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Quaternary Research 68 (2007) 261–270
QUATERNARY RESEARCH
www.elsevier.com/locate/yqres

Post-Glacial climatic change on Boothia Peninsula, Nunavut, Canada

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Received 30 August 2006
Available online 2 July 2007

Abstract

A high temporal resolution pollen diagram from a lake in the mid-Arctic region of the Boothia Peninsula, Nunavut, Canada, documents the history of the regional vegetation and climate for the past 7200 yr. Major tundra pollen taxa in the core include Cyperaceae and *Salix*, with Cyperaceae comprising over 50% of the pollen in the early and late Holocene. Tree pollen, transported from far to the south, comprised a large percentage of the pollen sum, with *Pinus* accounting for 30% of the pollen in some levels of the core. Pollen percentages and concentrations of taxa typical of the mid-Arctic were highest in the mid-Holocene, corresponding to warm conditions. Decreasing pollen concentrations indicate cooling temperatures, with more rapid decreases occurring around 4200, 3800–3400, and 2500 cal yr BP. Pollen percentages of *Salix*, Cyperaceae, and *Artemisia* increased in the past 35 yr in response to global warming. Reconstructions of July temperature using the modern analog technique showed that the mid-Holocene (5800–2800 cal yr BP) was approximately 1 °C higher than during the past 1000 yr.
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Keywords: Pollen; Boothia Peninsula; Lake Sediments; Holocene; Arctic; Modern Analogue Technique; Paleoclimatology; Little Ice Age; Medieval Warm Period

Introduction

The earth's climate is changing and the Canadian Arctic is already feeling the impacts of global warming (e.g. Overpeck et al., 1997). However, predictions of future climate change impacts are difficult because of the complex response of ecosystems to climate variations. One source of information about possible future impacts is the study of the past; by analyzing how Arctic ecosystems were affected by past climate changes, we can better infer possible future impacts.

A major proxy indicator of past climates is the pollen produced by plants, some of which are deposited in lake sediments. Pollen assemblages are related to the vegetation, which, in turn, is related to the climate (Bennett and Willis, 2001). Pollen diagrams prepared from lake sediment cores document the history of the regional vegetation through time. Using various analyses, modern pollen assemblages can be related to the modern climate and these relations, in turn, can be used to estimate past climates from the fossil pollen assemblages (Gajewski, 2002).

Several pollen records have been prepared from the coastal regions of Greenland (Fredskild, 1973; Bay and Fredskild, 1997; Wagner et al., 2000, among others). Pollen records from the Canadian Arctic include studies from Ellesmere Island (Hyvärinen, 1985), Prince of Wales Island (Gajewski and Frappier, 2001), Banks Island (Gajewski et al., 2000), and Somerset Island (Gajewski, 1995), as well as several pollen diagrams from Baffin Island (Andrews et al., 1979; Short et al., 1989; Wolfe et al., 2000). Modern samples for use in calibration are available from Banks (Ritchie et al., 1987), Somerset (Gajewski, 1995), Ellesmere (Gajewski et al., 1995) and Baffin Island (Kerwin et al., 2004), as well as a set of samples from across the central and eastern Arctic islands (Gajewski, 2002).

Although these studies have provided descriptive estimates of the paleoenvironments of the Arctic during the Holocene, there still remain questions about the postglacial climate of the region (Gajewski and Atkinson, 2003). Several deficiencies have been identified, including a low density of sites, low temporal resolution of the existing pollen diagrams, problems with radiocarbon dating of the cores and a lack of quantitative estimates of past climates (Gajewski et al., 1995; Gajewski and Atkinson, 2003; Bigelow et al., 2003; Kauffman et al., 2004).

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doi:10.1016/j.yqres.2007.04.003

https://doi.org/10.1016/j.yqres.2007.04.003 Published online by Cambridge University Press

This study presents a new pollen diagram from a lake on the Boothia Peninsula. The diatoms from this core had been previously analyzed (LeBlanc, 2002; LeBlanc et al., 2004). The pollen diagram was prepared at higher temporal resolution than previously published studies. Sediment analysis (including sediment loss-on-ignition LOI) was also performed at high resolution. Past climates were estimated using the modern analogue technique (MAT). The analysis of the pollen assemblages from this core, along with the quantitative estimation of the past climate, will be a step toward the goal of providing a network of sites from the Arctic islands that document the Holocene climatic history.

Site description

The study site, Lake JR01 (unofficial name; Fig. 1; 69 °54′N, 95 °4.2′W, 120 m.a.s.l.) is located in the southwestern part of the Boothia Peninsula. The bedrock in the region consists of Precambrian Shield. Boothia Peninsula is a plateau with low, rolling hills characterized by thick glacial deposits and little relief (Dyke, 1984). The region is in the mid-Arctic vegetation zone near the transition to the low-Arctic, with continuous herbaceous cover dominated by *Dryas, Salix* and S*axifraga* tundra (Bliss, 1988). Climate data from nearby Pelly Bay, Taloyoak and Shepherd Bay indicate cold, dry winters and short, cool, damp summers (Dyke, 1984). The site is closest to the community of Taloyoak (location: 69 °32′N, 93 °31′W) which has a mean annual temperature and precipitation of −15.4 °C and 153.4 mm respectively (Dyke, 1984, from Atmospheric Environment Service, 1975). Lake JR01 is approximately 700 by 350 m in size with two small stream inputs that enter the lake via sedge meadows (LeBlanc et al., 2004). It is a typical Arctic oligotrophic lake with pH of 8.10 and water conductivity of 220 μS cm^{-1} (LeBlanc et al., 2004).

Methods

Lake sediment cores were collected from Lake JR01 on the Boothia Peninsula, Nunavut with a 5-cm diameter Livingstone corer through 5.4 m of water from an ice surface. The base of the lake sediments was not reached due to an insufficient number of drive rods; nevertheless, the core did reach sediments dating to 7200 cal yr BP. The uppermost part of the sediment (0.8 m) was sampled in a plastic tube with piston to ensure that the sediment–water interface was collected. The upper 20 cm of sediment were sub-sampled into plastic bags at 0.5-cm intervals; the remainder of the core was stored at 4 °C in plastic wrap and aluminium foil (LeBlanc et al., 2004).

