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The Terrestrial Record of Postglacial Vegetation and Climate from the Arctic/Subarctic of Eastern Canada and West Greenland

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See table of contents

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Article abstract

Pollen data from lake-sediment cores from southern Labrador, indicate that vegetation after déglaciation ca. 10,500 years ago (10.5 ka BP) ranged from herb tundra in the north to birch shrub tundrain the south. By 8 ka BR the vegetation was more dense as alder arrived and possibly spruce in low abundance. At 7ka BP, fir arrived, followed by abundant black spruce, signifying the development of the boreal forest. By 6 ka BR spruce (boreal forest and forest tundra) expanded over a large area in southern and central Labrador. Trees reached their northern most limits and greatest densities prior to 3 ka BR after which tundra expanded into some areas previously occupied by trees.

North of Hudson Strait a barrens was replaced by herb tundra on southern Baffin Island after 8 ka BP. Shrub tundra became more widespread at 7 ka BR with an increase in birch abundance, and then many areas reverted to herb tundra at 4 ka BP. North of central Baffin Island the few sites available suggest a polar desert throughout the entire post-glacial time, with an increase in plant abundance in early postglacial time.

Across Baffin Bay in Greenland, the period prior to 7.5 ka BP is characterized by barrens in northwest Greenland. More favourable conditions after this time permitted development of herb tundra in the north and shrub tundra in the south. Climatic deterioration in Greenland is reflected in declining pollen influx in northern sites at 5 ka BP. Farther south, deterioration is indicated by declining influx and/or declining shrub percentages beginning at 3.5 ka BP and at 2.2 ka BP inthe southernmost sites.

The pollen records evidence a post-glacial thermal maximum that began asearly as 7.5 ka BP. The thermal maximum ended as early as 5 ka BP in the Canadian high Arctic and as recently as1 ka BP or 2 ka BP in Ungava.

The Terrestrial Record of Postglacial Vegetation and Climate from the Arctic/Subarctic of Eastern Canada and West Greenland

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SUMMARY

Pollen data from lake-sediment cores from southern Labrador, indicate that vegetation after deglaciation *ca.* 10,500 years ago (10.5 ka BP) ranged from herb tundra in the north to birch shrub tundra in the south. By 8 ka BP, the vegetation was more dense as alder arrived and possibly spruce in low abundance. At 7 ka BP, fir arrived, followed by abundant black spruce, signifying the development of the boreal forest. By 6 ka BP, spruce (boreal forest and forest tundra) expanded over a large area in southern and central Labrador. Trees reached their northernmost limits and greatest densities prior to 3 ka BP, after which tundra expanded into some areas previously occupied by trees.

North of Hudson Strait a barrens was replaced by herb tundra on southern Baffin Island after 8 ka BP. Shrub tundra became more widespread at 7 ka BP, with an increase in birch abundance, and then many areas reverted to herb tundra at 4 ka BP. North of central Baffin Island the few sites available suggest a polar desert throughout the entire postglacial time, with an increase in plant abundance in early postglacial time.

Across Baffin Bay in Greenland, the period prior to 7.5 ka BP is characterized by barrens in northwest Greenland. More favourable conditions after this time permitted development of herb tundra in the north and shrub tundra in the south. Climatic deterioration in Greenland is reflected in declining pollen influx in northern sites at 5 ka BP. Farther south, deterioration is indicated by declining influx and/or declining shrub percentages beginning at 3.5 ka BP and at 2.2 ka BP in the southernmost sites.

The pollen records evidence a postglacial thermal maximum that began as early as 7.5 ka BP. The thermal maximum ended as early as 5 ka BP in the Canadian high Arctic and as recently as 1 ka BP or 2 ka BP in Ungava.

