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Late Quaternary Pollen Records and Vegetation History of the Southwest Yukon Territory: A Review

Palynologie du Quaternaire supérieur et histoire de la végétation du sud-ouest du Yukon

Pollen-Belege und Vegetationsgeschichte des südlichen Yukon-Gebiets im späten Quatemär: ein Überblick.

Xia-Cheng Wang and Marie-Anne Geurts

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See table of contents

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Article abstract

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LATE QUATERNARY POLLEN RECORDS AND VEGETATION HISTORY OF THE SOUTHWEST YUKON TERRITORY: A REVIEW

Xia-Cheng WANG and Marie-Anne GEURTS, Department of Geography, University of Ottawa, 165 Waller Street, Ottawa, Ontario K1N 6N5.

ABSTRACT This paper is a summary of all known late Quaternary palynostratigraphic records from the southwest Yukon Territory. Thirty two pollen sites available by the end of 1988 are reviewed. Most pollen records in the region are of Holocene age. During the late-glacial to early Holocene, the southwest Yukon supported a herb-dominated tundra vegetation which was replaced by a birch-dominated shrub-tundra at about 10,000 yr BP. Spruce invaded the area between 9000 and 8600 yr BP at different localities, and a southward time transgression is visible in the Aishihik Basin. The current regional vegetation has been stable since 7600-8000 yr BP when dense spruce forest and/or spruce forest-tundra was established in most localities. In the Snag area, however, dense spruce forest developed only around 5700 yr BP, which is about 2000 years later than in the Aishihik Basin. The exotic pine pollen records in the region exhibit an interesting pattern, suggesting a frequent shift of the atmospheric circulation system. Anomalous records of alder pollen from the Aishihik Basin and adjacent regions suggest that alder has never been widespread in these areas due to aridity, and alder pollen is greatly overrepresented in pollen spectra. Spruce arrival dates suggest that further investigations in the Tintina Valley, Yukon River Valley, and Carmacks region might provide useful information concerning the spruce migration routes.

RÉSUMÉ *Palynologie du Quaternaire supérieur et histoire de la végétation du sud-ouest du Yukon.* Cet article est un compte rendu synthétique de tous les diagrammes palynostratigraphiques connus du sud-ouest du Yukon. Les 32 profils disponibles à la fin de 1988 ont été compilés. La plupart des séquences datent de l'Holocène. Durant le tardiglaciaire et au début de l'Holocène, le sud-ouest du Yukon était occupé par une toundra dominé par les herbes. Ce paysage a rapidement été remplacé par une toundra arbustive dominée par le bouleau vers 10 000 BP. L'épinette a colonisé la région entre 9000 et 8600 BP à différents endroits et un métachronisme vers le sud est visible dans le bassin d'Aishihik. La végétation régionale est devenue stable depuis 7600-8000 BP avec l'établissement d'une forêt d'épinettes dense ou d'une toundra forestière à épinettes dans la plupart des endroits. Dans la région de Snag, cependant, la forêt d'épinettes s'est développée vers 5700 BP, soit 2000 ans plus tard que dans le bassin d'Aishihik. Les fréquences du pollen exotique du pin ont un patron intéressant qui montrent de fréquents changements de circulations atmosphériques. Les fréquences anormales de l'aulne dans le bassin d'Aishihik et les régions voisines incitent à penser que l'aulne n'a jamais occupé la région en raison de l'aridité, et le pollen d'aulne est grandement surreprésenté dans les spectres polliniques. Les dates d'arrivée de l'épinette permettent de penser que des recherches dans la vallée Tintina, dans la vallée du fleuve Yukon et dans la région de Carmacks devraient fournir des renseignements utiles sur les voies de migration de l'épinette.

ZUSAMMENFASSUNG *Pollen-Belege und Vegetationsgeschichte des südlichen Yukon-Gebiets im späten Quaternär: ein Überblick.* Dieser Aufsatz ist eine Zusammenstellung aller bekannten palynostratigraphischen Belege vom südwestlichen Yukon-Gebiet aus dem späten Quaternär. Zweiunddreißig Pollen-Fundplätze, die Ende 1988 zur Verfügung standen, werder kompiliert. Die meisten Pollen-Belege der Gegend stammen aus dem Holozän. Während der Spätglazialzeit bis zum frühen Holozän gab es in Südwest-Yukon eine von Gras beherrschte Tundra-Vegetation, die um etwa 10 000 Jahre v.u.Z. von einer durch Birke beherrschten Busch-Tundra abgelöst wurde. Rottanne drang in das Gebiet zwischen 9000 und 8600 Jahren v.u.Z. an verschiedenen Plätzen ein, und im Aishihik-Becken ist eine Zeittransgression südwärts erkennbar. Die gegenwärtige regionale Vegetation existiert seit 7600-8000 Jahren v.u.Z., als dichter Rottannenwald und/oder Rottannenwaltundra sich an den meisten Orten ansiedelte. Jedoch entwickelte sich im Snag-Gebiet dichter Rottannenwald erst um 5700 Jahre v.u.Z., d.h. etwa 2000 Jahre später als im Aishihik-Becken. Die exotischen Kiefern-pollenbelege in der Gegend weisen ein interessantes Muster auf, welches einen häufigen Wechsel der atmosphärischen Strömungen vermuten läßt. Unregelmäßige Belege von Erlen-Pollen aus dem Aishihik-Becken und angrenzenden Gebieten legen nahe, daß Erlen wegen der Trockenheit in diesen Gebieten nie weitverbreitet waren, und Erlen-pollen ist in den Pollen-Spektren in hohem Maße überrepräsentiert. Die Ankunftsdaten der Rottanne deuten darauf hin, daß weitere Forschungen im Tintina-Tal, Yukonfluß-Tal und der Gegend von Carmacks nützliche Informationen über die Wanderrouten der Rottanne ergeben könnten.

Manuscrit reçu le 29 novembre 1989; manuscrit révisé accepté le 3 septembre 1990

INTRODUCTION

During the last few decades, a number of paleoecological investigations of the late Quaternary history of vegetation and climate in Yukon Territory, Alaska, and Northwest Territories have been carried out (Terasmae, 1961; 1967; 1973; Nichols, 1974; 1975; Hills and Sangster, 1980; Ager, 1983; Ager and Brubaker, 1985; Ritchie, 1984a; 1985). Among these numerous investigations, most pollen profiles are concentrated in the eastern Beringia (Hultén, 1937), *i.e.*, unglaciated Alaska, northern Yukon, and also in the adjacent Northwest Territories. Pollen sites which cover the vegetation history of late Quaternary time in Beringia provide a much longer record than sites in the glaciated southwestern Yukon and its adjacent areas. As an area that provided the late Cenozoic terrestrial link between the eastern and western hemispheres (Matthews, 1979), Beringia has drawn much attention, but its vegetation history during the Quaternary still remains in dispute (Matthews, 1982).

This paper is a compilation of late Quaternary pollen records from all known localities in the southwest Yukon Territory (Fig. 1). An attempt is made to synthesize the information for the reconstruction of the late Quaternary environmental history of the area.

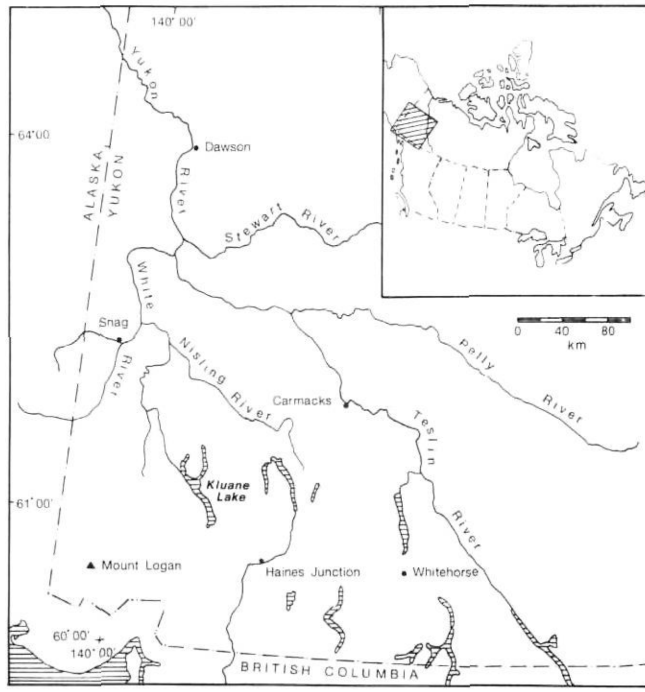

FIGURE 1. General setting of the southwest Yukon Territory.
Carte de localisation du sud-ouest du Yukon.

REGIONAL GEOGRAPHICAL SETTING

Most of the southwest Yukon Territory consists of rolling to hilly plateau areas (Fig. 2, Bostock, 1948; 1952). The St. Elias Mountains, the highest mountains of Canada with Mount Logan at 6,050 m (Hughes, 1987), are an important physiographic component in the southwest Yukon because of their influence on climate and impact on aeropalynology of the study area. The nomenclature of physiographic units hereafter follows those of Bostock (1948).

Regional aspects of the vegetation in the southwest Yukon Territory have been well documented (Oswald and Senyk, 1977; Rowe, 1972; Orloci and Stanek, 1979; Douglas, 1974; Johnson and Raup, 1964; Parent, 1988), and are typical of the northern sections of the boreal forest (Rowe, 1972, Fig. 3), with alpine tundra occurring at higher elevations. The dominant forest is very simple in structure and composition with only seven species of trees, of which white spruce (*Picea glauca*) is the most common (Johnson and Raup, 1964). Although black spruce (*Picea mariana*) is the most common and widely distributed species in the North American boreal forest, it is scarce in the southwest Yukon, where its favourite habitats are occupied by white spruce. Trembling aspen (*Populus tremuloides*) and balsam poplar (*Populus balsamifera*) are also common in the area; the former often occurs in the disturbed areas, and the latter on gravel fans or on floodplains (Johnson and Raup, 1964). White birch (*Betula papyrifera*) is also rare in southwest Yukon, having almost the same distribution as black spruce (Johnson and Raup, 1964). Lodgepole pine (*Pinus contorta*) and alpine fir (*Abies lasiocarpa*) are present at higher elevations throughout the eastern part.

Treeline lies between 1,060 m and 1,220 m on mountain slopes in the Dezadeash and Shakwak Valley area (Johnson and Raup, 1964) and about 1,158 m on the slopes of Ruby Range (Price, 1971). Above the treeline, alpine or arctic tundra occupies the landscape. Shrub tundra with dwarf birch (*Betula glandulosa*) and low willows (*Salix glauca*) often merge with timberline to form a forest-tundra ecotone. *Dryas* tundra occurs on higher plateaux. Bog, fen, and muskeg are widespread in lowland areas throughout the region.

Within this general context, present vegetation cover exhibits great variety due to the complexity of landform, and can be classified into different vegetation-landform units. The diversity of these units is one of the most striking features of the area.

The St. Elias Mountains provide a great barrier against the influence of Pacific airmasses in the southwest Yukon, and the Mackenzie Mountains provide a barrier against cold polar airmasses, thus affecting the precipitation patterns. Mean annual precipitation (Fig. 4) ranges from about 200 mm per year, immediately in the areas of rain shadows of the Coast-St. Elias Mountains, to 400 mm in the north of the region. The mountainous topography of the region also greatly affects the temperature pattern. Average annual temperature (Fig. 5) decrease from about -2°C in the south to -5°C near Dawson, and from -10°C to -15°C over higher terrain. Official extreme daily temperatures of 36.1°C and -62.3°C have been recorded at Mayo on June 14, 1969 and Snag on February 3, 1947 respectively (Wahl and Goos, 1987). Under these physiographic conditions, the southwest Yukon exhibits a severe continental climate, despite its proximity to the Pacific Ocean (Workman, 1978).

