GEOLOGICAL SURVEY OF CANADA · 1842 ·

BULLETIN 62

A PALYNOLOGICAL AND GEOLOGICAL STUDY OF PLEISTOCENE DEPOSITS IN THE JAMES BAY LOWLANDS, ONTARIO

J. Terasmae and O. L. Hughes

1960

A PALYNOLOGICAL AND GEOLOGICAL STUDY OF PLEISTOCENE DEPOSITS IN THE JAMES BAY LOWLANDS, ONTARIO (42 N$\frac{1}{2}$)

2,500—1960—1638

GEOLOGICAL SURVEY
OF CANADA

BULLETIN 62

A PALYNOLOGICAL AND GEOLOGICAL STUDY OF PLEISTOCENE DEPOSITS IN THE JAMES BAY LOWLANDS, ONTARIO (42 N½) 42 I J

By

J. Terasmae and O. L. Hughes

DEPARTMENT OF
MINES AND TECHNICAL SURVEYS
CANADA

Nov 9 1960

ROGER DUHAMEL, F.R.S.C.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1960

Price 50 cents Cat. No. M42-62

PREFACE

Intertill, non-glacial sediments have for many years been recognized along several of the rivers crossing James Bay Lowland, but they have never been studied in detail. In the project reported here Hughes studied the sediments along the Missinaibi and Opasatika Rivers and Terasmae the palynology of samples collected by Hughes. These combined studies have done much to clarify the late Pleistocene history of the region.

J. M. HARRISON,
Director, Geological Survey of Canada

Ottawa, February 23, 1960

82101-7—2

CONTENTS

Illustrations

82101-7—2½

A PALYNOLOGICAL AND GEOLOGICAL STUDY OF PLEISTOCENE DEPOSITS IN THE JAMES BAY LOWLANDS, ONTARIO

Abstract

Stratigraphic studies of Pleistocene deposits in the James Bay Lowlands have shown that the sequence begins with glacial deposits overlying bedrock. This part of the sequence consists of two members, the lower drift and the middle drift. These glacial deposits are overlain by layers of peat, silt and clay, here named the Missinaibi beds, which in turn are overlain by glacial deposits of the main Wisconsin glaciation. Marine clay, commonly fossiliferous, overlies the upper glacial drift and is overlain by post-glacial fluvial, lacustrine, and organic deposits.

Palynological studies have been made of both the Missinaibi beds and the post-glacial deposits. Vegetation during the deposition of the Missinaibi beds was similar to that present now in the James Bay Lowlands. On basis of palynological evidence an interstadial rank is proposed for the Missinaibi beds, and radiocarbon dating suggests an age of 55,000 to 64,000 years.

Résumé

Des études stratigraphiques des dépôts pléistocènes des basses terres de la baie James ont démontré que la succession commençait par des dépôts glaciaires surjacents à la roche saine. Cette portion de la succession comprend deux divisions, le drift inférieur et le drift moyen. Ces dépôts glaciaires sont recouverts par des couches de tourbe, de limon (silt) et d'argile, qu'on nomme ici couches Missinaibi, qui à leur tour ont été recouverte par des dépôts glaciaires de la principale glaciation d'âge Wisconsin. De l'argile marine, souvent fossilifère, recouvre le drift glaciaire supérieur et est elle-même recouverte par des dépôts fluviaux, lacustres et organiques d'origine post-glaciaire.

On a fait des études micropaléobotaniques tant des couches Missinaibi que des dépôts post-glaciares. La végétation, à l'époque de la formation des couches Missinaibi, ressemblait à celle qu'on trouve actuellement dans les basses terres de la baie James. En se fondant sur des preuves micropaléobotaniques, l'on croit que les couches Missinaibi représentent un inter-stadiaire. Quant à leur âge, la méthode au radiocarbone permet de l'établir entre 55,000 et 64,000 ans.

INTRODUCTION

The non-glacial deposits of the James Bay Lowlands have been known since 1875, when Robert Bell (1879)[1] examined deposits of "lignite" along the banks of Missinaibi River above its junction with Opasatika River. It was James Macintosh Bell (1904), however, who established the Pleistocene age of the lignites on Missinaibi, Soweska, Kwataboahegan, Abitibi, and Nettogami Rivers from their occurrence between two till sheets, but erroneously included with them some exposures of lignite of Mesozoic age. Keele (1920) established the Mesozoic age of certain of the lignite deposits and suggested that all the "lignites" of James Macintosh Bell might be of Mesozoic age. Williams (1921), however, considered similar deposits on Albany River to be interglacial.

Confusion as to the age of the deposits described by Robert Bell, James Macintosh Bell, and Keele was removed by McLearn (1927), who established the presence in James Bay Lowlands of three types of organic deposits: (1) lignite deposits of "Upper Jurassic or early Lower Cretaceous" age, (2) Pleistocene sand containing lignite redeposited from the Upper Jurassic or early Lower Cretaceous beds, and (3) Pleistocene interglacial deposits.

With the advent of radiocarbon age dating, the buried organic deposits of the James Bay Lowlands became worthy of further investigation. In 1954 the junior author during the course of his detailed studies of the Pleistocene stratigraphy along the Missinaibi and Opasatika Rivers, collected samples from these deposits. In 1958 additional samples were obtained through the courtesy of G. M. Brownell[2] from bore-holes at Otter Rapids on Abitibi River. To supplement these, samples taken by M. Y. Williams from the banks of the Albany River were available in the collections of the Geological Survey of Canada. These three suites of samples form the basis of the palynological studies and radiocarbon dates given in this report. Additional information was however gained from studies of samples of post-glacial peat deposits from widely separated parts of the Lowlands collected by H. Sjörs of Stockholm, Sweden, by W. K. W. Baldwin, National Museum of Canada, and by the writers.

PLEISTOCENE STRATIGRAPHY

The Pleistocene deposits exposed in the James Bay Lowlands, along Missinaibi and Opasatika Rivers, consist of five main units: (1) a lower drift exposed at a single locality on Missinaibi River (*see* Fig. 1, 24M); (2) a middle drift consisting of till and glaciofluvial sand and gravel; (3) layers of peat, organic silt, and clay, here named the Missinaibi beds; (4) an upper drift consisting

[1] Dates in parentheses are those of references cited at the end of this report.
[2] Geology and Soil Mechanics Section, Hydro-Electric Power Commission of Ontario.