RÉSUMÉ

Des données polliniques provenant de carottes de sédiments lacustres du sud du Labrador indiquent que la végétation qui a suivi la déglaciation il y a 10 500 ans (10,5 ka BP) a varié de la toundra herbeuse au nord à la toundra arbustive à bouleaux au sud. À 8 ka BP, la végétation est devenue plus dense, alors que les aulnes sont apparus et peut-être aussi quelques épinettes dispersées. À 7 ka BP, les sapins sont apparus, suivis par un peuplement abondant d'épinettes noires, signes du développement d'une forêt boréale. À 6 ka BP, le couvert d'épinettes (forêt boréale et toundra selvatique) a envahi une grande portion du sud et du centre du Labrador. La couverture arbustive a atteint sa limite septentrionale et sa densité maximale, juste un peu avant 3 ka BP, puis la toundra a ré-envahi certaines zones autrefois selvatiques.

Au nord du détroit de Hudson, sur la partie sud de l'île de Baffin, une toundra herbeuse a remplacé une lande après 8 ka BP. À 7 ka BP, la couverture de toundra arbustive est devenue plus importante et le bouleau y était plus abondant, et à 4 ka BP, nombre de zones sont redevenues des zones de toundra herbeuse. Les données existantes sur quelques sites situés sur la partie nord de l'île de Baffin indiquent la présence d'un désert arctique durant toute la période post-glaciaire, avec un accroissement de l'abondance des plantes au début de la période post-glaciaire.

De l'autre coté de la baie de Baffin, le niveau chronologique de 7,5 ka BP est caractérisé par la présence de landes

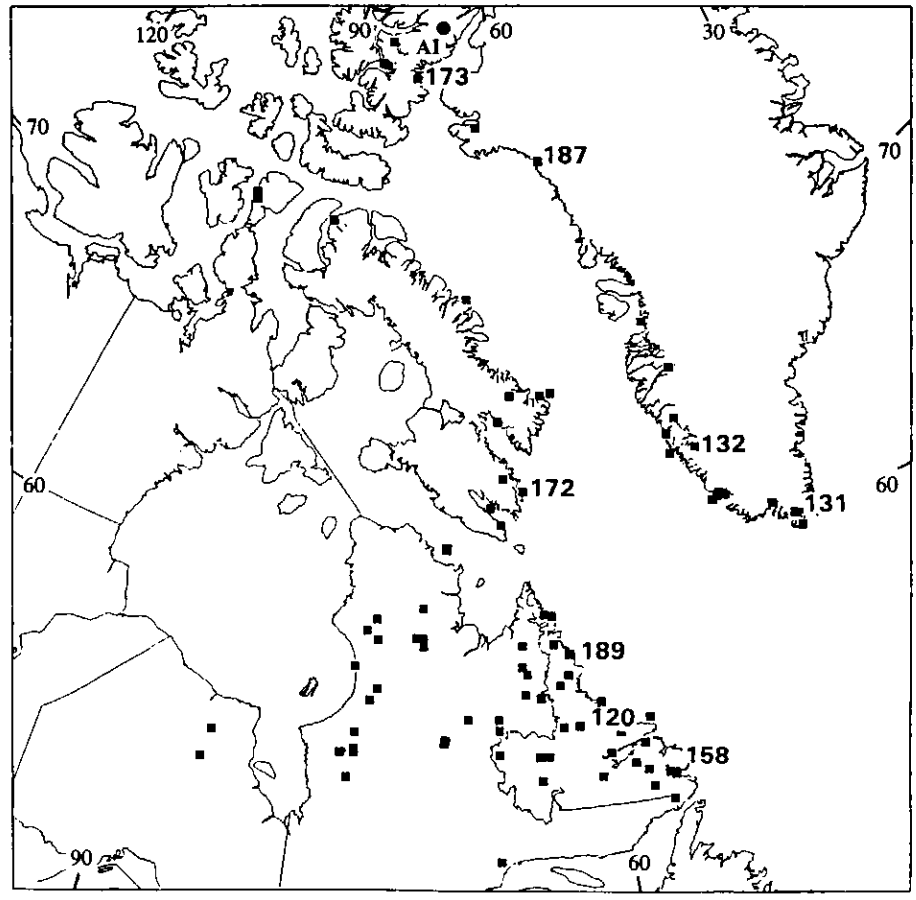

Figure 1 *Lake-sediment pollen sites in the northwest Atlantic region, numbered according to PALE (Paleoclimate from Arctic Lakes and Estuaries) database. AI = Agassiz Icecap. See Table 1 for site names.*