Climatic records (Environment Canada, 1982) from the abandoned Aishihik climatic station show that there are seven months in which the mean daily temperature is lower than the

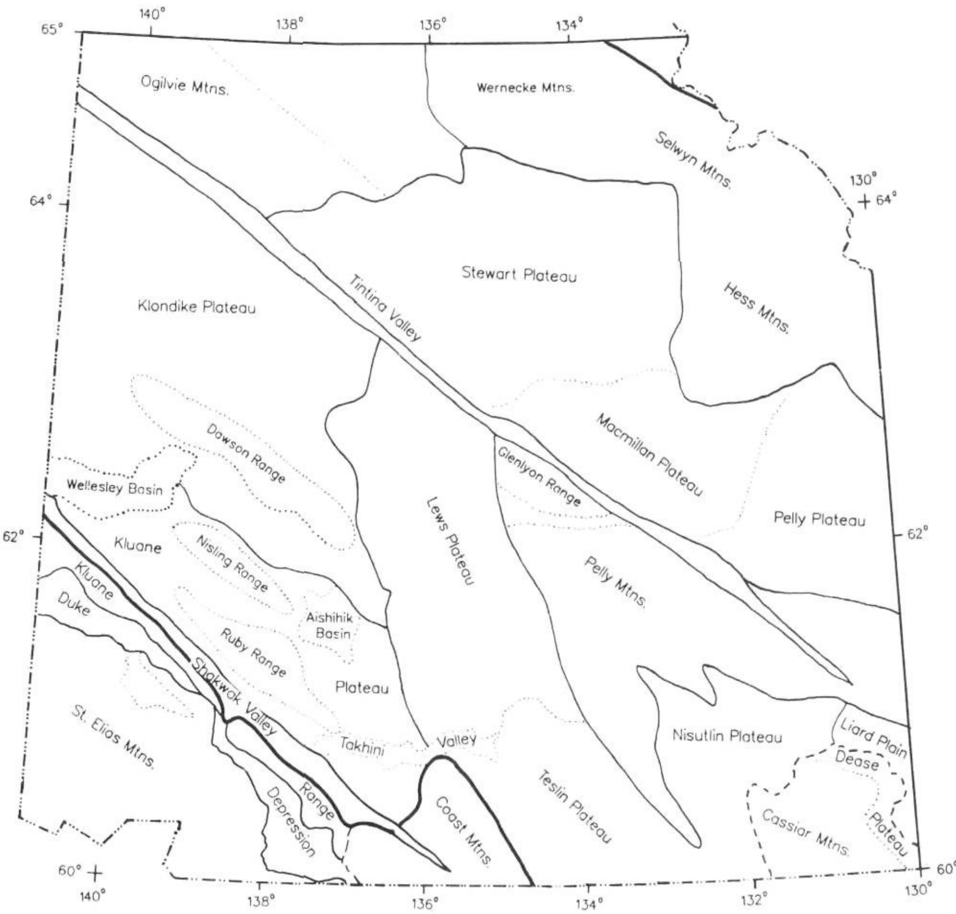

FIGURE 2. Physiography of the southwest Yukon Territory (after Bostock, 1948, 1952).

Physiographie du sud-ouest du Yukon (selon Bostock 1948, 1952).

freezing point, and similar temperatures are recorded at the climatic stations of Snag, Kluane, and Carmacks (Table I). The Aishihik Basin receives an average of 256.3 mm precipitation per year, with 63.2% as rainfall. 79.1% of annual rainfall and 50% of annual total precipitation occurs in June, July and August (Table I). This precipitation regime makes the region one of the driest in Canada.

THE DATA BASE AND METHODS

The study of pollen records in southwest Yukon started in the early 1950's, as a part of an investigation along the Alaska Highway which reported 75 peat sections and 40 pollen diagrams (Hansen, 1953). However, most of these records have no ^{14}C date control and only tree pollen was counted. Despite the relatively long history of pollen analysis in the region, most palynological investigations in the southwest Yukon were conducted only during the last decade. By the end of 1988, 32 pollen sites were available in published papers and unpublished theses (Fig. 6). It is possible that more pollen records have been documented but still remain unpublished. Table II lists the locations, site characteristics, and principal references for our data set from the southwest Yukon.

The majority of these pollen study sites is within the time span of Holocene, and so far only one long profile including the Late Pleistocene has been reported (Rampton, 1971).

TABLE I

Mean Temperature (°C) and precipitation (mm) of selected stations in southwest Yukon

Month	Aishihik		Carmacks		Snag		Kluane	
	T	P	T	P	T	P	T	P
Jan.	−23.6	11.7	−28.2	18.4	−30.4	17.2	−20.5	7.2
Feb.	−16.9	9.1	−19.4	12.5	−22.0	16.0	−15.4	5.9
Mar.	−12.2	10.1	−11.6	10.6	−14.1	12.4	−10.9	5.2
Apr.	−3.7	8.3	−0.1	7.1	−2.2	17.9	−1.8	7.9
May	4.2	22.4	7.1	15.5	6.4	28.9	5.4	22.1
Jun.	9.8	41.1	12.5	37.4	12.0	58.3	10.3	32.3
Jul.	12.1	48.5	14.5	42.3	14.0	61.1	12.6	47.0
Aug.	10.3	40.5	12.4	34.1	11.5	39.0	11.2	34.1
Sep.	5.1	24.5	6.7	25.1	5.2	29.0	6.3	17.2
Oct.	−2.6	16.0	−2.0	17.7	−6.1	21.0	−1.6	16.3
Nov.	−13.6	12.4	−13.8	18.6	−19.3	18.8	−9.7	17.7
Dec.	−21.9	11.7	−24.0	14.9	−28.2	18.9	18.5	11.0
Year	−4.4	256.3	−3.8	254.3	−6.1	338.5	−2.7	223.9

Note: Data from Environment Canada (1982)

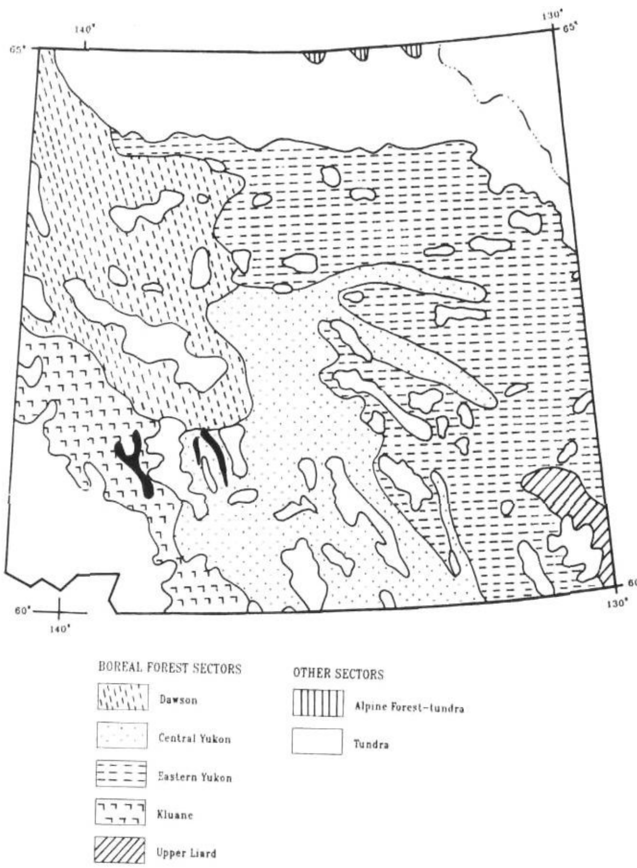

FIGURE 3. Modern vegetation of the southwest Yukon Territory (after Row, 1972).

Végétation actuelle du sud-ouest du Yukon (selon Row, 1972).

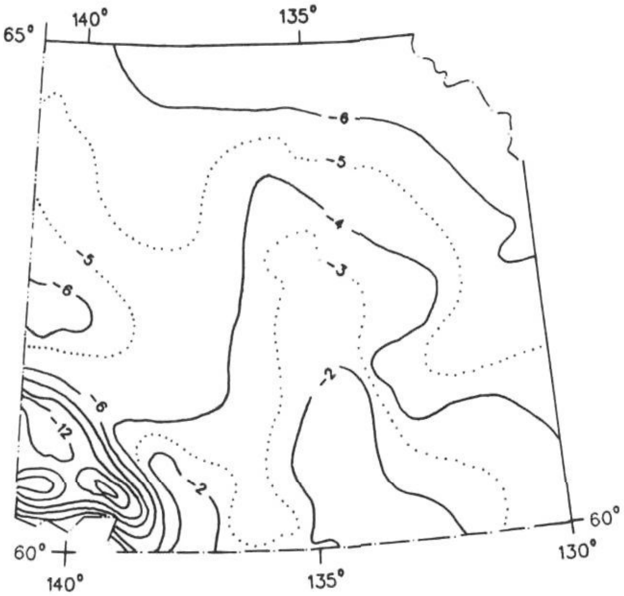

FIGURE 5. Annual mean daily temperature of the southwest Yukon Territory (after Walh and Goos, 1987).

Moyennes annuelles des températures journalières du sud-ouest du Yukon (selon Walh et Goos, 1987).

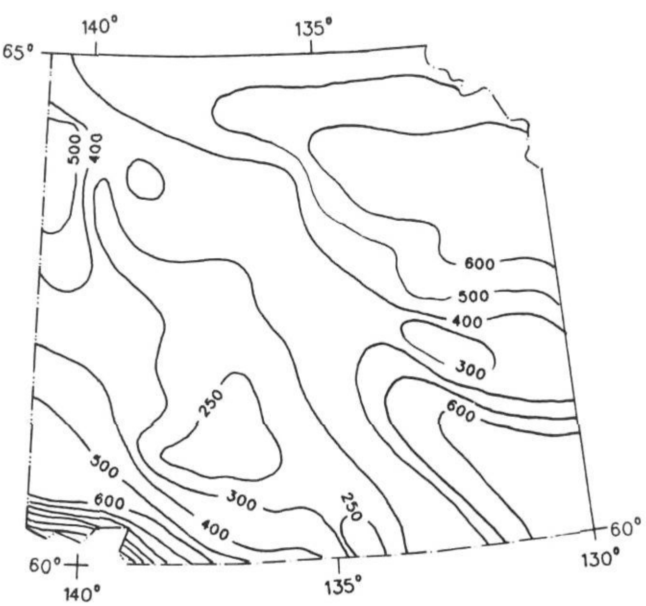

FIGURE 4. Annual mean total precipitation of the southwest Yukon Territory (after Walh and Goos, 1987).

Moyennes annuelles des précipitations totales du sud-ouest du Yukon (selon Walh et Goos, 1987).

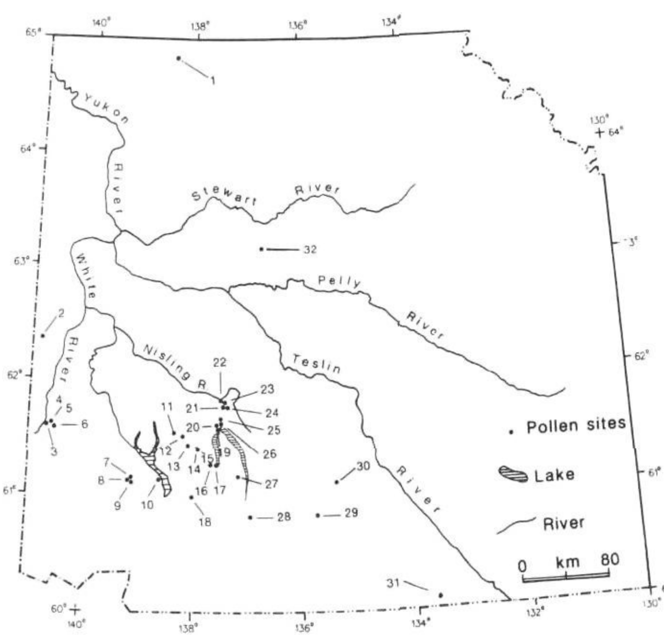

FIGURE 6. Location map of pollen sites of the southwest Yukon Territory, referred to in the text and listed in Table II.

