A pollen-stratigraphic study of late-Quaternary vegetational change at Porter's Lake, Nova Scotia, with reference to marine intrusion.

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Submitted in partial fulfillment of requirements for an honours Bachelor of Science degree at Dalhousie University

March 6, 1986.

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ABSTRACT

Late-Quaternary sea level rise has caused two marine intrusions into Porter's Lake, Nova Scotia (Smith, 1984), resulting in an interesting ecological history. Stratigraphic studies of the lake include work on diatoms and Arcellaceans (thecamoebians). Pollen stratigraphy of one 10-m. core (PL-4) is carried out to add detail to knowledge of late-Quaternary climate and vegetation in Nova Scotia, and to see whether the pollen record reflects changes in hydrology or the watershed subsequent to marine intrusion. The pollen diagram from Porter's Lake is similar to that from Penhorn Lake, a nearby freshwater lake. No conclusive evidence of marine intrusion is recorded in the core.

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INTRODUCTION

Palynology

Pollen analysis, or palynology, is the most widely used technique in reconstructing past vegetation and climate (Ogden, 1961). Pollen is abundant and identifiable, and reflects vegetational assemblages quantitatively. Pollen is produced by flowering plants in large quantities every spring, and transported by wind, water, birds, insects, or other animals. Pollen usually falls to the ground within 50km. of the source (Livingstone, 1968), although some grains may travel for tens or even hundreds of kilometers (Ogden, 1971). Some pollen falls into the anaerobic environment of bogs and lake bottoms, where it is not subject to oxidation, and is preserved in the stratigraphic record.

Pollen is more amenable to quantitative techniques than are macrofossils such as leaf fragments, twigs, and so on. The major obstacle to drawing meaningful interpretations from pollen counts is differential production, dispersal, ballistics, sedimentation, and preservation (Ogden, 1977). Efforts to devise appropriate statistical treatments have attracted numerous workers, including Davis (1960), Ogden (1969), Mosimann and Greenstreet (1971), and Davis and Webb (1975). Despite the difficulties mentioned, regional similarities in vegetational cover are recorded with surprising consistency in the pollen record. At the same time, the record is highly sensitive to local differences in vegetation (Livingstone, 1968).

Reason for Study

The study area, Porter's Lake, is a coastal lake which has twice undergone marine intrusions (Smith, 1984). The earlier one is thought to have occurred later than 6000rybp (Ogden, pers. comm.) and the second about 550-300rybp (Smith, 1984). The lake is now connected to the Atlantic Ocean through a narrow silled channel. Largely because of this history, several types of study of the lake are being done by Dr. F. Medioli, Dr. J. G. Ogden III, and Dr. D.B. Scott and their students at Dalhousie University. B. Laidler is currently studying thecamoebian (Arcellacean) stratigraphy, and D. Smith (1984) studied diatom stratigraphy. With the current analysis, Porter's Lake will become one of the most intensively studied sites in Eastern Canada (Ogden, pers. comm.).

The purpose of this study is to provide and interpret a pollen diagram from a core in Porter's Lake, thus adding detail to the knowledge of late-Quaternary climate and vegetation in Nova Scotia. Interpretation is done largely with reference to nearby (within 35km) lakes and the Bedford Basin. A goal is to detect anomalies in the pollen record which might reflect hydrological changes after marine intrusion.

Interpretation of Pollen Data

There are three major ways of interpreting pollen data. In the first, pollen spectra (pollen assemblages at given times) are matched with surface spectra of regions whose climate and vegetation are known. In the second, pollen abundances are related to vegetational abundances at the same time, by statistical means based on "a satisfactory understanding of the production of pollen by vegetation, the dissemination of the pollen, and its preservation in the sediment" (Livingstone and Estes, 1966). The third method is to qualitatively identify trends in climate and vegetation by a knowledge of the type of environment each pollen type represents, and is the method employed in this study. 4 sites - Penhorn Lake, Bedford Basin, Silver Lake, and Bluff Lake - are extensively used for comparative purposes (Fig.1, Fig.3).

Previous Work

Von Post performed the first modern percentage pollen analysis in Oslo in 1916 (Faegri and Iversen, 1964). Eastern Canada was the first part of North America to be studied by pollen analysis (Auer, 1927; 1930; 1933). Early work in Nova Scotia included studies by Livingstone and Livingstone (1958); Livingstone and Estes 1967; Killam (1951); Ogden (1960); and others. Many of these studies are summarized by Livingstone (1968). More recent investigations in Nova Scotia include those by Railton (1972); Hadden (1975); Green (1976); Miller *et al* (1982); and Ogden (pers. comm.). At present there is a total of approximately 25 pollen stratigraphic sequences with 67 radio carbon dates for Nova Scotia (Ogden, pers. comm.).

Study Area (After Smith, 1984)

Porter's Lake is located 25km. northeast of Halifax, N.S. (Fig.1). It has a tidal connection with the Atlantic Ocean through a narrow silled channel (Rocky Run), and extends about 15km. inland. Its maximum width is 2.8km. Porter's Lake has a surface area of 19 square km, and a watershed area of 148 square km.

The area has a cool, moist, temperate climate with approximately 140cm. of precipitation annually. The mean temperature is -5°C to -7.5°C in January and 12.5°C to 15°C in July (N.S. Dept. of Lands and Forests, 1977). The forest vegetation is predominantly spruce and fir near the coast, and spruce, fir, and hemlock farther inland.

The lake is composed of 4 major basins separated from each other by shallow sills and/or narrow passages (Fig.3). Basin 1 is the northernmost basin. Basin 4 discharges into the Atlantic Ocean over a 1m. deep sill at Rocky Run. Most of the fresh water in the lake comes from the watershed of Basin 1. Seawater has infiltrated the entire lake (Elliott, 1978). Salinities average 1ppt. in Basin 1. This is very low compared with seawater, which is about 30ppt, (Miller _et al_, 1982), but high compared with most Nova Scotia lakes. A pronounced halocline exists in most vertical sections of the lake, with salinities at least 5 times greater at 10-15m. depth than at the surface.

The Porter's Lake watershed is underlain by Cambro-Ordovician metasediments and by Carboniferous granite. The bedrock

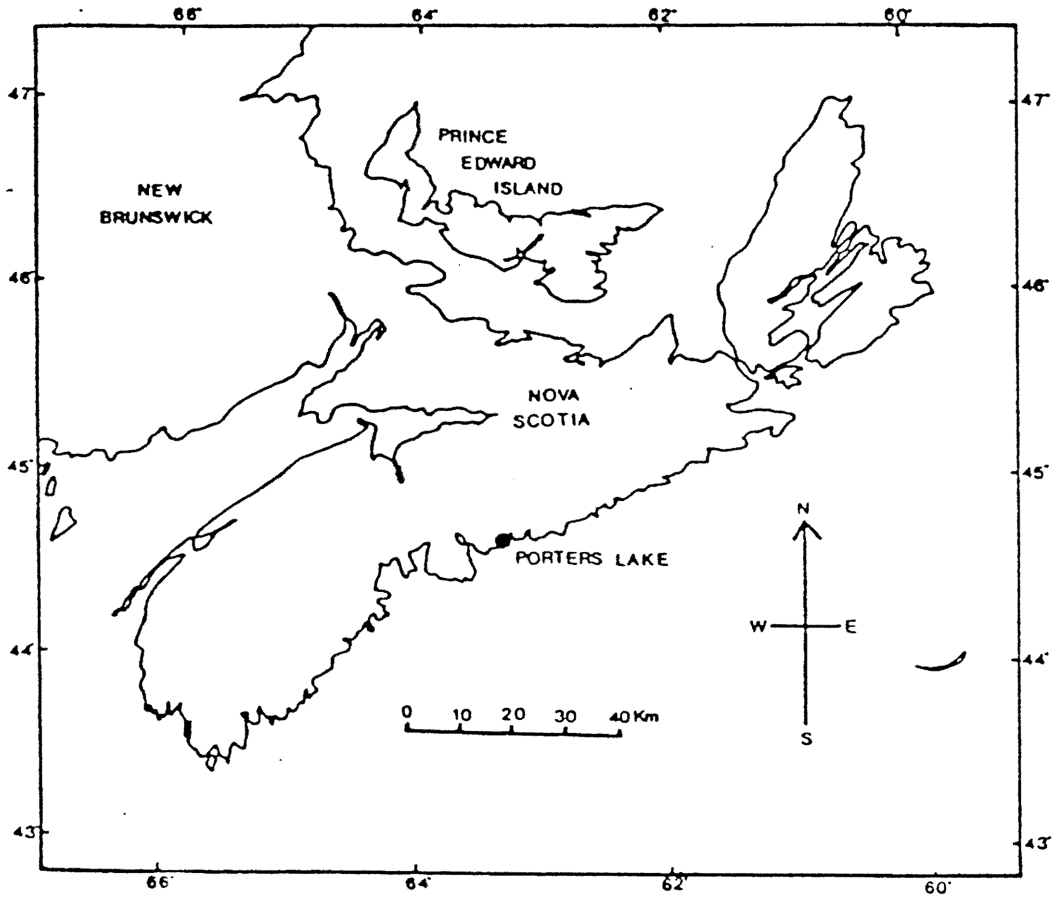
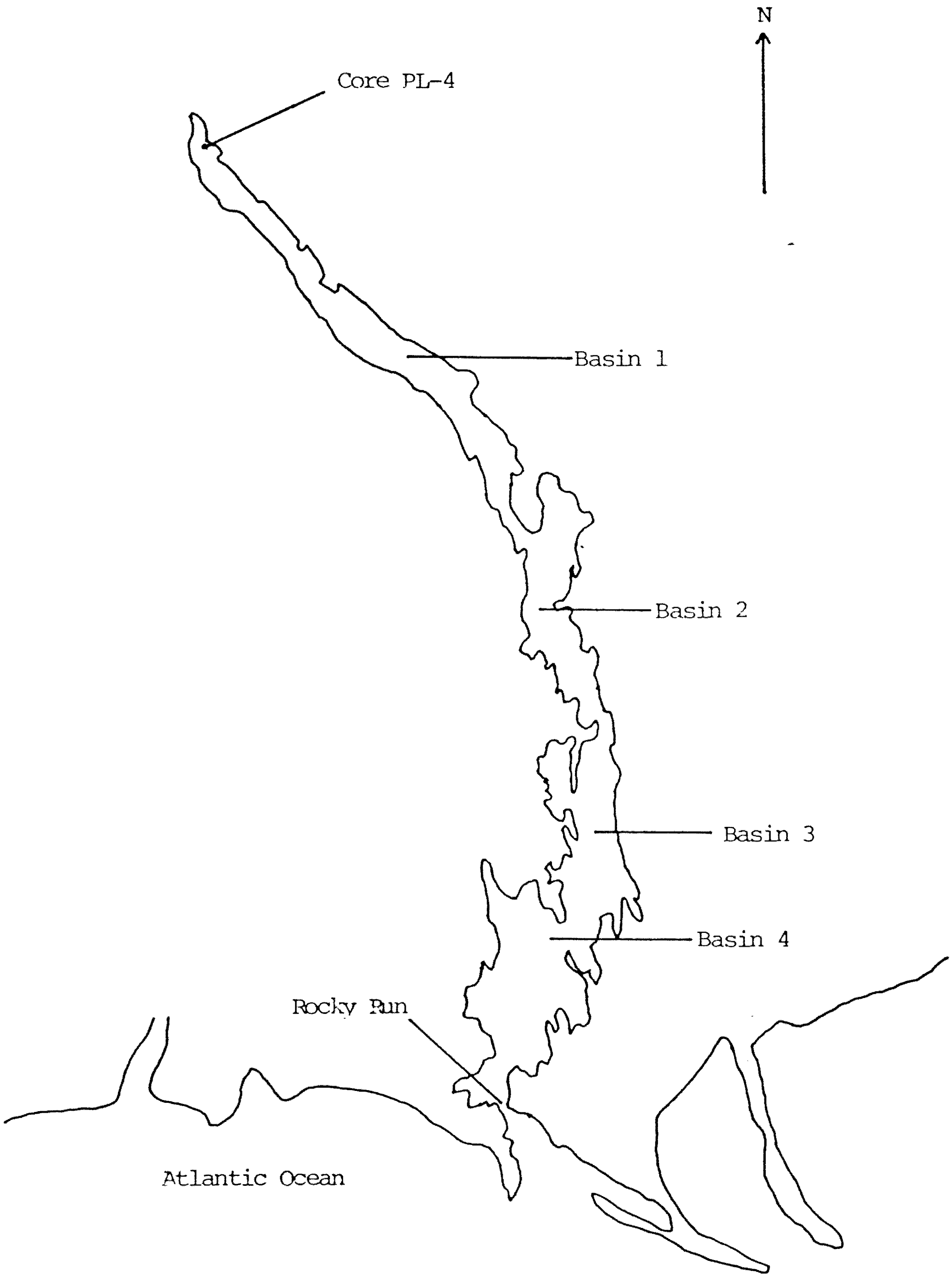


Figure 1. Location map of Porter's Lake, Nova Scotia. (Smith, 1984)

Figure 2. Porter's Lake (after Smith,1984)



