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PALEOECOLOGY OF JOHN KLONDIKE BOG, FISHERMAN LAKE REGION, SOUTHWEST DISTRICT OF MACKENZIE

J.V. MATTHEWS, JR.

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PALEOECOLOGY OF JOHN KLONDIKE BOG, FISHERMAN LAKE REGION, SOUTHWEST DISTRICT OF MACKENZIE

Abstract

Pollen and macrofossils, the latter including mollusca, insects, as well as fruits and seeds of higher plants, were recovered from the sediments of a 4.7 m core taken at the site of a small bog near Fisherman Lake in southwest District of Mackenzie. The core sequence spans approximately the last 9600 years. Its pollen and macrofossil contents largely portray the change of a small pond or lake into an elevated, frozen bog. Despite the domination of the pollen diagram by local vegetation, two regional trends are evident: the migration into the Fisherman Lake area of alder 8700 years ago and pine 6700 years ago.

Apparently none of the pollen and macrofossil data portrays the mid-Holocene Altithermal, and in fact the only indication of climatic change in the entire core sequence may be the indirect evidence of permafrost development at the site during the Little Ice Age 300 to 500 years ago.

Résumé

Des pollens et des macrofossiles, notamment des mollusques et des insectes, de même que des fruits et des graines de plantes plus évoluées ont été extraits des sédiments contenus dans une carotte de 4,7 m qui a été prélevée à l'emplacement d'un petit marécage situé à proximité du lac Fisherman, dans le sud-ouest du district du Mackenzie. La carotte présente une succession chronologique de sédiments qui couvre à peu près les 9 600 dernières années. Son contenu de pollens et de macrofossiles témoigne en grande partie de la transformation d'un petit étang ou d'un petit lac en un marécage élevé et gelé. Bien que dominé par de la végétation locale, le diagramme pollinique fait ressortir deux tendances régionales: la migration d'aulnes dans la région du lac Fisherman il y a 8 700 ans, et la migration de pins dans la même région il y a 6 700 ans.

Apparemment aucune des données sur les pollens et les macrofossiles ne rend compte du stade altithermal (Altithermal), qui a marqué le milieu de l'Holocène; en fait, le seul indice d'une variation climatique que l'on trouve dans toute la succession chronologique de sédiments est peut-être le signe indirect de la formation de pergélisol à cet endroit au cours de la Petite époque glaciaire (Little Ice Age) il y a entre 300 et 500 ans.

INTRODUCTION

Fisherman Lake in the southwest corner of District of Mackenzie, Northwest Territories (Fig. 1), is within a region possessing numerous archeological sites (Millar, 1968; Fedirichuk, 1970; Cinq-Mars, 1973). To provide an environmental record to which the archeological sequence of the area might be compared, in 1970 I initiated preliminary paleoecological studies at Fisherman Lake. Because the archeological sites themselves were poor candidates for yielding well preserved pollen, attempts were made to raise cores from small lakes nearby; but the efforts failed due to the presence of reworked glacial lake clay which proved impenetrable using the Livingstone-type piston corer. Thus, in 1971, with Geological Survey of Canada helicopter and technical support, more appropriate sites were sought. One of these, hereafter informally referred to as John Klondike bog[1], yielded a 5 m long core.

The bog is located near Fisherman Lake and its archeological sites (Fig. 1) but is outside the area underlain by heavy glacial lake clay (Rutter et al., 1973a). Technical difficulties with the coring apparatus and time restrictions did not allow sampling of the entire organic fill in the bog basin, but the 4.7 m of core that was obtained provides a record of approximately the last 9600 years. For all of that time the bog area apparently possessed a mixed spruce-deciduous forest similar to that of the present, though it seems probable that during the early part of the period neither pines nor alders grew in the region. Most of the pollen and macrofossil fluctuations recorded by the core sequence document local changes at the coring site – from an open pond initially, then to a shoreline, and finally to a raised, frozen bog. No evidence of regional climatic change was found in that portion of the core deposited during the Holocene Altithermal.

Although the avowed objective of discovering regional environmental change was not met by this study, the John Klondike sequence does illustrate how macrofossils and microfossils might be used together to provide a detailed local environmental record. Hopefully this attempt at documenting regional and local environmental changes during the Holocene will be the first of many in the Mackenzie Basin, for it is only through such paleoecological research that we may assess the environmental changes caused by man (both prehistoric and industrial) within the context of naturally occurring fluctuations. Significant in this regard is that the Fisherman Lake basin is not only the locus of numerous archeological sites but is also within a producing natural gas field (Pointed Mountain, Amoco-Westcoast Transmission, Owen and Van Byk, 1975).