Carte de localisation des diagrammes polliniques du sud-ouest du Yukon cités dans le texte et dans le tableau II.

TABLE II

Summary of palynostratigraphic sites in southwest Yukon Territory

Site #	Site Name	Lantitude (N)	Longitude (W)	Altitude m a.s.l.	Sediment	Reference
1	Chapman Lake	64°55'	138°23'	?	bog	Terasmae and Hughes (1966)
2	Antifreeze Pond	62°21'	140°50'	701	lac.	Rampton(1971)
3	Heart Lake	61°36'	140°35'	1250	lac.	Birks(1980)
4	Triangle Lake	61°36'	140°34'	?	lac.	Birks(1980)
5	Cotton Pond	61°37'	140°35'	1250	lac.	Birks(1980)
6	Gull Lake	61°35'	140°30'	1365	lac.	Birks(1980)
7	Grizzly Duke	61°10'20"	139°04'30"	1310	peat	Bourgeois et Geurts(1983)
8	Volcano-Grizzly	61°08'15"	139°05'30"	1380	peat	Bourgeois et Geurts(1983)
9	Tourbiere Volcano	61°07'15"	139°02'10"	1600	peat	Bourgeois et Geurts(1983)
10	Williscroft Creek	61°00'	138°33'	823	peat	de Bastiani(1988)
11	Shaky Hand Creek	61°33'	138°21'	?	min.	Campbell(1987)
12	Bonanza Pup	61°27'57"	138°05'37"	1600	min.	Campbell(1985)
13	Alaskite Rock Glacier	61°31'38"	138°07'33"	1675	min.	Campbell(1985)
14	Kettle Camp-OS	61°21'	138°04'	?	peat	Campbell(1987)
15	Kettle Camp-MS	61°21'	138°04'	?	min.	Campbell(1987)
16	High Bog	61°16'47"	137°07'47"	1615	peat	Wang(1989)
17	Bear Lakes	61°16'05"	137°36'07"	1143	peat	Wang(1989)
18	Jenny Lake	61°02'	138°22'	?	lac.	Stuart *et al.* (1988)
19	Moose Depression	61°35'26"	137°30'57"	953	lac.	Wang(1989)
20	Aishihik Kettle	61°36'23"	137°32'48"	954	peat	Wang(1989)
21	Upper Mackintosh Creek	61°45'53"	137°14'40"	1060	peat	Wang (1989)
22	Upper Nisling Valley	61°51'13"	137°21'43"	975	peat	Wang(1989)
23	Middle Mackintosh Creek	61°49'00"	137°15'09"	1001	peat	Wang (1989)
24	Mackintosh Creek-HB1	61°45'08"	137°12'43"	1040	lac.	Beaudet (1986)
25	Polecat Lake	61°40'45"	137°27'12"	935	bog	Wang(1989)
26	Aishihik Pingo	61°39'16"	137°27'	940	min.	Geurts et Dewez (1985)
27	Ittlemit Lake	61°14'07"	137°11'47"	1180	peat	Wang(1989)
28	Alaska Highway	52° - 65°	113° - 148°	?	bog	Hansen(1953)
29	Two Horsemen Pond	60°51'	135°45'	?	lac.	MacDonald and Cwynar (1985)
30	Cinquefoil-Dwindling Ponds	61°05'	135°30'	?	lac.	MacDonald and Cwynar (1985)
31	Kettlehole Pond	60°04'	133°48'	760	lac.	Cwynar (1988)
32	Buggy Pond	63°04'	136°26'	?	lac.	MacDonald and Cwynar (1985)

Abbreviations: lac. = lacustrine; min. = mineral

Among these records, less than half are from lacustrine sediments, the others coming from peat bogs. Few of them are from mineralic sections. Most of these records have at least one ^{14}C date or volcanic ash layer for chronological control.

In this paper, we review all information available from these pollen sites, and attempt to highlight the late Quaternary vegetation history of the region. Some pollen diagrams have been selected for more detailed discussion and redrawn in an abbreviated form from the original. Samples of unpublished sites in Aishihik Basin and vicinity (Wang, 1989) were collected from frozen peat cores and treated using standard preparation methods (Faegri and Iversen, 1975) in the laboratory.

POLLEN STRATIGRAPHY AND VEGETATION HISTORY

THE KLONDIKE PLATEAU

Terasmae and Hughes (1966, site 1) reported a pollen sequence from a 4.2 m core of frozen peat at Chapman Lake (64°55'N, 138°23'W) in the Ogilvie Mountains which represents a vegetational history for the past 13,870 years. Cyperaceae and Gramineae dominated pollen zone 1 while zone 2 was characterized by an abrupt rise of *Betula*. Zone 3 represented a *Picea-Alnus* assemblage. Although the second site at Gill Lake investigated by Terasmae and Hughes (1966) lacked the herbaceous zone of the Chapman Lake profile, the basic pattern of these two profiles has been repeatedly recognized at many sites in the northwest (Ritchie, 1985).

THE WESTERN KLUANE PLATEAU

Only one pollen diagram, from Antifreeze Pond (62°21'N, 140°50'W, 701 m a.s.l.; Rampton, 1971; Fig. 7, site 2) near Snag, has been published in this region, and provides the longest Quaternary pollen record in the entire southwest Yukon Territory. This 6.4 m sequence covers an interval from about 31,000 yr BP to the present. The original percentage diagram was divided into 6 pollen zones. Rampton (1971) concluded that pollen zone 1 represents a sedge-moss or fell-field vegetation stage, and Zone 2 a shrub tundra vegetation in the area under slightly less severe climatic conditions. Sedge-moss tundra with a cold summer climate prevailed in the area during zone 3 time, from 27,000 to 9980 yr BP. The postglacial environmental history is represented by pollen zones 4 to 6, which indicate a transition from shrub tundra via *Picea* woodland to mature *Picea* forest. Zone 4 represents a time interval from 9980 yr BP to 8710 yr BP during which the area was covered by a shrub tundra similar to zone 2 but characterized by increased precipitation. Spruce invaded the area about 8710 yr BP at the beginning of zone 5, and a spruce forest or woodland vegetation was interpreted from pollen records. A sharp rise of *Alnus* pollen at 5700 yr BP marks the end of zone 5 and the beginning of zone 6. The vegetation and climate in the area during this period has been interpreted as similar to those at present. It is also suggested by macrofossil evidence that the treeline was higher than at present at least three times since 5700 yr BP; however such changes were not registered in pollen record.

ST. ELIAS MOUNTAINS AND ADJACENT REGIONS

There are nine pollen sites known from this region, including four pollen profiles from the Klutlan Glacier area (Birks, 1980), three pollen profiles from the Grizzly Creek area in Donjek Range (Bourgeois and Geurts, 1983), one pollen profile from Williscroft Creek near Kluane Lake (de Bastiani and Geurts, 1987; de Bastiani, manuscript), and one profile from the Jenny Lake area near the southern end of Kluane Lake (Stuart *et al.*, 1989). All these sequences, except for the Jenny Lake profile cover a time span of only late Holocene.

The four short profiles from Gull Lake and Triangle Lake at the Klutlan Glacier area represent the vegetation history of the last 1230 years (Birks, 1980, site 3-6). Pollen records on the upland at Gull Lake (65°35'N, 140°30'W, 1365 m a.s.l.; site 6) suggest an initial species-rich treeless vegetation after the White River eruption at about 1230 yr BP. *Picea* pollen percentages of about 25% were interpreted as the result of long distance transport. As Birks (1980) has noted, the pollen spectra of zone 1 closely resemble the *Picea-Betula*-Glumiflorae-Herb pollen assemblage of Wisconsinan age defined by Lichti-Federovich (1973) for the old Crow River area in north Yukon and zone 1 and 3 of Wisconsinan age at Antifreeze Pond (Rampton, 1971). The pollen spectra of zone 2 suggest that this vegetation cover was replaced by birch-alder-willow shrub tundra. The following stage of vegetation development in the region as represented by zone 3 is an open spruce forest similar to the present vegetation around the lake. The profile from Triangle Lake (61°36'N, 140°34'W;

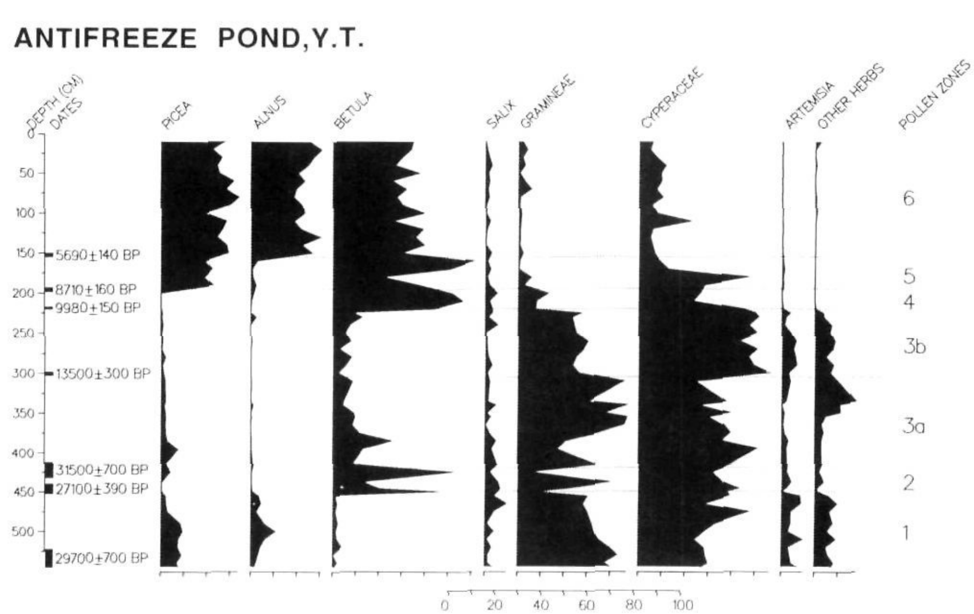

FIGURE 7. Summary percentage pollen diagram of Antifreeze Pond (redrawn from Rampton, 1971).

Diagramme simplifié des pourcentages polliniques d'Antifreeze Pond (redessiné d'après Rampton, 1971).

site 4) provided pollen records of a vegetation succession from a *Salix-Shepherdia canadensis* stage via open spruce woodland to a dense spruce forest.

Bourgeois and Geurts (1983, site 7-9) reported three pollen sections from the Grizzly Creek basin in the Donjek Range. Three pollen zones were identified from these profiles presenting evidence for vegetation development in the area during the last 2000 years. The oldest zone represents a vegetation which is comparable to that of the present with a climate similar to or slightly colder than today. The subsequent zone represents a drier and warmer climate than before causing a strong decrease of *Picea* in the pollen spectra (a break of pollen production). Zone 3 represents vegetation and climate conditions similar to those of zone 1 thus marking the return of zone 1 environmental conditions to the area.

More recently, Stuart *et al.* (1989) reported a 1.73 m sequence at Jenny Lake (61°02′N, 138°22′W, site 18) located about 55 km northwest of Haines Junction in the southwest Yukon. The sequence is divided into 5 pollen zones (Fig. 8) which cover the period from 12,500 yr BP to the present. Zone 1 is interpreted as a shrub-tundra assemblage which ranges from about 12,500 to 9500 yr BP. Zone 2 from 9500 to 8500 yr BP is dominated by *Alnus* therefore representing an *Alnus* shrub-tundra. Zone 3 represents an interval of *Picea* forest in the area, from 8500 to 4500 yr BP. Zone 4 is characterized by an increase of *Alnus* from 15% to about 25%, and a decrease of *Picea*. A *Picea-Alnus* woodland is reconstructed from about 4500 to 2000 yr BP. Zone 5 covers an interval from about 2000 yr BP to the present, characterized by a return of *Picea* dominance in the area. The authors have concluded that pollen records of this sequence do not support the belief that the southwest Yukon supported an extensive grassland vegetation during much of the Holocene (Johnson and Raup, 1964; Workman, 1978), and therefore argued for a re-evaluation of the hypothesis that early prehistoric hunters and gatherers in the area were adapted to grasslands.