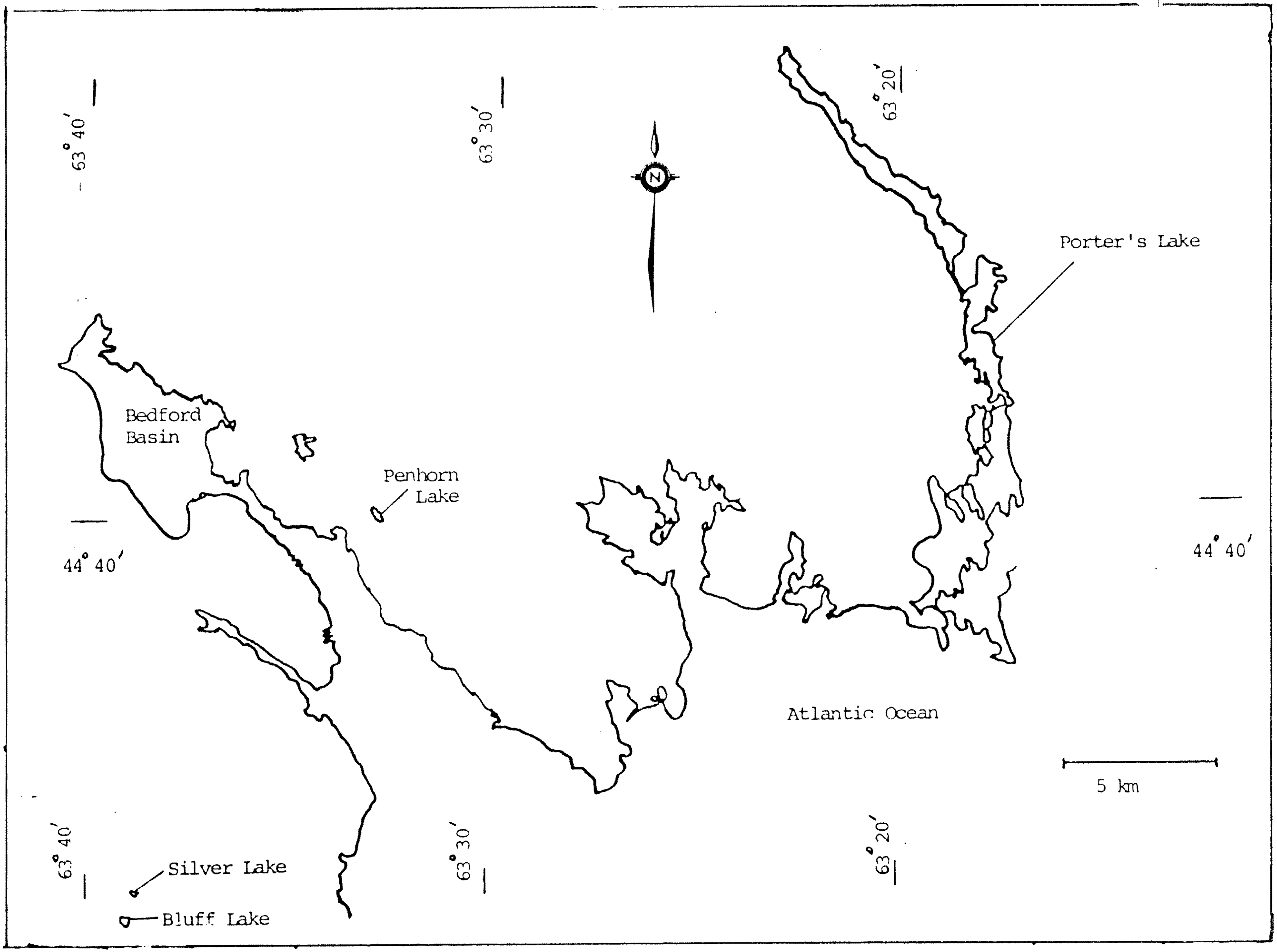


Fig. 3. Location map of Penhorn Lake, Bedford Basin, Silver Lake, Bluff Lake

is overlain by glacial till deposited during the most recent glaciation, the Wisconsinan. The glaciation deposited a terminal moraine 30-40km off the southern shore of Nova Scotia at about 18,800y.b.p. (King, 1969). Deglaciation occurred in southern Nova Scotia about 10,000-12,000ybp (Prest and Grant, 1969).

Sampling Procedure

A 1052cm. core was collected by D.B. Scott and B.R. Laidler in October, 1982. The core(core PL-4), was taken from the northernmost end of Basin 1 (Fig.3) using a square-rod Livingstone corer at a water depth of 13.6m. When extruded, the top 10cm. of the core was found to be unconsolidated and was poured off in 3cm. intervals. Beginning at 21cm. depth and every 20cm. thereafter, samples of about $9cm^3$ were taken and stored under refrigeration in glass vials.

Laboratory and Mounting Procedure

2 subsamples of $1.0cm^3$ or $2.0cm^3$ each were taken from each level, using a stainless steel volumetric sampler. One subsample from each level was used for loss on ignition analysis. This was dried at 105°C for 24-48 hours in a tared porcelain crucible and then weighed. The sample was then ashed in a muffle furnace at 420°C for 4-6 hours and reweighed. The difference between the two weights is the loss on ignition and is expressed as a percent of the dry weight of the sediment.

The second subsample was suspended in 5%KOH (to deflo-culate) and passed through a 110μm nylon screen, using suction. The residue remaining on the screen was washed through with 30-70 ml of distilled water delivered from a spray bottle. The remaining procedure consists of a series of chemical treatments designed to deflocculate sediment (10%KOH), remove carbonate (10%HCl), remove silicate (48-52%HF), and remove cellulosic material (acetolysis). Fig.4 is a checklist of all the steps involved. As noted, some steps were not always required. "CWC" denotes centrifuging at 2100rpm for 5-6 minutes, rinsing with distilled water, and centrifuging again for 5-6 minutes at 2100rpm. 5ml x 5600/ml of 25μm microspheres were added to each sample either after sieving or after the first treatment with KOH, for use in another study (Ogden, 1986).

Before mounting, enough distilled water was added to each sample to give a volume of approximately 1ml. This was to facilitate later estimation of Absolute Pollen Frequency (APF). Approximately 0.01 ml of pollen sample was transferred to each microscopic slide using a 145mm. Pasteur pipette. Just enough basic fuchsin-glycerine jelly was added from the tip of a small steel spatula to support a 22mm. square coverslip. The sample and jelly was thoroughly mixed with the spatula before applying the coverslip. Slides were labelled as to core depth and stored at room temperature.

Any modifications in the skill of the investigator with experience are not cumulative through the core, as the last batch

SEDIMENT PREPARATION

Core ____________ Field Book ____________

Date ____________ Sample Size ____________

Sample treatment: Prepared by:

Sample no.								
Depth cm.								
Tube no.								
Sieve								
Sed. disc								
KOH 10%								
cwc								
HCl 10%								
cwc								
HF 48%								
cwc								
HCl 10%	This step is usually omitted for lacustrine samples.							
cwc								
Acetic ac.								
Acetolysis								
Acetic ac.								
cwc								
KOH 10%								
cwc								
95% EtOH	This step and the following five apply to a different							
100% EtOH	mounting procedure than the one used for this study.							
Stain								
Acetone								
Benezene								
Silic. Oil								
Mount	In basic fuchsin-glycerine jelly							
Store								

Loss on Ignition:

Cruc. no.	Sample no.	Depth cm.	Gross Dry wt.	Tare	Gross Ign. wt.	Tare	Ign. wt.	Loss on Ign.	% Loss	Color ash

Figure 4. Laboratory Checklist.

of 8 samples to be processed and counted spans 700cm of core.

Counting Procedure

Counting was performed at a magnification of 250X using a Leitz Ortholux microscope, or at 630X for difficult identifications. At least 200 grains were counted per slide, except near the bottom of the core where the scarcity of pollen grains made it impossible. In most slides, 300-400 grains were counted. Ogden (1977) found that where the number of pollen grains is reasonably high (eg. ca.300 or more pollen grains), changes in rank order drop to less than 5%, as counting incremental totals increase. At depths greater than 862cm., pollen densities were too low to allow statistically useful counts even after many traverses, so a maximum of 10 traverses per slide was counted. Traverses were approximately evenly spaced across the slide, with care given to obtaining counts near the edges and middle of the slides in case of uneven distribution of larger or smaller grains. Microspheres were counted, along with about 20 of the most abundant pollen and spore types (Fig.5).

Pollen Identification

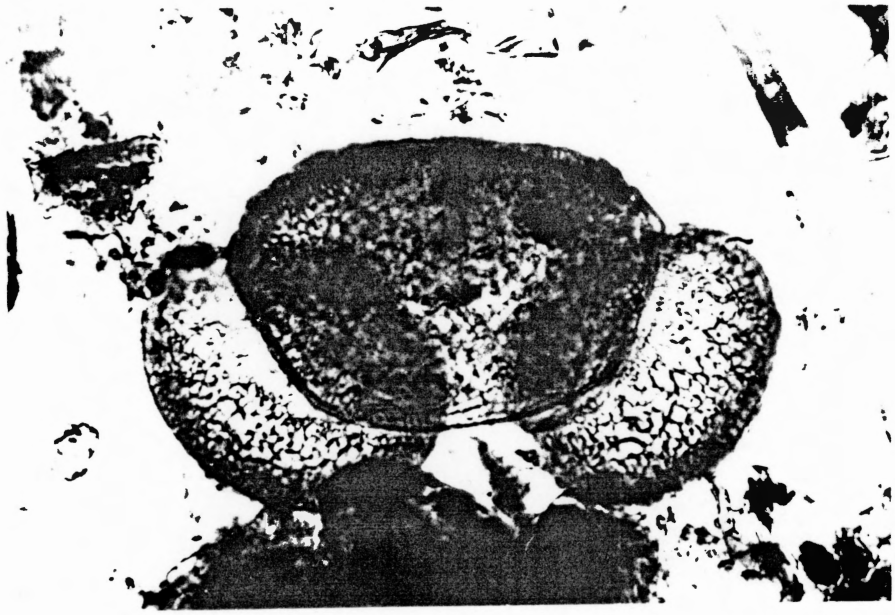
Pollen grains were identified mainly on the basis of overall shape, size, presence or absence of bladder, number and configuration of pores and furrows, sculpturing of the exine (external covering), and shape of the exine adjacent to pores. No attempt was made to become familiar with pollen microstructure;

it was considered sufficient to be able to differentiate among about 20 of the more abundant pollen types found in the area, and to recognize when a grain did not fit into that category. Ogden (1977) has shown that the use of 18 pollen types accounts for 69% of pollen types and 92% of the pollen sum at 44-45°N. References used in pollen identification included Bassett et al (1978), McAndrews et al (1973), Ogden (1984), Ogden (mimeo., 1967), Ogden (pers. comm.) and reference slides.

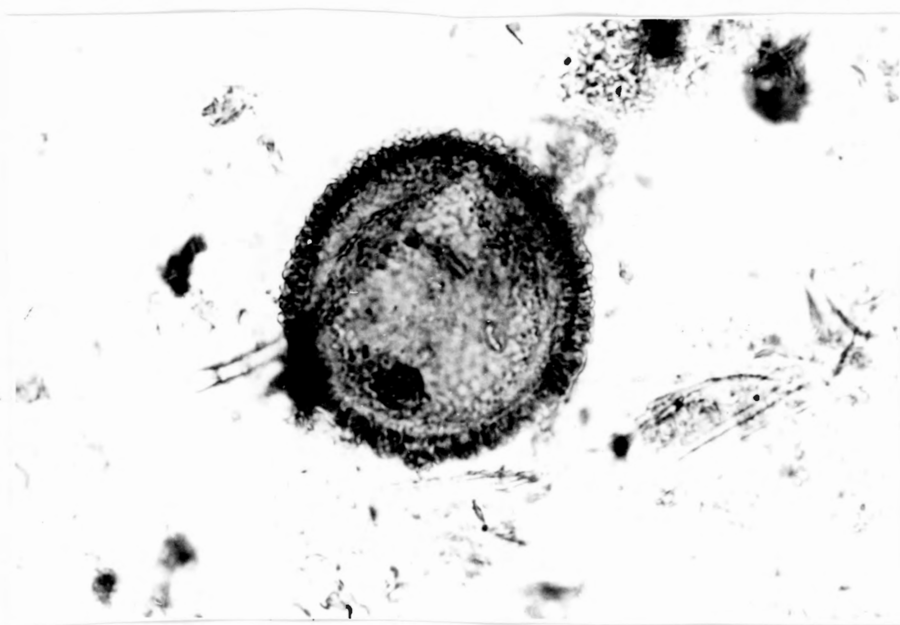
Absolute Pollen Frequency (APF)

APF was determined by increasing sample volume to 1ml before slide preparation. Thus, the 0.01ml transferred to the slide represents 0.01 of the pollen density of the original $1cm^3$ subsample.

45.36 traverses cover a $22mm^2$ area at 250X (field of view = 0.485mm). APF for a 1ml sample is obtained by multiplying the average number of grains per traverse by (45.36 x 100).



