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LATE HOLOCENE POLLEN AND PRESENT-DAY VEGETATION, PRUDHOE BAY AND ATIGUN RIVER, ALASKAN NORTH SLOPE

D. A. Walker,* S. K. Short, † J. T. Andrews,‡ P. J. Webber*

ABSTRACT

Four peat profiles of late Holocene age and a single stratum of peat of middle Holocene age were radiocarbon dated, and their pollen spectra analyzed. The samples were from four sites close to Prudhoe Bay on the arctic coast of Alaska and from one site at the edge of the Brooks Range, Alaska, near Galbraith Lake. Nearly all levels in the pollen profiles showed significant amounts of *Picea* and *Pinus* tree pollen. At sites near the coast the quantities of *Alnus* and *Betula* pollen were also high despite the fact that the floristic limits of these genera occur 120 and 70 km to the south. The pollen profiles were frequently dominated by Cyperaceae pollen. Because the prevailing winds in May and June across the Prudhoe Bay region are from the east and east-northeast, the high percentages of *Picea* and *Pinus* in the diagrams may represent pollen transport from the forest-tundra ecotone and boreal forest of northwestern Canada. Many important taxa in the present vegetation were not represented in the pollen profiles, and difficulties of making inferences regarding past vegetation and climate are emphasized.

INTRODUCTION

In 1974 two sections of organic-rich sediments from the river-cut banks of the Putuligayuk and Kuparuk rivers near Prudhoe Bay and some fibrous peat, underlying blue-gray clay outcropping in low sea cliffs, were collected. In 1974 and 1975 additional river-bank sections were collected along the Sagavanirktok River and the Atigun River near Galbraith Lake (Figures 1 and 2). The four sections from the Putuligayuk, Kuparuk, Sagavanirktok, and Atigun exposures all varied in their lithostratigraphy and in the character of buried organic strata. We processed samples for pollen content in order to (1) see what variations in pollen content occurred within the four sections, and (2) attempt to recognize pollen assemblages characteristic of the present vegetation communities at Prudhoe Bay and the Atigun River. Earlier workers, notably Colinvaux (1967) and Livingstone (1955, 1957), concluded that there has been little change in the pollen spectra from the Alaskan North Slope during the late Holocene.

*Institute of Arctic and Alpine Research and Department of Environmental, Population and Organismic Biology, University of Colorado, Boulder, Colorado 80309.

†Institute of Arctic and Alpine Research and Department of Anthropology, University of Colorado, Boulder, Colorado 80309.

‡Institute of Arctic and Alpine Research and Department of Geological Sciences, University of Colorado, Boulder, Colorado 80309.

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PRESENT VEGETATION AND CLIMATE

The present-day environment of the Prudhoe Bay region (148°30'W, 70°20'N, 5 msm) is summarized in Walker et al. (1980).

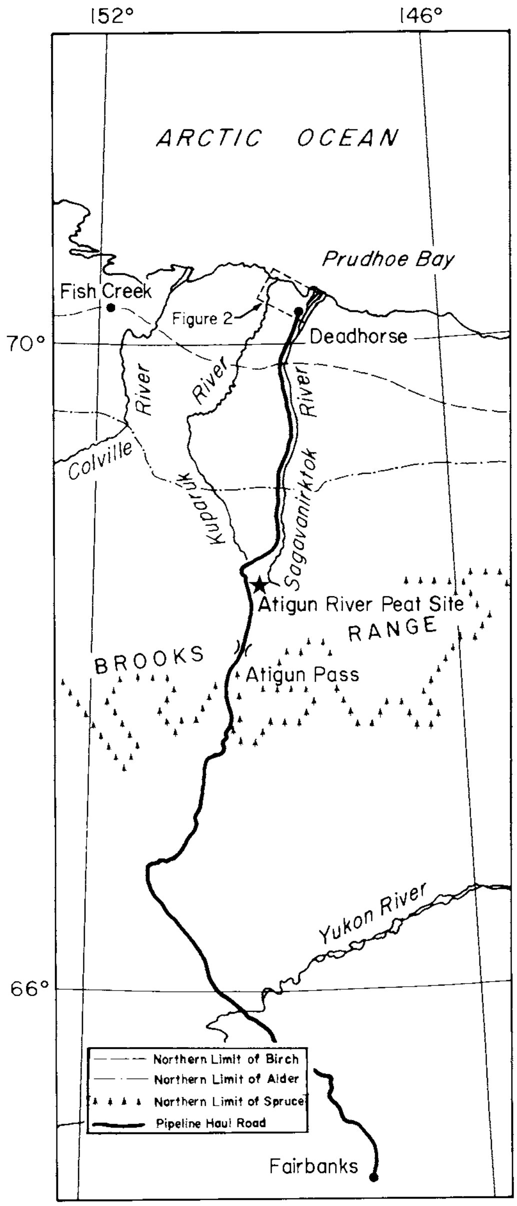

FIGURE 1. General location map of the area north of Fairbanks, Alaska, showing the location of Atigun River and the Prudhoe Bay area, and northern limits on birch, alder modified from Hultén (1968) and spruce (from University of Alaska, 1975).

The climate is a modified arctic coastal climate. The 8-yr (1970 to 1977) annual mean at the Atlantic Richfield Company (ARCO) airfield, located 6.0 km from the coast, is -13°C. Annual precipitation at Prudhoe Bay is about 200 mm, about one third of which falls in summer. Winds at Prudhoe Bay during May and June, the months when most tree pollen is likely to be released (Zasada et al., 1978), are most frequently from the east and east-northeast. Southerly winds occur periodically in mid-summer during warm spells when the Arctic Front retreats as far north as the coast. During winter the dominant winds are from the east-northeast and west-southwest. South of the Arctic Coastal Plain, summer winds are much more variable (Everett, 1980).

