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CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA

BULLETIN 46

CONTRIBUTIONS TO
CANADIAN PALYNOLOGY

By

J. Terasmae

- Part I **The Use of Palynological Studies in
Pleistocene Stratigraphy**
- Part II **Non-glacial Deposits in the St. Lawrence
Lowlands, Quebec**
- Part III **Non-glacial Deposits along Missinaibi
River, Ontario**

EDMOND CLOUTIER, C.M.G., O.A., D.S.P.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
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PREFACE

Palynology, or the study of pollen grains and plant spores, provides a comparatively new and powerful tool to unravel the complexities of Pleistocene stratigraphy. It suffers from the usual limitations of palæontology as applied to the recent geological periods, where subdivisions are finer than the grosser evolutionary changes in the recoverable organisms. Palynology has, however, two great advantages: widespread, even distribution of forms, and the ease of their recovery in numbers large enough to permit the use of statistical methods.

In this bulletin the author first presents a general account of the advantages and limitations of palynology in the study of Pleistocene stratigraphy. This is followed by two papers on specific problems which not only add to our knowledge of the Pleistocene history of Eastern Canada but are also excellent examples of the use of this promising tool.

J. M. HARRISON,

Director, Geological Survey of Canada

OTTAWA, May 21, 1957

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PART I

The Use of Palynological Studies in Pleistocene Stratigraphy

Introduction

The relationship of a palynological study, which is essentially botanical in its nature, to Pleistocene stratigraphy and chronology is not clear to many geologists, and its usefulness for stratigraphic purposes not fully understood. During the last 4 years the writer has had the opportunity of working in the field with parties studying the Pleistocene geology and has used palynological methods to solve stratigraphic relationships not otherwise clear. This report presents some of the conclusions reached.

Despite advances made in geology in the last few decades, the problem of relating stratigraphic units has remained difficult. Geologists are therefore continually on the lookout for new methods that may be applied to these problems.

The study of pollen grains and spores, little used as yet in bedrock geology, has been applied successfully to the stratigraphic study of post-glacial deposits. Moreover, the usefulness of spores and pollen grains as index fossils for establishing, with greater precision, the age of coals, for subdividing coal-bearing beds and correlating coal seams and layers, and for other stratigraphic purposes, has, though only recently, been demonstrated.

Woods (1955)¹ has discussed the use of pollen and spore analysis for oil exploration, and he states that the success already achieved indicates that these fossils will prove to be a useful supplement to the foraminifera and other fossils presently used by economic palaeontologists. However, the study of pollen and spores has one significant advantage over that of, for example, foraminifera and ostracods in that the last two forms occur only in marine and some brackish-water sediments whereas the first two are found in all types, including freshwater (continental) deposits. This makes it possible to correlate between marine and continental deposits, which is of great stratigraphic importance.

¹ Dates in parentheses are those of references cited at the end of Part I.

Historical Note

The term "palynology", meaning the study of pollen grains and spores, was introduced in 1944 by two British workers, Hyde and Williams (Erdtman, 1952). Previous to that year, the study was named "pollen analysis" or "pollen statistics" according to the main purpose and origin of the work.

Pollen analysis, one aspect of applied palynology, was first officially recognized in Oslo, Norway, in 1916, when Lennart von Post presented a paper on the fossil pollen of forest trees in the bogs of southern Sweden, at the sixteenth meeting of the Scandinavian Naturalists. Since then palynology has evolved gradually but with long periods of stagnation, doubt, and hesitation. The beginning of the science was, however, much earlier.

According to Erdtman (1943), the Swiss geologist J. Früh was one of the pioneers of pollen analysis. In his paper "Kritische Beiträge zur Kenntnis des Torfes" (1885) he recorded nearly all the common types of local tree pollen and many types of spores and herb pollen. While making a study of lake deposits in Sweden, F. Trybom (1888), a Swedish zoologist, encountered pollen grains of pine and spruce. Due to their resistance to decay he considered them to be serviceable index fossils.

From 1895 onward, C. A. Weber, a German peat stratigrapher, made important contributions to pollen analysis. He introduced quantitative calculations of different pollen types, later expressing the pollen frequencies as percentages of the total amount of forest tree pollen. In 1897 the Danish archaeologist G. Sarauw made a palynological study of post-glacial submarine peat dredged near Copenhagen.

Due credit should be given to the work of G. Lagerheim (1860-1926), although he did not himself publish anything on pollen analysis. While examining samples of gyttja (organic lake mud) for algae and protozoa he observed many fern and moss spores, and gradually his interest in the study of fossil pollen grew. Some of his analyses were published by Witte (1905) and N. O. Holst (1909), more in other reports of the Geological Survey of Sweden and in papers by von Post, Samuelsson (1910), Sernander (1911), and others.

Lagerheim's investigations furnished a reliable means by which, step by step, from one layer to the next, the changes may be followed in the assemblages of plant species whose pollen and spores are preserved, and the relative frequency (abundance) of these species. Few people realized the importance of these investigations at the time, but among them was Wesenberg-Lund, a Danish limnologist, who writes that it may be reasonably anticipated that pollen investigations will play an ever increasing role in Quaternary geology. The use of pollen diagrams was introduced by von Post, who studied micropalæontology under Lagerheim.

Use of Palynological Studies in Pleistocene Stratigraphy

From 1916 onward there has been a rapid expansion of palynological work, first in Europe and then in North America and elsewhere. In 1950 palynology was, for the first time, recognized as a separate section of the International Botanical Congress in Stockholm, Sweden.

In Canada, little has been accomplished. The most important contributions were by H. P. Hansen in Western Canada and by V. Auer and C.-G. Wenner in Eastern Canada. A few scattered papers have also been published by other workers. Recently a significant contribution was made by J. E. Potzger and A. Courtemanche, who made an extensive study of post-glacial peat deposits in the province of Quebec. Another interesting study is now being made by N. W. Radforth of McMaster University. This is a study of organic terrain in the Canadian North, and aims to establish the relationship between the vegetation and the plant microfossils in organic deposits formed from this vegetation.

Principles of Pollen and Spore Analysis

An essential part of the reproduction of higher plants through seeds is the formation and liberation of pollen grains and their transfer from the stamens to the receptive stigmas. The spores of mosses and ferns and the pollen of many flowering plants are dispersed by wind, those of others are distributed by insects. Vast numbers of pollen grains and spores are set free into the air during flowering, even by plants that are pollinated by insects. The small size of them (generally 10 to 100 microns in diameter) allows them to settle so slowly that they may be carried long distances by air currents and reach great altitudes in the atmosphere.

When eventually the pollen and spores come to rest on lakes, bogs, snowfields, oceans, and dry land most are destroyed, but in suitable environments, especially where oxygen is deficient, they may be embedded and preserved. This is particularly true in the anearobic muds at the bottom of lakes and in growing peat deposits. As such deposits accumulate they bury the showers of pollen and spores falling into them, so building millimetre by millimetre a consecutive record of the plant life of the time. The outer wall (exine) of a pollen grain or spore is extremely resistant, and in suitable deposits, may remain apparently unaltered for thousands and indeed millions of years. The significance of pollen analysis rests upon the legibility, permanence and correct interpretation of this record.

By using appropriate methods the palynologist is able to recover the microfossils from the sediment and, because pollen grains and spores exhibit a striking range of characters, identification is possible. Pollen grains and spores vary greatly in size and shape; they display a wide variation in the number, shape, and disposition of germ pores and other openings (apertures) in the wall; the wall structure is diagnostic and its surface commonly displays elaborate and intricate sculptures.

Contributions to Canadian Palynology

In deposits of Pleistocene age it is possible to determine the parent plants of fossil pollen grains and spores and to refer them to modern families, genera, and sometimes species. This relationship is gradually lost in older (Mesozoic and Palaeozoic) deposits, but even if the parent plant of a fossil pollen grain or spore cannot be determined and it is designated simply by a letter or a number, it is still a scientific tool of great value. The ubiquity of these microfossils and the changes in the pollen and spore assemblages in time, caused by evolution and changing climates and habitats, provide the palynologist with a time scale common to all deposits in a region, formed during the same interval.

The identification, however, is only one side of the story. Another, and no less important part, is the interpretation of the fossil pollen and spore record. It is here that the botanical training of a palynologist is most important because the fossil record must be interpreted in terms of vegetation, environment, and climate. For geological interpretation however botanical training alone is not sufficient. A knowledge of the geology of the area under discussion is also necessary, and the final correct interpretation must take into account both botanical and geological evidence, and any other biological information available.

The results of a palynological study are generally compiled and presented as a pollen diagram (*see* Figure 1). A series of samples is taken vertically across a sedimentary sequence and the pollen grains and spores are extracted from each sample. Differences in the composition of these assemblages, which result from differences in the nature and relative abundance of the plants living at the time, constitute the basis for stratigraphic palynology.

It is customary to divide the pollen and spore assemblages arbitrarily into three major parts: the arboreal pollen (AP), the non-arboreal pollen (NAP), and spores. The AP is considered separately from the rest because the composition of the forest cover and its changes from one time to another are the most useful data for palynological interpretation. Furthermore the pollen from forest trees is generally distributed more uniformly and over wider areas than non-arboreal pollen (NAP). NAP is likely to occur in small, local, non-representative concentrations. This is because forest trees not only produce more pollen but release it higher above the ground than shrubs and herbs. There are, of course, exceptions as for example the high pollen production of some weeds in open areas.