Abies balsamea (Balsam fir)
(160 μm long)



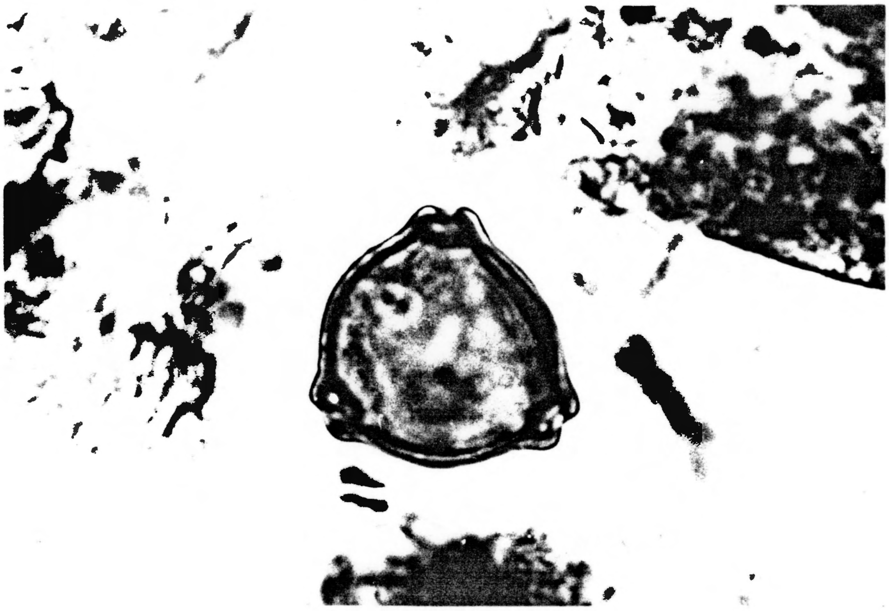
Tsuga canadensis (eastern hemlock)
(80 μm)

Fig. 5. Some pollen types common in PL-4

Picea sp. (Spruce)
(95 μm long)

Pinus sp. (Pine)
(80 μm long)

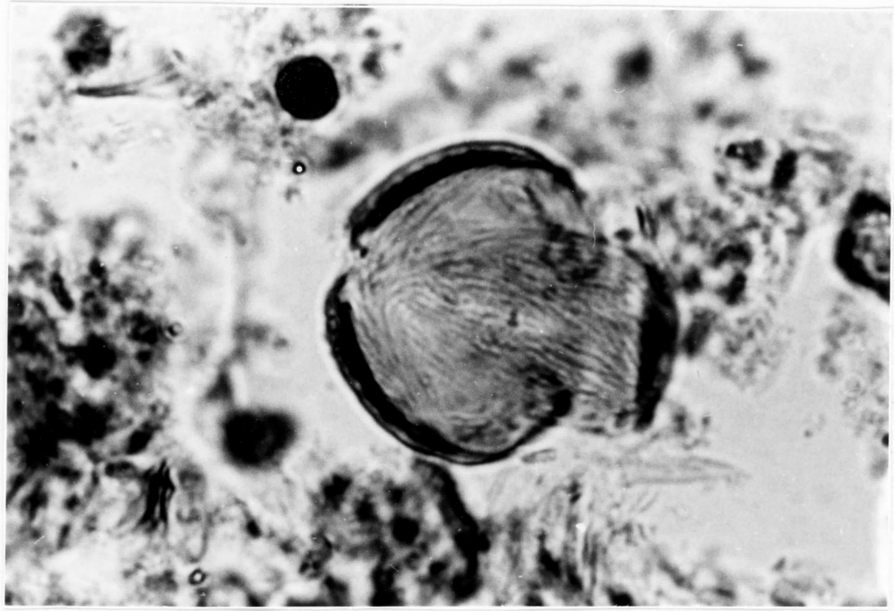
Fig. 5. Some pollen types common in PL-4



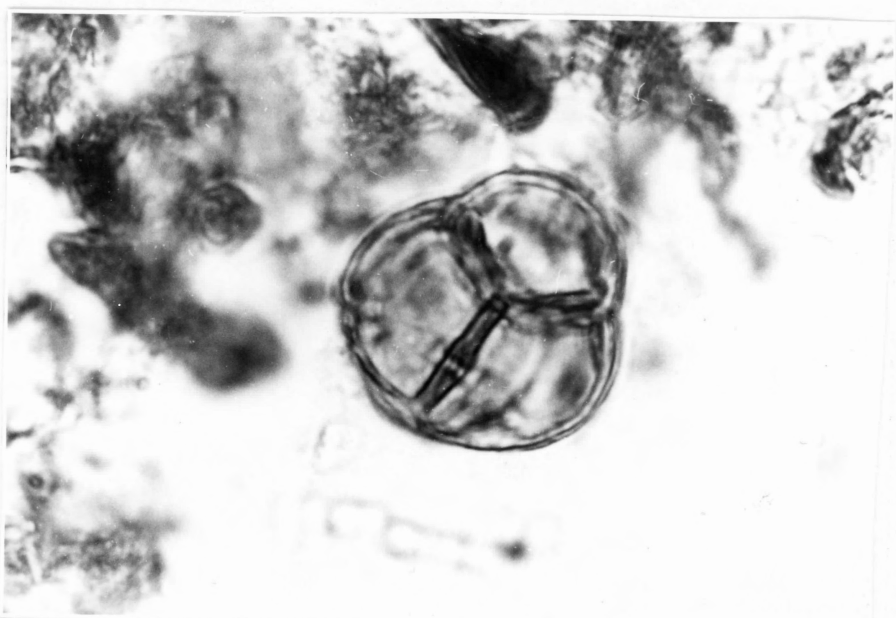
Betula sp. (Birch)
(25µm)

Carpinus sp. (Ironwood)
(29µm)

Fig. 5. Some pollen types common in PL-4

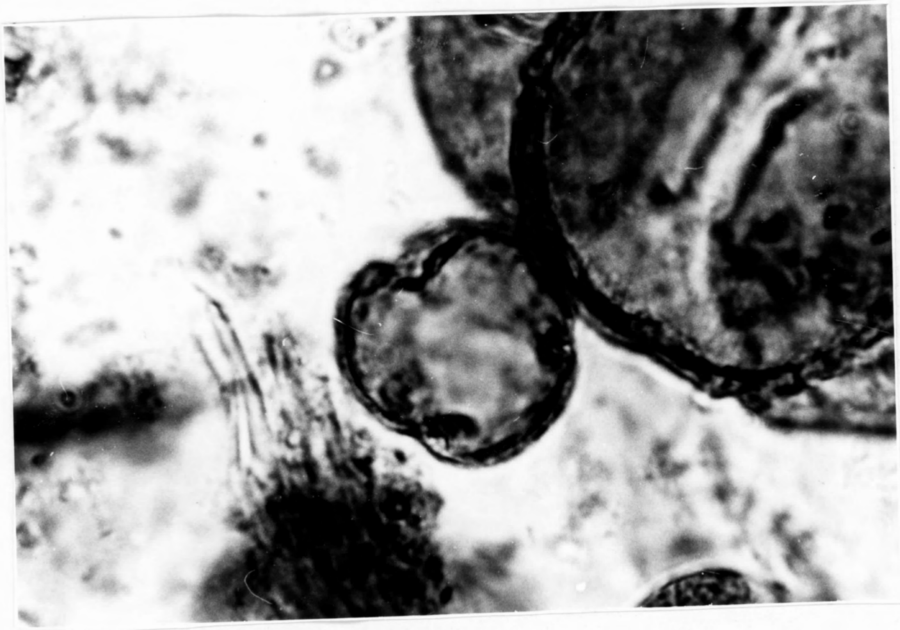


Acer sp. (Maple)
(30 µm)

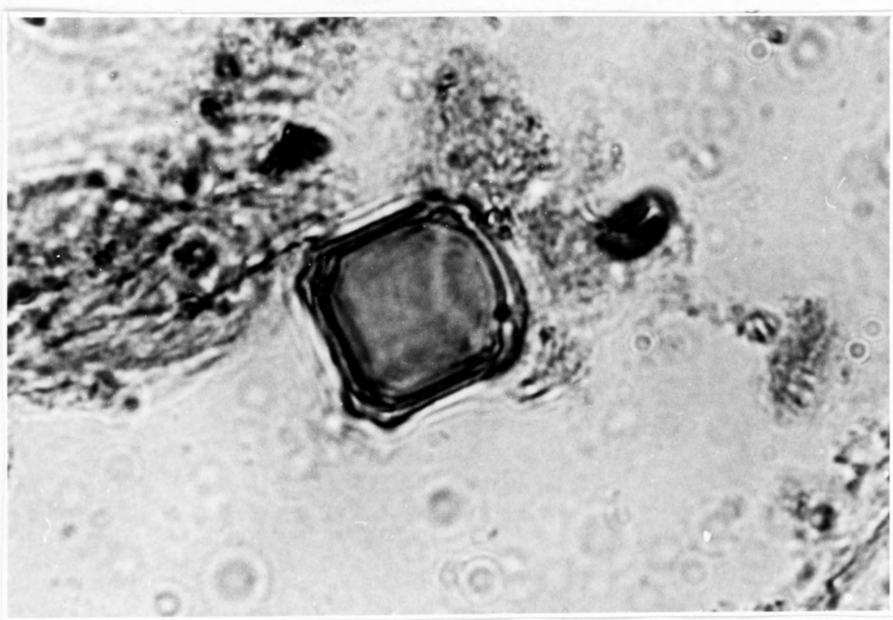


Ericaceae (Heath family)
(25 µm)

Fig. 5. Some pollen types common in PL-4

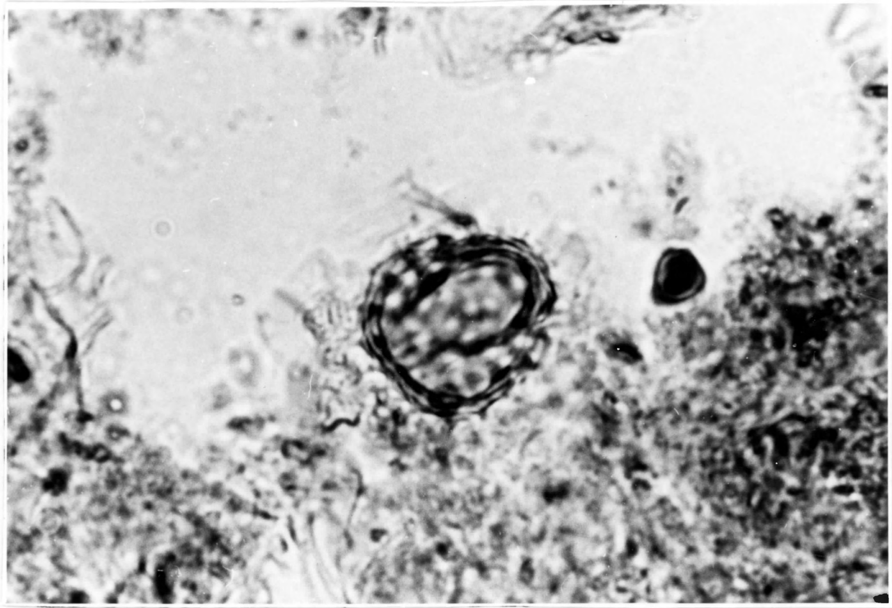


Quercus rubra (Red Oak)
(21 μm)

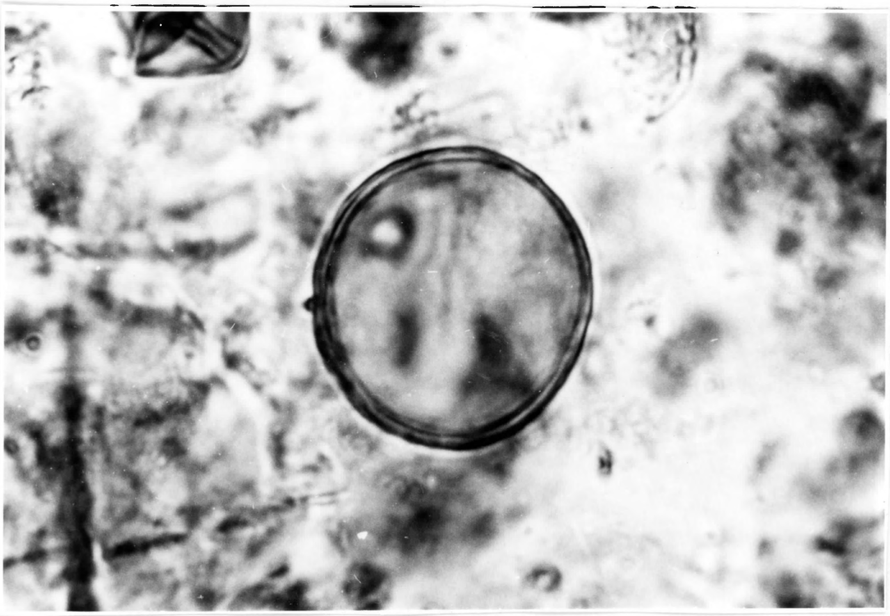


Alnus sp. (Alder)
(18 μm)

Fig. 5. Some pollen types common in Pi-

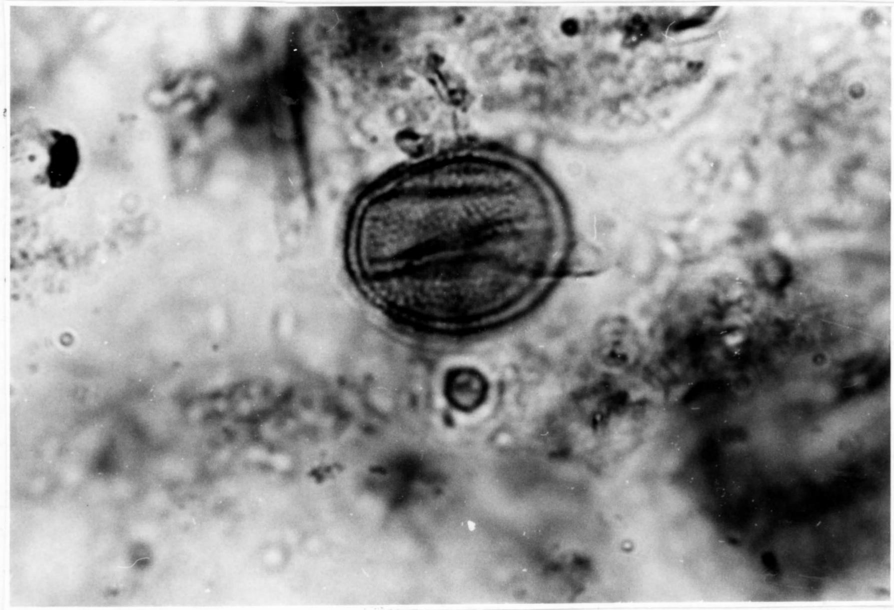


Compositae (Composite family)
(15 μm)



Graminae (Grass family)
(28 μm)

Fig. 5. Some pollen types common in PL-4



Fraxinus sp. (Ash)
(20 µm)

Fig. 5. Some pollen types common in PL-4

RESULTS

Sediment Stratigraphy

The stratigraphy of core PL-4 spans a period from 10,000 -0rybp, during which clay-rich mud was replaced by organic-rich mud. The contact between sediment types is unknown because the core was described from samples taken at 20 - cm intervals. Figure 6 shows the gross features of the core.

