Article

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VEGETATION OF THE CONTINENTAL NORTHWEST TERRITORIES AT 6 KA BP

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ABSTRACT Pollen records are used to reconstruct vegetation in the continental Northwest Territories at 6 ka (6000 ^{14}C yr BP). *Picea glauca, P. mariana, Larix laricina, Populus tremuloides, P. balsamifera, Alnus crispa* and *A. incana* were present throughout their modern ranges in the Boreal and Subarctic Forest Zones by 6000 BP. *Pinus banksiana*, however, had not yet reached its present northern limits. Population densities of the dominant trees, *Picea glauca* and *Picea mariana*, were close to, or as high as, present. In the Mackenzie Delta region the range limit of *Picea glauca* was approximately 25 km north of its modern location just prior to 6000 BP. In contrast, the northern limits of the forest in central Canada were similar to present. The tundra vegetation close to the edge of the forest was similar to modern Low Arctic Tundra. Development of extensive *Sphagnum* peatlands had begun in the forested areas and the adjacent Low Arctic Tundra. Palaeoecological information regarding vegetation at 6000 BP remains lacking for the northeastern half of the study area. Therefore, the nature of the vegetation in much of the area now occupied by Low Arctic and Middle Arctic Tundra remains unknown. Important vegetation changes that occurred following 6 ka include: (1) the advance of *Pinus banksiana* to its present northern range limits, (2) the retreat of the northern range limits of *Picea glauca* in the Mackenzie Delta region between 6000 and 3500 BP and (3) the rapid and marked increase in the population density of *Picea mariana* in the treeline zone of the central Northwest Territories at 5000 BP followed by a decline at 4000 BP.

RÉSUMÉ *La végétation des Territoires du Nord-Ouest continentaux à 6 ka BP.* La reconstitution de la végétation de la partie continentale des Territoires du Nord-Ouest à 6 ka a été faite à partir des données polliniques. *Picea glauca, P. mariana, Larix laricina, Populus tremuloides, P. balsamifera, Alnus crispa* et *A. incana* avaient déjà atteint leur répartition moderne dans les zones des forêts boréales et subarctiques à 6 ka. *Pinus banksiana*, toutefois, n'avait pas encore atteint sa limite nordique. Les densités de population des arbres dominants, *Picea glauca* et *P. mariana*, étaient aussi fortes ou presque que maintenant. Dans la région du delta du Mackenzie, la limite de *Picea glauca* était à environ 25 km au nord de sa limite actuelle juste avant 6 ka. Par contre, la limite septentrionale de la forêt dans la partie centrale du Canada était semblable à l'actuelle. La végétation de la toundra située à proximité de la marge forestière était semblable à celle de la toundra du bas Arctique moderne. Le développement de vastes tourbières à sphaigne était déjà commencé dans les zones forestières et dans la toundra du bas Arctique adjacente. Les données paléoécologiques sur la végétation à ~6 ka sont déficientes pour la partie nord-est de la région à l'étude. Dès lors, la nature de la végétation dans la plus grande partie du territoire maintenant occupée par la toundra du bas Arctique et du moyen Arctique est encore inconnue. Les grands changements apportées à la végétation après ~6 ka comprennent : 1) la remontée de *Pinus banksiana* jusqu'à sa limite septentrionale actuelle, 2) le recul de la limite septentrionale de *Picea glauca* dans la région du delta du Mackenzie entre 6000 et 3500 BP et 3) l'augmentation rapide et prononcée de la densité de la population de *Picea mariana* dans la zone de la limite des arbres du centre des Territoires du Nord-Ouest à 5000 BP suivie d'un déclin à 4000 BP.

ZUSAMMENFASSUNG *Die Vegetation der kontinentalen Nordwest-Territorien um 6 ka v.u.Z.* Man benutzte Pollen-Belege, um die Vegetation in den kontinentalen Nordwest-Territorien um 6 ka (6000 ^{14}C Jahre v.u.Z.) zu rekonstruieren. Picea glauca, P. mariana, Larix laricina, Populus tremoluides, P. balsamifera, Alnus crispa und A. incana hatten um 6000 v.u.Z. schon ihre moderne Verteilung in den nördlichen und subarktischen Waldgürtelzonen erreicht. Jedoch hatte Pinus banksiana noch nicht seine gegenwärtigen nördlichen Grenzen erreicht. Die Populations-Dichte der vorherrschenden Bäume, Picea glauca und Picea mariana war fast so hoch oder so hoch wie gegenwärtig. In der Gegend des Mackenzie-Deltas war die Grenze von Picea glauca kurz vor 6 ka etwa 25 km nördlich von ihrer modernen Position. Im Gegensatz dazu war die nördliche Grenze des Waldes in Zentralkanada der gegenwärtigen ähnlich. Die Tundra-Vegetation nah an der Waldgrenze war der modernen Tundra der niederen Arktis ähnlich. Die Entwicklung ausgedehnter Sphagnum-Torfmoore hatte in den bewaldeten Gebieten und der angrenzenden Tundra der niederen Arktis begonnen. Für die nordöstliche Hälfte des erforschten Gebiets gibt es keine paläoökologische Information in Bezug auf die Vegetation um 6000 v.u.Z. Deshalb bleibt die Art der Vegetation in einem großen Teil des heute von der niederen arktischen und mittleren arktischen Tundra eingenommenen Gebiets unbekannt. Zu wichtigen Vegetationswechseln, die auf 6 ka folgten, gehören: (1) das Vordringen von Pinus banksiana zu seiner heutigen nördlichen Grenze, (2) der Rückzug der nördlichen Grenze von Picea glauca im Gebiet des Mackenzie-Deltas zwischen 6000 und 3500 v.u.Z. und (3) die schnelle und deutliche Zunahme in der Populationsdichte von Picea mariana in der Zone der Baumgrenze der zentralen Nordwest-Territorien um 5000 v.u.Z., gefolgt von einer Abnahme um 4000 v.u.Z.