The first step, once the pollen and spores have been separated from the matrix of the sample, is to mount a suitable quantity on a microscope slide so that each grain is distinct from its neighbours. A certain area of this slide is then traversed under a microscope and all pollen grains and spores of different species within it are identified and counted. The traversed area is generally such that there are at least 150 to 200 AP grains present, and the total of these grains is used as the basis (100 per cent) of the entire

Use of Palynological Studies in Pleistocene Stratigraphy

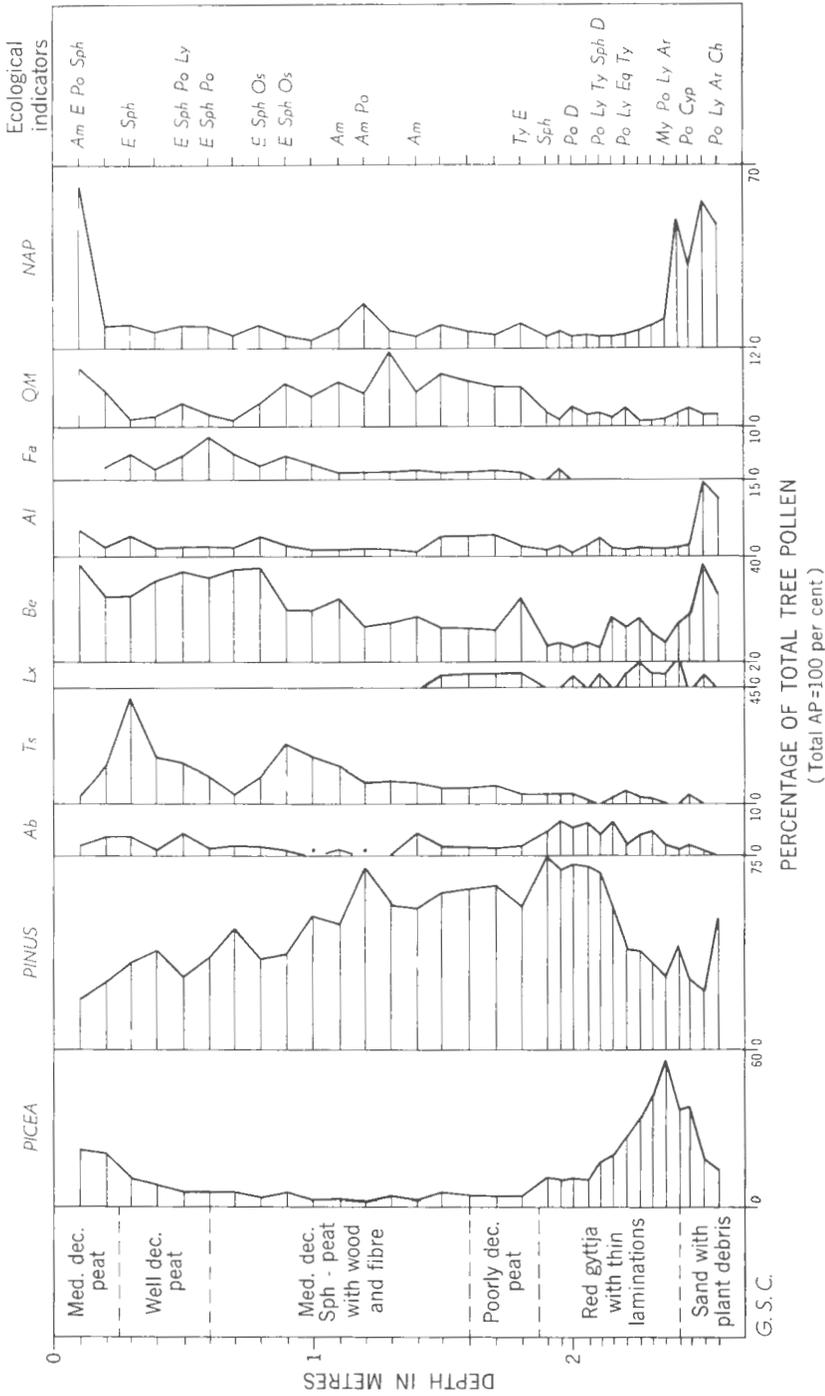


Figure 1. Pollen diagram of St. Germain bog near Drummondville, Quebec.

Contributions to Canadian Palynology

sample. The second step is to compute the percentage of each AP species with respect to the total number of AP grains counted. The third step is to express, in a similar manner, the total number of NAP grains or the number of grains of each NAP species as a percentage of the total AP count. The spores counted are treated similarly.

The total AP count is used as basis for all three groups, because NAP and spores may occur erratically and the ratio NAP to AP may indicate the density of forest cover.

The percentage of each species, etc., in succeeding layers is plotted as a histogram, and it is general practice to join the tops of individual columns in this histogram and call this line a "pollen curve". These pollen curves together make up the pollen diagram for the section. Not all curves are drawn to the same scale; curves for rare species are plotted on a suitably exaggerated scale so that detailed changes may be clearly visible.

The left-hand vertical column shows the character and thickness of the sedimentary sequence. The level or depth at which each sample was taken is indicated in the succeeding columns by a horizontal line in the correct position. The ecological indicators represented in the column at the extreme right are defined, in this paper, as plant species (represented by their pollen grains or spores) that have restricted and definite habitat requirements or limited geographic or stratigraphic distribution. With such plants, even a single pollen grain may be sufficient as an indicator, and a statistical treatment has no value. A key to the abbreviations is given in the Appendix at the end of this bulletin.

It is general practice to treat the NAP collectively and pollen species of particular interest in the NAP are indicated by a symbol in the column of ecological indicators (for example, E-*Ericaceae*, Sph-*Sphagnum*, Ly-*Lycopodium*).

A pollen diagram is commonly modified in order to emphasize certain features; indeed many different types of pollen diagram have been proposed by palynologists. All have advantages and disadvantages and one can be selected that displays best the features that are the particular aim of the study.

When the palynological study of an area is undertaken one of the initial steps is to set up a standard pollen diagram. Such a diagram is analogous to a geological section which is compounded of partial sections. In the same way a standard pollen diagram is compounded of numerous partial diagrams and represents an idealized account of the palynological history of the area in which all significant changes are noted. It thus serves as a standard of reference. If a partial section whose stratigraphic position is not known is then made anywhere in the area it may be possible to determine its position by fitting the partial diagram into the standard diagram.

Use of Palynological Studies in Pleistocene Stratigraphy

It is appropriate to mention here the difference between the study of plant macrofossils and that of pollen grains and spores. One major difference lies in the fact that microfossils are generally produced in great numbers, spread over wide areas by wind, and much more uniformly distributed through the layers of sediments than macrofossils, which represent vegetation that grew at or close to the site where the fossils were collected. As a consequence of this, microfossils can be collected with little effort in numbers large enough for statistical methods to be applied, which can be rarely done with macrofossils. Furthermore, a satisfactory collection of macrofossils can only be made from reasonably well-exposed strata, whereas a collection of microfossils can be made even from diamond drill-core.

Recent investigations by the writer have shown that nearly all types of Pleistocene deposits contain pollen grains and spores. There are, however, some, like coarse, waterlain deposits, dune sand, glacial till, varved clays, and strongly calcareous deposits, in which plant microfossils, at least of primary origin, are rare or absent. Secondary microfossils, derived by erosion from earlier deposits, may be present in glacial till and late glacial clay or early glacial varved clay. In the last two, secondary microfossil assemblages may be superimposed on assemblages of primary origin and the record thereby confused. In oxydized deposits, too, plant microfossils may be rare or absent. In samples from marine marsh deposits and surface humus layers less resistant pollen types are commonly partly or wholly destroyed. On the other hand samples of lichen from the Baker Lake area, Northwest Territories, contain fairly abundant pollen and spores.

Pollen diagrams have been used successfully for dating certain geological and archaeological events but the method nevertheless has its limitations. It must be emphasized that a pollen diagram is only a record of past vegetation and flora. It is true that by pollen analysis a palynologist can date events in a relative sense, but in order to arrive at an age estimate expressed in years some other method, such as the radiocarbon method or varve counting, must be employed. Once certain regionally recognizable zones in pollen diagrams have been so dated pollen diagrams alone may be used for estimates of absolute age. Whether or not certain zones in pollen diagrams from regions remote from one another are contemporaneous may, however, be difficult to decide.

Other limitations, such as differential destruction of pollen grains and spores, local over-representation or under-representation of some species, long distance transport of pollen by wind, and secondary deposition may present difficult problems.

Lack of adequate reference data in the form of descriptions and study of modern pollen (fundamental palynology) may make it impossible to identify certain pollens or to reach any general conclusions from them.

Dating and Correlation of Interglacial and Interstadial Intervals

The radiocarbon method provides the student of Pleistocene stratigraphy with an important means of dating, and so correlating, events during the last 30,000 years, and less accurately up to 50,000 years. A study of pollen and spore spectra, on the other hand, can be used to correlate events beyond, as well as within, the 30,000-year limit and, furthermore, pollen grains and spores are found in deposits that cannot be dated by the radiocarbon method at all. Pollen analysis also yields information on the climate, ecological conditions, and the approximate length of non-glacial intervals, and may settle the question as to whether a non-glacial interval should be called interglacial or interstadial.

It is therefore desirable that the non-glacial intervals be described in palynological terms. This has been successfully done by West (1955) in Britain (East Anglia) and by Woldstedt (1955, pp. 528-529) in Western Germany, where the pollen diagrams from the Weichsel-Saale interglacial are sufficiently different from those of the Saale-Elster interglacial to allow identification by palynological means.

In Eastern Canada pollen analysis has been used by the writer to study the buried, non-glacial deposits at St. Pierre, Quebec, at Toronto, Ontario, and on the Missinaibi River in northern Ontario. Recently this study has been extended to buried peats in Nova Scotia, British Columbia, Northwest Territories, and the Arctic Islands.

In the foregoing it has been assumed that complete or nearly complete pollen sequences are available for correlation, covering most of at least one non-glacial interval. If only parts of the sedimentary sequence are preserved, from say the early, middle or late part of the non-glacial interval, matters tend to be much more complex. The investigator must then determine both the age of the interval and the position of the partial sequence within it. Geological data may supply some of the information and add useful criteria as to the environment in which the sediments were deposited.

