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Late-Pleistocene and Holocene palynology in southeastern Québec
La palynologie de l'Holocène et de la fin du Pléistocène dans le sud-est du Québec

R. J. Mott

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Résumé de l'article

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LATE-PLEISTOCENE AND HOLOCENE PALYNOLOGY IN SOUTHEASTERN QUÉBEC

R. J. MOTT, Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario K1A 0E8.

ABSTRACT Several relative and absolute pollen profiles from the Appalachian Region outline the vegetational history of the region. The earliest reliable date of 11,200 radiocarbon years BP, from the watershed area of the Mégantic Hills on the Québec-Maine border, dates the spruce pollen maximum, indicative of spruce woodland conditions. A second site in the same area shows tundra conditions existed prior to this time, but no radiocarbon dates are available to indicate the length of time these conditions persisted. About 10,000 radiocarbon years BP or less, the character of the vegetation changed and closed forest conditions prevailed. Spruce was still present, but balsam fir and birch increased and other deciduous species appeared. The continued increase in thermophilous deciduous species and hemlock and white pine during early- and mid-Holocene resulted in forests in which these taxa were more prominent than at present. An increase in spruce and decline in thermophilous taxa in the last few millenia produced the extant forests types.

RÉSUMÉ *La palynologie de l'Holocène et de la fin du Pléistocène dans le sud-est du Québec.* Plusieurs diagrammes polliniques, relatifs et absolus, provenant de la région des Appalaches, retracent l'histoire de la végétation dans la région. Le plus ancien âge sur lequel on peut compter et établi grâce à la méthode du radiocarbone est de 11 200 ans BP. Cet âge, provenant de la région de la ligne de partage des eaux des collines de Mégantic, sur la frontière entre le Maine et le Québec, date le maximum du pollen d'épinette. La région était alors couverte d'une pessière ouverte. Un deuxième site, de la même région, démontre que des conditions de toundra prévalaient avant cette période, mais aucune datation au radiocarbone ne peut préciser leur durée. Il y a environ 10 000 ans, le caractère de la végétation s'est transformé et des conditions de forêt fermée ont alors prévalu. L'épinette était encore présente, mais l'abondance du sapin baumier et du bouleau s'est accru et d'autres espèces à feuilles caduques sont apparues. Le développement continu des espèces thermophiles à feuilles caduques, des pruches et des pins blancs, au début et au milieu de l'Holocène, a engendré des forêts où ces taxons étaient relativement plus abondants qu'ils ne le sont aujourd'hui. Le développement de l'épinette et le déclin des taxons thermophiles, pendant les derniers millénaires, ont engendré les types de forêts que l'on connaît de nos jours.

РЕЗЮМЕ ИЗУЧЕНИЕ ПЛЕЙСТОЦЕНОВОГО И ГОЛОЦЕНОВОГО ПЕРИОДОВ В ЮГО-ВОСТОЧНОМ КВЕБЕКЕ МЕТОДАМИ ПАЛИНОЛОГИИ. Ряд относительных и абсолютных пыльцевых профилей полученных в Аппалачинской области дают представление о вегетационной истории этой области. Самая ранняя надежная радиоуглеродная датировка для этой области составляет 11 200 лет. Она указывает на то, что именно столько лет тому назад между водоразделом, которым служат горы Мегантик Хиллс и границей между провинцией Квебек и штатом Мэйн наблюдалось максимальное количество еловой пыльцы свидетельствующей о том, что в те времена эта местность была покрыта еловым лесом. Получены, однако, доказательства того, что в еще более древнее время на месте этих лесов была тундра. Но, у нас нет радиоуглеродной датировки, которая давала бы представление о том, сколько лет в этой области была тундра. Установлено, с помощью радио-углерода, что десять тысяч лет тому назад леса покрывавшие указанную область оставались столь же густыми, но начали изменять свой характер. Хотя ель и не исчезла совсем, на ряду с ней стала появляться бальзамическая пихта, береза и другие лиственные породы дерева все в большем количестве. Все продолжавшееся распространение термофильных пород лиственных деревьев, а также и таких, как гемлок (цуга) и веймутова сосна в течении раннего и среднего голоцена, привело к тому, что эти породы дерева стали более распространенными, чем в настоящее время. За последние тысячелетия, однако, ель начала опять распространяться за счет сокращения термофильных пород. В результате леса приобрели тот характер, который сохранился до сих пор.

INTRODUCTION

Southeastern Québec, that area of the province lying southeast of the section of the St. Lawrence River between Montréal and Québec City, is an area of diverse landforms. Adjacent to the St. Lawrence River is the broad, flat Lowlands Region underlain by marine clays deposited during the Champlain Sea episode. Relief is low except in the Montréal area where bedrock knobs project above the low plains to form the Monteregian Hills. Contrasting the Lowlands is the rugged terrain of the Appalachians to the southeast. The Appalachian Province (DUBOIS, 1974) comprises the Appalachian Platform, consisting of the Appalachian Piémont, the Lower Appalachian Plateau and the Higher Appalachian Plateau; the Sutton Mountains, a northern extension of the Green Mountains; the middle Chaudière River Hills, a southward extension of the Notre Dame Mountains; and the Mégantic Hills or Frontier Mountains, a part of the White Mountains of the State of Maine (Fig. 1).

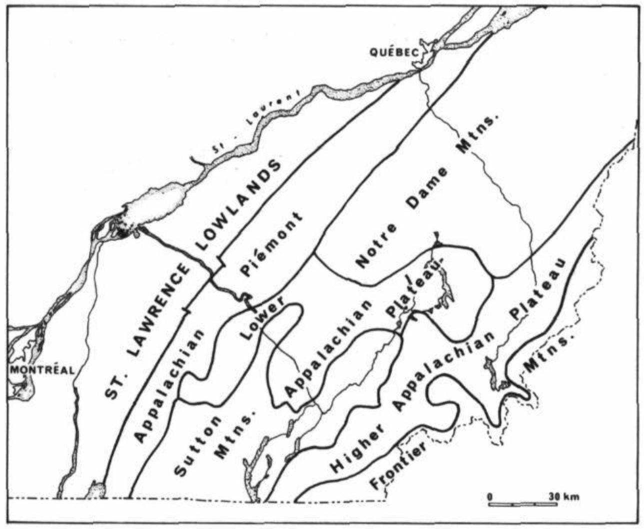

FIGURE 1. Physiographic regions of southeastern Québec (after DUBOIS, 1974).