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INTRODUCTION

In this paper pollen records from lake sediments and peats are used to reconstruct key attributes of the vegetation of the continental Northwest Territories at 6 ka (6000 ^{14}C years BP). These attributes are: (1) the general geographic distribution of tree species and important shrubs, (2) the population densities of the dominant boreal conifers, *Picea glauca* (white spruce), *P. mariana* (black spruce) relative to the modern densities, and (3) the general extent of *Sphagnum* dominated muskeg. These attributes were chosen for reconstruction because they represent important facets of vegetation relevant to specifying boundary conditions for climate models and examining carbon cycling during the postglacial. Climate models suggest that changes in the distribution of the boreal forest could have a significant impact on global climate (Bonan *et al.*, 1992). Boreal forest vegetation has been shown to be an important sink for atmospheric carbon (D'Arrigo *et al.*, 1987). Boreal, Subarctic and Low Arctic peatlands function as important stores for the long-term sequestering of carbon (Gorham, 1991).

SETTING

The continental Northwest Territories can be subdivided into four major bioclimatic zones (Ecoregions Working Group, 1989; Fig. 1). A small area of Middle Arctic Tundra occupies the extreme northeastern tip of the region. Plant cover is discontinuous with *Salix* spp. and ericoids being the common shrubby plants. Temperatures are extremely low during the long winters and mean daily temperatures greater than 0°C only occur during two summer months. Low Arctic Tundra occupies most of the northeastern half of the study area. The vegetation on uplands is often dominated by *Betula glandulosa* (shrub birch) with ericoids. Poorly drained lowlands are occupied by *Eriophorum* spp. (cotton grasses) meadows or *Sphagnum* peatlands with *Salix* spp. (willows), and ericoids. *Alnus crispa* (green alder) is common on moist sites along rivers and lakes near the southern limits of the Low Arctic Tundra Zone. The climate is typified by very short and cool summers with mean July temperatures averaging below 10°C and long harsh winters with January temperatures averaging –35°C. Tundra vegetation is also found at upper elevations in the mountains that bound the Territory to the west.

The Subarctic Zone is a transitional band of open forest and forest-tundra lying between the Low Arctic Tundra and the closed forest of the Boreal Zone. Both *Picea glauca* and *P. mariana* may be found on uplands. Poorly drained lowlands are occupied by extensive areas of *Picea mariana-Sphagnum* muskeg (peatland). *Betula glandulosa, Salix, Myrica gale* (bog myrtle), and various ericoids are common shrubs on poorly drained sites. *Larix laricina* is also encountered on moist sites. *Pinus banksiana* (jack pine), *Betula papyrifera* (paper birch), *Populus tremuloides* (aspen) and *P. balsamifera* (balsam poplar) are generally restricted to well drained sites at the southern edge of the Subarctic Zone. Tundra sites in the Subarctic Zone are dominated by plant species typical of the Low Arctic Zone. During four to five months of the summer mean daily temperatures exceed 0°C and July mean daily temperatures are generally greater than 10°C.

The Boreal Zone is characterised by closed forest with well drained sites dominated by *Picea glauca, Pinus banksiana, Populus* spp. and *Betula papyrifera* and extensive lowlands dominated by *Picea mariana* and *Larix laricina* (larch) on *Sphagnum* peatlands and fens. Growing seasons are slightly longer than in the Subarctic Zone and daily mean temperatures during July may reach 15°C.

Aside from portions of the Mackenzie Mountains and the extreme northwest, the continental Northwest Territories were glaciated during the Late Wisconsinan (Dyke and Prest, 1987). Ice retreat started in the west by 12 ka and proceeded in an easterly direction. It was not until 7000 to 6000 BP that the last remnants of continental ice had disappeared from eastern Keewatin (Dyke and Prest, 1987).

DATA AND METHODS

The data used here come from published and unpublished fossil pollen records from lake sediments and peats (Fig. 1). Only sites with radiocarbon chronologies that extend to 6 ka (~6000 ^{14}C yr BP) or older are included. Determination of which fossil samples best represent the 6 ka time-slice was made by extrapolating ages on the basis of the radiocarbon dates. Exact chronological models for each record followed those favoured by the original authors. Ages are reported as years BP rather than corrected calendar ages ka (Stuiver and Reimer, 1993) in order to facilitate comparison with earlier published studies.

Most available data come from sites at the western edge of the study area with a particular concentration along the Mackenzie River. Little information is available from the northeastern half of the continental Northwest Territories, although several records exist that extend back to 5000 BP (Nichols, 1975; Kay, 1979). Studies in the central portions of the Territories (Moser and MacDonald, 1990; MacDonald *et al.*, 1993) indicate that important changes in vegetation occurred between 6000 and 5000 BP. Therefore, extrapolation of 6 ka vegetation conditions from these younger records is problematic. There are no sites available from the present Middle Arctic Tundra Zone at the extreme northeastern tip of the continental Northwest Territories.

