"The Last (Koy-Yukon) Interglaciation in the Northern Yukon: Evidence from Unit 4 at Ch'ijee's Bluff, Bluefish Basin"

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THE LAST (KOY-YUKON) INTERGLACIATION IN THE NORTHERN YUKON: EVIDENCE FROM UNIT 4 AT CH'IJEE'S BLUFF, BLUEFISH BASIN*

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ABSTRACT The effects of predicted anthropogenic warming can be assessed in part by documenting responses to past warming events. One of the most pronounced warmings was the last interglaciation — stage 5 of the marine isotope record. A large multinational and multidisciplinary project (CELIA) was launched recently in order to gain detailed knowledge of the climate during stage 5. Several key exposures were identified by CELIA; one of them is Ch'ijee's Bluff on the Porcupine River, northern Yukon. Pollen, plant and insect macrofossils and stratigraphic evidence from Ch'ijee's Bluff show that the part of Ch'ijee's Unit 4 that is above and younger than Old Crow tephra (OCt) was deposited during an interval of climate warmer than present. When OCt was dated at 85 ka BP, the subsequent warming interval was presumed to be correlative with the early part of marine isotope stage 3. New dates on OCt show it to be 140-150 ka BP, and this means that the warm interval discussed here is more likely of stage 5 than stage 3 age. We apply the informal epithet, "Koy-Yukon interglaciation", to it and compare the Ch'ijee's Bluff Unit 4 sequence with other east Beringian sites that contain both Old Crow tephra and putative interglacial deposits.

RÉSUMÉ *Indices de la dernière interglaciation (Koy-Yukon) dans l'unité n° 4 de Ch'ijee's Bluff, bassin du Bluefish, dans le nord du Yukon.* Les conséquences du réchauffement anthropique attendu pourraient en partie être évaluées à partir de nos connaissances sur les réchauffements climatiques antérieurs. Le réchauffement climatique le plus important s'est produit au cours du dernier interglaciaire (stade isotopique 5). Dans le but d'acquérir une meilleure connaissance du climat durant le stade 5, on a créé un important projet multidisciplinaire et multinational (CELIA). On a identifié plusieurs coupes clés dont celle de Ch'ijee's Bluff, de la Porcupine River, dans le nord du Yukon. Les indices fournis par le pollen, les végétaux, les macrofossiles d'insectes et la stratigraphie de Ch'ijee's Bluff démontrent que la partie de l'unité n° 4 plus jeune que le tephra de Old Crow et située au-dessus a été déposée durant un intervalle plus chaud qu'aujourd'hui. Quand on a daté à 85 ka BP le tephra de Old Crow, on présumait que l'intervalle de réchauffement subséquent était corrélatif au stade isotopique 3. Les nouvelles dates le font maintenant remonter à 140-150 ka BP, ce qui signifie que le réchauffement climatique appartient plutôt au stade 5. On lui a attribué le nom informel de «interglaciaire de Koy-Yukon». On a comparé la séquence de l'unité n° 4 avec celle d'autres sites de Béringie qui renferment à la fois le tephra de Old Crow et des dépôts considérés comme étant interglaciaires.

ZUSAMMENFASSUNG *Die letzte (Koy-Yukon) Interglazialzeit im nördlichen Yukon: Belege von der Einheit 4 in Ch'ijee's Bluff, Bluefish Basin.* Die Auswirkungen einer erwarteten anthropogenen Erwärmung kann man teilweise abschätzen, indem man die Ergebnisse vergangener klimatischer Erwärmungen dokumentiert. Eine der herausragendsten klimatischen Erwärmungen war die letzte Interglazialzeit — Stadium 5 des marinen Isotop-Belegs. Kürzlich hat man ein breitangelegtes multinationales und multidisziplinäres Projekt (CELIA) gestartet, um detaillierte Kenntnis über das Klima während des Stadium 5 zu erhalten. CELIA hat mehrere Schlüssel-Schnitte identifiziert; einer davon ist Ch'ijee's Bluff am Porcupine River, nördliches Yukon. Die von Pollen, Pflanzen, Insektenmakrofossilen und Stratigraphie von Ch'ijee's Bluff gelieferten Anhaltspunkte zeigen, dass der Teil der Ch'ijee's-Einheit 4, der über Old Crow Tephra (OCt) liegt und jünger ist, während eines klimatischen Intervalls, das wärmer war als gegenwärtig, abgelagert wurde. Als man OCt auf 85 ka v. u. Z. datierte, nahm man an, dass das folgende Erwärmungs-Intervall mit dem frühen Teil des marinen Isotop-Stadiums 3 korrelierte. Neue Daten auf OCt zeigen, dass dieses 140-150 ka v. u. Z. alt ist, und das bedeutet, dass das warme Intervall, von dem hier die Rede ist, wohl eher dem Stadium 5 als dem Stadium 3 zugehört. Wir benutzen die informelle Bezeichnung "Koy-Yukon Interglazialzeit" und vergleichen die Ch'ijee's Bluff 4-Sequenz mit anderen Plätzen von Ost-Bering, die sowohl Old Crow Tephra enthalten wie auch Ablagerungen, die man für interglaziale Ablagerungen hält.

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INTRODUCTION

From 1975 until 1985 the Quaternary stratigraphy and paleoenvironmental history of the northern Yukon was studied by a multidisciplinary and multi-institutional team working under the umbrella of the Yukon Refugium Project (Morlan, 1980). Much of the research activity of the project was focused on exposures within the Bonnet Plume, Bell, Bluefish and Old Crow basins (Hughes *et al.*, 1981) (Fig. 1). Of these only the Bonnet Plume basin has been glaciated. River bluff exposures in the other basins, particularly Old Crow and Bluefish basins reveal suites of sediments spanning the late Tertiary to the Holocene (Matthews *et al.*, 1987a; Schweger, in press). Exposed sediments in all four basins also record the advance of Late Wisconsinan Laurentide ice onto the east flank of the Richardson Mountains (Fig. 1) either by till as in the Bonnet Plume Basin or by glaciolacustrine sediments as in the Bell, Bluefish and Old Crow basins (Hughes *et al.*, 1981).

One of the river bluff sections that has received intense study during the course of the Yukon Refugium Project is Ch'ijee's Bluff (in the past informally designated "Twelvemile Bluff", "HH-228", "Big Bluff" and "Porcupine Loc. 100"), on the Porcupine River, 9.7 km southwest of the village of Old Crow (Fig. 1) (Matthews *et al.*, 1987b). This 4 km long exposure is located approximately in the centre of the Bluefish Basin. Unit 4 at Ch'ijee's Bluff contains both Old Crow tephra, an important stratigraphic marker for Alaska-Yukon (Westgate, 1988; Westgate *et al.*, 1985) and organic horizons containing pollen, bryophyte fragments, vascular plant macroremains such as seeds and needles and various types of insect fragments.

These fossils portray some unique and heretofore poorly documented details of the late Pleistocene climate of the northern Yukon. In particular they provide definite evidence of the last interglaciation, which is here informally named the "Koy-Yukon interglaciation" (a reinterpretation of the "Koy-Yukon thermal event" discussed in Schweger and Matthews, 1985 and below). Elements of this history have been recounted elsewhere (Schweger and Matthews, 1985); new evidence presented here requires revision of previous concepts and conclusions. Ch'ijee's Bluff is an important datum for study of the last interglaciation in northern North America and because of this it has been designated as one of a number of northern reference sites scheduled for detailed study under project CELIA (Climate and Environment of the Last Interglacial in Northern North America).

METHODS

Ch'ijee's Bluff is a large and stratigraphically complex section, with precipitous parts of it being essentially inaccessible. The following discussion concerns data collected at several stations located along the length of the section (Fig. 2), particularly Station 4, where the most detailed study of the interglacial sediments has been conducted.

Samples for pollen analysis were collected from a cleaned exposure at a number of levels, with the most complete series coming from Station 4 (Fig. 2). A zinc bromide ($ZnBr_2$) heavy liquid processing technique was employed to concentrate fossil pollen. One to four microscope slides per sample were counted in order to reach a sum greater than 200 grains; in some cases the entire prepared sample was examined. Because it is not possible to compute sedimentation rates with the information at hand, no effort was made to calculate pollen influx values.

Sediments examined for macrofossils were collected at selected levels within Unit 4. The size of most samples was at least 1 kg, except for Sample N (initial volume — 30 kg). The smaller samples were sieved with 40 mesh/inch sieves and all residue >40 mesh examined and picked for fossils. If the volume of sediment was too great to permit use of this technique, a fraction of the >40 mesh residue was examined for plant and insect macrofossils then the remainder processed using a light oil flotation technique (Coope, 1979) to concentrate the insect fragments.

GEOGRAPHIC AND CLIMATIC SETTING

Ch'ijee's Bluff is located in the Bluefish Basin (Fig. 1), one of several structural basins that interrupt the Porcupine Plain and Plateau physiographic region of the northern Yukon (Bostock, 1948). Both the Bluefish Basin and adjacent Old

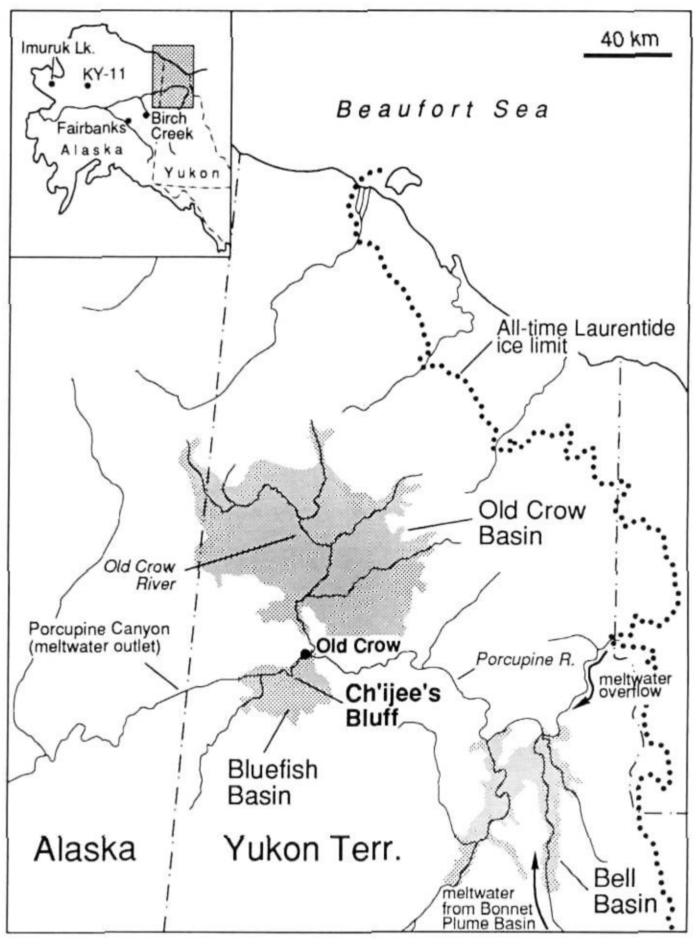


FIGURE 1. Regional map showing location of Ch'ijee's Bluff, Bluefish and Old Crow basins and other sites in Alaska (inset map) which are mentioned in the text.

Carte de localisation de Ch'ijee's Bluff, des bassins de Old Crow et de Bluefish et des autres sites en Alaska (carton) dont on parle dans le texte.

Crow Basin contain a thick sequence of Neogene sediments. The bases of some of the river bluffs are of late Tertiary age, and similar sediments continue beneath the surface for hundreds of metres (Lawrence, 1973; Matthews and Ovenden, in press).

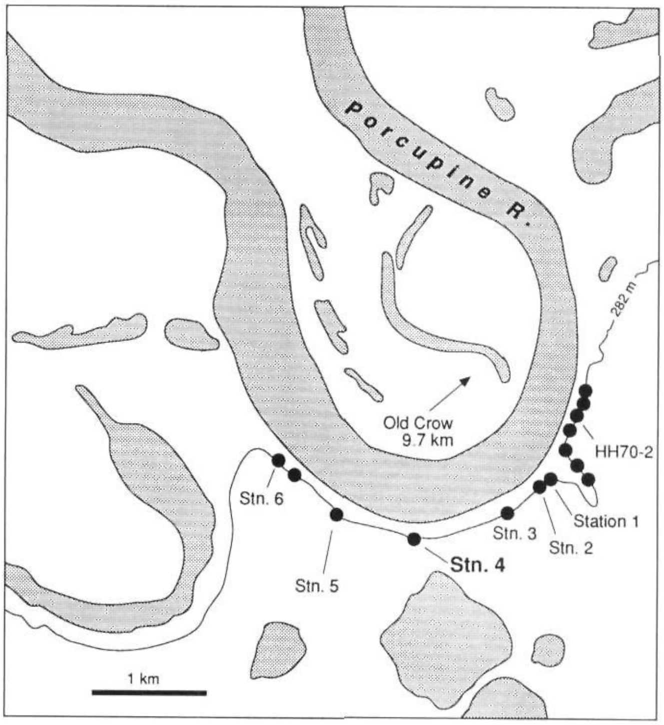


FIGURE 2. Location of sample stations at Ch'ijee's Bluff.
Emplacements des sites d'échantillonnage à Ch'ijee's Bluff.

Old Crow and the Ch'ijee's Bluff exposures are within a small area differing from the surrounding region by slightly lower mean annual temperatures (below −10°C) and slightly higher mean July temperatures (Wahl and Goos, 1987), indicating a higher degree of climatic continentality. Mean annual precipitation is between 200 and 300 mm/yr. Although the better drained areas in the Old Crow region are forested with typical northern conifer vegetation, the large area of poorly drained terrain within the basins causes trees to be scarce. Regional tree line crosses the Old Crow Basin with a few trees barely colonizing the drainages of streams entering the Old Crow Basin from the north (Fig. 1). Further detail on regional vegetation is provided in Cwynar (1982), Welch and Rigby (1971), Ovenden and Brassard (1989) and Ritchie (1984). Bluefish Basin lies within the High Subarctic Ecoclimatic Region (Ecoregions Working Group, 1989). The boundary between discontinuous and continuous permafrost zones passes through or very near Bluefish Basin; as a consequence, the region contains areas of both high-centred and low-centred ice wedge polygons.