Regions physiographiques du sud-est du Québec (d'après DUBOIS, 1974).

Most of the previous pollen studies conducted in this area have been in the Lowlands and consequently post-date the Champlain Sea. As early as 1930, AUER (1930) published two brief pollen profiles from peat bogs south of the St. Lawrence River, one near Lévis and the other near Valleyfield. POTZGER (1953) also included profiles from two bogs from southeastern Québec in his study of a series of bogs across southern Québec. While these were more complete than Auer's early attempts they included only tree pollen; shrubs and herbs were not counted. In his study of the postglacial deposits of the St. Lawrence Lowlands, TERASMAE (1960) included diagrams from 12 bogs. These diagrams were more complete but lacked radiocarbon dates for age control and correlation. Subsequently, the basal organic sediment from one of these sites was radiocarbon-dated and provided an age for the spruce pollen maximum in the area (TERASMAE, 1969). Two sites on Mont St. Hilaire near Montréal have been studied in detail and radiocarbon dates are available (LASALLE, 1966; TERASMAE and LASALLE, 1968). More recently RICHARD (1973, 1975a and b) has published six pollen diagrams from southeastern Québec. Three are from below the Champlain Sea limit in the Lowlands and Appalachian Piémont, and three are from higher elevations in the Appalachian Plateaus and in the Notre Dame Mountains. Richard (pers. comm.) is also studying a site in the Sutton Mountains. The locations of the above sites are shown on Figure 2.

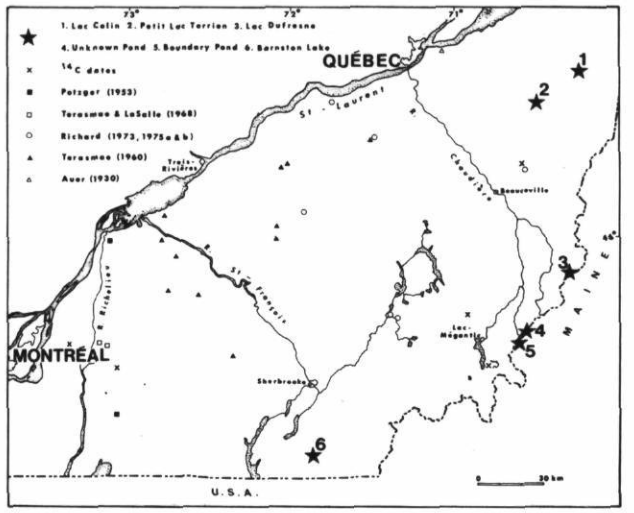

FIGURE 2. Site location map.

Localisation des sites.

This report will present the results of studies of six sites; three sites in the Frontier Mountains along the border between Québec and Maine, two in the Notre Dame Mountains, and an abbreviated basal portion of a profile on the Higher Appalachian Plateau (Fig. 2). Relative and absolute pollen determinations are used to outline the late-Pleistocene and Holocene vegetational changes that occurred in southeastern Québec.

SITE LOCATIONS

The locations of the six sites studied are shown in Figure 2. Two of the sites, Boundary Pond (No. 5: 45°34'N, 70°40.5'W) and Unknown Pond (No. 4: 45°36'N, 70°38'W) are about 15-20 km east of Lac Mégantic, Québec, on the Maine side of the international boundary. The former is at an elevation of 603 m and the latter at 489 m. A third site, Lac Dufresne (No. 3: 45°51'N, 70°21'W), is about 35 km northeast of Unknown Pond on the Québec side of the international boundary at an elevation of 650 m. All three sites are within the *White Mountain* physiographic region. Two other sites are located in the Notre Dame Mountains physiographic region. Petit Lac Terrien (No. 2: 46°35'N., 70°36.5'W.) is 5-6 km northeast of St-Nazaire-de-Buckland at an elevation of 404 m, and Lac Colin (No. 1: 46°43'N., 70°17.5°W.) is 13 km northwest of St-Fabien-de-Panet at an elevation of 658 m. The sixth site is Barnston Lake (No. 6: 45°06.7'N., 71°53'W.) located 0.8 km north of Barnston at an elevation of 415 m. This site is within the Higher Appalachian Plateau region.

SEDIMENTOLOGY AND CHRONOLOGY

The sediments outlined below for each site are also shown in the stratigraphic column adjacent to the corresponding pollen diagram. The radiocarbon dates are shown with each diagram and are listed in Table I.

BOUNDARY POND (No. 5)

At Boundary Pond, 380 cm of dark brown, firm algal gyttja overlies 22 cm of light brown, silty, organic clay which grades into stiff, sticky grey clay. A radiocarbon date of 11,200 ± 200 years BP (GSC-1248) is from the basal organic sediment at a depth of 389-392 cm. The four other radiocarbon dates obtained from this core are shown in Table I.

UNKNOWN POND (No. 4)

Unknown Pond has 678 cm of algal gyttja, with *abundant coarse plant detritus, overlying 5 cm of or*ganic silt with pebbles. This in turn overlies 10 cm of calcareous silty gyttja, 2 cm of moss detritus and 5 cm of calcareous organic silt with a second moss layer over grey clay. The basal radiocarbon date of 14,800 ± 220 years BP (GSC-1339) is from the interval 695-700 cm in the calcareous organic silt unit immediately above the grey clay. A second age determination (GSC-1404, 12,600 ± 280) was obtained for the interval 685-688 cm in the calcareous silty gyttja. These, and two other dates are shown in Table I. The validity of the dates from this site will be discussed later.

LAC DUFRESNE (No. 3)

The bottom sediments of Lac Dufresne comprise 362 cm of dark brown gyttja, containing some coarser plant detritus, which becomes silty toward the base, overlying and grading into 4 cm of brownish-grey clay with some organic content; this overlies grey clay to an unknown

TABLE I

Radiocarbon dates from lake sites.

Datations au radiocarbone.