TABLE I

Approximate pollen values used to infer presence of selected plant taxa at 6 ka

Taxon	Threshhold
Picea undif.	20%
Picea glauca	5%
Picea mariana	15%
Pinus banksiana/P. contorta	15%
Larix	>1 occurrence
Populus	>1 occurrence
Betula	10%
Alnus	10%

The presence or absence at 6000 BP of important tree and shrub taxa (*Picea glauca, P. mariana, Pinus* spp., *Larix laricina, Populus* spp., *Betula* spp., *Alnus crispa, A. incana*) in the local vicinity of each fossil pollen site were used to determine critical threshold pollen percentages. The minimum threshold percentages (Table I) used were taken from the modern relationship between plant distribution and pollen percentages in western Canada (MacDonald and Ritchie, 1986). Such thresholds may underestimate the range of taxa, particularly during the early stage of range expansion when plant populations are small and scattered (*e.g.* MacDonald and Cwynar, 1991). The level of taxonomic differentiation of pollen varies for different authors and different sites and in many cases pollen from *Picea, Betula, Populus,* and *Alnus* were not differentiated to the level of species.

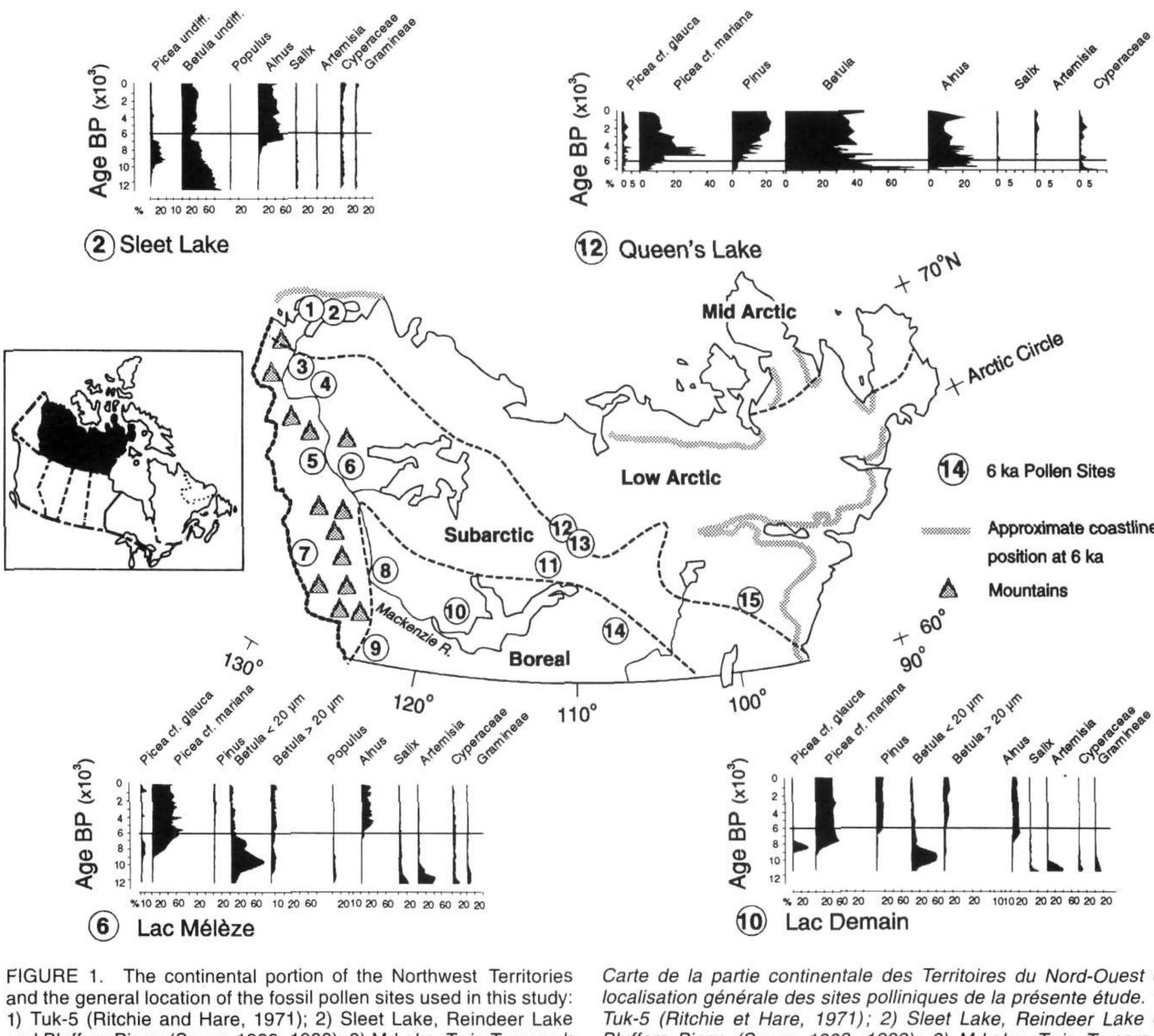

FIGURE 1. The continental portion of the Northwest Territories and the general location of the fossil pollen sites used in this study: 1) Tuk-5 (Ritchie and Hare, 1971); 2) Sleet Lake, Reindeer Lake and Bluffers Pingo (Spear, 1983, 1993); 3) M-Lake, Twin Tamarack Lake (Ritchie, 1977; 1984b; 1985a); 4) S-W Lake (Ritchie, 1984a); 5) Bells Lake, Keele Lake, Andy Lake (Szeicz *et al.*, in press); 6) Lac Mélèze (MacDonald, 1987); 7) Natla Bog (MacDonald, 1983); 8) Eildun Lake (Slater, 1985); 9) John Klondike Bog (Matthews, 1980); 10) Lac Demain (MacDonald, 1987); 11) Cambridge Lake (MacDonald, unpublished); 12) Queen's Lake, McMaster Lake (Moser and MacDonald, 1990; MacDonald *et al.*, 1993); 13) Toronto Lake, Waterloo Lake (MacDonald *et al.*,1993); 14) Porter Lake (Ritchie, 1985b); 15) Raleigh Lake 3 (MacDonald, unpublished). Summary pollen diagrams of selected taxa are presented for Sleet Lake (1) and Queen's Lake (12) which lie in the modern Low Arctic Zone, Lac Mélèze (6) which lies in the modern Subarctic Zone, and Lac Demain (10) which lies in the modern Boreal Zone.