Every cm down the core, 0.5 cm^3 samples were extracted for loss-on-ignition (LOI) analysis, an index of the amount of organic matter and carbonate. The samples were ignited at

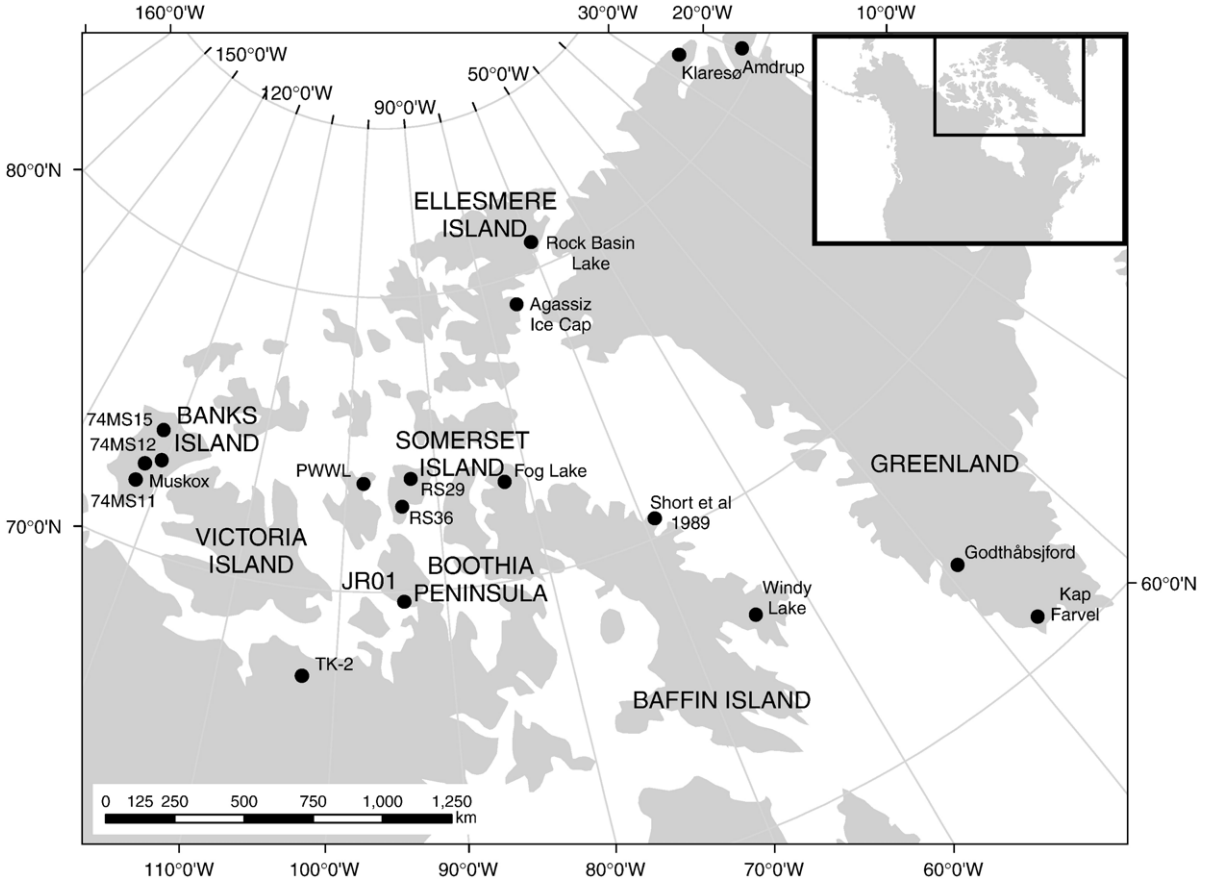


Figure 1. Location of Lake JR01 in the Canadian Arctic. Other sites mentioned in the text are also plotted.

https://doi.org/10.1016/j.yqres.2007.04.003 Published online by Cambridge University Press

550 °C for 4 h and at 950 °C for a further 2 h to obtain estimates of the organic and carbonate content.

Two cm^3 of sediment were extracted at intervals down the core for pollen analysis. Sediment was processed using standard methods of Faegri and Iverson (1975) with the addition of a heavy liquid separation step for most samples. Two tablets of *Lycopodium* were added to each sample to enable the calculation of pollen concentrations (Bennett and Willis, 2001). All samples were treated with 10% HCl, 10% KOH and acetolysis solution (Faegri and Iverson, 1975). Some samples were treated with concentrated HF and sieved through a 7-μm fine mesh after soaking in warm sodium-pyrophosphate (Cwynar et al., 1979). In the remaining samples, pollen grains were separated from the sediment matrix using sodium polytungstate with a specific gravity of 1.95 instead of adding HF. Several wash steps and another 10% HCl treatment were also performed when using the sodium polytungstate method. A comparison between replicates of the same sample processed using the two methods showed no statistical difference in the pollen counts (Zabenskie, 2006), so all samples processed using both methods are used in this study. Silicon oil was added to each sample for final storage.

Small aliquots of the processed sediment were placed on a slide and the pollen grains were counted under a microscope at 400×. The pollen grains were compared to pollen reference material, as well as texts such as McAndrews et al. (1973), Faegri and Iverson (1975) and Kapp (2000) under 1000× oil immersion for critical identification. A pollen sum of at least 300 grains was generally achieved for each level. Typically, several slides had to be counted at each level to obtain this pollen sum due to the low concentration of pollen grains in the sediments. The pollen sum for each level was calculated by summing the total pollen (trees, shrubs, herbs and spores) for that level.