Site	Core Interval (cm)	GSC Laboratory dating No.	Uncorrected age (^{14}C years BP)	$\delta\,^{13}C$ (‰)	Corrected age (^{14}C years BP)	Reference
Boundary Pond (No. 5)	389-392	1248	11,200 ± 200			GADD *et al.* (1972)
	341-344	1932	7750 ± 150	−25.0	7750 ± 150	
	257.5-262.5	1895	5730 ± 130	−25.5	5720 ± 130	
	167.5-172.5	1934	3080 ± 120			
	82.5-88.5	1954	1420 ± 80	−26.8	1390 ± 80	
Unknown Pond (No. 4)	695-700	1339	14,900 ± 220	−33.4	14,800 ± 220	GADD *et al.* (1972)
	685-688	1404	12,700 ± 280	−31.2	12,600 ± 280	GADD *et al.* (1972)
	512-518	1907	4990 ± 140	−26.0	4970 ± 140	
	117.5-122.5	1929	2780 ± 180	−23.0	2810 ± 180	
Lac Dufresne (No. 3)	357-363	1294	11,200 ± 160			GADD *et al.* (1972)
	345-349	2345	9660 ± 140			
	214-219					
Lac Colin (No. 1)	688-694	2282	11,100 ± 180			
	664-668	2325	9020 ± 100	−27.0	8990 ± 100	
	468-472	2329	6360 ± 110			
	296-300	2333	4900 ± 90			
	147.5-152.5	2337	3360 ± 100			
Petit Lac Terrien (No. 2)	626-638	312	12,640 ± 190			GADD (1974)
Barnston Lake (No. 6)	485-495	420	11,020 ± 330			LOWDON *et al.* (1967)

depth. A radiocarbon date of 11,200 ± 160 years BP (GSC-1294) was obtained for the basal organic sediment from 357-362 cm depth. Dates from two other intervals are given in Table I.

LAC COLIN (No. 1)

A total 887 cm of sediment was recovered from Lac Colin, 694 cm of which contained organic matter, and the remainder was laminated grey clay. Of the organic sediment, the upper 676 cm were brown algal gyttja which was laminated toward the base, 11 cm were layered silty gyttja and 7 cm were black and grey, banded organic clay. The basal interval of 688-694 cm yielded a radiocarbon date of 11,100 ± 180 years BP (GSC-2282). Four other dates from the core are listed in Table I.

PETIT LAC TERRIEN (No. 2)

The lake bottom sediments from Petit Lac Terrien comprise 574 cm of dark brown algal gyttja with some coarser organic detritus which becomes laminated at depth, 12 cm of calcareous, laminated marly gyttja and 56 cm of somewhat organic grey clay with abundant moss layers. This overlies an inorganic grey clay to unknown depth. A radiocarbon date of 12,640 ± 190 years BP (GSC-312; GADD 1964) was obtained for the interval 626-638 cm, within the organic clay.

BARNSTON LAKE (No. 6)

A complete core was not recovered from Barnston Lake; only the top metre and the metre interval between 450 and 550 cm were obtained. Brown algal gyttja to 455 cm depth becomes laminated and shelly at the base and overlies 35 cm of buff and grey, laminated, shelly marl with some dark bands of gyttja. This overlies soft, bluish-grey clay with no organics present. A radiocarbon date of 11,020 ± 330 years BP (GSC-420, LOWDON *et al.*, 1967) was obtained for a 10 cm interval of the marl above the contact with the clay. Despite the presence of calcareous marl, the date does not appear anomalous when compared to the pollen profile, but some contamination by old carbonates is a distinct possibility.

HISTORY OF DEGLACIATION

Pre-Classical Wisconsin glacial and non-glacial deposits in southeastern Québec have been described by various authors (GADD, 1971; GADD *et al.*; 1972 McDONALD and SHILTS, 1971). For the purposes of this report, a brief description of the history of retreat of the last ice is pertinent.

GADD *et al.* (1972) have summarized the history of deglaciation for the region, and it is this summary that forms the basis for the following brief account. The front of active ice retreated down the topographic slope from the White Mountains to the St. Lawrence Lowlands. The area between Lac Mégantic and the international boundary was the first to be uncovered by the ice and the Frontier Moraine in the upper Chaudière valley is the oldest in Québec. The proglacial lakes ponded between the ice and the divide drained to the southeast through valleys crossing the divide. A relatively old date of 14,800 ± 220 years BP (GSC-1339) on lake bottom sediment in Unknown Pond, located in such a spillway, is apparently anomalous and does not provide a reliable minimum date for deglaciation as discussed later.

Various moraines and proglacial lake sediments in the St. Francis and upper Chaudière River valleys mark the retreat of the ice downslope. Evidence of northward moving ice in the Thetford Mines-Beauceville area (LAMARCHE, 1971) complicates the pattern of deglaciation and the exact significance of this phenomenon is not completely resolved. A prominent complex of moraines along the edge of the Appalachian platform marks a major halt in the retreat of the icefront as the ice downwasted in the St. Lawrence Lowlands. The proglacial lakes, which ponded in front of the ice, must have drained either southwestward into the Champlain Valley or northeastward along the ice front into the Gulf of St. Lawrence. Further retreat of the ice into the Lowlands followed, and the Drummondville Moraine formed at a lower elevation parallel to the Appalachian front. Non-fossiliferous rhythmites connected with the moraine attest to the presence of large proglacial lakes along the ice front. The ages of the Drummondville and Highland Front Moraines are difficult to assess. However, since both pre-date the Champlain Sea episode, they are older than the oldest Champlain Sea dates. If the Highland Front system is correlative with the St. Antonin Moraine farther east then it is at least 12,720 years old (LEE, 1963).

Continued retreat of the ice allowed incursion of the Champlain Sea into the Lowlands. A recent date on Champlain Sea shells in the Ottawa area provides a minimum date of 12,800 ± 220 years BP (GSC-1859) for inundation of the Lowlands (RICHARD, 1974). If this and other relatively old Champlain Sea shell dates are valid (the possibility exists that they may be somewhat too old due to contamination by old carbonates), then the sea began much earlier than previously suspected. With invasion of the sea into the Lowlands the ice front retreated north of the St. Lawrence valley and formed the St. Narcisse Moraine. Radiocarbon dates on shells in marine sediments associated with formation of the moraine indicate an age of about 11,000 years BP for the moraine (LASALLE and ELSON, 1975). Subsequent uplift of the land caused the sea to fall below an elevation of about 100 m by about 9500 years BP in the Lowlands.