Carte de la partie continentale des Territoires du Nord-Ouest et localisation générale des sites polliniques de la présente étude. 1) Tuk-5 (Ritchie et Hare, 1971); 2) Sleet Lake, Reindeer Lake et Bluffers Pingo (Spear, 1983, 1993); 3) M-Lake, Twin Tamarack Lake (Ritchie, 1977,1984b, 1985a); 4) S-W Lake (Ritchie, 1984a); 5) Bells Lake, Keele Lake, Andy Lake (Szeicz et al., *in press); 6) Lac Mélèze (MacDonald, 1987); 7) Natla Bog (MacDonald, 1983); 8) Eildun Lake (Slater, 1985); 9) John Klondike Bog (Matthews, 1980; 10) Lac Demain (MacDonald, 1987); 11) Cambridge Lake (MacDonald, non publié); 12) Queen's Lake, McMaster Lake (Moser et MacDonald, 1990; MacDonald* et al., *1993); 13) Toronto Lake, Waterloo Lake (MacDonald* et al.,*1993); 14) Porter Lake (Ritchie, 1985b); 15) Raleigh Lake 3 (MacDonald, non publié). Diagrammes polliniques abrégés de certains taxons de Sleet Lake (1) et de Queen's Lake (12) situés dans la zone du Bas Arctique actuelle, du lac Mélèze (6) situé dans la zone subarctique actuelle et du lac Demain (10) situé dans la zone boréale actuelle.*

The 6000 BP population density of the dominant boreal forest trees, *Picea glauca* and *P. mariana*, relative to modern population densities was assessed by comparing the pollen accumulation rates (PARs) of these taxa at 6000 BP with the average PAR's from the same sites for the late Holocene to present.

The presence of *Sphagnum* peatlands was inferred by the presence of *Sphagnum* spores. The extent of those peatlands relative to modern conditions was assessed by comparing accumulation rates of *Sphagnum* spores at 6000 BP at fossil sites with the average accumulation rates of *Sphagnum* at the same sites over the late Holocene.

RESULTS

By 6000 BP those areas of the western Northwest Territories that lie within the Boreal and Subarctic Zones today supported *Picea* dominated forest (Figs. 1 and 2). The expansion of both *Picea glauca* and *P. mariana* into the southwestern half of the study area occurred rapidly between 10,000 and 9000 BP (Ritchie and MacDonald, 1986). Examination of pollen accumulation rates for *P. glauca* and *P. mariana* indicate that not only were the range boundaries of these species similar to present, but the density of *P. glauca* tree-cover in the modern forested areas was likely as high as it is today (Fig. 3). The density of *P. mariana* tree cover was approaching or had reached modern densities (Fig. 3). Therefore, by 6000 BP forest was likely present over much the same area as is now occupied by the modern Boreal and Subarctic Zones.

Evidence from the Tuktoyaktuk Peninsula (Sites 1,2 – Fig. 1) including pollen records, plant macrofossils and surface finds of sub-fossil stumps indicate that *P. glauca* forest or forest-tundra was present approximately 50-75 km north of the modern physiognomic limit of spruce trees just prior to or at 6000 BP (Ritchie and Hare, 1971; Spear, 1983, 1993; Ritchie, 1984b). *P. mariana* may also have been present at low densities (Spear, 1993). The radial