The Prudhoe Bay landscape is dominated by ice-wedge polygons, thaw lakes, and drained thaw lakes. The vegetation (Figure 3) reflects the microtopography with wet tundra plant communities, dominated by sedges and mosses, occurring in poorly drained sites. Better-drained sites on the edges of streams and on the raised polygon rims have a more diverse composition with small prostrate shrubs, lichens, and herbs mixed with sedges, grasses, and mosses. At Franklin Bluffs, 70 km inland from the coast, the vegetation contains many species that are more characteristic of the dwarf shrub–cottongrass tundra which dominates vast areas of northern Alaska.

The vegetation of the Prudhoe Bay region was analyzed on the basis of percentage cover of the various taxa corresponding as far as was possible to the pollen taxa recognized in the peat profiles (Figure 4). Fifty plots were included in this analysis. The plots were classified as one of six tundra types: (1) dry prostrate shrub tundra, (2) moist graminoid tundra, (3) wet graminoid tundra, (4) very wet (true emergent) graminoid tundra, (5) riparian scrub, and (6) sand dune barrens. Table 1 lists the names of the plant communities that were included within the six broader tundra categories. Plant taxa were sampled on the basis of percentage cover and grouped into higher taxa (mostly plant families). Two orders of moss, Bryales and Sphagnales, were recognized and all lichens were placed together in "lichens." *Artemisia* was separated from the Compositae because of its special interest in arctic pollen studies. The percentage cover of each family was summed within each tundra category and expressed as relative cover (RC), where RC is equal to the mean percentage cover of each higher taxa family times 100 divided by the total cover of all higher taxa families. The mean relative cover for each higher taxa family within each tundra type is expressed in graphic form (Figure 4). The diagram can be compared with current pollen rain and pollen from fossil peats to see which plant groups are over- or under-represented in pollen diagrams. Several points are worth noting:

(1) The high percentages of sedges (Cyperaceae) and mosses (Bryales) in all tundra types except dry tundra, and sand dune barrens, indicates an herbaceous tundra.

(2) The small percentage of willows (Salicaceae) in all except a few streamside communities, and the lack of birch (*Betula*) and alder (*Alnus*) further emphasizes the first point. Most of the willows in the region are prostrate willows, e.g., *Salix arctica* and *Salix reticulata*. Erect dwarf willows occur along a few streams inland from the coast and are mainly *Salix lanata* less than 15 cm tall. Birch (*Betula nana* ssp. *exilis*) has been recorded at Franklin Bluffs, 70 km inland from the coast (Koranda, 1960) and at Fish Creek (Figure 1) near the Colville River 40 km west of Prudhoe Bay (Komárková and Webber, 1978). The nearest known alders (*Alnus crispa*) are about 100 km south of the region.

(3) The relative scarcity of heath plants (Ericaceae) and *Sphagnum* (Sphagnales) and the abundance of *Dryas* are indicative of a calcareous environment. The Prudhoe Bay region is, for the most part, alkaline due to loess deposition from the Sagavanirktok River (Walker et al., 1980). At Prudhoe Bay the only heath consists of *Cassiope tetragona* in snowpatch areas. Other members of the Ericaceae, including *Ledum, Vaccinium*, and *Arctostaphylos*, are more common in acidic tussock dwarf-shrub tundra west of the Kuparuk River. Heath plants also occur just south of Prudhoe Bay and are common in the Franklin Bluffs vicinity. *Dryas integrifolia* and *Saxifraga*

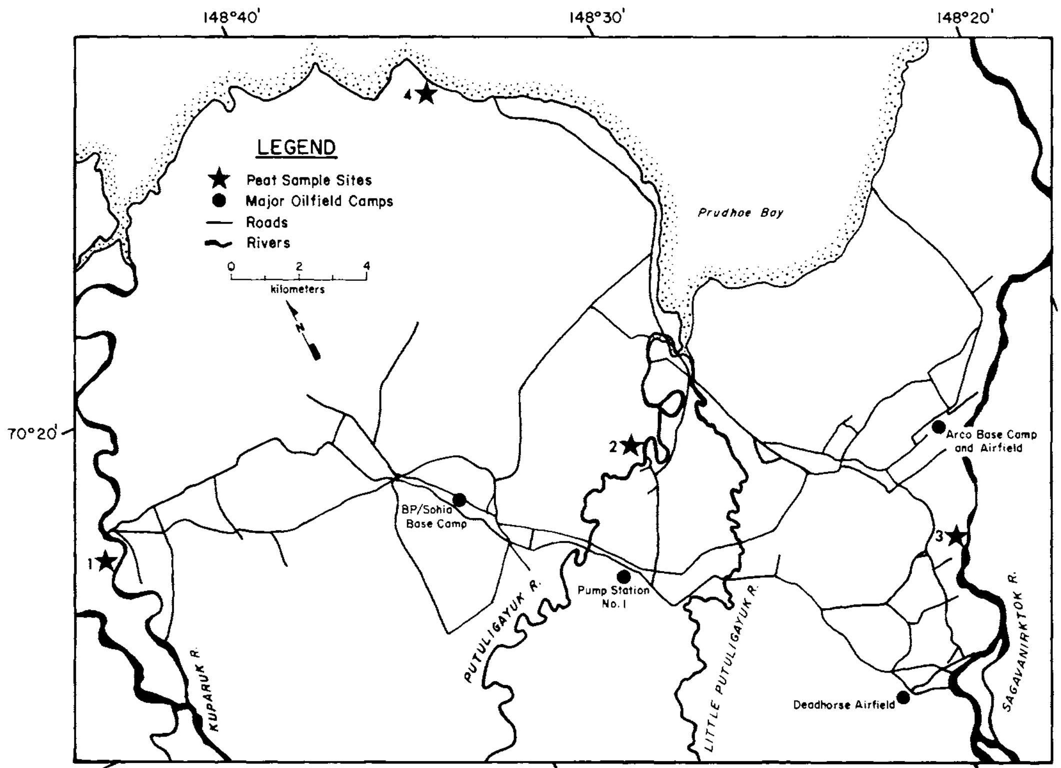

FIGURE 2. Location map of the sites where peats were sampled in the vicinity of Prudhoe Bay.

oppositifolia (Saxifragaceae) are calciphiles that occur on nearly all moist to dry microsites within the region.