STRATIGRAPHY OF CH'IJEE'S BLUFF

Hughes (1972) was the first to systematically describe the Ch'ijee's Bluff section in a modern context, and his generalized stratigraphic framework is still applicable. Six major units are evident (Fig. 3).

UNIT 1

Unit 1 is usually exposed as a gently sloping bench at the base of the section. It is composed of partly oxidized and iron-cemented alluvial sand, grit and minor gravel with interstitial clay. Lenses of organic detritus with abundant pieces of conifer

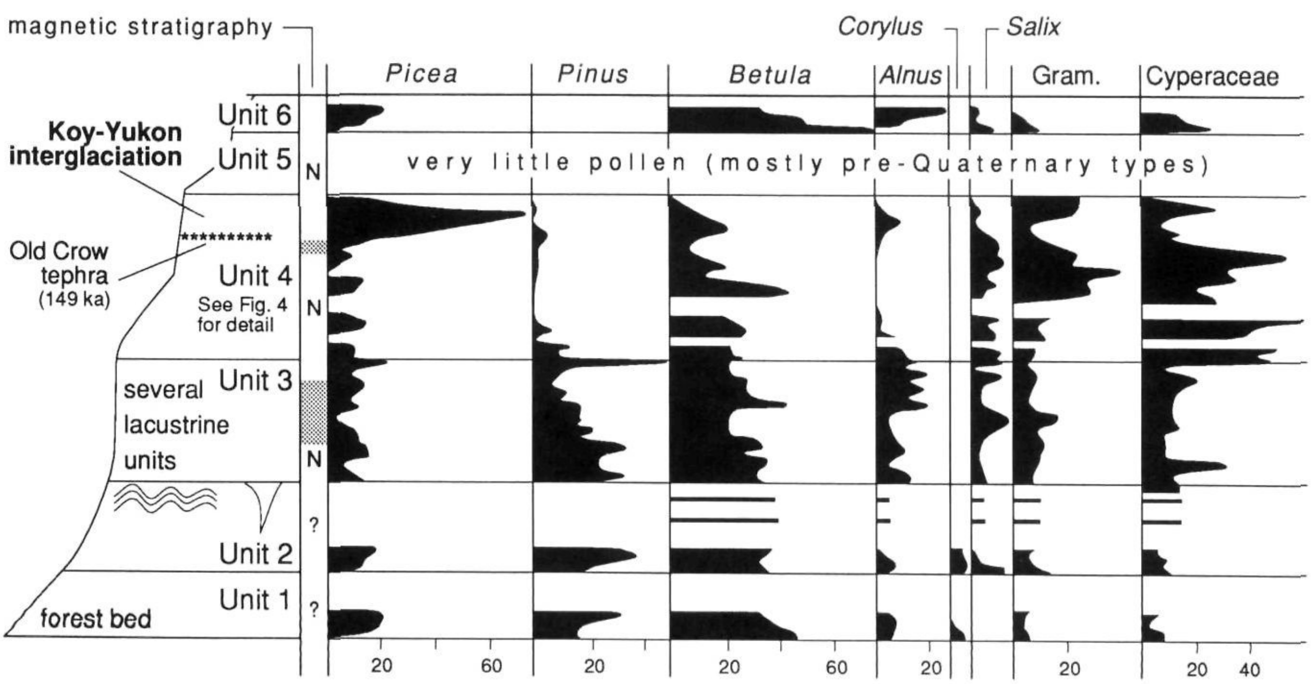


FIGURE 3. Generalized stratigraphy palynology (modified from Lichti-Federovich, 1974) and magnetic polarity record (Pearce *et al.*, 1982) of Ch'ijee's Bluff.

Stratigraphie palynologique généralisée (modifiée à partir de Lichti-Federovich, 1974) et les données de polarité magnétique (Pearce et al., *1982) de Ch'ijee's Bluff.*

wood up to 50 cm diameter, conifer cones (*e.g.*, from spruce, two-needle and five-needle pine, larch) and other macrofossils occur in places (Matthews *et al.*, 1987b; Matthews and Ovenden, in press). Early pollen work (Lichti-Federovich, 1974) showed significant percentages of spruce (*Picea*), pine (*Pinus*) and hazel (*Corylus*) in this unit. Two-needle pines now grow near Dawson City, approximately 450 km to the south; modern representatives of five-needle pines grow no closer than approximately 2200 km south of the site.

UNIT 2

Resting disconformably on Unit 1, the basal part of Unit 2 comprises uncemented but irregularly oxidized sand with minor gravel and silt lenses. The unit grades upward into bedded sand and silt. A zone of pronounced frost involutions and occasional ice-wedge pseudomorphs occurs within the upper metre. There are only scant pollen data and no macrofossil data from Unit 2. The basal sediments show relatively high percentages of spruce and enough pine to suggest that both were growing near the site, or at least in the northern Yukon.

UNIT 3

Unit 3, 20 m thick, forms a nearly vertical face clearly visible along the entire length of the bluff. It consists of beds of dark grey to dark brownish grey silty clay to clayey silt, some laminated, others massive. Most of the sediments were probably deposited in a large lake or lakes that filled the Bluefish basin and Old Crow basins during the early Pleistocene or late Tertiary (Heginbottom and Vincent, 1986; Schweger, in press) possibly due to movement on one of the many faults that cross the Porcupine River (Norris, 1976). The unit contains a magnetically reversed interval (Fig. 3) which may represent the upper part of the Matuyama chron (Westgate *et al.*, 1985). Thus Unit 3 is at least 700 ka BP in age. A major hiatus, probably including most of the middle Pleistocene is represented by the disconformable boundary of Units 3 and 4. Unlike glaciolacustrine sediments higher in the section, Unit 3 contains adequately preserved pollen. High pine percentages probably mean that pine was growing in the region at the time of deposition. Few samples from Unit 3 have been studied for plant and insect macrofossils, but those that have contain *Larix* and in one case a fossil of the extinct beetle *Micropeplus hopkinsi*.

UNIT 4

Primarily because it contains the Old Crow tephra (OCt), a key marker horizon for correlation of the Early Wisconsinan deposits in east Beringia (Westgate *et al.*, 1983; Westgate *et al.*, 1985; Schweger and Matthews, 1985), Unit 4 has been studied in more detail than any of the other units of Ch'ijee's Bluff. Much of our argument concerning the interglacial age of the sediments in the upper part of Unit 4 relies on the accuracy of the latest dating of OCt at 149 ka BP by Westgate (1988). OCt was deposited when climate at Ch'ijee's Bluff was much colder than now (see below), a fact which supports the new date, because at 149 ka, the tephra fall occurred during marine isotope stage 6, a period of worldwide cold climate.

There is not, however, universal agreement on the age of OCt. A recent discussion of its age (Béget *et al.*, 1990) suggests the tephra fall may have occurred as long ago as 230 ka BP. If this were so, it would be difficult to maintain that Unit 4 sediments and fossils discussed here referred to the last interglacial. This new age estimate is the result of an extrapolation rather than a new date. Furthermore, some of its implications with respect to the glacial history of east Beringia (*e.g.*, no Illinoian age glaciations in the Canadian Cordillera — Matthews *et al.*, 1990) are nearly incredible. For purposes of this paper, we reject the extrapolated age of Béget *et al.* (1990) and accept Westgate's (1988) isothermal fission track date as the best current age estimate.

Figure 4 shows a summary and interpolation of the stratigraphy at five different stations where Unit 4 is exposed (Fig. 2). Three sub-units are recognized.

Unit 4a, 5-8 m in thickness, consists largely of alluvial sand and gravel containing occasional wood fragments and lenses of organic detritus and other paludal deposits. The lower contact is disconformable and sharp; the upper boundary with Unit 4b is gradational. A few ice-wedge pseudomorphs occur in the sand and gravel of Unit 4a, but they do not form continuous horizons as is the case higher in the section. At Station 5 Unit 4a contains two organic horizons associated with paleosols (Fig. 4).

Unit 4b, consists of 4-6 m of fine alluvial sand, lacustrine silt and organic silt or peat formed in fens and bogs. As indicated earlier, it contains Old Crow tephra (Schweger and Matthews, 1985; Westgate *et al.*, 1983). It also contains a paleomagnetic excursion several metres below OCt which has been recorded in a similar stratigraphic position with respect to OCt at several other sites in eastern Beringia (Westgate *et al.*, 1985). In as much as the OCt is now dated at 149 ka BP, this excursion is not likely to be the Blake event as originally proposed (Schweger and Matthews, 1985).

One laterally continuous horizon of ice-wedge pseudomorphs as well as several intermittent peat horizons occur in Unit 4b. At some sites the pseudomorphs intrude the tephra, showing that the ice wedges formed during or shortly after tephra deposition. This implies a cold climate — colder than at present — in agreement with pollen and macrofossil evidence from samples associated with the tephra (see below).

The lowest of the peat beds in Unit 4b (source of macrofossil Sample H) is well below the level of OCt and therefore older than 150 ka BP (Westgate, 1988 and below). Another intermittent organic horizon occurs slightly below Old Crow tephra and in some places is seen to be slumped into the ice-wedge pseudomorphs (Fig. 4). One of these organic horizons, represented by Sample A at Station 1 is dated at >53 ka BP (Table I: GSC-2676), but its position with respect to the tephra means that it is at least as old as 150 ka BP (see below and Westgate, 1988).

The upper parts of Units 4b and 4c were studied in detail only at Station 4, which also happens to mark the last known downstream occurrence of Old Crow tephra. At Station 4 the sediments are primarily silt and fine sand with several organic to peaty horizons. One of the latter fills an ice-wedge pseudomorph located at about the same level as others in Unit 4b.

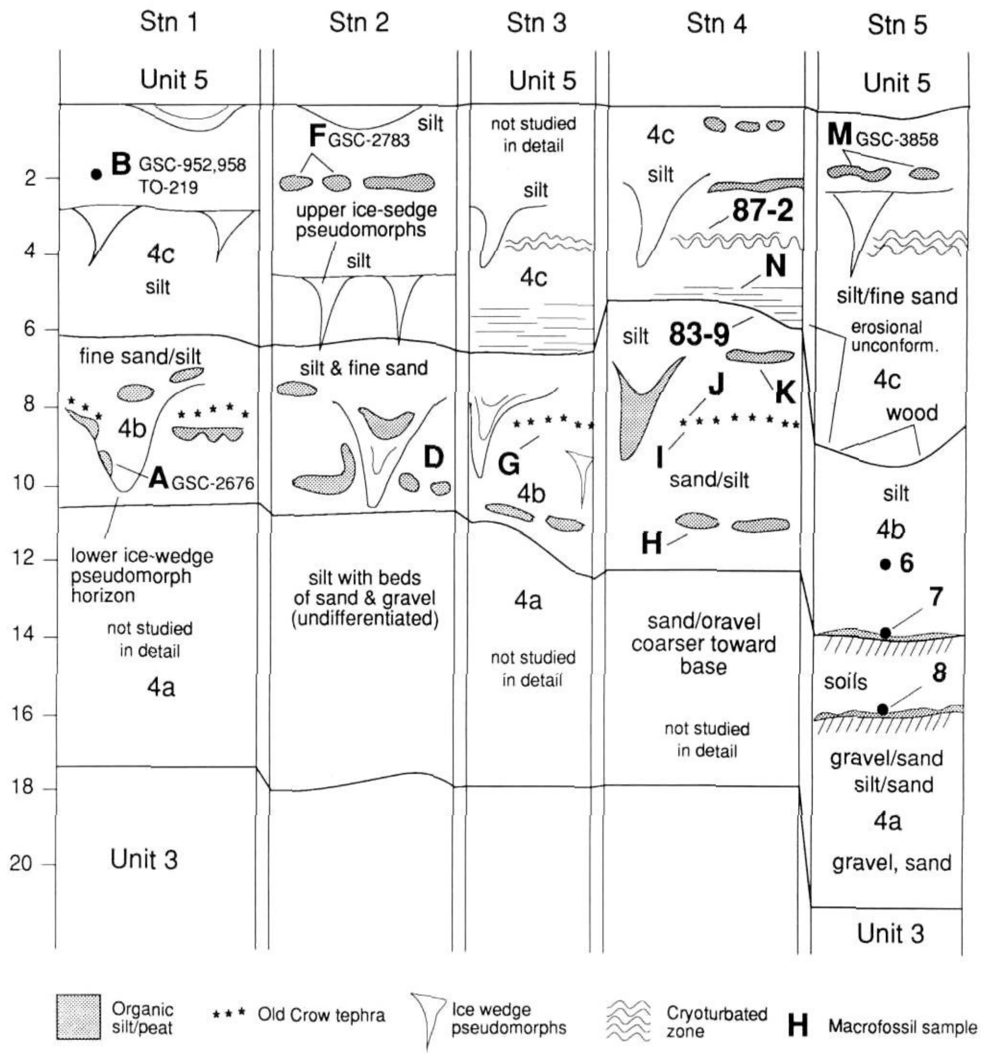


FIGURE 4. Simplified and interpolated stratigraphy of Unit 4 at Ch'ijee's Bluff (see Fig. 2 for location of stations). Bold-faced letters and numbers indicate macrofossil and pollen samples discussed in the text and shown in Tables II,III,IV,V and VI.

Stratigraphie simplifiée et interpolée de l'unité n° 4 de Ch'ijee's Bluff (voir l'emplacement des sites à la fig. 2). Les lettres et les chiffres en caractères gras identifient les macrofossiles et les échantillons de pollen dont on parle dans le texte et dans les tableaux II à VI.