A 2.75 m pollen section at Williscroft Creek (61°00′N, 138°33′W, 823 m a.s.l.) in the Kluane Lake area (de Bastiani et Geurts, 1987; P. M. de Bastiani, pers. comm., 1987) represents a time interval from 5480 yr BP to present during which a dense spruce forest covered the landscape in the area. It has been concluded that "the low altitude forest was not affected by Neoglacial climatic fluctuations such as observed at high altitude sites" (P. M. de Bastiani, pers. comm., 1987). Such a conclusion is consistent with that of Stuart *et al.* (1989).

THE RUBY RANGE

Seven pollen sequences have been recovered from the Ruby Range (Fig. 6, Table II; site 11-17), and three of them provide detail information about late Holocene vegetation changes in the area, therefore, were summarized in this section. So far only one of these pollen diagrams has been published (Wang, 1988a).

Campbell (1987) analyzed a 2.34 m section from Shaky Hand Creek (61°33′N, 138°21′W; site 11) in the central Ruby Range near the Aishihik Basin. The pollen profile was divided into seven local pollen zones which he interpreted as representing a small-scale, short-duration, climatic oscillation regime over the past 4500 years. Two different states of the oscillation have been proposed which include a present cold and semi-arid condition and a warmer and drier climate. However, due to severe problems with ^{14}C date determinations, the absolute chronology of these events is uncertain.

Pollen records from a 26 cm section in the Bear Lakes area (61°16′05″N, 137°36′07″W, 1143 m a.s.l.; Wang and Geurts, 1987; Wang, 1988a; Fig. 9; site 17) represent a history of vegetational and climatic variation during the last 1230 years. Both pollen record of zone 1 and macrofossil evidence suggest that the area was covered by spruce forest tundra after the deposition of the White River ash. Natural fire was interpreted as being responsible for an abrupt decline of spruce pollen at the beginning of zone 2, and reforestation in

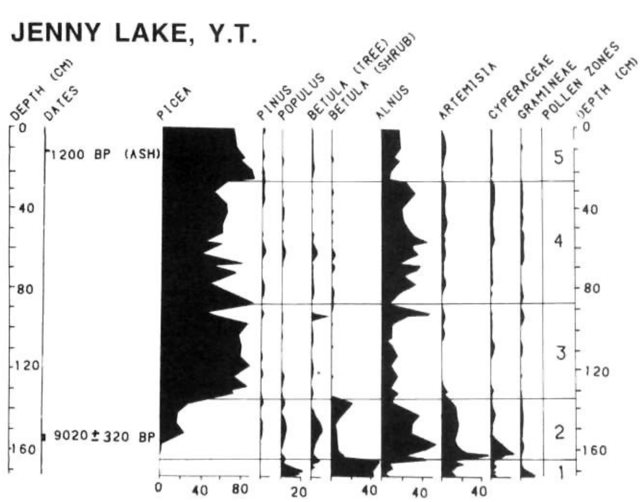

FIGURE 8. Summary pollen percentage of Jenny Lake (redrawn from Stuart *et al.*, 1989).

Diagramme simplifié des pourcentages polliniques de Jenny Lake (redessiné d'après Stuart et al.*, 1989).*

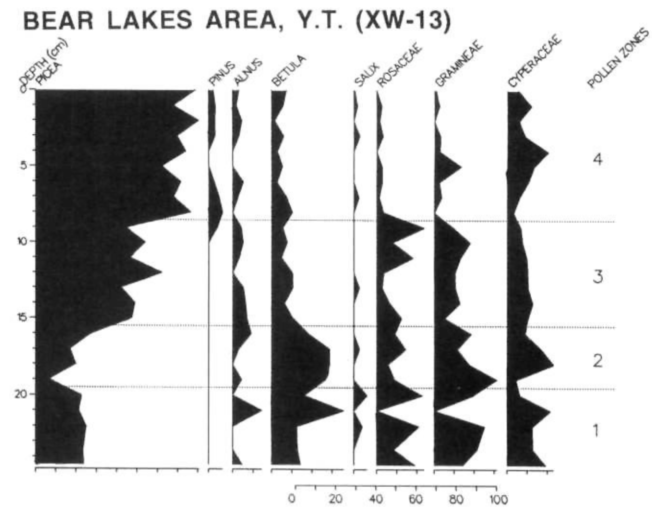

FIGURE 9. Summary pollen percentage diagram of Bear Lakes bog (redrawn from Wang, 1989).

Diagramme simplifié des pourcentages polliniques de la tourbière de Bear Lakes (redessiné d'après Wang, 1989).

the area occurred quickly after the fire as a result of the strong reforestation potential of the prefire vegetation. Zone 3 represents a spruce forest vegetation, while an abrupt increase of spruce pollen in zone 4 and the associated occurrence of two isolated *Pinus* pollen peaks, have been interpreted as an indication of the occurrence of colder and moister climatic condition and a frequent shift of atmospheric circulation systems in the area. This interpretation is consistent with the evidence of glacier advance in the St. Elias Mountains during the Little Ice Age (Denton and Karlén, 1977).

Pollen records of High Bog (61°16'47"N, 137°07'47"W, 1615 m a.s.l.) in the Bear Lakes area (Wang, 1989; Fig. 10; site 16), where a *Betula glandulosa* dominated shrub-tundra with the occurrence of *Eriophorum* sp. and Ericaceae occupies the landscape at present, indicate that the initial vegetation cover in this area prior to 4000 yr BP was a very sparse shrub-tundra, which was replaced by a sedge-dominated mesic or wet community. This vegetation type was then replaced by a dwarf birch-dominated shrub community around 650 yr BP. *Picea* pollen in the sequence was interpreted as a result of long distance transport from the adjacent valley.

HIGH BOG, BEAR LAKES AREA, Y.T. (XW-8)

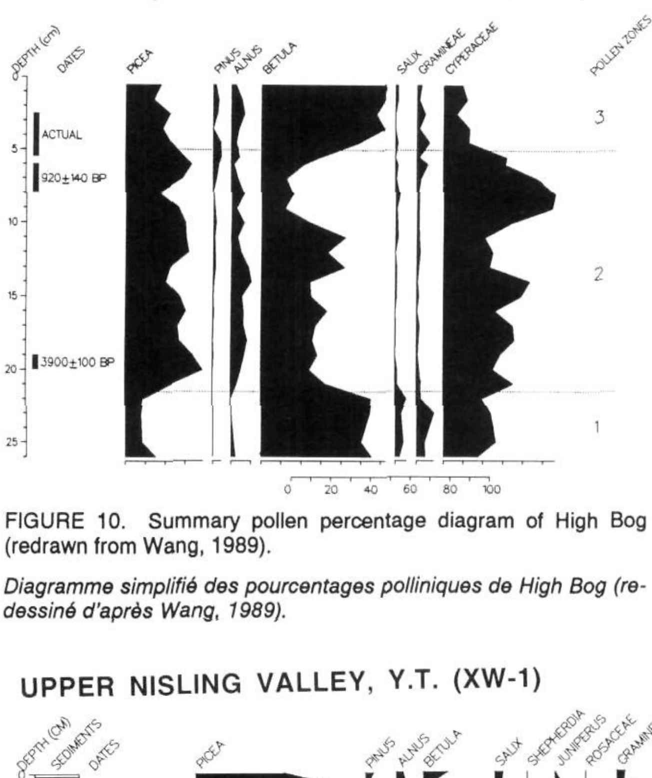

FIGURE 10. Summary pollen percentage diagram of High Bog (redrawn from Wang, 1989).

Diagramme simplifié des pourcentages polliniques de High Bog (redessiné d'après Wang, 1989).

THE AISHIHIK BASIN AND ADJACENT REGION

This area is the most extensively investigated region for pollen stratigraphy in the southwest Yukon. Nine pollen profiles have been analyzed, and eight of them represent a history of longer than 8000 years.

The pollen profile of Upper Nisling Valley (XW-1) from a peat bog at the northern edge of the Aishihik Basin provides a triple-zoned sequence (61°51'13"N, 137°21'43"W, 975 m a.s.l.; Wang, 1989; Fig. 11; site 22). Forty eight samples were analyzed in an interval of about 2.5 cm from this 108 cm core. Twenty two pollen taxa were recognized, and three numerical zonation procedures (CONISS, Grim, 1987; ZONATION, Gordon and Birks, 1972; CONZONE, Wang, 1988b) were used to supplement the empirical zonation of the sequence. The chronology of the profile was established on the base of four ^{14}C dates plus the presence of White River ash layer (1230 yr BP). The area presently supports a white spruce forest, while Cyperaceae is the dominant taxon colonizing the bog. Grass, dwarf birch and willow are also common on the bog. A set of 20 moss polster samples from four vegetation-landform units in the basin were combined with the palynostratigraphic data to conduct a Principal Component Analysis (PCA, Adam, 1974), Principal Component Biplot (PCB, Gordon, 1982), and a Correspondence Analysis (CA, Gordon, 1982) for numerical comparison. Pollen zone 1 in this sequence suggests that spruce invaded the area at least 9000 years ago, and a *Picea-Betula-Shepherdia canadensis* woodland occupied the area until 7900 yr BP. Spruce forest, which covers the area at present became established at 7900 yr BP, while from 4000 yr BP spruce forest remained in the area but willow and Cyperaceae play

UPPER NISLING VALLEY, Y.T. (XW-1)

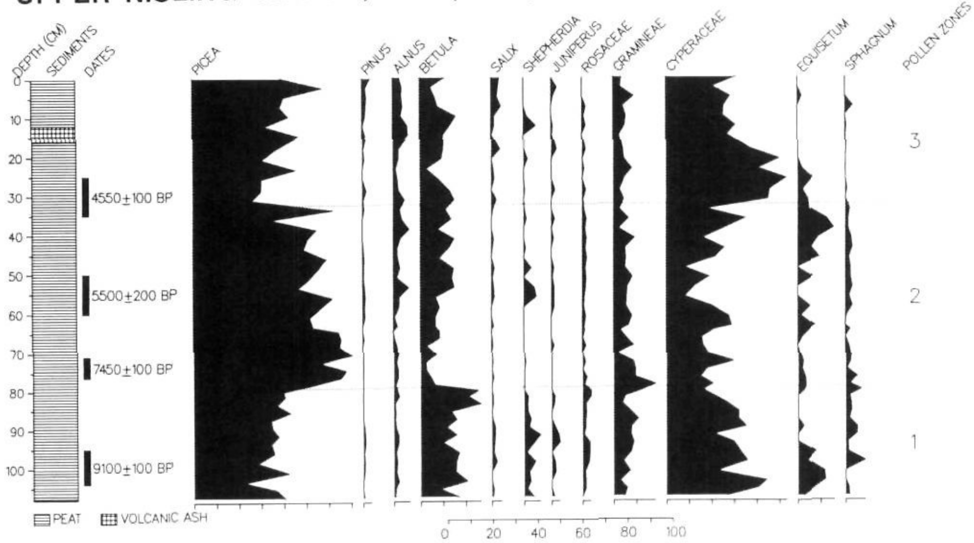

FIGURE 11. Summary pollen percentage diagram of Upper Nisling Valley (redrawn from Wang, 1989).

Diagramme simplifié des pourcentages polliniques de Upper Nisling Valley (redessiné d'après Wang, 1989).

more important roles in local vegetation. High values of Cyperaceae percentages accompanied with the high pollen accumulation rates (Fig. 12) caused the decrease of spruce pollen percentage, even though the regional vegetation cover shows little change. Such an interpretation is supported by the pollen accumulation rate data and a summary pollen diagram based on a pollen sum of tree and shrub taxa.