VEGETATION

The forests of southeastern Québec are dominated by broadleaved deciduous species in the southwestern part of the region and by coniferous species at higher elevations to the east and northeast. ROWE (1972) classifies the vegetation as part of the Great Lakes-St. Lawrence Forest Region. According to GRANDTNER (1966) four climax domains can be distinguished. These domains shown in Figure 3, are *Domaine de l'érablière à caryers* in the southwestern Lowlands, *Domaine de l'érablière laurentienne* in the central and northeastern Lowlands areas and lower elevations in the Appalachians, *Domaine de l'érablière à bouleau jaune* at higher elevations in the eastern Appalachians and the Sutton Mountains, and *Domaine de la sapinière* in parts of the Frontier Mountains and Notre Dame Mountains to the northeast.

L'érablière à caryers is a broadleaved forest dominated by sugar maple *(Acer saccharum)*; bitternut and shagbark hickory *(Carya cordiformis, C. ovata)*; bur and red oak *(Quercus macrocarpa, Q. rubra)*; linden *(Tilia americana)*; black, white and red ash *(Fraxinus nigra, F. americana, F. pennsylvanica)*; and ironwood *(Ostrya virgiana)*. Butternut *(Juglans cinerea)*, white elm *(Ulmus americana)* and blue-beech *(Carpinus caroliniana)* are also present. Conifers are sparse except on the coarser soils and areas disturbed by fire and erosion.

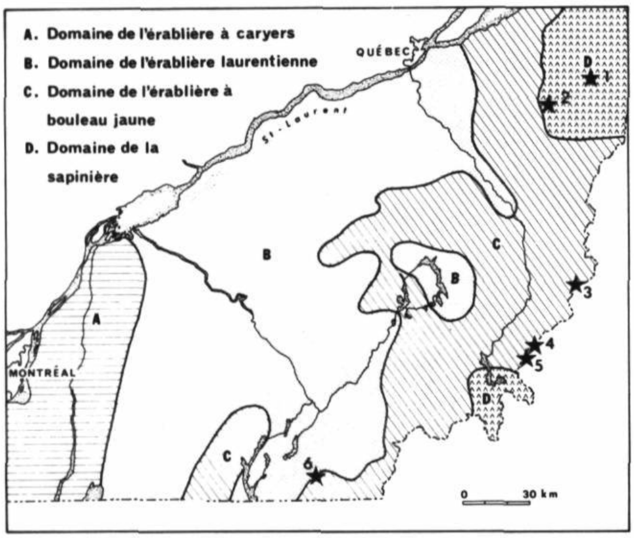

FIGURE 3. Forest vegetation of southeastern Québec (after GRANTNER, 1966).

Végétation forestière du sud-est du Québec (d'après GRANTNER, 1966).

L'érablière laurentienne is also a deciduous forest, but accompanying sugar maple is beech *(Fagus grandifolia)*. Linden, ironwood, white ash and butternut are abundant but the hickories, bur oak and blue-beech are essentially absent. Balsam fir *(Abies balsamea)* and white birch *(Betula papyrifera)* occur sporadically. Yellow birch *(Betula alleghaniensis)* is present and white pine *(Pinus strobus)* is common.

Sugar maple is mixed with yellow birch and beech in the *érablière à bouleau jaune*, and balsam fir and white birch are much more abundant. White ash, butternut, white elm and red oak are absent. Hemlock *(Tsuga canadensis)* and white pine are common and white spruce *(Picea glauca)* occurs sporadically.

The *sapinière* has a coniferous forest character with balsam fir and white birch dominating. White spruce is abundant and hemlock and white pine are present. Red spruce *(Picea rubens)* occurs in small numbers. Most of the thermophilous hardwood species common at lower elevations are absent.

CLIMATE

The general temperate, humid-continental climate of southeastern Québec varies somewhat with topography of the region as would be expected. The mean annual temperature of 5.0°C in the southwestern half of the region drops to 2.5°C at the higher elevations of the Notre Dame and Frontier Mountains. Mean annual precipitation increases from 100 cm in the lowlands to about 110 cm in the highlands. Mean annual snow-fall has a similar pattern. The reverse is true for mean annual potential evapotranspiration which decreases from 600 mm in the Montreal area to 500 mm in the eastern border area and to 475 mm in the Notre Dame Mountains. The prevailing southwesterly winds of summer change to northwesterly in winter.

POLLEN ANALYSIS

METHODS

Those cores analyzed for absolute pollen content (*i.e.* Boundary Pond and Lacs Dufresne and Colin) had 1 ml (1 cc) subsamples removed at intervals shown on the pollen diagrams. A measured aliquot (usually 1 ml) of a standardized *Eucalyptus globulus* pollen mixture (BENNINGHOFF, 1962) was added to the sediment samples. The sediment-exotic pollen mixture was then subjected to a physical and chemical treatment involving disaggregation in hot 10% KOH, screening through 48 mesh screens, digestion in hot HF acid, dilute HCl acid, dilute HNO_3 acid, acetolysis mixture, dehydration in butanol and suspension in silicone oil. Absolute pollen contents were determined using the ratio of fossil pollen per sample to fossil pollen counted equal to the ratio of exotic pollen per sample to exotic pollen counted. Influx rates (*i.e.,* grains/cm^2/year) were then calculated using the sedimentation rate obtained from the radiocarbon dates. The influx rate for total pollen is shown to the right of the three pollen diagrams for which absolute calculations were made.

RESULTS

Abbreviated pollen diagrams for the six sites studied are shown in Figures 4 to 9. Only the most significant taxa are shown along with the total pollen influx values. Percentages were calculated on the basis of total pollen excluding aquatics and exotics. Influx rates are shown as grains per square centimetre per year (gr/cm^2/yr). Pollen zones are delineated to aid in discussion and are numbered in sequence from the top down. These zones are defined on the basis of kind and relative abundance of palynomorphs, but absolute abundances were taken into account in some instances.

Zone 8 — Herbaceous Pollen Zone

Four of the six sites (Unknown Pond, Lacs Colin and Dufresne, and Petit Lac Terrien) exhibit a basal zone dominated by sedge (Cyperaceae) pollen accompanied by abundant birch *(Betula)*, alder *(Alnus)* and willow *(Salix)* and smaller amounts of other herbaceous pollen types. Where alder pollen was differentiated, green alder *(Alnus crispa)* is the species involved. A fifth site, Barnston Lake, has an equivalent zone high in birch, alder, willow and herbaceous pollen but lacking abundant sedge. Although only a few measurements were made on the size of the birch pollen in this zone, they generally appear to be the small shrub birch type (*i.e., Betula glandulosa)*. Tree pollen is limited to small numbers of spruce *(Picea)* and jack pine *(Pinus banksiana/resinosa* type) but not enough to indicate the presence of these trees in the immediate area. Where absolute values have been determined the numbers are low; total influx rates range about 1,000 grains/cm^2/year or less. All evidence indicates tundra conditions were prevalent at this time at the five sites.