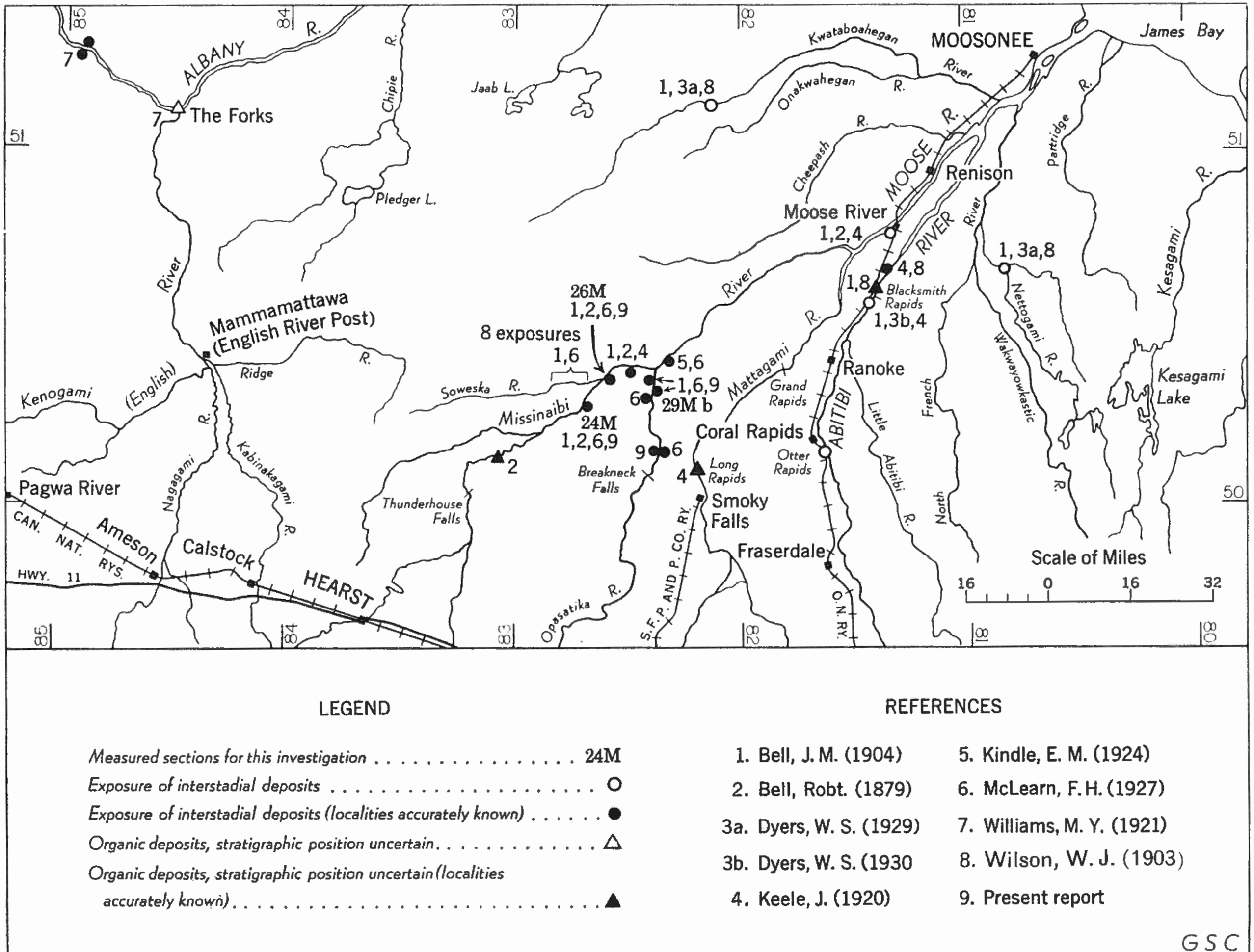


Figure 1. *Index map of James Bay Lowlands region showing exposures of Pleistocene deposits.*

mainly of till; and (5) marine clay, sand, and silt. Locally, this sequence is truncated and overlain by fluviatile deposits which underlie terraces along the rivers. The lower drift, probably the unit described by J. M. Bell (1904, p. 162) as "thirteen feet or more of a hard dense clay conglomerate", was not exposed at locality 24M when it was visited by McLearn in 1926, but was visible for about 100 feet midway along the line of exposures in 1954. At that time two sections from the Missinaibi beds were measured in some detail and samples collected for radiocarbon dating and palynological study.

Section at Locality 24M, Southeast Bank of Missinaibi River, 6 Miles Upstream from the Mouth of Soweska River

	Thickness (feet)
Fluviatile deposits	
Topsoil: silty	0.8
Gravel: silty	0.6
Total	1.4
Upper drift	
Till: blue-grey, clayey; rare boulders	7.0
Silt and clay; thinly bedded (varves?)	3.0
Clay: blue-grey, massive; till lenses (?) containing 1 or 2% pebbles and coarse sand	4.0
Total	14.0
Missinaibi beds	
Silt with plant detritus	0.3
A[1]-Clay: dark grey; $\frac{1}{4}$- to $\frac{1}{2}$-inch clay laminae with $\frac{1}{8}$-inch silt partings	4.3
Silt: dark brown; plant detritus	2.7
Peat: brownish black, with sand laminae gradational upward into sand with streaks of peat	1.6
Peat: hard, platy, alternate dark brown and black. Samples collected for radiocarbon determinations	2.1
Colluvium: dark brown; lenticular in section; compressed and flattened wood at base; contains microscopic plant detritus	2.9
Total	13.9
Middle drift	
Gravel: contains leached and friable limestone pebbles	0.9
B-Gravel: impure, silty	5.5
Till: dark grey-brown; irregular inclusions of yellowish sand	9.5
Silt: dark grey-brown to olive; contains tiny foreset beds that dip southeastward	9.0
Sand: yellow to reddish brown with a few pebbles	2.0
Till: brown, silty, sandy, flaky, rather loose	13.0
Till: grey-brown, sandy, compact	2.5
Sand: medium to coarse-grained, yellowish to rusty coloured	6.8
Gravel: fine	2.1
Clay and silt: distinctly varved (12 varves counted); clay in lower varves gritty; lenticular in section	1.8
Clay: dark grey, gritty	1.4
Total	54.5
Lower drift	
Till: dark rusty brown, weathers to pale pinkish brown; hard, dense	8.4
Concealed to river level, presumably till	2.0
Total exposed	10.4

[1] A to B, parts of sections studied for plant microfossils.