(4) The sand dunes have a very distinctive assemblage of plants that contrasts markedly with that of the surrounding tundra areas. Gramineae, represented mainly by *Elymus arenarius* and *Dupontia fisheri*, and *Artemisia*, represented by *A. borealis, A. glomerata*, and *A. arctica*, have relatively high percentages. Both of these groups of plants flower profusely within the region. *Dryas, Artemisia*, and *Salix ovalifolia* are the major components of more stable sand dune communities; whereas, the active dunes are colonized by *Elymus*.

(5) Grasses are important in both the dry sand dune environment and the emergent environment. In the dunes *Elymus, Dupontia*, and *Deschampsia* are important and in shallow lakes *Arctophila fulva* is often dominant.

The Atigun River site (149°20′W, 68°20′N, 730 msm) is located about 150 km south of Prudhoe Bay. The locality contains a small area of sand dunes along the northern bank of

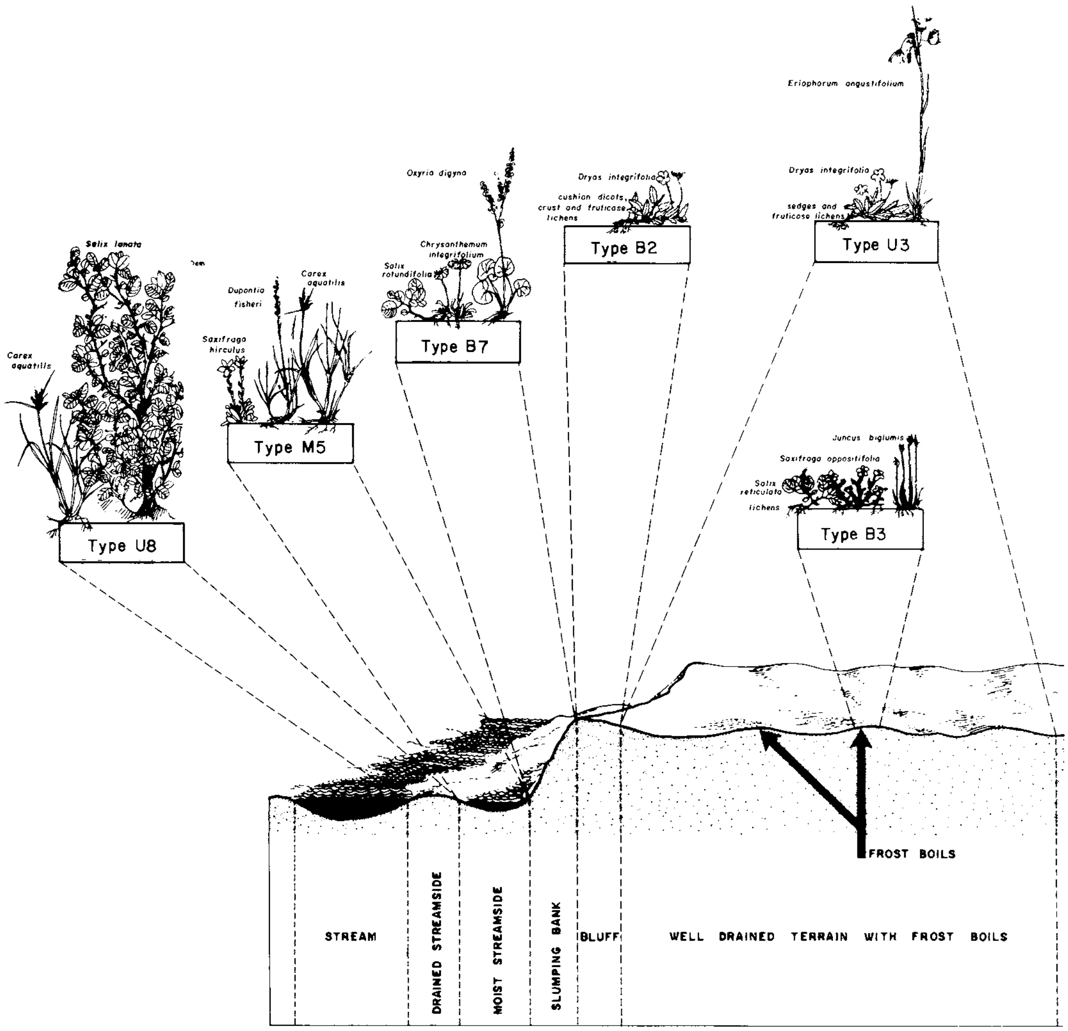

FIGURE 3. Association between topography and vegetation types in the vicinity of Prudhoe Bay modified from Webber and Walker (1975).

the Atigun River before it enters the Atigun Canyon in the Brooks Range. The site presents an interesting comparison to the Prudhoe Bay region because it is an alkaline tundra with most of the same tundra elements except they occur in a warmer summer climate. The nearest weather station to the Atigun River site is Galbraith Lake located 5 km northwest. The 1976 mean July temperature there was 10.6°C compared to 4.1°C at the Prudhoe Bay ARCO airfield station. The difference in accumulated thawing degree-days (TDD) is even more striking with 571 TDD in 1976 at ARCO and 1006 TDD at Galbraith Lake. The climatic difference is reflected in differences in both the stature and composition of the plant communities (Table 2). Dwarf (0.1 to 0.5 m tall) and medium height (0.5 to 2 m tall) shrubs occur abundantly along the Atigun River. A survey of the major families (Figure 5) shows the increased importance of Ericaceae and Salicaceae. The dune vegetation at the Atigun River site is quite different from that at Prudhoe Bay. Several species of