Neither the tephra, peats, nor the lower pseudomorph zone are evident in the upper part of Unit 4b downstream from Station 4 (Fig. 4). They were probably removed during a phase of planation and downcutting, which may have been associated with the start of the alluvial cycle responsible for the lower part of Unit 4c.

Unit 4c (6-10 m thick) consists mostly of silt and sand, with abundant woody or peaty concentrations and like Unit 4b also contains a conspicuous horizon of ice-wedge pseudomorphs, though somewhat smaller than those of the lower zone. The lowest sediments in 4c are lacustrine and alluvial silt with local concentrations of wood including logs up to 25 cm in diameter. The lacustrine sediments give way higher in the section to a zone of tightly folded cryoturbation structures, which are stratigraphically below the upper most pseudomorph horizon. Both the cryoturbation horizon and the pseudomorph zone are seen at other stations along the length of the exposure (Fig. 4). The pseudomorph horizon in Unit 4c is truncated at several stations. At some sites a discontinuous peat horizon formed of autochthonous pond deposits and dated at >37 ka BP at Station 2 (Sample F: GSC-2783, Fig. 4, Table I) occurs in the upper part of Unit 4c.

Another intermittent organic horizon occurs higher in Unit 4c, *e.g.*, approximately 1-2 m beneath the contact with Unit 5 at Station 5 (Sample M, Fig. 4). It has been dated at >47 ka BP (GSC-3858, Fig. 4, Table I), which is perplexing in view of finite dates of 32 and 30.5 ka BP (GSC-952) from an equivalent or lower level at one of the upstream stations (Sample A at Station 1, Fig. 4, Table I). The most plausible explanation for this discrepancy is that the peat at Station 5 though somewhat fibrous and appearing to be autochthonous is of thaw lake origin and potentially contains rebedded, older wood and other organic debris.

At several stations (*e.g.*, Stations 1 and 2, Fig. 4) channel or sag structures occur at the contact of Units 4c and 5. Some probably represent ice bodies which thawed when the region was inundated by the lake responsible for Unit 5 sediments. Others may be channels cut at about the time of meltwater flooding of the basin.

UNIT 5

In a previous description of the Ch'ijee's Bluff exposure (Matthews, 1975), Unit 4a and combined Units 4b and 4c were assigned to individual units. Thus Unit 5 of that study is not the

TABLE I

Radiocarbon Dates from Ch'ijee's Bluff

Date No.	Age	Unit/Station	Material	Comments
GSC-121	10 740±180	6	peat	Marly peat approx. 1.1 m below surface. Associated with pollen data published by Lichti-Federovich (1974)
GSC-952	32 400±770	4c/1	shells	*Pisidium* shells from a zone 1.5-2.4 m below top of Unit 4 which is rich in shelly material, including ostracods as well as plant and insect macrofossils (Matthews, 1975; Blake, 1984).
TO-219	30 590±220	4c/1	shells	Accelerator date from same sample of *Psidium* shells used for GSC-952. Associated with macrofossil Sample B (see also Matthews, 1975)
GSC-199	>41 300	4b/6	wood	1.6 m below top of Unit 4 (McAllister and Harington, 1969; Lichti-Federovich, 1974; C. R. Harington, pers. comm., 1990). Approximately the same horizon as sample for GSC-952
GSC-958	>37 000	4c/1	wood	Wood from approximately same level as GSC-952. Probably rebedded from an older unit
GSC-1189	>39 000	4c?/6	organic detritus	5.2 m below top of Unit 4. Not shown on Figure 3. Associated with pollen sequence in Lichti-Federovich (1974).
GSC-2676	>53 000	4b/1	wood	*Salix* fragments isolated from autochthonous peat filling and adjacent to large ice wedge pseudomorph and below Old Crow tephra (Blake, 1984). Hence actual age is >150 000 ka BP.
GSC-2783	>37 000	4c/2	wood	Woody fragments isolated from pond peat sampled for pollen and macrofossils (Sample F in Tables II and III) (Blake, 1984).
GSC-3858	>47 000	4c/5	wood	Wood fragments isolated from discontinuous peat approximately 1 m below top of Unit 4 (Blake, 1984). Overlying massive silt contains fossils indicating start of meltwater inflow to the basin. The peat is now thought to represent basal organics of a thaw lake deposit; hence dated material is likely to be rebedded from an older unit. See sample M in Tables III and V.

same as Unit 5 of this report. In this paper Unit 5 is defined as the sequence of ice-rich glaciolacustrine silt and clay that caps Unit 4. It liquefies and flows when exposed, which causes distinctive retrogressive-thaw/flow slides at the top of the section. Similar features are seen at the tops of river exposures throughout the Old Crow and Bluefish Basins.

The silt and clay of Unit 5 is glaciolacustrine in origin and was deposited when glacial meltwater was diverted into the area starting at approximately 30 ka BP. A date from another exposure in the Bluefish Basin (HH75-24: McCourt, 1982) shows that the highest lake level may not have been attained until after 20.8 ka BP (GSC-3964: Blake, 1987). In the nearby Old Crow Basin dates on fluvial sediments capping the same glaciolacustrine unit indicate that the lake was in the process of draining by 12.5 ka BP (I-3574: Blake, 1984; Harington, 1977).

Unit 5 is notable because of its low organic content. Organic debris such as have been seen in all other units are absent. Even pollen is rare, probably because the sediments were deposited rapidly in a large, deep lake. Of the palynomorphs that are present, most are pre-Quaternary types.

UNIT 6

Unit 6 consists of 1.2 to 6 m of silt with wood and organic detritus grading upward into woody peat. Most of the silt is probably fluvial with local lenses of pond sediment. The peat near the top is locally overlain by up to one-half metre of cliff-top loess. Unit 6 contains large ice-wedges. They intrude sediments as old as 10.7 ka BP and may have started to form during the early Holocene. Some of them display flat tops which are below the current permafrost table, indicating a period of deeper regional thawing during the Holocene. At least one ice wedge at Ch'ijee's Bluff contains a rejuvenated wedge on top of a thawed down wedge signifying a subsequent period of cooling only slightly before the present.

PALYNOLOGY

SPECTRA FROM STATIONS OTHER THAN STATION 4

Lichti-Federovich (1974) conducted the first detailed pollen study of Ch'ijee's Bluff. Her samples came mostly from a downstream section (Station 6, Fig. 2) but the uppermost ones, including several associated with Old Crow tephra (Table II), come from Station HH70-2 at the upstream end of the section (Fig. 2).

Pollen samples have been collected immediately above and below OCt at Station 4, but have yielded very poorly preserved, rare pollen. Therefore, it is necessary to refer to samples from another station in order to determine environmental conditions at the time of the tephra fall. Two such samples (1 and 2, Table II) were analyzed by Lichti-Federovich but never published by her. Both are from Station HH70-2 shown in Figure 2. One was collected 12 cm above and the other 8 cm below the tephra. The one above the tephra is dominated by Cyperaceae pollen which might be the result of temporary vegetation caused by disturbance associated with the ash fall. One of the authors (CES) has demonstrated a similar abrupt shift to high Cyperaceae percentages in samples immediately above the Little Timber tephra, an early Quaternary to late Tertiary tephra in the Old Crow Basin. The pollen sample from below Old Crow tephra (Sample 1, Table II) contains a low percentage of spruce (*Picea*), high percentage of birch (*Betula*) and relatively high percentages of grass (Gramineae) and sedge (Cyperaceae). It suggests that the tephra was deposited when birch-

TABLE II

Miscellaneous pollen samples from Ch'ijee's stations other than Station 4[a]

Sample Number	1[b]	2[c]	3	5	6	7	8[d]	9[e]
Station	70-2	70-2	1	2	5	5	5	5
Equivalent Macro. Sample.			A	F				M
Unit #	4b	4b	4b	4c	4a	4a	4a	4c
Picea	7	4		32	+	+		2-21
Pinus	1			+[f]		+		
Larix				+				+
Alnus		1	+	8		2		1-2
Betula	7	40	6	13	6	45	12-38	10-16
Coryloid type						+	0-+	
Salix	11	8	2	5	4	3	3-11	2-5
Populus				+				
Cyperaceae	49	11	78	28	86	32	44-74	44-65
Gramineae	14	28	8	6	2	8	1-5	10-16
Artemisia	+		+	+	1	1	1-2	+
Other Compositae	1	1	2		1			
Ericaceae	+	+		5		5	0-1	+
Rosaceae undif.			+	1	1	1	2-5	1
Rosa type								+
Rubus chamaemorus				+				
Liliaceae								+
Potentilla undif.				+				+
Chenopodium-Amaranthus	3		2					1-2
Umbelliferae				1				1
Valeriana								1
Caryophyllaceae	1	+	+		1	1	0-1	
Polemonium			+			1		
Epilobium							0-2	
Ranunculus type	+	+						
Thalictrum	+	+				+	+	
Caltha type						1	0-1	+-2
Phlox sibirica	+		+					
POLLEN SUM	257	364	479	518	200	288	200	200-519
Unknown Pollen	+	+						+-2
Indeterminable			19	3	18	10	6-20	3-7
Lycopodium	+			1				+-1
Sphagnum			1	2		3	0-27	1-3
Monolete spore	+					1	0-1	0-1
Trilete Spore	+		+					0-1
Pediastrum				1				
Botryococcus				2				
Pre-Quat. palynomorphs				+				1

a. All samples studied by CES except 1 and 2 which were studied by Lichti-Federovich and first published in Schweger and Matthews (1985). All pollen percentages are rounded to the nearest whole value; therefore, some totals may not sum to 100%.
b. Lichti-Federovich sample HH 70-2b (0.4a): Approximately 12 cm above Old Crow tephra
c. Lichti-Federovich sample HH 70-2b (0.16b): Approximately 8 cm below Old Crow tephra
d. Range of values for two samples (Sch 4-7-81-23&24) from the same autochthonous peat; pollen total for both = 200 grains
e. Range of values for four samples from same stratigraphic horizon.
f. + indicates values less than 1%

dominated tundra existed in the Bluefish Basin and climate was colder than at present. This finding agrees with the evidence from macrofossils in samples above and below the tephra at Station 4 (see below).

Sample 3 in Table II comes from a peat draped into an ice-wedge pseudomorph of the lower pseudomorph horizon at Station 1. It is the same peat shown in Figure 5 of Westgate *et al.*, 1983 and the source for macrofossil Sample A (Fig. 4). This peat probably formed shortly before deposition of Old Crow tephra and hence is approximately 150 ka in age. The pollen spectrum is dominated by Cyperaceae (78%) and Gramineae (8%), with 6% *Betula* and 2% *Salix*, indicating that the peat formed when the region was tundra and regional climate was colder than at present. The abundance of Cyperaceae pollen is probably due to local presence of sedges, which the macrofossil data show (see below) were probably *Carex aquatilis* and *Eleocharis*.

Three other pollen samples in Table II come from Unit 4a. They are from three silt beds, each less than a metre in thickness, in the sandy peat gravel of Unit 4a at Station 5. Sample 7 is from a paleosol composed of a 3-5 cm thick organic horizon capping a cryoturbated gravelly silt. In Table II, percentages for sample 8 show the range of values of two separate samples from an autochthonous peat lower in the unit and overlying yet another cryoturbated silt (paleosol?). The differences of pollen percentages are most likely due to differential representation of local sedge pollen. All three spectra show that at least for part of the time during deposition of 4a, shrub tundra existed at the site of Ch'ijee's Bluff.

Sample 5 in Table II comes from an autochthonous peat (Sample F, Fig. 4). *Picea* dominates (32%) along with Cyperaceae (28%) and *Betula* (13%). *Alnus* reaches 8% and there are trace quantities of *Populus* and *Larix*. This pollen record represents at least boreal woodland vegetation and possibly a boreal forest environment and climate like that of the present.

Pollen sample 9 represents a combination of four samples collected over a 12 m lateral distance in the same peat horizon (Sample M, Fig. 4). The peat is up to 50 cm thick and located 1.2 m below the base of the Unit 5 glaciolacustrine clay. Cyperaceae pollen (44-65%) dominates these spectra along with Gramineae (10-16%), and *Betula* (10-14%); *Picea* ranges from 2 to 21% and there are consistently low values (1-2%) for *Alnus*. The collection site was no doubt within the regional limit of spruce and climate was probably also like that of the present. According to Lichti-Federovich (1974) climate cooled abruptly shortly after deposition of the peat, but it should be noted that her samples indicating this trend come from Station HH70-2 at the upstream part of the section. The possible thaw lake origin of the peat yielding sample 9 may mean that the pollen spectra are mixed assemblages of dubious significance.