The base of the core (1052cm, about 10,000rybp) is of light olive brown silty mud which is overlain by light red-brown clay-rich mud at 1021cm (9750rybp). This grades into a light brown mud at 961cm (9500rybp) and to medium brown mud by 921 cm (9300rybp). The core is of dark brown organic mud from 862 cm (9000rybp) to the surface (0rybp). This mud is typical of lacustrine sedimentation, and is not visibly interrupted in any way, as might be expected from a marine intrusion.

Carbon - 14 Age Determination, and Sedimentation Rate

A single radio carbon date for core PL-4 gave an age of 6930±250rybp at 855-859cm. depth (Lab no. GX-9528). An average sedimentation rate using this age is 1.2mm/yr, which would result in the time scale at the left hand side of Fig.6. Correlation of the Porter's Lake pollen diagram with diagrams from Penhorn Lake, Silver Lake, Bluff Lake, and Bedford Basin makes it clear that such a time scale is improbable. The time scale at the right hand side of Fig.6 was arrived at by comparison with the above named diagrams and is the only one used in this study.

Loss on Ignition and Absolute Pollen Frequency

Loss on ignition (LOI) and Absolute Pollen Frequency (APF) results are summarized in Table 4 and Fig.6. LOI indicates a maximum in organic sedimentation (43%) at about 8000-7000 rybp. Organic content decreases toward the top of the core (18% at 0cm), and more sharply at the bottom (~1% at 950cm, or 9500rybp).

Absolute Pollen Frequency (APF) values are approximate. The curve resembles the LOI curve, recording relatively sparse pollen at the top and bottom of the core.

The Pollen Diagram

The pollen zones identified originally by Deevey (1957) and used extensively by palynologists in Nova Scotia (eg. Livingstone and Livingstone, 1958; Livingstone, 1968; Hadden, 1975, Miller *et al*., 1982) are applicable to the Porter's Lake pollen diagram. Livingstone defined the pollen zones for Nova Scotia as follows:

Zone C: Mixed temperate hardwood and hemlock.
Zone B: Pine with spruce and fir.
Zone A: Spruce and fir with pine.
Zone L: Sedge and willow with major or minor birch.

It is possible that the bottom of the Porter's Lake diagram represents the end of Livingstone's Zone L, but the data base is too small below 860cm to make any meaningful interpretation. The earliest pollen zone which is identifiable on the diagram is Zone A.

TABLE 1 Loss on Ignition and Absolute Pollen Frequency (APF)

Depth (cm)	Loss on ignition (%)	APF
3-5	17.0	4.2×10^4
21	22.6	8.1×10^4
61	30.0	1.3×10^5
121	40.0	1.1×10^5
161	29.5	1.6×10^5
201	37.4	1.8×10^5
261	26.7	2.1×10^5
361	31.0	1.7×10^5
441	45.4	1.3×10^5
481	37.3	-
501	36.4	1.8×10^5
541	41.0	1.3×10^5
581	31.1	-
601	35.0	1.5×10^5
661	21.8	1.9×10^5
721	-	1.6×10^5
761	40.3	2.9×10^5
821	29.0	1.3×10^5
862	12.2	8.3×10^4
899	5.2	1.7×10^4
921	4.6	2.7×10^4
941	0.7	3.0×10^3
961	0.5	1.8×10^3

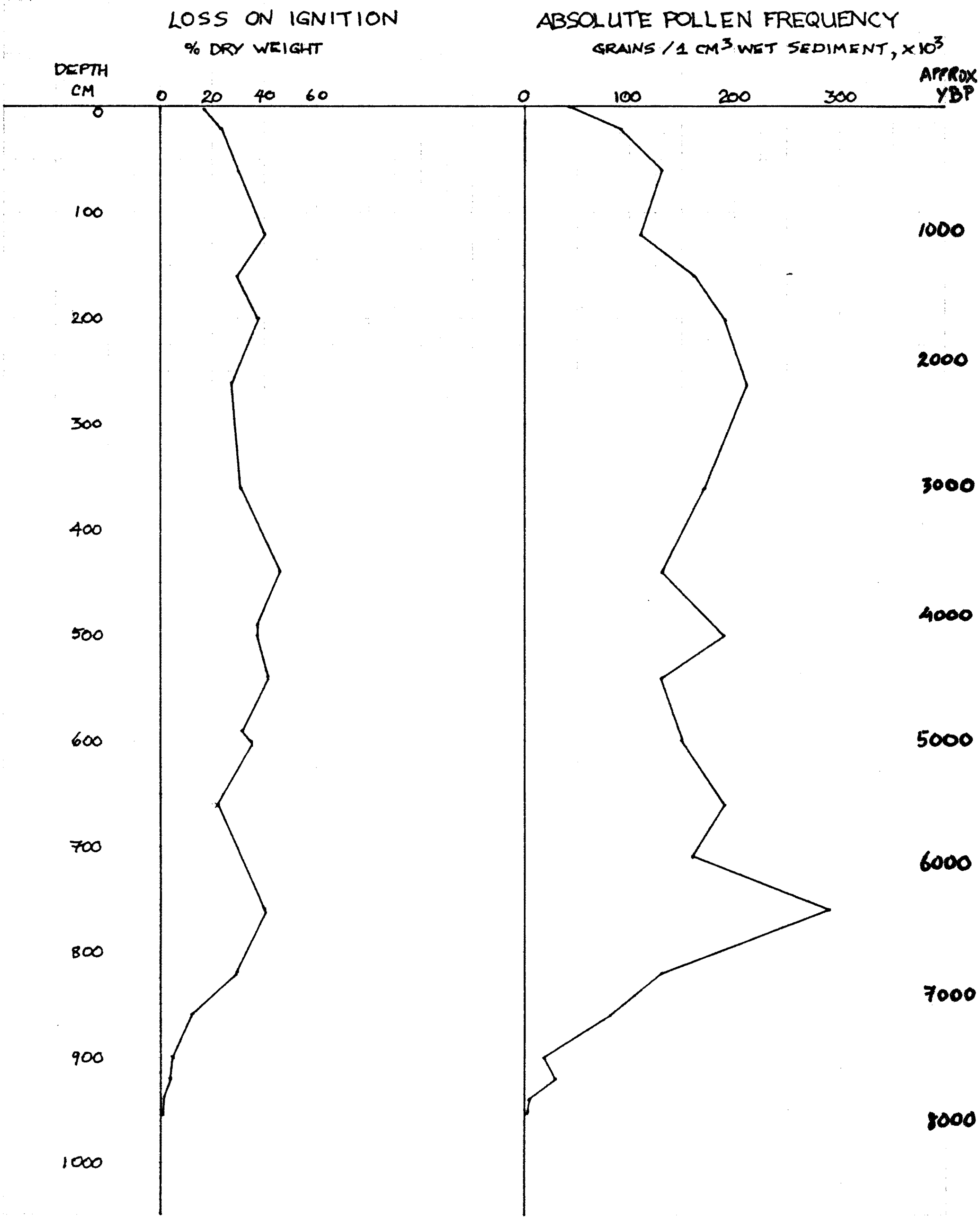


Fig. 6. Loss on ignition, Absolute Pollen Frequency

Table 2. Raw pollen data for 21 samples in PL-4

RAW POLLEN DATA FOR 21 SAMPLES

ID	DEP	AB	LAR	PIC	PIN	TSU	ACR	BET	CRP	CRY	FAG	FRX	JUG	POP	QUE	TIL	ULM	ALN	MYR	SAL	ERI	COM	CYP	GRS	SPH
PL4	3	5.	0.	67.	58.	10.	3.	24.	4.	0.	0.	0.	0.	0.	14.	0.	1.	21.	5.	0.	2.	4.	0.	0.	298.
PL4	21	22.	0.	59.	49.	36.	1.	59.	25.	0.	0.	0.	0.	0.	13.	0.	0.	15.	12.	0.	3.	5.	0.	0.	372.
PL4	61	10.	0.	43.	76.	58.	3.	33.	7.	0.	0.	0.	0.	0.	19.	0.	0.	4.	6.	0.	0.	0.	0.	0.	260.
PL4	121	9.	0.	29.	103.	56.	1.	92.	50.	0.	0.	0.	0.	0.	26.	0.	0.	27.	0.	0.	1.	3.	5.	0.	27.
PL4	161	5.	0.	31.	41.	62.	0.	32.	11.	0.	0.	0.	0.	0.	19.	0.	0.	8.	2.	0.	1.	0.	0.	0.	66.
PL4	201	8.	0.	39.	115.	57.	7.	97.	42.	0.	0.	0.	0.	0.	29.	0.	2.	10.	0.	0.	6.	0.	2.	0.	39.
PL4	261	7.	0.	26.	46.	79.	0.	78.	19.	0.	0.	0.	0.	0.	20.	0.	0.	5.	4.	0.	0.	0.	0.	0.	50.
PL4	361	5.	0.	23.	53.	34.	0.	74.	9.	0.	0.	0.	0.	0.	6.	0.	0.	5.	4.	0.	0.	1.	0.	0.	65.
PL4	441	4.	2.	14.	190.	12.	2.	48.	46.	0.	0.	0.	0.	0.	14.	0.	0.	9.	2.	0.	1.	1.	0.	0.	19.
PL4	501	0.	0.	4.	79.	101.	6.	64.	19.	0.	0.	0.	0.	0.	26.	0.	1.	13.	2.	0.	0.	2.	3.	0.	13.
PL4	541	0.	0.	6.	133.	49.	1.	83.	10.	0.	0.	0.	0.	0.	37.	0.	1.	22.	0.	0.	0.	4.	3.	0.	2.
PL4	601	1.	0.	28.	210.	57.	1.	40.	0.	0.	0.	5.	0.	0.	39.	0.	1.	13.	1.	0.	2.	2.	3.	1.	14.
PL4	661	0.	0.	11.	135.	41.	0.	35.	8.	0.	0.	0.	1.	0.	18.	0.	0.	2.	0.	0.	0.	1.	1.	1.	67.
PL4	721	4.	0.	49.	231.	13.	0.	59.	12.	0.	0.	2.	0.	0.	37.	0.	2.	9.	1.	0.	0.	3.	2.	0.	20.
PL4	761	0.	0.	39.	178.	1.	1.	41.	3.	0.	0.	0.	0.	0.	28.	0.	1.	0.	1.	0.	0.	1.	1.	0.	55.
PL4	821	9.	0.	49.	129.	18.	0.	68.	5.	0.	0.	3.	0.	0.	16.	0.	2.	7.	1.	0.	0.	0.	1.	1.	5.
PL4	862	0.	0.	74.	48.	3.	0.	15.	14.	0.	0.	0.	0.	0.	9.	0.	0.	4.	3.	0.	3.	4.	0.	1.	141.
PL4	899	0.	0.	4.	14.	0.	1.	1.	1.	0.	0.	0.	0.	0.	2.	0.	0.	0.	2.	0.	3.	0.	0.	3.	84.
PL4	921	0.	0.	11.	13.	2.	0.	13.	5.	0.	0.	0.	0.	0.	4.	0.	0.	1.	0.	0.	0.	0.	2.	0.	104.
PL4	941	0.	0.	1.	0.	0.	0.	1.	0.	0.	0.	0.	0.	0.	2.	0.	0.	0.	0.	0.	0.	0.	0.	0.	26.
PL4	961	0.	0.	0.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	32.

LEGEND

DEP - Depth in cm.
AB - Fir (*Abies*)
LAR - Larch (*Larix*)
PIC - Spruce (*Picea*)
PIN - Pine (*Pinus*)
TSU - Hemlock (*Tsuga*)
ACR - Maple (*Acer*)
BET - Birch (*Betula*)
CRP - Hornbeam (*Carpinus*)
CYP - Hickory (*Carya*)
FAG - Beech (*Fagus*)
FRX - Ash (*Fraxinus*)
JUG - Walnut (*Juglans*)
POP - Poplar (Populus)
QUE - Oak (*Quercus*)
TIL - Basswood (*Tilia*)
ULM - Elm (*Ulmus*)
AlN - Alder (*Alnus*)
MYR - Bayberry (*Myrica*)
SAL - Willow (*Salix*)
ERI - Heath family (Ericaceae)
COM - Composite family (Compositae)
CYP - Sedge family (Cyperaceae)
GRS - Grass family (Graminae)
SPH - Microspheres