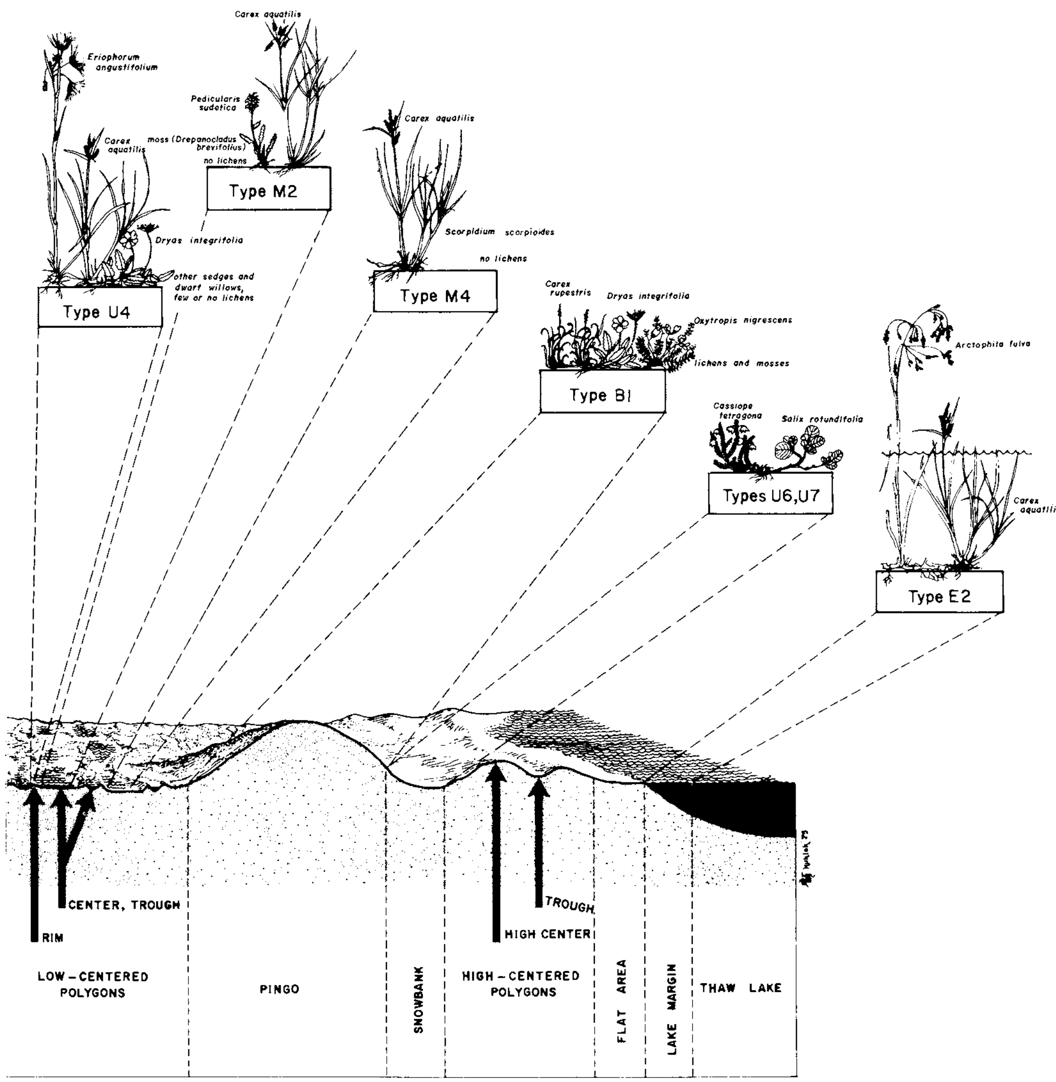

FIGURE 3 (Cont.)