Zone 7 — Spruce Pollen Zone

All of the pollen profiles show a prominent spruce zone either above the basal Herb Pollen Zone or at the base of the profile in the case of Boundary Pond. Maximum relative values are around 40% but range as high as 70% at Petit Lac Terrien and as low as 25% at Boundary Pond. Coincident with the increase in spruce pollen are decreases in birch, alder, willow and most of the herbaceous pollen types prominent in Zone 8. Ab-

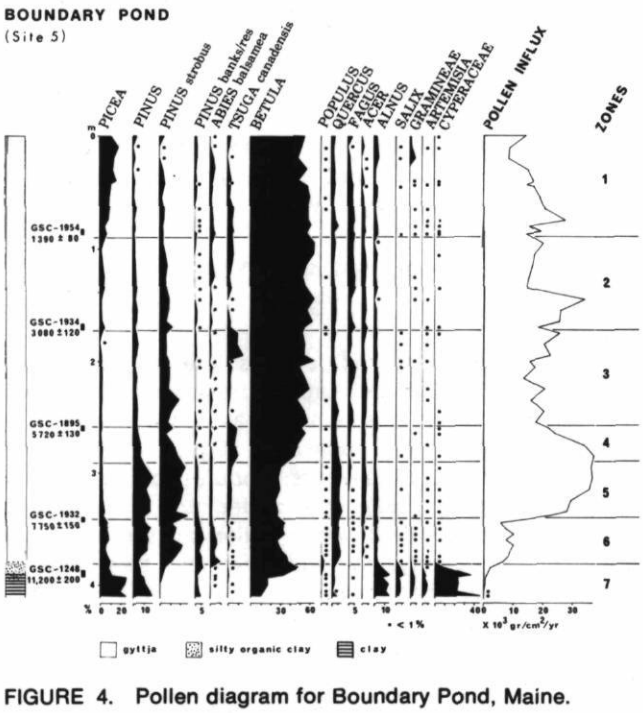

FIGURE 4. Pollen diagram for Boundary Pond, Maine.

Diagramme pollinique de Boundary Pond, Maine.

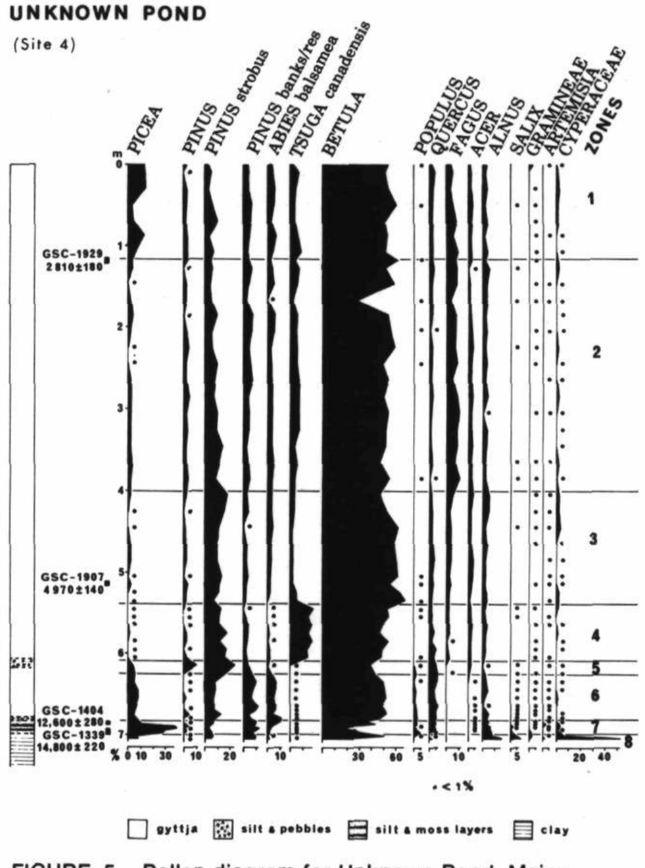

FIGURE 5. Pollen diagram for Unknown Pond, Maine.

Diagramme pollinique de Unknown Pond, Maine.

solute pollen values are somewhat higher than the basal zone but are not high enough to indicate closed forest conditions. A spruce woodland is envisaged for this time, the *pessière ouverte* or *taïga* of Richard (RICHARD, 1973, 1975a; RICHARD and POULIN, 1976). Whether or not a closed spruce forest existed at the time of peak spruce pollen deposition is still not known for certain. Although the spruce pollen percentages indicate a spruce forest, the absolute pollen rates may not be as convincing. Maximum total pollen influx rates exceed 1,000 grains/cm²/year with highest values at Lac Colin of about 5,000 grains/cm²/year. Spruce rates alone reach 1,800 grains/cm²/year. Reliable absolute pollen deposition rates for tundra and northern boreal forest environments are not yet available making an accurate interpretation of the spruce pollen zone impossible. The influx rates determined by DAVIS *et al.* (1975) that led them to speculate on the absence of the spruce "Boreal Forest" period in Maine and northern New England and the Maritime provinces in general, appear to be inaccurate because of the erroneous estimates for sedimentation rates. A closed boreal forest was probably not present but spruce trees must have been present in some abundance on the landscape throughout northeastern North America.

At Lac Colin the decline in spruce values at the top of Zone 7 is accompanied by a marked increase in green alder pollen which eventually exceeds 50%. Less prominent increases in alder pollen can also be seen in the Petit Lac Terrien and Barnston Lake profiles (alder types were not differentiated in these diagrams), but no increase is present at the other sites. RICHARD and POULIN (1976) reported a similar green alder peak in the Charlevoix region northeast of Québec City and postulated a climatic deterioration about 9750 years BP following the spruce maximum. If this interpretation is correct, then the effects of the change were felt as far south as Lac Colin in the Notre Dame Mountains but not in the Frontier Mountains. However, the alder increase may simply be a successional change and not reflect a climatic deterioration.