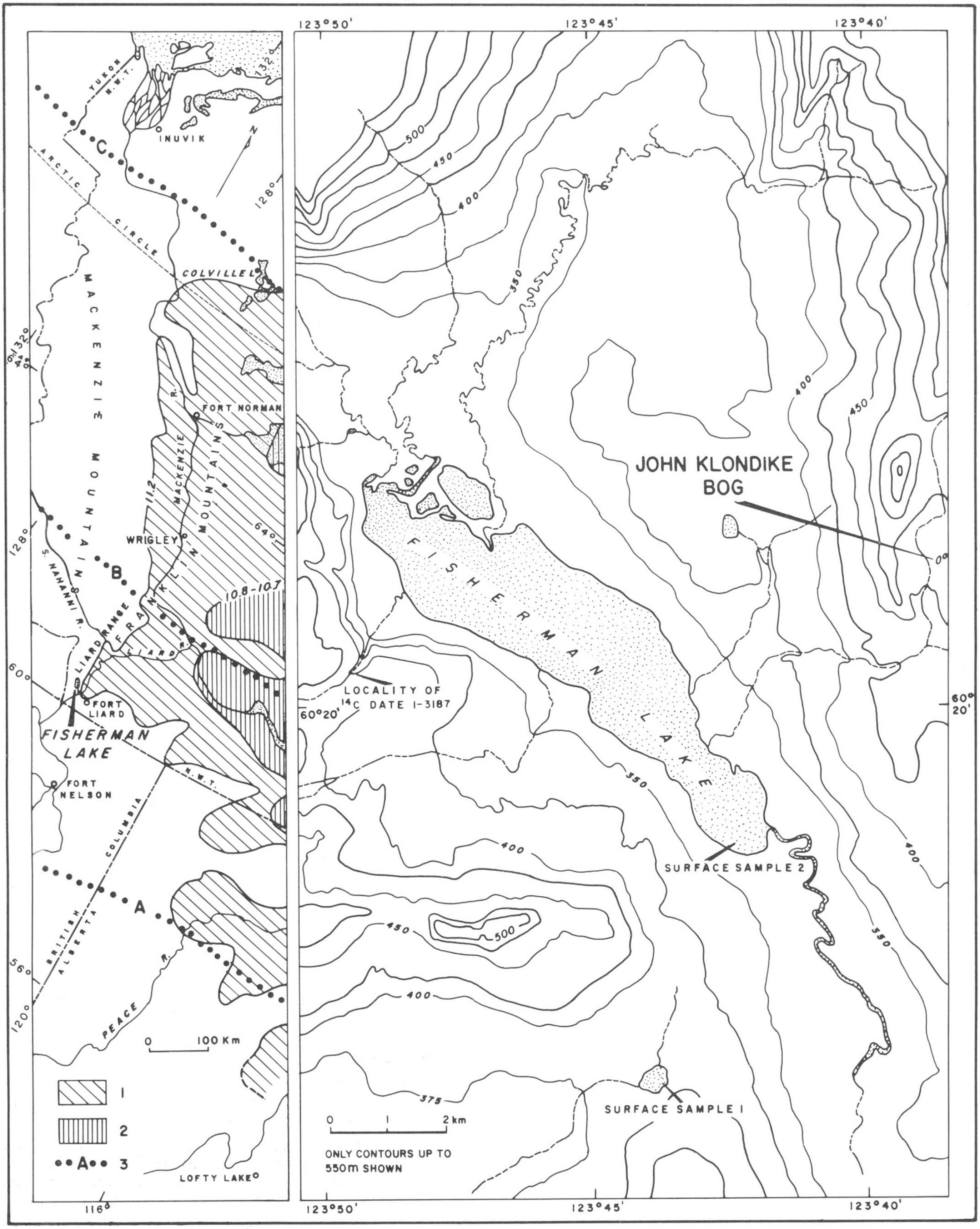
Acknowledgments

J.F.V. Millar (University of Saskatchewan) provided funds and support to initiate this study, which I subsequently completed after joining the Geological Survey of Canada.

I thank N.W. Rutter and C.E. Schweger (University of Alberta) for access to unpublished information and comments on an early draft of this manuscript, and R.J. Mott whose critical comments considerably improved the final version.

Thanks are also extended to David Walker (GSC) and Lou Ling (Carleton University) for their help with SEM photomicrography.

[1]Named after John Klondike, a well known Slavey Indian from Fort Liard whose trapline is near the site.



INUVIK
ARCTIC CIRCLE
YUKON
N.W.T.
COLVILLE L.
MACKENZIE MOUNTAINS
MACKENZIE R.
FORT NORMAN
FRANKLIN MOUNTAINS
WRIGLEY
11.2
10.8-10.7
S. NAHANNI R.
LIARD RANGE
LIARD R.
FORT LIARD
FISHERMAN LAKE
FORT NELSON
N.W.T.
BRITISH COLUMBIA
ALBERTA
PEACE R.
LOFTY LAKE
0 100 Km
1
2
A 3
C
B
A
116°
120°
128°
132°
56°
60°
123°50'
123°45'
123°40'
60°20'
500
450
400
350
JOHN KLONDIKE BOG
FISHERMAN LAKE
LOCALITY OF
14C DATE I-3187
SURFACE SAMPLE 2
SURFACE SAMPLE I
375
0 1 2 km
ONLY CONTOURS UP TO
550m SHOWN

METHODS

A Smit split-tube corer with 6 inch (15.24 cm) diameter barrel was used to penetrate the perennially frozen sediments of the bog. Core samples of 4 cm thickness were collected at 10 cm intervals except near the base of the sequence where presence of ice lenses necessitated adjustment of the sample interval. The walls of the hole were only exposed for a short time between each core drive and did not thaw and slough; however, in order to ensure that no such down-core contaminants were sampled, a few centimetres of sediment at the end of each core segment were discarded. Because the core increments contained ice lenses and saturated sediments, pollen and macrofossil samples were collected on the spot before thawing could begin. In addition to the pollen samples, larger 10 cm increment samples were collected at selected levels for macrofossil analysis and radiocarbon dating (Fig. 2).

Pollen samples were screened through a fine sieve (0.025 cm) and then processed using treatments of KOH, HF (if necessary), and acetolysis. In all but a few cases a minimum of 200 pollen grains were tabulated. Fragments of **Picea** and **Pinus** pollen were counted and weighted to achieve a more accurate representation of their abundance. Macrofossils of plants and insects as well as shells of molluscs and ostracodes were picked from the residue remaining on the sieve of each pollen sample and in addition from the >0.03 cm fraction of the larger samples.

Figure 2 is a diagram of pollen and spore frequencies and provides a list of plant and insect macrofossils associated with the individual pollen samples and the larger samples.

VEGETATION

The Fisherman Lake basin is within the Boreal Forest Region near the boundary of the Upper Mackenzie Forest Section and the Alpine Forest-Tundra Zone (Rowe, 1972). More specific vegetation characterization of the basin is found in an unpublished report by C.E. Schweger (University of Alberta) and in Nahanni National Park region, just north of Fisherman Lake, in Scotter and Cody (1974).

In the Fisherman Lake region forests below an elevation of approximately 700 m are dominantly of aspen **(Populus tremuloides)** with isolated stands of white spruce **(Picea glauca)** in areas not recently burned and along watercourses. Black spruce **(Picea mariana)** occurs on poorly drained sites and forms open, depauperate stands on bogs (such as the coring site) where drainage is poor and the substrate cold due to localized permafrost.

Figure 1. *Location map showing Fisherman Lake basin and Mackenzie Valley. In the legend of the regional map*

(1) shows the area covered by Laurentide ice approximately 11.2 thousand years ago. Note that ice impinged on the east flank of Liard Range, blocking northward drainage;

(2) signifies the area covered by Laurentide ice approximately 10.7 thousand years ago;

(3) shows lines demarcating permafrost zones (after Zoltai and Tarnocai, 1975):

C, southern boundary of continuous permafrost zone;

B, southern boundary of widespread discontinuous permafrost zone;

A, southern limit of discontinuous permafrost.

Thus Fisherman Lake is within an area of scattered and localized permafrost.

Between an elevation of 750 m and timberline at 1160 m conifers dominate, with **Picea glauca** being the predominant species, but included are stands of lodgepole pine **(Pinus contorta)** and subalpine fir **(Abies lasiocarpa)** at some treeline or near-treeline sites. C.E. Schweger (unpublished report, 1972) found no evidence of these latter two species in the lowlands near the lake, and they are presumed to be absent as well in the vicinity of John Klondike bog. Jack pine **(Pinus banksiana)** occurs on the lowlands east of Liard River and lodgepole pine is abundant on low elevation, well drained, sandy sites south of Fisherman Lake in the Upper Liard Forest Section (Rowe, 1972). The two species are sympatric in the Nahanni National Park region to the north (Scotter and Cody, 1974).

In the ecoregion classification system established for Mackenzie Valley and adjacent areas (Crampton, 1973), Fisherman Lake basin is included in Land Area 6: regions with climate warm enough for formation of podzolic dytric brunisols on well drained sites, and in Land System 3: freely drained soils, absence or near absence of permafrost with spruce-deciduous forest cover. The coring site is one of the rare areas within the region that is underlain by permafrost. The peatlands classification system of Zoltai and Tarnocai (1975) places the basin near the edge of Peatland Region IV, representing the southern fringe of the discontinuous permafrost zone in which the dominant peatland forms are peat plateaus, palsen, bogs, fens, and collapse scars. Though not a peat plateau, the coring site is a raised surface underlain by frozen ice-rich sediments and bordered on one side by a minerotrophic fen. Like peat plateaus in the lowlands to the east of Liard River, surface vegetation consists of **Sphagnum** mosses, abundant ericaceous plants (e.g., **Empetrum nigrum, Ledum palustre, Vaccinium, vitis-idaea, Vaccinium uliginosum**), shrub birches, and scattered depauperate black spruce **(Picea mariana).** Well drained sites surrounding the basin are dominated by stands of quaking aspen **(Populus tremuloides)** in which **Alnus crispa** is commonly an important understory component (C.E. Schweger, unpublished report, 1972).