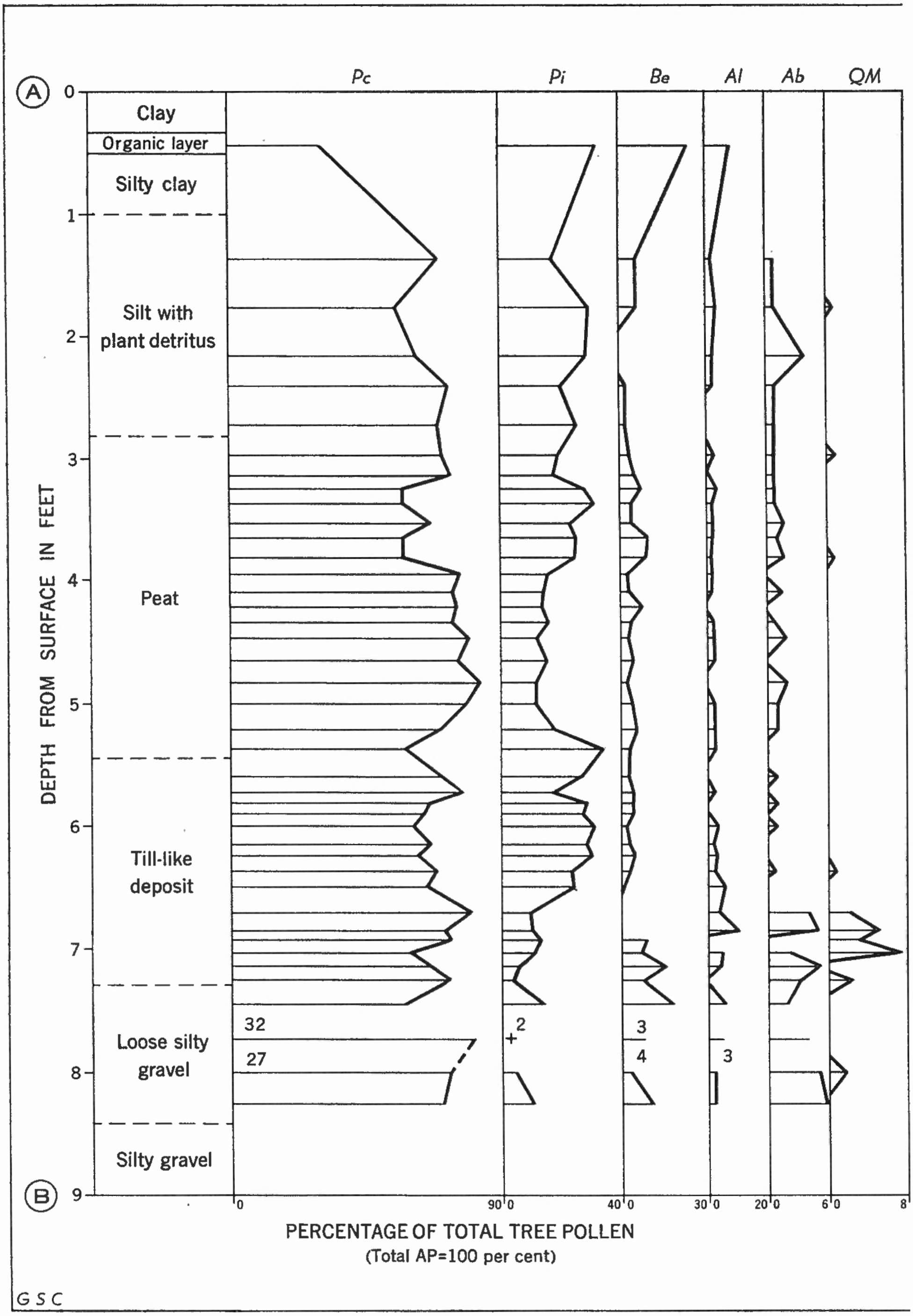
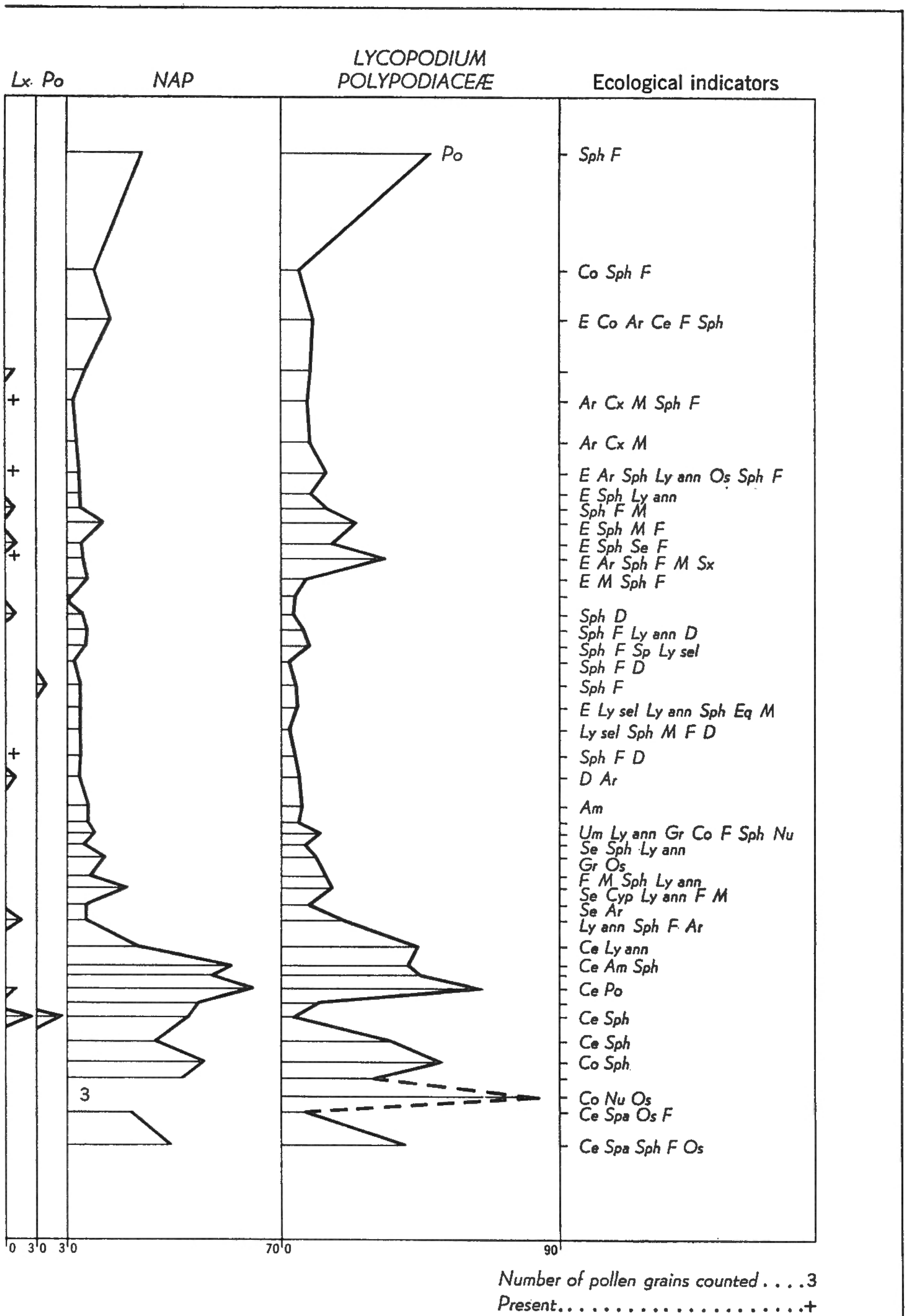


Figure 2. *Pollen diagram of the non-glacial sequence*



at locality 24M on Missinaibi River, northern Ontario.