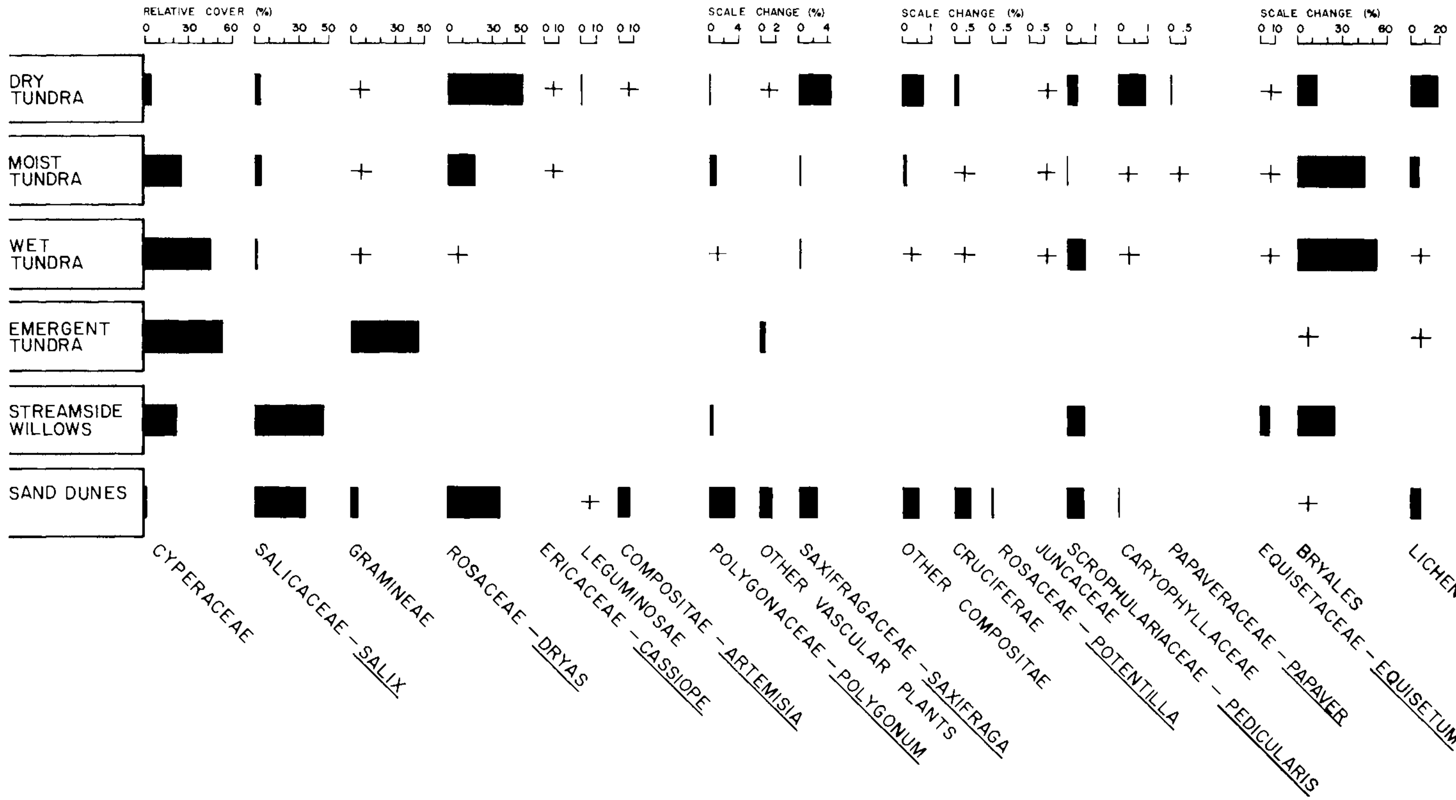

FIGURE 4. Composition of vegetation in six major vegetation categories at Prudhoe Bay, Alaska (see text for explanation).

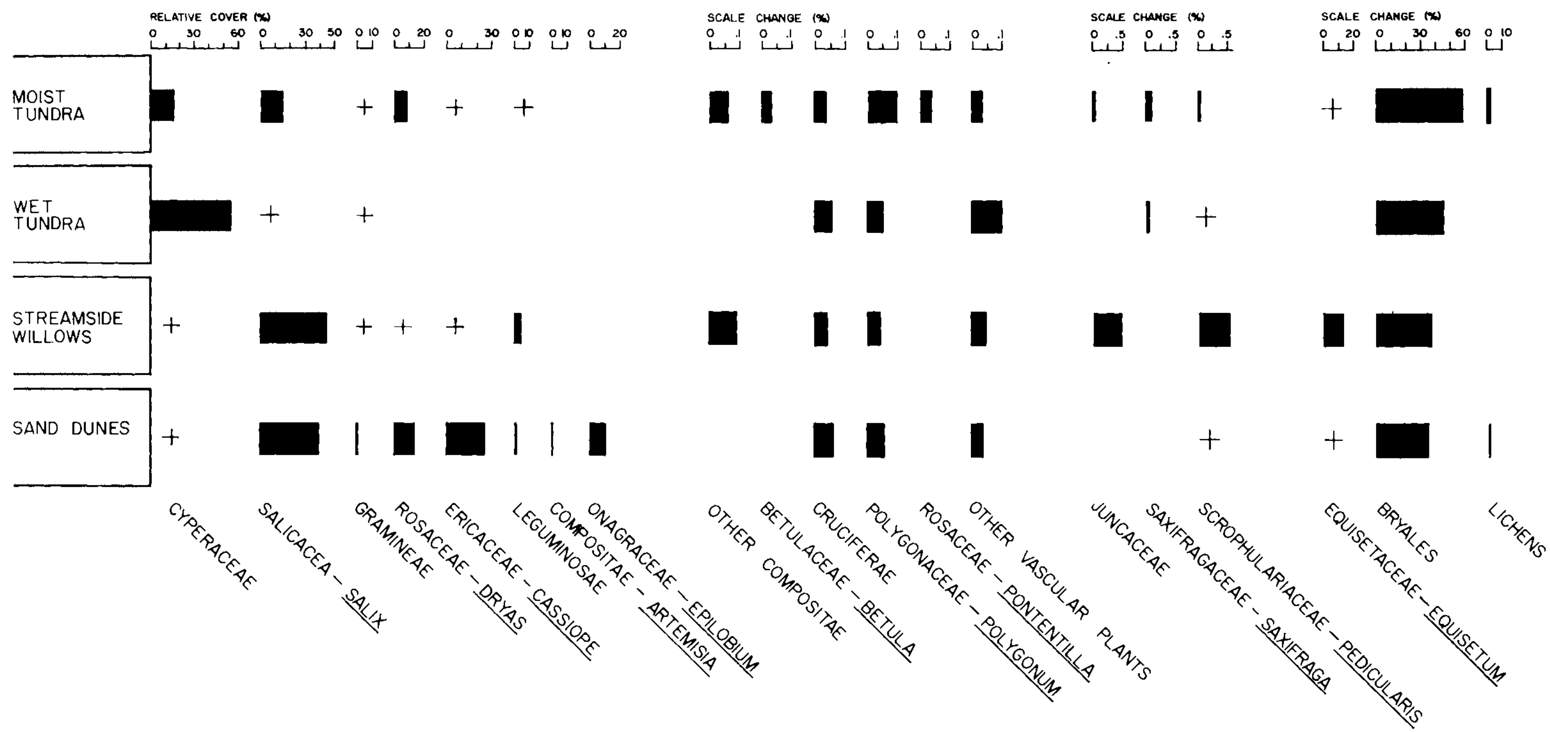

Figure 5. Composition of vegetation in four major vegetation categories at the Atigun River site.