The chronology for this core was determined using ^{210}Pb for the uppermost sediments and ten radiocarbon dates for the remainder of the sequence. Nine bulk sediment samples in one-cm increments were sent to MyCore Scientific Inc., Deep River, Ontario for ^{210}Pb analysis. Plant material, larval chironomid head capsules and other chitinous material were picked from five sections of the core (from 1 to 3 cm of sediment core per ^{14}C sample) and sent to Beta Analytic Inc., Miami, Florida for accelerator mass spectrometry (AMS) ^{14}C analysis. The oldest date was obtained from a second core that had been correlated to the first sequence using magnetic susceptibility. Several radiocarbon dates previously obtained (LeBlanc et al., 2004) were also used; these were also based on material individually picked from the core. Calib501 (Reimer et al., 2004) was used to convert the radiocarbon ages to calendar year ages; the mean of the "sigma two" values was used as the calibrated radiocarbon age (Reimer et al., 2004). Sample ages were estimated by linear interpolation between the calibrated ^{14}C ages and the ^{210}Pb ages were used for the uppermost sediment.

A principal components analysis (PCA) was performed on the combined modern and fossil pollen to aid in the interpretation of the fossil assemblages. Modern pollen were obtained from Whitmore et al. (2005), where only "Arctic" sites according to Fedorova et al. (1994) were extracted from the modern database. A pollen sum including only local and regional pollen was used in the PCA and a correlation matrix was utilized.

July temperatures were estimated from the fossil pollen assemblages using the modern analog technique (MAT) (Sawada, 2006). Modern pollen and climate data were obtained from Whitmore et al. (2005); only sites designated as "Arctic" and "Forest-tundra" in the database (Fedorova et al., 1994) were retained as possible analogs. A pollen sum of local and regional pollen was used and the difference between the fossil and modern pollen assemblages was measured using a squared chord distance (SCD). The top five analogs were retained and July temperatures were based on the average of these values.

Results

Chronology and sediment stratigraphy

A 4.84-m sediment core was collected from Lake JRO1. The core is mostly homogeneous in colour, except for light banding in the lowest 2 m (LeBlanc, 2002).

Unsupported ^{210}Pb was detected within the uppermost nine cm of the core with the amount of ^{210}Pb decreasing to the 9-cm level. A constant rate of supply (CRS) model was used to derive the ages for these uppermost sediments. The ten AMS radiocarbon dates together with the ^{210}Pb series provided a reliable chronology with no age reversals (Table 1; Fig. 2) and

Table 1
Radiocarbon dates used to establish the chronology of lake sediment core JR01

Depth (cm)	^{14}C yr BP	Laboratory no.	2σ cal age range	Cal yr BP	Material dated
30–35*	1290±40	Beta-156532	1093–1297	1195	Bryophytes, leaf and branch frags
59–61	2120±40	Beta-204646	1991–2301	2146	Plant material and chironomids
95–100*	2410±40	Beta-156533	2345–2699	2522	Bryophytes, leaf and branch frags
153–154	3030±40	Beta-204647	3081–3356	3219	Plant material and chironomids
220–225*	4290±40	Beta-156534	4729–4971	4850	Bryophytes, leaf and branch frags
295–300*	4890±40	Beta-156535	5584–5717	5651	Bryophytes, leaf and branch frags
349–350	4990±40	Beta-210910	5606–5885	5746	Plant material and chironomids
395–396	5000±40	Beta-204648	5624–5892	5758	Plant material and chironomids
453–456	6160±40	Beta-204649	6948–7165	7057	Plant material and chironomids
544–549*	6320±40	Beta-156536	7163–7409	7286	Bryophytes, leaf and branch frags

Dates used by LeBlanc (2002) are indicated by *. Calibration based on Reimer et al. (2004).

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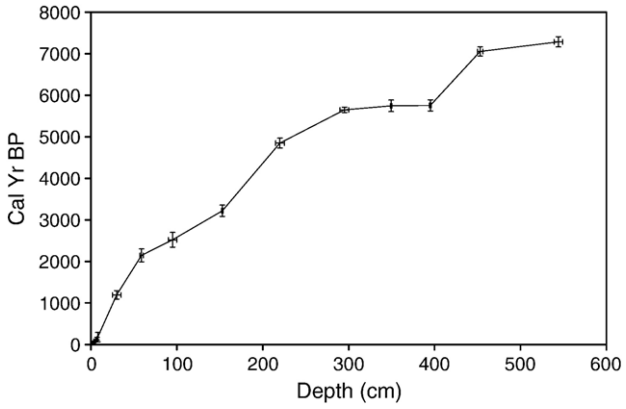


Figure 2. Age-depth curve for Lake JR01.

the age-depth curve was established by linear interpolation between all available dates. This interpretation implies periods of more rapid sedimentation between, for example, 5700 and 5600 cal yr BP and 7300 and 7000 cal yr BP. Both periods of time correspond to small changes in magnetic susceptibility (Fig. 3). There is no reason to exclude any of the dates, as all are based on comparable material and there is no evidence of contamination or re-deposition of old carbon that would make some ages too old. Variations in magnetic susceptibility and loss on ignition (Fig. 3) throughout the core suggest the possibility of changes in lake production or sediment input to the lake. Although the changes in the sedimentation rate implied by accepting all the dates do affect the pollen influx, they occur at the same time as changes in percentages (below). Thus, we consider the chronology reasonable. Sedimentation rates varied between 0.02 and 0.10 cm/yr for the past 5600 cal yr BP, with a general trend toward a decreasing sedimentation rate in the more recent past.

The organic and carbonate content generally have an inverse relationship along the length of the core (Fig. 3). Loss-on-ignition (LOI) is inversely related to magnetic susceptibility as well. LOI remained constant from the base of the core to 6300 cal yr BP at approximately 27%, it then increased to above 30%, and remained high until 4900 cal yr BP. LOI then slowly decreased, with a sharp decrease at 4400 cal yr BP to a value of 20%, returning to 27% by 4000 cal yr BP. Between 2600 and 2460 cal yr BP organic content values decreased to 20%, increasing again after 2460 cal yr BP. In AD 1961, the organic content reached a low of 12%; then increased steadily reaching values greater than 33% by AD 1977. Carbonate content estimated by ignition at 950 °C showed an inverse trend to that of LOI, although changes were not as abrupt.