Table 3. Percentages for 21 pollen samples in PL-4

PERCENTAGES FOR 21 POLLEN SAMPLES

ID	DEP	AB	LAR	PIC	PIN	TSU	ACR	BET	CRP	CRY	FAG	FRX	JUG	POP	QUE	TIL	ULM	ALN	MYR	SAL	ERI	COM	CYP	GRS
PL4	3	2.3	0.0	30.7	26.6	4.6	1.4	11.0	1.8	0.0	0.0	0.0	0.0	0.0	6.4	0.0	.5	9.6	2.3	0.0	.9	1.8	0.0	0.0
PL4	21	7.4	0.0	19.7	16.4	12.0	.3	19.7	8.4	0.0	0.0	0.0	0.0	0.0	4.3	0.0	0.0	5.0	4.0	0.0	1.0	1.7	0.0	0.0
PL4	61	3.9	0.0	16.6	29.3	22.4	1.2	12.7	2.7	0.0	0.0	0.0	0.0	0.0	7.3	0.0	0.0	1.5	2.3	0.0	0.0	0.0	0.0	0.0
PL4	121	2.2	0.0	7.2	25.6	13.9	.2	22.9	12.4	0.0	0.0	0.0	0.0	0.0	6.5	0.0	0.0	6.7	0.0	0.0	.2	.7	1.2	0.0
PL4	161	2.4	0.0	14.6	19.3	29.2	0.0	15.1	5.2	0.0	0.0	0.0	0.0	0.0	9.0	0.0	0.0	3.8	.9	0.0	.5	0.0	0.0	0.0
PL4	201	1.9	0.0	9.4	27.8	13.8	1.7	23.4	10.1	0.0	0.0	0.0	0.0	0.0	7.0	0.0	.5	2.4	0.0	0.0	1.4	0.0	.5	0.0
PL4	261	2.5	0.0	9.2	16.2	27.8	0.0	27.5	6.7	0.0	0.0	0.0	0.0	0.0	7.0	0.0	0.0	1.8	1.4	0.0	0.0	0.0	0.0	0.0
PL4	361	2.3	0.0	10.7	24.8	15.9	0.0	34.6	4.2	0.0	0.0	0.0	0.0	0.0	2.8	0.0	0.0	2.3	1.9	0.0	0.0	.5	0.0	0.0
PL4	441	1.2	.6	4.1	55.1	3.5	.6	13.9	13.3	0.0	0.0	0.0	0.0	0.0	4.1	0.0	0.0	2.6	.6	0.0	.3	.3	0.0	0.0
PL4	501	0.0	0.0	1.3	24.7	31.6	1.9	20.0	5.9	0.0	0.0	0.0	0.0	0.0	8.1	0.0	.3	4.1	.6	0.0	0.0	.6	.9	0.0
PL4	541	0.0	0.0	1.7	38.1	14.0	.3	23.8	2.9	0.0	0.0	0.0	0.0	0.0	10.6	0.0	.3	6.3	0.0	0.0	0.0	1.1	.9	0.0
PL4	601	.2	0.0	6.9	52.0	14.1	.2	9.9	0.0	0.0	0.0	1.2	0.0	0.0	9.7	0.0	.2	3.2	.2	0.0	.5	.5	.7	.2
PL4	661	0.0	0.0	4.3	53.1	16.1	0.0	13.8	3.1	0.0	0.0	0.0	.4	0.0	7.1	0.0	0.0	.8	0.0	0.0	0.0	.4	.4	.4
PL4	721	.9	0.0	11.6	54.5	3.1	0.0	13.9	2.8	0.0	0.0	.5	0.0	0.0	8.7	0.0	.5	2.1	.2	0.0	0.0	.7	.5	0.0
PL4	761	0.0	0.0	13.2	60.3	.3	.3	13.9	1.0	0.0	0.0	0.0	0.0	0.0	9.5	0.0	.3	0.0	.3	0.0	0.0	.3	.3	0.0
PL4	821	2.9	0.0	15.9	41.7	5.8	0.0	22.0	1.6	0.0	0.0	1.0	0.0	0.0	5.2	0.0	.6	2.3	.3	0.0	0.0	0.0	.3	.3
PL4	862	0.0	0.0	41.6	27.0	1.7	0.0	8.4	7.9	0.0	0.0	0.0	0.0	0.0	5.1	0.0	0.0	2.2	1.7	0.0	1.7	2.2	0.0	.6
PL4	899	0.0	0.0	12.9	45.2	0.0	3.2	3.2	3.2	0.0	0.0	0.0	0.0	0.0	6.5	0.0	0.0	0.0	6.5	0.0	9.7	0.0	0.0	9.7
PL4	921	0.0	0.0	21.6	25.5	3.9	0.0	25.5	9.8	0.0	0.0	0.0	0.0	0.0	7.8	0.0	0.0	2.0	0.0	0.0	0.0	0.0	3.9	0.0
PL4	941	0.0	0.0	25.0	0.0	0.0	0.0	25.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PL4	961	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LEGEND

DEP - Depth in cm.
AB - Fir (*Abies*)
LAR - Larch (*Larix*)
PIC - Spruce (*Picea*)
PIN - Pine (*Pinus*)
TSU - Hemlock (*Tsuga*)
ACR - Maple (*Acer*)
BET - Birch (*Betula*)
CRP - Hornbeam (*Carpinus*)
CYP - Hickory (*Carya*)
FAG - Beech (*Fagus*)
FRX - Ash (*Fraxinus*)
JUG - Walnut (*Juglans*)
POP - Poplar (Populus)
QUE - Oak (*Quercus*)
TIL - Basswood (*Tilia*)
ULM - Elm (*Ulmus*)
AlN - Alder (*Alnus*)
MYR - Bayberry (*Myrica*)
SAL - Willow (*Salix*)
ERI - Heath family (Ericaceae)
COM - Composite family (Compositae)
CYP - Sedge family (Cyperaceae)
GRS - Grass family (Graminae)
SPH - Microspheres

POLLEN TOTALS FOR 21 SAMPLES

IDENT	DEPTH	SUMAP	SUMSAP	SUMNAP	TOTPOL	PCTAP	PCTSAP	PCTNAP
PL4	3	186.	28.	4.	218.	85.3	12.8	1.8
PL4	21	264.	30.	5.	299.	88.3	10.0	1.7
PL4	61	249.	10.	0.	259.	96.1	3.9	0.0
PL4	121	366.	28.	8.	402.	91.0	7.0	2.0
PL4	161	201.	11.	0.	212.	94.8	5.2	0.0
PL4	201	396.	16.	2.	414.	95.7	3.9	.5
PL4	261	275.	9.	0.	284.	96.8	3.2	0.0
PL4	361	204.	9.	1.	214.	95.3	4.2	.5
PL4	441	332.	12.	1.	345.	96.2	3.5	.3
PL4	501	300.	15.	5.	320.	93.8	4.7	1.6
PL4	541	320.	22.	7.	349.	91.7	6.3	2.0
PL4	601	382.	16.	6.	404.	94.6	4.0	1.5
PL4	661	249.	2.	3.	254.	98.0	.8	1.2
PL4	721	409.	10.	5.	424.	96.5	2.4	1.2
PL4	761	292.	1.	2.	295.	99.0	.3	.7
PL4	821	299.	8.	2.	309.	96.8	2.6	.6
PL4	862	163.	10.	5.	178.	91.6	5.6	2.8
PL4	899	23.	5.	3.	31.	74.2	16.1	9.7
PL4	921	48.	1.	2.	51.	94.1	2.0	3.9
PL4	941	4.	0.	0.	4.	100.0	0.0	0.0
PL4	961	1.	0.	0.	1.	100.0	0.0	0.0

LEGEND

DEPTH- cm
SUMAP-- Sum arboreal pollen
SUMSAP- Sum shrub pollen
SUMNAP- Sum herb pollen
TOTPOL- Sum terrestrial pollen
PCTAP- Percent avoreal pollen
PCTSAP- Percent shrub pollen
PCTNAP- Percent herb pollen

Table 4. Pollen totals for 21 samples in PL-4

Zone A (ca. 9200-8900rybp) in Porter's Lake is characterized by a spruce maximum (> 40%) and a high proportion of pine (35%). Birch increases to 20% and fir shows a small peak (3%).

The pine pollen zone ("B," sensu Livingstone, 1968) does not appear in this diagram, because the characteristic pine maximum occurs contemporaneously with substantial amounts of oak (10%) instead of preceding it. Livingstone (1968) pointed out the same phenomenon in Bluff Lake and Silver Lake, (Fig.8,9) although in those diagrams, ash and maple were also present in "considerable amounts." Hadden (1973) chose to identify as Zone B a zone in which pine and oak rose contemporaneously, but the marked time lag between pine and oak peaks in Bedford Basin backs up the distinction made by Livingstone (1968).

The transition from Zone A to Zone C is marked by a steep increase in pine and a steep decrease in spruce. Birch reaches a peak at the transition time, while shrubs, herbs, maple and ironwood drop to zero or a few percent. Fir appears in Porter's Lake and in Bedford Basin (Miller, 1982). Oak is constant at 5%.

Zone C (8900-0rybp) is usually divided in one of 2 ways in Nova Scotia. In areas with a bimodal hemlock distribution (ie, 2 hemlock peaks) like Porter's Lake, subzone C-2 is generally designated as enclosing the hemlock low (e.g. Hadden, 1973). In areas with a single hemlock peak, like the Bedford Basin, subzone C-2 contains the peak (e.g. Miller _et al_, 1982; Livingstone, 1968).

Subzone C-1 (8900-7200rybp) in Porter's Lake is marked by an increase in hemlock from 5% to its first maximum at 30%, and by the dominance of pine, which reaches a maximum at 60%. Spruce decreases from 15% to almost zero. Interestingly, spruce also decreases in Penhorn Lake, but is constant in Bluff Lake, Silver Lake, and Bedford Basin.

The C-1 - C-2 transition is marked by a rapid increase in pine and a rapid decrease in hemlock. Spruce reaches a low of 1% while maple shows a small peak (4%).

Subzone C-2 (7200-6500ybp) includes a hemlock minimum (3 %) and an early pine maximum (55%) followed by a decrease in pine. The pine trend is similar to that in subzone C-2 in Bluff, Silver, and Penhorn lakes, whereas in Bedford Basin pine increases during C-2.

Porter's Lake is unique in the area in having a distinctly bimodal hemlock distribution. The hemlock distribution in Silver Lake and Bluff Lake is somewhat bimodal, but Livingstone (1968) described it as a single peak. At Penhorn Lake and Bedford Basin there is a distinct single peak.

Ironwood reaches a maximum in the early parts of subzone C-2 and then decreases. Maple, oak, and the shrubs and herbs are constant. Fir increases slightly. Spruce increases to 10% in Porter's Lake but only to a few percent in Penhorn Lake, while maintaining a representation of 20-40% in the other local areas.

The C-2 - C-3 transition is located at a birch maximum in Porter's Lake, where ironwood and oak begin to increase.

Subzone C-3 (6500-0ybp) encloses the second hemlock peak. Pine, birch, and hemlock co-dominate; this contrasts with Penhorn Lake, Bluff Lake, Silver Lake, and Bedford Basin, where birch is clearly dominant. Spruce increases to a maximum of 30% near the top of the core. Fir, shrubs, herbs, oak, and maple all increase in Subzone C-3 at Porter's Lake.

INTERPRETATION AND DISCUSSION

Livingstone's (1968) pollen diagrams from Bluff Lake and Silver Lake have been redrawn by Ogden (unpubl. ms.). The redrawn versions are used here because they are easy to compare with the Porter's Lake diagram. The dates shown on the Bluff Lake, Silver Lake, and Penhorn Lake diagrams were determined by Ogden using an age/depth regression based on 5 radiocarbon dates from Penhorn Lake (Fig.10) and Silver Lake (Fig.9)(Ogden, unpubl. ms.). The pollen zones marked on diagrams of Porter's Lake and Penhorn Lake were assigned by the author. Those for Bluff Lake and Silver Lake are as assigned by Livingstone (1968), and those for Bedford Basin are as assigned by Miller et al.

Very low pollen counts from 9500-9000rybp may result from dilution of the pollen record by a period of rapid inorganic sedimentation. This idea is supported by loss on ignition data which indicate very low organic content from 9500-9000rybp.

Zone A

Zone A, the spruce zone, is recognized as the first post-glacial zone and represents a cool climate (Hadden, 1975). It contains a spruce peak in each of the four Halifax-area lakes (Silver Lake, Porter's Lake, Bluff Lake, Penhorn Lake).

The spruce peak in Nova Scotia has been interpreted in the past to represent climatic deterioration following Zone L; more recently, it has been attributed to the first arrival of spruce in the region (Hadden, 1975). Any earlier spruce and pine are

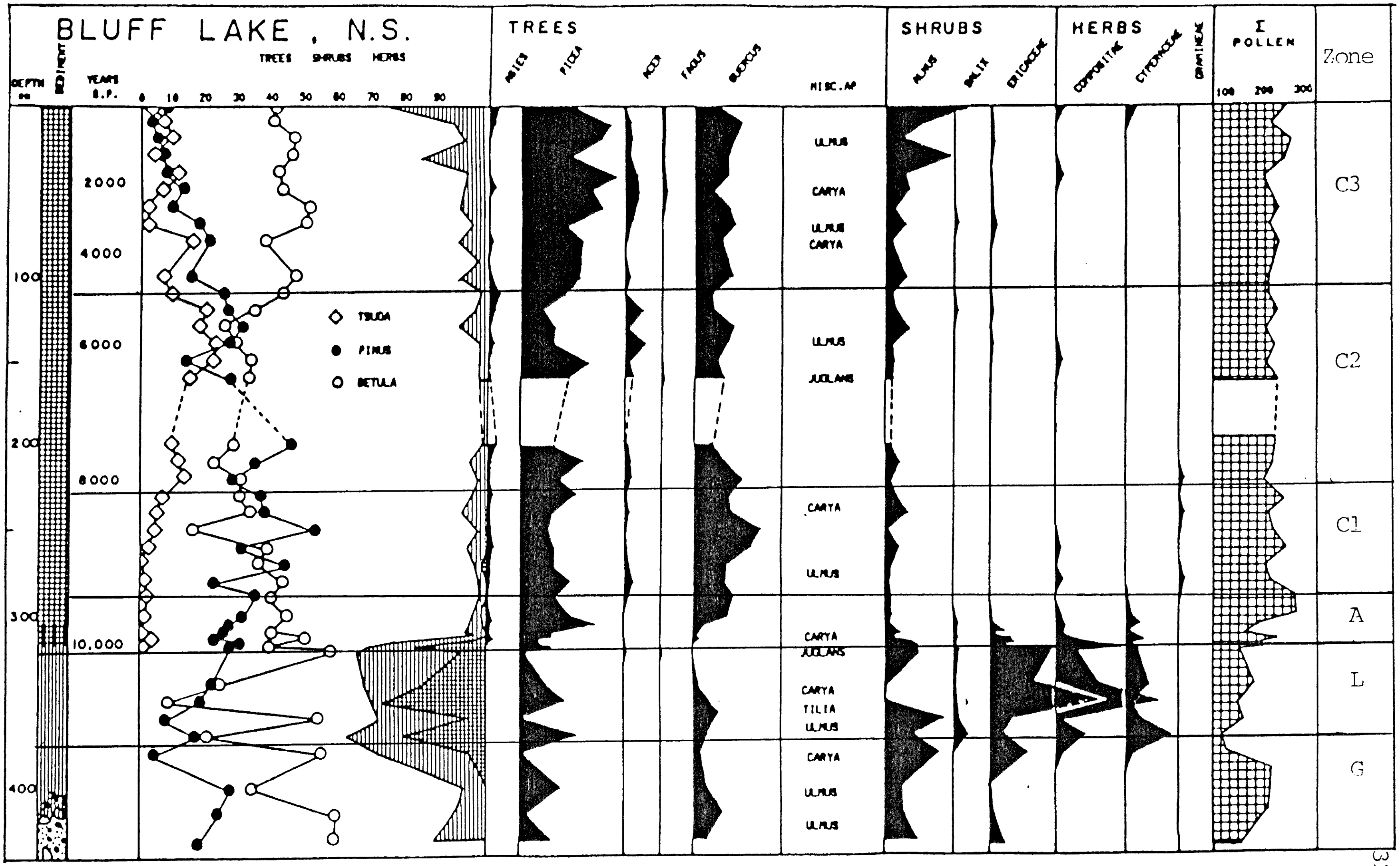


Fig. 8. Bluff Lake pollen diagram. (Ogden, pers. comm.) Zones are as defined by Livingstone, 1968.