Further south to the Upper Mackintosh Creek area, a 305 cm lacustrine sediment core was analyzed (61°45′08″N, 137°12′43″W, 1040 m a.s.l.; Beaudet, 1986, Fig. 13; site 24). Forty three samples were processed, and thirty three taxa were recorded. The sequence is divided into three local pollen zones. Four ^{14}C dates were obtained to define the chronology of the sequence. Interpretation of the pollen record suggests that the area was covered by a herb tundra followed by a birch-dominated shrub tundra at about 9900 yr BP. Spruce arrived in the area at about 8900 yr BP. The modern spruce woodland vegetation developed at about 8000 yr BP and has experienced little change since then. However, the conclusion that the high *Picea* pollen percentage of zone 1 indirectly supports the spruce refugium hypothesis in unglaciated southwestern Yukon and/or Alaska (Beaudet, 1986) probably needs to be reconsidered. The extremely low pollen concentration might not support the presence of spruce in the region, and high portion of corroded grains of *Picea* pollen might suggest redeposition (Wang, 1989).

The second pollen sequence from the Upper Mackintosh Creek area was recovered (61°45′53″N, 137°14′40″W, 1060 m a.s.l.; Wang, 1989; Fig. 14; site 21) from a peat core about 2.5 km away from the site investigated by Beaudet (1986). Thirty nine samples were analyzed from this 107 cm long sequence, and 28 taxa were identified. White spruce woodland occupies the hill slopes at present, while *Betula glandulosa* or *Salix glauca* dominated community widespread on the well drained valley bottom. A Cyperaceae (*ca.* 85%) dominated community with the occurrence of *Betula glandulosa* or *Potentilla fruticosa* patches occupies the wetland area at core site. The zonation of the diagram was helped by numerical techniques. PCA, PCB and CA were employed with a combination data set including 20 surficial samples to per-

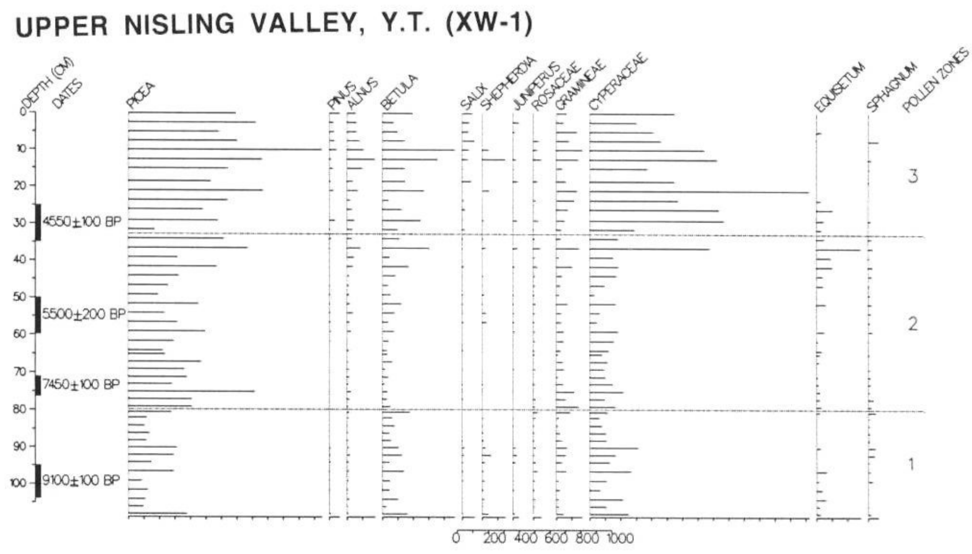

FIGURE 12. Summary pollen accumulation rate diagram of Upper Nisling Valley (redrawn from Wang, 1989).

Diagramme simplifié des taux d'accumulation pollinique de Upper Nisling Valley (redessiné d'après Wang 1989).

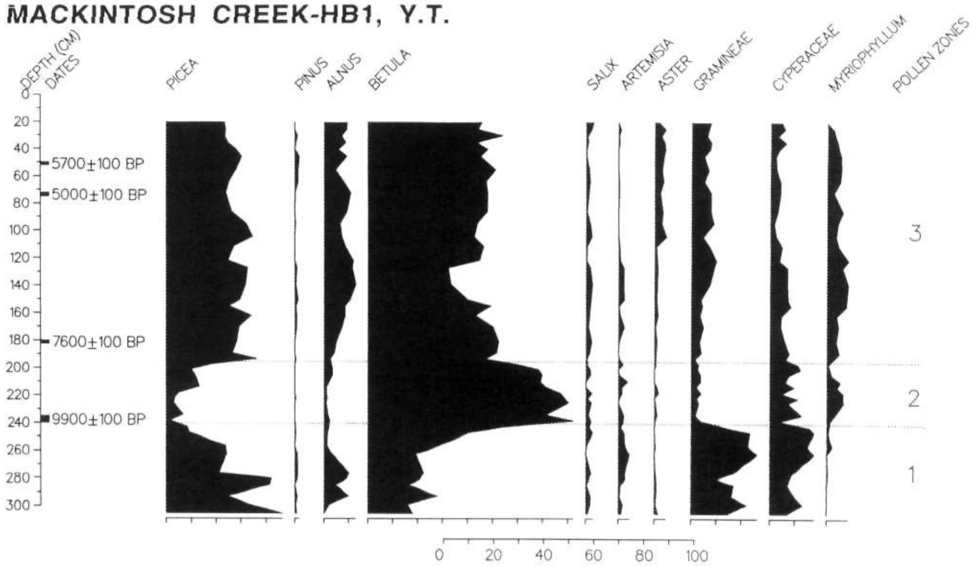

FIGURE 13. Summary pollen percentage diagram of Mackintosh Creek (redrawn from Beaudet, 1986).

Diagramme simplifié des pourcentages polliniques de Mackintosh Creek (redessiné d'après Beaudet, 1986).

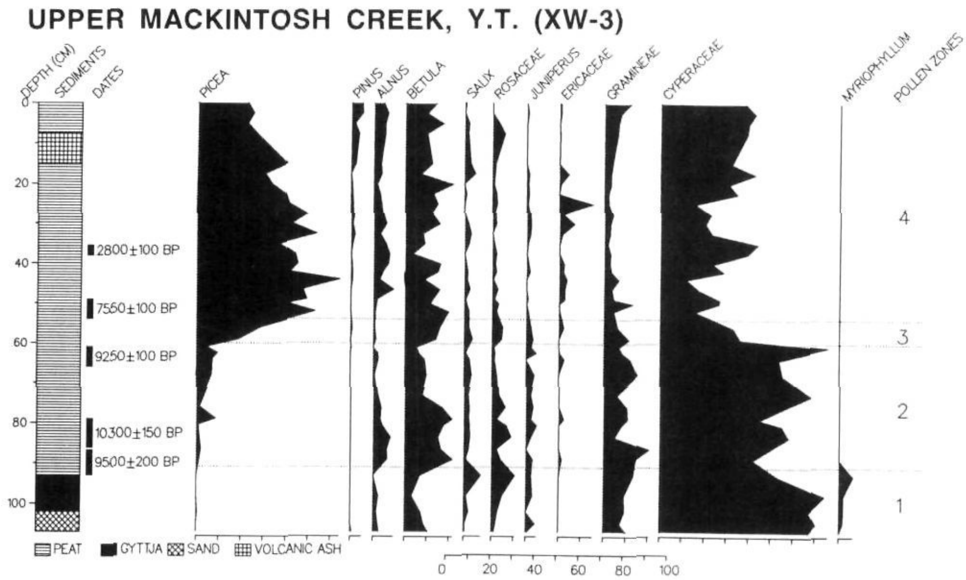

FIGURE 14. Summary pollen percentage of Upper Mackintosh Creek (redrawn from Wang, 1989).

Diagramme simplifié des pourcentages polliniques de Upper Mackintosh Creek (redessiné d'après Wang, 1989).

form the comparison of modern and fossil pollen data, and facilitate the interpretation. Pollen zone 1 is a sedge-moss assemblage with considerable values of *Myriophyllum* pollen suggesting a shallow water pond, while zone 2 represent a marsh environment with a *Betula-Salix* shrub-tundra vegetation in the area. As suggested by zone 3, spruce invaded the area at about 8800 yr BP which initiated a short-lived transitional vegetation of sparse forest-tundra. Zone 4 represents a spruce woodland vegetation which has experienced little change since 7700 yr BP.

Four pollen diagrams are available from the central Aishihik Basin (Fig. 6, Table II). The pollen sequence of Aishihik Pingo (61°40'N, 137°27'W; site 26) is the first published diagram in the basin (Geurts et Dewez, 1985), which provides information of local environmental conditions. This sequence suggests that the silts which form the flanks of the pingo were deposited in the late glacial period, while the pingo was growing prior to the deposition of White River ash and was reactivated after this event. Unfortunately this sequence has no ^{14}C date control.

The environmental history of the central Aishihik Basin can be determined from three sequences reported in Wang (1989; site 19, 20, 25). In the Polecat Lake area (61°40'45"N, 137°27'12"W, 935 m a.s.l.), where a white spruce forest occupies the landscape at present, a 329 cm sequence was divided into four local pollen zones, representing a vegetation history of a birch tundra in the beginning and a spruce forest tundra thereafter, then replaced by a dense spruce forest at about 7500 yr BP. A notable environment change from shallow water pond to marsh at 5700 yr BP was reflected in the pollen spectra and sediment type of zone 4. The upper 90 cm of the core, however, was not analyzed due to the apparent cryoturbation of the sediments.

Pollen zone 1 of Aishihik Kettle diagram (61°36'23"N, 137°32'48"W, 954 m a.s.l.; Wang, 1989; site 20) in the central Aishihik Basin probably represents the oldest herbaceous-rich assemblage in the area, dominated by sedges, grass, and considerable values of sage pollen. However, the core does not have dateable material for defining the chronology of this assemblage. Zone 2 of this sequence represent a spruce forest vegetation in the area, which is consistent with the records from other sites. A sedimentation hiatus was found between zone 1 and zone 2 as suggested by sediment stratigraphy and pollen spectra.