Section at Locality 26M, Southeast Bank of Missinaibi River, ¾ Mile Downstream from Mouth of Soweska River

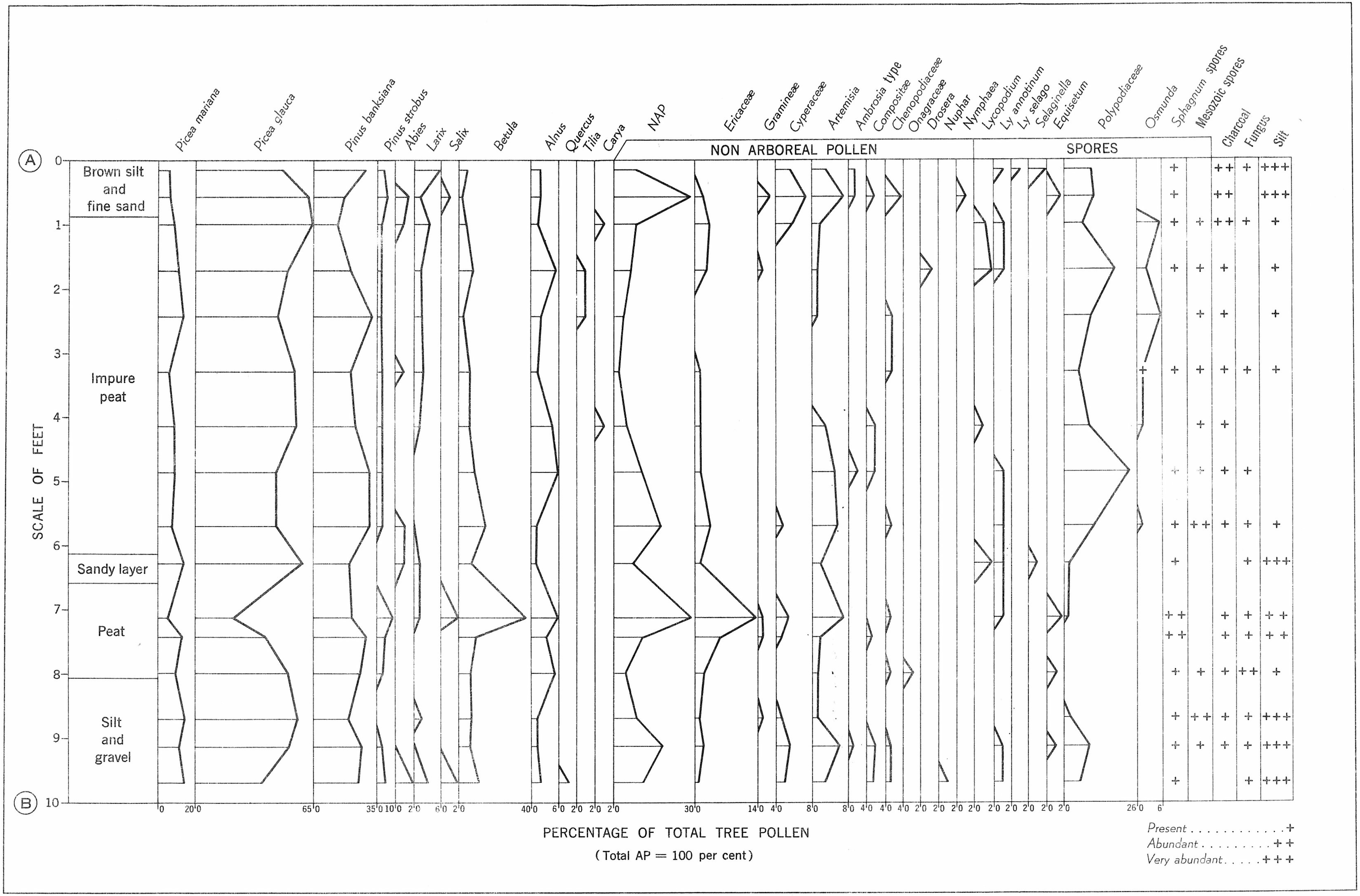
	Thickness (feet)
Fluviatile and marine deposits	
Topsoil: silty	1.2
Silt, clay: poorly defined bedding	1.4
Clay: brown, stiffly plastic; marine shells	3.5
Total	6.1
Upper drift	
Till: greenish grey at top grading downward to dark grey	3.7
Missinaibi beds	
Clay: blue-grey, soft, plastic	2.3
A-Sand: very fine-grained, dark brown, organic	1.5
Peat: impure, silty	2.2
Peat: relatively pure, platy	2.2
Sand: medium-grained, dark brown, organic	0.4
Peat: relatively pure, platy	0.8
B-Gravel: dark grey-brown, silty	1.1
Total	10.5
Middle drift	
Till: sandy; ash-grey podzolic layer in upper 0.4 foot; yellow-brown below podzolic layer grading downward into compact flaky grey-brown till	14.3
Concealed to river level, probably till	11.0
Total, greater than	25.3

The upper drift is not well developed at locality 26M. At a point 200 feet downstream from locality 26M both the upper drift and the marine deposits have been removed by stream erosion and the Missinaibi beds are overlain directly by fluviatile deposits. Miss F. J. E. Wagner identified eight freshwater and three terrestrial molluscs from samples of these river deposits.

At several localities, however, as at 29M (b) described below, the upper drift attains thicknesses of 20 feet or probably more. The marine deposits are very thin at locality 26M and are absent at locality 24M, but in other places, as on the north bank of Soweska River 500 feet from the mouth, fossiliferous marine deposits are as much as 20 feet thick.

Section at Locality 29M (b), West Bank Opasatika River, 3 Miles Above Mouth

	Thickness (feet)
Upper drift and marine deposits	
Concealed, probably till overlain by marine clay and sand	28.5
Upper drift	
Till: dark grey, rather sandy, compact	19.6
Missinaibi beds	
Peat: impure, silty	1.5
Silt: grey-brown, organic	0.4
Sand: medium-grained, red-brown	2.0
Total	3.9



Printed by the Surveys and Mapping Branch

Figure 3. Pollen diagram of the non-glacial sequence at locality 26M on Missinaibi River

Middle drift

Silt: pale blue-grey, compact	1.8
Till: silty, pale blue-grey, very hard, compact	4.7
Concealed to water level, probably till	1.5
Total, greater than	8.0

PALYNOLOGICAL STUDY OF THE MISSINAIBI BEDS

A summary of palynological investigations of the buried non-glacial deposits along the Missinaibi River made prior to 1958 has been previously presented (Terasmae, 1958). Further palynological studies have revealed additional information of sufficient importance to warrant publication.