GEOLOGICAL SETTING

Regional

John Klondike bog is located within Fisherman Lake Valley at an elevation of approximately 460 m a.s.l. (Fig. 1). Fisherman Lake lies in a synclinal basin underlain by Early Cretaceous sandstone and shale (Stott, 1960) and is flanked on either side by branches of the Liard Range (Franklin Mountain system) – anticlinal mountains formed of Permian sandstone, shale, and limestone (Harker, 1963). Summits near the lake are near 1200 m a.s.l., but Pointed Mountain, a prominent local landmark, rises to 1405 m.

Presence of erratics on the summits of the surrounding mountains, as well as the morphology of the Fisherman Lake basin, leaves little doubt that the area was glaciated. Rutter and Boydell (1973) recognized three distinct phases of glaciation in an adjacent area to the north, although Rutter (personal communication, 1976) now doubts the existence of the third and youngest phase. During the earliest advance, Laurentide ice moving from the east overtopped the Liard Range, depositing erratics from the Canadian Shield on summits; the second, more topographically controlled advance filled the valleys of the Liard Range to an elevation of approximately 670 m. A similar sequence is evident in the Fisherman Lake region, although there, as in the area studied by Rutter and Boydell, the chronology of events is poorly known.

It might be concluded from Rutter's (1974) data on the southward rise in elevation of meltwater features in the Mackenzie Mountains that both Fisherman Lake basin and the surrounding peaks were overridden by Laurentide ice during the late Wisconsinan. It now appears more probable that the meltwater features that he was mapping are of early, instead of late, Wisconsinan age (Rutter, 1978); consequently the "second, more topographically controlled advance" mentioned above may mark the actual extent of late Wisconsinan Laurentide glaciation in the Fisherman Lake area. Glaciolacustrine sediments occurring in the basin to an elevation of approximately 450 m undoubtedly were deposited when retreating late Wisconsinan glaciers no longer occupied the basin but still impinged on the east flank of Liard Range, thus blocking northward drainage of the Liard River system (Fig. 1; Rutter et al., 1973b)[1].

John Klondike bog (elevation 460 to 470 m) is near the probable maximum elevation of the glacial lake; but since by 9500 years ago Laurentide ice lay well to the east of Mackenzie River (Prest, 1969), it seems unlikely that even the oldest sediments in the bog sequence are correlative with the glacial lake phase. According to one interpretation (Prest, 1969), Fisherman Lake basin was free of both glacial ice and ponded meltwater by 10 500 years ago (Fig. 1).

Fisherman Lake is a remnant of the glacial lake that once occupied the basin. Two facts: (1) a low terrace ringing the lake and seeming to close at the incised outlet and (2) the location of archeological sites at slightly higher elevation than the present lake level (J.F.V. Millar, personal communication, 1971) suggest that at some time during the Holocene the lake level was several metres higher than at present.

Local Stratigraphy

Stratigraphy of the core sequence is given in Figure 2. The term "sedge peat" (probably equivalent to "sedge-fen peat" of Zoltai and Tarnocai, 1975) refers to sediments composed mainly of sedge stem and leaf fragments which accumulated at the periodically flooded, constantly damp margin of a small pond.

What is here called "gyttja" (Fig. 2) would undoubtedly be classed by others as "coarse gyttja" because of its content of seeds and other large plant and animal macrofossils. It probably accumulated at the constantly submerged nearshore region of a pond or lake and as such is intermediate between Zoltai and Tarnocai's (1975) sedge-fen peat and aquatic peat. Moreover, it is clear from their descriptions that they would call "aquatic peat" some of the sediments classed here as "calcareous gyttja". For the most part the calcareous fraction is predominantly large mollusc fragments; however, in basal samples the fine fraction as well is calcareous.

At the time of coring – early June – all sediments below 10 cm were frozen, but some of this is surely seasonal frost. The active layer in the Fisherman Lake area is slightly thicker than 50 cm (Zoltai and Tarnocai, 1975) but certainly not as great as 150 cm, the level in the core at which the first segregated ice bands occur.

PALYNOLOGY

Surface Samples

Surface pollen spectra reflecting the present regional pollen rain (Fig. 2) are necessary for interpretation of fossil pollen spectra, especially in this case because no other palynological data are available for the southwestern part of the Northwest Territories. Sample A (Fig. 2) is from pooled subsamples of surface litter and moss polsters collected at several randomly chosen sites on the bog near the coring site and consequently is equivalent to the 0 cm level of the core. Sample B is from the **Sphagnum** dominated portion of the collapsed bog near the core site. Sample 1, from a small lake located south of Fisherman Lake, and sample 2, from the south end of Fisherman Lake, (Fig. 1), are from nearshore lakebottom sediments. Samples 1 and 2 represent the regional pollen rain, whereas samples A and B portray to a greater extent local vegetation conditions at the coring site.

Several features are common to the surface samples. In three of them **Picea** and **Pinus** percentages are relatively high; in sample B they are probably somewhat lower only because of over-representation of alder pollen. **Pinus** pollen in the four samples must be somewhat allochthonous because the only pines growing in the region today are restricted to the subalpine zone of the surrounding mountains. **Betula** percentages average near 10 per cent, slightly below values for alder. Little or no grass pollen is present, and sedge (Cyperaceae) values do not exceed 10 per cent.

The chief distinction between the set of samples from near the site and the two from the lakes is the high percentage of **Sphagnum** spores in the former. This is evidently a reflection of the abundance of **Sphagnum** on the bog and provides a clue as to how the development of such an elevated bog might be recognized in a pollen sequence (Zoltai and Tarnocai, 1975). Ericaceous plants such as **Ledum**, **Vaccinium**, and **Empetrum** are abundant near the coring site yet Ericales pollen accounts for less than 5 per cent of the pollen rain in samples A and B. Finally, although **Populus** is the dominant tree in forest communities surrounding the bog, it is poorly represented in the surface spectra, undoubtedly a reflection of the well known susceptibility of **Populus** pollen to rapid degradation (Havinga, 1964; Lichti-Federovich and Ritchie, 1965).

Pollen Zones

Results of pollen analyses are presented in terms of relative abundance (per cent), there being too many uncertainties associated with dating the rate of deposition to warrant an absolute pollen influx diagram.

The core sequence has been divided into three zones, one of which contains four subzones (Fig. 2). The zonal boundaries reflect changes of pollen frequencies thought to represent regional vegetational changes, whereas the subzones of zone C more likely portray local vegetational change. The zones are not formal pollen assemblage zones (Cushing, 1967).

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[1] Millar (1968) cited a ^{14}C date of 32 700 $^{+1900}_{-1500}$ years (I-3187) on wood fragments from between reworked till and overlying glaciolacustrine sediments at an exposure near Fisherman Lake (Fig. 1). This date could be interpreted to mean that the last glaciers to occupy the lower parts of the basin were early Wisconsinan and that a second, late Wisconsinan advance, which did not enter the basin but did block northern flow of Liard River, accounts for the glaciolacustrine sediments. However, there is no evidence at the exposure to suggest that the reworked till and glaciolacustrine sediments represent separate glacial advances, and Millar justifiably urged cautious interpretation of the date.