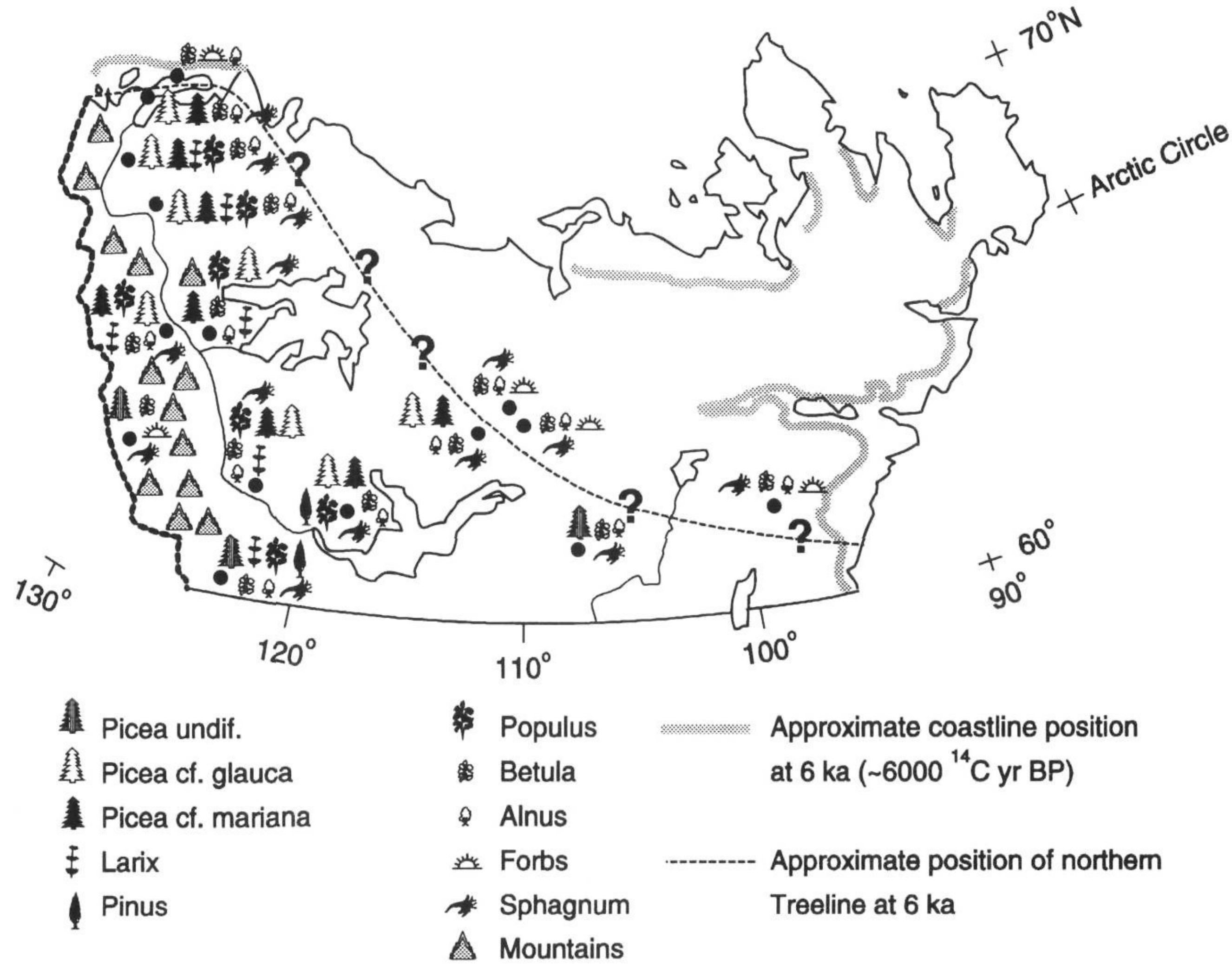

FIGURE 2. A general synthesis of the vegetation of the continental Northwest Territories at 6 ka (6000 ^{14}C yr BP) based upon available fossil pollen data.

Synthèse générale de la végétation de la partie continentale des Territoires du Nord-Ouest à 6 ka, fondée sur les données palynologiques fossiles disponibles.

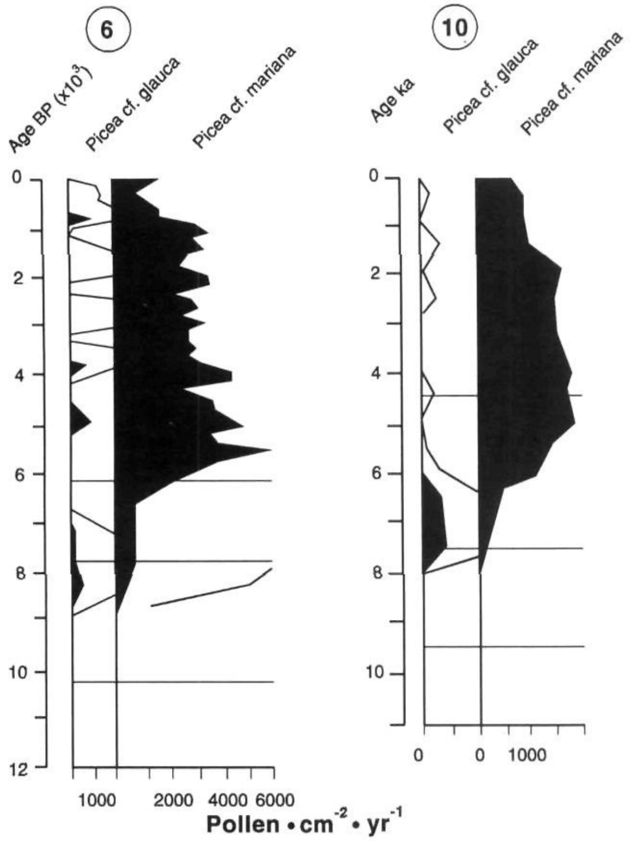

FIGURE 3. Pollen accumulation rates of *Picea* cf. *glauca* and *P.* cf. *mariana* from Lac Mélèze (6) and Lac Demain (10).