The maximum values of magnetic susceptibility occurred in the early portion of the record (LeBlanc, 2002). Values decreased until 5700 cal yr BP, then remained relatively low but variable until 4700 cal yr BP. Magnetic susceptibility then increased slowly until 4000 cal yr BP, during a period of decreasing organic matter. At 4000 cal yr BP magnetic susceptibility values started to decrease, reaching lowest values at 2600 cal yr BP, in parallel with LOI. A large peak at 2950 cal yr

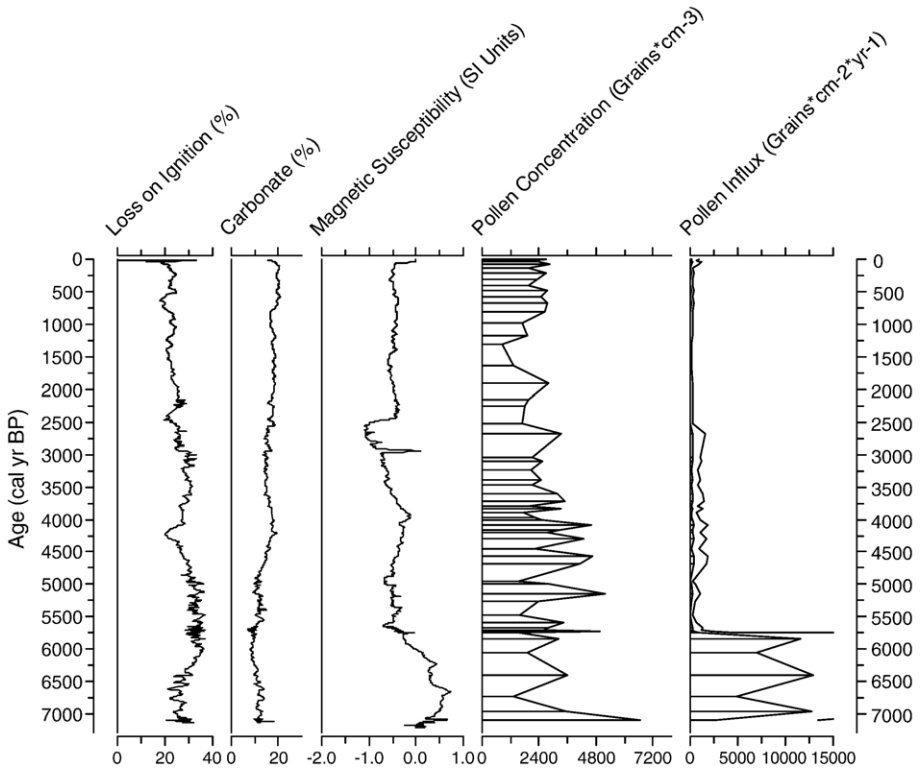


Figure 3. Sediment parameters, pollen concentrations and pollen influx of Lake JR01. A second curve on the influx graph corresponds to a 5× exaggeration.

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BP is attributed to a pebble in the core (LeBlanc, 2002). Magnetic susceptibility increased sharply between 2600 and 2430 cal yr BP and remained constant for the remainder of the core.

Total pollen concentrations were highest in the early Holocene, reaching up to 6400 grains/cm^3. Concentrations decreased after 4000 cal yr BP, reaching lowest values between 2600 and 800 cal yr BP. Pollen concentrations increased between 1500 and 750 cal yr BP and remained steady at approximately 2400 grains/cm^3 for the past 1000 yr. Pollen influx values were highest prior to 5750 cal yr BP. Influx greatly decreased at a time coinciding with a change in the sedimentation rate (Fig. 3). Influx again decreased 2500 cal yr BP and increased slightly during the past 750 yr.

Pollen stratigraphy

Cyperaceae is the most abundant pollen taxon, with percentages reaching greater than 50% in the early part of the core and in the uppermost few pollen spectra (Fig. 4). Percentages were high prior to 5700 cal yr BP then gradually

