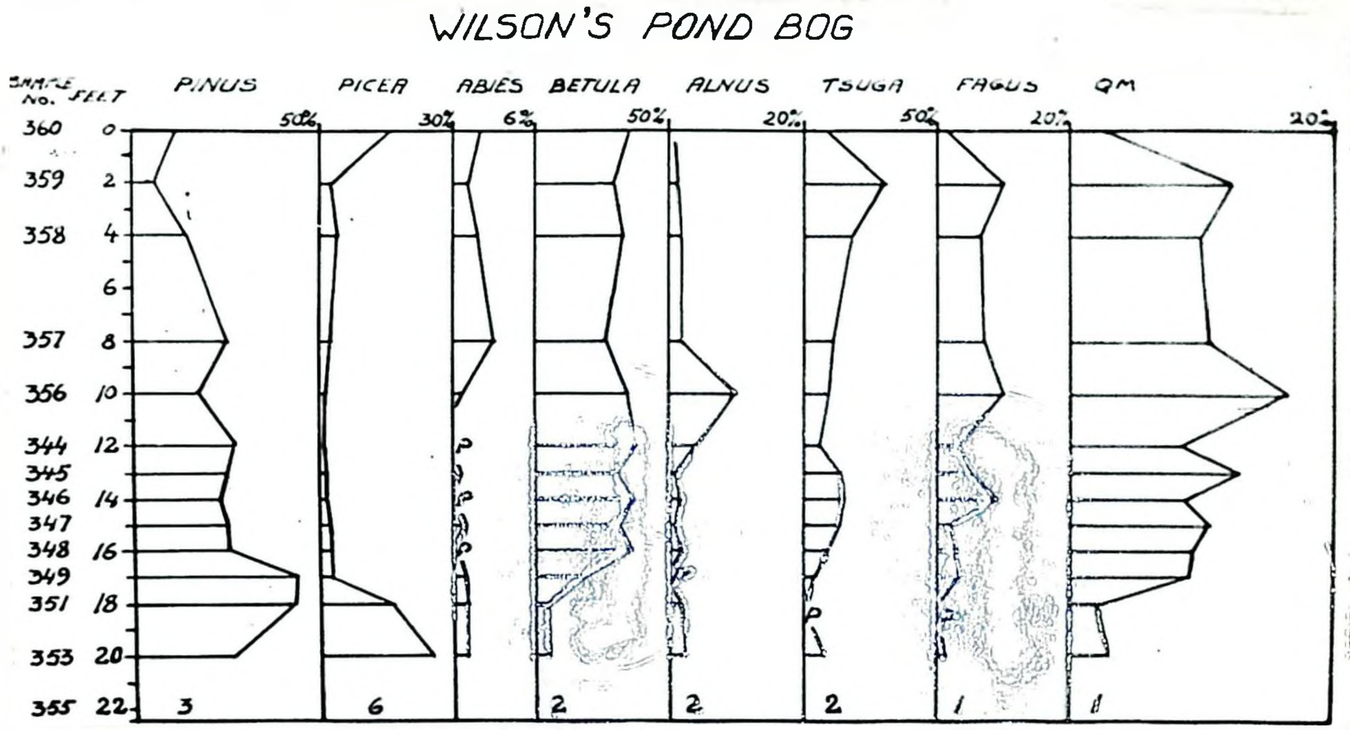

Figure 10. Pollen diagram from the Wilson's Pond bog, P.Q.

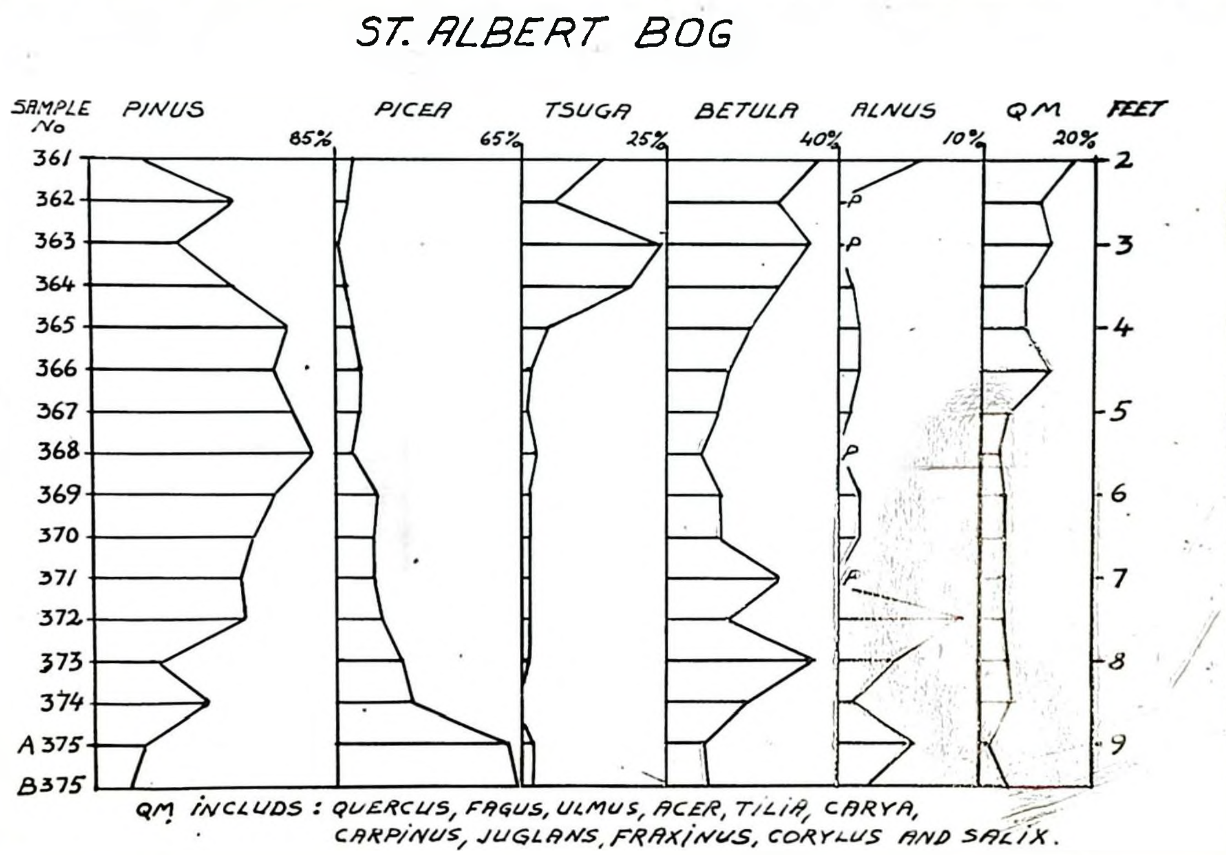

Figure 11. Pollen diagram from the St. Albert bog, P.Q.

During the early stages of this investigation the St. Pierre and the Les Vieilles Forges interglacial deposits were thought to be of Two Creeks age, deposited during the last interval of deglaciation within the Wisconsin glaciation. This was supported by the first radiocarbon date. The subsequent palynological studies, however, did not support this hypothesis at all, for the following reasons. The Two Creeks interval has been described, both on this continent and in Europe, as a short, cold interval of deglaciation. This is supported by studies of the type locality at Two Creeks, Manitowoc County in Wisconsin. Wilson (1936) found that the northern exposure of the Two Creeks forest bed yielded only _Picea_ pollen and the southern exposure gave 97.5% _Picea_, 1% _Betula_, 0.5% _Pinus_, 0.5% _Asplenium_ and 0.5% Ericaceae. It has been suggested that the microfossil evidence, which apparently indicates a cold climate, may indicate a pioneer vegetation and not necessarily a cold climate. Even so, the short duration of the interval did not allow migration of "warmth" indicating trees to that locality. The writer feels that if the Mankato - Cary interval in Wisconsin was short in duration and exhibits a cold-climate microfossil assemblage, the same interval in Quebec could not have been enough longer to allow any considerable migration of forest trees. The microfossil assemblage from the St. Pierre interval suggests at least boreal climate for that interval. At this point of the study the writer was quite sure that the St. Pierre interval was not identical with the Two Creeks interval. The later radiocarbon dating also supported this view.

One question still remained unanswered. Why was the first radiocarbon determination of ca. 11,000 years so different from the later ones which suggested an age older than 30,000 years ?

The most likely cause of error is the collecting of the sample. As the peat layers stand out in relief from the vertical face of the section and as it is extremely difficult to excavate the hard, compressed peat, it is possible that wood, at least partly exposed, was included in the sample. This would cause an error in the C-14 determination as the original radioactivity of the material is very low. Also the methods for determining radioactive C-14 in various samples, have been greatly improved during recent years. Strict rules have been suggested for the preservation of the samples to exclude possibilities of contamination. Even a small amount of contamination may cause serious errors if the original radioactivity of the sample is very low.

The geological and palynological studies of the Toronto formation and similar studies in the St. Lawrence Lowland suggested a critical examination of the current Wisconsin stratigraphy in order to relate the St. Pierre interval and the Toronto formation to the Pleistocene stratigraphy.

The division of the Wisconsin glaciation into substages was done by Leighton in 1933 who established the substages as Mankato, Cary, Tazewell and Iowan (the oldest). According to Ruhe (1952) the major interval within Wisconsin was first regarded as between the Mankato and Cary substages but later geological evidence indicated that this interval occurred between the Cary and Tazewell substages.

	Leighton 1933	Schultz 1945,	Stout 48	Fry 195	Ruhe 1951	
WISCONSIN	Mankato	W-3 Mankato	Bignell loess	Bignell loess	Mankato	Upper Wisconsin
		Two Creeks forest bed	Brady soil			
	Cary	W-2 Tazewell-Cary			Cary	
				Brady soil	Bradyan interval	
	Tazewell	" Peorian "	"Peorian " cycle complex	Peoria loess	Tazewell	Lower Wisconsin
	Iowan	W-1 Iowan			Iowan	

Figure 12. The Wisconsin stratigraphy according to Ruhe (1952).

From figure twelve additional information is available to support the most recent division of the Wisconsin glaciation. In 1950 Ruhe recognized four Wisconsin drifts - Iowan, Tazewell, Cary and Mankato - in northwestern Iowa and demonstrated a major twofold division of the Wisconsin drifts on a basis of a statistical analysis of the drift topographies. The major time break was shown to be the Tazewell-Cary interval. No evidence was found to show comparable time breaks representing the Iowan-Tazewell or Cary-Mankato intervals.

In 1950 Flint recognized a major twofold division of the four drifts of the Wisconsin in South Dakota and concluded that the Iowan and Tazewell were closely related in time and that the Cary and Mankato were a second closely related pair. The current opinion (Ruhe, 1952),

"Places the Brady soil as a correlative of the Tazewell-Cary interval rather than the Two Creeks forest bed (Cary-Mankato interval), as originally defined by Schultz and Stout. It is suggested here that the name Bradyan interval be applied to the major break in the Wisconsin sequence, the Tazewell-Cary interval."

Quite recently Hough (1953) published his intriguing information on sediment cores taken from the ocean bottom in the Southeastern Pacific. Several test-borings showed that, "only red clay occurs below 4100 meters, whereas only globigerina ooze occurs above 3600 meters; between these depths either red clay or globigerina ooze occurs, depending on locality." Supported by Kuenen's investigations (1950,p. 369) the red clay was interpreted as indicative of cold climate, and the globigerina ooze was interpreted as deposition during a warm climate. A mixture of clay and ooze indicates intermediate climate. The critical sample was taken from a depth of 3930 meters at a point in the path of a surface current which moves from extreme southern latitudes, bringing subantarctic water northward up the west coast of South America. Variations in the temperature or volume of this current might be expected to result from climatic changes, and these in turn should affect the type of sediment deposited. The age determinations were made by the per cent of equilibrium method for uranium, ionium and radium, described by Urry in 1942. The whole core, about 190 cm long, covers the Wisconsin, Illinoian and Kansan glaciations and the two interglacial periods together with the post glacial time.

The results of this investigation seem reliable enough to consider them seriously when dealing with Pleistocene stratigraphy. In the present case the writer is most concerned with the Wisconsin glaciation (see figure 13).

Hough correlated his Wisconsin substages with the Eastern American Pleistocene stratigraphy in the following way.

Hough's substage		Age in years
VI		11,000
	Mankato	
V		15,000
	Cary	
IV		26,000
III	Tazewell	37,000
II	Iowan	51,000
I	Farmdale	64,000

The Farmdale substage was introduced by Leighton and Willams in 1950.

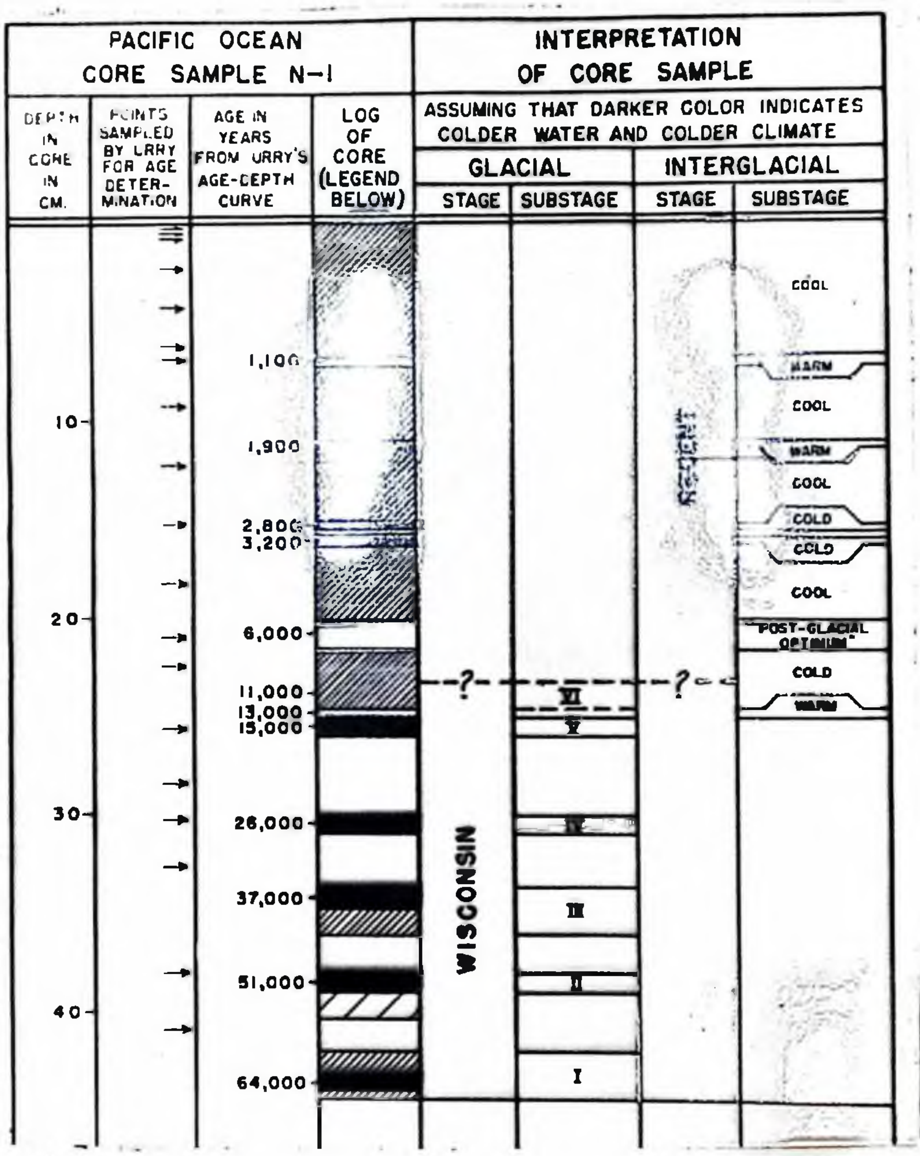

Figure 13. Wisconsin stratigraphy based on ocean bottom sediments (after Hough, 1953).

A question, related to the foregoing, now arises. Is the number of distinct glacial substages within the Wisconsin known with certainty for the North American continent?

A careful study of this problem shows that the division of the Wisconsin glaciation into substages is based on widely scattered evidence. It is quite possible that so far evidence has not been found of some additional ice readvances of substage magnitude, or that they have not been recognized.

If the interpretation of the ocean bottom core is correct, corresponding cold and warm periods should have been present also on the continent.

Recently Flint (1955) has suggested the presence of an additional substage in the Early Wisconsin.