Taux d'accumulation pollinique de Picea *cf.* glauca *et de* P. *cf.* mariana *au lac Mélèze (6) et au lac Demain (10).*

growth-rates measured from two sub-fossil stumps of *P. glauca* are comparable with trees growing in the modern forests of the Inuvik region (Site 3 – Fig. 1; Ritchie, 1984b). Fossil pollen evidence and *Picea* needles from a peat section located above the modern treeline in the Mackenzie Mountains (Site 7) indicate that at some sites forest grew perhaps several 10's to 100 m above its present limits at 6000 BP (MacDonald, 1983) and the density of forest cover at higher elevations was greater than at present (Szeicz *et al.*, in press). However, the upper limits of tree growth may not have been significantly higher than present at all locations (Site 5; Szeicz *et al.*, in press). In contrast, fossil pollen evidence from central Canada (Sites 12,13,14 – Fig. 1) does not indicate a northward extension of *Picea* treeline at 6000 BP (Moser and MacDonald, 1990; MacDonald *et al.*, 1993).

At 6000 BP other key boreal forest genera, including *Larix, Populus, Betula,* and *Alnus* were also present throughout their modern range boundaries in the southwestern half of the study area (Fig. 2). The *Larix* pollen likely represent *L. laricina* which is the only species of the genus found in the Canadian boreal forest. Identification of *Populus* pollen to the level of species has not been published for most sites in the study area. It has been assumed that both *Populus balsamifera* and *P. tremuloides* were present by 6000 BP (Ritchie, 1984b; MacDonald, 1987). Although separation of *Alnus* pollen by species has not been done at all sites, there are enough data (Ritchie, 1984a, b; MacDonald, 1987; Moser and MacDonald, 1990) to indicate that both *Alnus crispa* and *A. incana* were present throughout their modern ranges by 6000 BP. Macrofossil evidence from Sleet Lake on the Tuktoyaktuk Peninsula (Site 1) confirms the presence of *A. crispa* by 6500 BP (Spear, 1983). Only in the high elevations of the central Mackenzie Mountains (Site 7) is there evidence that *Alnus* had not reached its modern abundance in the vegetation by 6000 BP (MacDonald, 1983). *Betula* pollen grains with diameters greater than 20 µm dominate or are very common from 6000 BP pollen profiles from forested regions in the study area and suggest that arboreal birch (*Betula papyrifera*) was present (Ritchie, 1984a, b; MacDonald, 1987). However, this criterion must be used with caution (Ives, 1977). The pollen percentages or accumulation rates of *Larix, Populus, Betula,* and *Alnus* at sites located in the modern Boreal and Subarctic Zone do not vary in any large or uniform manner between 6000 BP and the present (Ritchie, 1977, 1984a, b; 1985a, b; Slater, 1985; MacDonald, 1987; Szeicz *et al.*, in press – Fig. 1). This suggests that, in general, the relative and absolute dominance of these genera in the forested region of the study area has not changed greatly since 6000 BP.

Pinus banksiana was present at least as far as the southwestern edge of the Territories (Sites 10 and 13), but had likely not expanded to its modern range limits in the Mackenzie Valley (between Sites 8 and 6). *Pinus contorta* grows today only in the very southwestern corner of the study area (Site 9) and was likely close to or at its present range boundaries in this region at 6000 BP (Matthews, 1980; MacDonald and Cwynar, 1985).

Abundant *Sphagnum* spores deposited in lake sediments at 6000 BP (Fig. 4) suggest that the extensive peatlands that characterize the boreal forest of the continental Northwest today had begun to develop. In some regions, peatland cover may have been, at the very least, as extensive as it is today (Fig. 4). This conclusion is supported by radiocarbon dates from the base of peatlands in the Northwest Territories. These dates suggest extensive peatland development occurred between 8000 and 4000 BP (Zoltai and Tarnocai, 1975).

Evidence of the nature of tundra vegetation remains sparse. However, sites in areas that were likely dominated by tundra at 6000 BP near the Mackenzie Delta (Site 2 – Spear, 1993) and in central Canada (Sites 12,13,14 — Moser and MacDonald, 1990; MacDonald *et al.*, 1993) present pollen assemblages for the period 6000 BP that are very similar to modern pollen assemblages from Low Arctic Tundra sites (Ritchie, 1974; MacDonald and Ritchie, 1986; Ritchie *et al.*, 1987). These assemblages are dominated by *Alnus, Betula*, Cyperaceae and a variety of herbs (Fig. 1 – Site 12).