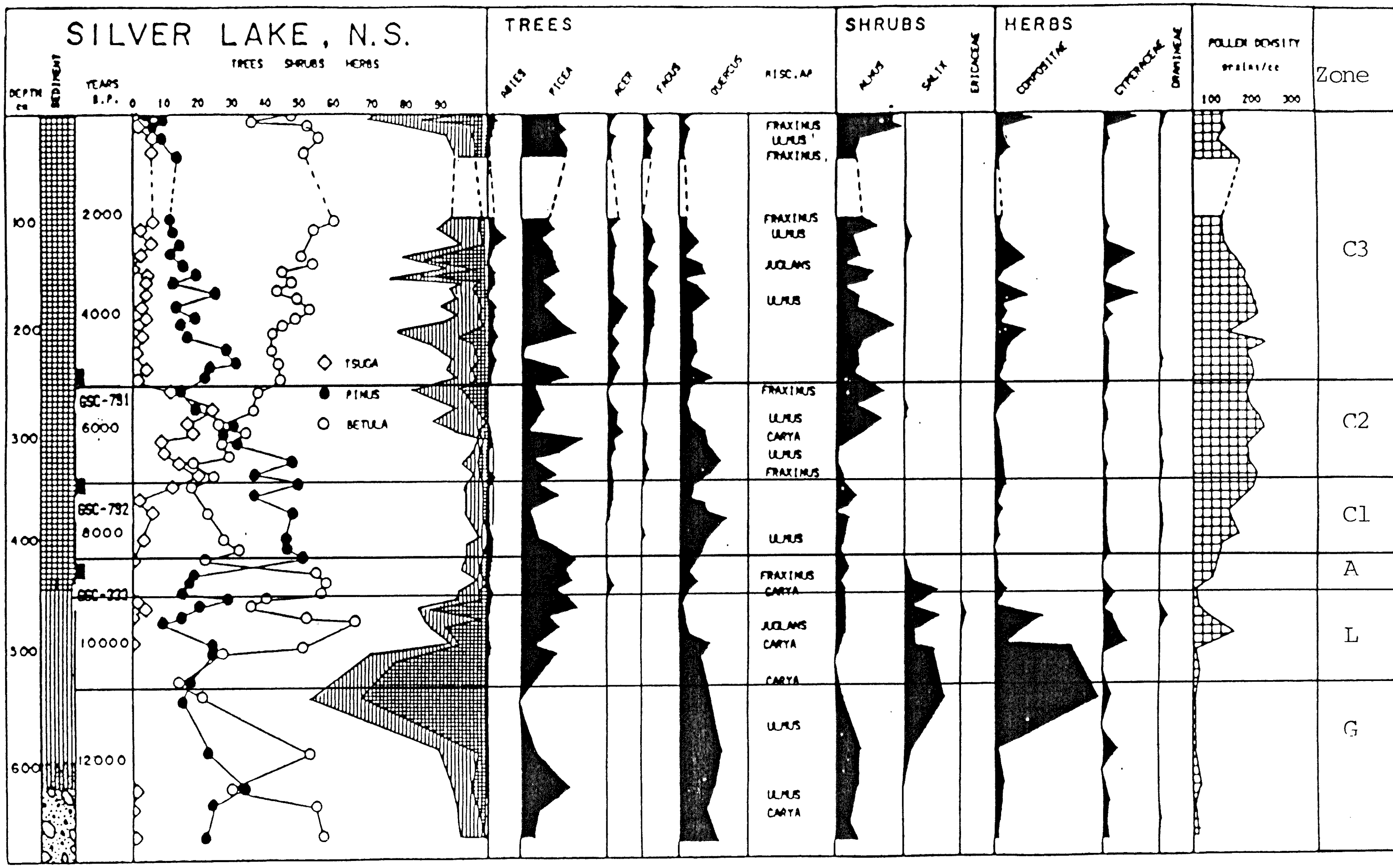


Fig. 9. Silver Lake pollen diagram (Ogden, pers. comm.)

Zones are as defined by Livingstone, 1968.

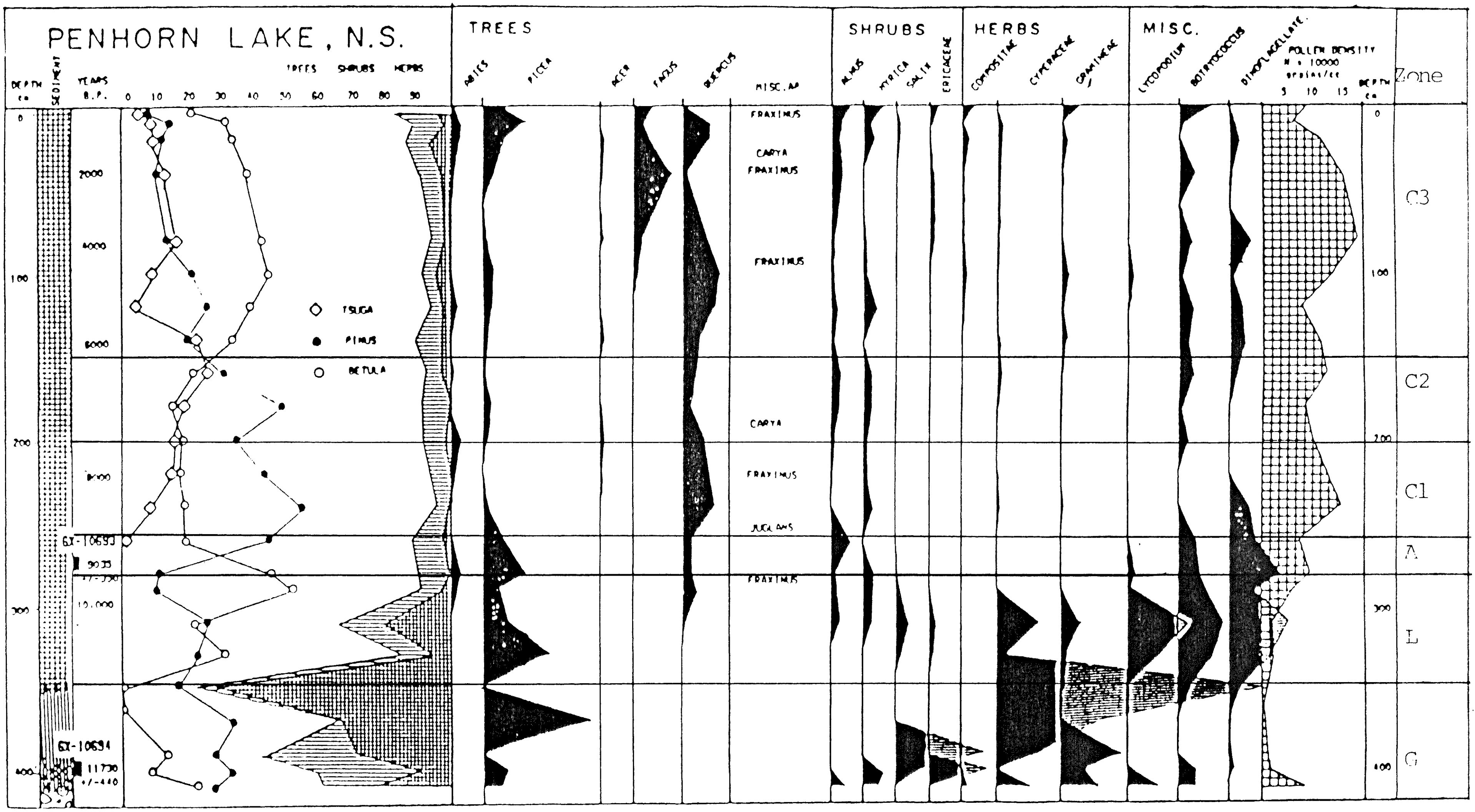


Fig. 10. Penhorn Lake pollen diagram (Ogden, pers. comm.)

Zones are as determined by the author.

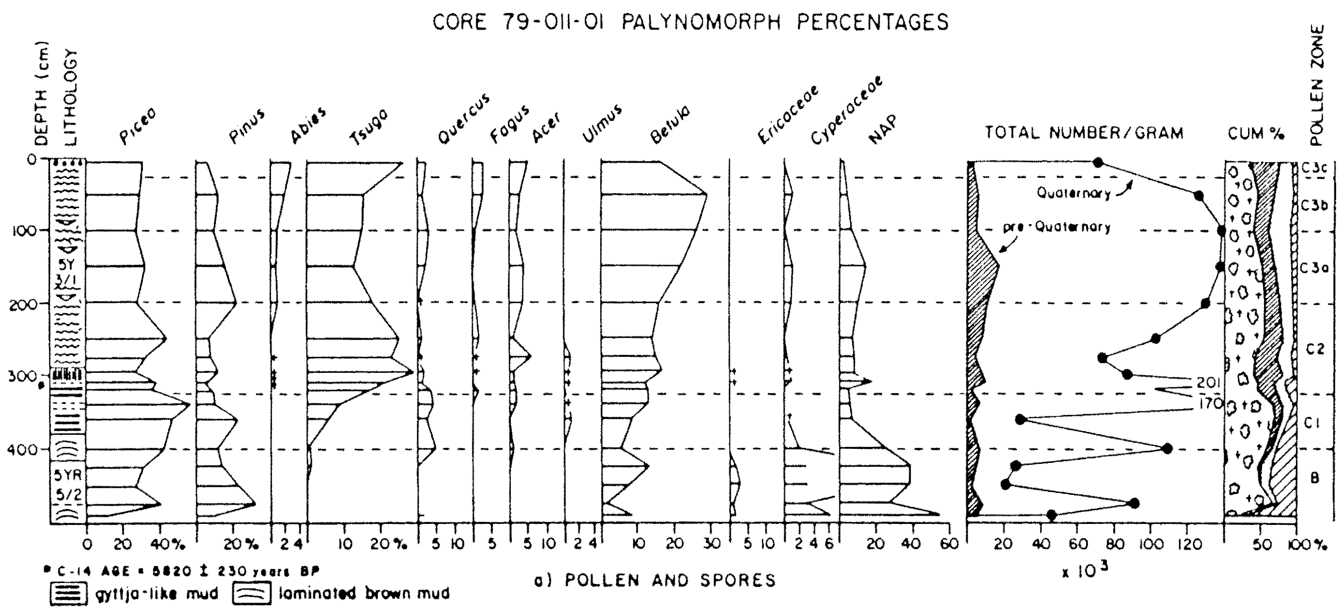


Fig. 11. Bedford Basin pollen diagram (Mudie et al, 1982)

attributed to long-distance transport (Hadden, 1975).

This peak is contemporaneous in Porter's Lake (9200-8900 rybp), Penhorn Lake (9800-8800rybp), Silver Lake (9500-8500rybp), and Bluff Lake (9800-9600rybp), possibly indicating establishment of spruce in the whole region at about the same time.

The substantial oak abundance in Porter's Lake appears contradictory since spruce normally indicates a moist environment and oak a dry one. Abundances are 5-10% in Porter's Lake, Silver Lake, and Bluff Lake. Long distance transport may account for some of the oak, and a few oak trees in situ in open areas might result in a high pollen/stem ratio (Hadden, 1975).

An increase in organic sedimentation and APF implies the transition from parkland to closed boreal forest (Ogden, pers. comm.).

Zone C

This zone contains mostly boreal forest elements, with deciduous trees, shrubs, and herbs increasing with time.

Subzone C1

The high pine pollen density in this subzone has been regarded by some workers as a statistical artifact due to overrepresentation of pine (Livingstone, 1968; Hadden, 1975). Further doubt is cast on the meaning of the pine maximum because it is not found in all sequences (eg. Bluff Lake, Bedford Basin). As pointed out by Hadden (1975), a peak in pine pollen density, such as that at Porter's Lake, must mean pine pollen is more abundant at that time than elsewhere in the sequence. Vegetational trends can therefore be identified despite possible over-representation. Livingstone (1968) also concludes that the pine pollen zone represents a time of genuinely high pine tree abundance.

The pine zone is contemporaneous not only in the Halifax area but throughout Nova Scotia. It occurs at Porter's Lake at 9000-8000rybp; Silver Lake, 8500-6500rybp; Penhorn Lake, 8800-7000 rybp; Bluff Lake, 8800-7500rybp; Wreck Cove, 8200-7000 rybp (Hadden, 1975); and Salmon River, 8770-5540rybp (Hadden, 1975). This indicates a widespread vegetational and probably climatic event. Bedford Basin ages (7500-6000rybp) are approximated by this author using two radiocarbon dates, which may account for the discrepancy with the other dates.

Combined with the decrease in spruce at Porter's Lake, the pine high may indicate summers too warm for spruce, but suitable for pine (Hadden, 1975). This interpretation is complicated by dissimilar spruce trends in C1 subzones in different cores, and by dissimilarities in the trends of hardwoods, shrubs, and herbs. Because the sequences are different between geographically close cores, factors other than climate alone are probably in effect.