Millar (1968) also stated that the stratigraphy of the exposure yielding this date implied two separate phases of glaciolacustrine deposition ("glacial Lake Liard I and II"), and he has recovered artifacts beneath the sediments which he has related to the second lake phase (J.F.V. Millar, personal communication, 1970). The archeological implications are obvious and, like the ^{14}C date listed above, have been alluded to elsewhere (Reeves, 1973, p. 5), but I doubt the existence of two glaciolacustrine phases since "glacial Lake Liard II" sediments are not, in my opinion, of glaciolacustrine origin.

Zone A, including approximately the lower 90 cm of core, is characterized primarily by high percentages of **Betula, Picea,** and **Pediastrum,** combined with less than three per cent of **Pinus** and **Alnus.**

The boundary between zones A and B marks the rise of **Alnus** percentages, which then fluctuate between 10 and 30 per cent for most of the remainder of the sequence, including surface sample A. **Betula** percentages are slightly depressed in zones B and C, but this is probably due to the constraints imposed by higher percentages of alder and sedge pollen.

Zone C starts with the initial rise of **Pinus** percentages. The pine curve maintains a level of about 10 per cent through the remainder of the core. Per cent of pine is somewhat higher in surface sample A.

Boundaries between subzones C_1, C_2, and C_3 are drawn at the points where the **Myriophyllum** curve rises then falls. Within subzone C_2 sedge pollen percentages increase and remain high (20 to 40 per cent) until a decline in the upper part of subzone C_3. The most pronounced distinction of subzone C_4 is the high percentage of **Sphagnum** (matched in surface samples A and B); equally significant, though less obvious, is the rise in per cent of Ericales pollen and low percentages of sedge pollen.

MACROFOSSILS

Most plants listed in the macrofossil portion of Figure 2 can be ranked according to degree of aquatic adaptation. Thus species of **Potamogeton,** as well as **Myriophyllum exalbescens** and **Ranunculus trichophyllus,** usually grow completely submerged and attached to the bottoms of ponds at depths of up to 3 m. More emergent and occurring near shorelines are **Hippuris vulgaris, Utricularia,** and the sedges (Cyperaceae), **Eleocharis palustris,** and **Scirpus validus.** Another sedge, **Carex atherodes,** will grow in water up to 1.2 m deep (e.g., in northern Alberta), but usually, like specimens of **C. aquatilis,** it grows in shallower, marshy areas. **C. aquatilis** is an important pioneer species of shoreline sites and commonly forms a conspicuous vegetation ring at the margin of ponds. It dominates swampy areas in northern Alberta and southern Northwest Territories (Raup, 1935; Owen and Van Eyk, 1975). **Carex retrosa, Cicuta,** and **Rorripa islandica** also grow on damp sites near ponds, but not necessarily at the water's edge. **Carex canescens** is common to northern Alberta bogs and swamps (Raup, 1935).

Black spruce, **Picea mariana,** and ericaceous shrubs such as **Ledum decumbens** and **Vaccinium vitis-idaea** grow in poorly drained areas, but not usually in standing water. **Alnus crispa** also grows on such sites as well as forming an important component of the understory of aspen stands (Schweger, 1972; Jeffrey, 1964). **Alnus incana** is a pioneer species on active floodplains of large streams and lakes (Viereck and Little, 1972; Jeffrey, 1964). Plate 1 includes SEM (scanning electron microscope) photos of some fossils mentioned above and listed in Figure 2.

Fragments of insects and other invertebrates (Fig. 2, Plate 1) were less abundant than those of plants or molluscs. Ephippia of the cladoceran **Daphnia** commonly occur in terrestrial sediments, but like the statoblasts of Bryozoans, they are most abundant in pond or lake sediments. Note that **Daphnia** ephippia are numerous in the sample from the 220 cm interval and occur in samples as shallow as the 70 cm level. Both chironomid larvae and dytiscid beetles (e.g., **Hydroporus** sp.) live in water, the latter usually in the littoral zone where aquatic plants grow. Individuals of the beetle genus **Donacia** feed on emergent aquatic plants. The rove beetle **Olophrum rotundicolle** (Sahlb.) (E of Plate 1) lives at the damp margins of ponds and fens in the same type of habitat that is preferred by many species of the spider genus **Erigone** (R. Leech, personal communication, 1970).

CHRONOLOGY

Radiocarbon dates (Table 1) used for this study are included in the pollen diagram (Fig. 2) and are plotted as a function of the depth at which the material used for dating was collected (Fig. 3). The deflection within zone A, which is evident in Figure 3, may be the result of more rapid deposition of the "very calcareous gyttja", but spurious ^{14}C dates could also be the cause. For example, some of the dated samples may be influenced by "old" carbon since the material submitted (e.g., for GSC-1786, GSC-1787, and GSC-1871) consists partly (mostly in the case of GSC-1871) of the remains of submergent aquatic plants like **Myriophyllum** and **Potamogeton** which obtain part of their assimilated carbon from dissolved CO_3 ions, (the "hard water effect" Godwin, 1969; Shotton, 1967, 1972) which in this case likely originate from solution of Paleozoic limestone.

The validity of the sedimentation curve shown in Figure 3 is further compromised by the presence of segregated ice bands in parts of the core. These ice lenses formed after deposition of the sediments as the latter became frozen; and therefore, they represent an almost instantaneous lengthening of the core, causing steepening of the sedimentation curve.

For all of the above reasons, the dates cited in Figure 2 must be used with caution in extrapolating the age of zonal boundaries (see Karrow and Anderson, 1975). The 8700 year old date (GSC-1871) should be considered as the maximum age for the zone A-B boundary, and similarly GSC-1787 (6660 ± 290 years), though probably less influenced by the hard water effect than GSC-1871, is a maximum estimate for the start of zone C. The basal date in the sequence, 9590 ± 320 years (GSC-1890) should be considered a minimum date because the sample consisted entirely of shells.

Extrapolated ages for zonal boundaries in the upper part of the core are probably more reliable. Thus according to Figure 3, the age of material at 110 cm level (a large macrofossil assemblage discussed below) is about 2000 years old; the zone C_2/C_3 boundary dates at 1500 to 1600 years; the peak of grass pollen within zone C_3 at 600 years; and the initial rise of **Sphagnum** marking the start of zone C_4 at 300 to 500 years B.P.

DISCUSSION

When John Klondike bog was cored virtually no paleoecological research had been initiated in the upper Mackenzie drainage system. The nearest detailed studies to the south were at Lofty Lake (Fig. 1) and Alpen Siding Lake in northern Alberta (Lichti-Federovich, 1970, 1972); in the other direction for comparable paleoecological data one had to look as far north as Colville Lake or Tuktoyaktuk Peninsula (Fig. 1; Nichols, 1972; Ritchie, 1972). Hansen (1950) has published results of pollen analyses of cores taken near Fort Nelson, British Columbia (Fig. 1) and at other sites along the Alaskan Highway, south of Fisherman Lake; but the utility of his data is limited because his core sections were undated and because he dealt only with tree pollen. Thus John Klondike bog is the site of the first more or less detailed paleoecological study in a vast area of the Northwest Territories. But it will not long remain unique for studies of a number of cores from upper and middle Mackenzie Valley are now nearly complete (C.E. Schweger, personal communication, 1977; J.C. Ritchie, personal communication, 1978), and preliminary results from one highly significant site near Wrigley (Fig. 1), Northwest Territories, have already been cited (Slater, 1978).