The problem of correlating between partial sequences of the same age or of distinguishing between partial sequences of different ages but from the same non-glacial interval would seem to be most difficult. Yet, by a careful, detailed study of plant microfossils combined with all other available evidence it may be possible.

Dating and Correlation of Post-glacial Deposits

Palynological studies of post-glacial deposits have helped to determine the relative ages of glacial lakes, beaches, spillways, etc. The pollen and spore assemblages found in sediments at critical levels in such features can be checked against the standard pollen diagram of the region and help the investigator to estimate the age of events, at least in a relative sense.

Use of Palynological Studies in Pleistocene Stratigraphy

When sufficiently numerous zones in the standard pollen diagram have been dated by the radiocarbon method the pollen diagrams can be used to estimate the absolute age of sediments. It is then possible to trace the synchronous shore features of an ancient glacial lake and if these features have been tilted, due to differential uplift, such a study would help to estimate the trend and amount of differential uplift that has occurred. In addition similar reasoning can help to determine the regions of greatest uplift in post-glacial time and help to locate the centres of past glaciation, where, presumably, was the greatest weight of ice, the maximum depression of the earth's crust, and the greatest subsequent uplift.

Recognition of Gaps in a Sedimentary Sequence

Gaps in a sequence of deposits can, in some cases at least, be recognized by a palynological study. A sudden change from temperate to arctic conditions for example would suggest a significant hiatus, or again beds containing a microfossil assemblage that indicates temperate conditions directly overlain by glacial deposits would suggest that part of the non-glacial interval is not represented. In such cases, however, the rate of accumulation of deposits must be considered, for a thin bed formed by slow accumulation may be overlooked if samples are not closely spaced.

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PART II

Non-glacial Deposits in the St. Lawrence Lowlands, Quebec

Introduction

The presence of non-glacial deposits in the St. Lawrence Lowlands has been known for some time and A. P. Coleman (1941)¹ reported the discovery of buried peat in a section at Donnacona.

During the study and mapping of the Pleistocene geology of Becancour map-area in the St. Lawrence Lowlands in 1951, N. R. Gadd (1955) of the Geological Survey of Canada observed several exposures of buried non-glacial deposits, including layers of peat. Subsequent field work and mapping of adjacent map-areas in 1952-55 yielded numerous additional exposures of these deposits, and during the field seasons of 1953 and 1954 the writer had an opportunity to study them in detail. Each section was measured and described, and samples of the non-glacial layers were collected for pollen analysis. The palynological studies were later concentrated on the three best sections at St. Pierre, Les Vieilles Forges, and Pierreville (*see* Figure 2). According to Gadd's studies all exposures are of equivalent stratigraphic beds.

The non-glacial sequence is underlain and overlain by glacial till and associated deposits. A piece of wood from the St. Pierre section was sent for radiocarbon (C 14) dating by Gadd and the age of 11,050 \pm 400 years (L-190 A)² was announced. This suggested that the non-glacial sequence was of Two Creeks age.

Pollen analysis, however, showed that the peat could not have been deposited during the Two Creeks interval and the wood was therefore resubmitted for radiocarbon dating. This time, ages of more than 40,000 years (W-189) and more than 30,840 years (Y-242) were obtained. The greater age was confirmed when wood and peat samples from the lower peat layer in the Les Vieilles Forges section were submitted for radiocarbon

¹ Dates in parentheses are those of references cited at the end of Part II.

² Letters and numbers in parentheses refer to laboratories where the radiocarbon dating was made and to their sample numbers.

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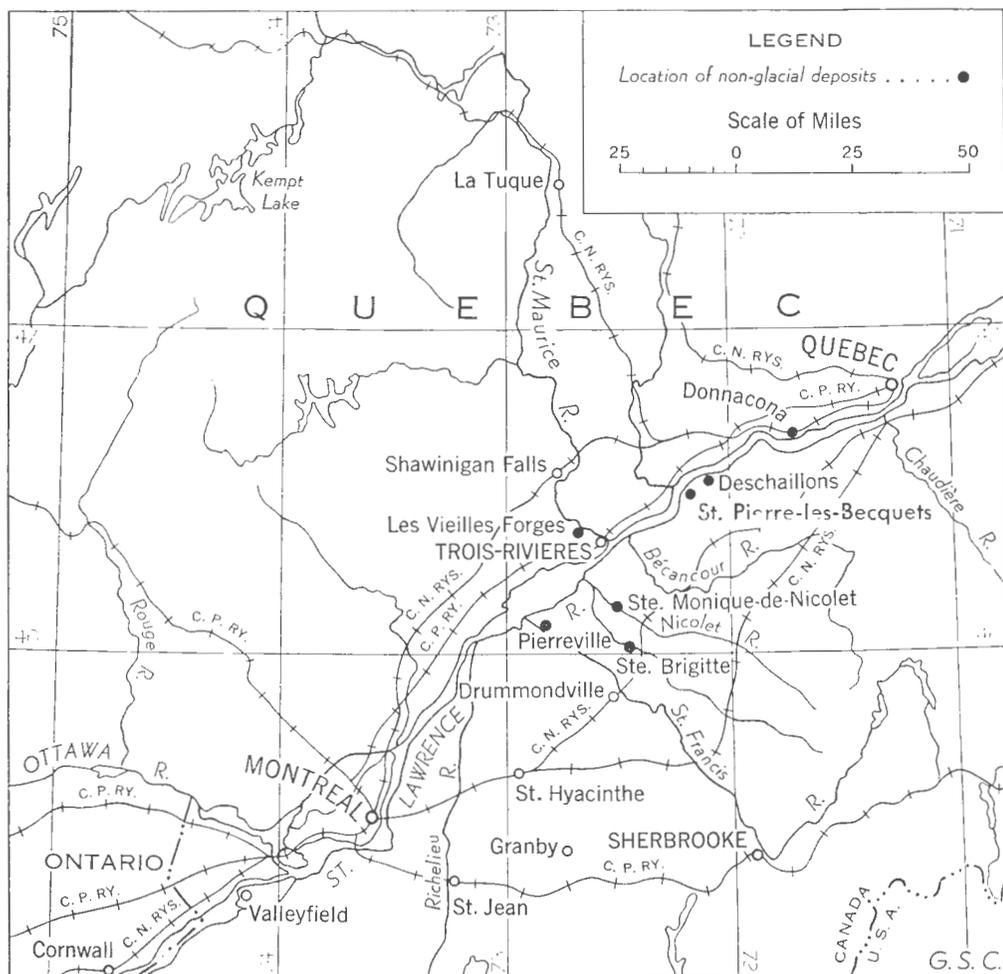


Figure 2. Index map of St. Lawrence Lowlands region showing location of non-glacial deposits.

analysis and yielded ages of more than 29,630 years (Y-254) and more than 30,840 years (Y-255). Wood from Pierreville was also dated at more than 29,630 years (Y-256).

The radiocarbon determinations therefore set the age of this sequence as older than 40,000 years, and hence older than any known Wisconsin interstadial interval. Palynological studies, however, indicate that the interval is not the Sangamon interglacial stage. The non-glacial interval was accordingly named the St. Pierre interval by Gadd, after St. Pierre-les-Becquets where the sequence was first recognized.

Non-glacial Deposits, St. Lawrence Lowlands

The writer wishes to express his indebtedness to Dr. M. W. Bannan of the University of Toronto for identification of samples of wood from the St. Pierre peat.

Pleistocene Stratigraphy

The late Pleistocene sequence of events in the St. Lawrence Lowlands region is briefly outlined below, the interpretation being based on the results of investigations by Gadd (1955).

The earliest Pleistocene deposit is a reddish glacial till of unknown age immediately overlying bedrock. This basal till is overlain by a sequence of varves and possibly outwash deposits. This is followed by a sequence of non-glacial deposits, but no evidence has been found of a marine invasion of the Lowlands in the interval following the deposition of the basal red till. During the deposition of the middle and upper parts of this non-glacial sequence, silts and sands containing plant detritus and peat beds were deposited on the flat bottomlands of river valleys. The non-glacial period came to an end with the deposition of a succession of varves deposited in a proglacial lake. The varved clay is overlain by outwash and till, deposited by the advancing Wisconsin ice-sheet.

Due to the weight of ice, the central part of the St. Lawrence Lowlands was depressed as much as 500 to 600 feet below present sea-level, and when the ice retreated from the Lowlands, the region was invaded by the sea. There was, however, a short period of lacustrine conditions in the Lowlands prior to the marine invasion, as indicated by stratified silts and sands immediately overlying the upper till and outwash deposits.

The latest marine inundation in the St. Lawrence Lowlands region has been named the Champlain Sea and is represented by thick deposits of marine sand, silt, and clay. Glacio-marine conditions existed during at least part of that time. Large amounts of meltwater from the ice brought about brackish-water to almost freshwater conditions where the major streams entered the basin.

The palynological study of early post-Champlain Sea peat showed that the marine period came to a close prior to the post-glacial thermal maximum, believed to have occurred about 5,500 years ago.

Non-glacial Deposits

DESCRIPTION OF STRATIGRAPHIC SECTIONS

The St. Pierre Section

The St. Pierre section (*see* Figure 2) is about 110 miles downstream from Montreal on the south shore of the St. Lawrence River. It is about 1 mile southwest along highway 3 from the village of St. Pierre-les-Becquets and about $\frac{1}{4}$ mile up a creek from the highway. Bands of peat are exposed in the face of a 10-foot, intermittent waterfall.