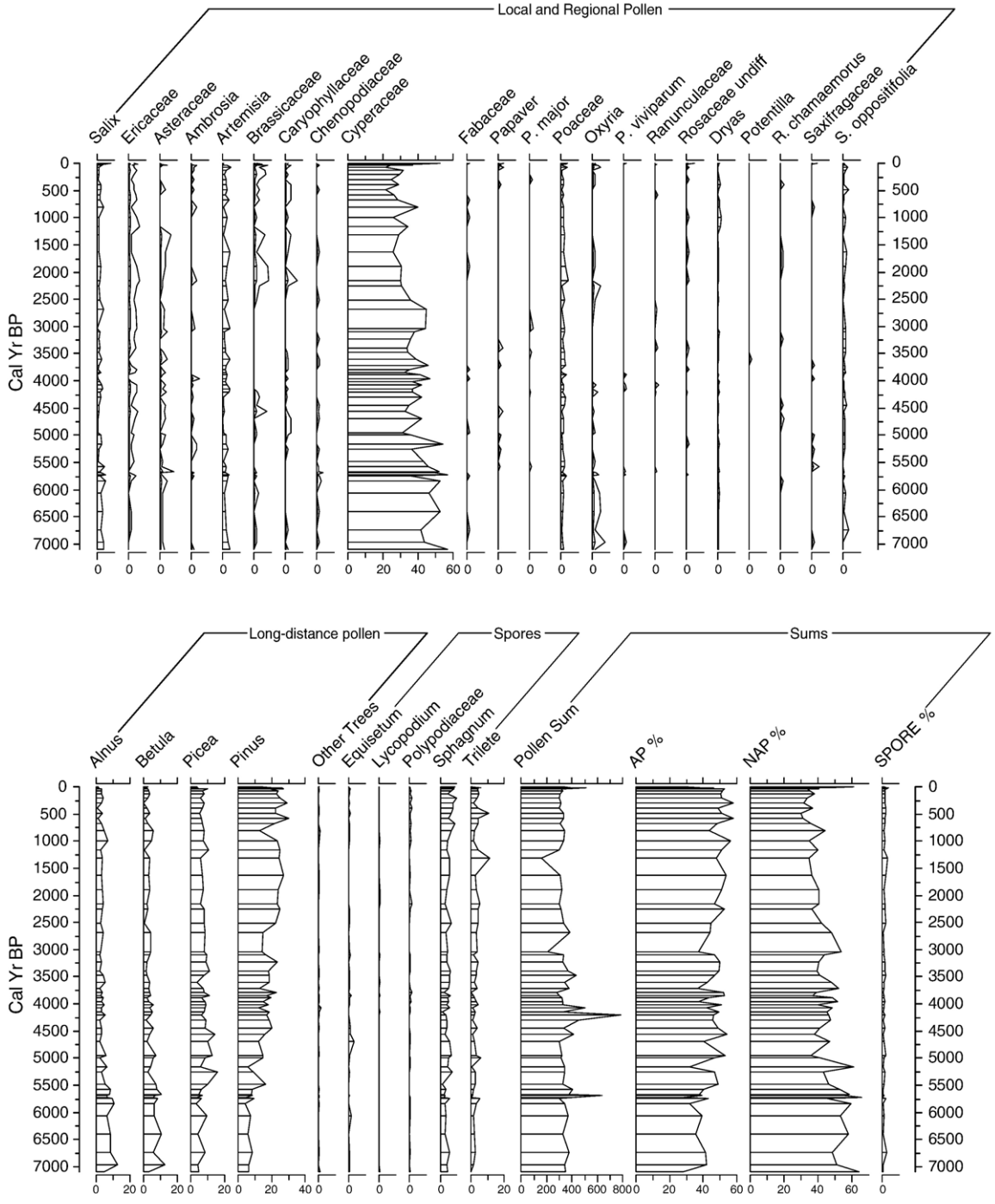


Figure 4. Pollen percentage diagram of Lake JR01. Pollen sum is total pollen and spores. A second curve on selected graphs corresponds to a 5× exaggeration.

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decreased between 5700 and 2700 cal yr BP. Between 2700 and 1500 cal yr BP, Cyperaceae pollen percentages decreased further; this was followed by an increase 1000 cal yr BP and a decrease within the uppermost sediment. During the past 40 yr, Cyperaceae pollen percentages again increased, reaching values close to 60%.

Salix pollen percentages were generally highest in the early Holocene, with values reaching 4%, and then decreasing to 0.6% by 5600 cal yr BP. *Salix* percentages remained between 0.5 and 4% through most of the core. Again, *Salix* pollen percentages increased in AD 1965 to over 8%, the highest values attained in the record.

We include in the category "local and regional pollen" taxa from plants today growing on the tundra of Boothia Peninsula. Many of the percentages of local and regional pollen taxa were found with values below 1% and slightly higher for Poaceae and *Artemisia*. Higher values of *Oxyria* and Chenopodiaceae pollen percentages were found in the early Holocene. Several other taxa, including Poaceae, Caryophyllaceae, Brassicaceae and *Artemisia* had higher pollen percentages in the late Holocene. For example, pollen percentages of Brassicaceae decreased to 0 between 4200 and 2700 cal yr BP, with percentages in the early part of the core close to those found in the late Holocene. Pollen percentages of several taxa, including *Plantago major, Polygonum viviparum*, Ranunculaceae, *Papaver*, Rosaceae, *Potentilla* and *Rubus chamaemorus* were generally absent from the base of the core until 5600 cal yr BP. Between 5700 and 5600 cal yr BP, few pollen grains of Chenopodiaceae, Asteraceae, Fabaceae, *Oxyria, P. major, P. viviparum*, Ranunculaceae, *Papaver*, Rosaceae, and Saxifragaceae were counted (Fig. 4). Few pollen grains of taxa such as *P. major, P. viviparum*, Ranunculaceae and *Papaver* were found from 2600 to 750 cal yr BP.

Long-distance pollen constitutes pollen of plants that are not currently growing in the region. These are mostly tree pollen, but some pollen taxa from shrubs found in the forest-tundra or the southern portion of the shrub tundra (notably *Betula* and *Alnus*) are included here. Long-distance pollen accounts for a majority of the pollen found in the core, with *Pinus* alone accounting for 30% of the pollen in some levels. *Pinus* percentages were low prior to 5500 cal