Table 1 Radiocarbon dates

Lab.No.	Age[1]	Sample Depth (cm)	Material	Pretreatment and Comments
GSC-1888	930 ± 70	40-50	Sedge peat, fibrous	Sieved (0.102 mm opening) to remove silt and colloids; oven dried; 6.7 g dry.
GSC-1786	4320 ± 130	250-260	Calcareous gyttja	20% HCl for 24 h; Calgon for 30 minutes to disaggregate clay and silt particles; sieved (0.102 mm opening); oven dried; 6.7 g dry.
GSC-1787	6660 ± 290	330-350	Calcareous gyttja	20% HCl for 24 h; sieved (0.102 mm opening); oven dried; 3.7 g dry. Bulk of sample removed by acid pretreatment. Dated material consisted of aquatic and terrestrial plant fragments.
GSC-1871	8700 ± 350	385-400	Very calcareous gyttja	20% HCl for 24 h; Calgon for 30 minutes to disaggregate clay particles; sieved (0.102 mm opening); oven dried; 1.7 g dry. Noncalcareous dated matter consisted mostly of fragments of submergent aquatic plants (e.g. **Myriophyllum**). Highly calcareous nature of sediment indicated by small amount of residue after acid treatment.
GSC-1890	9590 ± 320	465-470	Very calcareous gyttja (true marl)	No HCl or other acid pretreatment; sieved (0.254 mm opening); air dried; 4.6 g dry. Dated material consisted entirely of mollusc and ostracod fragments.

[1] years before present; error value = ± 2σ

Local Environmental Change

That most of the changes of pollen frequencies do reflect local rather than regional change could have been predicted from pollen data alone, but the macrofossils (Fig. 2) provide powerful substantiating evidence of this fact.

Basically the pollen and macrofossil records portray the movement of shoreline across the coring site as part of a small lake or fen evolved into a raised marginal bog. High percentages of **Pediastrum** and abundance of molluscs in the lower parts of the core are evidence of open water conditions, whereas increasing frequency of macrofossils of submerged and emergent aquatic plants in the upper part of the core reflects an approaching lake shoreline. The rise of **Myriophyllum** pollen percentages in zone C_2 corresponds with abundance of **Myriophyllum exalbescens** fruits in the macrofossil samples, and most, if not all, of the **Myriophyllum** pollen probably represents that species. Sedge percentages rise abruptly in zone C_2, and this is correlated with an increase in the abundance of macrofossils of sedges such as **Carex**, **Scirpus**, and **Eleocharis**. Abundance of **Eleochraris palustris** type and **Scirpus validus** fruits in the 80 to 160 cm interval is undoubtedly a reflection of the proximity of the coring site to the emergent vegetation zone of a former pond margin. Movement of the shoreline across the site is indicated first by the peak of **Carex aquatilis** fossils in the 20 to 60 cm level, followed by a rise in number of **Carex canescens** macrofossils in the uppermost part of the core. The abrupt rise of **Sphagnum** percentages, an increase in the abundance of bryoid fragments, and a slight rise of Ericales pollen percentages within the top 10 cm mark the final phase in the formation of the existing frozen, elevated bog.

The peak of grass pollen within zone C_3 is an enigma. If, like the rise of sedge pollen, it also represents the transgressing shoreline, one would expect to see macrofossils of aquatic grasses like **Glyceria** or **Beckmannia**. None are present, so it is possible that the peak of grass pollen marks a regional event – perhaps a time when the Fisherman Lake area was less forested than now. However, if the grass peak is as old as the extrapolated date of 600 years, it cannot refer to the deforested era recalled by John Klondike, one of the oldest native residents in the area (C.E. Schweger, unpublished report, 1972).

As well as permitting more precise interpretation of the pollen record, macrofossils indicate the character of the pond waters, and thus allow potential comparison with present-day conditions.

The present-day tolerance limits of many species listed in Figure 2 are known (Moyle, 1945). Combined tolerance ranges of some of the species at the 110 cm level of the core suggest that the water of the pond approximately 2000 years ago was hard, with an alkalinity range of 70 to 187 ppm; sulphate concentration 0 to 17 ppm; and pH 7.7 to 8.7 (Fig. 4). If the few fossils of **Potentilla palustris** indicate that this plant was growing at the pond margin, the total alkalinity was probably not above 150 ppm and the pH no higher than 7.7 (Moyle, 1945). A pH of 7.7 is considerably higher than the pH of fens in the region today (Lavkulich, 1973).

Admittedly these data apply to only one level of the core. The ideal situation would be a record of water chemistry history during the entire aquatic phase of the core sequence which could then serve as a baseline for comparison with present day changes, especially those that are man related.

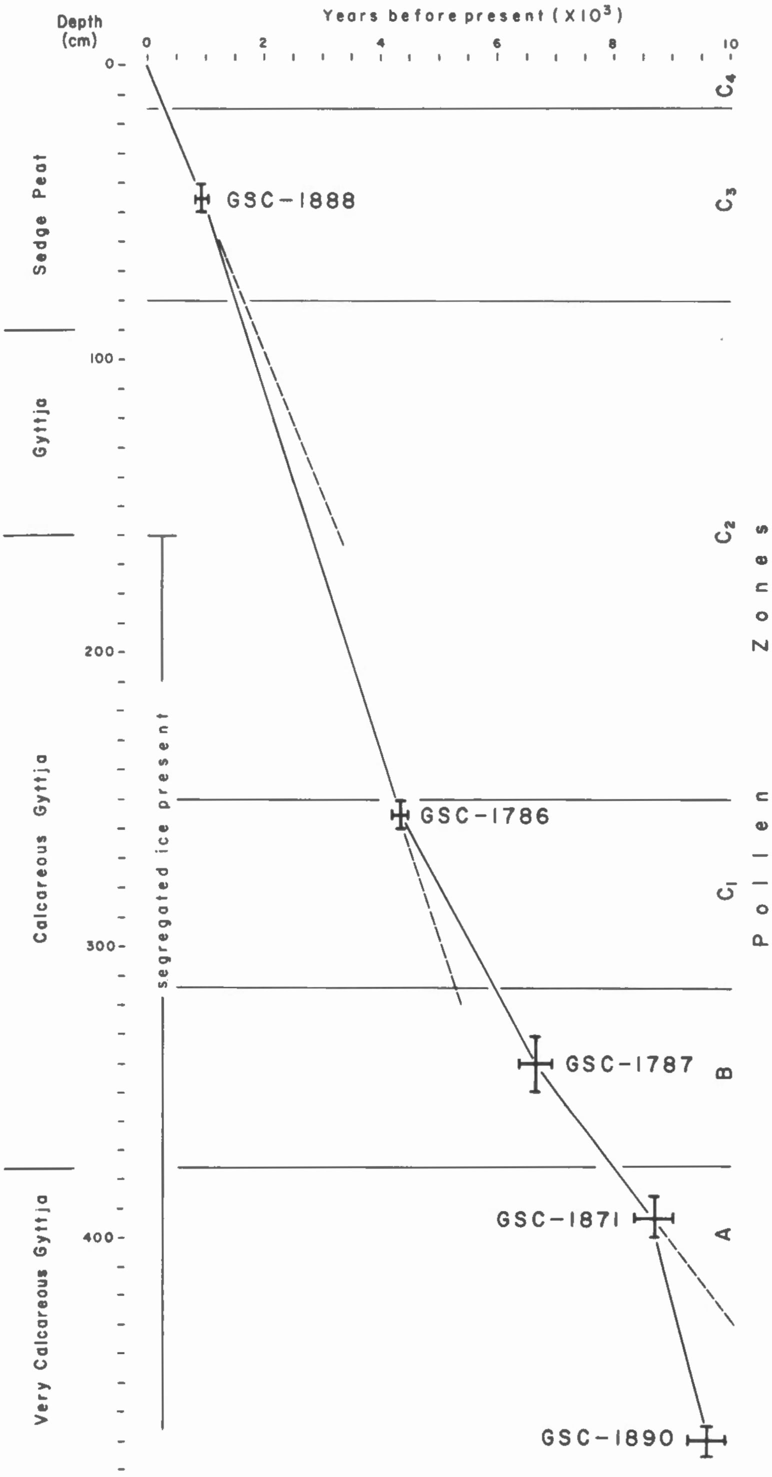


Figure 3. *Sedimentation curve for John Klondike bog illustrating anomalies of the ^{14}C dates (cf. Fig. 2). The height of the symbol is the increment of sediment sample used for dating and the width is 2 sigma error on the radiocarbon age determination.*