TABLE 1
Prudhoe Bay plant communities contained in each tundra category

Tundra category	Stand type[a]	Community[a]
Dry Tundra	B1	DRY *Dryas integrifolia, Carex rupestris, Oxytropis nigrescens, Lecanora epibryon* PROSTRATE SCRUB
	B2	DRY *Dryas integrifolia, Saxifraga oppositifolia, Lecanora epibryon* PROSTRATE SCRUB
Moist Tundra	U1	MOIST *Carex aquatilis, Ochrolechia frigida* GRAMINOID MEADOW
	U2	MOIST *Eriophorum vaginatum, Dryas integrifolia, Tomenthypnum nitens, Thamnolia vermicularis* GRAMINOID MEADOW
	U3	MOIST *Eriophorum angustifolium, Dryas integrifolia, Tomenthypnum nitens, Thamnolia vermicularis* GRAMINOID MEADOW
	U4	MOIST *Carex aquatilis, Dryas integrifolia, Salix arctica, Tomenthypnum nitens* GRAMINOID MEADOW
Wet Tundra	M1	WET *Carex aquatilis, Carex rariflora, Saxifraga foliolosa* GRAMINOID MEADOW
	M2	WET *Carex aquatilis, Drepanocladus brevifolius* GRAMINOID MEADOW
	M4	VERY WET *Carex aquatilis, Scorpidium scorpioides* GRAMINOID MEADOW
Emergent Tundra	E1	VERY WET *Carex aquatilis* GRAMINOID MEADOW
	E2	VERY WET *Arctophila fulva* GRAMINOID MEADOW
Riparian Scrub	U8	MOIST *Salix lanata, Carex aquatilis* DWARF SCRUB
Sand Dune Barren	B9	DRY *Elymus arenarius, Dupontia fisheri,* BARREN
	B5	DRY *Dryas integrifolia, Salix ovalifolia, Artemisia borealis,* BARREN
	B13	DRY *Salix ovalifolia, Artemisia borealis,* BARREN

[a]Data from Walker et al. (1980); see Figure 4.

TABLE 2
Atigun River plant communities contained in each tundra category[a]

Tundra category	Community
Moist Tundra	MOIST *Carex bigelowii, Dryas octopelala, Salix reticulata, Tomenthypnum nitens* TUSSOCK GRAMINOID MEADOW
Wet Tundra	VERY WET *Carex aquatilis, C. saxatilis, Drepanocladus revolvens* GRAMINOID MEADOW
Streamside Willow	MOIST *Salix lanata, S. alaxensis, Hedysarum alpinum, Equisetum arvense* SCRUB
Sand Dunes	Stable dunes DRY *Dryas octopetala, Arctostaphylos rubra, Rhododendron lapponicum, Ditrichum flexicaule, Thamnolia vermicularis* PROSTRATE SCRUB
	Tops of active dunes DRY *Salix glauca, S. alaxensis, S. niphoclada, S. reticulata, Arctostaphylos rubra* SCRUB
	Interdune areas DRY *Equisetum arvense, Anemone multifida, Epilobium latifolium* BARREN
	DRY *Epilobium latifolium* BARREN

[a]See Figure 5.

medium height willows (*Salix glauca, S. alaxensis*, and *S. niphoclada*) cover the tops of most dunes along the river. The grass *Elymus* is not present, although other species of Gramineae are plentiful. More stable areas are dominated by dryas (*Dryas octopetala*) and bearberry (*Arctostaphylos rubra*). Upland areas beyond the dunes proper are dominated by sedge tussocks (*Carex bigelowii*).

SITES AND STRATIGRAPHY

Kuparuk River

This section is exposed on the north bank of the river (Figure 6). The surface vegetation consisted of Type B2 vegetation (Figure 3) (Walker et al., 1980) dominated by *Dryas integrifolia*, cushion dicotyledons, and lichens. This vegetation unit is typical of river bluff assemblages in the area. The section is 2.5 m high and consists of three lithostratigraphic members: (1) a lower member of gravel and sandy gravel; (2) a middle member of silts with significant amounts of organic material; and (3) an upper stratum of sandy silt reflecting an eolian episode. Within the middle member are two distinct spongy peats composed of the moss *Drepanocladus brevifolius* and stems of *Carex aquatilis*. At present, these elements typically occur around pond margins or in the basins of low-centered polygons (Webber and Walker, 1975: 83); they constitute the major vegetation in the Type M2 vegetation type (Figure 3).

Our interpretation of the stratigraphy is as follows: (1) the lower member represents river gravel; (2) the river swung away from the site and overbank silts were deposited during spring floods; (3) polygon formation led to the development of low-centered polygons (unit 4, Figure 6) which were partly covered by a period of eolian sand deposition (unit 5) and subsequently by more Type M2 vegetation as ponds once again occupied the low-centered polygons. Unit 6 consists of silts and plant remains. Examination of the plant fossils within this unit indicates that they are not in situ and thus we interpret this episode as one characterized by high spring floods with significant overbank deposition. Finally, the upper member (unit 7, Figure 6) suggests a locally drier environment where deposition is primarily eolian sands and silts from the alluvial fill of the river channel.

The basal date of 3470 ± 100 (Gif-3666) provides an age for the onset of overbank deposits and plant colonization. The date on the upper organic-rich sediments of 2300 ± 110 (Gif-3667) gives an estimate of the onset of eolian accumulation.

Putuligayuk River

This site is on the edge of a river-cut. The surface vegetation consists of vegetation Type B2, typical of well-drained sites (Figure 3). The major vascular plants includes *Dryas integrifolia* and *Saxifraga oppositifolia* with *Carex rupestris* also common.

The section is 2 m high, but the lower part is hidden by slump (Figure 7). Five main units were identified and four ^{14}C dates have been obtained (Table 3). Vegetation Type M2 occurs halfway through the section in unit 3. The top horizon consists of a yellowish brown fine silt that we correlate with unit 7 of Figure 6.

The initial basal ^{14}C date of 3270 ± 100 BP (Gif-3668) was obtained from in situ plant remains associated with a former pond estimated to have been deeper than 30 cm and possibly a Vegetation Type E1 habitat. Abundant remains of willow twigs and leaves occur within unit 1 and these are associated with a large number of small gastropod shells. Later dating of two other levels (DIC-674 and DIC-673) suggested that the original basal date was too young, and thus another sample was submitted for analysis. This new date of 3675 ± 195 BP (Table 3) is statistically similar to dates immediately above and below. Our interpretation is that the peat growth was rapid between 75- and 40-cm depth and then slows down. D. M. Hopkins (pers. comm., 1980) suggests that the reversal of dates indicates reworking of sediments in a thawed lake. However, Vegetation Type M2 plant remains indicate (Figure 3) a polygon association.