Summarizing the available geological and palynological evidence and the radiocarbon dates (Kulp, 1951, 1952; Suess, 1954 a, b; Rubin and Suess, 1955; Flint and Rubin, 1955) the writer suggests the following sequence of events for the Wisconsin glaciation.

There is indication of a rather recent glacial advance in the western mountains about 3,000 years ago (Rubin and Suess, 1955).

The Mankato advance occurred approximately 10,000 years ago in eastern North America preceded by the Two Creeks (Cary-Mankato) interval about 11,000 years ago.

According to Flint and Rubin (1955), a major glaciation affected the Great Lakes region beginning 25,000 or more years ago and reaching its maximum about 18,000 years ago. This glaciation supposedly includes the Cary, Tazewell and maybe all Early Wisconsin substages that have been recognized.

Then there is a well established interval about 30,000 - 40,000 years ago, im ediately followed by another glaciation. Palynological information on material from this interval suggests a climate considerably cooler than the present. Further, palynological studies also suggest that in two sections the whole interval is represented, beginning with a subarctic climate, then changing to boreal and temperate and back to subarctic again.

On the basis of all information at hand, the St. Pierre interval is not identical with the Two Creeks interval; it is older and the climatic conditions were more favourable during the St. Pierre interval. Whether the St. Pierre interval could be correlated with the Bradyan interval is questionable because of the difference in age. After consideration of present information the Bradyan interval would be placed in the Middle Wisconsin, and the St. Pierre interval, in the Early Wisconsin. The palynological evidence does not favour the idea of correlating the St. Pierre interval with the Sangamon interglacial period, because during Sangamon, a long and warm interglacial period, the climatic conditions should surely have been more favourable than the present.

How is the foregoing discussion related to the studies of the Toronto formation ? The writer will suggest the following correlation with the current Pleistocene stratigraphy.

The Mankato ice advance did not reach the Toronto region. This is supported by studies in the St. Lawrence Lowland where the Mankato end moraine lies very close to the highland areas and the associated till and outwash deposits are of little extent or magnitude. The ice border at the Mankato maximum may have curved southwestward from the Ottawa region and reached the Two Creeks locality in Wisconsin but not the Toronto region. This, of course, is for the present a hypothesis. The surface till in the Toronto region in this case would be of Cary age and the recognized deglacial interval preceding that glaciation could be the correlative to the Bradyan interval. Presence of the St. Pierre interval in the Toronto region is suggested by discovery of the peat boulders at Markham. The age of those 'boulders' is more than 30,000 years and the microfossil assemblage suggests a boreal climate at the time of that peat formation.

The middle complex of tills and varves has been correlated with the Early Wisconsin, and the writer suggests that the interglacial Don beds belong to the Sangamon interglacial period. The age of samples from the Don beds is beyond the dating range of the C-14 method and microfossils and megafossils suggest a climate warmer than the present. The basal till would be a remnant of the Illinoian glaciation.

One might ask why the Don beds cannot be correlated with the next older interglacial period - the Yarmouth. First, it is in this particular case unlikely that a glaciation (Illinoian) consisting of several substages and a long interglacial period (Sangamon) of about 200,000 years could pass unrecorded. Secondly, in the plant fossil and microfossil assemblage there should be evidence of numerous extinct species and as the Yarmouth interglacial has been estimated to have lasted about 300,000 years there should be evidence of plants of distinctly southern distribution as the Yarmouth interval is supposedly the warmest interglacial stage; these are so far lacking in the Don beds samples.

3. Importance of Palynological Studies for Paleobotany, Geological Stratigraphy and Phytogeography

Out of this study several problems have emerged that suggest the direction and need for further investigations. First and foremost much more effort should be put into the study of pollen grains and spores of modern plants. Knowing their morphology and taxonomical relationships, a palynologist would be in a much better position to pass judgement on the ancient climatological and ecological environment reflected in the plant microfossil assemblages.

The evolutionary trends within the plant kingdom during the geological past could be traced if the relationships between pollen and spore types and their parent plants were known. Establishing the advanced and primitive palynological features within taxonomical groups may help considerably in paleobotanical discussions. A small contribution has been made along these lines by studying the pollen morphology of several tree genera for this investigation.

At the present time several workers are making palynological studies of deposits of different ages and the knowledge of ancient pollen and spore types is rapidly expanding. Difficulties in classifying the ancient pollen and pore types hav often appeared and quite artificial systems have been created. However, drawing lines between species in this material could be made easier by palynological studies of modern material. For example, the descriptive pollen morphological studies made in chapter four give examples as to the variation of material within the limit of one species and so help to suggest where to draw limits in more ancient material.

The usefulness of palynological studies in stratigraphy has been soundly established in practice. Nevertheless, improvements can be made also in this field. As far as the Pleistocene stratigraphy is concerned much could be gained by studying the inter-relations between vegetation and pollen and spore spectra in various deposits under formation. The expansion of palynological studies towards the north would supply the worker with information, necessary in the interpretation of the late glacial environments when considerable plant migration took place. Significant work of great value in this connection has been contributed by Radforth (1952, 1953, 1954) in his studies of the organic terrain in the Canadian north.

Investigation of surface samples for their pollen and spore content will help to establish the relationship between vegetation and the pollen spectrum within a particular area. However, there is great need for more extensive palynological studies of the Pleistocene deposits and similarly of the older deposits. Within the Pleistocene and particularly within the post glacial time one could with the help of radiocarbon dating build up sequence of pollen diagrams for different areas where recognizable horizons in the diagram are dated by the C-14 method. After this has been done the diagrams alone could be used to determine the age of certain events much more accurately than is possible now.

Intensive palynological studies would greatly help the phytogeographer to establish ancient plant distribution patterns and hence the migration of plants, thus aiding in the solution of many problems that puzzle the botanist at the present time.

The need for improvements in palynological methods must be stressed because such improvement can very well be made in such matters as the chemical treatment of samples of various deposits, photographing the microfossils, studying the fine-structure of the pollen and spore wall, classifying the microfossils and even in exploring the errors that inevitably are present in our interpretation.

An interesting problem has proved to be the palynological study of stratified sediments, in which category the varved sediments can also be included. The writer believes, that this study may reveal clues about their deposition; for example, whether the strata in question represent annual deposition. This is the general interpretation of varves, in contrast to which there is the view that varves are due to changes other than seasonal sequence of sedimentation. It may well be that under suitable conditions only one layer may be deposited each year without reaching the appearance of varves. A careful study of microfossils in these deposits may prove the character of deposition.

Study of the interglacial sequence of varves in the St. Pierre section has shown that microfossils are abundant in the varves immediately overlying the peaty sequence and gradually decrease in number towards the top of the section when ice advanced over the locality.

Exactly the opposite is the case when post-glacial varves are studies. The number of microfossils (pollen grains and spores) is very low in the proximal varves and increases towards the top of the varved section.

A careful palynological study of lake sediments in relation with the limnological problems would likely prove mutually profitable.

VI CONCLUSIONS AND SUMMARY

During this investigation methods have been developed to explore Pleistocene sediments, other than peat, for microfossils and to utilize Canadian Pleistocene microfossils for stratigraphical studies.

Particular attention was paid to the reliability of analytical methods for this study. A resistance test made on several types of modern pollen, showed that the chemical treatments used for this study did not change the original microfossil composition in the sample.

It has been established that a count of 100 - 150 microfossils in one sample is sufficient to yield reliable percentages of the components. It was found practical to examine more material besides that yielding this count and to record all potential microfossils, not present in the basic count, for later interpretation.

Special study was carried out on the pollen morphology of a number of tree species to permit identification of the fossil material and to make a more accurate interpretation of the results possible. This investigation showed, that taxonomical units, for example in _Betula_ and _Alnus_, are reflected in the pollen morphology. It was found that pollen morphological characters alone are not sufficient to distinguish between different species of Pinus, because of the overlap of characters. Ecological reasoning and size measurements must be used along with the pollen morphological features to permit identification of Pinus species among fossil pollen.

The pollen morphological characters of Abies, Picea, Betula, Alnus, Fraxinus, Acer and Carya, are sufficient to identify at least some species of these genera.

The palynological and paleobotanical evidence, together with studies of diatoms and fresh-water shells, suggest a climate about 3° - 5° F. warmer than the present for the interval when the Don beds were deposited. This difference in annual mean temperature is significant in view of present knowledge. There is a difference of 5° F. between the annual mean temperature for Hamilton and Toronto, the latter having the lower annual mean temperature. This difference is accompanied by a difference in the tree flora. Between Toronto and Ottawa there is a 10° F. difference in the annual mean temperature and it is accompanied by a significant difference in the tree flora. || ? No

A radiocarbon date on wood from the Don beds has yielded an age of more than 40,000 years.

Palynological evidence has proved that none of the recognized intervals within the Wisconsin supported climatic conditions as warm as the present.

In view of this evidence the writer has suggested that the warm climate Don beds belong to the Sangamon interglacial stage.

The Scarborough beds represent deposition during the closing period of a deglacial interval and the palynological evidence suggests a boreal climate, changing towards arctic conditions. The middle part of the Scarborough beds shows a pollen assemblage characteristic of coniferous forest. A few remnants of the previous deciduous type of forest, however, still survived.

The following correlation with the recognized Pleistocene stratigraphy has been suggested for the Toronto formation.

Lithology	Stratigraphy
Surface till	Cary
Interstadial sand	A major interval (Bradyan ?) within Wisconsin
Middle till complex	Lower Wisconsin
Scarborough and Don interglacial beds	Sangamon interglacial
Basal till	Illinoian

The results of this study clearly suggest several problems for further investigation in the palynological field.

First on the list of desiderata stands the need for fundamental studies in palynology - to expand the knowledge of the pollen and spore morphology of modern plants and to study the taxonomical units of the current classification of plants.

The analytical treatment methods should be investigated for further improvements.

Extensive studies of the post glacial and modern sediments combined with fundamental palynology would probably benefit the studies in such fields as stratigraphy, paleobotany, phytogeography, limnology and taxonomy.

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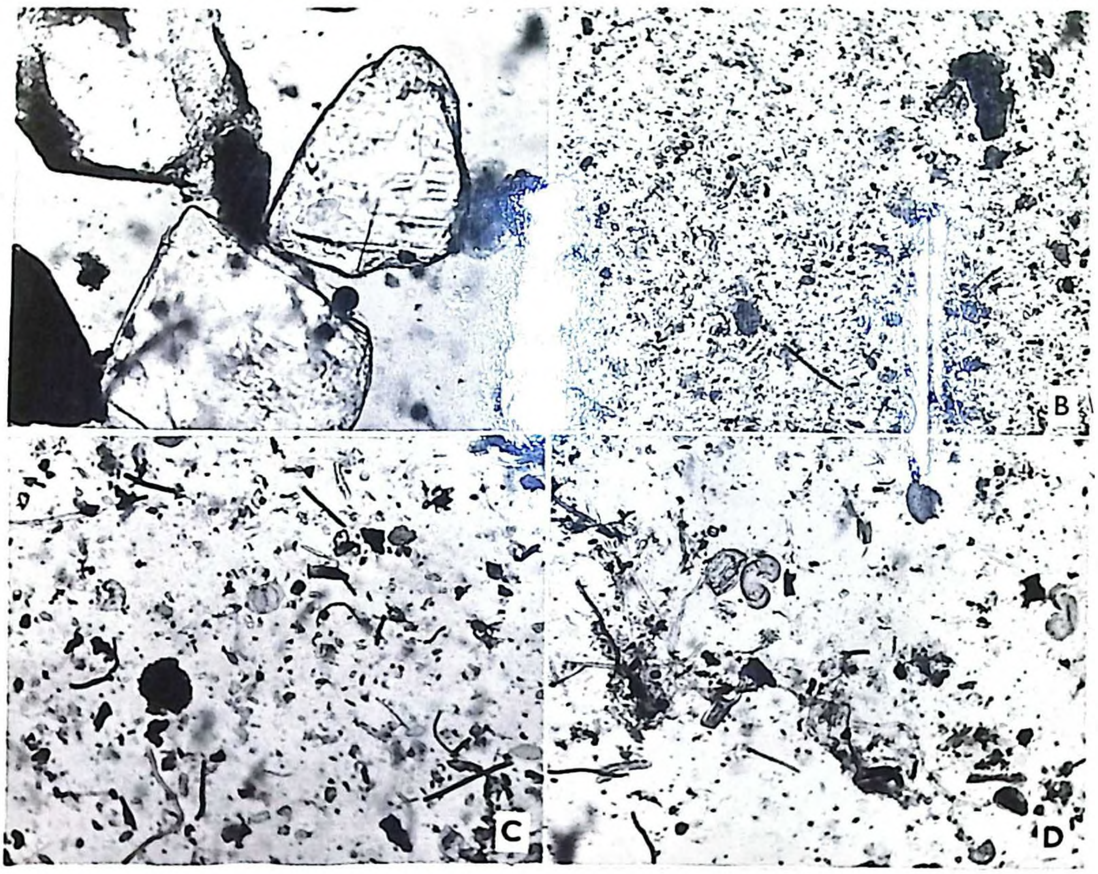
NOTE. For this investigation and also for photomicrography a monocular microscope, manufactured by Cooke, Troughton and Simms Ltd., York, England, has been used. This microscope is supplied with eyepieces 6 x (used for measuring) and 10 x (used in general work). The following objectives have been used: low magnification (Cooke 16 mm; N.A. 0.28; 10x), high dry (Cooke 4 mm; N.A. 0.65; 40x), and oil immersion (Cooke 1.8 mm; N.A. 1.3; 95x).

For photomicrography the Leitz' Ibso attachment with a Leica camera and an eyepiece 10x has been used.

All details shown in the following plates have been obtained with the above described microscope.

PLATE I



Various stages during preparation of a sample of coarse water-laid sand for microscopical analysis.

Figure A. Untreated material in a corn syrup mount.

Figure B. Same material after multiple washing with water.

Figure C. Same material after treatment with hydrofluoric acid.

Figure D. The final result after acetolysis.

All photomicrographs were taken using the low magnification.

PLATE II

Various types of pollen grains and spores isolated from Pleistocene deposits.

Figure 1. Don sand. Pollen grain of Caryophyllaceae, diameter 37 u.

Figure 2. Recent peat (sample # 280). 6-rugate pollen grain; diameter 22 u.

Figure 3. Interstadial peat. Pollen grain of Umbelliferae; 83 x 37 u.

Figure 4. Lake bottom sediment (sample # 374). Cf. *Eriocaulon*; a spiraperturate pollen hrain, diam. 31 u.

Figure 5. Scarborough silt. Cf. *Polygonum*, diam. 37 u.

Figure 6. Markham peat (3-4 cm). Unidentified microfossil, diameter 26 u.

Figure 7, 8, 11, 12, 13, 14. Spores of *Osmunda* from post glacial peat, representing various stages of preservation. Figure 11 shows the surface of the spore in silhouette.

Figure 9. A trilete spore from recent peat (sample # 351).

Figure 10. Sample of varved clay. A spore of cf. *Pteridium*, diameter 33 u. The trilete mark is obscured by poor preservation.

Figure 15. Dundas Marsh (2 cm). *Sparganium* sp. Diam. 26 u.

Figure 16, 17. (Figure 16)- *Cornus stolonifera* (Ottawa 30);

PLATE II

58 x 49 u. (Figure 17)- post glacial peat (sample # 95), cf. *Cornus*; 33 x 54 u.

Figure 18, 22. Lake sediment. *Nuphar* sp. (Figure 18, 33 x 25 u, sample # 346; figure 22, diam. 42 u, sample # 258).

Figure 19, 23. Unidentified pollen grain, diameter 50 u, sample # 197.

Figure 20, 24. Subrecent peat, sample # 280. *Ambrosia* sp., diameter 22 u. Focussing at the equatorial plane and pole respectively.

Figure 21, 25. Two photomicrographs of a 3-colpate, spinuliferous pollen grain showing the principle of the LO-analysis.