The C1 subzone and C2 subzone are concluded by Livingstone (1968) to represent a warmer climate than is present in Halifax County.

The Cl subzone in Porter's Lake looks more like the Cl subzone in Penhorn Lake than in any of the other locations mentioned, suggesting that the vegetation and hydrology of Porter's Lake are most similar to those in Penhorn Lake.

Subzone C2

Many Nova Scotia pollen diagrams reflect a warming interval (Cl) followed by a warm maximum (C2) and then climatic deterioration (C3). Because the optimal hemlock climate is warmer than the optimal spruce or pine climate, this trend is most commonly expressed as increasing hemlock frequently in Cl to a maximum in C2 and a decline in C3. In Porter's Lake, however, hemlock frequency distribution is bimodal, with maxima in Cl and C3, and a minimum in C2. As noted earlier, this pattern has been observed in pollen diagrams from other parts of the province. The hemlock minimum probably represents a period of maximum warmth, that is, temperatures exceeding those which are optimal for hemlock growth. The other alternative, ie. that the hemlock minimum reflects a short cool internal, is unlikely in view of strong evidence for the regional climatic trends outlined at the beginning of this paragraph (see Livingstone, 1968; Hadden, 1975). The subzone is well matched by the C2 zone at Penhorn Lake, but very poorly by the C2 zone of Bedford Basin. The lower part of the diagrams at Silver Lake (7000-5800rybp) and Bluff Lake (8000-6500rybp) contains intervals equivalent to the C2 subzone in Porter's Lake. There is no part of the Bedford Basin diagram which matches the C2 subzone in Porter's Lake.

Subzone C3

A rise in spruce and fir seen in subzone C3 at Porter's Lake is almost certainly due to a cooler, moister climate, or at least lower summer temperatures (Livingstone, 1968). The Penhorn Lake diagram shows increases in spruce and fir similar to those at Porter's Lake. At Bluff Lake, spruce increases from 4500-3000 rybp but does not increase from 3000-0rybp. At Silver Lake, spruce is constant throughout most of C3 (4000-0rybp), increasing only from 4800-4300rybp. In the Bedford Basin, spruce is constant throughout C3, from 4000-0rybp. The fir increase recorded at Porter's Lake is also recorded at Bedford Basin and Penhorn Lake, while at Silver Lake and Bluff Lake, the fir percentage is erratic.

Porter's Lake therefore has spruce and fir assemblages most like those at Penhorn Lake in the C3 subzone.

The C3 subzone in Porter's Lake is at least as interesting for what it does not contain as for what it does contain. It does not show strong birch dominance which characterizes the Bedford Basin, Penhorn Lake, Silver Lake, and Bluff Lake, and which probably results from climatic conditions because it is a regional phenomenon. There is some local factor at Porter's Lake which does not favour birch colonization, or at least, birch pollen preservation.

Beech is conspicuously absent from the Porter's Lake core. It becomes established in most parts of Nova Scotia from about 7000-2000rybp (e.g., Livingstone, 1968), and there are few Nova Scotian pollen diagrams totally lacking beech representation, although Livingstone (1968) records one in the Gaspe. Regional variation in ages of earliest continual representation are as follows: Bedford Basin, 5000rybp; Silver Lake, 7000rybp; Bluff Lake, 3000rybp; Penhorn Lake, 4600rybp. A count of two slides from the Porter's Lake core, which was not recorded on the pollen diagram, did reveal one grain of beech pollen in 100 grains counted at 121cm., and 1 grain of beech pollen in 50 grains counted at 61cm, but the small numbers suggest that the beech was not locally derived. Beech grows best in rich, mature soils (Livingstone, 1968), and the soil at Porter's Lake is generally poor (Smith, 1984), which may partially explain the absence of beech.

Also not obvious from the pollen record is any evidence of change in hydrology or watershed characteristics which might result from marine intrusion of Porter's Lake. The Porter's Lake diagram is similar to the Penhorn Lake diagram in all of its gross features, and much of its detail, throughout the timespan covered (about 9500 years). A possible exception is in zone C3 of Porter's Lake, where birch dominance does not occur. There are a number of factors which could affect birch frequency, such as soil cover or disease; there is no reason to suspect marine intrusion has had more influence than other factors.

CONCLUSION

A comparison of one core from the north end of Porter's Lake with cores from nearby lakes and Bedford Basin shows that the pollen record in Porter's Lake is most similar to the record in Penhorn Lake throughout its history. Pollen sedimentation in Porter's Lake is like that in a fresh-water lake despite a salinity of about 1ppt in Porter's Lake. While it is possible that birch frequency in subzone C3 reflects a change in lake hydrology or watershed characteristics after a marine intrusion, there is no evidence in the core lithology or pollen record to support this idea.

ACKNOWLEDGEMENTS

I would like to thank my supervsisor, Dr. J.G. Ogden, III, for his assistance in sample processing and pollen identification, and for his ideas and guidance throughout this project. The staff in Audio-Visual Services at Dalhousie were most obliging in preparing photographs on short notice. I thank Elizabeth Jong for typing the manuscript.

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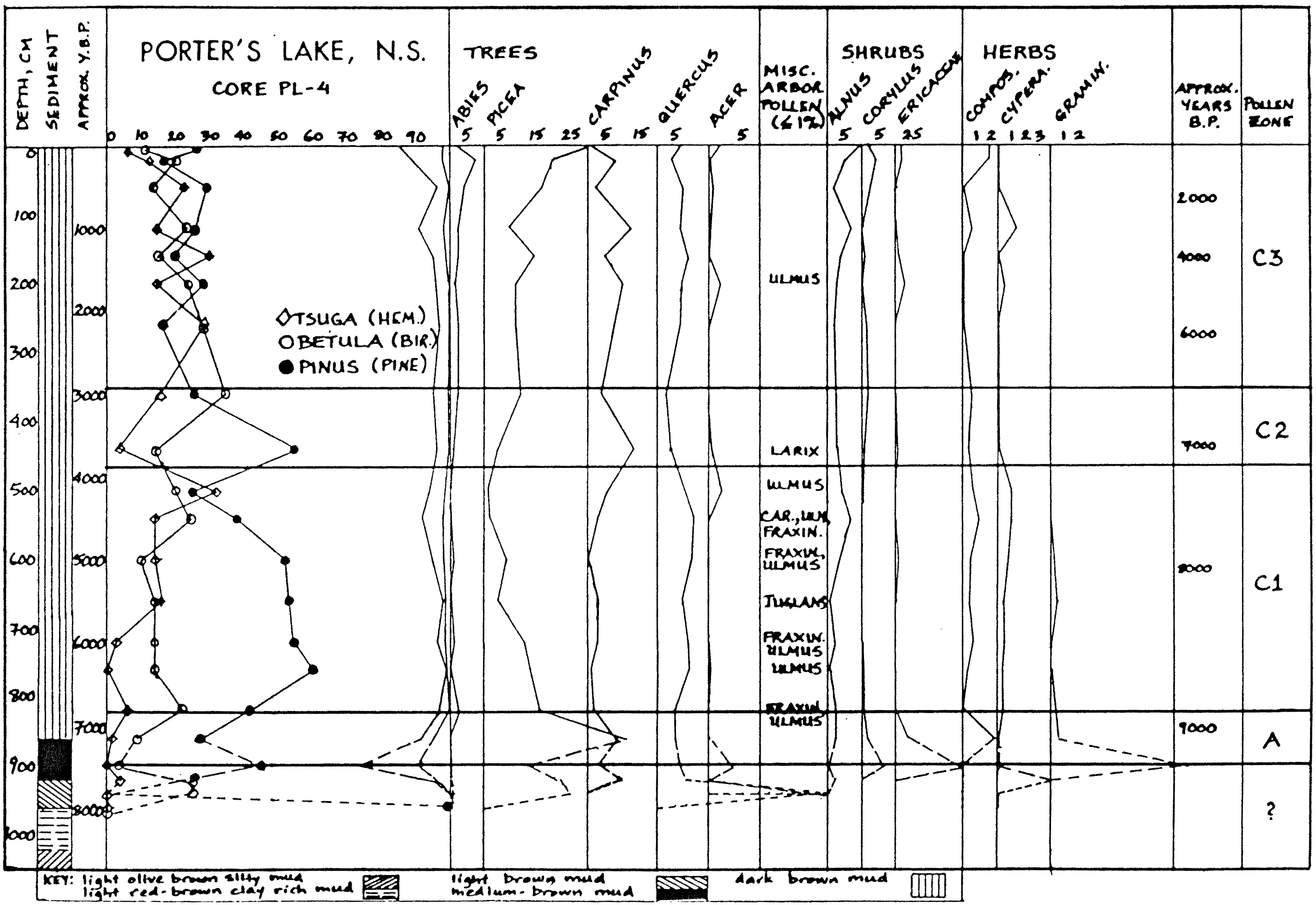
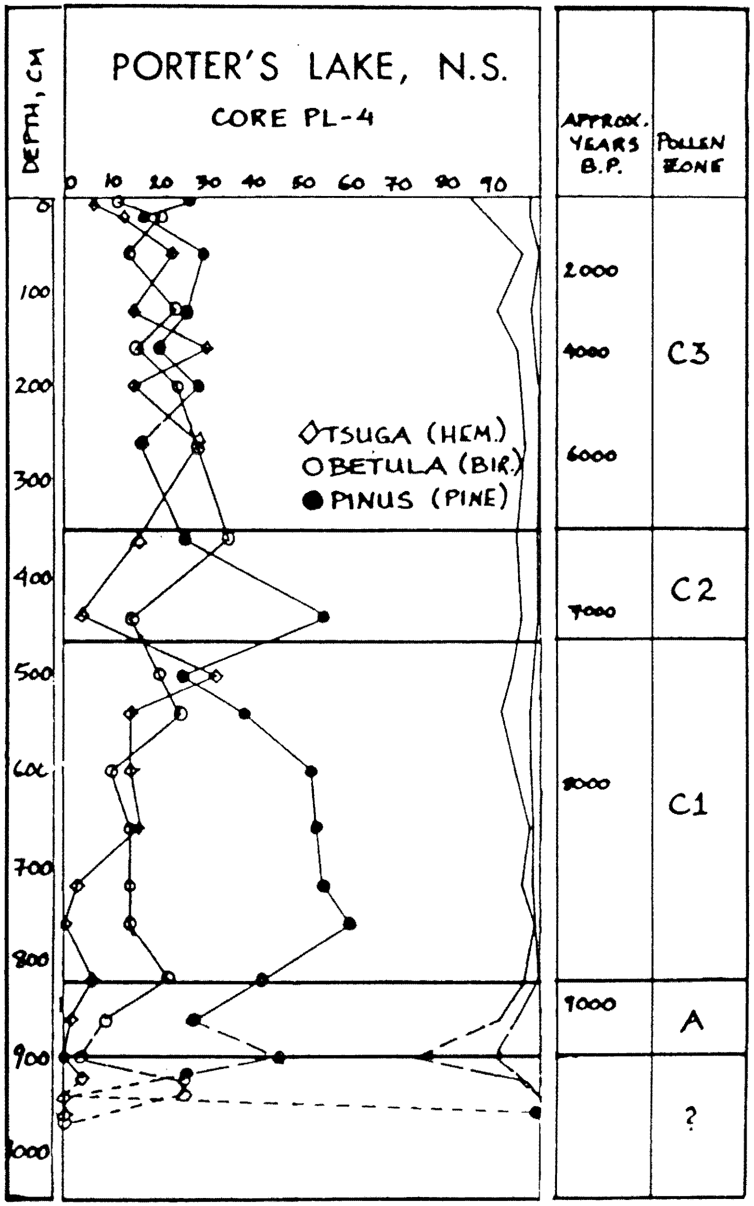
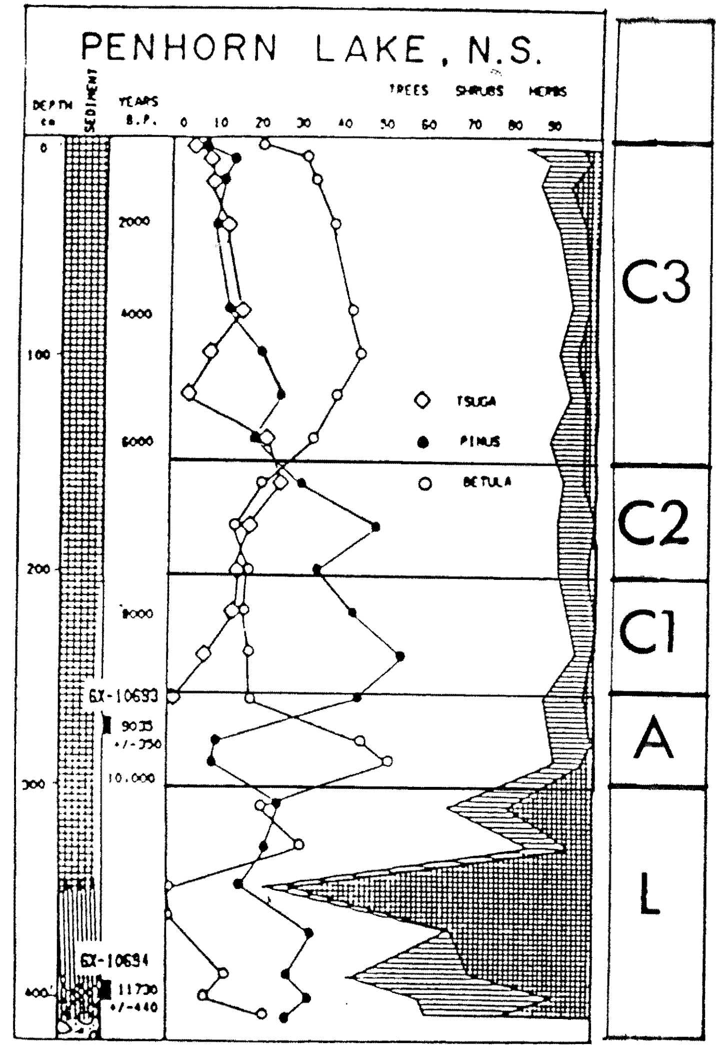
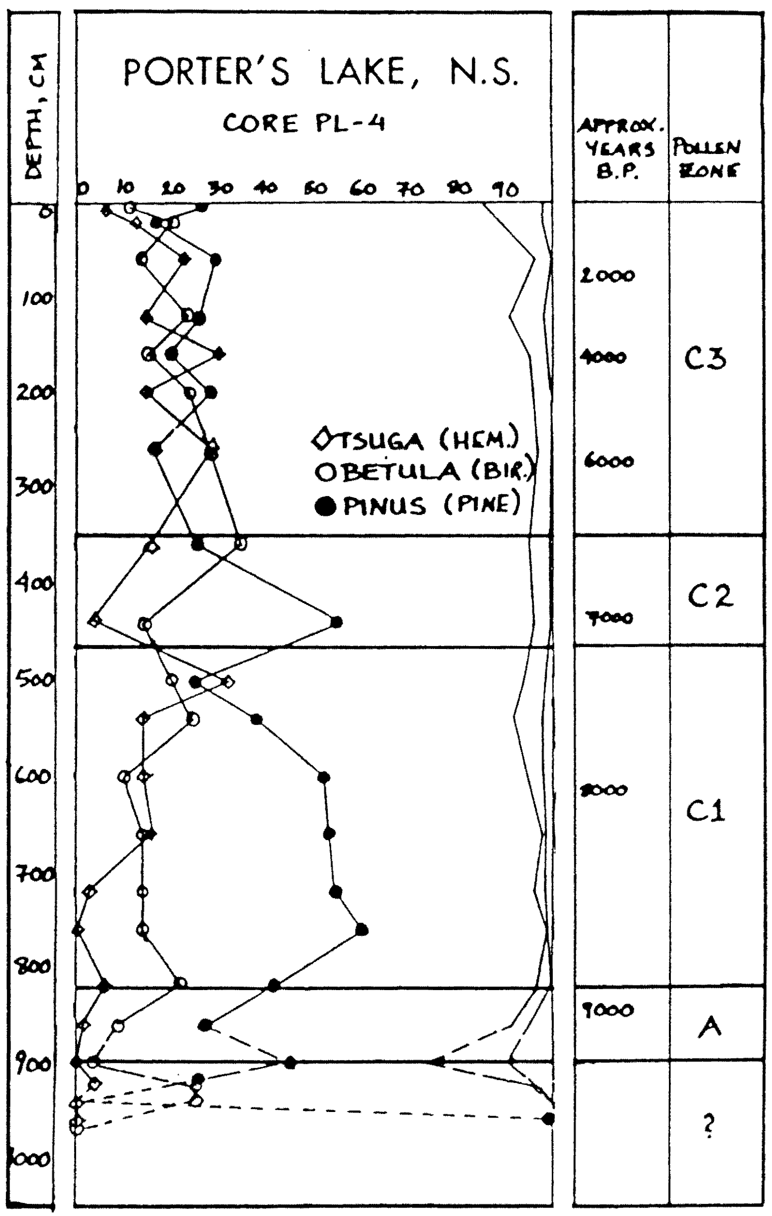
APPENDIX