Sagavanirktok River

The stratigraphy in the 1.32-m section is complex with alternation between sandy to silty organic units strata (Table 4). The section is dated at 1210 ± 110 (Gif-3664) at the base, to nearly modern near the top (190 ± 100 [Gif-3665, Table 3]). The alternation of inorganic and organic-rich sediments indicates a variable depositional history with the area being occasionally inundated with eolian deposits from the adjoining alluvial ter-

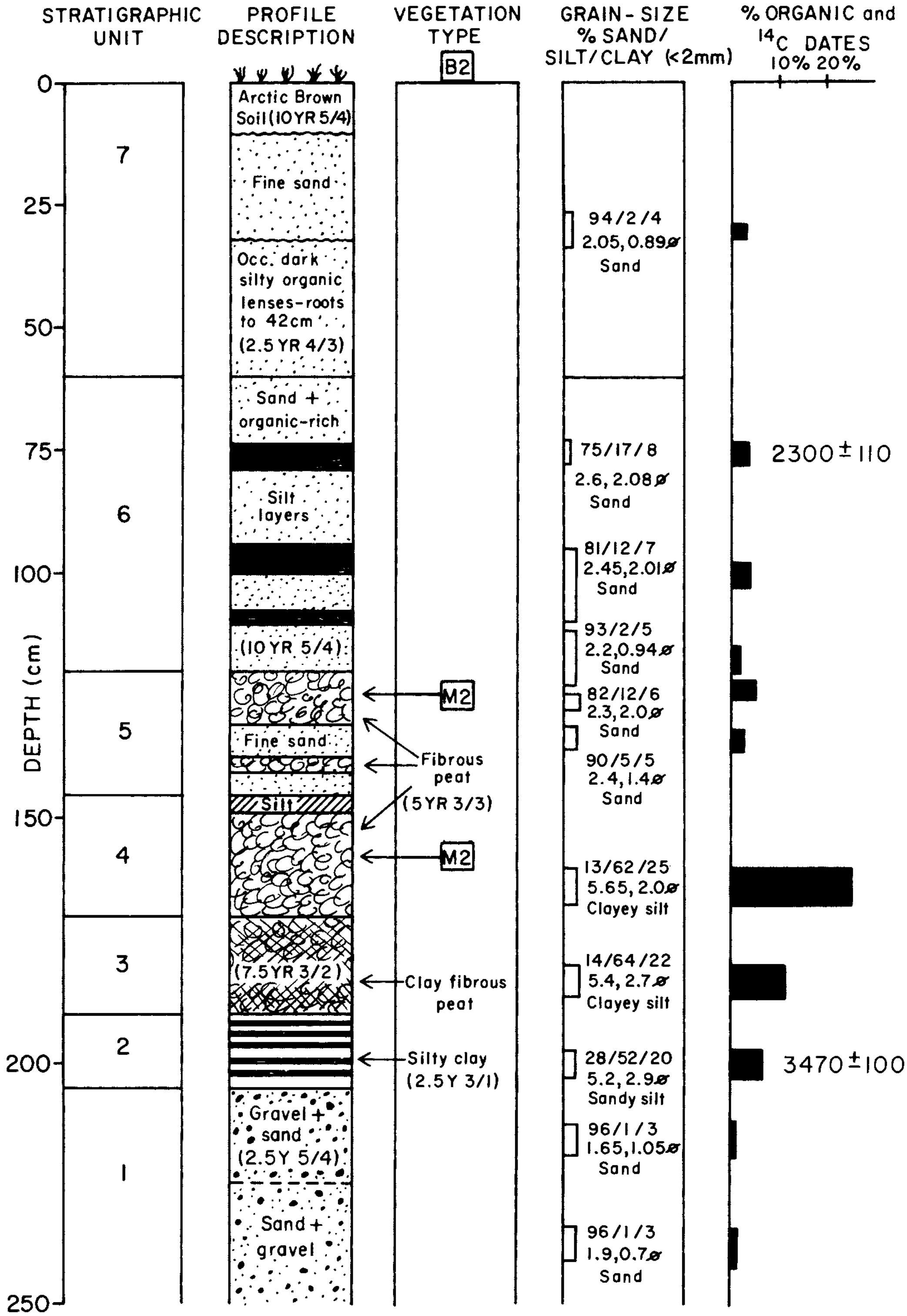

FIGURE 6. Stratigraphy and ¹⁴C dates on the Kuparuk River (see Figure 2 for location, site No).

rain. These conditions were interspersed with moisture periods (in terms of local habitat) when shallow thaw ponds allowed the in situ growth of *Carex aquatilis* and the mosses *Drepanocladus* and *Calliergon* spp. The basal date is most likely associated with a Vegetation Type U4 or Type M5. The surface vegetation on top of the slumped bank is typical of Vegetation Type B1 (Figure 3).

TABLE 3

Radiocarbon dates from peaty sediments, Prudhoe Bay region

Section	Depth	Lab. number	Date (BP)
Coastal cliffs	30 cm	Gif-4044	6480 ± 130
Kuparuk River	74 cm	Gif-3667	2300 ± 110
	195-205 cm	Gif-3470	3470 ± 100
Putuligayuk River	21-23 cm	DIC-673	2570 ± 80
	41.5-43.5 cm	DIC-674	3750 ± 90
	62-65 cm	GX-6469	3675 ± 195
	73-75 cm	Gif-3668	3270 ± 100
Sagavanirktok River	Near surface	Gif-3665	190 ± 100
	ca. 1.35 m	Gif-3664	1210 ± 110
Atigun River	Base of peat ca. 6.5 m	DIC-442	3080 ± 65