PLATE II

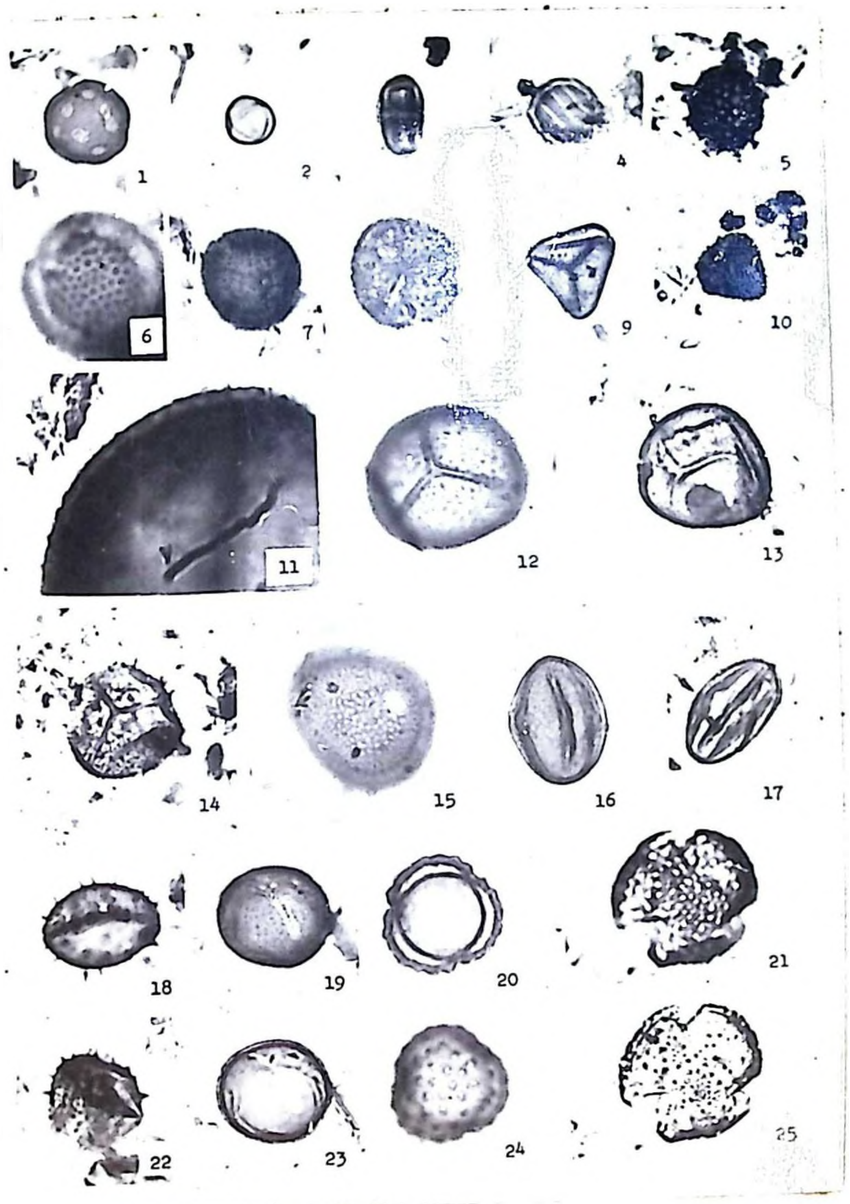


PLATE III

Figure 1, 2, 3, 4. Tilia americana L. Figure 1 and 2, oil immersion showing pattern at different focussing. Figure 4, high dry magnification. Figure 3, the same pollen grain further enlarged to show change in detail of pattern.

Figure 5. Sample from varves of interstadial section at Deschaillon, P.Q. Tilia sp., diameter 29 u.

Figure 6, 7. Same sample as in figure 5. Tilia sp., diameter 38 u. Focussing at different level showing pattern.

Figure 8, 9. Post glacial peat (sample # 197). Pollen grain of Oenotheraceae, diameter 67 u, figure 8 (high dry magnification) and figure 9 (oil immersion) showing sporoderm stratification and apertures at the equatorial plane.

PLATE III

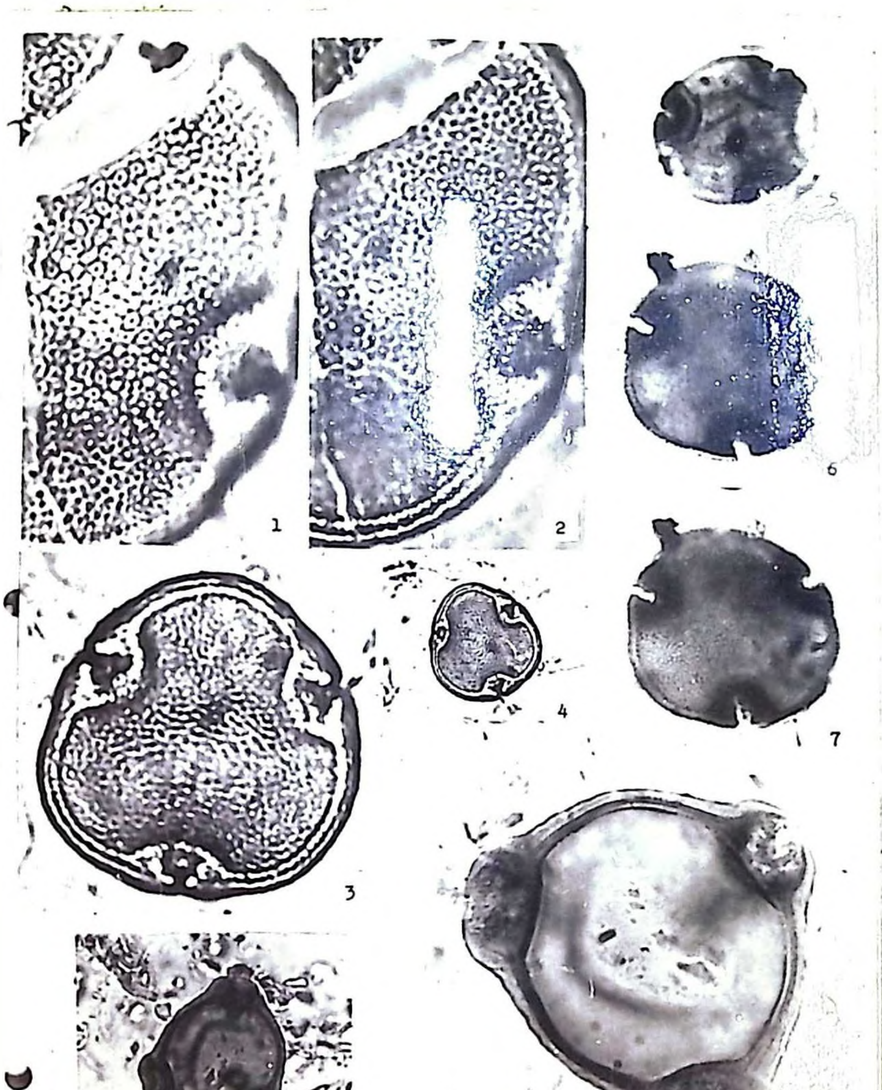


PLATE IV

Figure 1 - 4. Unidentified pollen grain, 37 x 33 µ, from interstadial peat at Lynn Canyon Park, B.C., has three colpate and three colporate apertures; fig. 2, polar pattern; fig. 3, intercolpate pattern; fig. 4, optical section at equatorial plane.

Figure 5 - 8. Nyssa biflora (modern material); fig. 5, aperture; fig. 6, optical section in equatorial plain; fig. 7, interaperturate pattern; fig. 8, polar pattern.

Figure 9-10. Trilete spore, equat. diam. 28 u, often present in post glacial peat (sample # 273).

Figure 11. Probable secondary pollen of Tilia, diam. 40 u. Dundas Marsh (surface - 0).

Figure 12. Pollen grain of cf. Liliaceae, polar axis 41 u. Post glacial lake sediment (sample # 95).

Figure 13-14. Acer macrophyllum (modern). Oil immersion, showing striation.

Figure 15. Fraxinus excelsior (modern); oil immersion, showing reticulation.

Figure 16. Fraxinus pennsylvanica (modern). Oil immersion showing reticulation in relation to F. excelsior.

Figure 17. Pseudotsuga sp., diam. 100 u, (fossil).

Figure 18. Menyanthes trifoliata (modern). Striation (oil immersion).

Figure 19. Ulmus americana (modern). Pattern (oil imm.).

PLATE IV

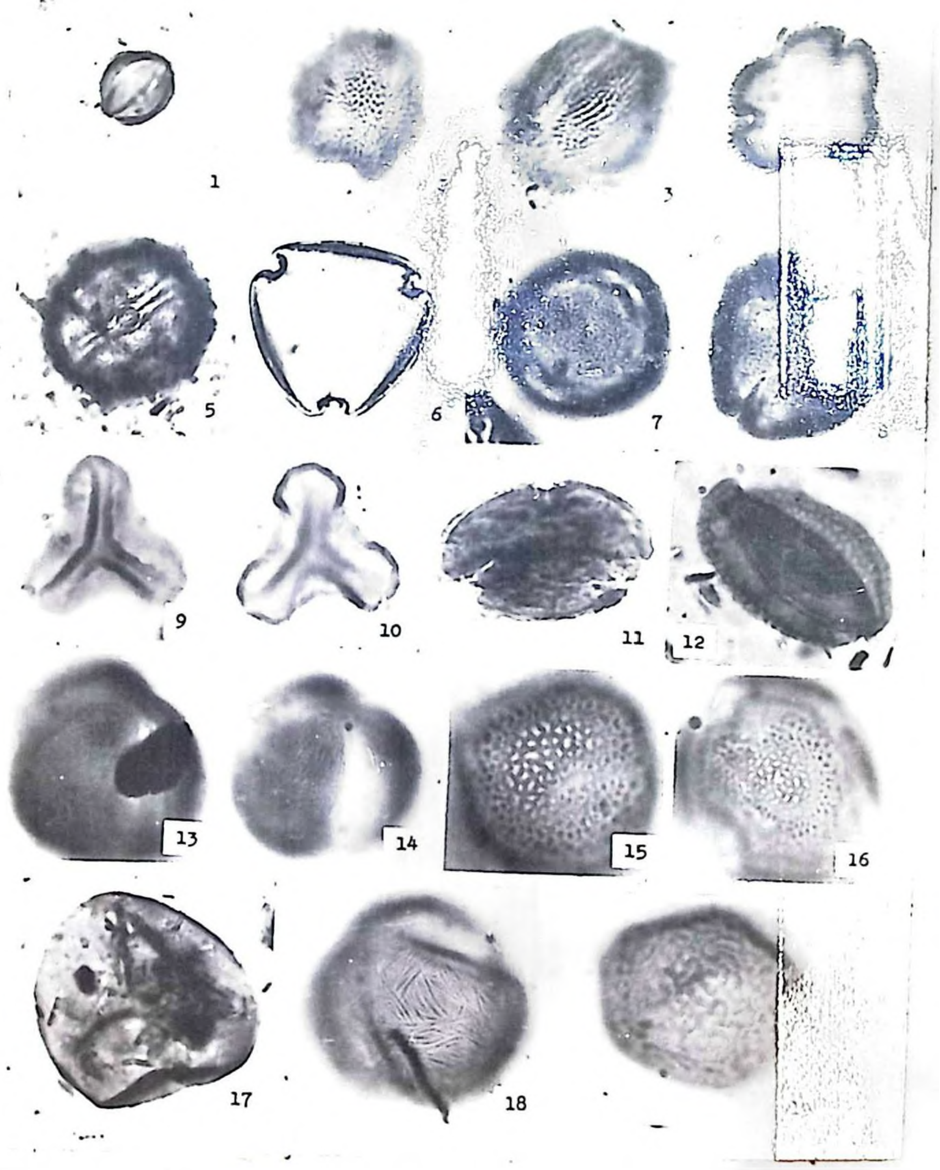
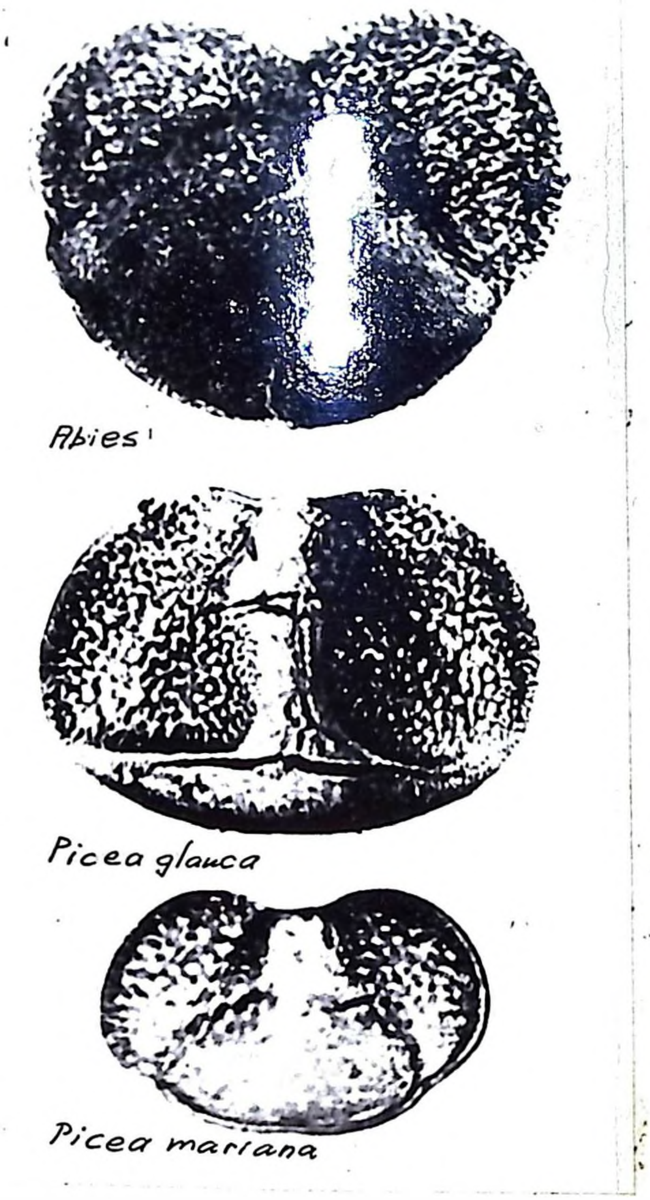


PLATE V



Reproduction from Potzger (1953) tp show the relative size of <u>Abies</u>, <u>Picea glauca</u> and <u>Picea mariana</u>.

PLATE VI

Figure 1. *Chamaecyparis nootkatensis* (Ottawa 4).

Figure 2. *C. nootkatensis* (oil imm.), showing pila.

Figure 3. *Taxus brevifolia* (UBC 5625).

Figure 4. *Populus tremula* (modern material from Sweden).

Figure 5. *Populus balsamifera* (Ottawa 33).

Figure 6. *Populus tremuloides* (Ottawa 54).

Figure 7. *Populus trichocarpa* (UBC 32062).

Figure 8, 9. *Thuja occidentalis* (Ottawa 23).

Figure 10. *Thuja plicata* (UBC 5301).

Figure 11. *Quercus alba* (McM 189), oil imm., showing pattern.

Figure 12 - 16. Corrosion of various pollen grains during the course of deposition.

Figure 17, 18. Cf. *Nymphaea odorata*, diam. 28 u. Oil immersion showing spacing of pila. Lake sediment (sample No. 357).

Figure 19. Cf. *Nymphaea odorata*, 33 x 25 u. Lake sediment (sample No. 346).