Nevertheless, the example of the assemblage from 110 cm depth does show the value of plant macrofossils for obtaining quantitative estimates of water chemistry, and with more attention to this approach in northern Canada, detailed information such as that now available for Minnesota (Birks, 1972) should be forthcoming.

Regional Environment

Though local environmental change dominates the pollen diagram, not all facets of regional vegetation are obscured. For example, it is clear from both the spruce pollen curve and the macrofossil record that spruces have grown near the site for the entire time period encompassed by the core sequence. Similarity of spruce and birch percentages in the core to those in the surface samples probably means that forest conditions, essentially like those of the present, have prevailed in the Fisherman Lake region for most of the last 9500 years. Poplars could have been just as abundant as at present and still be completely unrepresented in the pollen diagram; however, during the early period of core deposition alders and pines in the Fisherman Lake region were either rare or present but producing very little pollen (Matthews, 1975). The first explanation seems most probable, for both pine and alder are normally prolific pollen producers and are usually well represented in the contemporary pollen rain, even in those regions where their cover values are low.

Two changes of pine pollen frequencies seem to be indicated in the diagram, the first being the initial rise of pine percentages at the 320 cm level and the second marked by the higher percentages of pine in the surface samples from the core site. A comparison of spruce/pine ratios for each level (Fig. 5) suggests that the 320 cm change in pine percentages is the only significant one; however, the ratio change at 320 cm could be related to a shift in abundance of either of the two components in Figure 5 and consequently not necessarily be an indication of a real increase in the influx of pine pollen. But spruce macrofossils occur both below and above the 320 cm level of the core (Fig. 5) which means that spruces were growing near the site before the recorded shift occurred in spruce/pine ratios. This fact implies that the drop in the ratio above the 320 cm level is the result of a real increase in influx of pine pollen. The obvious conclusion is that pines first moved into the Fisherman Lake area during the mid-Holocene, about 6700 years ago, and, providing the higher pine percentages in the surface samples are not significant, pines have never been much less or more abundant than now during the last 6700 years. This means that pines probably invaded the area via a subalpine route and have remained in that altitudinal zone ever since. **Pinus contorta** and **Pinus banksiana** are not sympatric in the Fisherman Lake region today, though they are to the north in the Nahanni National Park region (Jeffrey, 1964; Scotter and Cody, 1974). On the basis of the John Klondike bog data it would appear that at no time during the Holocene were the two species found together in the Fisherman Lake region, for if they had been, one would expect **P. banksiana**, which grows on lowland sites, to have contributed much more pine pollen to the pond at the bog site than is indicated by the pollen sequence in Figure 2.

Slater (1978) showed that pine pollen, presumably allochthonous, started to arrive in significant quantities in the Wrigley area (Fig. 1) around 2000 years ago. Anderson (1975) speculated

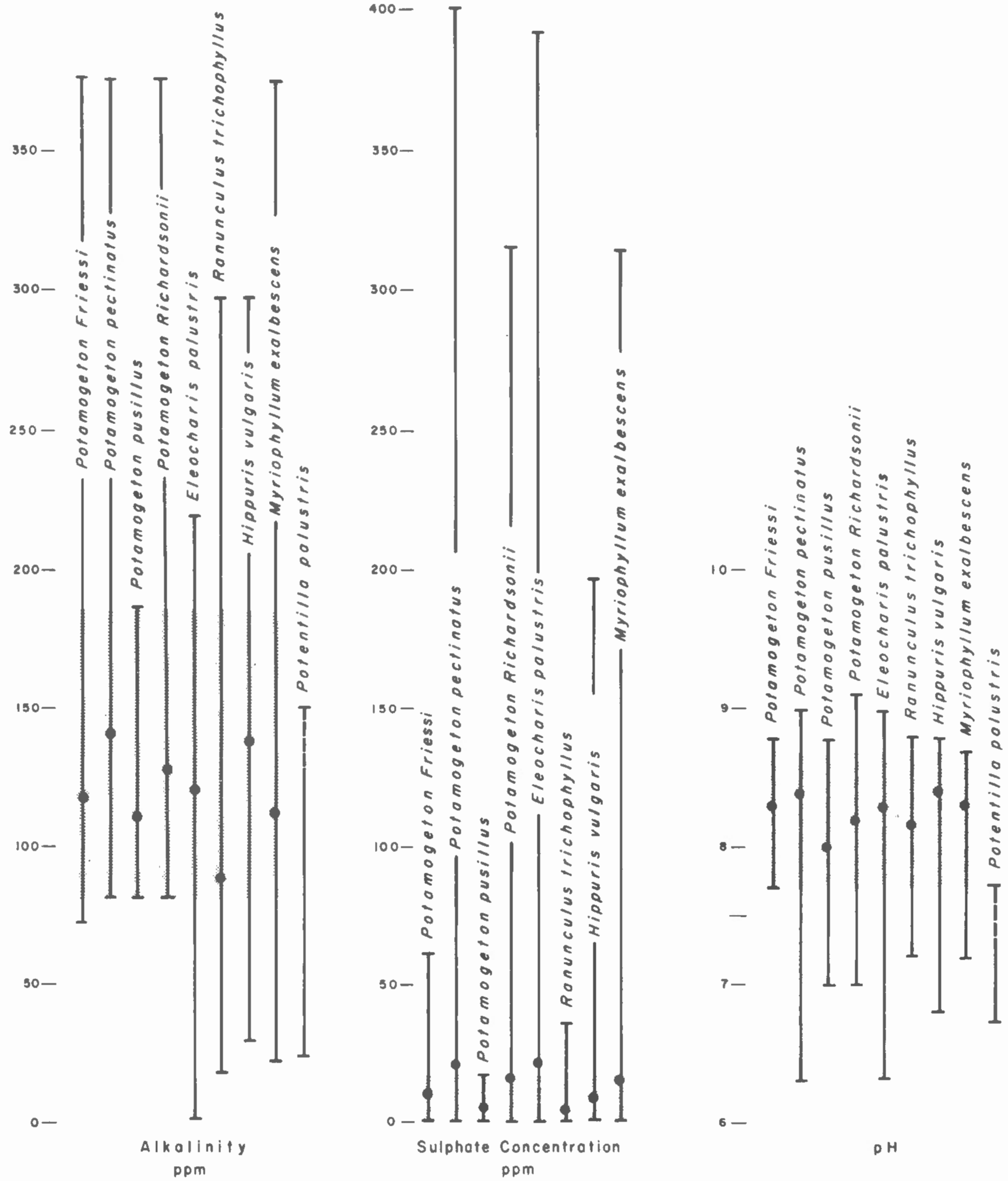


Figure 4. *Chemical tolerance ranges for plant taxa from the macrofossil assemblage at the 110 cm level of core (Fig. 2). Black dot = median value; alkalinity (total alkalinity) = ppm $CaCO_3$; sulphate concentration = ppm SO_4 ion. Tolerance data from Moyle (1945).*

Plate 1

Illustrations of plant and insect fossils from John Klondike bog.