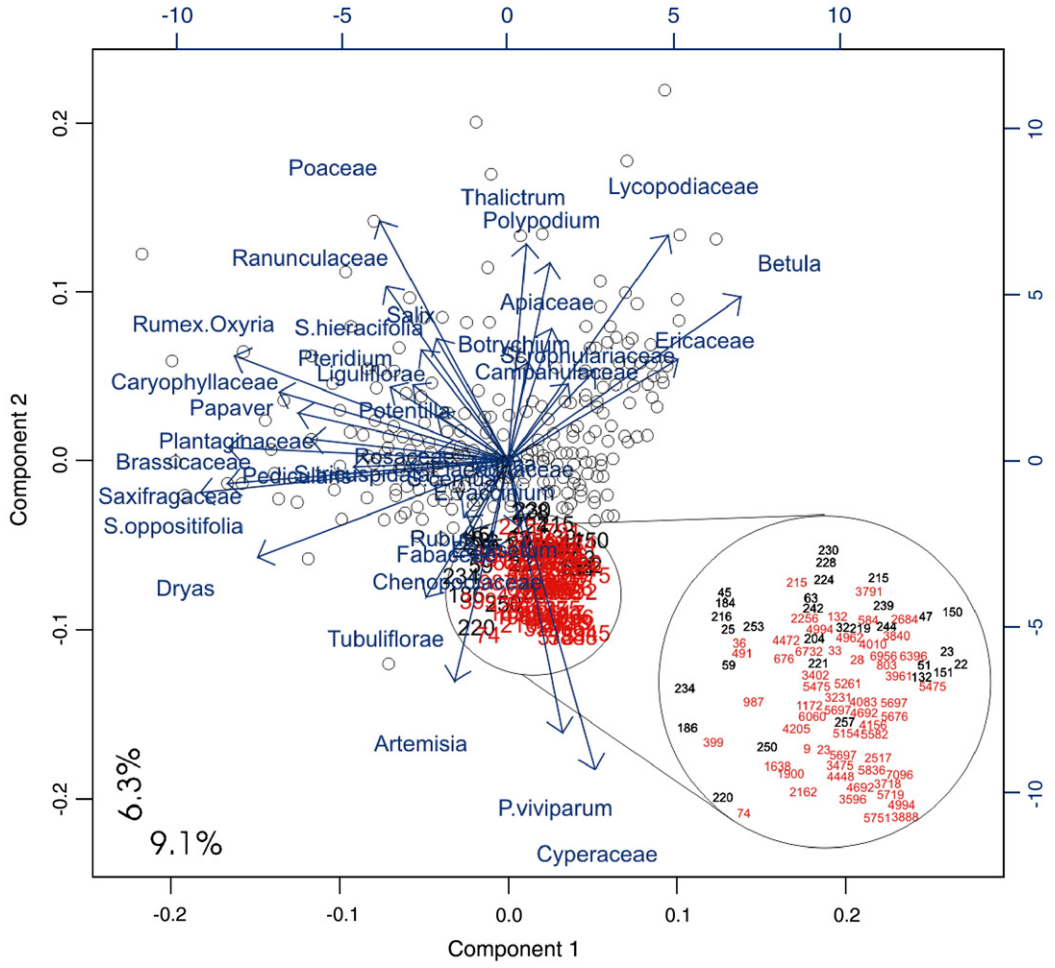


Figure 5. Principal components analysis of fossil pollen spectra from Lake JR01 and modern (bold) pollen samples from Whitmore et al. (2005). See text for details. Open circles on the main diagram correspond to modern pollen samples. The inset circle encompasses fossil samples and modern samples that are mapped in Figure 6. Numbers in bold correspond to modern pollen sample codes, and black numbers are the cal yr BP of fossil assemblage scores.

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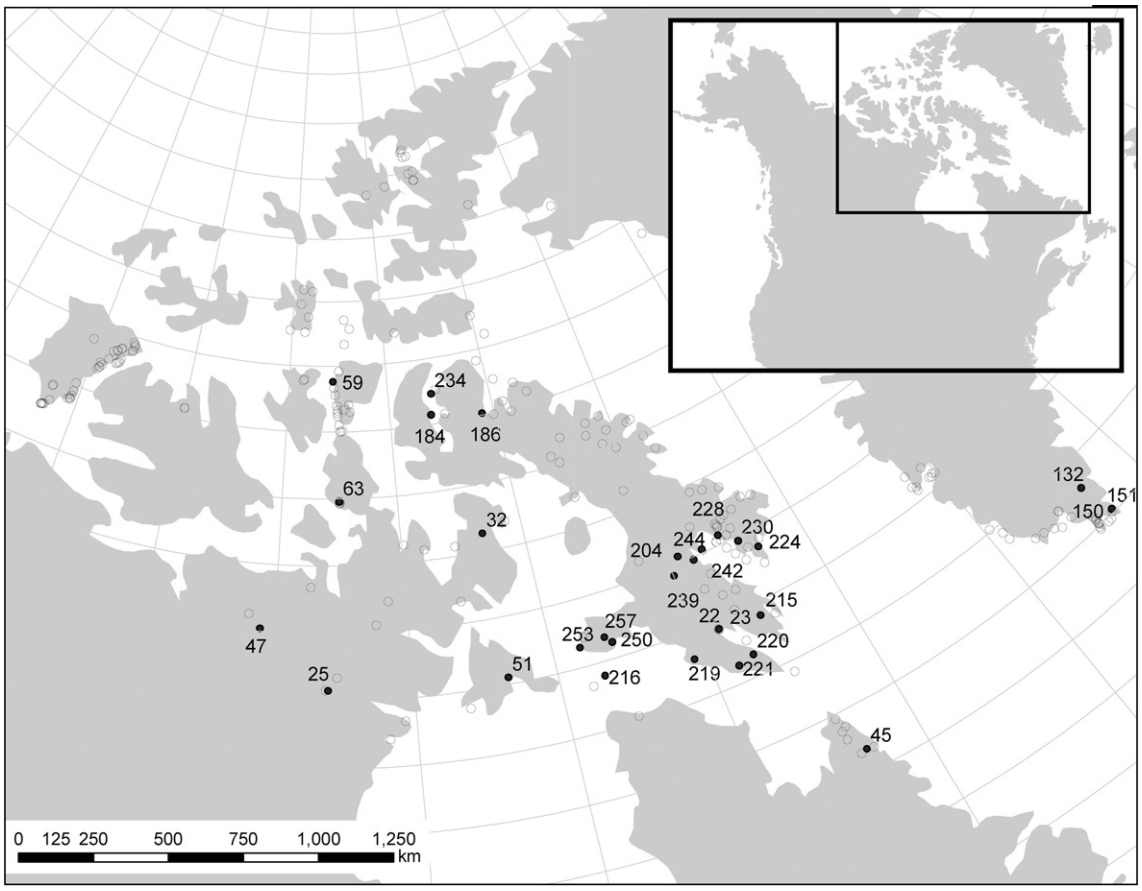


Figure 6. Map of modern pollen sites that ordinate in the same general position with the fossil pollen (closed circle with sample code) and those modern sites not relating to the fossil pollen (open circle) as shown in the inset of the PCA (Fig. 5).

yr BP, with values of 10%. Values increased to 20% by 4500 cal yr BP and then continued to slowly increase during the middle and late Holocene. Superimposed on this long-term trend were periods of lower values, most notably around 4200, 3200–2500 and 1200–500 cal yr BP. *Picea* percentages remained more constant in the core at approximately 10%. Minimum values were found between 2500 and 1250 cal yr BP.