Contributions to Canadian Palynology

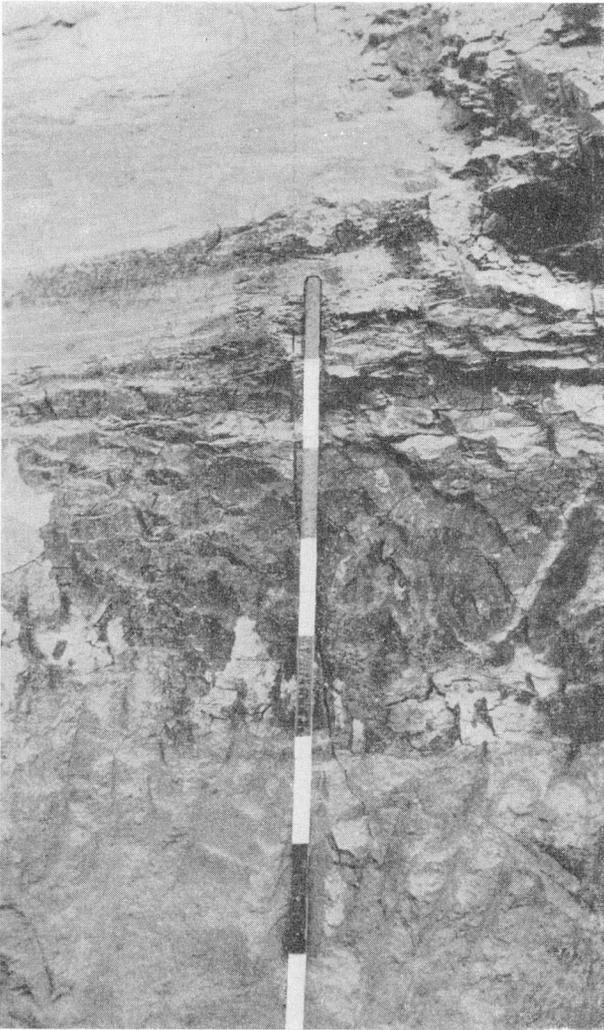
Measured downward from a plain whose elevation is about 120 feet above sea-level, Gadd described the section as follows:

Lithology	Depth below surface (in feet)
Fine-grained, stratified sand at surface; some boulders	0 — 3.5
Unstratified silt with lenses of sand	3.5 — 8.5
Varved silt and clay; lower several feet of varves very thin	8.5 —75.0
Compact brown sand with abundant, finely divided organic matter	75.0 —76.5
Predominantly organic matter with some silt and wood	76.5 —78.25
Grey, silty sand	78.25—81.25
Predominantly organic matter with much wood	81.25—81.75
Grey, silty sand	81.75—83.25
Mainly organic matter with wood and insect remains	83.25—84.5
Grey, silty sand and silt to base of section	84.5 —87.0

Glacial till is exposed in the bottom of the creek a short distance downstream from this section.

The best exposed part of the non-glacial sequence, measured down from the base of the varved silt and clay, is described below in more detail.

Lithology	Depth (in inches)
Varved silt and clay	
Topmost peat layer (No. 1 layer)	0— 2
Blue-grey, silty, stratified clay; laminations resembling varves	2— 8
Brownish green, sandy silt	8—24
Hard, compressed, well decomposed peat with a few twigs (No. 2 layer, 24-46")	24—30
A layer of brown moss peat; numerous remains of <i>Drepanocladus</i> sp.	30—35
Hard, compressed, well decomposed <i>Sphagnum</i> peat; wood in lower part and twigs scattered throughout; specks of charcoal at one level; occasional unidentified fruits and seeds of plants, and wing covers of beetles. (Gadd collected wood for radiocarbon determinations from this layer)	35—46
Coarse sand coloured by humic matter from overlying peat	46—62
Grey, silty clay with lenses of sand	62—74
Brownish, peaty silt grading into peaty sand in lower half (No. 3 layer)	74—92
Grey, silty clay	92—122
Brown moss peat; abundant <i>Drepanocladus</i> sp.	122—124
Hard, well decomposed peat grading into peaty silt in lower half (No. 4 layer, 122-134")	124—134
Blue-grey silt and silty clay (compact); down to creek level	134—138



109946A

Plate IA

View of the thickest peat layer, exposed in the section of non-glacial deposits at St. Pierre.

Plate IB

General view of the St. Pierre section. The assistant is standing on the lower peat layer, pointing at the middle one, and the main peat layer is exposed above his head.



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Plate IC

View of a peat layer in one exposure of the non-glacial deposits at Les Vieilles Forges. The stump of a tree is shown embedded in the peat. Some of that wood was radiocarbon dated. The scale is in decimetres.

Non-glacial Deposits, St. Lawrence Lowlands

No. 1 peat layer consists of hard, compact peat exposed horizontally for about 20 feet. This layer lies in a zone that shows folded varves, broken peat slabs, and lenses of sand. The disturbance occurred either shortly after the basal varves were deposited or later, due to slipping and slumping along the base of the varved clay sequence.

No. 2 peat layer, the most prominent one, extends some 200 yards downstream from the waterfall, in which direction it is gradually concealed by slump and apparently pinches out. Its extension upstream from the waterfall and at right angles to the creek is unknown. It varies in thickness from place to place.

Where fully developed *No. 2 peat layer* consists of a bed of *Carex* (sedge) peat at the bottom, overlain by a bed of brown moss peat which is, in turn, overlain by another bed of *Carex* peat or *Sphagnum* peat. The lower *Carex* peat bed was observed downstream from the waterfall where *No. 2 layer* appears to pinch out. It is 2 to 4 inches thick and consists of *Carex* peat with many twigs, fragments of sedge, and wing covers of beetles. A few fruits of *Menyanthes* (buckbean) are also present. Wood in this layer has been flattened, but some specimens were examined by Dr. M. W. Bannan of the University of Toronto who reported as follows (personal communication):

I have examined four of the wood samples you left with me and have found all to be the same type of wood—either spruce or larch. The woods of these two genera are difficult to distinguish microscopically, but I should say that your specimens are probably spruce.

Close to the waterfall the upper *Carex* peat in *No. 2 layer* is gradually replaced by *Sphagnum* peat.

No. 3 layer is essentially composed of sand and silt with a concentration of finely disseminated plant detritus in the inorganic matrix.

No. 4 layer has brown moss peat at the top underlain by hard, compressed, well-decomposed *Sphagnum* peat, which grades in turn into peaty silt in the lower half of the layer. At one place a boulder about a foot in diameter was found resting on the underlying silt and extending upwards through the whole thickness of *No. 4 layer*. Occasional pebbles were also found at the bottom of *No. 4 layer*.

The Les Vieilles Forges Section

This section is exposed in the west bank of St. Maurice River $\frac{1}{4}$ mile downstream from the mouth of a small unnamed stream that flows across the highway near Les Vieilles Forges village at a point marked by a boulder cairn. This cairn bears a metal plaque and marks the site of Les Vieilles Forges, one of Canada's earliest iron smelting industries. The village of Les Vieilles Forges is on the west bank of St. Maurice River, about 6 miles northwest of Three Rivers (see Figure 2).

Contributions to Canadian Palynology

The section measured from the top down is as follows:

Lithology	Depth (in feet)
Medium-grained to coarse sand; crossbedded and stratified; probably sands of the Three Rivers delta	0— 83.0
Medium gravel	83.0— 83.3
Stratified silt and clay, thin sand partings; probably slack-water alluvial or lacustrine deposits	83.3— 84.8
Sandy, grey till with dominantly granitic components; a marked boulder pavement at top	84.8— 96.8
Fine sand with lenses of silty sand	96.8— 98.8
Grey, silty, fine sand	98.8— 99.3
Medium-grained to coarse sand	99.3—100.0
Silt and fine sand; thin-bedded, horizontal strata	100.0—101.0
Coarse sand with some southward dipping crossbedding; some bands of medium- to fine-grained sand	101.0—133.0
Compact fine sand	133.0—135.0
Brownish grey, medium-grained sand	135.0—155.6
Blue-grey, fine- to medium-grained sand	155.6—176.6
Stratified silt and fine sand; layering resembles varves, but materials generally coarser than that of normal varves, source possibly nearby; grades upwards into fine sand	176.6—196.6
Coarse sand with thin beds of silty clay	196.6—198.6
Stratified clay with sand between layers	198.6—199.1
Coarse sand	199.1—199.2
Silt with plant detritus	199.2—200.4
Peat with some wood, both much compressed	200.4—201.1
Blue-grey, silty, fine sand with finely disseminated organic matter	201.1—203.1
Brown silt with plant detritus	203.1—204.1
Peat and wood; much compressed; a black spruce stump 3 feet long with roots attached, excavated from base; samples for C-14 determinations collected	204.1—205.3
Blue-grey, silty sand with a few plant fragments	205.3—209.8
River level, remainder of section from borings	
Blue-grey, silty compact sand	209.8—224.8
Gravel (?)	(?)

The stratigraphic correlation between the sections at St. Pierre and Les Vieilles Forges is satisfactory and is supported by the accepted radio-carbon determinations.

The Pierreville Section

This section is exposed in the east bank of the St. Francis River about 1.5 miles southeast of Pierreville (*see* Figure 2). The stratigraphic sequence of deposits, measured from the top downward, is as follows:

Lithology	Depth below surface (in feet)
Grey till	0 — 3
Stratified silt	3 — 41
Stratified, massive, and crossbedded sand; 1-foot layer of peat near top	41 — 49
Varved, silty clay	49 — 82
Varves with reddish winter layers	82 — 87
Varves with red winter layers; concretions present, increasing in number downward	87 — 92.4
Stratified silty clay with concretions	92.4— 97.4
Brown-grey, silty clay	97.4—102.4
Red silt	102.4—106.4

Another section upstream from this exposure shows a red till overlying bedrock.

Exposures of buried, non-glacial deposits have also been discovered along the Becancour, Nicolet, St. Francis, and St. Maurice Rivers, in a brick yard at Deschaillons, and at Donnacona, about 25 miles west of Quebec City. All are in river valleys and the areal distribution of the exposures suggests that the non-glacial deposits extend parallel with the St. Lawrence River at least from Pierreville to Donnacona, a distance of 70 miles, and at right angles to the river, from a point near Les Vieilles Forges, about 6 miles north of the river to near Ste. Brigitte about 20 miles south of it.