Zone 6 — Balsam Fir Pollen Zone

Following the decline in spruce, and alder at those sites where it is present in large numbers, balsam fir *(Abies balsamea)* pollen increases abruptly to a low maximum. Although percentage values rarely exceed 10% absolute values show significant numbers compared to modern rates. Birch (probably white birch, *Betula papyrifera)* pollen also increases in abundance over the previous zone. Oak *(Quercus)* pollen is more abundant as are hardwood taxa in general. White pine *(Pinus strobus)* begins to increase at the base of this zone and gradually attains values exceeding 20%.

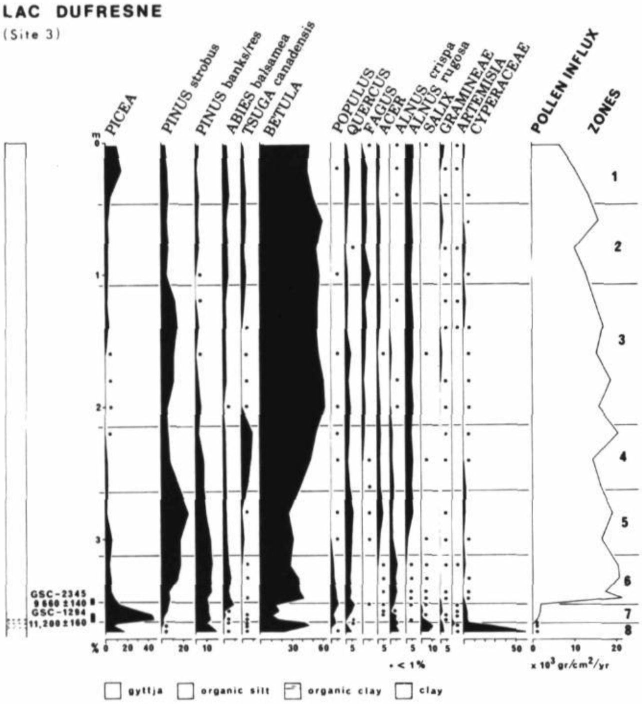

FIGURE 6. Pollen diagram for Lac Dufresne, Québec.

Diagramme pollinique du lac Dufresne, Québec.

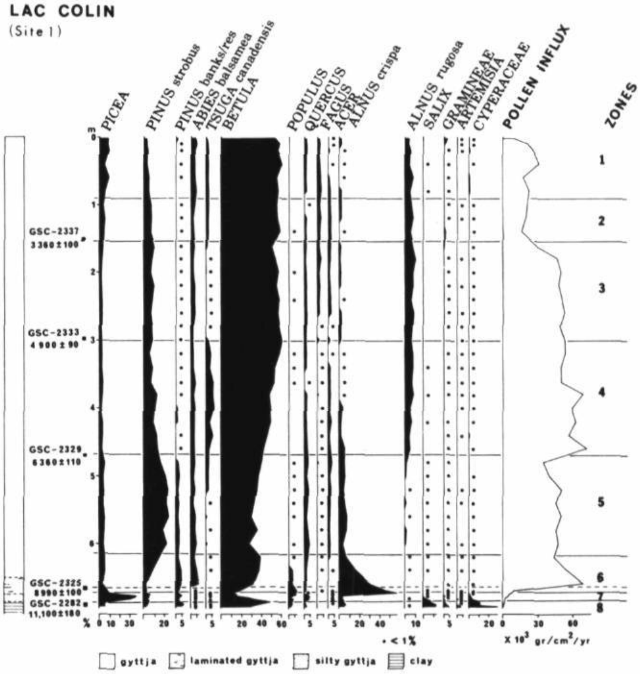

FIGURE 7. Pollen Diagram for Lac Colin, Québec.

Diagramme pollinique du lac Colin, Québec.

Absolute values for most taxa increase greatly at this time as shown by the total influx rates which jump to values exceeding 10,000 grains/cm²/year at Boundary Pond, 20,000 grains/cm²/year at Lac Dufresne and 50,000 grains/cm²/year at Lac Colin. A closed balsam fir-white birch association is postulated for this time.

Zone 5 — Pine Pollen Zone

Pine pollen, mainly white pine in these profiles, never becomes as abundant in southeastern Québec as it does in profiles from farther south and west. However, it does reach values exceeding 20%. Jack pine type *(Pinus banksiana/resinosa)* pollen usually declines in this zone except at Petit Lac Terrien. This profile was counted several years ago and some problem with differentiating pine pollen types may be involved. Certainly 20% pine pollen does not indicate abundant pine trees in the area since pine values of 20% are obtained in modern surface samples in north central Québec hundreds of miles from the nearest pine trees (TERASMAE and MOTT, 1965). However, some white pine was probably scattered throughout the forests of southeastern Québec. White birch was still abundant at this time judging by the amount of pollen present. Oak was also present, but balsam fir was somewhat less abundant. Of significance is the consistent presence of maple *(Acer)* pollen which, although not relatively abundant, indicates a strong maple presence in the region. Rates for total influx range from about 20,000 grains/cm²/year at Lac Dufresne to as high as 40,000 at Lac Colin. A maple forest with admixed oak and small numbers of some other hardwoods probably occupied the valleys and lower slopes with white birch and some white pine, balsam fir and minor spruce covering the upper slopes and ridges.

Zone 4 — Hemlock Pollen Zone

Like pine, hemlock *(Tsuga canadensis)* does not attain the prominence it does in pollen diagrams from other areas, but it does form a definite low maximum following the decline of pine pollen. Hemlock values are variable from site to site usually exceeding 5% but never greater than 20%. A marked increase in birch pollen abundance accompanies the increase in hemlock and can probably be attributed to an increase in yellow birch *(Betula alleghaniensis)*. Alder also increases somewhat, and where it has been differentiated it is speckled alder *(Alnus rugosa)* that is involved. Oak values decline in Zone 4 and maple values are slightly less. However, beech *(Fagus)* is consistently present in low numbers. These changes are discernable in the percentage profiles and can also be seen in the absolute values indicating real changes in the forest composition. A definite difference can be seen between the two sites from the Notre Dame Mountains (Petit Lac Terrien and Lac Colin) and the more southerly sites. In the former spruce and balsam fir values are higher and hardwood values are less.