PLATE VI

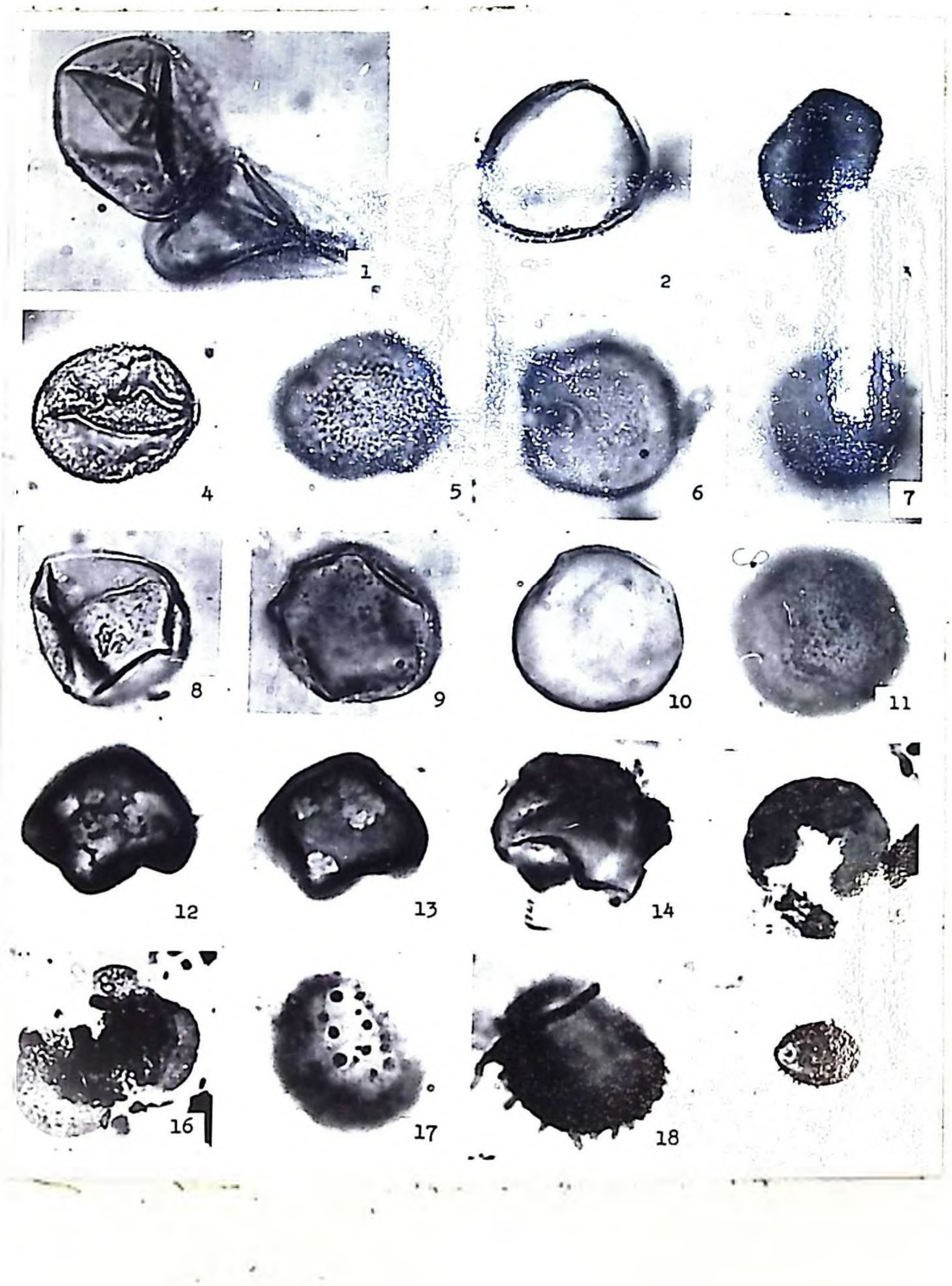


PLATE VII

Figure 1 - 4. Tsuga heterophylla (UBC 5600). Figures 1 and 2 show the pattern on the cap. Figures 3 and 4 show the subsaccate fringe in polar and equatorial view.

Figure 5 - 8. Tsuga mertensiana (UBC 5614). Figures 7 and 8 show the pattern on the bladder.

Figure 9 - 10. Picea excelsa (modern material from Sweden).

Figure 11. Recent peat. Abnormal pollen grain of Picea.

Figure 12. Carpinus sp., showing spacing of pores.

Figure 13, 14. Carpinus sp., figure 14 shows the aperture.

Figure 15. Quercus sp. General appearance.

Figure 16, 17. Larix laricina (modern); diam. 62 u.

Figure 18. Betula papyrifera var. neoalaskana (Ottawa 41), showing the faint pattern.

Figure 19. Betula papyrifera (Ottawa 44). A 4-aperturate pollen grain.

Figure 20. Same as figure 18. A pollen grain with a trilete tetrad scar.

Figure 21. Betula pumila (Ottawa 68). A 2-aperturate pollen grain.

Figure 22. Betula populifolia (Ottawa 71), showing pattern.

PLATE VII

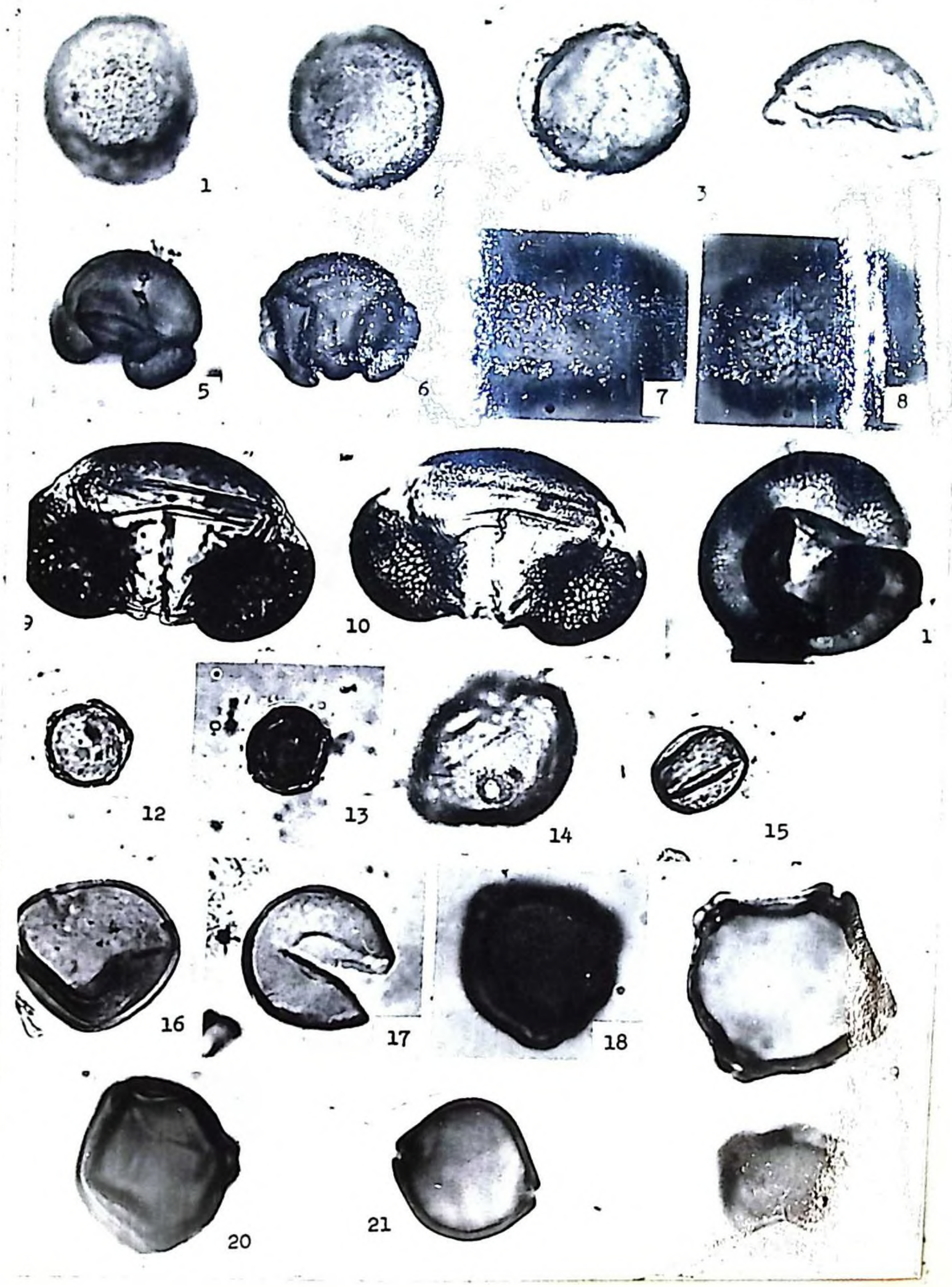


PLATE VIII

Figure 1. _Betula papyrifera_ (Ottawa 44).

Figure 2. _Betula glandulosa_, Herschmer, Man. (RBG).

Figure 3. _Betula papyrifera_ (Ottawa 44).

Figure 4. _Betula glandulosa_, Herschmer, Man. (RBG).

Figure 5. _Betula lutea_ (Ottawa 27).

Figure 6. _Betula glandulosa_, Herschmer, Man. (RBG).

Figure 7. _Alnus crispa_, diam. 21 μ. Interstadial peat, sample No. 116.

Figure 8. _Alnus_ sp., diam. 25 μ, showing arci. Recent peat, sample No. 98.

Figure 9. _Alnus crispa_ (Ottawa 51).

Figure 10. _Alnus crispa_, (Yukon, No. 9927).

Figure 11. _Alnus incana_ (Ottawa 45).

PLATE VIII

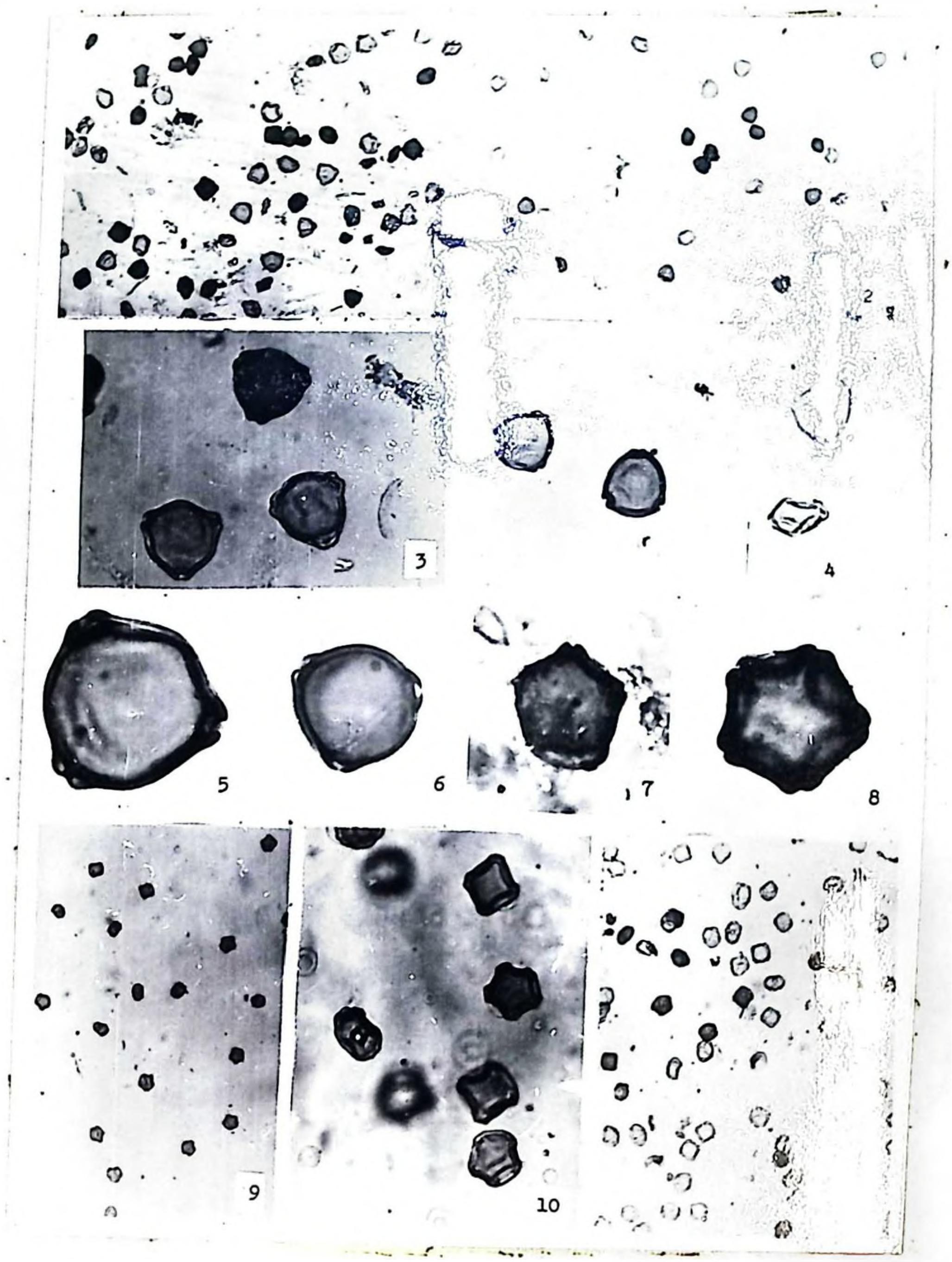


PLATE IX

Figure 1. *Alnus crispa* (Ottawa 49).

Figure 2. *Alnus rugosa* (McM 640/193).

Figure 3. *Pinus ponderosa* (UBC 5550).

Figure 4. *Pinus ponderosa* (UBC 5550).

Figure 5. *Pinus silvestris* (modern material from Sweden).

Figure 6. *Pinus monticola* (UBC 5527).

Figure 7. Abnormal pollen grain of *Pinus* (recent peat).

Figure 8. *Pinus resinosa* (Ottawa 8), abnormal grain.

Figure 9,-14. *Pinus resinosa* (Ottawa 8).

Figure 15. *Pinus strobus* (Ottawa 21).

PLATE IX

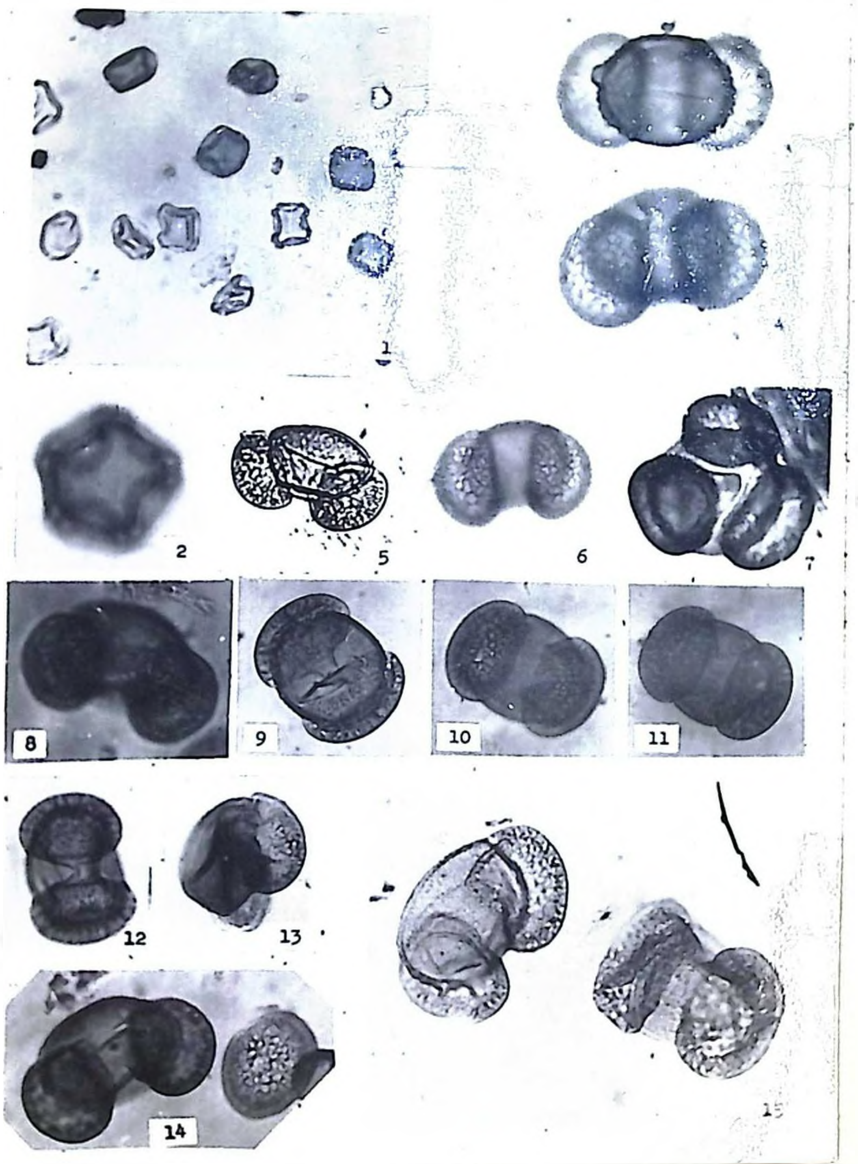


PLATE X

Figure 1 - 5. *Pinus strobus* (Ottawa 21).

Figure 6 - 11. *Pinus banksiana* (McM 180).

Figure 12 - 14 and 17. *Abies grandis* (UBC 5340).

Figure 15, 16. *Abies amabilis* (Ottawa 1). Young pollen tetrad.