A. Aerial view of John Klondike bog and adjacent fen. The coring site is not shown but was located near the margin of the fen in an area similar to that near the border of the spruce forest in the background. (Photograph by C.E. Schweger)

Plant and insect fossils:

B. **Carex canescens** L. (Cyperaceae); GSC-60813; perigynium and achene; 20 cm level of core.

C. **Carex canescens** L. (Cyperaceae); GSC-60813; achene removed from specimen in Fig. B.

D. **Rorippa islandica** (Oeder) Borbas (Cruciferae); GSC-60814; seed; 80 cm level of core.

E. **Olophrum rotundicolle** (Sahlb.) (Insecta, Coleoptera); GSC-60815; pronotum; 20 cm level of core.

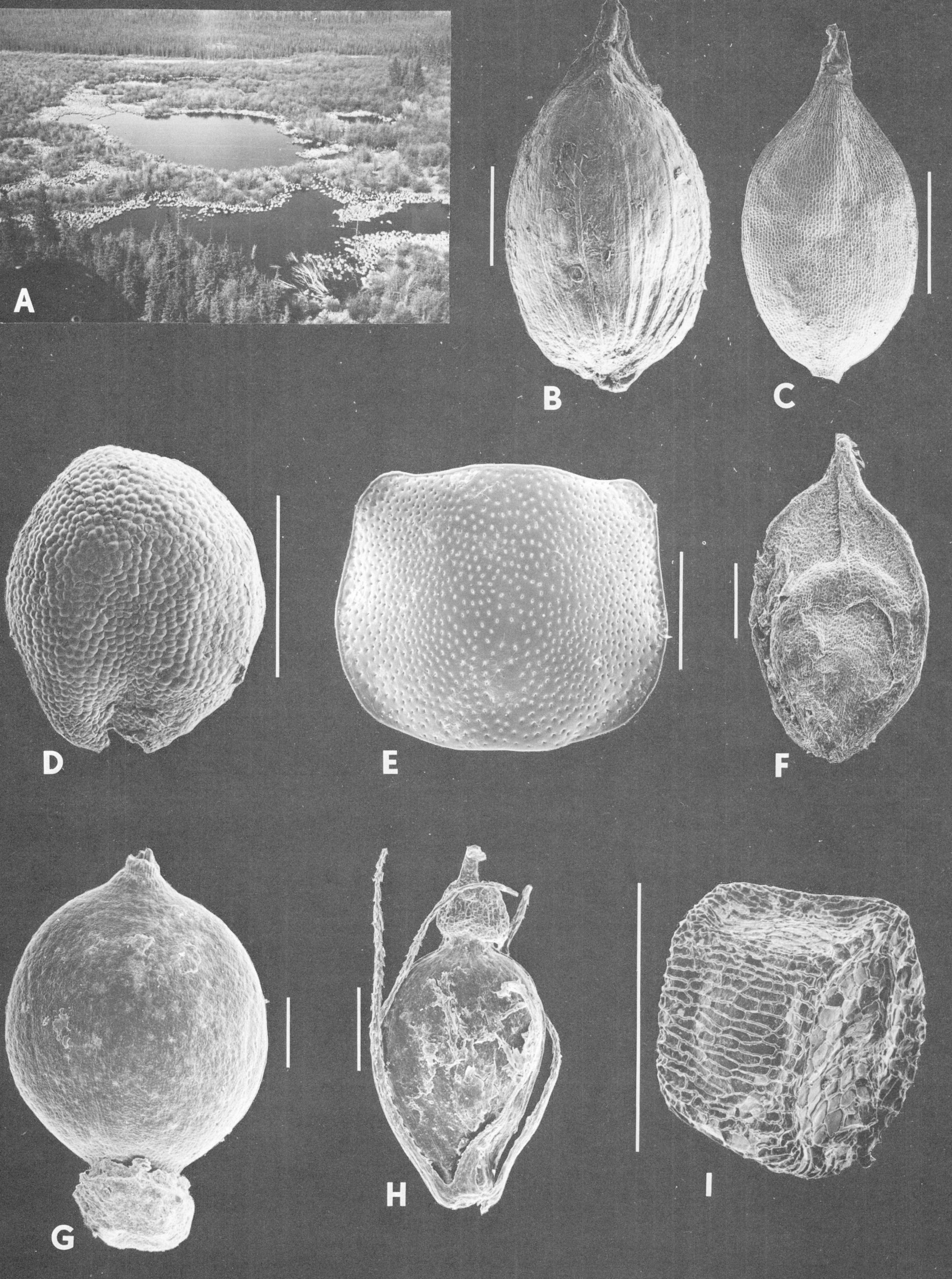
F. **Carex aquatilis** Wahlenb. (Cyperaceae); GSC-60816; perigynium with achene; 30 cm level of core.

G. **Scirpus validus** Vahl. (Cyperaceae); GSC-60817; achene; 150 to 160 cm level of core.

H. **Eleocharis palustris** (L.) R. and S. (Cyperaceae); GSC-60818; achene with barbed bristles; 80 cm level of core. Some authors consider **E. uniglumis** (Link) Schult. to be synonymous with **E. palustris**, but most list it as a separate species. Except under the best conditions of preservation, **E. uniglumis** and **E. palustris** achenes cannot be distinguished.