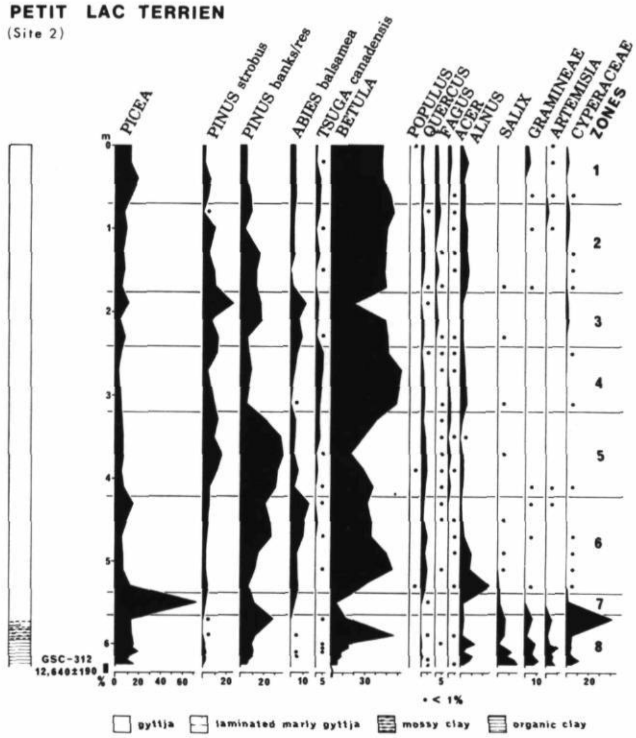

FIGURE 8. Pollen diagram for Petit Lac Terrien, Québec.
Diagramme pollinique du Petit Lac Terrien, Québec.

The forest of the region, reflected in the pollen assemblages noted above, was probably a maple-yellow birch association with some hemlock and oak and other hardwoods present in low numbers. White pine was not as abundant as previously. White birch, balsam fir and spruce dominated the ridges and were more prominent in the Notre Dame Mountains.

Zone 3 — Birch-Maple Pollen Zone

Birch is the most abundant pollen taxon in Zone 3 with values usually exceeding 60%. Yellow birch accounts for the majority of the birch pollen, but white birch pollen is still plentiful. Beech pollen is slightly more abundant in this zone especially at Unknown and Boundary Ponds. Although the percentage values for maple are relatively low, they are higher in this zone than in the surface spectra at all sites except Petit Lac Terrien, and maple was probably a prominent tree in the region. The forest composition probably remained much the same as in Zone 4, but hemlock was less prominent and beech was more prominent.

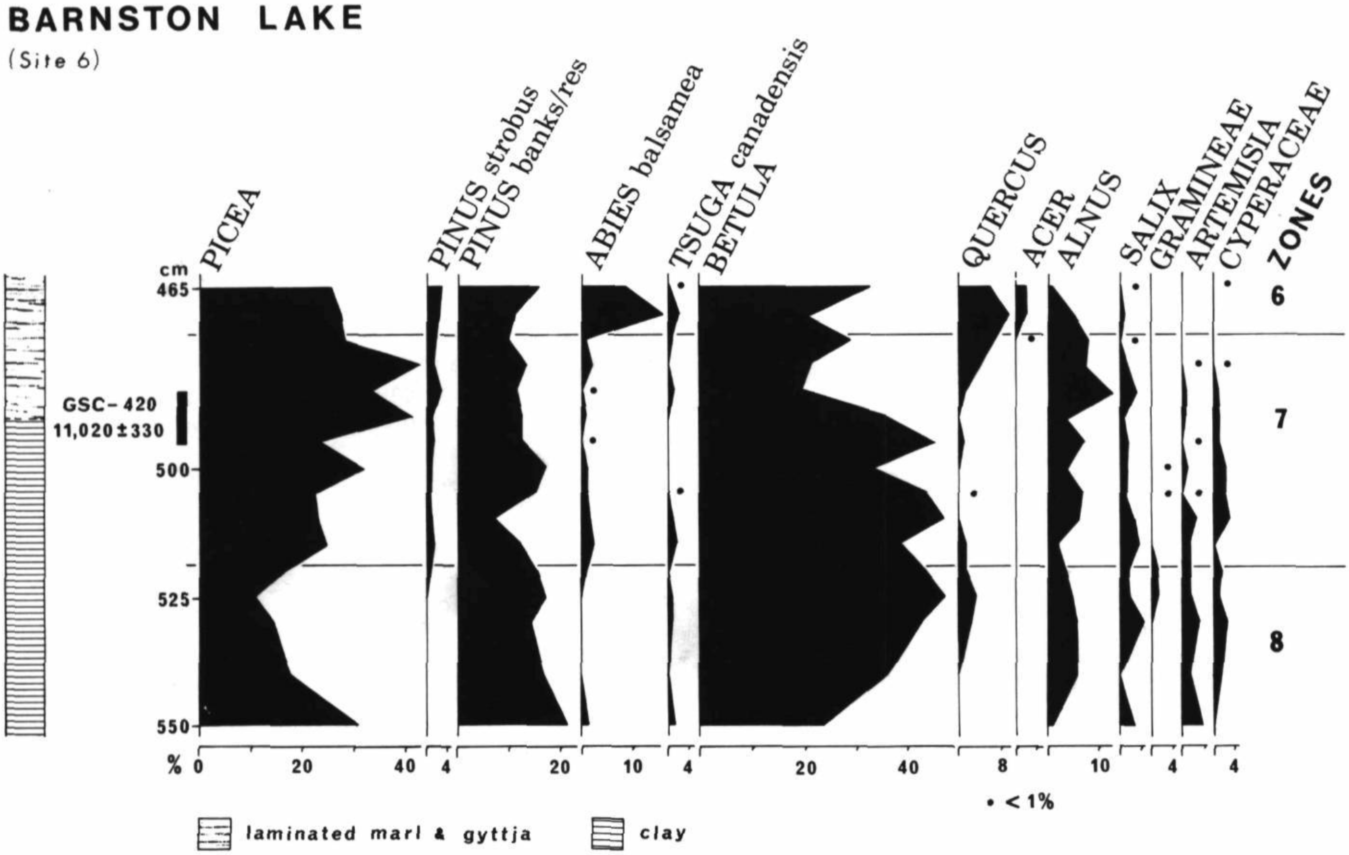

FIGURE 9. Pollen diagram for Barnston Lake, Québec. *Diagramme pollinique du lac Barnston, Québec.*

Zone 2 — Birch-Beech Pollen Zone

Beech pollen reaches its highest values in Zone 2 in an assemblage still dominated by birch pollen. Maple pollen remains at its former abundance as do most other taxa. Again the forest composition changed little, but beech definitely became more plentiful, especially at the more southerly sites.