The most detailed pollen records from the Aishihik Basin were recovered from the Moose Depression core (61°35'26"N, 137°30'57"W, 953 m a.s.l.; Wang, 1989; Fig. 15; site 19). This 157 cm sequence consists of 32 samples taken at an approximately 5 cm intervals. The chronology of the sequence was established by three ^{14}C dates and a conspicuous layer of White River ash. Dense white spruce forest occupies the area at present. *Picea glauca* dominated forest with the occurrence of *Salix glauca, Betula glandulosa*, and *Empetrum nigrum* is developed on the moderately drained kame or glacial-fluvial deposits and is the major plant community in the area. *Salix glauca* dominated community with the occurrence of *Potentilla fruticosa, Castilleja* sp., *Achillea* sp., and Leguminosa developed on the flat marginal parts of Moose depression. A Cyperaceae dominated community is commonly developed on fine-grained mineral soil of lowland flats or in the organic accumulating depressions such as central part of Moose depression. Zonation of the pollen sequence was supported by numerical techniques, and PCA, PCB, and CA methods were employed with a combined data set consisting of twenty surficial moss polster samples collected from the Aishihik Basin and adjacent regions for the direct comparison of fossil and modern spectra. A pollen accumulation rate diagram (Fig. 16) was constructed using the standard exotic marker suspension method (Benninghoff, 1962; Matthews, 1969). Five pollen zones were recognized from this sequence. After deglaciation, a stagnant ice pond on the former proglacial Aishihik Lake terrace was surrounded by a herb-dominated tundra vegetation. This vegetation cover was soon replaced by a dwarf birch-dominated shrub tundra at an extrapolated date of

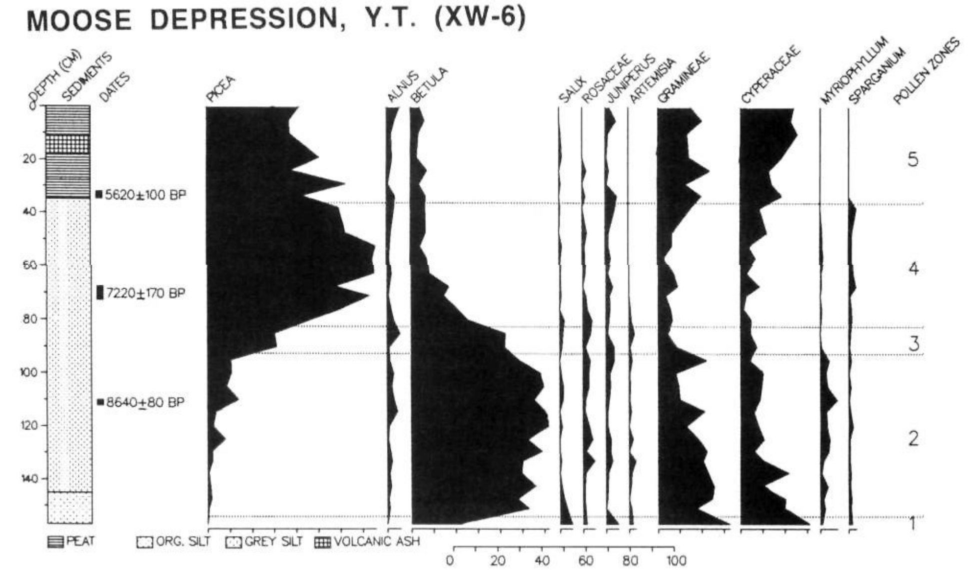

FIGURE 15. Summary pollen percentage diagram of Moose Depression (redrawn From Wang, 1989).

Diagramme simplifié des pourcentages polliniques de Moose Depression (redessiné d'après Wang, 1989).

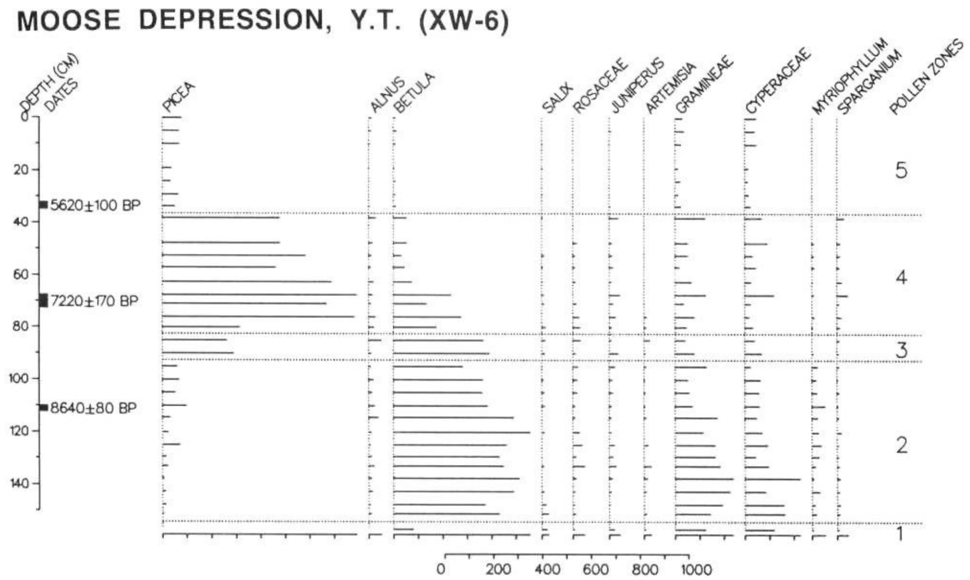

FIGURE 16. Summary pollen accumulation rate diagram of Moose Depression (redrawn from Wang, 1989).

Diagramme simplifié du taux d'accumulation pollinique de Moose Depression (redessiné d'après Wang, 1989).

ca. 10,000 yr BP, as happened in other localities in northern environments (Rampton, 1971; Beaudet, 1986). Spruce invaded the area at about 8600 yr BP, as suggested by the commonly accepted threshold of 10% pollen value in lake deposits (Ritchie, 1984a), and had its first dramatic rise at about 8000 yr BP. The second increase in *Picea* pollen at about 7600 yr BP marks the establishment of a spruce forest in the area, which has experienced little change since then. Replacement of organic silt by peat and the results of loss on ignition and grain size analysis suggest a sedimentary facies change at about 5700 yr BP. Significant increase of sedges and grass pollen and the vanish of aquatic taxa, *i.e. Myriophyllum* and *Sparganium*, in zone 5 support such a conclusion. Since then the depression has been a marsh to peat bog environment.

On the eastern Kluane Plateau near the south end of Aishihik Basin, a 240 cm peat core from the Ittlemit Lake basin (61°14'07"N, 137°11'47"W, 1180 m a.s.l.) produced four local pollen assemblage zones (Wang and Geurts, in press; Fig. 17; site 27). Sparse alpine forest-tundra occupies the area, and obvious vertical zonation of vegetation cover is developed along the slopes. *Eriophorum* sp. dominated community occupies the wetland at core site. Four ^{14}C dates provide the chronological control of the sequence. Pollen accumulation rates were calculated for the sequence. This sequence suggests that spruce arrived in this area by 9000 yr BP. This interpretation is supported by both percentage and accumulation rate data. Although spruce pollen percentages are high (36-46%), low spruce pollen accumulation rates (<360 grains/cm^2/yr^1) suggests that the area was covered by a forest tundra vegetation during the interval between 9000 and 5000 yr BP. By 5000 yr BP, local environmental change, probably a deterioration of local drainage conditions or an increase in soil moisture at the sampling site and vicinity, created a different habitat for this forest tundra vegetation cover which primarily affected the local taxa. Cyperaceae increase while Rosaceae and *Salix* decrease. Increased accumulation rate values for many taxa

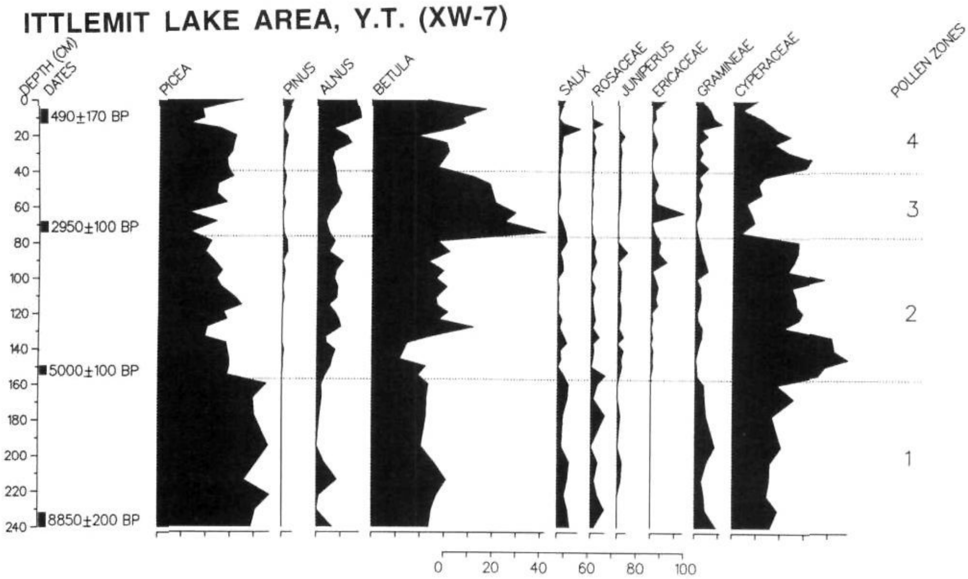

FIGURE 17. Summary pollen-percentage diagram of Ittlemit Lake Bog (redrawn from Wang, 1989).

Diagramme simplifié des pourcentages polliniques de Ittlemit Lake Bog (redessiné d'après Wang, 1989).

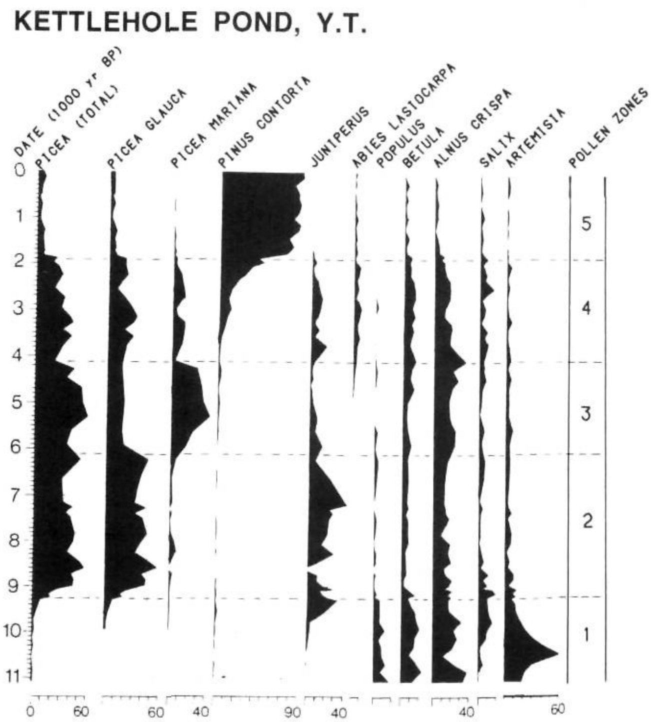

FIGURE 18. Summary pollen percentage diagram of Kettlehole Pond (redrawn from Cwynar, 1988).

Diagramme simplifié des pourcentages polliniques de Kettlehole Pond (redessiné d'après Cwynar, 1988).

suggest an amelioration of the pollination environment for most plants in the area. *Alnus* invaded the area shortly after 5000 yr BP. Rises of *Alnus* pollen in both percentage and accumulation rate data in the middle Holocene is a common feature of many pollen sequences in northwest North America (Ritchie, 1984a; 1984b; Rampton, 1971; Ager, 1975; Matthews, 1974; MacDonald, 1987.) However, this event occurred about 1000 to 2000 years later in the Ittlemit Lake area than the other places. Beginning around 3000 yr BP, a *Betula*-dominated local community replaced the previous Cyperaceae-dominated one, causing a change of shrub constituents in the vegetation. This *Betula*-dominated community lasted for about 1100 years and was replaced by the Cyperaceae-dominated community again around 1900 yr BP. A further increase of *Alnus*, associated with an increase of *Pinus* pollen, occurred at about 500 yr BP, which corresponds to the advance of glaciers in the St. Elias mountains. However, the regional forest tundra environment has not changed significantly during the last 1900 radiocarbon years.

TESLIN PLATEAU

A recent study (Cwynar, 1988) at Kettlehole Pond (60°04'N, 133°48'W, 760 m a.s.l.; Fig. 18; site 31) provides the first pollen sequence in this region. Five pollen zones were recognized from this 446 cm lake core, and fifteen ^{14}C dates were obtained to establish the chronology of the sequence and facilitate the determination of pollen accumulation rates. Pollen zone 1 represents a *Populus* woodland with an understory of *Shepherdia canadensis* and extensive open areas dominated by *Artemisia* existing between 11,030 and 9250 yr BP, which implies an initial period of aridity when summer was probably warmer than that of modern climate. Pollen records of zone 2 suggest that a more mesic forest community developed as indicated by the increase of *Picea glauca* and decrease of *Populus* at 9250 yr BP, which indicate an increased effective moisture condition. *Juniperus*, however, expanded earlier than this event, at 9700 yr BP. A significant shift of white spruce woodland with *Juniperus* to a mixed spruce forest in which *Picea mariana* was the dominant species occurred at 6100 yr BP, marking the beginning of pollen zone 3, and suggesting a wetter climate between 6100 and 4100 yr BP. Pollen zone 4 represents a time interval between 4100 and 1900 yr BP in which the area was covered by a white spruce forest with *Juniperus* again, marking the beginning of a prolonged period of increasing aridity and culminating in the development of the modern semi-arid climate. Pollen zone 5 suggests that modern open *Pinus contorta* woodland has been established since 1900 yr BP, and black spruce was eliminated in the area at the beginning of the zone.