dans le nord-ouest du Groenland. Puis, des conditions climatiques plus clémentes ont permis le développement d'une toundra herbeuse au nord et d'une toundra arbustive au sud. À 5 ka BP, la diminution de l'apport de pollen mesuré sur des sites nordiques au Groenland correspond à une détérioration du climat Plus au sud, la détérioration climatique est marquée par une diminution de l'apport de pollen ou par une diminution de la proportion d'arbustes commençant à 3,5 ka BP et à 2,2 ka BP dans les sites plus méridionaux.

Le registre de données polliniques indique l'existence d'un maximum thermique commençant dès 7,5 ka BP. Ce maximum thermique s'est estompé dès 5 ka BP dans le Haut-Arctique canadien mais assez récemment (1 ka BP ou 2 ka BP) dans l'Ungava.

INTRODUCTION

This paper presents a synopsis of vegetation history and paleoclimatology derived from pollen analyses of lake-sediment cores from the lands bordering the northwest Atlantic Ocean (Labrador Sea and Baffin Bay). A number of new pollen sites have been added in this critical area of the Arctic since previous reviews (Anderson, 1985; Bradley, 1990; Fredskild, 1985a; Lamb and Edwards, 1988; Ritchie, 1987; Short *et al.*, 1985; Webb *et al.*,1993; Williams and Bradley, 1985), but many gaps in spatial coverage remain (Fig. 1). This review concentrates on new data, and, among previously published sites, highlights those that contain the longest records, are well dated, and are considered typical of their regions. The longest pollen sequences date from 10 ka BP to 12 ka BP and come from areas deglaciated first, which are near coastlines. Accuracy of chronological control is limited by the difficulty of obtaining reliable radiocarbon dates on sediment cores from high-latitude lakes. The dates used here are those reported in the publications cited. They are uncorrected and most often bulk sediment dates.

LABORADOR-UNGAVA

The concentration of lake-sediment pollen sites is highest in Labrador–Ungava. Webb *et al.* (1993; fig. 17.4.c) used 44 sites from the Quebec–Labrador region. For a complete list of sites and literature citations, see Webb *et al.* (1993). The oldest sites are located in southeastern Labrador where deglaciation occurred earliest.

Table 1 Location and names of lake sediment core sites discussed in this paper.

Name	Site	Area
LABRADOR-UNGAVA		
Lake Hope Simpson	158	southeastern Labrador
Gravel Ridge	120	central Labrador
Ublik Pond	189	northeastern Labrador
CANADIAN ARCTIC ISLANDS		
Robinson Lake	172	southern Baffin Island
Rock Basin Lake	173	high Arctic
WEST GREENLAND		
Langesø	187	northwestern Greenland
Johannes Iverson Sø	132	western Greenland
Isoëtes Sø	131	southwestern Greenland