The Missinaibi River Sections

The pollen diagram for section 24M (*see* Fig. 2) shows that a forest formerly grew in this area. White spruce (*Picea glauca*) was the predominant species, but black spruce (*Picea mariana*), jack pine (*Pinus banksiana*), birch (*Betula*), alder (*Alnus*), balsam fir (*Abies balsamea*), and tamarack (*Larix laricina*) were also components of the forest. A few scattered pollen grains of white pine (*Pinus strobus*) and occasional grains of poplar (*Populus*), oak (*Quercus*), elm (*Ulmus*), and ash (*Fraxinus*) are probably of both local and distant (windblown) origin. The high proportion of non-arboreal pollen and fern spores near the base and also towards the top of the diagram indicates a less dense forest locally. The relatively high percentages (3-6%) of balsam fir and hardwood pollen at the 7-foot depth is probably the result of some pollen having been carried downstream by the Missinaibi River drainage system and pollen from the height of land to the south being carried north and northeast and redeposited when the rivers were in flood. Hardwood pollen rarely occurs in peat layers where no evidence of flooding was observed. Near the top of the pollen diagram the approaching glaciation is shown by the decline in the amount of spruce pollen and the increase in the amount of birch, alder, and non-arboreal pollen, and spores.

The pollen diagram for section 26M (Fig. 3) also shows that a white spruce forest covered the area during the time of accumulation of the sediments; black spruce, jack pine, tamarack, birch and alder were also components. That a bog developed at this site during the accumulation of the peat in the 7-to-8-foot interval is indicated by the decrease in the amount of white spruce and by the increase in the amount of birch, alder, and willow pollen, which is also supported by a corresponding increase in the amount of Ericaceae pollen and *Sphagnum* spores. The fern spores of Polypodiaceae and *Osmunda* throughout the impure peat layer, from 1 foot to 6 feet, indicate a fern-swamp environment.

Except in the peat layer at the 7-foot depth, spores of Mesozoic (Cretaceous) plants are present throughout the section. These spores, as well as the silt in the impure peat, are probably the result of periodic flooding.

The Otter Rapids Section, Abitibi River

Buried stratified sediments were encountered in bore-holes drilled to investigate the site of a new power development project by the Hydro-Electric Power Commission of Ontario. Through the courtesy of Mr. Brownell, who made the geological observations at the site, a number of samples from cores and descriptions of the deposits were made available to the writers. A palynological study of samples from fine sand and silt containing thin seams of finely divided plant detritus showed that these beds, which are both underlain and overlain by glacial till, contained pollen and spore assemblages identical with those of the Missinaibi beds. These sediments are therefore correlated with them.

The following assemblage of spores and pollen is representative of the Missinaibi beds in the Otter Rapids section:

	% of total (AP)
Arboreal pollen (AP)	
White spruce	51
Black spruce	12
Jack pine	30
White pine	1
Birch	3
Alder	3
Non-arboreal pollen (NAP)	
Gramineae	2
Cyperaceae	1
Artemisia	1
Ambrosia-type	1
Caryophyllaceae	1
Unidentified	2
Spores	
Polypodiaceae (ferns)	12
Lycopodium sp.	1
L. annotinum	3
Equisetum	1
Selaginella	3
Sphagnum spores	Present
Mesozoic spores	6
Miscellaneous	
Fungus remains	Occasional
Charcoal	A few fragments

Borings east and west of the Abitibi River at Otter Rapids show that the Missinaibi beds pinch out on both sides of the river. It is concluded, both from this and from the palynological evidence, that the Missinaibi beds were deposited along shallow, wide river channels where flooding occurred, perhaps annually. The present Abitibi River at this site has cut a much narrower and deeper channel during post-glacial time.

The Albany River Section

In 1920, M. Y. Williams (1921) observed peat layers in sections about 20 miles above the Forks of Albany River (*see* Fig. 1, index map), which were described by him as the upper and lower seam of interglacial lignite. A palynological study made on Williams' samples by the writer showed that the peat layers were of Pleistocene age and a correlation with the Missinaibi beds is suggested. Rouse (1956) made a palynological study of the lignite of the Cretaceous Mattagami formation; the pollen and spore assemblages from these deposits are entirely different from those of the Missinaibi beds. The upper peat layer from the Albany River section contains the following assemblage:

	% of total (AP)
Arboreal pollen (AP)	
White spruce	68
Black spruce	6
Jack pine	12
Birch	12
Alder	1
Poplar	1
Non-arboreal pollen (NAP)	
Chenopodiaceae	1
Compositae	2
Unidentified	1
Spores	
Lycopodium annotinum	1
Fungus remains	Present

A sample from the lower peat layer of the Albany River section also revealed pollen of white spruce, jack pine, and birch.

PALYNOLOGICAL STUDY OF THE POST-GLACIAL DEPOSITS

For reference and comparison three pollen diagrams (Figs. 4, 5, and 6) of post-glacial deposits have been prepared. The Attawapiskat River site is at lat. 53° 8′ N and long. 85° 18′ W, the Ogoki Post site is about 2 miles north of Albany River from the Ogoki Post at lat. 51° 39′ N and long. 85° 57′ W, and the Frederick House River bog about 4 miles west of Cochrane.

The samples for pollen analysis from the Attawapiskat River and the Ogoki Post were collected by W. K. W. Baldwin of the National Museum of Canada and H. Sjörs of Stockholm, Sweden. Dr. Sjörs also collected a sample of peat from the base of the peat section at the Attawapiskat River site for radiocarbon dating. Through the courtesy of Professor Hl. de Vries, Natuurkundig Laboratorium at Groningen, Holland, a radiocarbon date was obtained for the basal peat in the Attawapiskat River section showing an age of 4,700 ± 80 (GRO 1925) years. The three pollen diagrams of the post-glacial deposits show the character of vegetation during that time for each locality.

Examination of the post-glacial pollen record from the Ogoki Post site (Fig. 4) shows that a black spruce muskeg environment prevailed throughout the time covered by the pollen diagram. The locality is at some distance from the river and a bog environment is indicated by the abundance of black spruce pollen, the presence of Ericaceae, tamarack, birch, alder and *Rubus Chamaemorus* (cloudberry, baked-apple) pollen, and *Sphagnum* spores. The occurrence of pine, white spruce, and balsam fir pollen indicates the presence of better drained sites not too far away.

Studies of modern vegetation by Baldwin (1958 and 1959) and Sjörs (1959) have supplied much useful reference data for interpretation of the pollen diagrams.

Some of the birch pollen in the lower part of the Ogoki Post section has been tentatively identified as that of yellow birch (*Betula lutea*). The fossil birch pollen falls into three size groups: the smallest measure 21 to 24 microns in diameter, those in the middle group have an average size of 26 microns, and those in the largest measure 31 to 32 microns in diameter. A comparison with modern pollen in acetolysed preparations suggests that the pollen of the largest group is that of *Betula lutea.* Leopold (1956) in her graphs showing the size of modern birch pollen depicts a range of 40 to 45 microns for acetolysed preparations of *Betula lutea.* This discrepancy may be accounted for by the fact that one of the authors (Terasmae), in making preparations for study, heated the acetolysis mixture containing the modern pollen only to the boiling point and then removed the tubes from the waterbath, thus minimizing the swelling effect of the treatment, whereas Leopold (1956) boiled hers for 2 minutes. Nonetheless further study must be made before the identification can be regarded as certain.