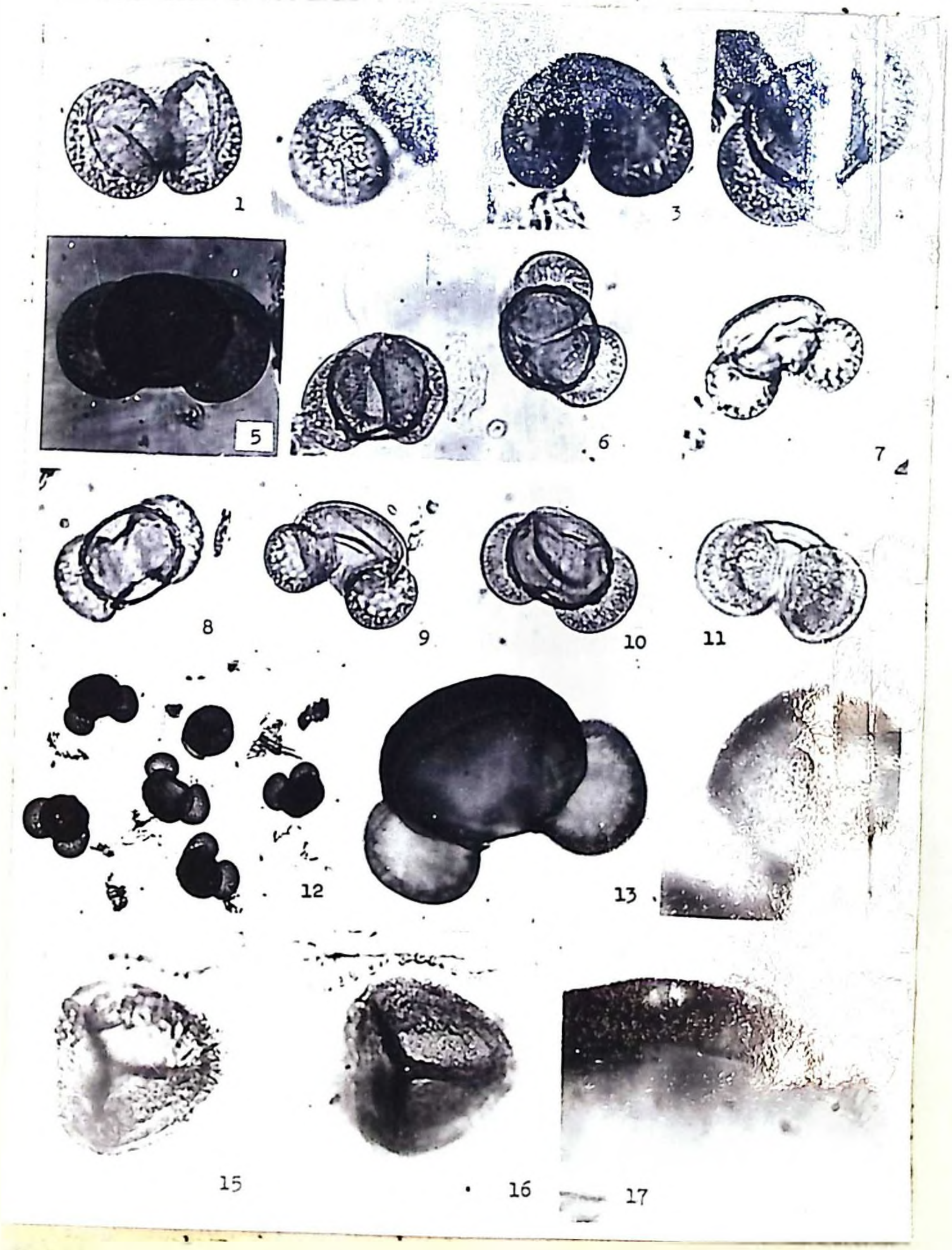


PLATE XI

Figure 1 - 4. *Abies amabilis* (Ottawa 1). Various stages of development of the pollen tetrad.

Figure 5. *Abies amabilis*. Enlarged detail of cap of a young pollen grain.

Figure 6. Fossil pollen grain of Abies. Detail of reticulation on air-sac.

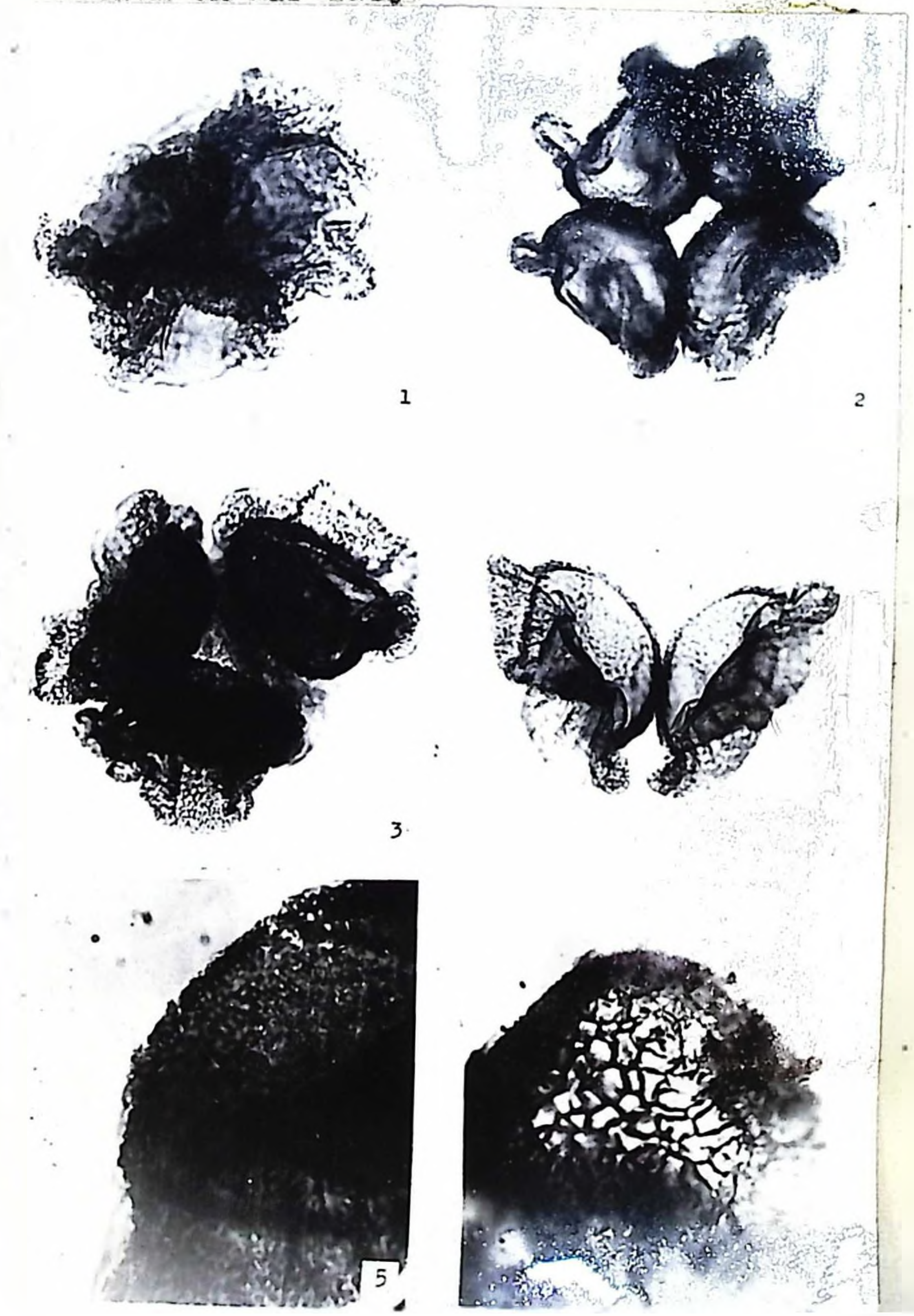


PLATE XII

Different pollen and spore types isolated from the sand samples collected from the Toronto Rapid Transit Subway exposures.

Figure 1 - 5. Pollen grains of *Pinus*.

Figure 6, 7,. *Ulmus* sp.

Figure 8. A cluster of *Betula* pollen.

Figure 9 - 12. Spores of Polypodiaceae.

Figure 13. Probable tetrad of *Betula* pollen.

Figure 14. *Carya* sp.

Figure 15. *Alnus* sp.

Figure 16. Artemisioid pollen type.

Figure 17. A 3-colporate non arboreal pollen grain.

Figure 18, 19. Unidentified pollen types.

Figure 20. A pollen grain of *Salix*.

PLATE XII

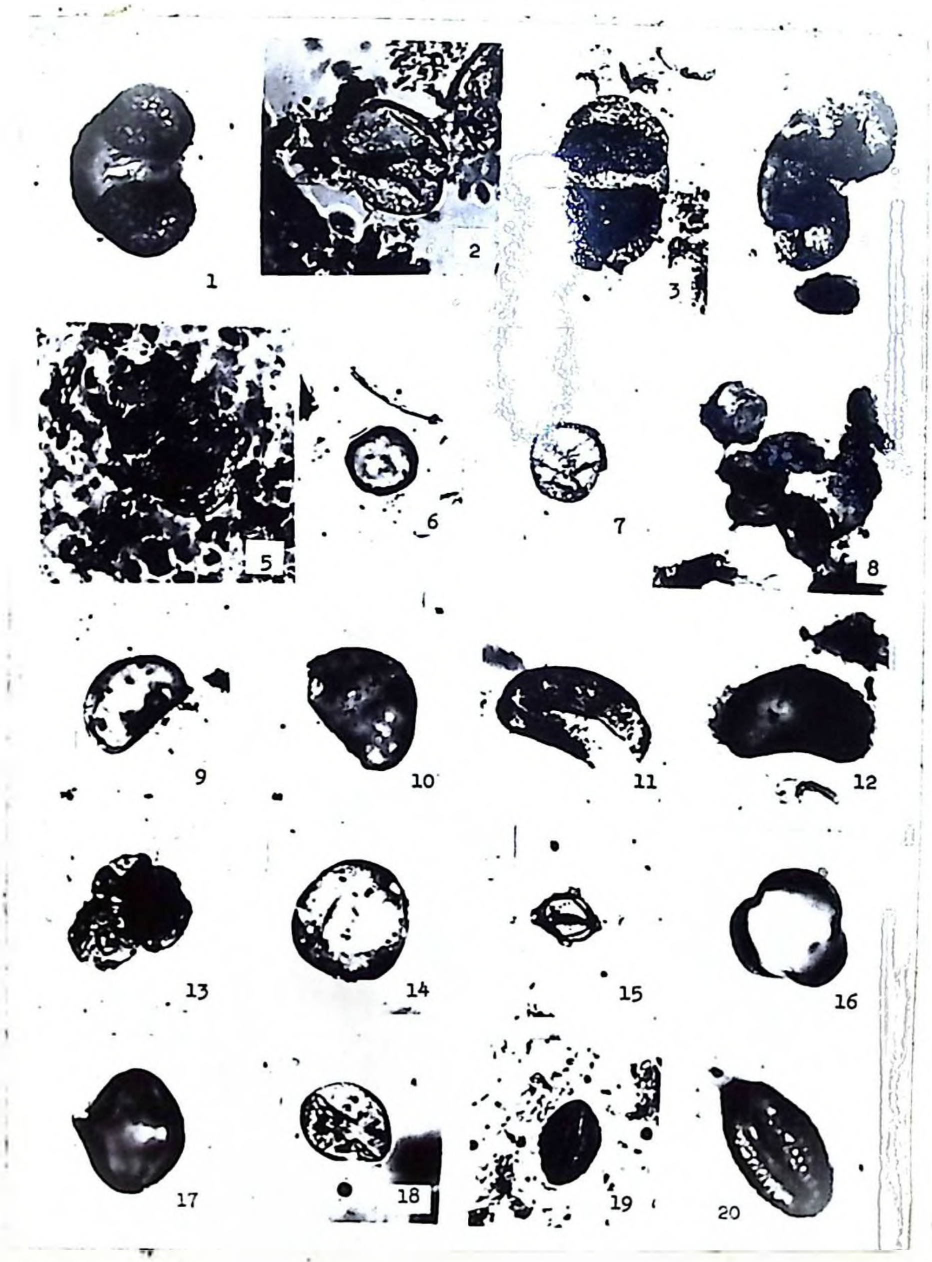


PLATE XIII

Figure 1 - 9. Various details of Picea pollen.

Figure 10 - 13. Abnormal pollen grains of Pinus.

Figure 14-15. Betula sp.

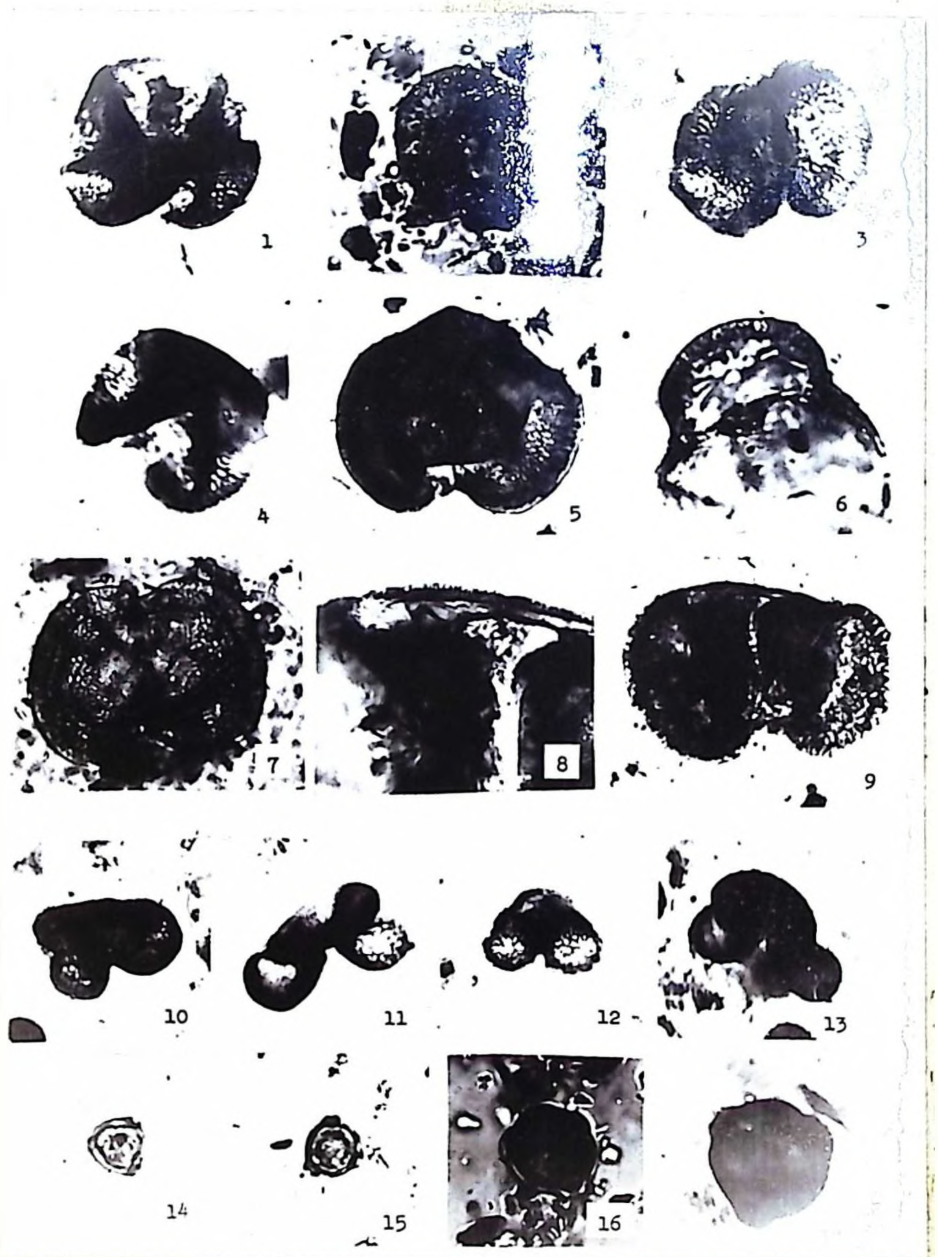


PLATE XIV

Pollen and spore types isolated from the sand samples collected from the Toronto Rapid Transit Subway exposures.

Figure 1. *Ambrosia*-type.

Figure 2 - 4. Pollen grains of Compositae.

Figure 5 - 7. Pollen grains of Caryophyllaceae.

Figure 8, 9. Unidentified pollen grains.

Figure 10. *Ambrosia*-type.

Figure 11, 12. Artemisioid pollen grains.

Figure 13 - 24. Unidentified pollen and spore types.