Results of Palynological Study

The present study is in no sense a thorough investigation but rather a test of the applicability of pollen analysis to this problem. The trial has proved encouraging and the results sufficiently consistent to warrant their publication.

As it is necessary to compare the plant microfossil assemblages from the non-glacial, buried beds with those from post-glacial deposits some fifteen pollen diagrams of post-glacial peats and lake sediments were prepared (*see* Figure 1). These bogs and lakes were all selected within the St. Lawrence Lowlands region.

The pollen diagram from the Les Vieilles Forges section (*see* Figure 4) seems to be representative of all the non-glacial sequences studied and it will be discussed first; pollen diagrams and descriptive notes for additional sections are presented as supporting evidence. A key to the abbreviations used is given in the appendix.

Contributions to Canadian Palynology

A striking feature is the apparently complete absence of hemlock pollen (*Tsuga canadensis*), for hemlock pollen is present in all post-glacial deposits in the area. Two possible explanations can be suggested. The non-glacial interval under discussion may have been too short to allow the type of vegetation now living to become established, or the climatic ecological conditions may not have been favourable for hemlock to migrate into the region. The writer suggests that both factors combined to bar hemlock from the St. Lawrence Lowlands during the St. Pierre interval.

Pollen from temperate-deciduous tree species of *Quercus* (oak), *Fagus* (beech), *Tilia* (basswood), *Carpinus* (blue beech), *Acer* (maple), *Ulmus* (elm), *Fraxinus* (ash), *Carya* (hickory), etc., (QM) forms only 2 to 5 per cent of the pollen found in the middle part of the St. Pierre interval. The limiting factor was probably temperature, which was cooler than at present.

The writer believes that the St. Pierre interval was not an interglacial stage but rather an interstadial substage of 6,000 to 7,000 years' duration. No conclusive evidence has been found that the bottom part of the non-glacial sequence was formed under arctic tundra conditions, although glacio-lacustrine conditions and subsequent erosion may have prevented or removed the microfossil record of that time. It is unlikely that the peat sequence was deposited during the late part of a long interglacial stage because of the absence of hemlock pollen and the very low QM values in the bottom part of the peat sequence.

Spruce (*Picea*) was the predominant genus throughout the St. Pierre interval but pine (*Pinus*) was also common. The abundance of the latter may indicate a moderately cool temperature. Occasional high values for birch (*Betula*) and alder (*Alnus*) pollen seem to be due to local ecological conditions rather than to changing temperature.

The pollen flora illustrated by the Les Vieilles Forges diagram indicates conditions much the same as those in the present Boreal Forest region (Halliday, 1937; Linteau, 1955). Furthermore the early post-glacial pollen assemblages from the St. Lawrence Lowlands resemble those of the St. Pierre interval. It is, therefore, tentatively suggested that the annual mean temperatures during the warmest part of the St. Pierre interval were about 3 to 5 degrees Fahrenheit lower than the present.

Climatic conditions remained fairly constant throughout the St. Pierre interval but with subarctic conditions prevailing near the bottom and top.

The amount of pollen in the varved clay overlying the peat in the St. Pierre section decreases rapidly upwards and the amount in the varved clay underlying the peat sequence in the Pierreville section decreases downwards. It is conceivable, therefore, that the lower sequence of varves in the Pierreville section represents the beginning of the St. Pierre interval. If so the

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deposition of the lower varves was followed by a period of erosion and the deposition of sands before the peat sequence.

A rough estimate of the duration of the St. Pierre interval may be reached by considering the following factors. The length of time represented by the varves above and below the peat section combined is at least 500 to 700 years. The length of the period of erosion and the deposition of the sand and gravel at the base of the peat section is harder to estimate. It appears to have been too short to allow such trees as hemlock to migrate into the area and may have been between 1,000 and 2,000 years. The peat sequence, which totals 3 feet of hard, compact peat, may represent the accumulation of 3,000 to 5,000 years. This is based on a time interval of 4,000 years for the accumulation of 30 inches of peat in Michigan, computed by means of radiocarbon dates for the top and bottom of the sequence (Zumberge and Potzger, 1956). By totalling these various estimates a tentative figure of 6,000 to 7,000 years is reached for the duration of the St. Pierre interval, a figure that is submitted with many reservations.

The pollen diagram of the St. Pierre section (*see* Figure 3) can be correlated with that from Les Vieilles Forges.

The pollen diagram of the Pierreville section (*see* Figure 5) can be correlated with that from the upper part of the Les Vieilles Forges sequence. The lower varves apparently represent the beginning of the St. Pierre interval. The scattered pollen of QM, at least in the top part of the varves, is possibly of secondary origin; i.e., derived by erosion and redeposition of deposits of some earlier warmer interglacial stage.

The pollen diagram from the Ste. Monique section (*see* Figure 6) seems to correlate with the lower part of the Les Vieilles Forges diagram. This section is in the north bank of the Nicolet River about 1 mile east southeast of Ste. Monique-de-Nicolet in Yamaska map-area.

The pollen diagrams from the Ste. Brigitte section and from section 11 (*see* Figure 7) can also be correlated with the Les Vieilles Forges diagram. The former section is in the east bank of the west branch of Nicolet River at Ste. Brigitte, just below the sawmill dam at the falls. Section 11 is in Yamaska map-area on the east branch of St. Francis River, a mile north of the south boundary of the map-area.

The non-glacial deposits at Donnacona and along the Becancour River yielded comparable plant microfossil assemblages and can be correlated with the Les Vieilles Forges section.

Stratigraphic Position of St. Pierre Interval

The results of the palynological study prove that the St. Pierre interval cannot be correlated with any of the known non-glacial intervals of the Wisconsin stage. Both the apparent length of the interval and the indicated climatic conditions that prevailed at the time prevent correlation with either

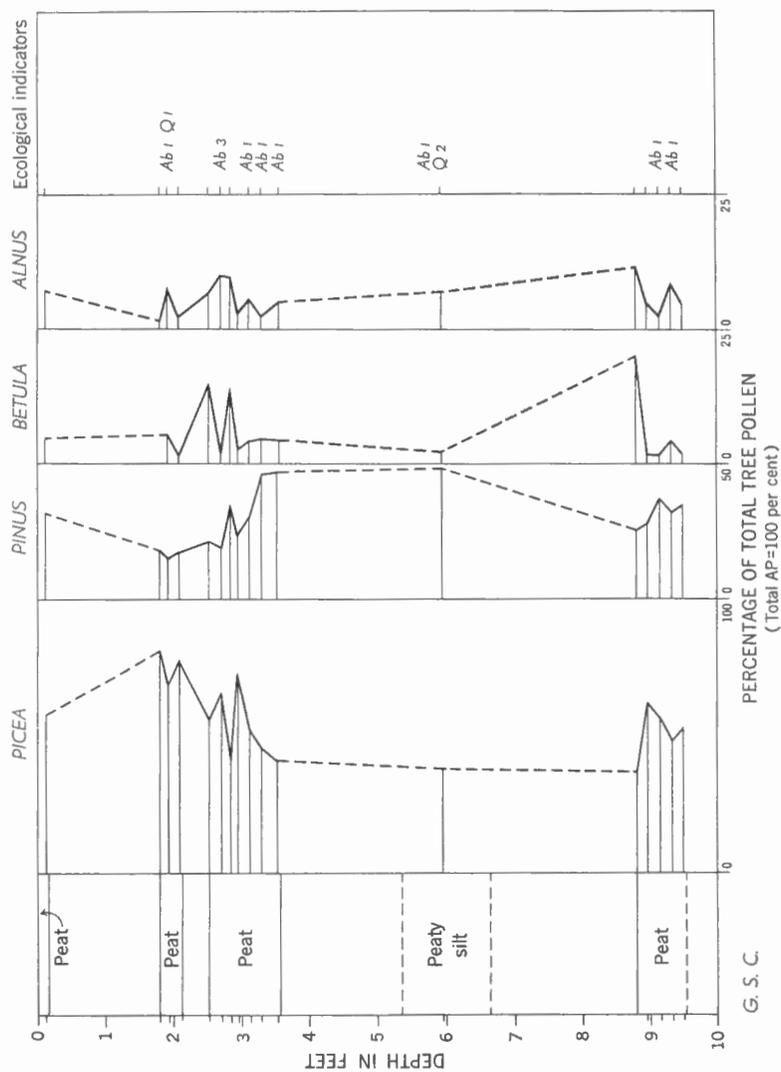


Figure 3. Pollen diagram of St. Pierre section.