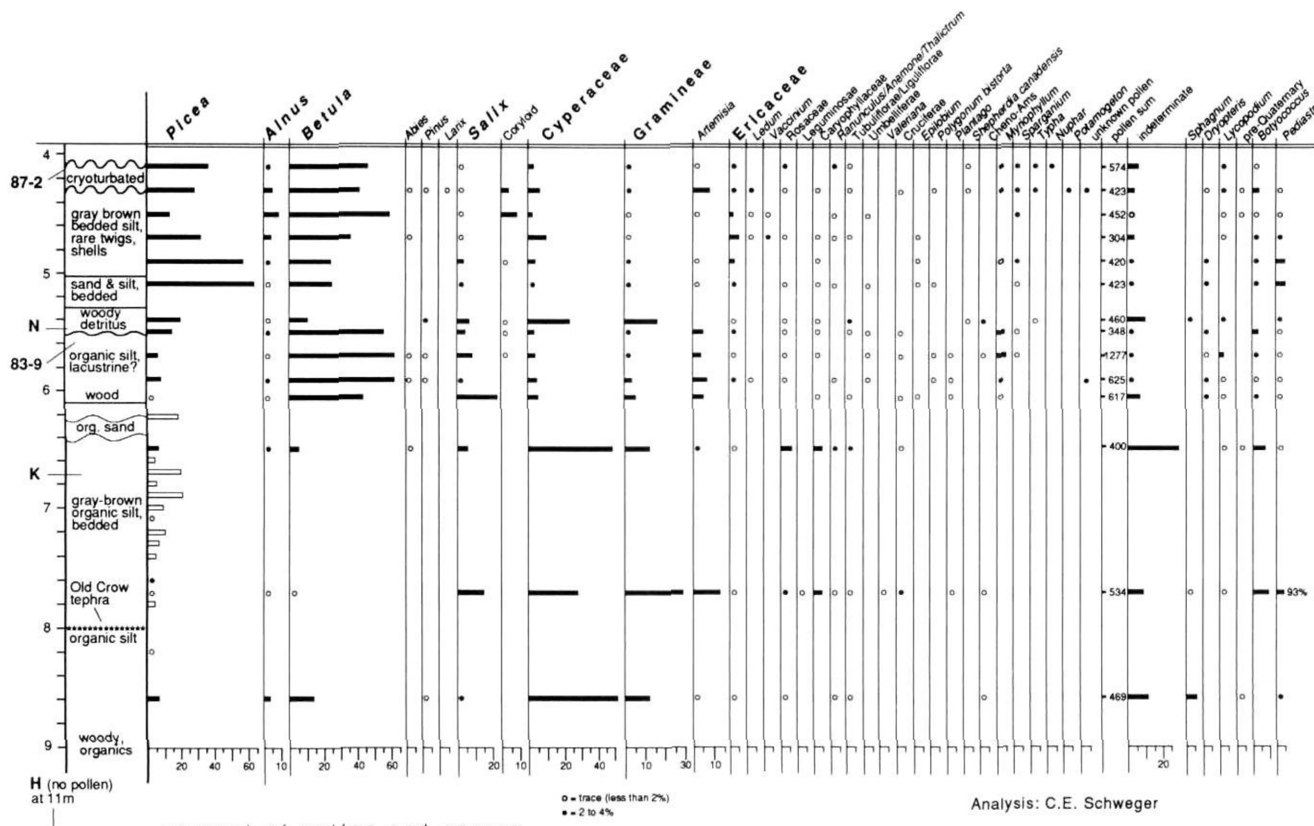


FIGURE 5. Pollen diagram from part of Unit 4 at Station 4 (Fig. 2). Depth is shown in metres below base of Unit 5 and follows numbers shown in Figure 4.

Diagramme pollinique d'une partie de l'unité n° 4 au site n° 4 (fig. 2). La profondeur est en mètres et suit la stratigraphie de la figure 4.

STATION 4 POLLEN DATA

The most important sequence of pollen samples discussed here is from Station 4 (Fig. 5) because it yielded several samples that undoubtedly represent interglacial conditions. The diagram charts samples collected over a 5 m vertical interval starting about 60 cm below OCt, with emphasis on the 2.5 m of the section known to include macrofossils indicative of warm climate. Unfilled bars in the *Picea* column of Figure 5 represent the results of preliminary counts on additional samples located between the level of Old Crow tephra and the base of Unit 4c.

The diagram shows a high peak of spruce pollen similar to that recorded from Unit 4 by Lichti-Federovich (1974) (Fig. 3) at Station 6 more than 1.5 km downstream from Station 4 (Fig. 2). The fact that this feature is seen at two widely separated stations means that it is more likely to reflect regional than local vegetation — always a concern when dealing with pollen from alluvium. Not evident in Figure 5 are the relatively high percentages of pine (well above trace levels) which Lichti-Federovich noted from Unit 4 (Fig. 3). This difference may be due to the fact that Lichti-Federovich's samples came from a part of the section with a significant erosional hiatus between Units 4b and 4c. In other words, the pine pollen in her spectra may being rebedded from older units. Indeed, the recast of her data presented in Figure 3 shows a small peak of pine pollen at about the position of this unconformity — exactly what would be expected if the pine pollen was rebedded from older sediments. Lichti-Federovich's spectra also differ from those in Figure 5 by having relatively high percentages of *Alnus* coincident with the peak in *Picea*. We have no explanation for this except that it may be due to differences in local vegetation at the two sites.

The pollen spectra associated with macrofossil Sample N (710-720 cm interval, Fig. 5) show approximately 15-20% *Picea*, 10% to almost 60% *Betula*, less than 10% *Salix*, 5-20% Cyperaceae and in one sample greater than 15% Gramineae pollen. These assemblages resemble modern surface pollen spectra from the northern Yukon except that *Alnus*, normally a major constituent in northern surface spectra, is present only as a trace. There is a trace of *Typha* pollen in one of these samples, which is significant because *Typha* does not occur as far north today (Fig. 6a). Two to four percent pine (*Pinus*) pollen occurs in one of the samples. Trace amounts of pine pollen are often seen in the northern Yukon, which is well beyond the northern limit of pines. But low *Pinus* percentages do not necessarily mean that pines were far from the site. One of the authors (CES) has recorded modern *Pinus* pollen percentages in the 2-7% range at the regional limit of *P. contorta* in the central Yukon (Hughes *et al.*, 1981).

The spectra from the 710 and 720 cm levels probably represent regional vegetation composed of a mixture of boreal plants (*Picea, Betula, Alnus, Shepherdia canadensis*), floodplain taxa (Gramineae, Chenopod-*Amaranthus, Artemisia*, other Compositae) and pond plants (*Salix*, Cyperaceae, *Potentilla palustris, Typha*).

Spruce percentages peak at greater than 65% in the sand between 740 and 760 cm and remain above 30% in all but one sample up to the 850 cm level. These values are much higher than is normally seen in surface samples from the region and must mark extensive tracts of closed spruce forest as opposed to the open spruce forests of the present. As with the other samples shown in Figure 5, *Alnus* occurs at frequencies below 10% and often below 4%. As indicated above, this may be a local effect.

Several of the samples in Figure 5 represent Unit 4b which contains OCt. The sample from the 490 cm level, like those associated with OCt at Station HH70-2 (see above), probably represents tundra conditions. Tundra conditions probably did not persist throughout the time represented by Unit 4b because of *Picea* percentages (open bars) rise to a peak at about the 580-590 interval. Macrofossil Sample K comes from about the same level has also yielded a few spruce needles.

PLANT MACROFOSSILS

STATIONS OTHER THAN STATION 4

Table III and IV list plant macrofossils from Unit 4 at Ch'ijee's Bluff. Table IV includes taxa identified in samples collected only at Station 4.

During deposition of Sample A, shrub birches grew close enough to contribute abundant nutlets or samaras, but the site of deposition was obviously a damp depression as signified by the abundance of achenes of *Carex aquatilis*. As indicated below, some of the insect fossils show that the peat from which this sample comes is autochthonous. Presence of abundant fungal sclerotia in a sample such as A is also usually a good indication that the sediments represent a surface or soil.

Fossils from Sample B at Station 1 have been discussed elsewhere (Matthews, 1975). All that need be noted here is that *Picea* was represented by a single needle, which might be a contaminant rebedded from older sediments.

The mosses from Sample F at Station 2 suggest a rich-fen assemblage indicating moderate minerotrophy and aquatic habitat. No upland taxa are represented. The Amblystegiaceae species suggest a non-shaded environment. *Carex* achenes, mostly *Carex aquatilis*, account for 70% of the vascular plant macrofossils. They are accompanied by other wetland taxa like *Menyanthes trifoliata, Potentilla palustris*, and *Ranunculus trichophyllus* type. Some of the *Menyanthes* seeds from Sample F are as small or smaller than 2 mm, a condition rarely seen in Quaternary assemblages, but relatively common in late Tertiary plant assemblages from the Arctic (Matthews and Ovenden, in press).

The pollen sample associated with Sample F contains a high percentage of *Picea* (see above). A few spruce needles are present in the macrofossil sample, but they certainly are not abundant as in some of the samples from Station 4 (see below). It is noteworthy that arboreal type birch nutlets are also present in Sample F. This supports the pollen evidence that vegetation (and climate?) was similar to that of the present.

Sample G comes from immediately beneath OCt at Station 3. At this site, in contrast with the situation at Station 4, the tephra is rebedded. Nevertheless, the macrofossil content of the sample is similar to those immediately above and below the tephra at Station 4.

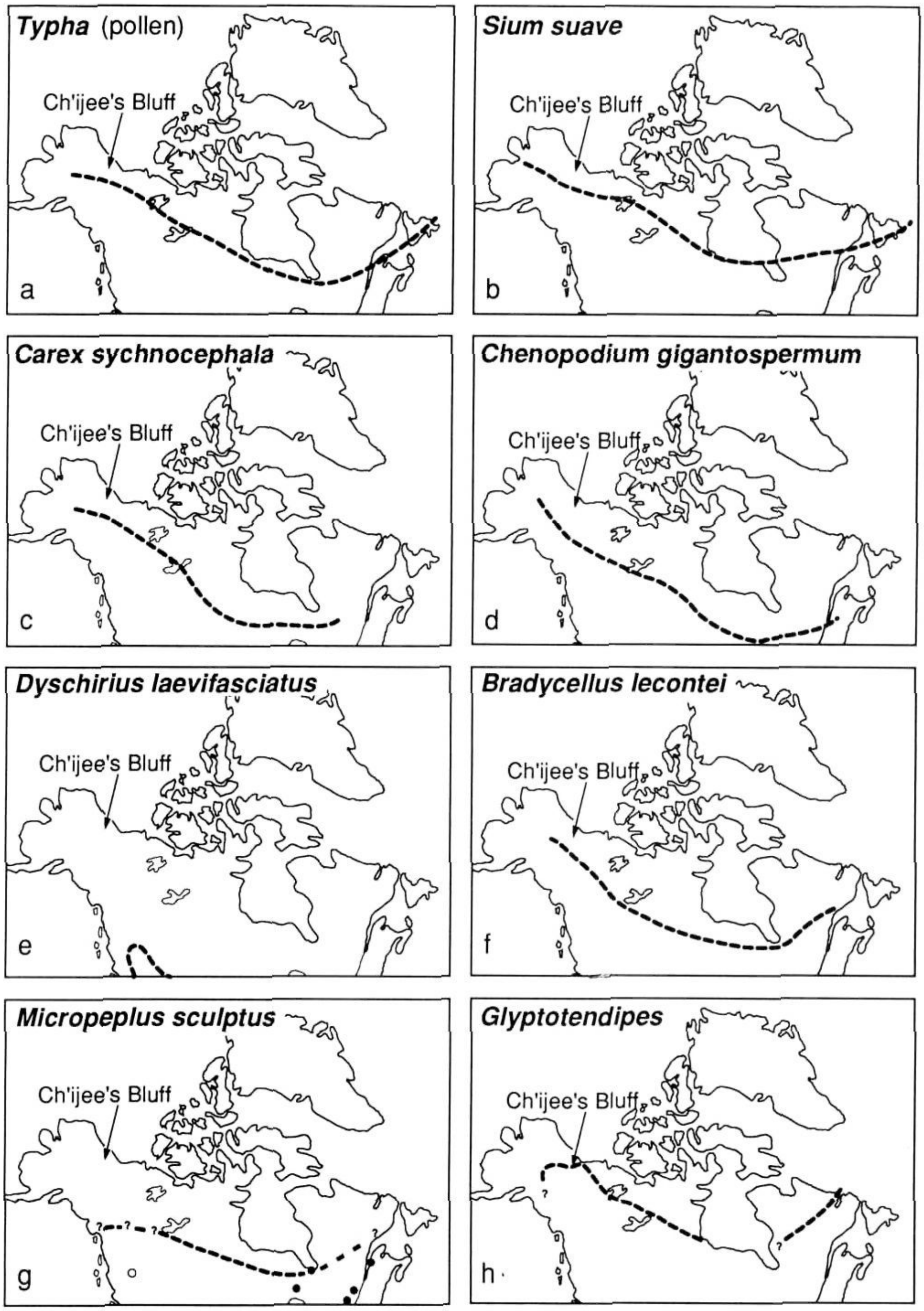


FIGURE 6. Present distribution of some plants and insects from interglacial units at Ch'ijee's Bluff. Distribution of plants in a,b, and c from Porsild and Cody (1980); *Chenopodium gigantospermum* (d) is from Bassett and Crompton (1982). Distribution of the carabid beetles *Dyschirius laevifasciatus* (e) and *Bradycellus lecontei* (f) from Lindroth (1968), Bousquet (1988) and D. Kavanaugh (California Acad. of Sciences, pers. comm., 1988). Distribution of the micropepline beetle *Micropeplus sculptus* (g) from J. M. Campbell (1978 and pers. comm., 1990). The rarity of *M. sculptus* localities is indicated by the dots; the open circle signifies a provincial locality only. Distribution of the chironomid fly *Glyptotendipes* (h) is from I. Walker, Queen's University (pers. comm. 1990) and Wiens *et al.* (1975).

Répartitions actuelles de quelques végétaux et insectes observés dans les unités interglaciaires de Ch'ijee's Bluff. Répartitions des végétaux (a,b et c) selon Porsild et Cody (1980); de Chenopodium gigantospermum *(d) selon Bassett et Crompton (1982); de* Dyschirius laevifasciatus *(e) et de* Bradycellus lecontei *(f) selon Lindroth (1968), Bousquet (1988) et D. Kavanaugh (California Acad. of Sciences, comm. pers., 1988); de* Micropeplus sculptus *(g) selon J. M. Campbell (1978 et comm. pers., 1990) (les rares sites de* M. sculptus *sont indiqués par des points; le cercle blanc montre un site uniquement provincial); de* Glyptotendipes *(h) selon I. Walker (Queen's University, comm. pers., 1990) et de Wiens* et al. *(1975).*

Sample M contained few plant macrofossils. This may mean that despite its apparent fibrous character it is well sorted, a condition seen in the basal peat of thaw lakes. Normally fungal sclerotia are abundant in autochthonous deposits. In this case they likely owe their abundance to sorting associated with the development of a thaw lake.