DISCUSSION AND SYNTHESIS

POSTGLACIAL VEGETATION HISTORY: SPATIAL AND TEMPORAL PATTERNS (TABLE III)

During early postglacial time, southwest Yukon supported a herb-dominated tundra vegetation as suggested by pollen records from Upper Mackintosh Creek (Beaudet, 1986; Wang, 1989), central Aishihik Basin (Wang, 1989), and the Snag area (Ramptom, 1971). This was a short-lived event in the area. A herb zone has been reported from the north in many localities from late glacial to early postglacial time. The basic characteristics of the herb zone of Aishihik Basin resemble those from north Alaska (Livingstone, 1955, 1957) but are somewhat different from those of the Hanging Lake area (Cwynar, 1982). This is due to the lack of great representation of *Artemisia* at Aishihik Basin, which is probably due to the high moisture of the soil in this lowland area. Therefore the herb zone from Aishihik Basin and the adjacent area represents a lowland sedge-grass-dominated community.

By approximately 10,000 yr BP, the vegetation of southwest Yukon was replaced by a birch-dominated shrub tundra in which the pollen content resembles the early Holocene records of northern and interior Alaska (Livingstone, 1955, 1957; Ager, 1975; Matthews, 1974; Edward and Brubaker, 1986; Anderson, 1988; Anderson *et al.*, 1988). It is notable that the pollen records of Jenny Lake (Stuart *et al.*, 1989) suggest a short-lived *Alnus* shrub tundra phase following the birch zone between 9500 and 8500 yr BP. High *Alnus crispa* pollen percentage has also been reported from Kettlehole Pond between 11,020 and 9250 yr BP (Cwynar, 1988; site 31). These findings seem to support the hypothesis that *Alnus* migrated from south to north along the British Columbia and Alaska coast (MacDonald, 1984).

Following the shrub tundra phase, spruce arrived by at least 9000 yr BP in the Upper Nisling Valley (Wang, 1989), 8900 to 9000 yr BP in the Upper Mackintosh Creek (Beaudet, 1986; Wang,1989), 8600 yr BP in the central Aishihik Basin (Wang, 1989), and 8700 yr BP in the Snag area (Rampton, 1971). Pollen records from Ittlemit Lake Basin show that the arrival of spruce in the basin occurred at about 9000 yr BP (Wang and Geurts, 1991). Such events marked the beginning of a short-lived spruce forest tundra environment in the area. A significant rise in spruce occurred at 7900 yr BP in the Upper Nisling Valley, at 8000 yr BP and 7700 yr BP in the Upper Mackintosh Creek area at low altitude (975 m a.s.l.) and high altitude (1,060 m a.s.l.) sites, and at 7500 to 7600 yr BP in the central Aishihik Basin area, which marks the beginning of spruce forest vegetation in the region. Spruce woodland replaced a shrub tundra phase at 8700 yr BP and dense spruce forest has been established at 5700 yr BP at the Antifreeze Pond area (Rampton, 1971). In the Jenny Lake area, spruce forest was established at 8500 yr BP (Stuart *et al.*, 1989). These vegetation changes, however, are not recorded in the pollen sequence from Ittlemit Lake Basin (XW-7), probably due to local environmental conditions. The Ittlemit Lake area is a small basin at a higher altitude (1,180 m a.s.l.) than the other sites and is surrounded by a rolling and mountainous topography which isolates the area from central and northern Aishihik Basin except for one pass to the east. Climatic stress due to high altitude seems to have suppressed the normal ecological succession in this case.

It is notable that the vegetation changes around 9000 yr BP and 8000 yr BP have been recorded across the North. In the lower Mackenzie River basin a *Picea-Betula* zone replaced a *Betula-Populus-Juniperus* zone at 9000 yr BP which marks the first occurrence of spruce in the area (Ritchie, 1984b). A more recent study (MacDonald, 1987) indicates that spruce forest came to dominate the Mackenzie River Valley between 10,000 and 8500 yr BP. At Hanging Lake in northern Yukon, Cwynar (1982) reported that an *Alnus crispa* zone replaced the previous Ericaceae zone at 8900 yr BP. Pollen records of the Upper Natla River area (MacDonald, 1983) suggest that spruce invaded the area at 8640 yr BP and subsequently rose at 7700 yr BP. In central Alaska, Matthews (1974) reported a replacement by *Picea-Betula-Alnus* zone of a *Betula*-herb zone at about 8000 yr BP. A decline of *Picea*, which may represent a warm and dry event, has been documented from Tanana Valley between 8400 and 6000 yr BP (Ager, 1975). The replacement of the herb zone by the birch zone (Livingstone, 1955, 1957) was also around 8000 yr BP. It is concluded, therefore, that the vegetation changes during early postglacial time as suggested by pollen records from this study in the Aishihik Basin and its adjacent area are related to the climatic variation and reflect synchronous modification of environmental conditions across the North.

After the establishment of forest and forest tundra vegetation in the study area at 7500-8000 yr BP, the area vegetation pattern remained relatively constant. However, it is worthwhile to note the change of pollen composition around 6000 yr BP. In central Aishihik Basin, the pond of XW-4 was infilled by approximately 5900 yr BP and became a marsh or peat bog. Moose Depression (XW-6) changed from a shallow pond to the present peat bog at 5700 yr BP. Rampton suggested an establishment of modern boreal forest accompanied by a rise of *Alnus* at 5700 yr BP (Rampton, 1971). Pollen records of Ittlemit Lake basin (XW-7) suggest a slightly later event at 5000 yr BP when a rise of *Alnus* and Cyperaceae was documented. A remarkable shift from white spruce woodland with *Juniperus* to a black spruce-dominated mixed forest at *ca.* 6100 yr BP has been reported from the Kettlehole Pond area (Cwynar, 1988). A change of pollen spectra with a tremendous increase of *Alnus* has also been recorded in the Lower Mackenzie River Delta at 5100 yr BP (Ritchie, 1984b). In northern Alaska, *Alnus-Betula* shrub tundra replaced previous *Betula*-Ericaceae shrub tundra at 6000 yr BP (Livingstone, 1955,1957), while in Tanana Valley spruce recovered and modern boreal forest was established at 6000 yr BP (Ager, 1975). In conclusion, these facts suggest a change of environmental conditions around 6000 yr BP as documented by the pollen records of southwest Yukon is consistent with the records across a wide region and therefore reflects the regional rather than local modification of the environment.

It is significant that the vegetation pattern has been stable since 5000-6000 yr BP, although it has been suggested that the tree line advanced three times during this interval

TABLEAU III

Late Quaternary vegetation history from selected localities in southwestern North America

Age	Alaska				North Yukon	N.W.T.		Southwest Yukon									Age
yr BP	Tanana Valley Ager (1975)	Black River Anderson et al (1988)	Brooks Range Livingstone (1955,1957)	Issabella Basin Matthews (1974)	Hanging Lake Cwynar (1982)	Natla River MacDonald (1983)	Mackenzie Delta Ritchie (1984b)	Kettlehole Pond Cwynar (1988)	Antifreeze Pond Rampton (1971)	Jenny Lake Stuart et al (1988)	Nisling Valley Wang(1989)	Mackintosh Creek Beaudet (1986)	Mackintosh Creek Wang(1989)	Polecat Lake Wang(1989)	Moose Depression Wang(1989)	Ittlemit Lake Wang & Geurts (in press)	yr BP
1000								Lodgepole Pine Zone		Spruce Forest						Spruce-Willow-Cyperaceae	1000
2000	Spruce-Birch-Alder Zone (Boreal Forest)										Spruce-Cyperaceae Zone (Forest)					Spruce-Birch-Alder	2000
3000							Spruce-Birch-Alder Zone	Spruce-Fir Zone	Spruce Forest	Spruce-Alder Woodland					Spruce Forest (Cyperaceae)		3000
4000		Alder-Spruce Zone	Alder-Birch Zone	Spruce-Birch-Alder Zone		Spruce-Birch Zone						Spruce Woodland	Spruce Woodland			Spruce-Alder-Juniper-Cyperaceae	4000
5000					Alnus crispa Zone			Black Spruce Forest						Marsh			5000
6000										Spruce Forest	Spruce-Birch Zone (Forest)						6000
7000	(Spruce decline)		Birch Zone				Spruce-Birch Zone		Spruce Woodland					Spruce Forest	Spruce Forest	Spruce-Willow-Gramineae	7000
8000						Birch Tundra		White Spruce-Juniper Zone			Spruce Woodland	Forest Tundra	Forest-Tundra	Spruce-Birch Forest Tundra	Spruce Forest Tundra		8000
9000	Spruce-Birch Zone								Shrub Tundra	Alder Shrub Tundra		Shrub Tundra	Shrub Tundra	Birch Tundra	Birch Shrub Tundra		9000
10000	Populus-Willow Zone		Herb Zone	Birch-herb Zone	Ericales Zone		Birch-Poplar-Juniper Zone	Poplar Woodland							Herb Tundra		10000
11000		Birch Zone								Birch Tundra		Herbaceous Tundra	Herbaceous Tundra				11000
12000																	12000
13000	Birch Zone (Shrub Tundra)				Birch Zone				Sedge-moss Tundra								13000
14000				Herb-Birch Zone													14000
15000	Herbaceous Tundra	Herb Zone			Willow-Cyperaceae Zone												15000

(Ramptom, 1971). Most of the sites with long pollen records in southwest Yukon are 60 to 640 m below the modern tree line, and minor climatic oscillations which could cause fluctuation of the tree line would probably not strongly influence pollen rain within the forest. Pollen profile XW-8 at High Bog is above modern tree line and therefore might provide some information. An increase of *Picea* pollen percentage and accumulation rate at about 4000 yr BP might suggest a slight tree line advance. This change, however, could be very limited since a favourable climatic condition may increase spruce pollen production which might change the composition of the regional pollen rain without significant change of the vegetation pattern. Such an interpretation is also consistent with studies at other parts of the area (Bourgeois and Geurts, 1983). The succession of vegetation development in the Bear Lakes area during the last 1,230 years, as reconstructed from profile XW-13, is probably a local rather than regional variation due to fire and reforestation processes. However, the variation of pollen spectra during the last few hundred years, *i.e.* increase of spruce pollen by 20% and occurrence of *Pinus* pollen peaks in zone 4, in that area has more regional significance, which reflects the changes of environmental conditions during the Little Ice Age.

PROBLEMS OF SPRUCE, PINE, AND ALDER POLLEN RECORDS

1) Spruce

The origin and postglacial migration routes of *Picea* in the North have been repeatedly discussed before (*e.g.* Ritchie, 1984a; MacDonald, 1984; Ritchie and MacDonald, 1986; MacDonald, 1987; Cwynar, 1988). Hopkins (1972) and Matthews (1976) initially proposed that spruce survived in Beringia during full-glacial time, but this idea was later abandoned (Hopkins *et al.*, 1981). However, current studies cannot reject of prove this proposition (MacDonald, 1984; Ritchie and MacDonald, 1986). Beaudet (1986) found a high spruce percentage peak prior to 10,000 yr BP in Upper Mackintosh Creek and interpreted his result as a possible support of the Alaska and/or Yukon spruce refugium hypothesis. However, this interpretation probably needs to be re-evaluated due to the extremely low pollen concentration and high portion of corroded spruce pollen grains, which might suggest redeposition.