Zone 1 — Birch-Spruce Pollen Zone

Towards the top of the five profiles that extend to the surface, spruce pollen percentages increase considerably, doubling or tripling in abundance from the previous zone. Birch pollen remains abundant but most hardwood genera decrease. These changes are mirrored by the absolute influx data where absolute spruce values increase as hardwoods, and pollen abundance in general, decrease considerably. The forest took on its present character with the resurgence of spruce and the deterioration of thermophilous hardwood genera to form sugar maple-beech and sugar maple-yellow birch associations at lower elevations and balsam fir-spruce-white birch associations at higher elevations.

CHRONOLOGY AND CORRELATIONS

The sequence of pollen assemblages outlined in the profiles described above are summarized in Figure 10. The pollen stratigraphy for four of the six sites are shown; Unknown Pond was omitted because of the obvious anomalous character of the radiocarbon dates, and Petit Lac Terrien because of the lack of radiocarbon control. Also shown is the vegetation history interpreted by RICHARD (1975a) for his Albion site to which the pollen stratigraphy has been added to make comparison with the pollen stratigraphy at the other sites possible.

Following deglaciation, tundra conditions prevailed over all of southeastern Québec. Reliable dates are not available to indicate how soon after deglaciation tundra type vegetation invaded the region. The date of 12,640 ± 190 (GSC-312) at Petit Lac Terrien is probably some-

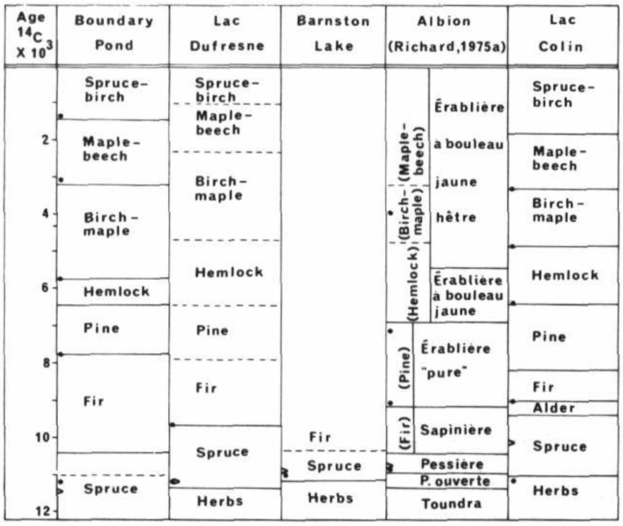

FIGURE 10. Palynostratigraphic correlations for southeastern Québec: • indicates positions of radiocarbon dates; > indicates maximum spruce pollen abundance.

Corrélations palynostratigraphiques pour le sud-est du Québec: • représente la position des dates au radiocarbone; > représente le maximum pollinique de l'épinette.

what anomalous due to contamination by old carbonates. Calcareous marly gyttja in the basal sediments attests to this. The basal date at Unknown Pond (GSC-1339, 14,800 ± 220) is probably invalid for the same reason since calcareous sediments are present near the base of the core. In fact, all of the dates from the latter site appear to be anomalously old when compared to dates on correlative pollen zones at nearby Boundary Pond. However, by 11,000 years BP at Lac Colin, and sooner at the other sites, spruce had begun to invade the tundra. The age of the spruce pollen maximum at each site is shown in Figure 10 and illustrates the time transgressive nature of the invasion. Spruce pollen abundance peaked some time prior to 11,200 years BP at Boundary Pond and did not reach a maximum at Lac Colin until about 10,100 years BP. Invasion appears to have been from the southeast along valleys through the mountains rather than from the Lowlands which were still inundated by the Champlain Sea at this time.

This spruce woodland vegetation persisted for a longer time at the higher sites before giving way to a balsam fir-white birch association. The incursion of balsam fir began at the Albion and Barnston Lake sites about 10,400 years BP but did not take over from spruce until about 9700 years BP at Lac Dufresne. It was even further delayed at Lac Colin where green alder followed the decline of spruce and fir did not become prominent until about 9000 years BP.

Because of the greater production of pine, hemlock and birch pollen, the succeeding peaks of these species mask even more significant increases in maple and beech which probably dominated the forests of the region. By about 9000 years BP. in the Albion area (RICHARD, 1975a) and about 8000 years BP in the Lac Colin and Boundary Pond-Lac Dufresne areas, maples were prominent trees in the landscape. Birch, still mainly white birch, was also prominent and white pine was present. Hemlock replaced pine to some extent after 7000 years BP and yellow birch became the dominant birch species especially at lower elevations. Whereas early plant migrations into the region appear to have been from the south through valleys in the mountains, the later incursions probably came out of the Lowlands after migration along the St. Lawrence River and Lake Champlain valleys now free of obstruction by the Champlain Sea.

Beech began to appear about 5500 years BP in increasing numbers, and by approximately 3500 years BP it was a prominent species of the regional forest. By about 1900 years BP in the Lac Colin area, and about 1500 years BP at the southern sites, spruce began to increase again and hardwood genera declined. The lack of a prominent resurgence of spruce at Richard's Albion site is probably a characteristic of the site unlike other low level sites (TERASMAE, 1969; RICHARD, 1973, 1975b). Obvious changes in the recent pollen spectra attributable to man's disturbance of the vegetation is not seen in the diagrams, although some sites show slight increases in ragweed type pollen *(Ambrosieae)* and grasses *(Gramineae)* indicative of agricultural activity, and declines in tree pollen numbers which may be correlative with logging activity.

CONCLUSIONS

The vegetation history of the Appalachian Region of southeastern Québec began following deglaciation with tundra conditions prevailing throughout the area. Spruce woodland gradually replaced the tundra and was itself replaced by closed balsam fir-white birch forests. As early as 9000 years BP at lower elevations, and by 8000 years BP in the higher areas, the forest began a dramatic change with invasion of hardwoods such as sugar maple and oak and such conifers as white pine. Eventually hemlock, yellow birch and beech entered the region and mixed hardwood forests dominated except on higher slopes and ridges where balsam fir and white birch persisted. A resurgence of spruce in the last few millenia led to the formation of extant forest types. This succession parallels, but with some local differences, the vegetational history of northern New England outlined by DAVIS (1976).

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