PLATE XIV

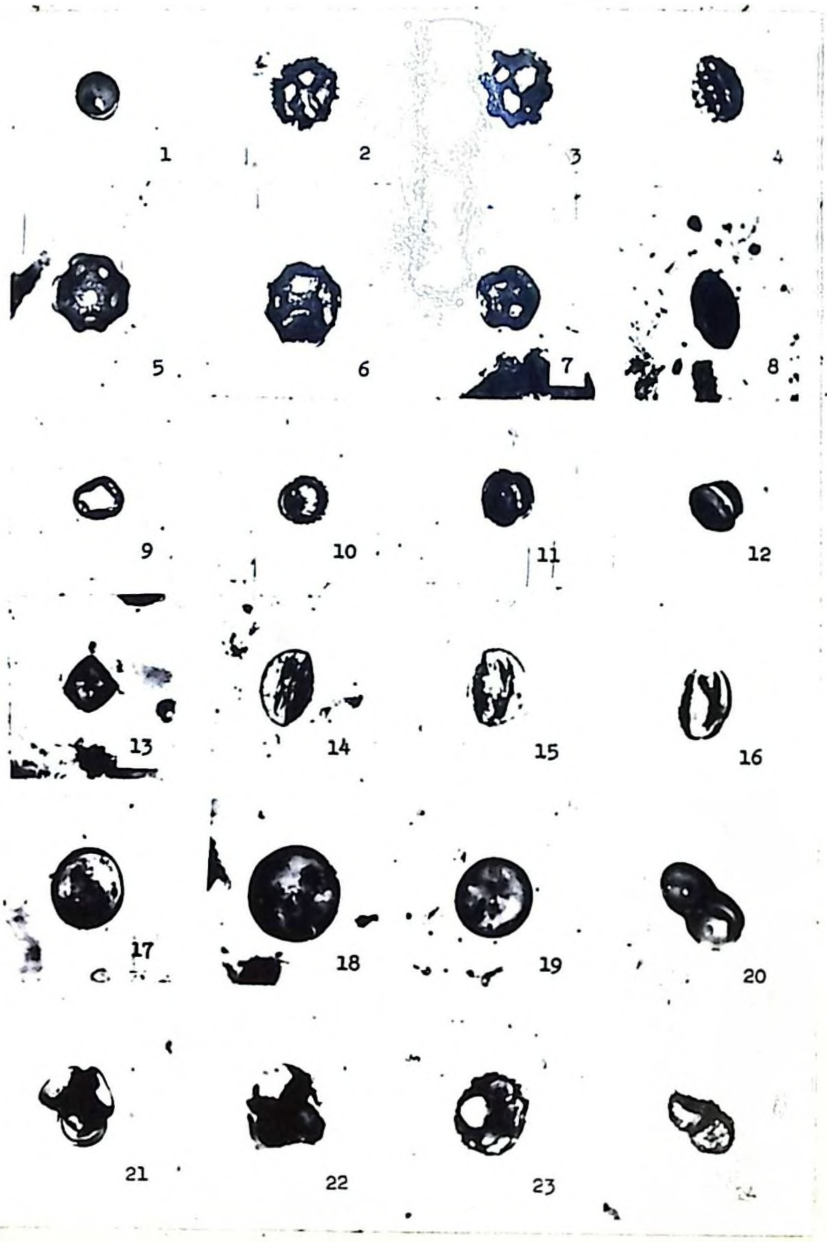


PLATE XV

Details from the sand samples from the Toronto Rapid Transit Subway exposures.

Figure 1. Rather well-preserved fragment of lignified tissue.

Figure 2. Lignified tissue fragments often found in samples.

Figure 3. General appearance of the washed residue of a sand sample.

Figure 4, 6. Cell-fragments with bordered pits.

Figure 5. A fragment of bark.

Figure 7. A cluster of unidentified spores.

Figure 8 - 12. Fungal reproductive structures, tentatively identified as Rhizophagites (Rosendahl, 1948).

PLATE XV

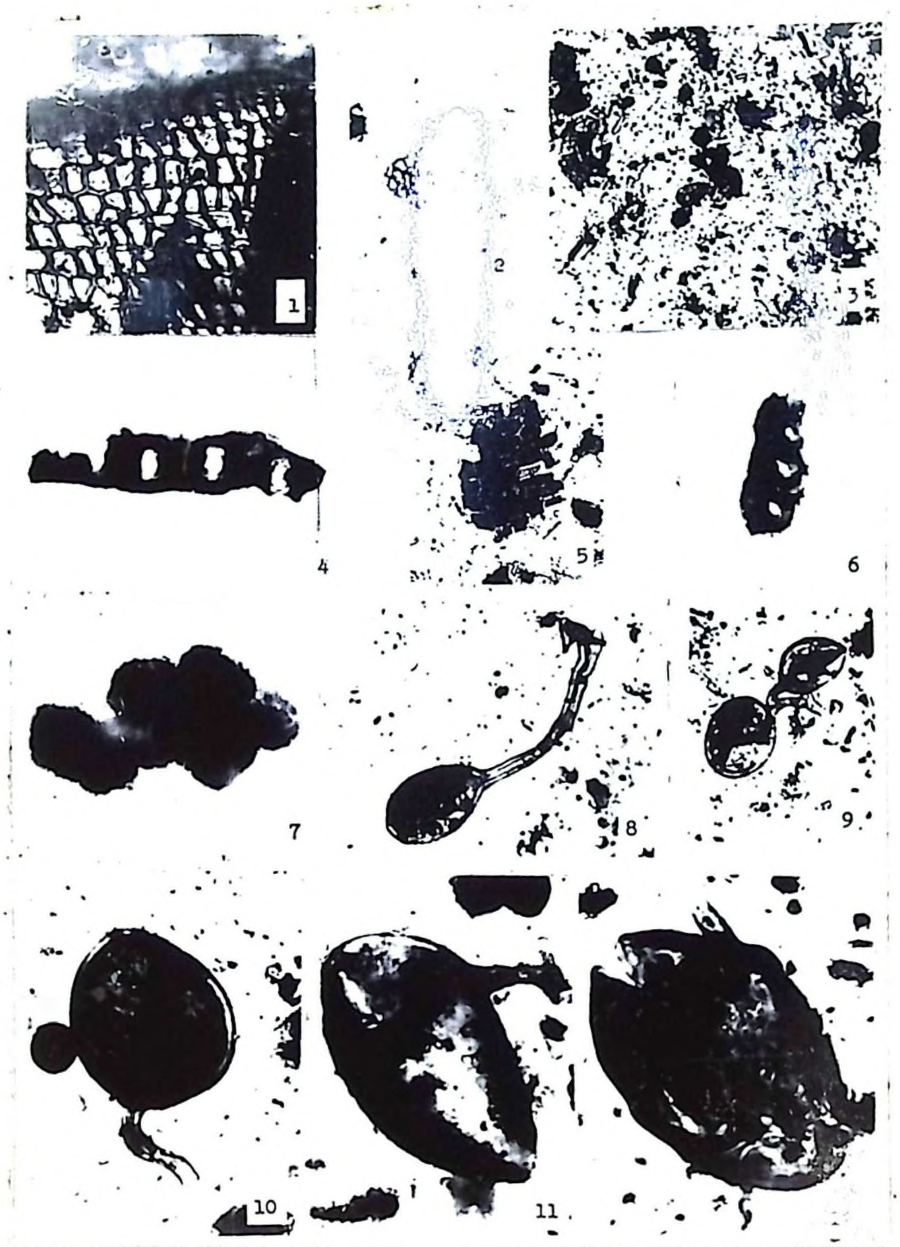


PLATE XVI

Details from the sand samples of the Toronto Rapid Transit Subway exposures.

Figure 1 - 3. Unidentified, thinwalled microfossils.

Figure 4. Probable poorly preserved pollen grain of *Pinus*.

Figure 5. Pollen grain of Gramineae.

Figure 6 - 8. Pollen grains of Cyperaceae.

Figure 9 - 15. Unidentified spore types.

Figure 16, 17. Fragment of lignified tissue.

PLATE XVI

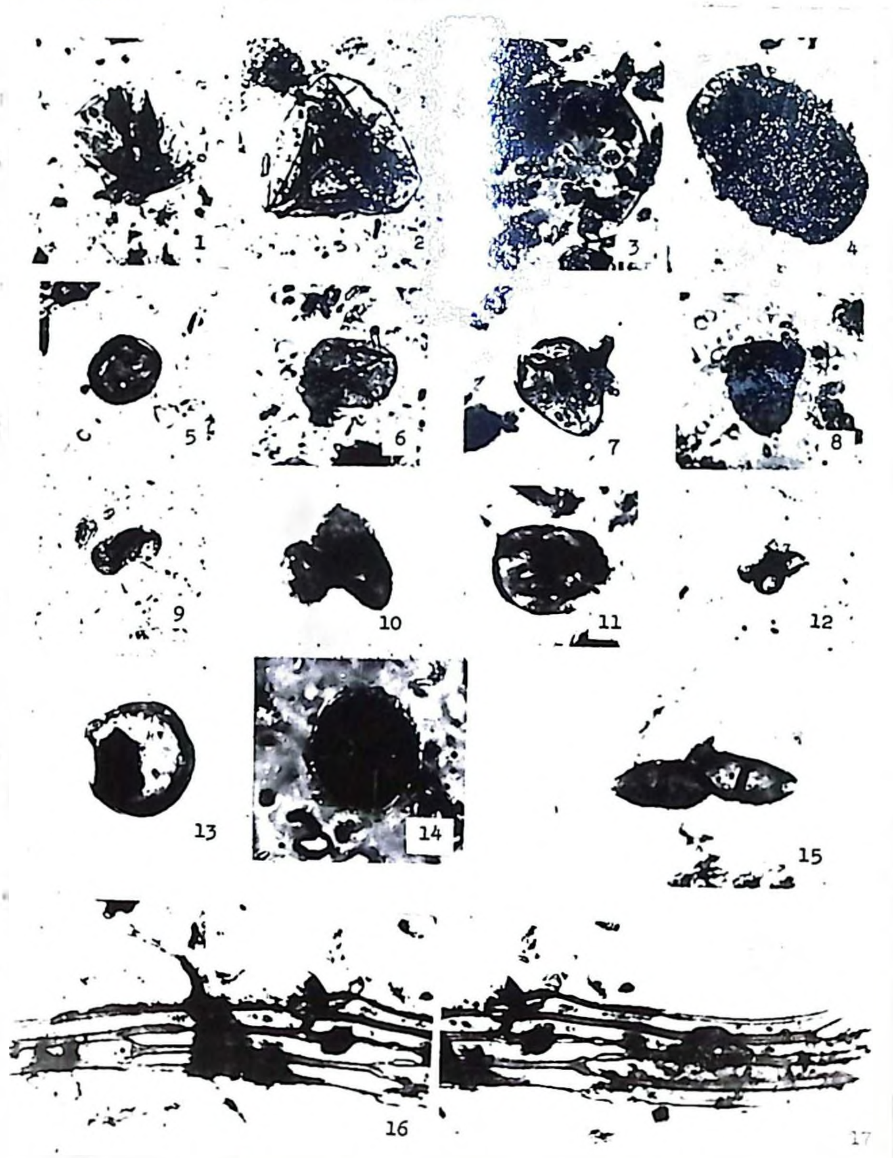


PLATE XVII

Figure 1 - 4. Types of microfossils, occurring abundantly in poorly decomposed, recent *Sphagnum* peat

Figure 5. Detail of leaf base tissue of *Typha latifolia*, (recent); distance between dark bands 62 - 83 u.

Figure 6. Fragment of fossil leaf base tissue of *Typha*.

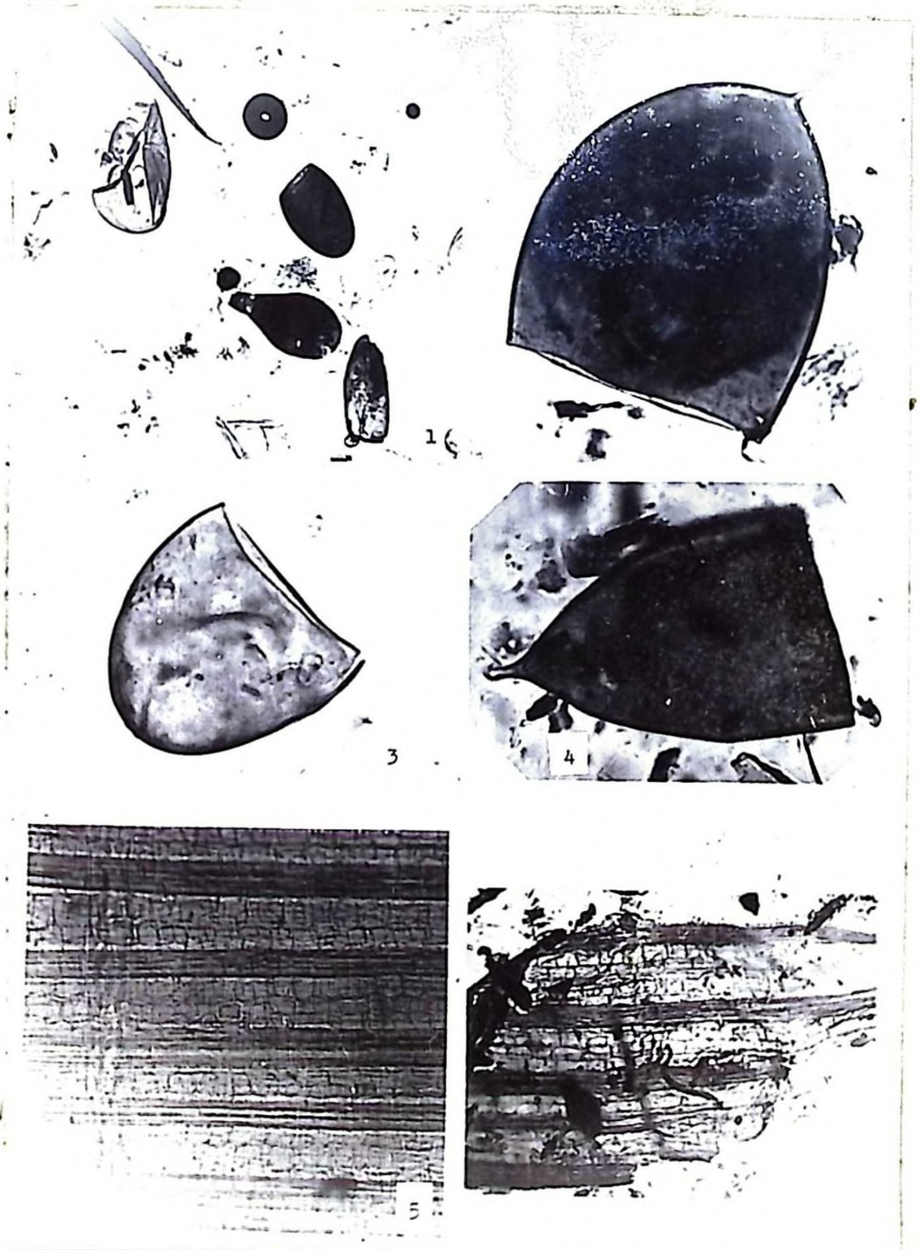


PLATE XVIII

Figure 1 - 4. Post glacial lake sediment, sample No. 375. Sponge needles. Length, fig. 1, 310 u; fig. 2, 285 u; fig. 3, 132 u; fig. 4, 220 u.

Figure 5. Peat. Unidentified microfossil, diam. 40 u.

Figure 6. Peat (# 358). Unidentified microfossil, diam. 58 u.

Figure 7. Peat (# 371). Unident. microfossil, diam. 124 u.

Figure 8. Peat (# 358). Amphitrema from Sphagnum peat.

Figure 9. Recent peat. Unident. fossil, diam. 39 u.

Figure 10. Unidentified microfossil from sand below the peaty sequence in the St. Pierre section, diam. 27 u.

Figure 11. Unident. fossil from peat (# 224). Diam. 29 u.

Figure 12. Abundant fossil in many post glacial sediments. Dundas Marsh (surface -0), length 54 u.

Figure 13. Unident. fossil. Recent peat. Diam. 116 u.

Figure 14. Recent peat. Unidentified spores, length of row 83 u.

Figure 15. Recent peat. Length of fossil 131 u.

Figure 16. Dundas Marsh (surface -0). Length of fossil 92 u.

Most of the above microfossils may occur abundantly in some post glacial sediments.