The pollen diagram from the Attawapiskat River site (Fig. 5) illustrates the development of vegetation in the James Bay Lowlands after the post-glacial marine inundation. Bog development, as evidenced by the presence of Ericaceae and *Rubus Chamaemorus* pollen and *Sphagnum* spores, was preceded by a phase of sedge and grass fen development with plentiful birch. The pollen of black spruce and tamarack signifies bog development, whereas the pollen of white spruce, pine, balsam fir, alder and willow indicates the existence of nearby sites with better drainage. Indeed drainage seems to have been a major factor in controlling the development of the vegetation in the James Bay Lowlands throughout post-glacial time. For the purpose of comparison and as an aid in interpreting the palynological data obtained from the Missinaibi beds, it is interesting to consider the present forest in the region.

The area covered by the index map (Fig. 1) is in the Hudson Bay Lowlands Section (B5) of the Boreal Forest Region of Canada ("Forest Classification for Canada", 1958, p. 9; revised in 1959).

> The vegetation of the section has in general a 'subarctic' appearance because of the predominance of an open cover of black spruce (*Picea mariana*) and tamarack (*Larix laricina*) in the swamps and muskegs. However, on the river-bank levees where conditions of better drainage obtain, forests of white spruce (*Picea glauca*), balsam fir (*Abies balsamea*), aspen (*Populus tremuloides*), balsam poplar (*Populus

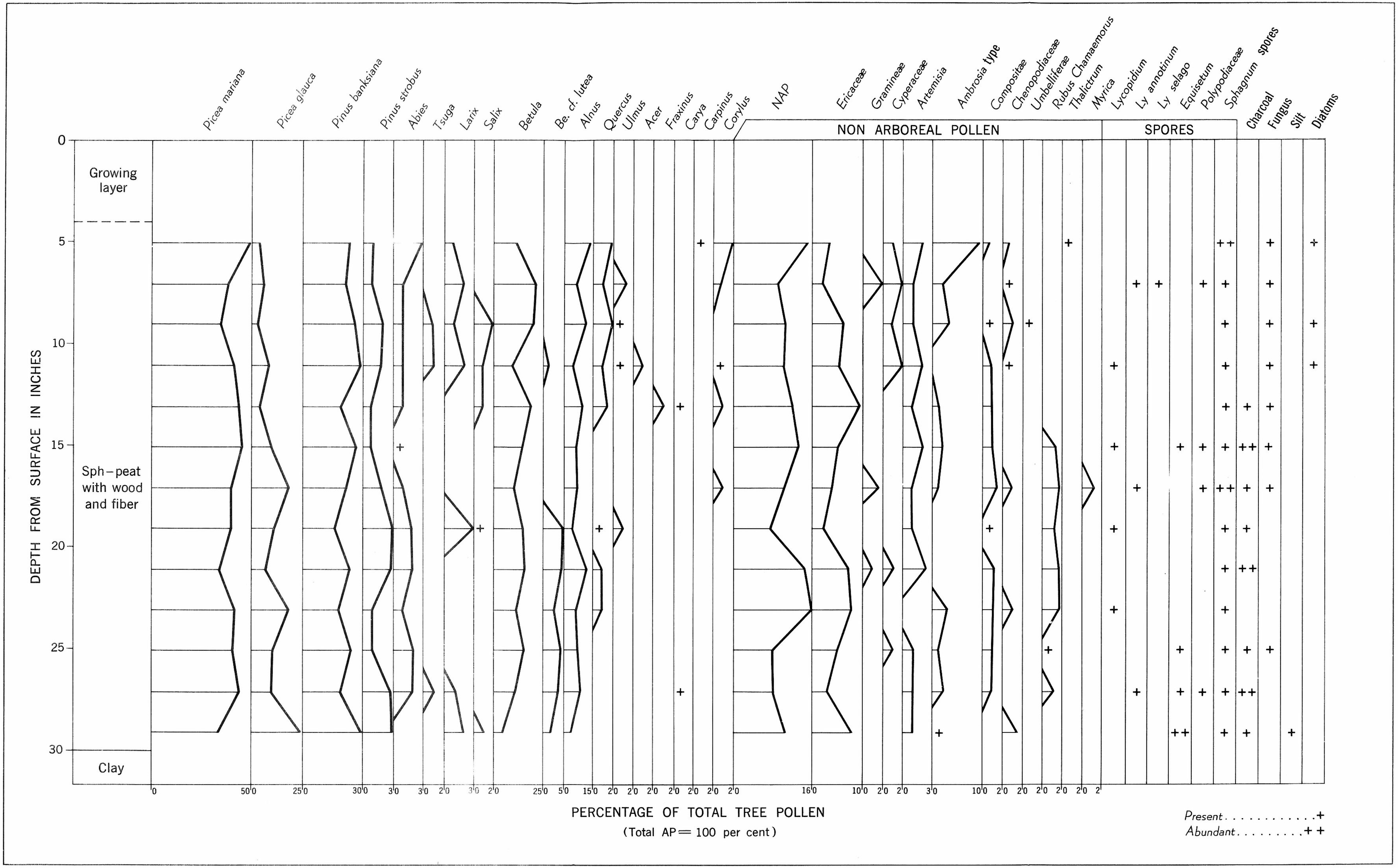
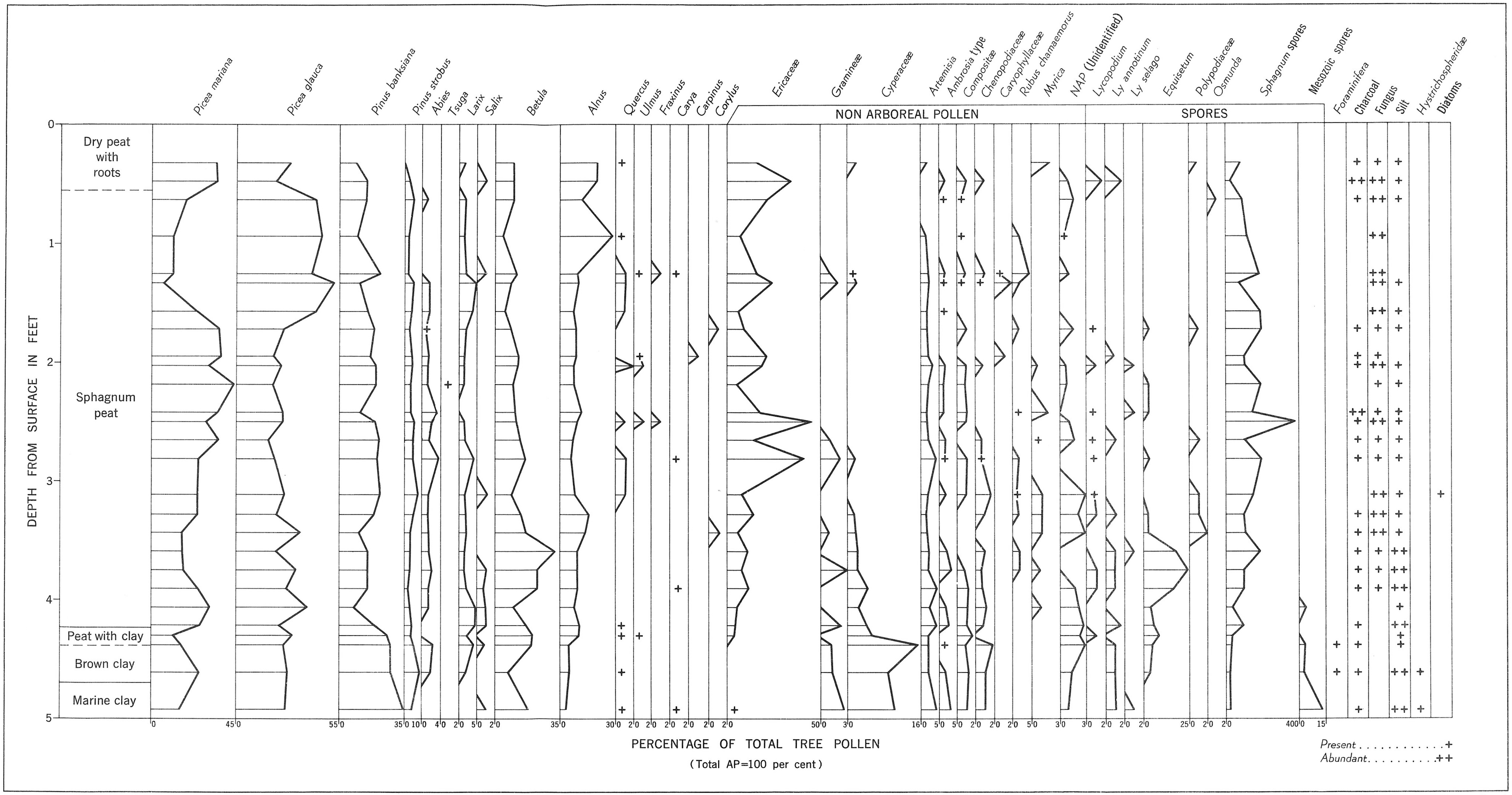