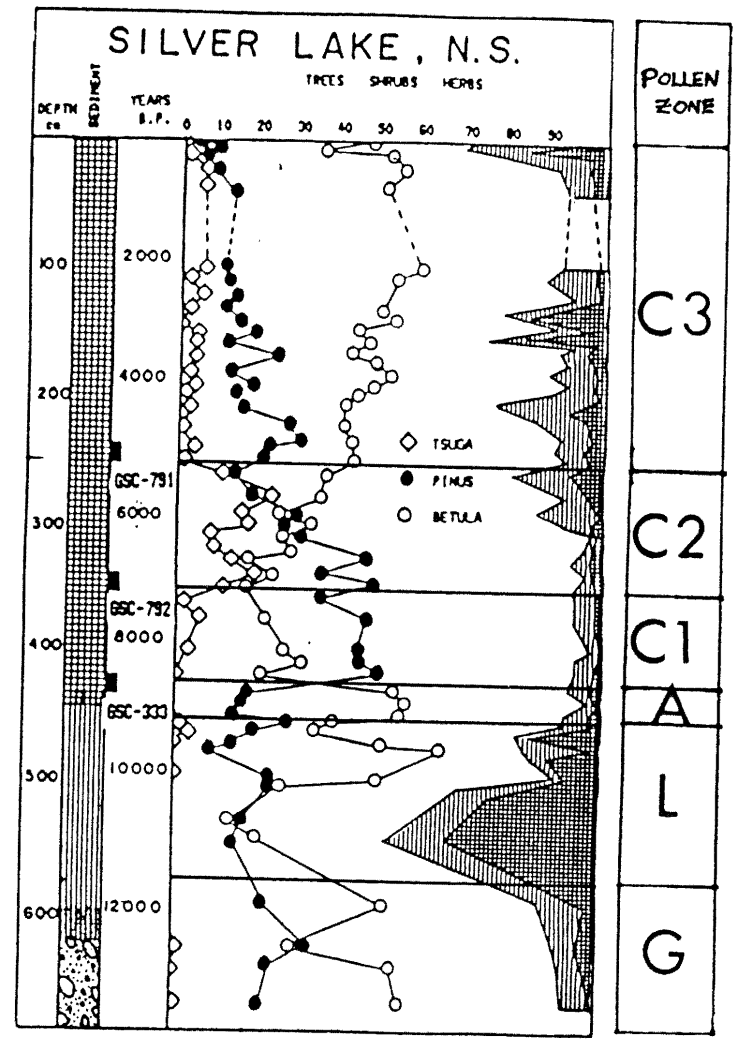
POLLEN DIAGRAMS REDRAWN FOR COMPARATIVE PURPOSES

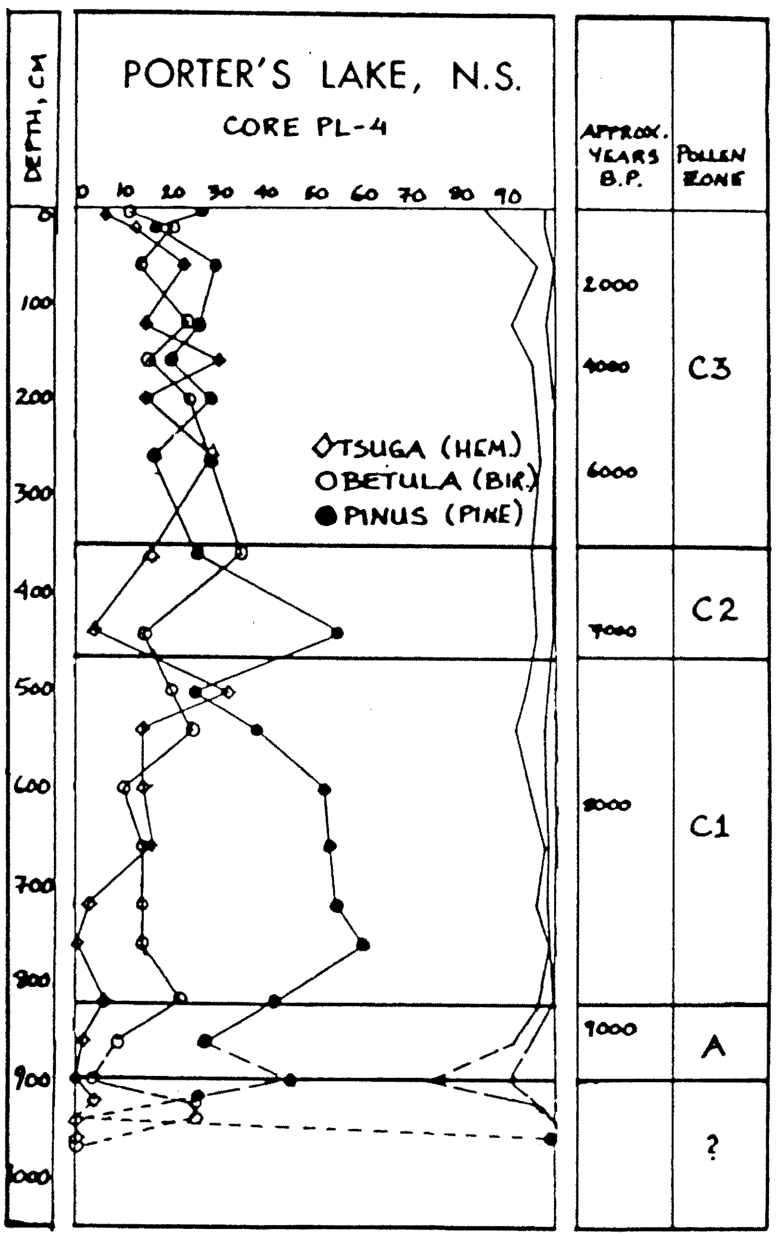

PORTER'S LAKE, N.S.
CORE PL-4
DEPTH, CM
SEDIMENT
APPROX. Y.B.P.
TREES
ABIES
PICEA
CARPINUS
QUERCUS
ACER
MISC. ARBOR POLLEN (≤1%)
SHRUBS
ALNUS
CORYLUS
ERICACEAE
HERBS
COMPOS.
CYPERA.
GRAMIN.
APPROX. YEARS B.P.
POLLEN ZONE
OTSUGA (HEM.)
OBETULA (BIR.)
PINUS (PINE)
ULMUS
LARIX
ULMUS
CAR., ULM, FRAXIN.
FRAXIN, ULMUS
JUGLANS
FRAXIN. ULMUS
ULMUS
FRAXIN ULMUS
C3
C2
C1
A
?
KEY: light olive brown silty mud
light red-brown clay rich mud
light brown mud
medium-brown mud
dark brown mud

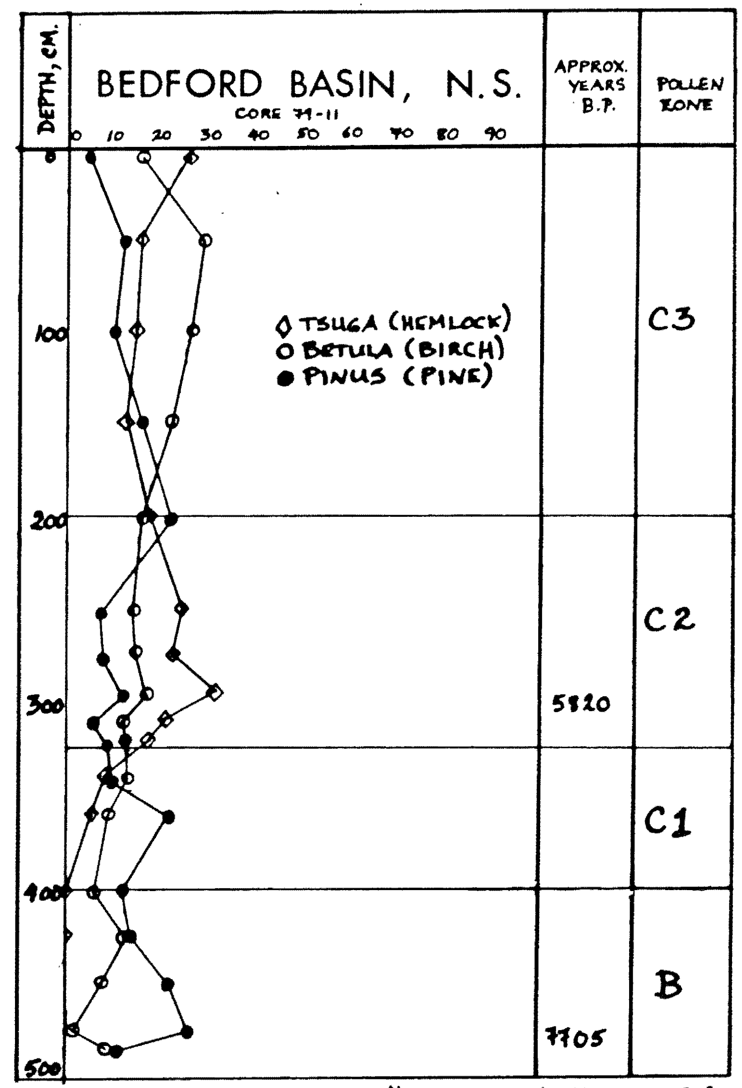

PORTER'S LAKE, N.S.
CORE PL-4
DEPTH, CM
APPROX. YEARS B.P.
POLLEN ZONE
0 10 20 30 40 50 60 70 80 90
0
100
200
300
400
500
600
700
800
900
1000
2000
4000
6000
7000
8000
9000
C3
C2
C1
A
?
TSUGA (HEM.)
BETULA (BIR.)
PINUS (PINE)


PENHORN LAKE, N.S.
DEPTH cm
SEDIMENT
YEARS B.P.
TREES
SHRUBS
HERBS
0 10 20 30 40 50 60 70 80 90
0
100
200
300
400
2000
4000
6000
8000
10,000
GX-10693
9035 +/-350
GX-10694
11730 +/-440
TSUGA
PINUS
BETULA
C3
C2
C1
A
L


PORTER'S LAKE, N.S.
CORE PL-4
DEPTH, CM
APPROX. YEARS B.P.
POLLEN ZONE
◇TSUGA (HEM.)
○BETULA (BIR.)
●PINUS (PINE)
C3
C2
C1
A
?


SILVER LAKE, N.S.
TREES SHRUBS HERBS
DEPTH cm
SEDIMENT
YEARS B.P.
POLLEN ZONE
GSC-791
GSC-792
GSC-333
TSUGA
PINUS
BETULA
C3
C2
C1
A
L
G





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