Betula and *Alnus* pollen percentages were highest in the early part of the core at 13% each and the curves of the two taxa were generally parallel. At 5700 cal yr BP, percentages gradually decreased, reaching a few percent by 5500 cal yr BP and maintaining this value through the rest of the core. Smaller fluctuations were apparent in both curves, for example, a short period of lower values between 3600 and 3150 cal yr BP.

Numerical analyses

Component 1 explained 9.1% of the variance and component 2 explained 6.3%. Taxa highly loaded on the first principal component included *Betula*, Ericaceae, and Lycopodiaceae (positive) and *Dryas, Papaver*, Caryophyllaceae, Brassicaceae, *Rumex*/*Oxyria*, Saxifragaceae and *Saxifraga oppositifolia* (negative). Taxa highly loaded on the second axis included Lycopodiaceae, *Polypodium*, *Thalictrum* and Poaceae (positive) and *Artemisia*, Cyperaceae, and *P. viviparum* (negative) (Fig. 5).

All fossil pollen levels were negatively loaded on component 2. Modern samples with similar scores as the fossil samples

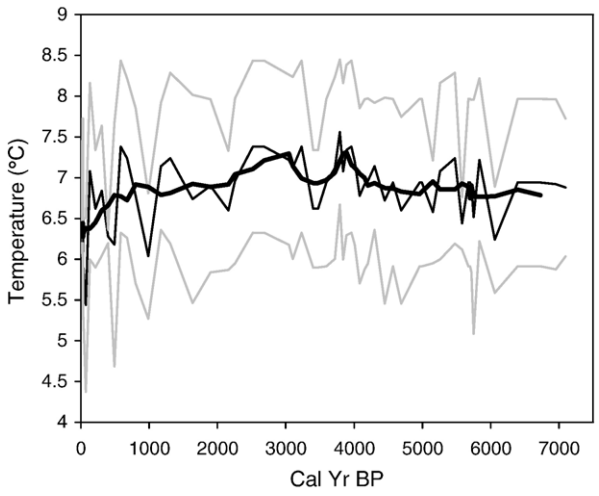


Figure 7. Temperature reconstruction of Lake JR01. Outer thin lines represent the minimum and maximum temperature of the 5 best analogs. Middle line represents the average of the maximum and minimum temperatures for each sample. Solid thick line represents the 5-point running mean.

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(Fig. 5) were mapped to illustrate the location of general "analogs" to the fossil samples (Fig. 6). In general, modern samples from the southern and eastern Arctic most closely resemble those of the fossil pollen spectra.

Reconstructed mean July temperatures remained around 6.6 °C before 5700 cal yr BP. July temperatures then increased to 7.8 °C between 5700 and 3800 cal yr BP and temperatures have decreased slightly during the past 3800 yr (Fig. 7).

Discussion

Maximum estimated July temperatures were reached between 5800 and 3000 cal yr BP, at which time they exceeded present-day values. High diatom concentrations and high productivity also occurred during this time and were interpreted as warmer temperatures (LeBlanc et al., 2004). During this same time, magnetic susceptibility values were at intermediate levels, suggesting a stable landscape.

A brief period of low temperatures between 5500 and 5000 cal yr BP was interpreted from a decrease in *Salix*, Fabaceae and Cyperaceae pollen percentages. During this time, percentages of pollen taxa transported from the south, such as *Alnus* and *Betula*, also decreased. This was followed by a brief period of high temperatures between 4500 and 3800 cal yr BP, corresponding to increases in Cyperaceae and *Salix* pollen. Cyperaceae and *Salix* pollen are more abundant in mid-Arctic pollen spectra (Gajewski, 2002), indicating warmer temperatures.

After 4200 cal yr BP, reconstructed temperatures decreased at the same time as a sharp decrease in loss-on-ignition and increase in carbonate content values. Total pollen concentrations increased, due in large part to increased input of *Pinus* pollen. Between 3800 and 3400 cal yr BP, shrub pollen transported from the low-Arctic, including *Betula* and *Alnus*, decreased, and reconstructed temperatures therefore decreased. Pollen percentages of some local and regional taxa, including Cyperaceae and *Oxyria* decreased as well. Temperatures increased again to 7 °C at 3100 cal yr BP, as the pollen percentages returned to the values they had attained before the cooling.

Between 2500 cal yr BP and the present, temperatures further decreased. During this time, pollen of taxa that are more abundant in high-Arctic modern samples, including Poaceae, Brassicaceae and *Oxyria* increased, while percentages of Cyperaceae, *Salix*, and *Dryas* decreased. *Pinus* pollen percentages increased during this time while other long-distance pollen (*Alnus, Picea* and *Betula*) decreased. *Pinus* pollen may be increasing during cooling periods simply because of the constrains of percentage calculations; as input of pollen from other taxa decreased, *Pinus* pollen, produced in large quantities and efficiently transported by the wind increased as a consequence. At this same time, loss-on-ignition decreased and magnetic susceptibility sharply increased. LeBlanc (2002) also interpreted a cooling at this time, based on decreasing diatom diversity.

A short warming, which could be interpreted as the Medieval Warm Period, occurred between 900 and 750 cal yr BP. The warming is indicated by small increases in the pollen percentages of *Alnus, Betula, Salix* and Cyperaceae and decreased pollen percentages of *Pinus*. The diatom production changed at this time, also interpreted as a warming (LeBlanc, 2002). Following this warming, temperatures cooled during the Little Ice Age (LIA) again as pollen percentages returned to their values before the warming. There were changes in the diatom assemblage at this time (LeBlanc et al., 2004) coinciding with the decrease in pollen percentages and cooler temperatures.

During the last 150 yr, a diverse and productive diatom flora was interpreted by LeBlanc (2002) as a consequence of recent warming. Pollen concentrations and loss-on-ignition values increased at this time, suggesting warmer conditions as did percentages of *Salix, Artemisia*, and Cyperaceae pollen. However, July temperatures reconstructed using the MAT remained stable during this time. This may be due to (a) the lack of vegetation response to the rapid warming, (b) the few surface samples available for reconstruction or (c) the use of an average of the temperature from the top 5 analogs in estimating past temperatures. The mean annual temperature at Taloyoak of 7.1 °C (Dyke, 1984) is warmer than the temperature reconstructed for Lake JR01. The difference between the Taloyoak and reconstructed temperature is probably because five analogs are averaged when deriving the reconstructed temperature and the long-distance pollen (indicators of warm air transport from the south) do not significantly increase during this time period.