Non-glacial Deposits, St. Lawrence Lowlands

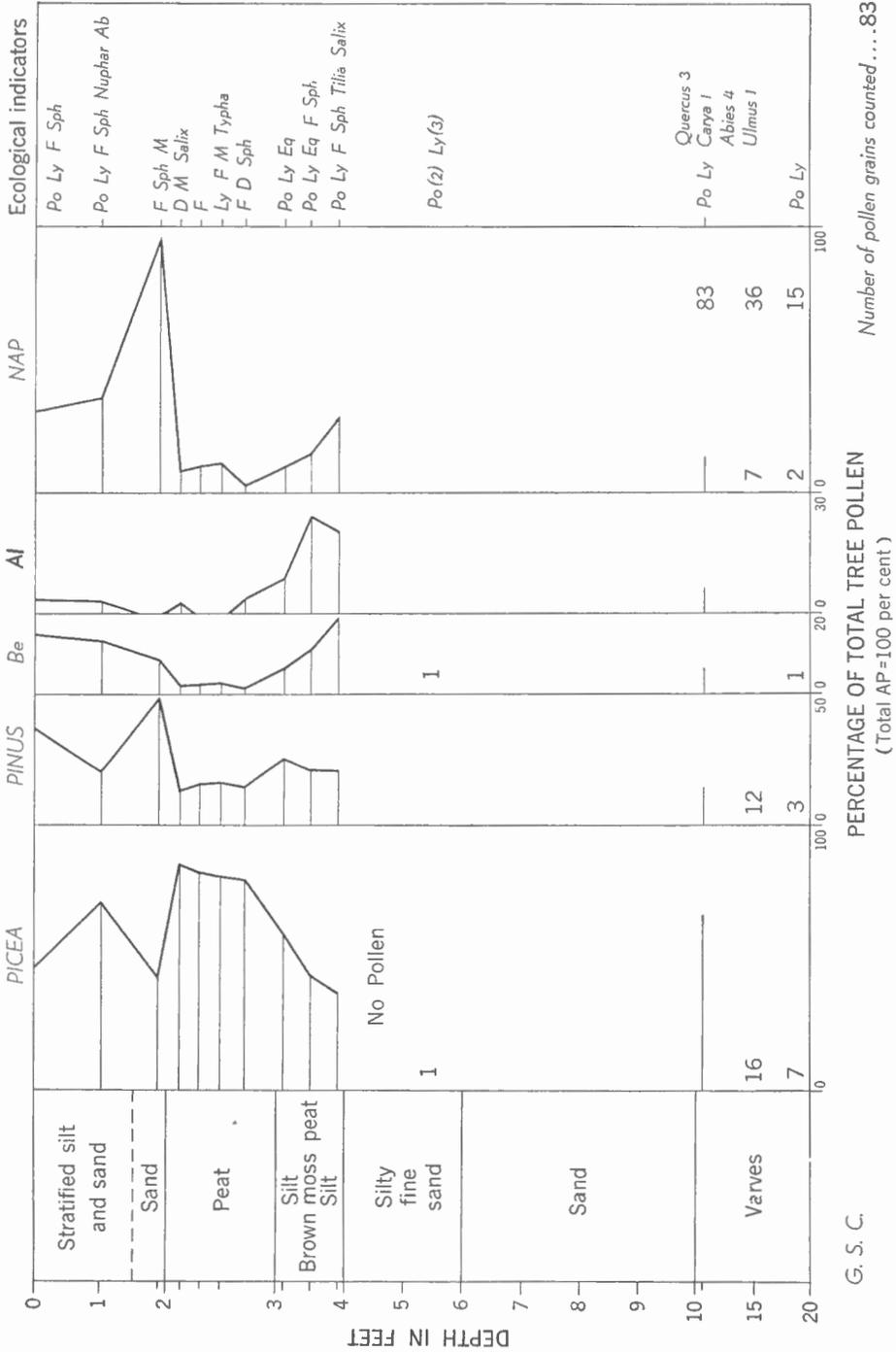


Figure 5. Pollen diagram of Pierreville section.

Contributions to Canadian Palynology

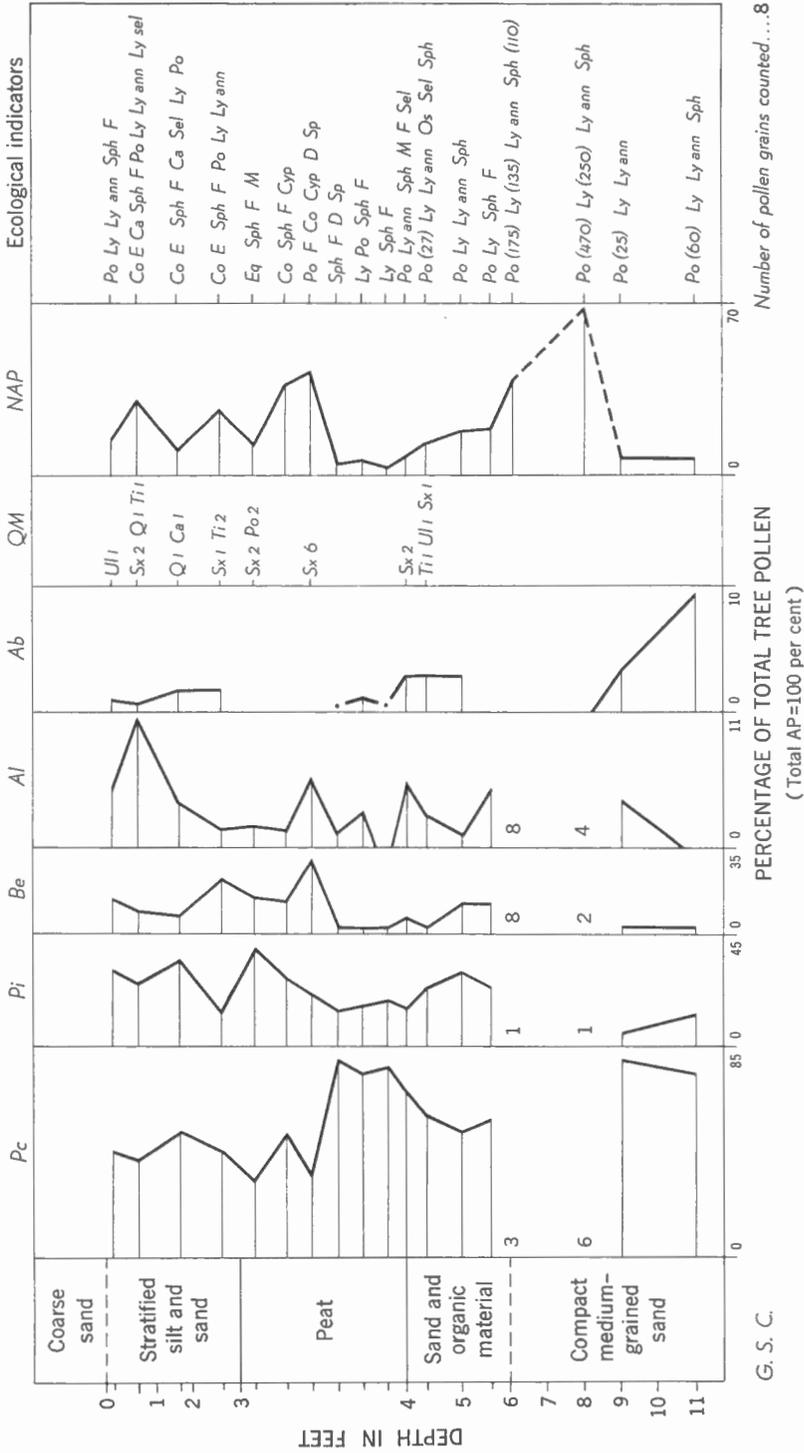


Figure 6. Pollen diagram of Ste. Monique section.

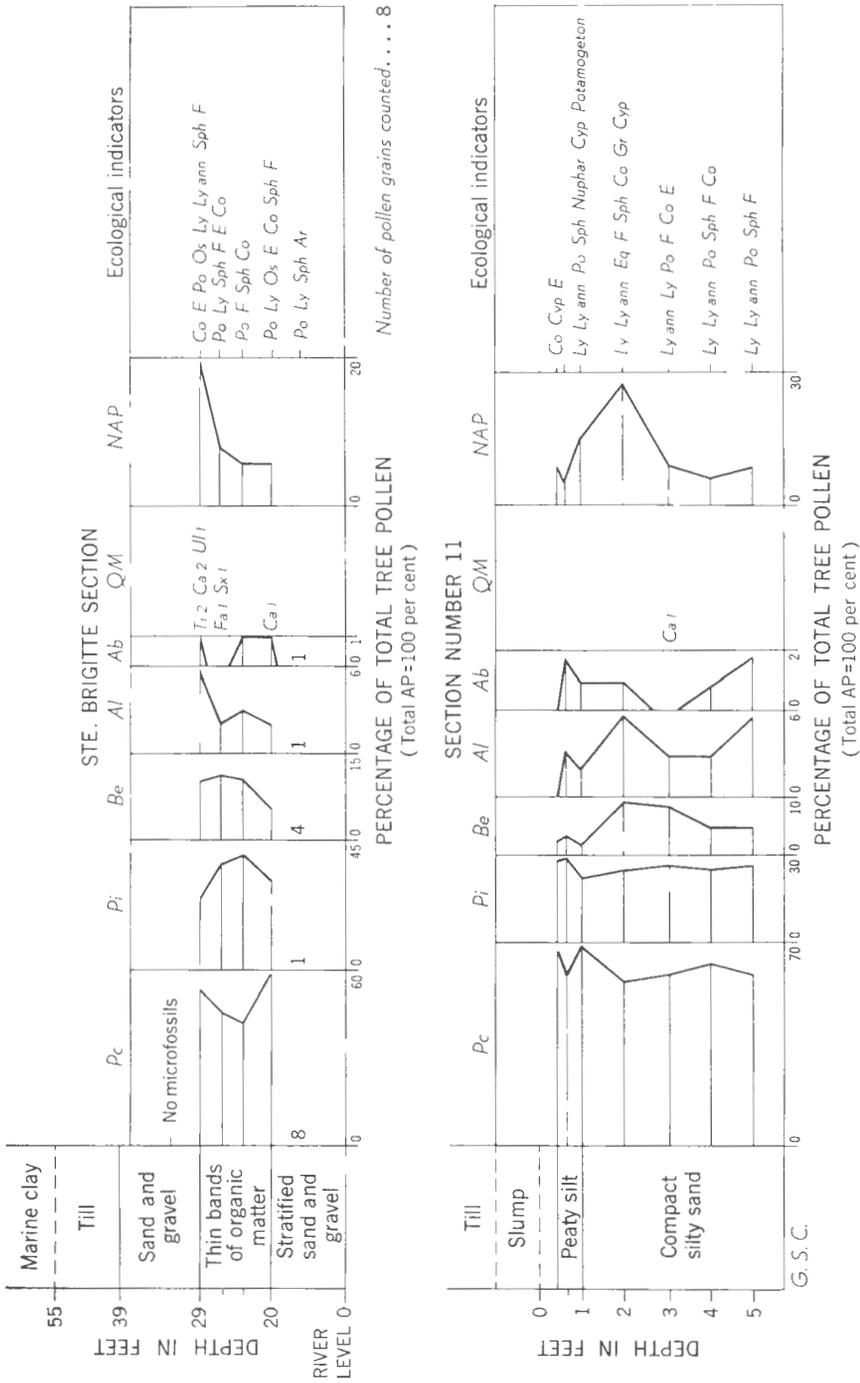


Figure 7. Pollen diagrams of Ste. Brigitte section and section Number 11.