STATION 4 PLANT MACROFOSSILS

Macrofossils from Unit 4 Station 4 are listed in Table IV. Sample H comes from a peaty horizon well below the lowermost ice wedge pseudomorph horizon and well below Old Crow tephra, making it older than 150 ka BP. Species composition of the mosses and the relative species diversity are an excellent representation of a minerotrophic fen (rich-fen). *Sphagnum squarrosum* and *Drepanocladus fluitans* indicate a slight acidophylous influence, possibly caused by accumulation of the autochthonous peat. The only upland moss species, represented by a single poorly preserved fragment, is *Dicranum groenlandicum*. No clear indication of shading is suggested, except by the presence of *Sphagnum squarrosum*. Vascular plant fossils from Sample H are dominated by *Carex aquatilis*. The presence of *Potentilla palustris* and *Menyanthes trifoliata* supports the conclusion based on bryophyte fossils, *i.e.*, it was not a seasonally dry site.

TABLE III

Plant Macrofossils from Ch'ijee's Bluff, Unit 4 (excluding Station 4)

Taxa	Stn-1 A	Stn-1 B	Stn-2 F	Stn-3 G	Stn-5 M
Fungal sclerotia	++				++
Bryophytes[a]	+	+		+	+
Calliergon giganteum (Schimp.) Kindb.			+		
Drepanocladus sp.			+		
Depanocladus exannulatus (B.S.G.) Warnst.			+		
Drepanocladus crassicostatus Janssens			+		
Pinaceae					
Picea sp.		+	+	+	
Sparganiaceae					
Sparganium hyperboreum Laest.			+		
Potamogetonaceae					
Potamogeton praelongus type	+				
P. filiformis Pers.		?			
P. Richardsonii (Benn.) Rydb.		+			
Potamogeton sp.			+	+	
Cyperaceae					
Carex aquatilis Wahlenb.	++		?	?	+
Carex spp.		+	+	++	
Eleocharis palustris-uniglumis typ.	+	+	+		+
Eleocharis sp.			+	+	
Araceae					
Calla palustris L.			+		
Salicaceae					
Salix sp.	+				
Betulaceae					
Betula sp. (large shrub/tree type)			+		
Betula sp. (dwarf shrub type)	++		+		
Chenopodiaceae					
Chenopodium sp.	+				
Caryophillaceae					
Stellaria sp.	+				
genus?	+		?		
Nymphaeaceae					
Nuphar sp.			+		
Ranunculaceae					
Ranunculus hyperboreus Rottb.			+		
R. trichophyllus type		+			
R. pedatifidus Sm.		cf.			
Ranunculus sp.	+				
Cruciferae					
Rorippa islandica type			+		
Rosaceae					
Potentilla palustris (L.) Scop.			+		
Potentilla sp.	+	+			
Rosa acicularis Lindl.			?		
Rubus idaeus type			+		
Haloragaceae					
Hippuris sp.			+		
Gentianaceae					
Menyanthes trifoliata L.			+		
Menyanthes small type			+		
Compositae					
genus?	+				

+ = taxon present; + + = taxon abundant; ? = identification questioned due to poor preservation; cf. = taxon well enough preserved for identification but identification is tentative.
a. Bryophytes studied by JJ only for Sample F

Samples I and J come from immediately below and above Old Crow tephra, respectively. The tephra at Station 4 has not been rebedded and appears to have been deposited in hummocky terrain, containing an abundance of willow (represented by upright stems, buried by the tephra). One of the samples contains a *Picea* needle, but this may be rebedded from an older deposit. Fruits of *Potamogeton* are abundant in the sample below the tephra. This, along with abundant *Carex* achenes and fruits of *Ranunculus trichophyllus* type suggests an aquatic environment. As indicated below the insect fossils do not support this conclusion.

The peat of macrofossil Sample K may be correlative with the one represented by Sample A at Station 1. Fossils are rare and those present offer little evidence except they do show that climate was not too cold for *Menyanthes*, a plant which does not grow in areas colder than low arctic tundra. The pollen data (Fig. 5) also suggest that Sample K was deposited during a period of relatively warm climate, at least warmer than during deposition of OCt.

Pollen data associated with sample 83-9 suggest birch-dominated shrub tundra. This is definitely not the conclusion to be drawn from the macrofossil list, containing taxa such as *Sagittaria, Carex sychnocephala* and *Ceratophyllum demersum*. Among the macrofossils are a few needles of *Picea*. Strangely, even though *Betula* is the most abundant pollen taxon in samples associated with 83-9, birch macrofossils were not seen.

Two macrofossil samples, N and 87-2 (Fig. 4) from Station 4 come from the zone of the pollen diagram containing highest percentages of *Picea* pollen. They stand apart from the others at the section by their diversity of taxa (a minimum of 78 species) among which are several that today do not now occur as far north as the site (Fig. 6b, 6c and 6d).

Sample N is from the basal 20 cm of Unit 4c at Station 4. Its sediments contain an abundance of snails and pelecypods and evidently represent an ox-bow pond. As indicated in Figure 4, similar sediments are found for some distance along the length of the exposure so it is probable that the ox-bow meander was at least as large as those typical of the present river system.

The most common species of mosses in assemblage N (Table IV) is *Hylocomium splendens*, represented by perfectly preserved sympodially branched fragments. This growth form is commonly found under well-developed coniferous forest can-

TABLE IV

Plant Macrofossils from Ch'ijee's Bluff, Unit 4 at Station 4

Taxa	H	I	J	K	83-9	N	87-2
Fungal sclerotia	++						
Characeae							
Chara sp.							+
Nitella sp.						+	+
Bryophytes[a]		+	+		+		
Hylocomium splendens (Hedw.) B.S.G.						++	
Calliergon giganteum (Schimp.) Kindb.	+						
Sphagnum squarrosum Crome	+						+
Sphagnum sect. *Acutifolia*						+	+
Sphagnum sect. *Cuspidata*							+
Tomenthypnum nitens (Hedw.) Loeske						+	
Drepanocladus sp.	++						
Drepanocladus uncinatus (Hedw.) Warnst.						+	++
Drepanocladus exannulatus (B.S.G.) Warnst.	+						
Drepanocladus fluitans (Hedw.) Warnst.	+						
Meesia triquetra (Richt.) Angstr.	+						
Aulacomnium palustre (Hedw.) Schwaegr.	+						
Bryum pseudotriquetrum (Hedw.)	+						
Dicranum groenlandicum Brid.	+						
Scorpidium scorpioides (Hedw.) Limpr.				+			
Isoetaceae							
Isoetes sp.						?	
Pinaceae							
**Picea* sp.	+	+		+	+	++	+
Juniperus communis L. (seed)						+	
Typhaceae							
Typha sp.							+
Alismaceae							
***Alisma gramineum* K. C. Gmel.						+	
Alisma sp.							++
**Sagittaria cuneata* Sheld.					+	+	
Sparganiaceae							
Sparganium hyperboreum Laest.						+	+
Sparganium sp.						+	
Potamogetonaceae							
Potamogeton praelongus typ.						+	
P. zosteriformis Fern.						+	
P. filiformis Pers.						+	
P. Richardsonii (Benn.) Rydb.						+	
P. pectinatus L.						+	+
Potamogeton sp.		++			+	+	+
Najadaceae							
Najas flexilis (Willd.)						+	
Gramineae							
**Glyceria* sp.						+	+
Beckmannia Syzigachne (Steud.) Fern.							+
Hierochloe sp.						?	?
Cyperaceae							
Carex aquatilis Wahlenb.	++	?	?			+	
Carex chordorrhiza L.	+					+	
Carex diandra type						+	
Carex rostrata Stokes						+	+
***Carex sychnocephala* Carey					+	+	++
Carex spp.		++	++		+	+	
Eleocharis acicularis (L.) R.&S.							++
E. palustris-uniglumis typ.					+	+	+
Eriophorum sp.						+	
Scirpus validus Vahl.						+	+
***Scirpus microcarpus Presl*						cf.	
Salicaceae							
Salix sp.	+	+					+
Betulaceae							
Betula sp. (shrub species)	+					+	+
Polygonaceae							
**Polygonum lapathifolium* L.						+	+
Polygonum amphibium tyype							+
Rumex maritimus L.					+		+
Chenopodiaceae							
Chenopodium sp.						+	+
***C. gigantospermum* Aellen						+	
Corispermum hyssopifolium L.						+	
Caryophyllaceae							
Moehringia sp.						?	
Ceratophyllaceae							
**Ceratophyllum demersum* L.					+	+	+
Nymphaeaceae							
Nuphar sp.						+	
Ranunculaceae							
Ranunculus sp.						+	
**R. sceleratus* type						+	+
R. hyperboreus Rottb.					+	+	+
R. trichophyllus type		++				+	+
R. pensylvanicus/Macounii type						+	
Anemone narcissiflora L.						+	
Cruciferae							
Rorippa islandica type					+	+	+
Rosaceae							
Potentilla sp.		++	++			+	+
Potentilla palustris (L.) Scop.	+				+	+	+
Potentilla norvegica L.					+	+	+
Rosa sp.			+				
Rubus idaeus type	+					+	
***Rubus spectabilis* Pursh.						cf.	
Haloragaceae							
Hippuris sp.						+	+
Myriophyllum spicatum type						+	
Umbelliferae							
***Sium suave* Walt.						+	
Genus?					+		+
Ericaceae							
Empetrum nigrum L.						+	+
Arctostaphylos alpina/rubra type						+	
A. uva-ursi (L.) Spreng.						+	
Andromeda polifolia L.						+	+
Primulaceae							
Primula sp.						+	
Cornaceae							
**Cornus stolinifera* Michx.						+	
Cornus suecica L.						+	
Gentianaceae							
Menyanthes trifoliata L.	+			+		+	
Menyanthes small type						+	+
Labiatae							
**Mentha* sp.						+	+
***Stachys* sp.						+	
**Scutellaria galericulata* L.						+	
Compositae							
***Bidens frondosa* type						+	

a. Bryophytes studied by JJ only for Samples H, N and 87-2

+ = taxon present; ++ = taxon abundant; ? = identification questioned due to poor preservation; cf. = taxon well enough preserved for identification but identification is tentative. *indicates taxa which seldom occur beyond tree line and have a northern distributional limit near Ch'ijee's Bluff today. **indicates taxa which apparently have their present northern distributional limit significantly south of Ch'ijee's Bluff.

opy. *Drepanocladus uncinatus* is also associated with mesic forest floor vegetation. *Sphagnum* and *Tomenthypnum nitens* indicate the presence of minerotrophic wetland habitats, in this case possibly small woodland depressions or the shoreline of an ox-bow pond.

Many of the vascular plant taxa in Sample N are either aquatic or hygrophilous in habit, as would be expected of a quiet backwater or cut-off meander of a large stream. Preservation of many of the fossils is exceptional. For example, though it is not ususual to find gemmules of freshwater sponges in Pleistocene samples, clusters of them still attached to their substrata are rare. Many of the *Carex* fossils still retain their enclosing perigynium, some of the *Potamogeton* fruits still possess the exocarp and mesocarp, rarely observed on fossils. In addition to abundant spruce needles (most of them the white spruce type — lacking resin canals), spruce seeds and spruce cone fragments, the sediments even contain spruce sporangia, still packed with pollen.

At least seven of the vascular plant species listed for Sample N are not currently found as far north as Ch'ijee's Bluff. Some of these are illustrated in Figure 7. Many other vascular plants from Sample N are restricted to sites within tree line and thus are at their regional limit at Ch'ijee's Bluff. Clearly the lacustrine sediments at the base of Unit 4c at Station 4 were deposited when climate was warmer than at present. No estimate of the actual difference in mean July temperature or any other mean value is possible because the autecology of the taxa represented by the fossils is little known. Furthermore most of them are aquatic or near aquatic species which are known sometimes to be unreliable indicators of macroclimatic conditions.

The macrofossil sample labeled 87-2 comes from the cryoturbated zone which can be seen in approximately the same position at a number of stations (Fig. 4). Plant fossils are abundant, yet not as diverse in the pond sediments of Sample N. The dominant moss, *Sphagnum*, suggests an allochthonous assemblage. All taxa represented indicate a wetland habitat, probably quite minerotrophic. The vascular plant macrofossils also suggest a wetland habitat. *Eleocharis acicularis* rarely represented in fossil assemblage from northern Canada is dominant. The species grows today on muddy shorelines. Fruits of *Alisma* are also abundant. No species of this genus occur in the Yukon today (Porsild and Cody, 1980).

Although there is always a danger in using negative evidence, there is one plant which is notable because of its absence from assemblages N and 87-2. These are the distinctive seeds of the extinct genus *Aracites*, which is thought to be a member of the family Araceae. *Aracites* seeds are extremely indurate and readily identified, so if they were growing anywhere in the vicinity of the pond which formed the base of Unit 4c, they would likely have occurred as fossils. They are abundant in most Tertiary assemblages from the north, including Ch'ijee's Unit 1 (Matthews and Ovenden, in press) and even occur in interglacial sediments in Labrador (Klassen *et al.*, 1988). Proof that they had become extinct in the north before the time of the last interglaciation would make them a potentially valuable fossil for correlating interglacial deposits from different sites.

INSECT AND OTHER ARTHROPOD FOSSILS

STATIONS OTHER THAN STATION 4

Tables V and VI list taxa of insects, other arthropods and animal fossils (excluding vertebrates) recovered from various levels of Unit 4 at Ch'ijee's Bluff. The fossils from Station 4 are shown in Table VI. The same convention on the use of asterisks to designate taxa of potential climatic significance is used in Table VI as for plants in Table IV.