DISCUSSION

The pollen data and ancillary macro-fossil evidence suggest that at 6 ka most of present Subarctic and Boreal Zones of the continental Northwest Territories supported

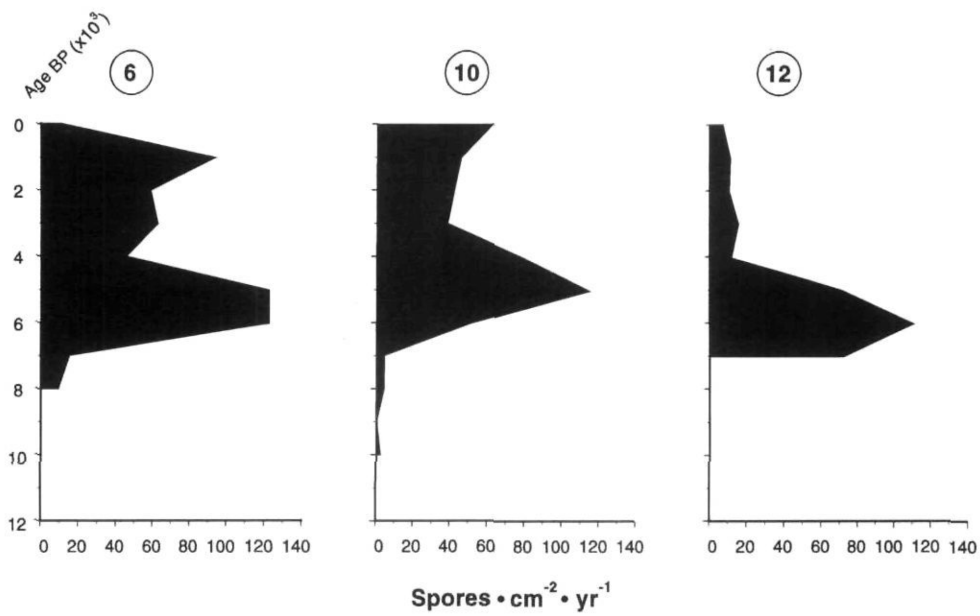

FIGURE 4. Accumulation rates of *Sphagnum* spores from Lac Mélèze (6), Lac Demain (10) and Queen's Lake (12).

Taux d'accumulation des spores de Sphagnum *au lac Mélèze (6) et au lac Demain (10).*

Picea dominated forest. The limits of forest were located north of the present treeline in the Mackenzie Delta region and possibly a hundred metres higher than present at some sites in the Mackenzie Mountains. In contrast, there is no evidence that the forest limit in the central portions of the Northwest Territories was north of its modern location. Treeline expansion in central Canada occurred between 5000 and 4000 BP (Moser and MacDonald, 1990; *MacDonald et al., 1993 – Site 12). Between 6000 and 3500* BP treeline in the Mackenzie Delta region retreated (Spear, 1983, 1993; Ritchie, 1984b). This regional variability in treeline behaviour may relate to the long-wave geometry of the arctic front (Moser and MacDonald, 1990), which has a general geographic correspondence with the location of the northern forest limits in the Northwest Territories (Bryson, 1967). *Pinus banksiana* was probably the only tree species that was not present near its modern range boundaries by 6000 BP. The species did not reach its modern range limits in the Mackenzie Valley until 4000 to 2000 BP (Slater, 1985; MacDonald, 1987). A similar slow rate of spread is evident for the movement of *Pinus contorta* into the Yukon Territory (MacDonald and Cwynar, 1985, 1991). Both species of pine require open and well-drained sites for seedlings to survive. The slow rate of northward expansion may reflect the difficulties that pine encountered in invading a continuous forest dominated by *Picea* (MacDonald and Cwynar, 1985). However, it is also possible that the northward spread of *Pinus banksiana* was controlled by some unknown climate change that had little impact on the other boreal tree and large shrub taxa.

Aside from the late Holocene invasion of some regions by *Pinus banksiana*, the vegetation of the forested regions of the continental Northwest Territories was generally similar to modern vegetation in the Boreal and Subarctic Zones of western Canada by 6 ka. This conclusion is confirmed by a mathematical comparison of fossil pollen samples from a number of sites in the continental Northwest Territories with modern pollen spectra from throughout northern North America (Anderson *et al.*, 1989).

Development of extensive *Sphagnum* dominated peatlands in both the forested regions and adjacent tundra areas of the Northwest Territories was underway by 6000 BP. The spread of peatlands likely occurred through both terrestrialization and paludification. Peatland initiation in the central portions of Alberta, Saskatchewan and Manitoba appears to have been delayed at many sites until after 6000 to 5000 BP, likely due to warm and dry conditions during the middle Holocene (Zoltai and Vitt, 1990). There is no evidence of a similar delay in the continental Northwest Territories. This suggests that at 6000 BP climatic conditions conducive for peat growth and accumulation were prevalent in the Territories.

The general pattern of vegetation distribution at 6 ka is reasonably well documented for the southwestern half of the continental Northwest Territories. The history of vegetation in the northeastern half remains uncertain. Efforts should be made to obtain fossil pollen records spanning the period from deglaciation to the present from areas of Low and Middle Arctic Tundra in the northeast. In addition, records from climatically sensitive ecotonal sites near treeline, or from sites which might be responsive to hydrological changes caused by climatic fluctuations may provide additional data on smaller climatic and vegetational changes during the 6 ka period.

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REFERENCES

Anderson, P., Bartlein, P.J., Brubaker, L.B., Gajewski, K. and Ritchie, J.C., 1989. Modern analogues of late-Quaternary pollen spectra from the western interior of North American. Journal of Biogeography, 16: 673-596.

Bonan, G.B., Pollard, D. and Thompson, S.L., 1992. Effects of boreal forest vegetation on global climate. Nature, 359: 716-718.

Bryson, R.A., 1967. Air masses, streamlines and the boreal forest. Geographic Bulletin, 8:228-269.

D'Arrigo, R., Jacoby, G.C. and Fung, I.Y., 1987. Boreal forests and the atmosphere-biosphere exchange of carbon dioxide. Nature, 329: 321-323.