A second hypothesis (Hopkins *et al.*, 1981; Ritchie, 1984a; MacDonald, 1984; Ritchie and MacDonald, 1986) postulates that spruce migrated from a southern refugium in the plains area of the United States, northward into south-central Manitoba, and from there moved rapidly through wind and possibly water transport to the Mackenzie Delta region. It has also been proposed that spruce migrated from the northern Yukon via the Porcupine Valley to central Alaska and arrived at Tanana Valley at 9500 yr BP. From there, spruce expanded rapidly southward into southwest Yukon (Ager, 1975; 1983). However, a recent study suggests that spruce arrived at Ped Pond area in the middle of Porcupine Valley at 8500 yr BP and at the Black River region, which is between northern Yukon and Tanana Valley, at 7500 yr BP. This result suggests that this region was not the route of *Picea* migration (Anderson *et al.*, 1988).

It has also been proposed that *Picea* could enter the Yukon from northern British Columbia via the Liard River Plain and subsequently migrate northward along the Tintina Trench (Spear, 1983; MacDonald, 1984; Cwynar, 1988). Spruce arrival dates deduced from pollen records of Aishihik Basin suggest a southward migration, although such a conclusion might be subject to the variation of ^{14}C dates (Wang, 1989). *Picea* invaded the Upper Nisling Valley at least 9000 yr BP, arrived in the Upper Mackintosh Creek area at 8900-8800 yr BP, and in the central Aishihik Basin at 8600 yr BP. However, evidence of this southward migration is not observed in the other part of the area. Data from the Ittlemit Lake Basin suggest that spruce arrived in this area at least 8900-9000 yr BP which is approximately 300-400 years earlier than that at the central Aishihik Basin. These results seem to suggest that spruce invaded the Aishihik Basin and its adjacent area via different migration routes, supporting the hypothesis that spruce invaded the Yukon via Liard River Plain (MacDonald, 1984; Cwynar, 1988). In this case, it is possible that spruce migrated from Tintina Trench via the uppermost Yukon River plain, southwestward into the Aishihik Basin and its adjacent area. However, it must be kept in mind that the differences in radiocarbon age of a single event between adjacent sites may not exclusively reflect the migration of taxa but can be due to error or variation of the radiocarbon date itself. As Birks and Birks (1980) have indicated, radiocarbon ages of a paleoecological event provide only an approximate measure of simultaneity at different sites because many sources of error and discrepancy exist in the method. This migration hypothesis, therefore, could be artificial, resulting from the error or deviation of ^{14}C dates and therefore requires further investigation in the southern Aishihik Basin and uppermost Yukon River plain area. Future investigation in the lower Nisling Valley may also be helpful.

2) Pine

The postglacial migration of lodgepole pine (*Pinus contorta*) has been previously examined (MacDonald, 1984; MacDonald and Cwynar, 1985). The pine pollen records from most sites especially in the Aishihik Basin and its adjacent regions, which beyond the distribution range of *Pinus contorta*, illustrate an interesting pattern. Although *Pinus* pollen has occurred in trace amounts since 9000 yr BP in the area, considerable values (>1%) were only registered in the pollen spectra after the deposition of White River ash in most sites. This phenomenon reflects the migration of *Pinus* into the southwest Yukon during late Holocene (MacDonald, 1984; MacDonald and Cwynar, 1985). Moreover, the *Pinus* pollen percentages show a close relation with the density of vegetation cover. High *Pinus* percentages are recorded from Upper Mackintosh Creek (XW-3), Ittlemit Lake Basin (XW-7), and the Bear Lakes region (XW-8, XW-13). All these localities supported a sparse vegetation of forest tundra or alpine shrub tundra (XW-8). This result may suggest that sparse vegetation cover has less effect on the filtration of regional pollen rain, or as an alternative, local vegetation only produces little pollen so exotic pollen is more prominent. Another interesting phenomenon is that sites at higher altitudes have a better representation of *Pinus* pollen, which is strongly overrepresented.

It is worthwhile to note that the *Pinus* pollen percentage exhibits a discontinuous representation and several peaks have been recorded. Isolated peaks of *Pinus* pollen percentages, despite low values, were registered in Upper Nisling Valley and Upper Mackintosh Creek as early as or prior to 8000 yr BP, and such a phenomenon was repeated several times in the records during the Holocene, especially during the last 1230 years when the values reached 1% or more. Although the chronology of these events can not be confidently correlated due to the difficulty of radiocarbon dating, at least one isolated peak was recorded at Ittlemit Lake Basin around 500 yr BP which is firmly controlled by a ^{14}C date. Similar spectra have also been observed from the Bear Lakes area (XW-13) and High Bog site (XW-8) at approximately the same time, based on linear extrapolation. Apparently, it is difficult to interpret the fluctuation of pine pollen with the normal migration model. The analysis of climatic data from the abandoned Aishihik Climatic Station (Environment Canada, 1982) reveals that the dominant directions of wind are S and SE throughout the year except in winter, when northerlies are more important. Moreover, the mean monthly wind speeds from spring to fall are higher than those during winter and two maxima occur in May and September (Fig. 19). During the pollination period of *Pinus contorta* in May and June (Bassett *et al.*, 1978), high mean monthly wind speeds and dominant SE and S winds might bring the pine pollen to the area and form these peaks. Airborne pollen records from the Gladstone Creek area, southwest Yukon Territory (Lagarec and Geurts, 1984) reveal that low pressure on Ruby Range and meridional circulation of air masses are favourable conditions for the

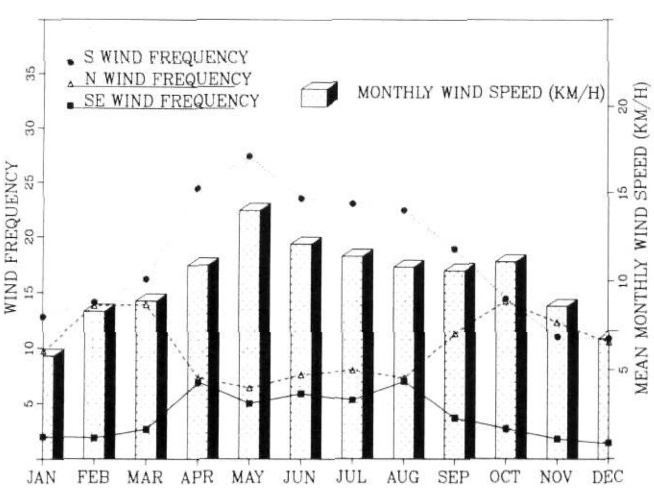

FIGURE 19. Distribution of wind percentage at Aishihik Station (modified from Wang, 1988a, data from Environment Canada, 1982).

Distribution des fréquences de vent à la station d'Aishihik (modifiée d'après Wang, 1988a, données extraites de Environnement Canada, 1982).

transport of airborne pollen to the study area. This is consistent with the prevailing wind direction during the summer in the area. These isolated *Pinus* peaks, moreover, may reveal a frequent shift of this low pressure and meridional circulation system.

On the other hand, favourable pollen formation conditions for *Pinus* consist of low radiation, cloudy conditions, and high humidity during late summer and fall (Lejoly-Gabriel, 1978). Isolated peaks of *Pinus* pollen around 500 yr BP may indicate a wetter climate during the pollen formation period in late summer and fall and an increase of southeast wind frequency during the flowering period in the following year. This interpretation is consistent with the extension of glaciers in the St. Elias Mountains during the Little Ice Age (Denton and Karlén, 1977).

3) Alder

The obvious rise of *Alnus* pollen, to higher than 20% around 8000-6000 yr BP following the expansion of spruce, has been reported from most pollen sites in northern and central Yukon (such as Ovenden, 1982; Cwynar, 1982; Ritchie, 1982), the Northwest Territories (such as Ritchie and Hare, 1971; Ritchie, 1977; 1984b; MacDonald, 1987), the Snag, Kettlehole Pond, and Jenny Lake areas in southwestern Yukon (Rampton, 1971; Cwynar, 1988; Stuart *et al.*, 1989), and eastern Alaska (Ager, 1975, 1983; Edwards and Brubaker, 1986; Anderson *et al.*, 1988). However, such a rise is not registered in the pollen records from the Aishihik Basin and its adjacent area. The percentage of *Alnus* in most localities in the Aishihik Basin and adjacent regions rarely exceeds 10%, and remains *ca.* 5% in most sections described in this paper. Although a rise of *Alnus* pollen has been recorded from the Ittlemit Lake Basin and High Bog site in the Bear Lakes area, its value is still not comparable with those at other sites in the North. Pollen spectra in this region illustrate that *Alnus* pollen is better represented at sites with higher altitude (profile XW-7, XW-8, and XW-13), which suggests a strong overrepresentation from regional or extraregional sources. This interpretation is consistent with the previous conclusion that alder pollen is usually overrepresented in the pollen spectra from high altitude sites (Bourgeois and Geurts, 1983; Campbell, 1985, 1987). Other anomalies of *Alnus* pollen representation have also been found from the southwest Yukon at Two Horsemen (Cwynar, unpublished data, see Cwynar *et al.*, 1987) and Kettlehole Pond (Cwynar, 1988) sites, where *Alnus* expanded simultaneously with *Betula* before the rise of *Picea*. The occurrence of alder in the modern vegetation of the Aishihik Basin and adjacent regions is very sparse. Previous studies (MacDonald, 1984, 1987) indicate that *Alnus crispa* requires a relatively moist substrate, and development of organic soils with higher water-holding capacities in the continental interior might have allowed the species to expand in the middle Holocene. Severe climatic conditions with very low precipitation in the Aishihik Basin and the adjacent area might account for the extremely low representation of *Alnus* in the vegetation and thereby the low value of *Alnus* pollen spectra.

A previous study in the Jenny Lake area indicated that an *Alnus* shrub tundra developed between 9500 and 8500 yr BP, and a *Picea-Alnus* woodland between 4500 and 2000 yr BP (Stuart *et al.*, 1989). However, field investigation in the Kluane Lake area indicates that *Alnus* has a low representation in the modern vegetation in the area. Only one individual was observed in Cultus Creek and some small stands of *Alnus* in the steep Williscroft Creek canyon. It is very interesting to note that moss samples in a shrub tundra, where *Alnus* is present in the vegetation, yield 10-20% *Alnus* pollen (de Bastiani and Geurts, 1987; P.M. de Bastiani, pers. comm., 1987). Comparing the records in these areas and those from the Aishihik Basin, it can be presumed that Aishihik Basin has never been favourable for the expansion of *Alnus* during the middle and/or late Holocene.

It has been noted from previous studies in northwestern Canada and adjacent Alaska that *Alnus* is strongly overrepresented as a minor component of vegetation (<10%), contributing up to 50% of the regional pollen spectra (Ritchie, 1984a; MacDonald, 1984). However, modern pollen records from central and western Alberta indicate that *Alnus* with similar density often produces less than 10% of regional spectra (MacDonald, 1984; MacDonald and Ritchie, 1986). This fact might suggest the differential pollen production between southern and northern localities, or higher production of other taxa at southern sites. However, this hypothesis can not be properly evaluated without pollen accumulation rate or pollen concentration data.

SUMMARY AND CONCLUSION

The southwest Yukon Territory supported a herb-dominated tundra vegetation during the late-glacial to early Holocene which was soon replaced by a birch-dominated shrub-tundra. Spruce invaded the area between 9000 and 8600 yr BP at different localities, and a southward time transgression is visible in the Aishihik Basin. Regional vegetation has been stable since 7600-8000 yr BP when dense spruce forest and/or spruce forest tundra was established in most localities. In the Snag area, however, dense spruce forest developed only around 5700 yr BP, which is about 2000 yr later than that in the Aishihik Basin.

Pine pollen records in the region may suggest a frequent shift of the atmospheric circulation system. Records of alder pollen from the Aishihik Basin and adjacent regions indicate that alder has never been widespread in these areas due to the dryness, and alder pollen is greatly overrepresented in the pollen spectra. The well defined spruce arrival dates in the region suggest that further investigations in the Tintina valley, Yukon River Valley, and Carmacks Region might provide useful information concerning the spruce migration routes.

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