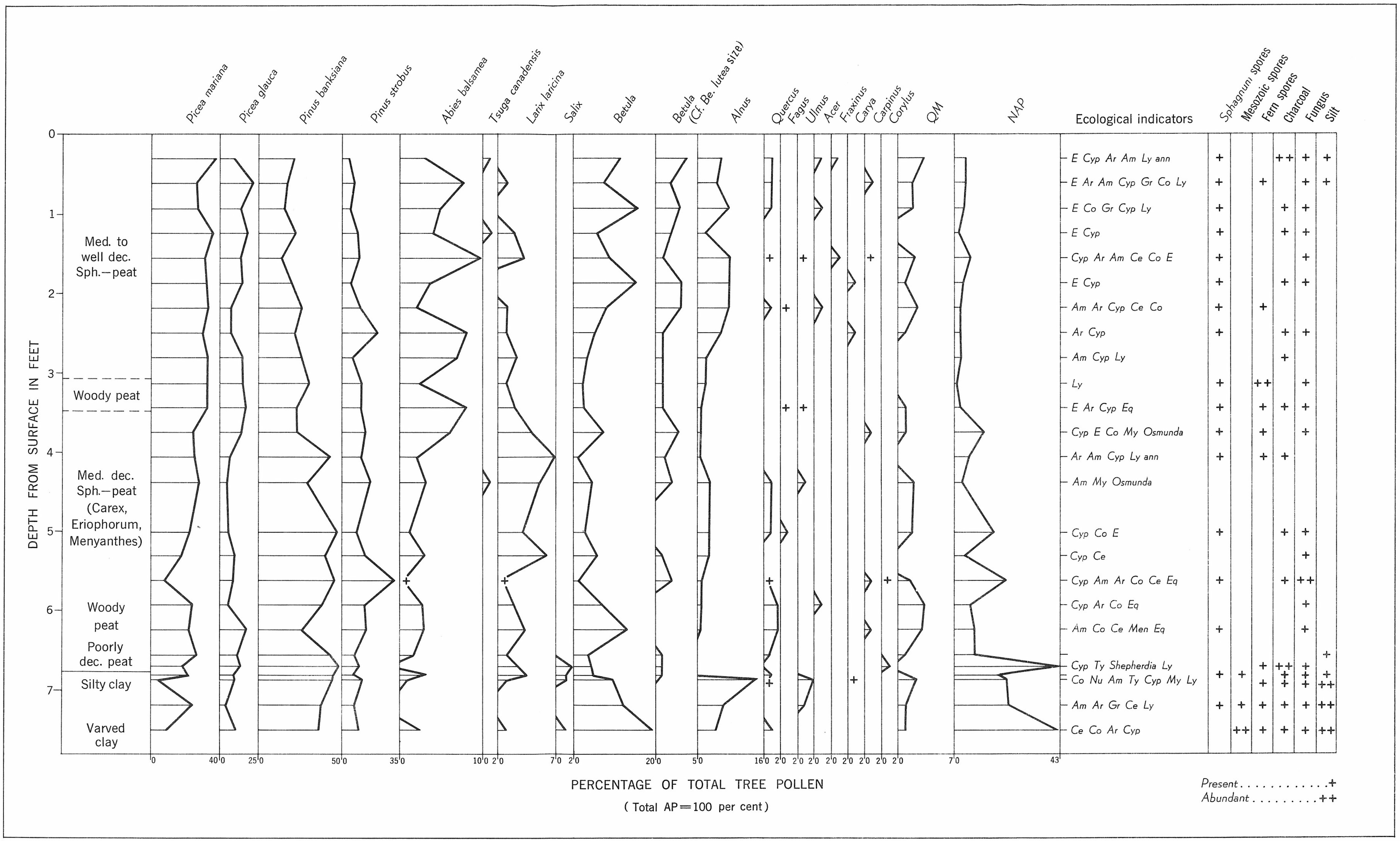
Figure 4. Pollen diagram of the Ogoki Post bog

Printed by the Surveys and Mapping Branch



Printed by the Surveys and Mapping Branch

Figure 5. Pollen diagram of the Attawapiskat River section



Printed by the Surveys and Mapping Branch

Figure 6. Pollen diagram of the Frederick House River bog

balsamifera) and white birch (*Betula papyrifera*) occur, in quality similar to those within the Northern Clay Section. The south James Bay area contains most of the exploitable timber resources, and logging activity for lumber and pulpwood is largely confined to areas in the vicinity of the major rivers there. Here also are found outposts of such species as white elm (*Ulmus americana*), black ash (*Fraxinus nigra*) and Eastern cedar (*Thuja occidentalis*). Jack pine (*Pinus banksiana*) is sparingly present. Northwestward the percentage of peatland and of lakes increases, and the prevalent forest is of stunted open-growth black spruce and tamarack. On the west side of James Bay, as on the coast of Hudson Bay in general, black spruce does not appear to be as well adapted to the sea-shore environment as white spruce, and the latter species forms the maritime tree line.