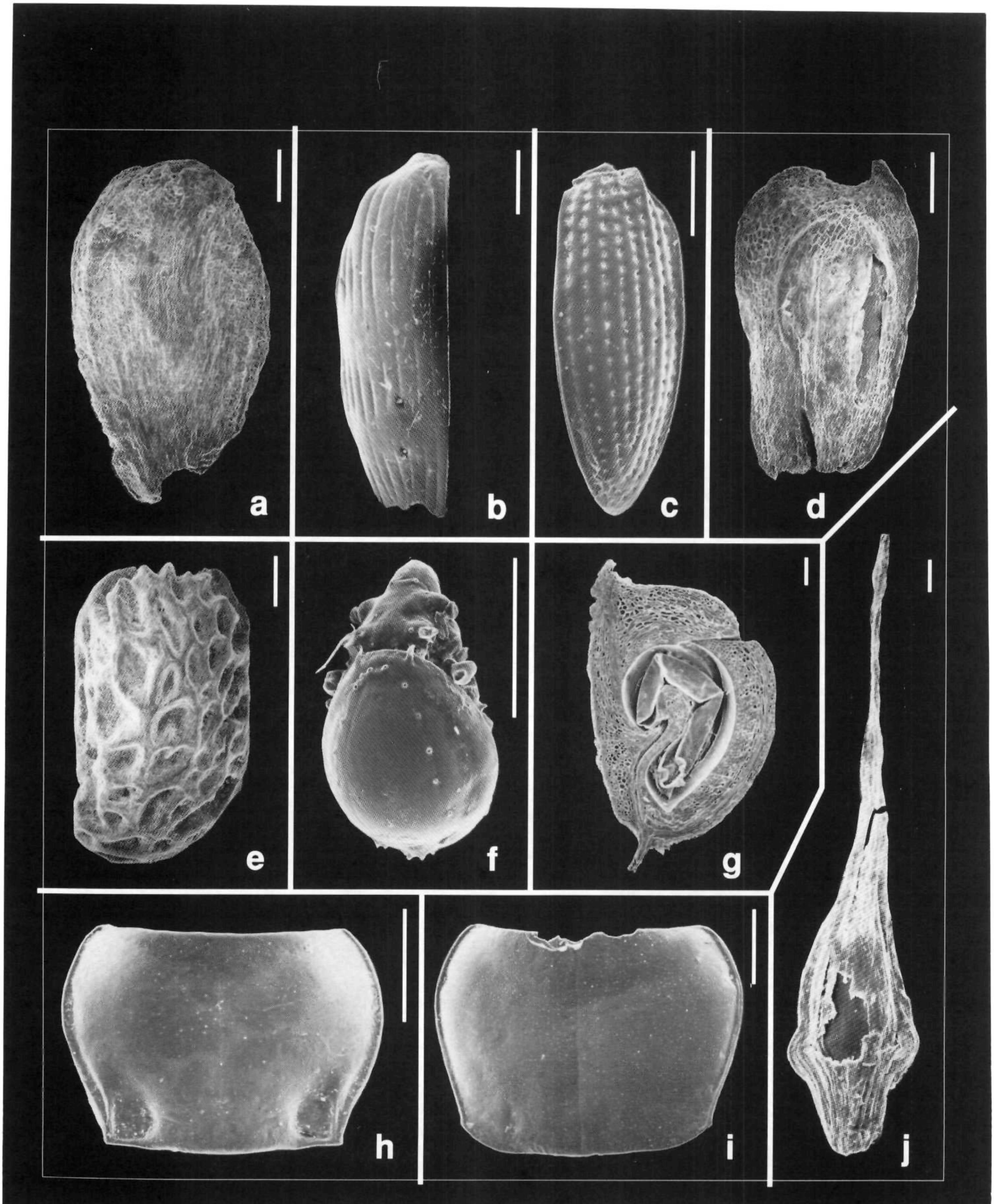
The poorly sorted character of the organic residue of Sample A from the ice wedge pseudomorph (Fig. 4), its high content of fungal sclerotia and particularly the inclusion of such fossils as those of larval click beetles (Elateridae: *Ctenicera*, Table V) suggest that the peat is an organic paleosol. The abundance of fossils of the beetles *Helophorus, Ochthebius* and *Stenus* shows that the site was poorly drained. Bark beetles (Scolytidae) and other taxa directly associated with trees are conspicuously absent; however, because the macrofossils include fossils of ants (Hymenoptera: Formicidae) and of Coleoptera such as *Helophorus oblongus* and *Agonum quinquepunctatum*, neither of which range far beyond tree line today, we believe tree line at the time of deposition may have been located in the northern Yukon only slightly south of the site.

The fossils from Sample B at Station 1 have been discussed previously (Matthews,1975) and are listed here only for the sake of comparison. They are the only ones in Unit 4 to come from a level with a finite ^{14}C date. The original sample from which fossils were extracted was small compared to others discussed here, this probably being the chief reason for the low fossil diversity. Nevertheless, it is noteworthy that the insects from this sample appear to be more indicative of cold tundra-like conditions than those in most of the other samples. A particularly interesting fossil, which was not noted in 1975, is the weevil *Connatichela artemisiae*, a species which, as the name implies, feeds on *Artemisia*. The Sample B assemblage is the only one from Unit 4 to contain the weevil *Stephanocleonus* (formerly listed as *Cleonus*), which is another taxon often seen in sediments deposited in dry tundra.

Insect fossils are relatively rare in Sample F, but include among the dominating aquatic and semi-aquatic component a few fossils of beetles, such as the carabid *Diacheila polita*, which usually live in mesic tundra sites. *Olophrum rotundicolle* is abundant as would be expected of the sedge-dominated margin of a subarctic pond. Sample G yielded very few insect fossils other than fragments of the weevil *Lepidophorus lineaticollis*. Fossils were more abundant in Sample M. Unless they are rebedded from older sediments, the fossils of the ground beetle *Blethisa catenaria* in Sample M probably imply existence of tree line conditions shortly before deposition of Unit 5 (Nelson, 1983; Morgan *et al.*, 1986).

STATION 4 ARTHROPOD FOSSILS

A few arthropod fossils have been recovered from the peat of Sample H (Fig. 4) below OCt. The most important fossil is the one representing the ground beetle species *Patrobus septentrionis*. In North America, this species is seldom found beyond tree line except on the Pribilof Islands and coastal


a
b
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e
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FIGURE 7. Scanning electron micrographs of selected plant and arthropod macrofossils from Ch'ijee's Bluff Unit 4. Scale bar = 300 μ. a) Plant: *Alisma gramineum* K. C. Gmel. (Alismataceae); GSC-98839 (SEM neg. 40.438); fruit; Station 4, macrofossil Sample N; b) insect: *Dyschirius laevifasciatus* Horn (Coleoptera: Carabidae); GSC-98840 (SEM neg. 40.307); fragment of left elytron showing patches with effaced striae: Station 4, Sample N; c) insect: Coleoptera; Elmidae; GSC-98841 (SEM neg. 40.421); right elytron; Station 4, Sample N; d) plant: *Sagittaria cuneata* Sheld. (Alismataceae); GSC-98842 (SEM neg. 40.439); fruit; Station 4, Sample N; e) plant: *Rubus* cf. *spectabilis* Pursh. (Rosaceae); GSC-98843 (SEM neg. 40.380); endocarp; Station 4, Sample N; f) oribatid mite: *Epidamaeus* cf. *E. tenuissimus* Hammer (Acari: Damaeidae); GSC-98844 (SEM neg. 40.392); dorsal view; Station 1, Sample A; g) plant: *Potamogeton pectinatus* L. (Potamogetonaceae); GSC-98845 (SEM neg. 40.371); sectioned fruit; Station 4, Sample N; h) insect: *Bembidion convexulum* Hay (Coleoptera: Carabidae); GSC-98846 (SEM neg. 40.431); pronotum; Station 4, Sample N; i) insect: *Bradycellus lecontei* Ciski (Coleoptera: Carabidae): GSC-98847 (SEM neg. 40.441); pronotum; Station 4, Sample N; j) plant: *Carex sychnocephala* Carey (Cyperaceae); GSC-98848 (SEM neg. 40.366); perigynium with achene showing in torn area; Station 4, Sample N.

Micrographies par balayage électronique de végétaux et de macrofossiles d'arthropodes choisis de l'unité n° 4 de Ch'ijee's Bluff. Échelle = 300 μ. a) Végétal: Alisma gramineum *K. C. Gmel. (Alismataceae); GSC-98839 (SEM neg. 40.438); fruit; site n° 4, échantillon de macrofossile N; b) insecte:* Dyschirius laevifasciatus *Horn (Coleoptera: Carabidae); GSC-98840 (SEM neg. 40.307); fragment d'élytre droit montrant des parties où les stries sont effacées: site n° 4, èchantillon N; c) insecte: Coleoptera: Elmidae; GSC-98841 (SEM neg. 40.421); élytre droit; site n° 4, échantillon N; d) végétal:* Sagittaria cuneata *Sheld. (Alismataceae); GSC-98842 (SEM neg. 40.439); fruit; site n° 4, échantillon N; e) végétal:* Rubus cf. spectabilis *Pursh. (Rosaceae); GSC-98843 (SEM neg. 40.380); endocarpe; site n° 4, échantillon N; f) oribate:* Epidamaeus *cf.* E. tenuissimus *Hammer (Acari: Damaeidae); GSC-98844 (SEM neg. 40.392); vue dorsale; site n° 1, échantillon A; g) végétal:* Potamogeton pectinatus *L. (Potamogetonaceae); GSC-98845 (SEM neg. 40.371); fruit sectionné; site n° 4, échantillon N; h) insecte:* Bembidion convexulum *Hay. (Coleoptera: Carabidae); GSC-98846 (SEM neg. 40.431); pronotum; site n° 4, échantillon N: i) insecte:* Bradycellus lecontei *Ciski (Coleoptera: Carabidae): GSC-98847 (SEM neg. 40.441); pronotum; site n° 4, échantillon N; j) végétal:* Carex sychnocephala *Carey (Cyperaceae); GSC-98848 (SEM neg. 40.366); périgyne (la graine apparaît dans la déchirure); site n° 4, échantillon N.*

TABLE V

Arthropod and other Animal Macrofossils from Ch'ijee's Bluff, Unit 4 (excluding Station 4)

Taxa	Stn-1 A	Stn-1 B	Stn-2 F	Stn-3 G	Stn-5 M
PORIFERA					
HAPLOSCLERINA					
Spongillidae					
Spongilla type			+		
ANNELIDA					
TUBELLARIA			+		
BRYOZOA					
Cristatella mucedo Cuv.			+		
INSECTA					
HEMIPTERA (various fragments)					
Saldidae	+				
Gerridae	+				
Lygaeidae?		+			
HOMOPTERA					
Cicadellidae	+			+	
COLEOPTERA					
Carabidae					
Pelophila borealis Payk.	+				
Blethisa catenaria Brown					+
Elaphrus lapponicus Gyll.		+			
Diacheila polita Fald..	+		+		
Dyschirius frigidus/subarcticus type	+				
Bembidion dauricum Motsch.	+				
Bembidion (Peryphus) sp.		?			
Bembidion sp.			+	+	
P. (Cryobius) gerstlensis Ball	cf.				
P. (Cryobius) soperi Ball		+			
P. (Cryobius) kotzebuei Ball		?			
P. (Cryobius) tareumiut Ball		+			
P. (Cryobius) parasimilis Ball		+			
P. (Cryobius) pinguedineus Eschz.	+				
P. (Cryobius) brevicornis Kby.	+	+			+
P. (Cryobius) nivalis Sahlb.		+			
P. (Cryobius) ventricosus Eschz.		+		+	
P.(Cryobius) spp.		+			
Pterostichus costatus Men.		+			
Pterostichus haematopus Dej.		+			
**Agonum quinquepunctatum* Motsch.	+				
Amara alpina Payk.	+	+			
Amara bokeri Csiki		?			
Amara patruelis type	cf.				
Trichocellus mannerheimi R. Sahlb..	+				
Dytiscidae					
Agabus/Ilybius	+		+		
Colymbetes sp.		+	+		
Dytiscidae undet.			+		+
Hydrophilidae					
Hydrobius sp.	+				
Helophorus splendidus J. Sahlb.					+
**Helophorus oblongus* LeC	+				
Helophorus spp.	+				
Cercyon marinus Thoms.	+		cf.		
Hydraenidae					
**Ochthebius marinus* (Payk.)	+				
**Ochthebius kaszabi* Janssens	+				
Ochthebius sp.					+
Staphylinidae					
Eucnecosum/Arpedium type			+		
Olophrum boreale (Payk.)			+		
Olophrum rotundicolle Sahlb.			+ +		
Micralymma sp.	+				
Boreaphilus henningianus C. R. Sahlb.	+		+		
Stenus sp.	+ +		+ +		+
**Euaesthetus* sp.	+		+		+
Lathrobium sp.	+				+
Tachinus sp.	+				+
Tachinus brevipennis J. Sahlb.	+				
Tachyporus sp.	+				

Taxa	Stn-1 A	Stn-1 B	Stn-2 F	Stn-3 G	Stn-5 M
Aleocharinae	+				
Silphidae					
Thanatophilus tuberculatus Kby.	?				
Silpha sp.			+		
Silpha coloradensis Wick.		+			
Leiodidae					
Agathidium sp.	+				
Scarabaeidae					
Aphodius sp.		+			
Helodidae					
Cyphon sp.			+		
Byrrhidae					
Simplocaria sp.	+				
Curimopsis sp.		+			
Morychus sp.	?	+		+	
Elateridae					
Ctenicera sjaelandica (Muller)	cf.				
*Anthicidae					
Lappus sp.	?				
Colydiidae	+				
Chrysomelidae					
Donacinae			+		
Alticinae, genus?	+				
**Cassida flaveola* Thumb.	+				
Curculionidae					
Apion sp.	+				
Sitona sp.		+			
Connatichela artemisiae Anderson	+	+			
Lepidophorus lineaticollis Kirby	+	+		+ +	
Notaris bimaculatus (Fab.)	+				
Rhynchaenus rufipes (Lec.)	+				
Rhynchaenus sp.	+				
Phytobius sp. (*Mecopeltus* type)	+				
Lepyrus sp.		+			
Stephanocleonus sp.		+			
TRICHOPTERA					
Undet larval cases		+			
DIPTERA					
Undet. puparial ff.		+			
Chironomidae					
Chironomus type			+		
Bibionidae	+				
HYMENOPTERA					
Ichneumonidae	+	+			
Formicidae					
Formica type	+	?			
CRUSTACEA					
Notostraca (mandibles)					
Lepiduris sp.			+		
Cladocera (ephippia)					
Daphnia sp.			+		+
ARACHNIDA					
Acari	+		+		+
Damaeidae					
Epidamaeus cf. *E. tenuissimus* Hammer[1]	+				
Araneae					
Erigone sp.	+				
Lycosidae	+				

+ = taxon present; + + = taxon abundant; ? = identification questioned due to poor preservation; cf. = taxon well enough preserved for identification but identification is tentative. *indicates taxa which seldom occur beyond tree limit and have a northern distributional limit near Ch'ijee's Bluff today. 1. Identified by V. Behan-Pelletier, Agriculture Canada, Ottawa

Labrador (Lindroth, 1961). Its presence in Sample H may mean that tree line was close to Bluefish Basin. Additional evidence is required, especially study of pollen samples from the peat.