Contributions to Canadian Palynology

the Two Creeks or Bradyan interstadial periods. This conclusion is also supported by the radiocarbon dates, which indicate an age of more than 40,000 years for the St. Pierre interval.

Correlation with the Sangamon interglacial stage is unlikely for several reasons. Firstly, all pollen diagrams give evidence of a climate during the St. Pierre interval slightly cooler than the present, a climate that is supposed to be matched by that of the Sangamon interglacial, at least during some part of it. It may be argued that the peat sequence may have been deposited during an early or late phase of the Sangamon interglacial and hence show evidence of a cool climate only. Deposition of the peat sequence during a very early phase of the interval can be ruled out, however, because the sequence appears to grade into the overlying set of glacial lake deposits. Furthermore, the lower varves in the Pierreville section were deposited in close association with the lower red till. Secondly, there is no conclusive evidence of a long period of time between the episodes of deposition of the lower and upper sequences of glacial deposits. The 6 feet or so of sands that separate the peat sequence from the underlying varves admittedly represent an unknown length of time, but it seems inconceivable that the greater part of the Sangamon interglacial stage, some 100,000 years, could be represented by these sands.

The writer believes that the peat sequence of the St. Pierre interval represents deposition during most of that interval, and that the possible length of time represented by the sands between the peat and the lower varves at Pierreville is short, probably not more than 2,000 years. It therefore appears that the St. Pierre interval had a length of 5,000 to 7,000 years and that cool climatic (boreal) conditions prevailed throughout that time. The age of the non-glacial deposits, from radiocarbon dating, is greater than 40,000 years, and the deposits are therefore older than any known Wisconsin non-glacial deposits, the Farmdale-Iowan interstadial being only 22,000 to 25,000 years old.

Discussing the implications of some twenty-five "old" samples, dated by radiocarbon analysis, Flint (1956) suggested two possibilities; one, that they are most likely Sangamon, and the other that they "represent an interval (or intervals) that was ice-free at the localities of their occurrence, that antedates all of the Wisconsin drift of the literature, but that it is not as old, and perhaps not as long, as the Sangamon interglacial age." Speculating on the possibility of this latter concept Flint adds:

The concept of a post-Sangamon climatic sequence that consisted of one or more glaciations, separated from a succeeding Wisconsin glaciation (beginning prior to 25,000 years ago) by a cool and perhaps long interval of glacier recession, is not less compatible with the drift sequence in the Cordilleran region than the one currently followed. In many parts of that region a deeply weathered drift is succeeded by two less-weathered drifts, one of which is distinctly fresher than the other. Conceivably only the younger of the two is correlative with the Wisconsin drift of the Central Lowland. Similarly, in Europe, the much-debated break between

Non-glacial Deposits, St. Lawrence Lowlands

Würm I and Würm II, between Younger loess I and Younger loess II, and between Warthe drift and Weichsel drift could conceivably be the interval of glacial recession represented by 'old' samples discussed in this paper.

It has been suggested¹, however, that such "old" non-glacial intervals might better be regarded as Wisconsin "advance" substages in contrast to the Wisconsin "retreat" substages that begin with the Farmdale as recognized in Illinois. The Wisconsin is the name given to the last or most recent glacial period and this must surely include both the build-up and the waning periods of the overall glacial cycle. It may have begun as much as 100,000 years ago and there were surely some significant climatic changes during the development of the ice-sheet, just as in the case of its general retreat. These climatic changes resulted in fluctuations of the ice margin and hence in a repetition of glacial and non-glacial conditions in certain peripheral regions of the major ice-sheet. Breaks of substage rank are just as conceivable during the advance of Wisconsin ice as during its general recession. Advance substages may thus have occurred, as well as retreat substages of the Wisconsin glacial stage.

That the St. Pierre interval of the St. Lawrence Lowlands is not the equivalent of the Sangamon interglacial stage is indicated by the palynological study of the deposits and the estimated short duration of the interval. In view of this evidence, coupled with the radiocarbon dating of more than 40,000 years, it would appear that the St. Pierre interval may well represent one of the postulated non-glacial intervals during the advance of the Wisconsin glacial stage. This concept helps to explain the absence of a marine invasion of the St. Lawrence Lowlands early in the St. Pierre interval, because during the advance of the Wisconsin ice the weight of its mass and the length of its duration were not sufficient to depress the land below sea-level as was the case at a much later date, when the Wisconsin ice receded from the St. Lawrence Lowlands.

The writer feels that the hypothesis of Wisconsin advance substages is supported by both preliminary studies (Terasmae, 1955) and later investigation of the Toronto formation. The warm-climate Don beds may represent the Sangamon interglacial, but a break towards glacial conditions occurs near the top. The Scarborough beds were deposited during a period of cool climate that preceded the advance of glaciers over the Toronto area, and left a complex of till and stratified deposits.

The palynological studies of deep cores through the sediments of former Lake San Augustin, Catron county, in New Mexico, made by P. B. Sears and Kathryn H. Clisby (1955 and 1956) present a sequence of climatic events that, at least in a general way, support the hypothesis of a cool interval of non-glacial conditions antedating the known Wisconsin substages formed during retreat, but younger than the Sangamon interglacial proper.

¹ V. K. Prest (1957, personal communication).

Contributions to Canadian Palynology

Dr. J. Iversen's studies in Denmark (reported on at the radiocarbon conference at Andover, Mass. in October, 1956) also support the hypothesis of a "pre-Wisconsin" but post-Sangamon sequence of glacial and non-glacial events.

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Non-glacial Deposits Along Missinaibi River, Ontario

Introduction

The presence of buried, non-glacial deposits exposed along the major rivers in the lowlands southwest of James Bay has been known for a long time. Williams (1921)¹ described a few exposures of Pleistocene deposits along the Albany River, and a much more extensive study of Pleistocene deposits, including exposures of non-glacial sediments, was made by McLearn (1927), who described numerous exposures of non-glacial deposits along Missinaibi, Opatatika, and Soweska Rivers. Later these deposits were discussed by Coleman (1941) and Flint (1947). The chronological and stratigraphic position of the non-glacial deposits, however, has been the subject of much speculation.

The samples of non-glacial peats, collected by McLearn from sections along Soweska, Opatatika and Missinaibi Rivers, were studied by Auer (1927), who made pollen analyses and examined the macrofossils. His interpretation will be analysed later in this paper.

In 1954 a detailed stratigraphic study of exposures of the Pleistocene deposits along Missinaibi River was made by O. L. Hughes of the Geological Survey of Canada. All exposures were studied in much greater detail than heretofore and the sections were carefully described, measured, and sampled. Samples were also collected for radiocarbon (C-14) determinations.

The present paper is based on pollen analysis of a series of the samples collected by Hughes which together with his field notes was kindly made available to the writer. Although samples were available from several sections, that at locality 24M was selected as being most representative. This is a composite section. Locality 24M-A is in the south bank of the easterly flowing Missinaibi River, approximately 6 miles upstream from the mouth

¹ Dates in parentheses are those of references cited at end of Part III.

of the Soweska River; 24M-B is 200 feet downstream from 24M-A, and 24M-C is 25 feet southeast from 24M-B, in the side of a gully.

Study of samples from the other sections of non-glacial deposits along the Missinaibi and the Opatatika Rivers is planned in order to establish correlations.

Pleistocene Stratigraphy

For a general description of the Pleistocene deposits, of which the non-glacial deposits are a part, the writer cannot do better than to quote McLearn's account (1927, p. 31) of the sequence along Soweska River:

An earlier epoch of glaciation is recorded by the lower boulder clay. The retreat of the glacier is marked by the clay with the freshwater fauna. A retreating glacier would leave an uneven surface on which the drainage system would be disorganized and on which many shallow lakes and ponds would form; in them at first freshwater mollusks would live. With the growth of vegetation from the shore, bogs would form and gradually close over and fill the shallow lakes. The lower peat bed represents such a bog or an accumulation of vegetation which has fallen or drifted in from nearby bogs on the lake border and has been laid down with silt washed in from the sides or carried in by entering streams. An increase in the volume and transporting power of entering streams due to climatic change or change in the drainage system would result in a silting up of the bog and the formation of the lower layer of carbonaceous silt. On this site a bog again formed, or in fallen and drifted vegetation from a nearby bog accumulated, together with silt brought in by streams, and formed the upper peat layer. Again, there was a flooding by a silt-laden stream and another layer of carbonaceous silt was formed. Finally, the beginning of the later glaciation is heralded by the glacial lake clay, which was laid down in a lake formed by the ponding of northward flowing waters by an advancing glacier. The lake clay was finally overridden by the glacier which distributed and partly destroyed it and deposited boulder clay.

NON-GLACIAL DEPOSITS

The recent study by Hughes has provided more information on the sequence of the non-glacial deposits, details of which are given in the sections below.