The pollen diagram of the Frederick House River bog (Fig. 6) has been included to illustrate the history of the vegetation south of the James Bay Lowlands.

CHRONOLOGICAL POSITION OF THE MISSINAIBI BEDS

A comparison of the pollen diagrams of the Missinaibi beds with those of the post-glacial deposits in the James Bay Lowlands shows that the vegetation during the deposition of the Missinaibi beds was similar to that now present in the region. The generally lower percentages of balsam fir, white pine, and hardwood pollen in these beds and the absence of large-sized birch pollen (*Betula lutea*?) may indicate a somewhat cooler climate during that interval than now; there is certainly no indication in the palynological data that the climate was warmer.

Palynological studies made (Terasmae, 1959) in southern Ontario, St. Lawrence Lowlands, and Northern Canada have shown that as these studies are extended northward it is progressively more difficult to distinguish interglacial and interstadial deposits on the basis of palynological and palæobotanical evidence. The type of vegetation in southern Ontario, rich in species, is much more sensitive to climatic changes than that of the broad boreal and subarctic regions; hence, a change of climate and corresponding forest type is readily detected by palynological means in southern Ontario, whereas a change of climate of similar magnitude in the James Bay Lowlands may not be detected.

Several radiocarbon dates obtained for the Missinaibi beds have shown an age greater than 38,000 years (Terasmae, 1958), and preliminary information supplied by de Vries (personal communication) indicates probable radiocarbon age of more than 53,000 years (GRO 1435).

Palynological studies (Terasmae, 1960) suggest a warmer climate during at least part of the interglacial stage, represented by the Don beds at Toronto, than the present. As there is no evidence that the climate during deposition of the Missinaibi beds was warmer than the present and, as inferred from the studies made, the time interval was rather short (Terasmae, 1958), an interstadial rank is proposed for the Missinaibi beds.

This proposed interstadial rank leads to the conclusion that the Missinaibi beds are older than the recognized Wisconsin glaciation, and yet these beds are apparently younger than the recognized Sangamon Interglacial stage (Prest, 1957). This controversy surely suggests that further studies of this problem should be made and that the present subdivisions of the Wisconsin may be in need of revision.

REFERENCES

Auer, V.

1927: Botany of the Interglacial Peat Beds of Moose River Basin; *Geol. Surv., Canada,* Sum. Rept. 1926, pt. C, pp. 45-47.

Baldwin, W. K. W.

1958: Plants of the Clay Belt of Northern Ontario and Quebec; *Nat. Mus. Can.,* Bull. 156.

1959: Botanical Excursion to the Boreal Forest in Northern Quebec and Ontario; *Guidebook* for Field Trip No. 7, *IX Intern. Bot. Congress,* Montreal.

Bell, J. M.

1904: Economic Resources of Moose River Basin; Rept. *Ont. Bur. Mines,* vol. 13, pt. 1, pp. 135-179.

Bell, R.

1879: Report on an Exploration of the East Coast of Hudson's Bay; *Geol. Surv., Canada,* Rept. Prog. 1877-78, pt. C, pp. 1-37.

Canada Dept. North. Affairs Nat. Res.

1958: A Forest Classification for Canada. Revision of Forestry Br. Bull. 89, Forest Res. Div.

Dyer, W. S.

1929: Geology and Economic Deposits of the Moose River Basin; *Ont. Dept. Mines,* Rept. 1928, vol. 37, pt. 6.

1930: The Onakawana Lignite Deposit, Moose River Basin; *Ont. Dept. Mines,* Rept. 1930, vol. 39, pt. 6, pp. 1-14.

Hughes, O. L.

1956: Surficial Geology of Smooth Rock, Cochrane District, Ontario; *Geol. Surv., Canada,* Paper 55-41.

Keele, J.

1920: Clay and Shale Deposits of the Abitibi and Mattagami Rivers; *Ont. Dept. Mines,* vol. 29, pt. 2, pp. 31-51.

Kindle, E. M.

1924: Geology of a Portion of the Northern Part of Moose River Basin; *Geol. Surv., Canada,* Sum. Rept. 1923, pt. C1, pp. 21-41.

Leopold, E. B.

1956: Pollen Size-Frequency in New England Species of the Genus *Betula; Grana Palynologica,* vol. 1, No. 2, pp. 140-147.

McLearn, F. H.

1927: The Mesozoic and Pleistocene Deposits of the Lower Missinaibi, Opasatika, and Mattagami Rivers, Ontario; *Geol. Surv., Canada,* Sum. Rept. 1926, pt. C, pp. 16-44.

Prest, V. K.

1957: Pleistocene Geology and Surficial Deposits (Chap. VIII in "Geology and Economic Minerals of Canada" *by* C. H. Stockwell); *Geol. Surv., Canada,* Econ. Geol. Ser. 1, pp. 444-445.

Rouse, G. E.
1956: The Disclosure and Palaeobotanical Evaluation of Plant Microfossils from Selected Cretaceous Coal-bearing Strata of Canada; Unpub. Ph.D. thesis, McMaster Univ., Hamilton.

Sjörs, H.
1959: Bogs and Fens in the Hudson Bay Lowlands; *Arctic,* vol. 12, No. 1, pp. 3-19.

Terasmae, J.
1957: Paleobotanical Studies of Canadian Pleistocene Nonglacial Deposits; *Science,* vol. 126, No. 3269.
1958: Contributions to Canadian Palynology, Pt. III, Non-Glacial Deposits along Missinaibi River, Ontario; *Geol. Surv., Canada,* Bull. 46, pp. 29-34.
1959: Palynological Designation of Interglacial and Interstadial Intervals; *Proc. IX Intern. Bot. Congress,* Abstracts, vol. 2, p. 395.
1960: Contributions to Canadian Palynology, Part II—A Palynological Study of the Pleistocene Interglacial Beds at Toronto, Ontario; *Geol. Surv., Canada,* Bull. 56.

Williams, M. Y.
1921: Palaeozoic Stratigraphy of Pagwachuan, Lower Kenogami, and Lower Albany Rivers, Ontario; *Geol. Surv., Canada,* Sum. Rept. 1920, pt. D, pp. 18-25.

Wilson, W. J.
1903: Reconnaissance Surveys of Four Rivers Southwest of James Bay; *Geol. Surv., Canada,* Sum. Rept. 1902; Ann. Rept. 1902-3, pp. 222A-243A; Map 814.

Appendix

LIST OF ABBREVIATIONS

Pollen grains

AP —arboreal pollen

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

NAP—non-arboreal pollen

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

Spores

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

Miscellaneous

D —Diatoms
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.)
Sp —Sponge spicules