Samples I and J are associated with Old Crow tephra. They contain abundant fossils of the rove beetles *Micralymma* and *Tachinus* and the weevil *Lepidophorus lineaticollis*. The first two are commonly present in assemblages dominated by tundra and near tundra beetles, and in fact with rare exceptions are tundra beetles themselves. *Lepidophorus lineaticollis* lives among willows and alders along sandy shorelines of rivers, at dry sites within forests (*e.g.*, aspen and poplar stands) and at dry tundra sites. Its presence, in association with plant fossils representing a pond, is puzzling. A possible explanation is that the tephra was deposited in a very shallow, seasonally dry pond. This could account for the undulating form of the tephra at Station 4 as well as for the co-occurence of macrofossils of water plants such as *Potamogeton* and dry site insects like *Lepidophorus*. Both Samples I and J contain a few fossils of the pill beetle, *Morychus*, a common component of fossil assemblages representing dry tundra and in general all of the insect fossils support the conclusion that the tephra was deposited when trees were far removed from the Bluefish Basin.

The arthropod fossils from Sample K are undiagnostic of regional climatic conditions, except that the larvae of the fly *Xylophagus* do not often occur much beyond the limit of trees and tall shrubs because they live in wood (James, 1981). An abundance of fossils of the weevil *Lepidophorus lineaticollis* calls for a rather dry local environment.

The insects and other arthropod fossils from sample 83-9 support the plant macrofossil evidence for a poorly drained semi-aquatic site. And like the plant fossils, some of the insects (*e.g.*, Elmidae) suggest a rather warm regional environment. This was one of the few samples from Ch'ijee's Bluff that contained small bone fragments. Because of this find, the level of sample 83-9 is due for more intensive study in the near future. This will certainly result in a larger, more informative insect fauna and vascular flora.

Sample N and 87-2 are extremely diverse compared to those typical of subarctic sites, even those of Holocene age. A minimum of 120 species are represented by the fossils listed in Table VI. The number would undoubtedly be much higher if the starting volume of sample 87-2, which represents a slightly different environment than Sample N, was a large as the 30 kg processed for Sample N.

TABLE VI

Arthropod and other Animal Macrofossils from Ch'ijee's Bluff, Unit 4 at Station 4

Taxa	H	I	J	K	83-9	N	87-2
PORIFERA							
HAPLOSCLERINA							
Spongillidae							
Spongilla type						+	+
ANNELIDA							
HIRUDINEA						+	
TUBELLARIA						+	
BRYOZOA							
Cristatella mucedo Cuv.					+	+	
Fredericella sp.						+	
Plumatella sp.					+		
INSECTA							
ODONATA						+	
HEMIPTERA							
Corixidae						+	
Gerridae						+	
Family?						+	
HOMOPTERA							
Cicadellidae		+	+	+			
Psyllidae		+					+
COLEOPTERA							
Carabidae							
Nebria sp.							+
Diacheila polita Fald..						+	+
Blethisa multipunctata L.						+	
Loricera sp.							+
Dyschirius sp.						+	+
***D. laevifasciatus* Horn						+	
**Patrobus septentrionis* Dej.	+					+	
**Bembidion concolor* Kirby						+	
Bembidion concretum Csy.						+	
**Bembidion convexulum* Hay.						+	
Bembidion grapei Gyll.						+	
Bembidion intermedium Kirby						+	
**Bembidion quadrimaculatum* Lec.						+	
Bembidion sordidum typ.						+	
Bembidion transparens Gebl.						+	
Bembidion sp.		+			+		+
**Pterostichus adstrictus* Eschz.						+	
P. (Cryobius) sp.		+				+	
P. (Cryobius) ventricosus				+			
Pterostichus haematopus Dej.						+	
**Agonum consimile* Gyll.						+	
Agonum sp.					+	+	+
Amara sp.				+		+	
Harpalus sp.		+				+	
Trichocellus mannerheimi R. Sahlb.						+	
Trichocellus sp.							+
***Bradycellus lecontei* Ciski						+	
Dytiscidae							
Agabus/Ilybius						+	
Hydroporus sp.						+	+
Hygrotus sp.						+	
Colymbetes sp.			+		+	+	
Dytiscus sp.						+	
Dytiscidae undet.						+	+
*Noteridae						+	
Gyrinidae							
**Gyrinus* sp.						+	
Hydrophilidae							
Hydrobius sp.						+	
**Helophorus lacustris* type						+	
Helophorus spp.		+	+		+	+	
Cercyon marinus Thoms.						cf.	+
Hydrophilus sp.						+	
Genus?							+
Hydraenidae							
Ochthebius marinus (Payk.)						+	
Ochthebius kaszabi Janssens						+	
Ochthebius sp.	+				+		+
Staphylinidae							
Bledius spp.						+	
Aleocharinae, genus?						+	
Eucnecosum/Arpedium type	+				+	+	
Olophrum boreale (Payk.)					+	+	+
Olophrum latum Makl.	+					+	
Olophrum consimile Gyll.						+	
Olophrum rotundicole Sahlb.						+	
Acidota sp.						+	+
Micralymma sp.		+	++	+ +		+	+
Boreaphilus henningianus C.R. Sahlb.							?
Omalium sp.						+	
Stenus sp.	+		+			+	+
Euaesthetus sp.	+					?	
Lathrobium sp.						+	
Tachinus sp.		+					
Tachinus apterus grp.		+	++	+ +			
Tachyporus sp.						+	+
Aleocharinae							+
Gymnusa sp.						+	
Micropeplidae							
***Micropeplus sculptus* LeC.						+	
**Micropeplus tesserula* Curtis							+
Silphidae							
Silpha sp.						+	
Leiodidae							
Agathidium sp.				+			+
Leiodes sp.						?	
Ptilidae							
Acrotrichus sp.							+
Scydmaenidae							
Veraphus type						+	+
Scarabaeidae							
Aegialia sp.						+	
Helodidae							
Cyphon sp.						+	+
Byrrhidae							
Simplocaria sp.						+	+
Curimopsis sp.						+	+
Morychus sp.		+	+	+		+	
Cytilus alternatus (Say)						+	+
*Elmidae	+				+	+	+
*Heteroceridae							
Heterocerus spp.						+	
Elateridae							
Ctenicera sjaelandica (Muller)	+					?	?
Genus?					+		

Taxa	H	I	J	K	83-9	N	87-2
Anobiidae						?	
Melyridae						+	
Coccinelidae					+	+	
Cucujidae							
Pediacus sp.							+
Lathridiidae						+	+
Colydiidae						?	
Chrysomelidae							
Donacia sp.		+					
**Bromius obscurus* (L.)						+	
Alticinae, genus?						+	
**Cassida flaveola* Thumb.							?
Chrysolina sp.			+				
Phaedon sp.							?
Curculionidae							
Apion sp.				+		+	
Hypera sp.			+				
Lepidophorus lineaticollis Kirby			+ + +	+ +		+	+
Vitavitus thulius Kiss.						+	
**Grypus equiseti* (Fab.)						+	
Phytobius (Litodactylus type)						+	
Phytobius sp.							+
Hylobius sp.							+
Ceutorhynchus sp.							+
Rhynchaenus sp.		+					
Lepyrus sp.						+	
Stephanocleonus sp.						?	
Scolytidae							
**Carphoborus* sp.						+	+
**Phloesinus pini* Swaine						+	
**Phloeotribus piceae* Swaine						+	
**Orthotomicus caelatus* (Eich.)						+	
**Pityophthorus opaculus* LeC.						+	
TRICHOPTERA							
Brachycentrus typ.						+	
Genus?		+					+
DIPTERA							
Tipulidae						+	
Chironomidae							
Chironomus type					+ +	+	+
Glyptotendipes sp.						+ +	+ +
Xylophagidae							
Xylophagus sp.				+			
HYMENOPTERA							
Symphyta							
Tenthredinidae						+	
Ichneumonidae						+	+
Formicidae					+		
**Myrmica* sp.						+	
**Formica* type						+	+
**Camponotus* sp.						+	
CRUSTACEA							
Notostraca (mandibles)							
Lepiduris sp.						+	
Cladocera (ephippia)							
Daphnia sp.		+ +		+		+	+
ARACHNIDA							
Acari			+	+ +	+ + +		
Damaeidae							
Epidamaeus sp.						+	+
Hydrozetidae							
Hydrozetes type					+	+	+
Araneae							
Erigone		+					+

+ = taxon present; + + = taxon abundant; ? = identification questioned due to poor preservation; cf. = taxon well enough preserved for identification but identification is tentative. *indicates taxa which seldom occur beyond tree limit and have a northern distributional limit near Ch'ijee's Bluff today. **indicates taxa which apparently have their present northern distributional limit significantly south of Ch'ijee's Bluff.

A notable feature of Sample N is the diversity of bark-beetles (Scolytidae). At least four genera are present. 87-2 contained fewer species, probably because of smaller sample size. Although northern samples representing forest conditions usually contain a few bark-beetle fossils, seldom do they contain as many different types as this sample. Detailed study of bark-beetles is obviously a priority for future research.

Another distinctive feature of the Sample N fauna is the presence of fragments representing the Coleoptera families Elmidae and Heteroceridae. Both are essentially absent from the present northern Yukon fauna, though suitable habitat abounds. Significantly, two different species of Heteroceridae are present.

The distinctive ground-beetle *Dyschirius laevifasciatus* (Fig. 7b) lives near rivers, but apparently not much north of west central Alberta (D. K. Kavanaugh, California Acad. of Sciences, pers. comm. 1988; Bousquet, 1988) (Fig. 6e). Its fossils have been found in late Tertiary deposits from the Arctic (Matthews, 1977). This is the first record of its occurrence in a Quaternary age assemblage from the north.

Another ground-beetle, *Bradycellus lecontei* (Fig. 7i) occurs as far north as Dawson City in the Yukon Territory, which is still well to the south of the Old Crow region and Ch'ijee's Bluff (Fig. 6f). Fossils of the tiny beetle, *Micropeplus sculptus*, also occur as rare elements in late Tertiary assemblages from the Arctic (Matthews, 1977). Until now, they have not been seen in Quaternary assemblages from any northern site. The distribution map in Figure 6g shows that there are few collection localities for this species, probably because it occurs in habitat which is rarely collected (J. M. Campbell, Agriculture Canada, pers. comm., 1990). To date the only potential northern record is the provincial record from British Columbia (Campbell, 1978 and J. M. Campbell pers. comm., 1990). We suspect that it occurs as far north as northern British Columbia and southern Yukon, but probably not in the northern Yukon.

Both macrofossil Samples N and 87-2 contain a few fragments of the ground-beetle *Diacheila polita*. This seems to be a contradiction to the remainder of the fauna because in North America *D. polita* is usually found on mesic hypoarctic tundra. When found as a fossil it is usually said to be an indicator of treeless conditions (see above). This is not necessarily so; one of the authors (JVM) has collected *D. polita* well below tree line in a small open moss-dominated depression and it does occur within tree line in northern Scandinavia and Siberia (A. V. Morgan, Univ. of Waterloo, pers. comm., 1990). What the presence of *D. polita* fossils in Samples N and 87-2 probably means is that similar poorly drained, mossy depressions existed within the forest at Ch'ijee's Bluff or in the marshy zone surrounding the ox-bow lake.

Larval head capsules of the chironomid fly *Glyptotendipes* occur in Sample N and are abundant in 87-2. It is not usual to see a few chironomid head capsules in such sediments, but the abundance of *Glyptotendipes* is unexpected for such a northern site (I. Walker, Queens University, pers. comm., 1990). As Figure 6h shows it does not extend much beyond tree line today; although specimens have been collected from near Ch'ijee's Bluff in the Bluefish Basin (Wiens *et al.*, 1975).

Many of the insects listed for Samples N and 87-2 in Table VI are taxa that live in or near water. Unlike water plants, aquatic and hygrophilous insects do not appear to be as insulated from macro climatic changes. Thus, the fact that the insect fossils from Samples N and 87-2 display some of the same types of range disjunctions as the vascular plants strengthens our conclusion that the fauna and flora from the pond sediments in Unit 4c actually were deposited under warmer climatic conditions than today. As with the plants, too little is known about the autecology of the key insect species to allow us to infer details of climate change during deposition of lower Unit 4c compared to the present.