I. **Utricularia** sp. (Lentibulariaceae); GSC-60819; seed; 80 cm level of core.

Scale bar for all figures is 0.5 mm.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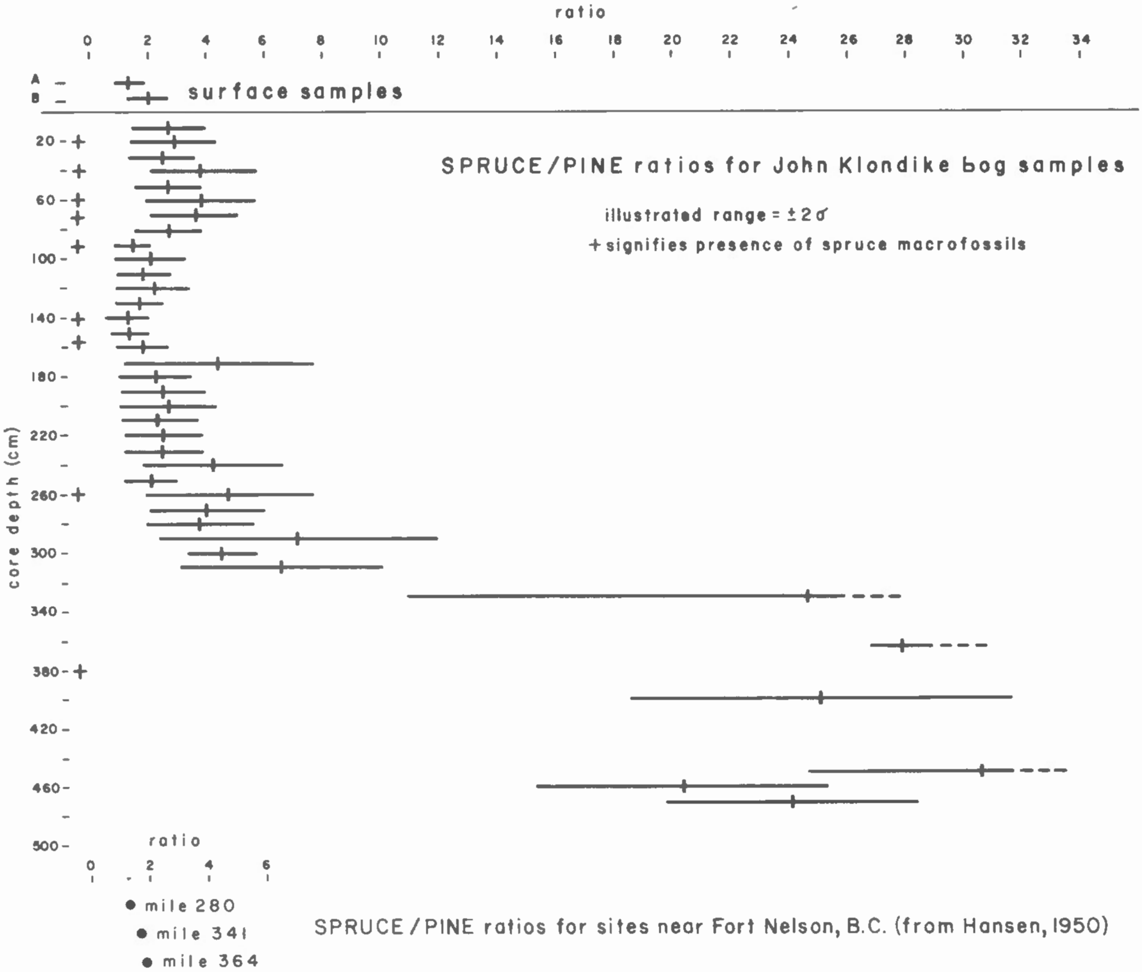

Figure 5. *Ratio of spruce to pine pollen (calculated using formula in Maher, 1963) in the John Klondike bog sequence compared to spruce/pine ratios in surface samples at the bog site and at sites along the Alaska Highway near Fort Nelson, British Columbia. Horizontal bar = 2σ variation about the mean (vertical tick mark). Fort Nelson data derived from Hansen (1950) using percentages of pine and spruce at the top of cores from the three indicated sites.*

that pine may have migrated into northeastern British Columbia during the early Holocene, but on the other hand most of Hansen's (1950, 1953) pollen diagrams from sites along the Alaska Highway show a rise of pine percentages only in their upper (presumably late Holocene) portions as is the case for the John Klondike core. At several of Hansen's sites nearest Fisherman Lake (Fort Nelson area, Fig. 1) the ratio of spruce/pine at the top of the cores is approximately the same as in the upper part of the John Klondike bog sequence (Fig. 5). When studies by C.E. Schweger (University of Alberta) on cores from the middle Mackenzie Valley are completed, we should know better how the rise of **Pinus** pollen in the John Klondike bog actually relates to migration history of pine during the Holocene. It is noteworthy that many cores under study do reveal a pattern similar to that shown at John Klondike, with pine percentages undergoing a single expansion after the rise of spruce and remaining at a rather constant value through the remainder of the cores (C.E. Schweger, personal communication, 1977).

The abrupt rise of alder percentages shown in Figure 2 probably also marks the migration of alder into the Fisherman Lake area, although in view of findings concerning alder in the Mackenzie Delta region (Matthews, 1975), such a conclusion must be considered tentative. At least it can be concluded that alders were either absent or rare near Fisherman Lake prior to 8700 years B.P. Alders did not become an important component of spruce-birch forests in the Wrigley area until around 6000 years B.P. (Slater, 1978).

Two species of alder, **Alnus crispa** and **Alnus incana,** presently grow in the Fisherman Lake region, but they cannot be reliably distinguished by their pollen, so it is impossible to know which species is represented by the initial rise of **Alnus** pollen at the 380 cm level of the core. It is probable, however, that **Alnus incana** was present in the region by approximately 2000 years ago since the 110 cm level of the core contained a single **Alnus incana** fruit. At present **A. incana** is rare or absent in the Fisherman Lake basin, but it is a member of riparian communities near Fort Liard, in fact all along the recent floodplains of large streams in the Liard-Mackenzie system (Jeffrey, 1964).

Providing the rise of alder and pine in the pollen diagram is the result of migration rather than climatic change, there is no feature of the diagram which can be related unequivocally to a mid-Holocene climatic fluctuation even though the core spans the time interval during which the well known Altithermal or Hypsithermal occurred. Perhaps the insensitivity of the John klondike sequence is to be expected, for it comes from an area deep within the boreal forest realm, far from the ecotonal areas such as treeline sites in the Mackenzie Delta or the Aspen-parkland region of central Alberta where climate-induced vegetation changes are better reflected in the pollen record (Ritchie, 1972; C.E. Schweger, personal communication, 1976). At John Klondike bog pollen evidence of a regional mid-Holocene climatic fluctuation may also be masked by pollen input associated with the local vegetational changes accompanying the development of the bog.

An abrupt rise of **Sphagnum** percentages at the top of the core, as well as the slight rise of Ericales and decline of sedge, undoubtedly marks the initial formation of the elevated bog existing at the site today. Permafrost probably invaded the site at that time and is partly responsible for the present elevated character of the bog (Zoltai and Tarnocai, 1975). In other words the entire 5 m sequence may have become frozen only during the last 300 to 500 years (the presumed date for initiation of zone C_4). This time period includes the Little Ice Age (Denton and Karlén, 1973), and I am tempted to view the slightly colder climate then as responsible for the formation of permafrost at the coring site. On the other hand, permafrost development any earlier was precluded because the coring site was covered with water until shortly before 500 years ago. So even if permafrost did first appear during the Little Ice Age, regional climate may have been cold enough for its development somewhat earlier.

In summary, the core from John Klondike bog is largely a record of local environmental change during the last 9600 years, but it does provide evidence of two important events – the migration of alder and of pine into the Fisherman Lake region. Macrofossils contribute to the interpretation of the pollen data and allow some estimates to be made of former water chemistry conditions.

In northern North America today the tempo of ecological research is undergoing a quantum expansion, largely as a result of large programs such as the International Biological Programme (IBP) and environmental studies associated with petroleum exploration and pipeline construction. Extremely sophisticated methods - computer modelling, satellite photogrammetry – are being used to increase our knowledge of present environmental conditions with the hope that his type of information may better facilitate assessment of the impact of man related activities on northern ecosystems. Paleoecological studies are often not included in such programs; yet they provide the only means for establishing what changes have occurred before the onset of man's influence and thus what component of present day environmental change is non-anthropogenic (Terasmae, 1967; Wright, 1974). It is apparent that paleoecological research is an important part of terrain analysis studies, such as those performed in Mackenzie Valley or the efforts in progress elsewhere in northwestern Canada.

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