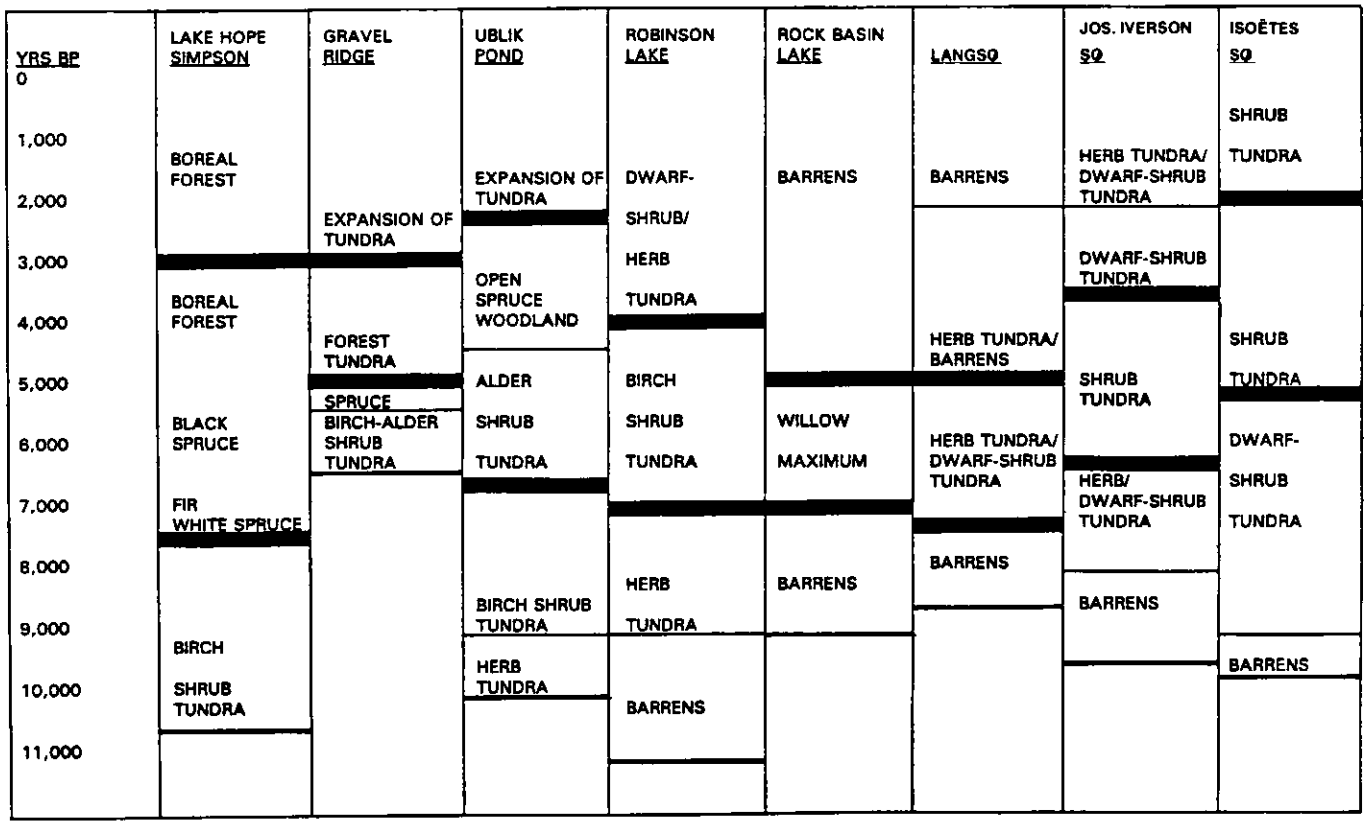

Figure 2 *Vegetational histories for the eight sites discussed in the text. The thick black lines bound the beginning and end of the Holocene thermal maximum at each site. See Figure 1 and Table 1 for site numbers and locations.*

At Lake Hope Simpson (Engstrom and Hansen, 1985) in southeastern Labrador (site number 158, Fig. 1; see Fig. 2 for summary), shrub tundra was present immediately upon deglaciation *ca.* 10.5 ka BP. Initially, the shrubs were predominantly willows; beginning at 9.5 ka BP, alder, birch and ericaceous shrubs became abundant. When forest became established at 7.5 ka BP, white spruce was abundant, followed at 7 ka BP by fir. Boreal forest, dominated by black spruce, developed at 6 ka BP and has persisted without major changes since then. The Holocene thermal maximum began in this area with the expansion of white spruce at 7.5 ka BP and ended at 3 ka BP with decreasing pollen influx. Several other sites in southeastern Labrador record events similar to those of the Lake Hope Simpson core (Engstrom and Hansen, 1985; Lamb, 1978, 1980, 1985).