Dyke, A.S. and Prest, V.K., 1987. Late Wisconsinan and Holocene history of the Laurentide Ice Sheet. Géographie physique et Quaternaire, 41: 237-264.

Ecoregions Working Group, 1989. Ecoclimatic regions of Canada. Canada Committee on Ecological Land Classification, Series 21.

Gorham, E., 1991. Northern peatlands: Role in carbon cycle and possible response to climatic warming. Ecological Applications, 1: 182-195.

Ives, J.W. 1977. Pollen separation of three North American birches. Arctic and Alpine Research, 9: 73-80.

Kay, P.A., 1979. Multivariate statistical estimates of Holocene vegetation and climate change, forest-tundra transition zone, N.W.T., Canada. Quaternary Research, 11: 125-140.

MacDonald, G.M., 1983. Holocene vegetation of the upper Natla River area, Northwest Territories, Canada. Arctic and Alpine Research, 15: 169-180.

——— 1987. Postglacial vegetation history of the Mackenzie River basin. Quaternary Research, 28: 245-262.

MacDonald, G.M. and Cwynar, L.C., 1985. A fossil pollen based reconstruction of the late Quaternary history of lodgepole pine (*Pinus contorta* ssp. *latifolia*) in the western interior of Canada. Canadian Journal of Forestry Research, 15: 1039-1044.

——— 1991. Postglacial population growth rates of *Pinus contorta* ssp. *latifolia* in western Canada. Journal of Ecology, 79: 417-429.

MacDonald, G.M., Edwards, T.W.D., Moser, K.A., Pienitz, R. and Smol, J.P., 1993. Rapid response of treeline vegetation and lakes to past climate warming. Nature, 361: 243-246.

MacDonald, G.M. and Ritchie, J.C., 1986. Modern pollen spectra from the western interior of Canada and the interpretation of late Quaternary vegetation development. New Phytologist, 103: 245-268.

Matthews, J.V., Jr., 1980. Palaeoecology of John Klondike Bog, Fisherland Lake region, southwest District of Mackenzie. Geological Survey of Canada Paper 80-22.

Moser, K.A. and MacDonald, G.M., 1990. Holocene vegetation change at treeline Northwest Territories, Canada. Quaternary Research, 34: 227-239.

Nichols, H., 1975. Palynological and palaeoclimatic study of the late Quaternary displacement of the boreal forest in Keewatin and Mackenzie N.W.T. Institute of Arctic and Alpine Research Occasional Paper 15.

Ritchie, J.C., 1974. Modern pollen assemblages near the arctic treeline, Mackenzie Delta region, Northwest Territories. Canadian Journal of Botany, 52: 381-396.

——— 1977. The modern and late Quaternary vegetation of the Campbell-Dolomite Uplands near Inuvik, N.W.T. Ecological Monographs, 47: 401-423.

——— 1984a. A Holocene pollen record of boreal forest history from the Travaillant Lake area, lower Mackenzie River basin. Canadian Journal of Botany, 62: 1385-1392.

——— 1984b. Past and present vegetation of the far northwest of Canada, University of Toronto Press.

——— 1985a. Late Quaternary climatic and vegetational change in the lower Mackenzie basin. Ecology, 66: 612-621.

——— 1985b. Quaternary pollen records from the western interior of Canada. p. 327- 352. *In* V.M. Bryant Jr. and R.G. Holloway, eds., Pollen records of late-Quaternary North American sediments. American Association of Stratigraphic Palynologists, Dallas.

Ritchie, J.C., Hadden, K.A. and Gajewski, K. 1987. Modern pollen spectra from lakes in arctic western Canada. Canadian Journal of Botany, 65: 1605-1613.

Ritchie, J.C. and Hare, F.K., 1971. Late Quaternary vegetation and climate near the arctic treeline of northwestern North America. Quaternary Research, 1: 331-342.

Ritchie, J.C. and MacDonald, G.M., 1986. Patterns of postglacial spread of white spruce. Journal of Biogeography, 13: 527-540.

Slater, D.S., 1985. Pollen analysis of postglacial sediments from Eildun Lake, District of Mackenzie, N.W.T., Canada. Canadian Journal of Earth Sciences, 22: 663-674.

Spear, R.W., 1983. Palaeoecological approaches to the reconstruction of treeline fluctuations in the Mackenzie Delta region, Northwest Territories: Preliminary results. Nordicana, 47: 61-72.

——— 1993. The palynological record of late-Quaternary arctic treeline in northwest Canada. Review of Palaeobotany and Palynology, 79: 99-111.

Stuiver, M. and Reimer, P.J., 1993. CALIB 3. Computer Program, Quaternary Isotope Laboratory. University of Washington.

Szeicz, J.M., MacDonald, G.M. and Duk-Rodkin, A., in press. Postglacial vegetation history of the Mackenzie Mountains. Palaeogeography, Palaeoclimatology, Palaeoecology.

Zoltai, S.C. and Tarnocai, C., 1975. Perennially frozen peatlands in the western arctic and subarctic of Canada. Canadian Journal of Earth Sciences, 12: 28-43.

Zoltai, S.C. and Vitt, D.H., 1990. Holocene climatic change and the distribution of peatlands in western interior Canada. Quaternary Research, 33: 231-240.