DISCUSSION

The climatic questions raised by the International Geosphere Biosphere Program (IGBP) require that we think of world futures in terms of the background of past climate. Some models of future anthropogenic climate change call for mean annual temperatures in the next 200 years to peak at higher levels than have occurred during the last hundred thousand years or more (Dickinson and Cicerone, 1986), *i.e.*, since the last interglaciation or stage 5 of the marine isotope record. Therefore, there is a need for more precise knowledge of the last interglaciation, particularly the way in which the biota responded to warming. Because they were different, we cannot gain information of the last interglaciation by study of the present interglaciation.

During parts of isotope stage 5 of the marine isotope record, the world contained less glacial ice and higher sea levels than at present, equaling or exceeding conditions during the maximum of the present interglaciation (Jouzel *et al.*, 1987; Ruddiman, 1985). July insolation at 65°N was 50% higher than during the past 10,000 years (Bartlein and Prentice, 1989). An integrated study of stage 5 in the northern part of North America has begun under project CELIA (Climate and Environment of the last Interglaciation in Northern North America), an initiative sponsored by the Boreal Institute for Northern Studies at the University of Alberta. Ch'ijee's Bluff has is one of the key project CELIA sites. Hence, what we describe here is merely the introduction and framework for more detailed studies to come in the near future.

THE CLIMATE RECORD OF CH'IJEE'S UNIT 4

If the present date on Old Crow tephra is correct, then in view of the paleoenvironmental data presented here, Unit 4 at Ch'ijee's Bluff probably spans a time from the Late Illinoian (start of marine isotope stage 6: Ruddiman, 1985) to the Late Wisconsinan, *i.e.*, it could represent as much as 170 ka. Unit 4c alone may span 100 ka.

Parts of Unit 4a were deposited when climate was cold enough for existence of tundra at Ch'ijee's Bluff pollen samples 7 and 8, Stn. 3). Scant evidence from Sample H in Unit 4b suggests that this peat represents a slightly warmer climate which allowed growth of rare trees in the region and the existence of insects that presently do not live far beyond treeline. But much work remains to be done with the lower part of Unit 4 before the details of this history are clear.

Climate was very cold at about the time of deposition of Old Crow tephra and for some time thereafter. However, there is evidence from preliminary study of pollen samples and macrofossil Sample K at Station 4 that climate warmed somewhat after 150 ka BP but prior to the major warm peak in Unit 4c. The lower horizon of ice-wedge pseudomorphs seen along the length of the exposure may be the result of this early warming interval. But pseudomorph horizon may also have resulted from the peak warming during deposition of Unit 4c. In any case these features show that for some period of time ground temperatures and depth of seasonal thawing were much greater than is the case for the region today or than at any time during the Holocene because Holocene ice-wedges at the top of the bluff have not thawed completely.

The base of Unit 4c records a period of climate much warmer than at present, though the exact amount in degrees cannot yet be estimated. Forest seems to have been much more closed than at present, and tree line was undoubtedly located further north. This may have been a time when trees extended onto the coastal plain of the northern Yukon as they seem to have done in Northern Alaska (Carter and Ager, 1989). This was also a time when downcutting created the erosional disconformity between Units 4b and 4c at the downstream part of the section (where OCt is missing).

The start of climatic cooling following peak warming in Unit 4c is probably recorded by a unique zone of cryoturbation structures. Information on the climate history subsequent to this event is scanty, but involves at least one more time of regional thawing (the upper ice-wedge pseudomorph horizon) prior to 37 ka BP. At about 30 ka BP climate was apparently colder than at present. Lichti-Federovich's (1973) upper three pollen samples from Unit 4 show a trend toward herbaceous tundra (Fig. 3) and macrofossil Sample B, from near the top of Subunit 4c is dominated by tundra insects (Matthews, 1975). But we cannot be certain that Sample B, or even Lichti-Federovich's upper Unit 4 samples represent the final climatic decline leading to the Late Wisconsinan. As in the case in the Old Crow Basin (Morlan *et al.*, 1990), the flooding of the basin during the early stages of that lake or multiple flooding events during the Late Wisconsinan (Thorson and Dixon, 1983) probably disrupted the portion of the record leading into the Late Wisconsinan.

THE KOY-YUKON INTERGLACIATION AND CORRELATIVE DEPOSITS IN EAST BERINGIA

The plant and insect fossils associated with the base of Unit 4c and the peak of spruce pollen in Lichti-Federovich's original pollen diagram were originally referred to a very warm interstadial by Schweger and Matthews (1985). At the time, the age of Old Crow tephra was estimated to be approximately

85 ka BP so the most appropriate age for overlying warm climate sediments was early stage 3 of the marine isotope record. Schweger and Matthews (1985) proposed the informal name Koy-Yukon thermal event, for this warm interval and suggested that it was correlative with previously recognized post OCt warming intervals in the Fairbanks area of Alaska and western Alaska. Now that the most recent date on Old Crow tephra shows that it is as old as 150 ka BP, the Koy-Yukon thermal event more likely represents some part of isotope stage 5. In other words it is the best candidate for the last interglaciation in the northern Yukon. Because of problems created by calling this interval the Sangamonian we have preserved the original local designation and refer the base of Unit 4c at Ch'ijee's Bluff to the Koy-Yukon interglaciation (informal terminology). The Koy-Yukon interglaciation may not be the terrestrial equivalent of isotope stage 5e. Note in Figure 5 that it is preceeded by a rise of spruce which is seen at other east Beringian sections that contain OCt (Fig. 8). Funder and others (1989) find that the warmest part of the last interglaciation in northwest Greenland occurred during a time probably correlative with marine isotope stage 5a rather than stage 5e. The same may be true in the Yukon and Alaska.

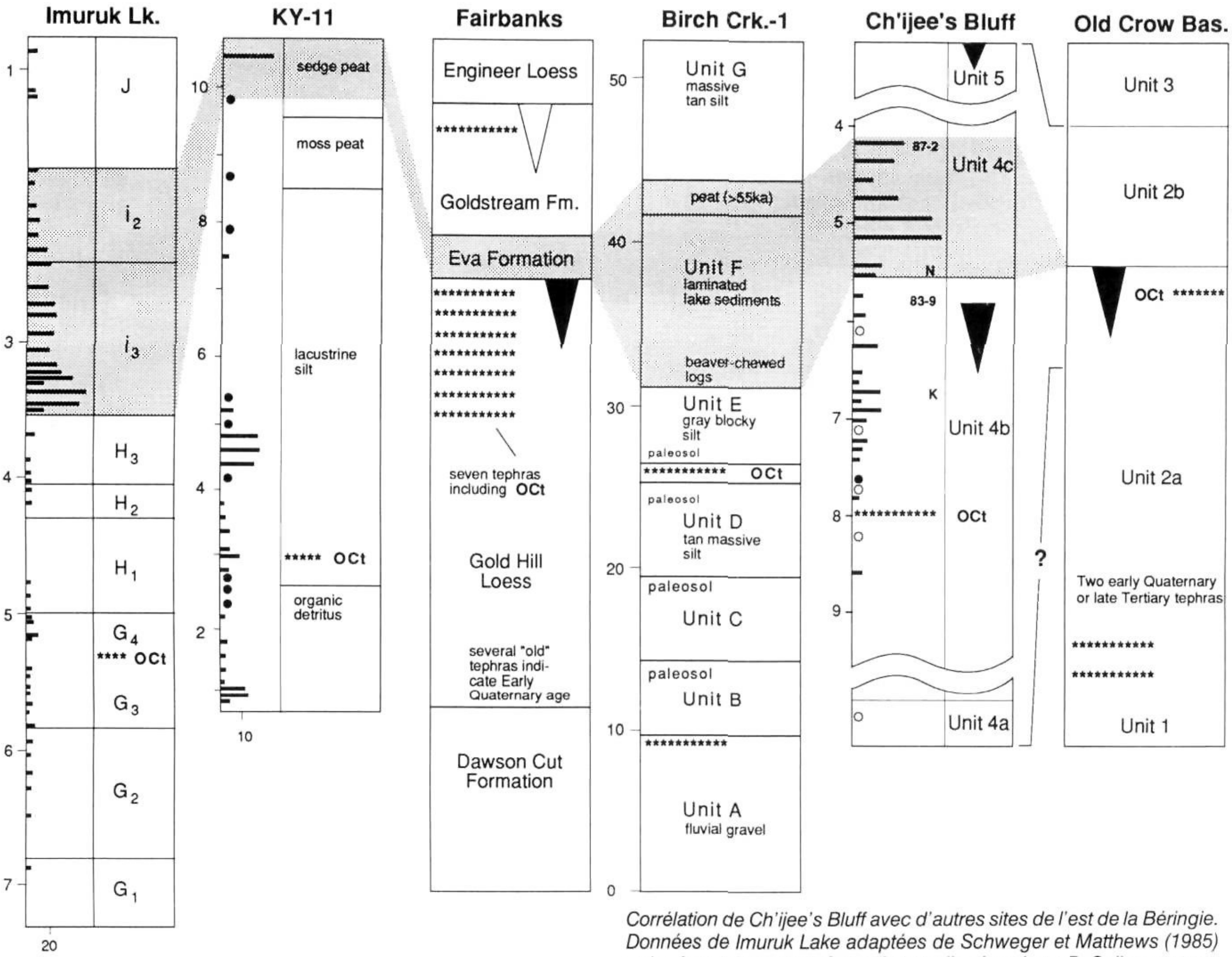

FIGURE 8. Correlation of Ch'ijee's Bluff with other sites in east Beringia. Imuruk Lake data adapted from Schweger and Matthews (1985) which presented a recast of work published on Imuruk Lake by P. Colivaux and students. KY-11 data from Schweger and Mattews (1985). Fairbanks data adapted from Péwé (1989). Birch Creek-1 data adapted from Edwards (1989). Ch'ijee's Bluff: this paper. Old Crow Basin from Schweger and Matthews (1985) and Matthews *et al.* (1987a). Bars shown in left column from Imuruk Lake, KY-11 and Ch'ijee's Bluff represent percentages of spruce pollen. Closed circles from KY-11 indicate less than 2%. Dark wedges represent ice-wedge pseudomorphs; with wedges represent ice-wedges which have not thawed completely. Stippled zone represents the last interglaciation as interpreted in this report. Possible correlation of Ch'ijee's Bluff Unit 4 and Old Crow Basin sections is shown by lines between the columns. OCt = Old Crow tephra.

Corrélation de Ch'ijee's Bluff avec d'autres sites de l'est de la Béringie. Données de Imuruk Lake adaptées de Schweger et Matthews (1985) qui présentaient une refonte du travail préparé par P. Colivaux et ses étudiants. Données de KY-11 de Schweger et Matthews (1985). Données de Fairbanks adaptées de Péwé (1989). Données de Birch Creek-1 adaptées de Edwards (1989). Ch'ijee's Bluff: présent travail. Données du bassin de Old Crow de Schweger et Matthews (1985) et Matthews et al. *(1987a). Les barres à la gauche des colonnes de Imuruk Lake, KY-11 et de Ch'ijee's Bluff donnent le pourcentage du pollen d'épinette. Les points noirs dans la colonne de KY-11 indiquent un pourcentage inférieur à 2%. Les points noirs dans la colonne de Ch'ijee's Bluff indiquent un pourcentage de 2-4%; les cercles blancs, inférieur à 2%. Les triangles noirs inversés sont des fentes de glace pseudomorphes; les triangles blancs sont des fentes de glace qui n'ont pas encore entièrement fondu. La zone en gris représente le dernier interglaciaire, tel qu'on l'interprète ici. La corrélation possible entre Ch'ijee's Bluff et le bassin de Old Crow est montrée par les lignes qui relient les deux colonnes. OCt = tephra de Old Crow.*

Figure 8 also shows the generalized stratigraphy of sections in the Old Crow Basin, which is near Bluefish Basin and Ch'ijee's Bluff (Fig. 1). A prominent unconformity marked in some cases by a turf and soil (Bombin, 1980) overlies silts and sands containing the Old Crow tephra and ice wedge pseudomorphs. This unconformity is overlain by several metres of alluvial and lacustrine sediments (Unit 4) which are capped by the glaciolacustrine clays of Unit 5 — the same unit seen at Ch'ijee's Bluff. At some Old Crow sections Unit 4 contains ice wedge pseudomorphs. In Schweger and Matthews (1985) it was suggested that the warming seen in Unit 4c at Ch'ijee's Bluff may be represented in Unit 4 of Old Crow Basin exposures. Recent accelerator dates on bones on the unconformity seem to rule this out. Instead, they suggest that sediments of Old Crow Unit 4 are no older than 38 ka. Unit 4 sediments at one of the best studied sections in Old Crow Basin also contain significant percentages of Paleozoic spores which are presumed to mark glacial meltwater overflow from the east upstream of Bell Basin (Fig. 1) (Hughes *et al.*, 1981; Walde, 1985). This finding, which is in substantial agreement with the new accelerator ^{14}C dates, probably means that Old Crow Unit 4 represents part of isotope stage 3 and early stage 2 rather than early stage 3 or stage 5 like Unit 4c at Ch'ijee's Bluff.

FUTURE WORK AT CH'IJEE'S BLUFF

This report is no more than an introduction to the complex biostratigraphic record preserved in Unit 4 at Ch'ijee's Bluff. While we believe these data do show that the last interglaciation occurs within Unit 4, there are many areas requiring future study. Some of the more obvious ones are:

(1) More detailed pollen work at Station 4 and documentation of similar trends by detailed work at several other stations. (2) Further study of insects and plant macrofossils, molluscs and vertebrates from closely spaced samples in Unit 4c at Station 4 and other stations. (3) Investigation of the significance of the rise in spruce percentages which occurs above OCt and below the zone of maximum warming in Unit 4c. (4) Study of changes in ring widths in wood found at the base of Unit 4c, with the aim of recognizing short term (100-1000 yr) climatic fluctuations during the time of peak warming. (5) Detailed paleomagnetic studies such as those conducted by Gillen and Evans (1989) on Unit 4. Such a study might allow the strata correlative with OCt to be recognized even when tephra is not present.

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