The following is a composite, representative section through the Pleistocene deposits at localities 24M-B and 24M-C measured downward from the surface of the plateau 109 feet above river level:

Lithology	Thickness (in feet)
Silty top soil	0.8
Impure silty gravel	0.6
Till, blue-grey, clayey; boulders rare	7.0
Thinly bedded silts and clays; imperfect varves?	3.0
Blue-grey clay; about 2% grit and pebbles; till lens? Layer A	4.0
Silt with plant detritus	0.3
Dark grey clay; $\frac{1}{4}$ - to $\frac{1}{2}$ -inch clay laminae with $\frac{1}{8}$ -inch silt partings	4.3
Dark brown silt with plant detritus	2.7
Peat with $\frac{1}{8}$ -inch sand layers; gradational upward into sand with streaks of peat	1.6

Non-glacial Deposits along Missinaibi River

Lithology	Thickness (in feet)
Peat, platy; alternate dark brown and black layers. Four samples collected for radiocarbon determinations	2.1
Till-like material; lenticular deposit, sandy and dark coloured; wood at base collected by Hughes for a radiocarbon determination	2.9
Gravel; limestone pebbles; much leached	0.9
Gravel; impure, silty	5.5
Till; very dark grey-brown; small irregular inclusions of yellowish sand	9.5
Silt; dark grey-brown, almost olive, minute foreset beds that dip about southeast	9.0
Sand; yellow to reddish brown with few pebbles	2.0
Till; brown, silty, sandy, flaky, rather loose	13.0
Till; grey-brown, sandy, compact	2.5
Sand; medium to coarse, yellowish to rusty coloured	6.8
Fine gravel	2.1
Clay and silt; varved with 12 varves visible; clay in lower varves gritty	1.8
Gritty clay	1.4
Till; sandy, dark rusty brown; weathers pale pink	8.4
Concealed to river level; presumably till as above	17 approx.

The areal extent of the non-glacial deposits is not known with certainty but according to McLearn (1927) exposures of these deposits were found at the mouth of Opasatika River and about 10 miles upstream. They also occur on Missinaibi River about 5 miles downstream from the mouth of Opasatika River and extend at intervals along a 15-mile stretch upstream from its mouth. The extent of the non-glacial deposits at right angles to the rivers is unknown.

The samples for pollen analysis were collected at locality 24M-B, where the face of the exposure was cleaned and trenched for sampling. The section, starting at the base of layer A, measured downward, is as follows:

Lithology	Depth (in feet)
Clay; not trenched	0— 7
Clay	7 — 9.8
Three-inch layer with concentration of plant detritus	9.8—10
Clay	10 —12.4
Silt with plant detritus	12.4—14.2
Peat	14.2—16.9
Till-like material, sandy	16.9—18.6
Till-like material, gravelly	18.6—19.6
Impure silty gravel	19.6—23.7
Till with associated deposits	Down to river level

Samples for pollen analysis were collected, starting from the 3-inch layer of silty plant detritus, downwards to the silty gravel.

Contributions to Canadian Palynology

Hughes interprets the deposit described as till-like as not a part of a till layer and suggests that its texture may be the result of frost action and other factors. Indeed the abundance of plant microfossils and other plant detritus proves that this deposit is not glacial till. It is lenticular horizontally.

Palynological Study

Samples of the non-glacial peat, collected by McLearn in 1926 from Soveska, Opatatika, and Missinaibi Rivers, were examined for pollen and macrofossils by V. Auer (1927). Auer had great difficulty in recovering microfossils from the hard, compressed peat, and, as he obtained so few, his studies were primarily qualitative. Inorganic deposits were not studied. Auer suggested that climatic conditions during the non-glacial interval closely resembled those of the present, on the basis of the following genera identified: *Picea* (spruce), *Pinus* (pine), *Abies* (balsam fir), *Betula* (birch), *Salix* (willow), *Carex* (sedge), *Eriophorum* (cotton-grass), *Equisetum* (horse tail), Ericaceae (heath family), *Scheuchzeria*, *Sphagnum* (peat-moss), *Hypnum* (brown-moss), and Polypodiaceae (ferns).

Improved techniques (Terasmae, 1955) have helped to overcome the difficulties of concentrating spores and pollen from materials of this nature and even inorganic sediments generally yield appreciable numbers of microfossils. Statistical methods are thus possible.

Study of the pollen diagram (*see* Figure 8) shows that a predominantly spruce-fir (*Picea mariana*, *Pc. glauca* and *Abies balsamea*) type of forest grew at this locality when the till-like material, underlying the peat layer, was deposited. Birch, alder and pine were of little importance. The low values of birch and alder and the conspicuous presence of pollen of temperate deciduous trees (*Quercus*, *Ulmus*, *Tilia*, *Carpinus*) in the bottom part of this layer may be interpreted as an indication of climatic conditions very nearly duplicating those of the present time.

No satisfactory explanation can be offered for the abundance of fern spores and NAP (predominantly Chenopodiaceae), as shown in the bottom part of the diagram. This phenomenon may be due at least partly to secondary pollen and the local habitat. The evidence from only one diagram is not sufficient to permit generalized conclusions for the region; the minor trends of the pollen curves particularly may reflect local conditions unless duplicated in other diagrams from the same region.

The fairly high percentages of pine pollen (*Pinus banksiana*), and low percentages of birch and alder shown by the middle and most of the upper part of the diagram indicate climatic and ecological conditions closely resembling those now present in the region. This hypothesis is supported by the low NAP and spore percentages and the dominance of spruce.

Non-glacial Deposits along Missinaibi River

Approaching glacial conditions are indicated by increasing percentages of birch, alder, NAP, and spores in the upper part of the sequence. A decline of spruce and the absence of fir pollen support this statement.

The climate throughout the non-glacial period remained fairly uniform and was probably slightly cooler than the present. No evidence has been found for a climate warmer than the present at any time in the interval.

LENGTH OF THE NON-GLACIAL INTERVAL

The length of the non-glacial interval can be estimated by assuming that the rate of accumulation of peat can be compared with that known for post-glacial peats. The gravel and till-like material underlying the peat, however, represent an unknown length of time.

It seems probable that the accumulation of more than 2 feet of hard, compact peat represents a period of about 3,000 years (Zumberge and Potzger, 1956). The inorganic sediments of the non-glacial sequence certainly represent several hundred years and, considering the length of time necessary to establish the type of vegetation suggested by the bottom part of the diagram, it is probable that at least 2,000 to 3,000 years are represented by erosion and the deposition of the gravel overlying the basal till. This would give an estimated length of 6,000 years for the non-glacial interval, but it may well have been longer.

Age of the Non-glacial Deposits

Both peat and wood from the buried, non-glacial deposits along the Missinaibi River have been dated by the radiocarbon method. The peat was dated at more than 29,630 years (Y-269), more than 38,000 years (W-241), and at $38,500 \pm 3,500$ years (Man.); and the wood dated at more than 30,840 years (Y-270) and more than 38,000 years (W-242). An age of more than 38,000 years is therefore indicated. Such an age is greater than the oldest accepted Wisconsin substage, the Farmdale, which is dated at some 25,000 years. It may be emphasized that the Farmdale substage should not be thought of as the first or oldest substage of the Wisconsin, but rather one that marks the maximum expansion of this ice-sheet in Illinois. A long time should be allowed for the build-up period of the glaciation and it seems logical that this period of build-up would be accompanied by advance substages just as the period of retreat would be accompanied by retreat substages. The buried, non-glacial deposits along the Missinaibi River may therefore represent a substage during the onset of the Wisconsin.

A correlation between the Missinaibi and the St. Pierre deposits of the St. Lawrence Lowlands is suggested by both stratigraphic and palynological evidence.

Contributions to Canadian Palynology

As explained in Part II for the St. Pierre interval, the concept that the non-glacial deposits of Missinaibi River were formed during an advance substage of the Wisconsin would account for the absence of marine beds below those of the non-glacial sequence. That the Missinaibi buried peats do not belong to the Sangamon interglacial is indicated by the palynological studies and the inferred cool climate and short duration of the non-glacial interval.

All in all a revision of the accepted Pleistocene stratigraphic column for eastern North America appears to be indicated but will have to await more and clearer evidence.

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Appendix

LIST OF ABBREVIATIONS

Pollen grains

AP	—arboreal pollen	Lx	— <i>Larix</i> (tamarack)
Ab	— <i>Abies</i> (fir)	Pc	— <i>Picea</i> (spruce)
Al	— <i>Alnus</i> (alder)	Pi	— <i>Pinus</i> (pine)
Ac	— <i>Acer</i> (maple)	Po	— <i>Populus</i> (poplar, aspen)
Be	— <i>Betula</i> (birch)	Q	— <i>Quercus</i> (oak)
Ca	— <i>Carya</i> (hickory)	QM	— <i>Quercetum mixtum</i> (includes temperate deciduous trees)
Cp	— <i>Carpinus</i> (blue beech)	Sx	— <i>Salix</i> (willow)
Cr	— <i>Corylus</i> (hazel-nut)	Ti	— <i>Tilia</i> (basswood)
Fa	— <i>Fagus</i> (beech)	Ts	— <i>Tsuga</i> (hemlock)
Fx	— <i>Fraxinus</i> (ash)	Ul	— <i>Ulmus</i> (elm)
Ju	— <i>Juglans</i> (butternut)		

NAP—non-arboreal pollen

Am	— <i>Ambrosia</i>	Gr	—Gramineae (grasses)
Ar	— <i>Artemisia</i>	My	— <i>Myrica</i>
Ce	—Chenopodiaceae	Nu	— <i>Nuphar</i>
Co	—Compositae	Ny	— <i>Nymphaea</i>
Cx	— <i>Carex</i>	Spa	— <i>Sparganium</i>
Cyp	—Cyperaceae (sedges)	Ty	— <i>Typha</i>
E	—Ericaceae	Um	—Umbelliferae

Spores

Eq	— <i>Equisetum</i>	Ly sel	— <i>Lycopodium selago</i>
F	—Fungus	Os	— <i>Osmunda</i>
M	—moss	Po	—Polypodiaceae (bean-shaped fern spores)
Ly	— <i>Lycopodium</i>	Sel	— <i>Selaginella</i>
Ly ann	— <i>Lycopodium annotinum</i>	Sph	— <i>Sphagnum</i>

Miscellaneous

D	—Diatoms	Sp	—Sponge spicules
P	—Means that a pollen or spore type is present in the sample but not encountered in the pollen count. (●=P in certain pollen diagrams.)		