There are no pollen sites in central Labrador with basal ages approaching 10 ka BP because of later deglaciation there. The record at Gravel Ridge (site number 120, Fig. 1; Lamb, 1985) begins *ca.* 6.4 ka BP with a brief birch–alder shrub tundra phase, followed by the arrival of spruce and development of open boreal forest (forest–tundra) at 5.4 ka BP. Expansion of tundra began at 3 ka BP. The thermal maximum extended from 5 ka BP to 3 ka BP. The delayed arrival of trees as well as the delayed thermal maximum at this site presumably are related to its proximity to residual glacier ice and to its relatively high elevation.

In northeastern Labrador, Ublik Pond (site number 189, Fig. 1; see Fig 2. for summary; Short and Nichols, 1977) was deglaciated by 10 ka BP, and the landscape was vegetated first by herb tundra, followed at 9 ka BP by shrub tundra with abundant birch. Alder became abundant at 6.7 ka BP, followed by development of open spruce woodland at 4.4 ka BP. Increasing herb pollen percentage after 2.4 ka BP reflects expansion of tundra and restriction of spruce trees to the most favorable sites. The interval between 6.7 and 2.4 ka BP was the thermal maximum in this area.

Seven sites spanning the shrub tundra, forest–tundra, and boreal forest in northwestern Quebec are recent additions to the literature (Gajewski *et al.*, 1993; Gajewski and Garralla, 1992). The sequence and chronology of these sites is similar to those of northeastern Labrador and north-central Quebec (Richard, 1981). After deglaciation around 6 ka BP, increasingly dense alder shrub tundra existed until it was replaced *ca.* 4 ka BP by spruce-dominated boreal forest and forest tundra within areas where these vegetation formations occur today. Beginning at 3 ka BP, deforestation occurred in the forest–tundra. The thermal maximum, when first alder shrub tundra and then boreal forest were at their densest, occurred 5 ka BP to 3 ka BP.

CANADIAN ARCTIC ISLANDS

Several new sites have been reported recently or are in preparation for this large, sparsely sampled region (Fig. 1). In southern Baffin Island, Robinson Lake (site number 172, Fig. 1; see Fig. 2 for summary; Mode, unpubl. data) is a well-dated site with a record that begins 11 ka BP. Several other sites in southern Baffin Island record the same sequence of vegetation and climate history (Mode and Jacobs, 1987; Mode, 1992; Mode *et al.*, 1994). A barrens dominated by grass was replaced by herb tundra at 9 ka BP. Birch shrub tundra expanded beginning at 7 ka BP and then contracted at 4 ka BP. Exotic alder influx also reached a maximum during this interval, which corresponds well with the time when alder reached its greatest abundance in Labrador (Richard, 1995; Short and Nichols, 1977). Pollen concentration decreased markedly at 2 ka BP. The thermal maximum occurred between 7 ka BP and 4 ka BP.

In the high Arctic, Rock Basin Lake on Ellesmere Island (site number 173, Fig. 1; see Fig. 2 for summary; Hyvärinen, 1985) records a barrens vegetation beginning at 9 ka BP and extending through the Holocene. The thermal maximum is recorded by maximum willow percentages between 7 ka BP and 5 ka BP. At two sites on Somerset Island (Gajewski, 1995) with basal ages of 10 ka BP and 11 ka BP, barrens vegetation existed throughout the Holocene. Willow was more abundant early than it was subsequently, but otherwise, there is little change. A peak in pollen accumulation rate that occurs between 6 ka BP and 5 ka BP represents the thermal maximum.