PLATE XVIII

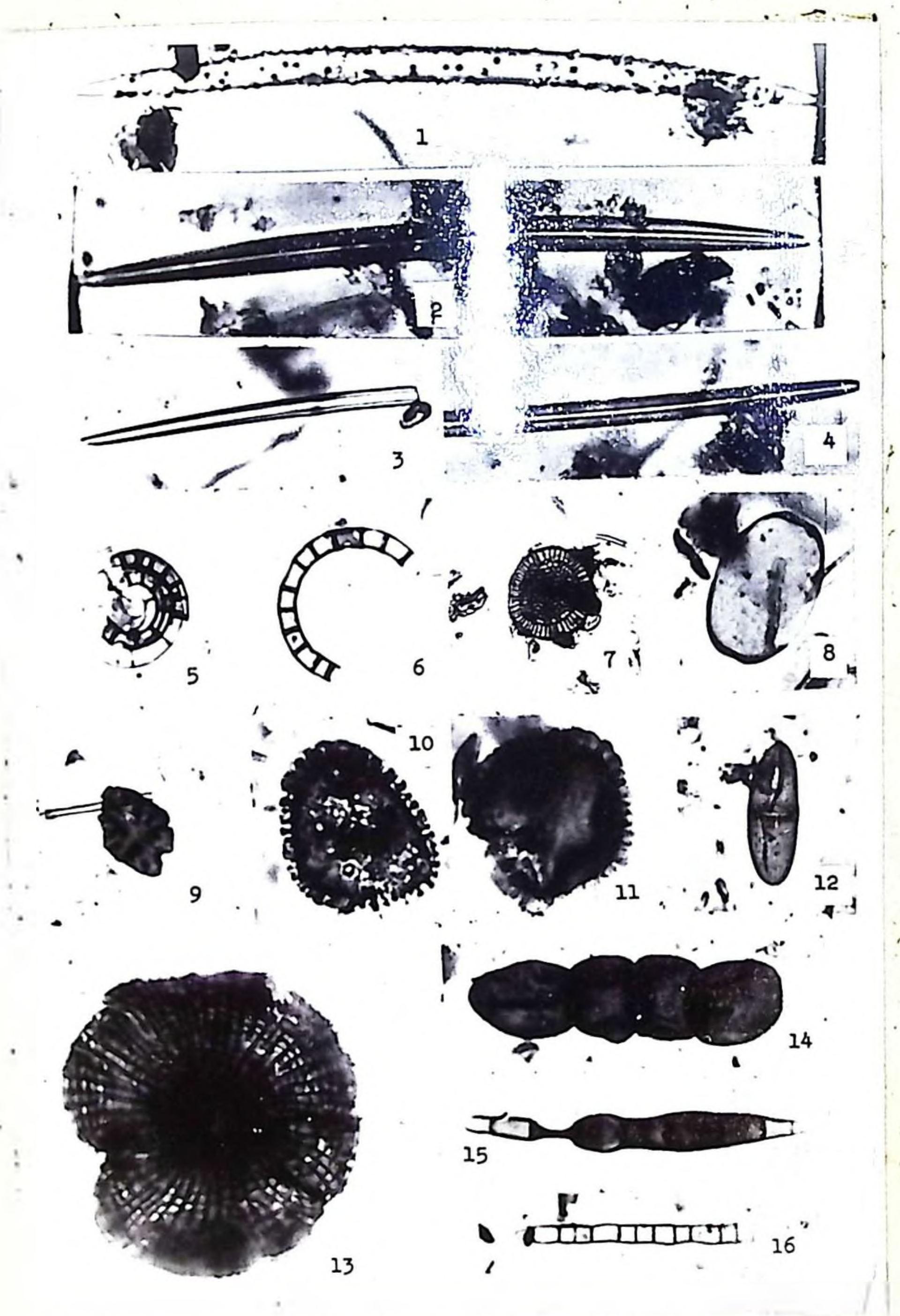


PLATE XIX

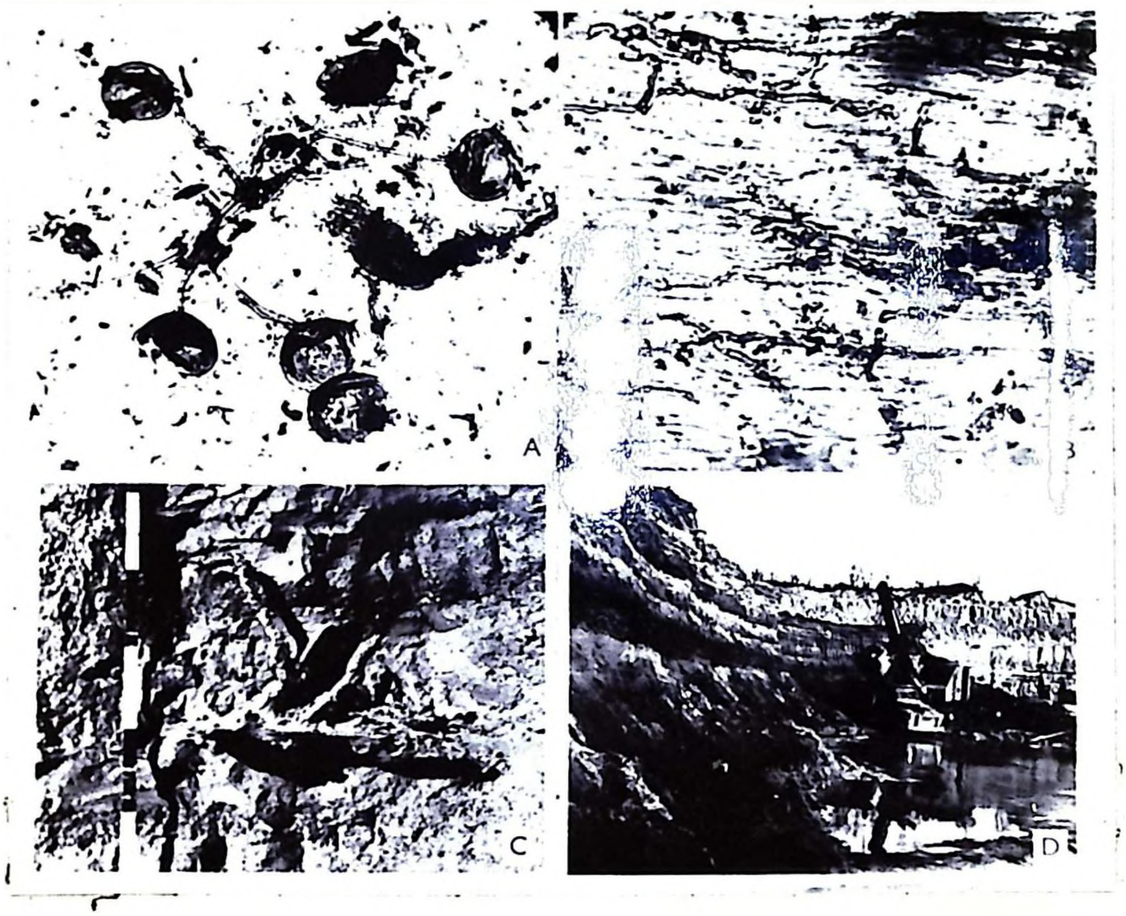


Figure A and B. Dundas Marsh bottom sample. A - reproductive structure of fungus, B - fungal growth in fossil wood.

Figure C. Interglacial Don beds. Part of a tree fossil in place.

Figure D. General view of interglacial Don beds. The dark band at the level of the power-shovel's scoop contains abundant plant fossils.

PLATE XX

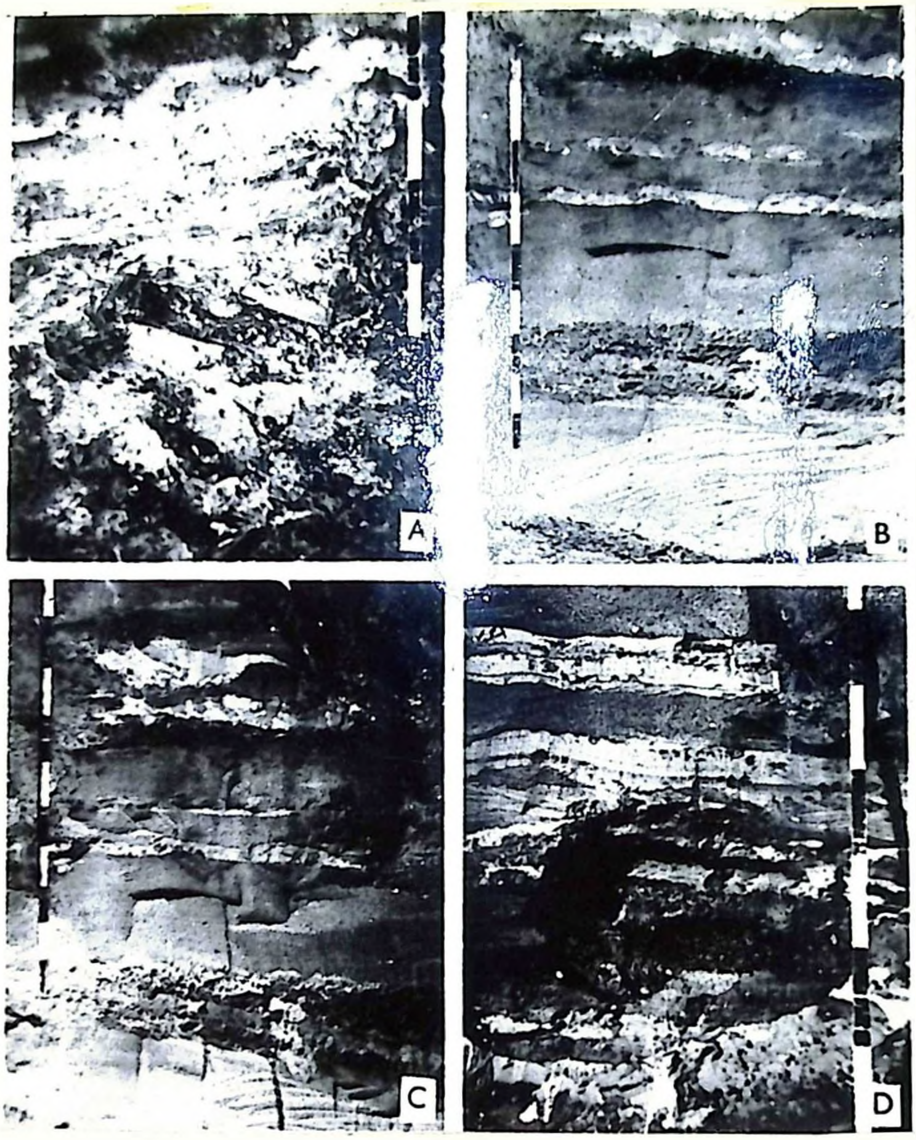


Figure A. Contact between basal till and interglacial beds (at level of lower end of the meter stick). Scale in decimetres.

Figure B and C. Lower part of the interglacial Don beds, showing the rapid change in deposition.

Figure D. Middle part of interglacial Don beds where plant fossils are found.

PLATE XXI

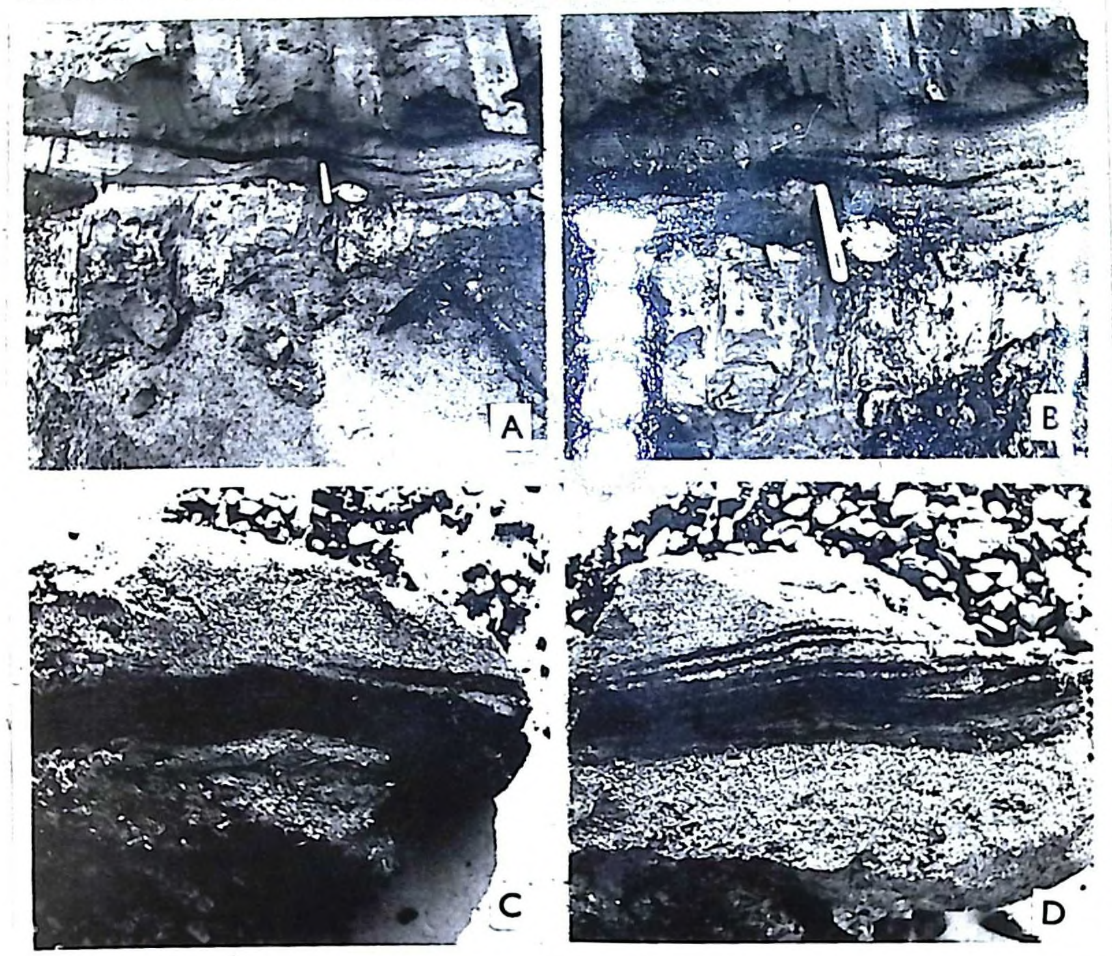


Figure A - D. Detail of the lens of fine plant debris that occurs in the middle part of the interglacial Don beds. Length of knife handle is about four inches. The plant debris is embedded in medium-grained sand.