The high-frequency variability in the unsmoothed temperature reconstruction may be due to several reasons. Pollen taxa found in Lake JR01 are derived from plants, many of which have wide ranges, including some that are circumpolar. Surface samples are lacking in the Arctic, therefore, a fossil sample could find comparable percentages in modern samples located a long distance away, or a sample located close by, leading to different temperatures reconstructed by adjacent samples in the sediment core. Many of the surface samples in the southern part of the range were moss polsters allowing for poorer analogs due to differential pollen capture efficiency of polsters and lake sediments. Finally, the use of a coarse gridded climate dataset will make the reconstruction appear more variable. A better gridded climate dataset and more surface samples would allow for better reconstructions from Arctic pollen sequences.

Magnetic susceptibility values tended to increase during periods interpreted as cooler temperatures. This is probably due to increased amounts of erosion due to reduced plant cover. Higher influx levels prior to 5750 cal yr BP are attributed to an increased sedimentation rate as influx levels remained low and stable throughout the Holocene.

Pollen concentrations are generally quite low in Arctic lake sediments. Compared with other studies in the Canadian Arctic, such as from Somerset Island (Gajewski, 1995; where concentrations were 4500 grains/cm^3 in the early Holocene), Lake JR01, a middle-Arctic site, had very high pollen concentrations. Concentrations were also lower in a pollen sequence from Prince of Wales Island (Gajewski and Frappier, 2001) where values only reached a maximum of 1500 grains/cm^3 in the mid-Holocene. Concentrations reached maximum values of

https://doi.org/10.1016/j.yqres.2007.04.003 Published online by Cambridge University Press

6000 grains/cm^3 in the early part of the JR01 core with values decreasing to 2000–4000 grains/cm^3 in recent sediments. In the high-Arctic of Ellesmere Island, (Baird Inlet; Hyvärinen, 1985) maximum pollen concentrations of 2000 grains/cm^3 occurred in the early Holocene.

The general stratigraphy of both the pollen percentages and pollen concentrations correspond with other pollen studies in the Arctic. Because the temporal resolution of most previous studies is coarse, only broad-scale comparisons can be made. Summer temperatures at Lake JR01 were lower in the early to mid-Holocene, as was interpreted on Banks Island (Gajewski et al., 2000) and TK-2, a site in the low-Arctic of continental Canada (Seppa et al., 2003). Temperatures warmed in the mid-Holocene, as shown by higher pollen percentages of Cyperaceae, *Dryas, Betula*, and *Alnus*, consistent with the interpretation of pollen diagrams from sites on Prince of Wales Island (Gajewski and Frappier, 2001), Somerset Island (Gajewski, 1995), Baffin Island (Short et al., 1989), Banks Island (Gajewski et al., 2000) and in the low-Arctic (TK-2; Seppa et al., 2003). The mid-Holocene warming generally occurred between ~6500 and 5500 cal yr BP, as was interpreted from diatom assemblages of Lake JR01 (LeBlanc et al., 2004). A late Holocene cooling, estimated at around 0.75 °C at lake JR01, was also recorded, occurring after 4000 cal yr BP, on Prince of Wales (Gajewski and Frappier, 2001), Somerset Island (Gajewski, 1995), Ellesmere Island (Hyvärinen, 1985), Baffin Island (Short et al., 1989), Banks Island (Gajewski et al., 2000) and at TK-2 in the low-Arctic (Seppa et al., 2003). A cooling on Baffin Bay (Andrews et al., 1979) occurred later than at JR01, perhaps due to its location further east, although chronological problems cannot be excluded.

The vegetation found throughout the Holocene at Lake JR01 could be interpreted as an herbaceous tundra dominated by Cyperaceae and *Salix*. The best modern analogs for the vegetation that grew in the region of the lake during the Holocene are from the southeastern part of the Arctic Islands, as shown by the map of the principal component scores (Fig. 6). Slight changes in local pollen percentages and concentrations during the Holocene suggest changes in vegetation density on the landscape, but still remaining mid-Arctic tundra vegetation throughout the past 7000 yr.

Summary

A 4.84-m lake sediment core from a lake in the mid-Arctic region of the Boothia Peninsula was analyzed at high resolution for pollen and sediment characteristics. An age-depth chronology was determined using ten calibrated radiocarbon dates and nine ^{210}Pb dates. Major pollen taxa in the core include Cyperaceae, *Salix, Picea, Pinus, Alnus*, and *Betula*. Increases of Poaceae, Brassicaceae and *Oxyria* are interpreted as being caused by cooler temperatures, as these pollen taxa are more abundant in modern high-Arctic samples (Gajewski, 2002). Warmer temperatures are interpreted from increases in Cyperaceae, *Salix, Betula, Picea* and *Alnus*. Higher percentages of the long-distance pollen are interpreted as warming because higher percentages would indicate stronger southerly winds.

As reconstructed using the modern analog technique, temperatures were cooler prior to 5700 cal yr BP, warmed during the mid-Holocene and cooled after 3800 cal yr BP. The temperature reconstruction in this study agrees with the interpreted temperatures in other pollen studies in Arctic Canada and with the interpretation of a diatom analysis of the same core (LeBlanc, 2002).

Acknowledgments

This work was supported with grants from the Natural Sciences and Engineering Council of Canada (NSERC), Canadian Foundation for Climate and Atmospheric Sciences (CFCAS) and Northern Scientific Training Program (NSTP). The Polar Continental Shelf Project (PCSP) provided logistic support; PCSP contribution number 019-06. We would like to thank P. Hamilton for help in the field, M. Sawada for help with the Modern Analog Technique and acknowledge M. LeBlanc for her analyses of the core.

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