WEST GREENLAND

In the high Arctic of northwestern Greenland, the record from Langesø (site number 187, Fig. 1; see Fig. 2 for summary; Fredskild, 1985b) begins at 8.6 ka BP with a barrens that gives way at 7.7 ka BP to herbaceous tundra with numerous dwarf shrubs (willows and heaths). Beginning at 5 ka BP, pollen influx decreases and arctic heather percentage increases. This indicates a reduction of vegetation cover and an increase in late-lying snow. After 2 ka BP, arctic heather percentages reach their maximum and exotic pollen influx derived from southerly winds almost ends. This represents the development of the high arctic barrens that exist in the area today. Exotic alder influx was greatest between 6 ka BP and 2.3 ka BP. The thermal maximum occurred between 7.5 and 5 ka BP.

In central west Greenland, Böcher and Fredskild (1993) reported one new site since Fredskild's (1985a) review of west Greenland pollen stratigraphy. They also presented a useful summary of the paleoclimate of west Greenland, based on the pollen records (fig. 23, Böcher and Fredskild, 1993). The pollen record from Johannes Iverson Sø (site number 132, Fig. 1; see Fig. 2 for summary; Fredskild, 1973; 1983) begins at 9.4 ka BP with a barrens composed of pioneer plants. At 8 ka BP, herb tundra with dwarf shrubs developed, followed at 6.3 ka BP by low-arctic shrub tundra with birch and juniper shrubs. By 3.5 ka BP, juniper shrubs became less abundant and pollen influx declined, indicating a reduction in shrub abundance. Marked reduction in pollen influx after 2 ka BP reflects further restriction in shrub coverage. The thermal optimum occurred between 6.3 ka BP and 3.5 ka BP.

Isoëtes Sø (site number 131, Fig. 1; see Fig. 2 for summary; Fredskild, 1973) is representative of several lake-sediment records from south and southwest Greenland (Fredskild, 1985a). A barrens of pioneer plants colonized the freshly deglaciated landscape at 9.6 ka BP. Beginning at 9.1 ka BP, this was succeeded by three phases of dwarf-shrub tundra, until, at 5.3 ka BP, a low arctic shrub tundra developed. At 3.8 ka BP, shrub birch became abundant. At 2.2 ka BP, shrub abundance declined and herb abundance increased, reflecting decreased shrubby cover. The thermal optimum occurred between 5.3 ka BP and 2.2 ka BP.

DISCUSSION

Although individual regions and sites have different vegetational histories, there is reasonable consistency in the interpretation of the timing of the Holocene thermal maximum. In six of the eight regions discussed (Fig. 2), the onset of the thermal maximum dates to

7±0.7 ka BP. The delayed onset at the other two sites (Gravel Ridge and Isoëtes Sø) may be due to the proximity of these sites to glacial ice: residual Labradorean ice in the former case and the Greenland Ice Sheet in the latter case.

The date of the termination of the thermal maximum is much more variable, ranging from as early as 5 ka BP in the high Arctic of Canada and Greenland (Rock Basin Lake and Langesö, respectively) to as late as 2.2 ka BP in southern Greenland (Isoëtes Sø). With the exception of two of the southernmost areas (Lake Hope Simpson and Gravel Ridge), the thermal maximum began and ended earlier with increasing latitude. This may reflect decreasing vegetational inertia as floras shrink and vegetation cover decreases with latitude.

The melt record of the Agassiz Ice Cap in Ellesmere Island (Fig. 1; Koerner and Fisher, 1990; Fisher *et al.*, 1995) indicates massive Early Holocene melting which reached a maximum *ca.* 8,600 radiocarbon years BP. This is somewhat in advance of the age of the thermal maximum interpreted from the high arctic pollen diagrams. A number of factors militated against the vegetation responding earlier to the warmth, including the limited extent of deglaciated terrain, the limited soil development, the thermal sink that the large residual ice masses represented, and the migration lag exhibited to varying degrees by many plants.

The terrestrial record of postglacial vegetation as represented at the sites discussed herein provides an indication of the rates of climatic change over the past 10,000 years. These data contribute to the evolving framework of past climatic changes in this arctic region, against which predictions of future climatic changes may be assessed.

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