PLATE XXII

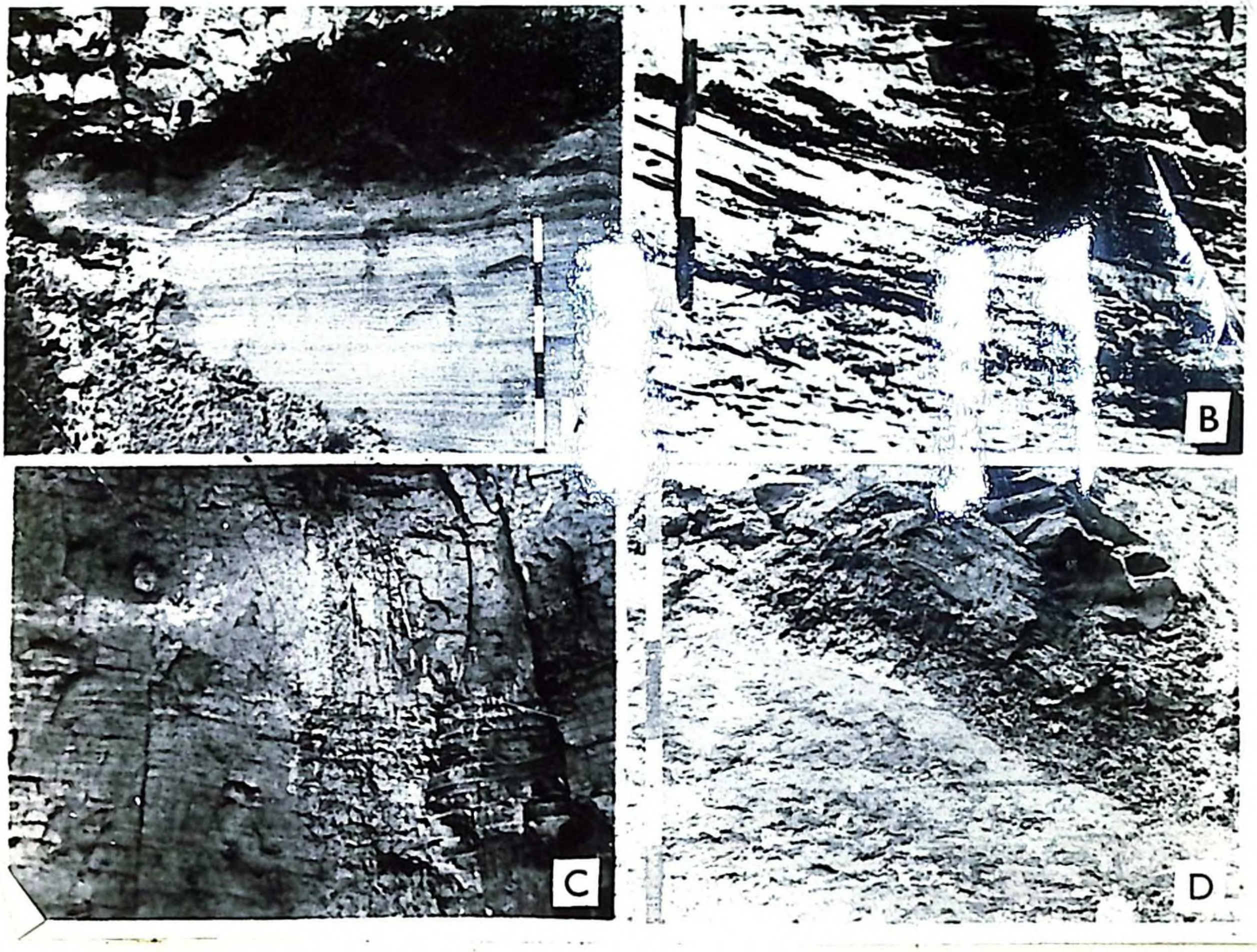


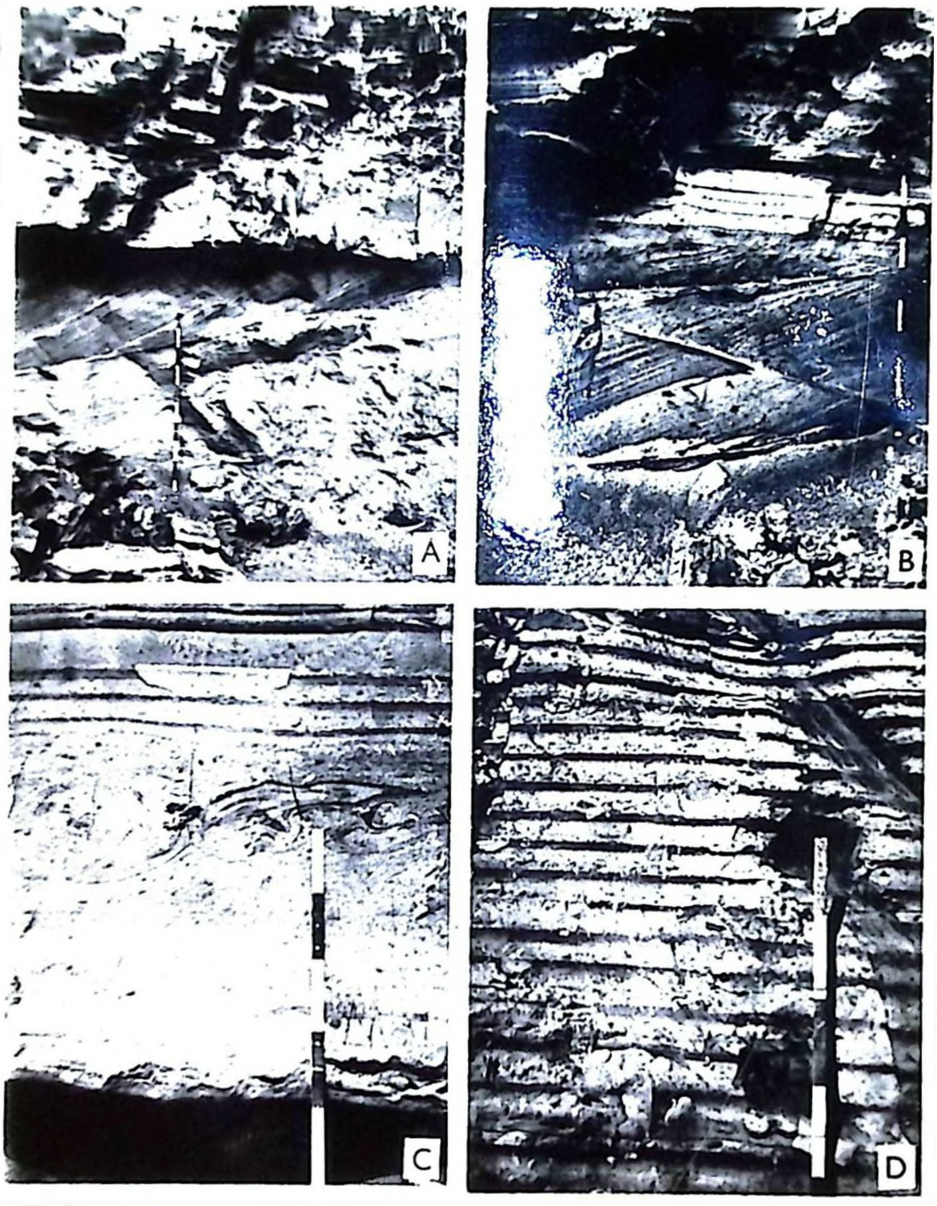
Figure A. Contact between upper Scarborough sand and the overlying till. Scale in decimetres.

Figure B. Fine plant debris embedded in the crossbedding of coarse sand.

Figure C. Contact between varves and overlying till in the middle till complex of the Toronto formation.

Figure D. Erosion of Scarborough beds (lower left); a chunk of clay is seen at upper right.

PLATE XXIII



Middle till complex. Scale in decimetres.

Figure A. Contact between crossbedded sand and till.

Figure B. Contact between crossbedded sand and varves.

Figure C. Till-like material (slump structure) between crossbedded sand and the overlying varves.

Figure D. Section of well developed varves.

PLATE XXIV

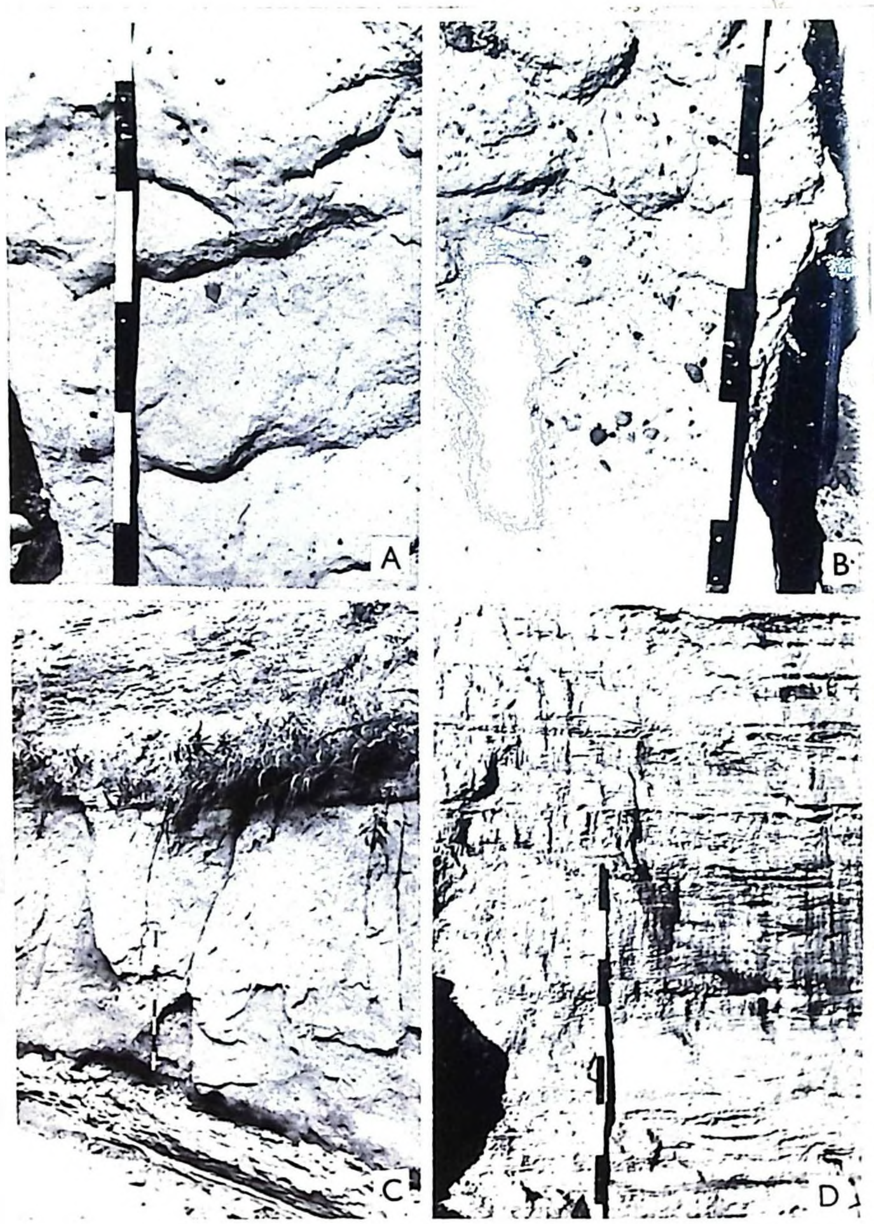


Figure A and B. Detail of till overlying Scarborough sand.
Scale in decimetres.

Figure C. A bed of massive silt and fine sand with plant debris in the Scarborough sequence.

Figure D. Stratified Scarborough silt with partings of fine plant debris.

PLATE XXV

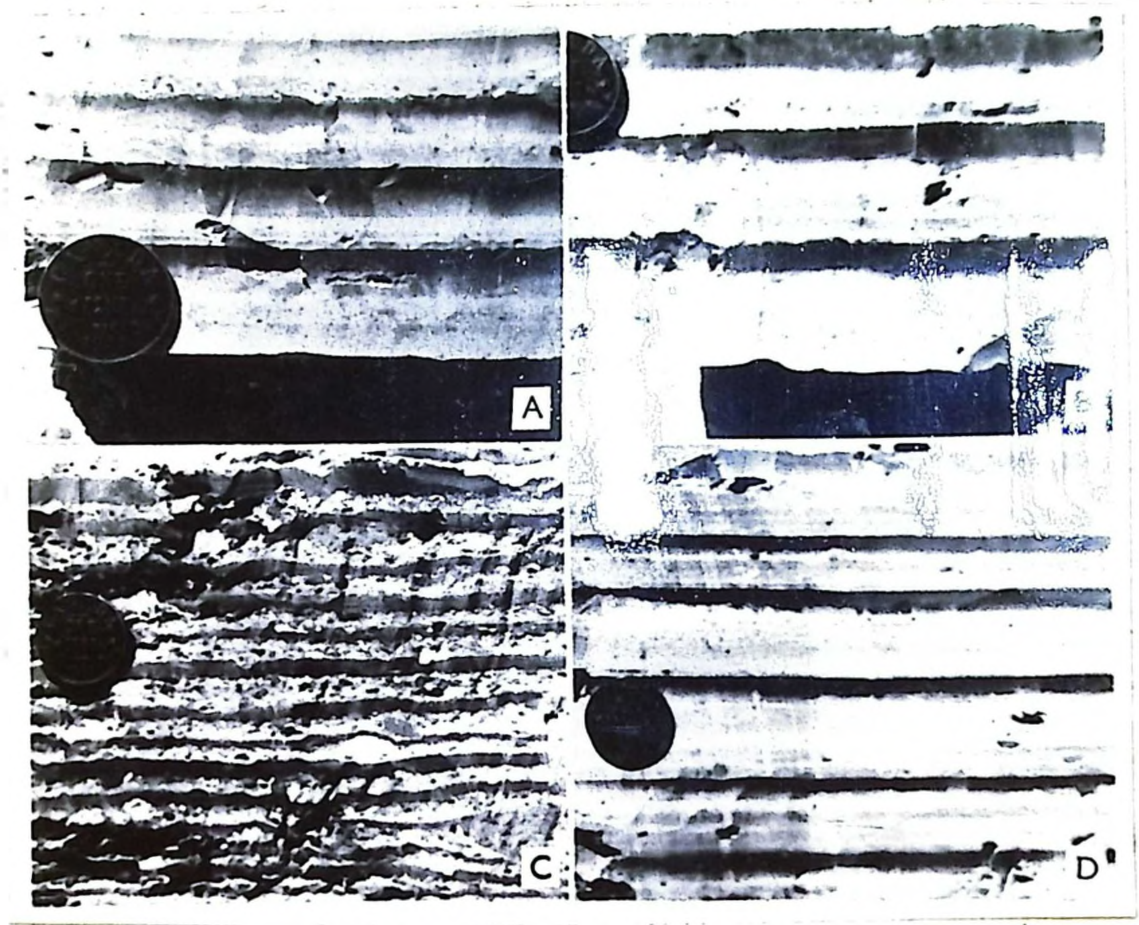


Figure A - D. Middle till complex, showing details of varves.

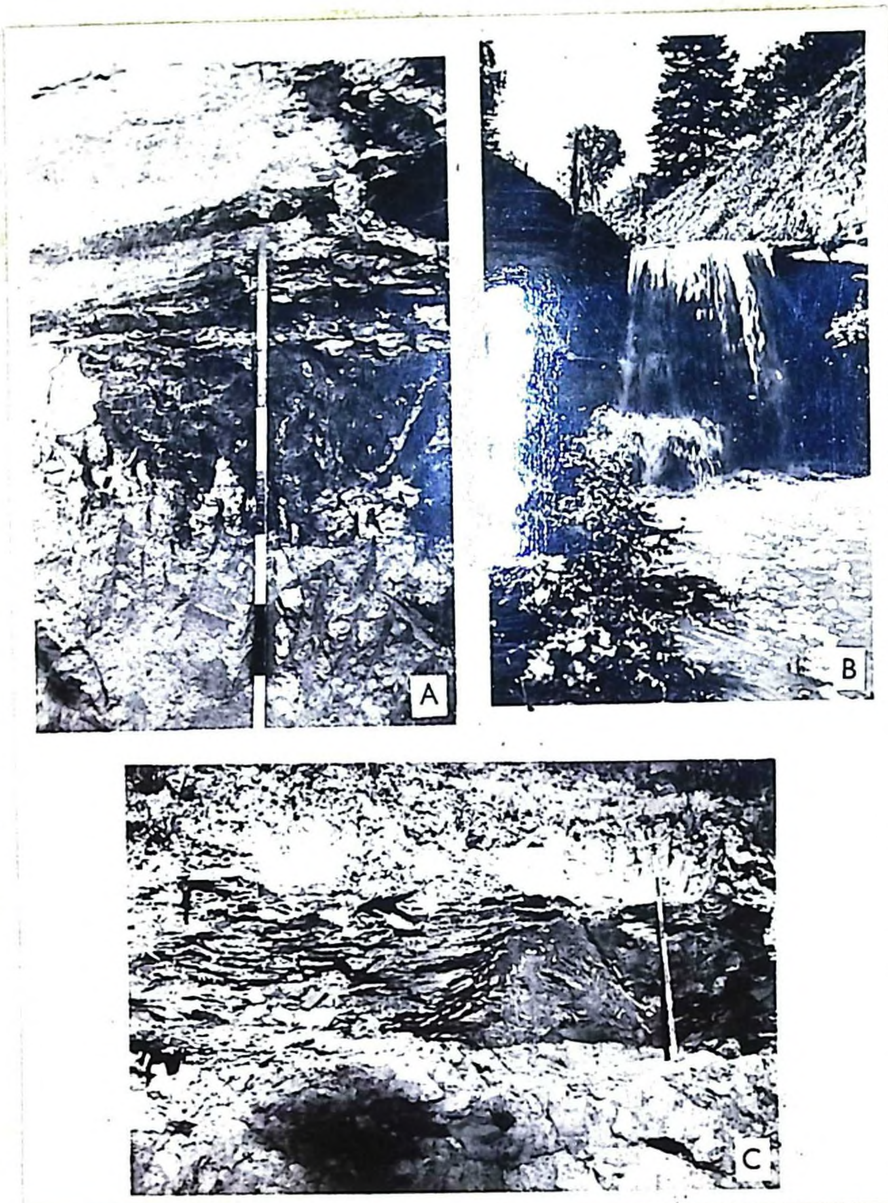
Figure A - relatively thick winter layers and good gradation.

Figure B - Poor gradation between winter and summer layers.

Figure C - Poorly defined varves deposited close to the ice.

Figure D - Normal variation in varves.

PLATE XXVI



The St. Pierre section. Scale in decimetres.

Figure A and C. Details of the thickest peat layer.

Figure B. General view of the section. The assistant stands on the lowest peat layer, points to the middle peaty silt layer and the water falls over the major peat layer.