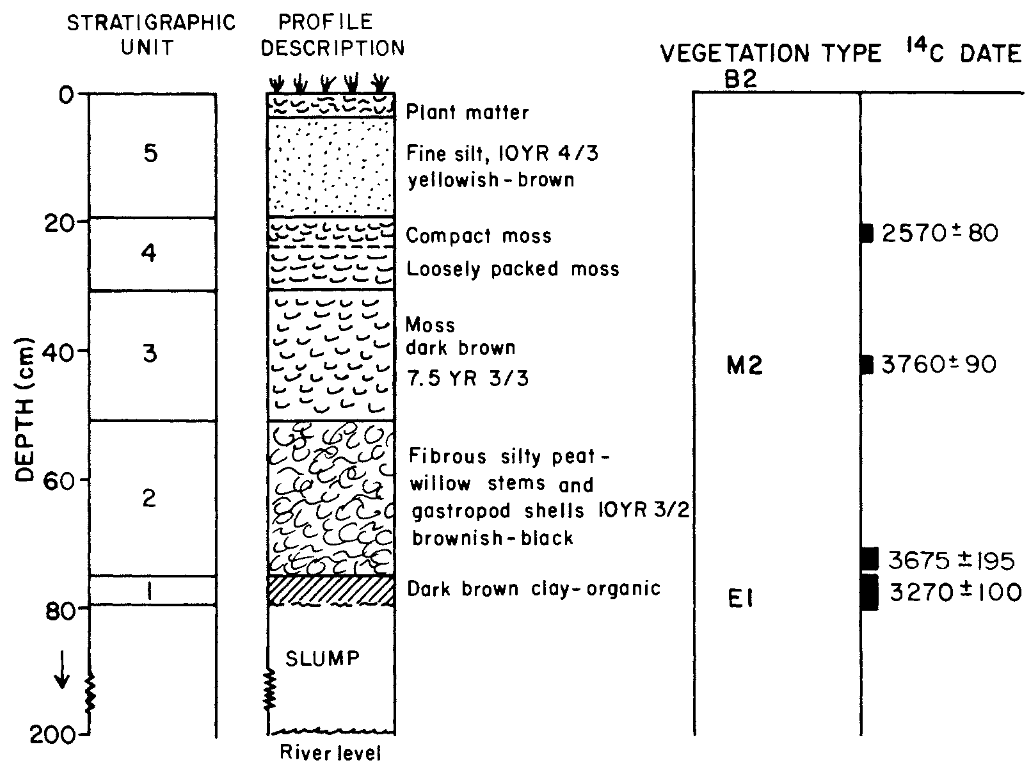

FIGURE 7. Section at the Putuligayuk River showing lithostratigraphy, vegetation types, and ^{14}C dates (see Figure 2 for location).

TABLE 4

Peat profile, Sagavanirktok River, Prudhoe Bay, Alaska[a]

This profile is taken from a large peat block that has fallen from the main river bank, which is east facing.

Overall weak stratigraphy in whole profile, but mineral matter is massive, sandy loam with thin beds of fine sandy loam.

Depth (cm)	Description
Surface	Crustose lichens (mainly *Lecanora epibryon*), *Chrysanthemum integrifolium, Dryas integrifolium, Oxytropis nigrescens*; thin surface layer 10YR 5/2, sandy loam.
0-2.5	10YR 5/2, fine sandy loam, massive, few roots (less than 2%), abrupt smooth boundary.
2.5-7.5	10YR 4/3, organic, massive, with 10YR 5/2 fine sand, common roots (2 to 20%), smooth boundary.
7.5-12.5	10YR 6/1, medium sand, with many 7/5YR 5/6 organic parts (*Carex* leaves and roots mixed with *Calliergon* moss), abrupt smooth boundary.
12.5-25	7.5YR 5/6, very organic (mostly *Calliergon* moss with some *Carex* stems and roots), with fine sandy loam, massive, abrupt smooth.
25-36	7.5YR 5/6, fine sandy loam, massive few or no mosses, mostly roots and root fibers.
36-48	A white band on the weathered exposed side of the peat block. Inside there is considerable plant material. Dominant color 7.5YR 5/8, very fine sandy loam or sandy loam, mostly fine roots with some mosses, with 10YR 4/3 mineral matter, massive, abrupt smooth.
48-58	Dark band. 7.5 YR 5/6, organic matter with 10YR 5/3 mineral matter, fine sandy loam, massive many roots, stems, leaves, etc. (*Carex*?), not many mosses.
58-64	10YR 5/6, mostly mineral matter (more than previous layers) less than 20% organic massive, abrupt.
64-66	Band of sand 10YR 5/1, medium sand with variegated colors.
66-68.5	Composition of peat changes to more, coarser *Carex* roots.
68.5-132	Many thin layers of mineral matter 10YR 4/3 (rubbed 10YR 3/2), weak platy structure throughout.

[a]Profile description by R. J. Parkinson, Ohio State University.

ATIGUN ROAD CUT

A fourth section was sampled farther inland to provide an initial estimate of the possible gradients in pollen spectra between the Brooks Range and the Coastal Plain. The section is on the west side of a road cut near the Atigun River (Figure 1). A ^{14}C date of 3080 ± 65 BP (DIC-442) was obtained from a sample of in situ willow twigs, with bark intact, from a depth of 6.5 m. Samples for pollen analysis were taken at 50- and 100-cm intervals. Hamilton (1979) has described an equivalent section (A3) and presented additional ^{14}C dates collected from similar units by P. E. Calkin and J. M. Ellis (SUNY, Buffalo) which range between ~740 and ~2510 BP (Hamilton, 1979: Table 1).

PALYNOLOGY

The pollen samples were prepared, counted, and processed in the Institute of Arctic and Alpine Research's (INSTAAR) Palynology Laboratory by Short and Andrew Millington. The procedures of this laboratory are specifically geared toward samples that have a large inorganic fraction and low pollen numbers per slide. Description of the laboratory procedures are given in Nichols (1975), Boulton et al. (1976), and Short and Nichols (1977) and are not repeated here in detail.

Relative pollen diagrams are usually based on counts of 100 pollen grains of taxa excluding *Sphagnum*, Ericaceae, and Cyperaceae. Percentages are computed with these three taxa outside the sum. However, in many of our levels an entire slide might only include ~50 grains due to the inorganic nature of the sediments and the often poor condition of the pollen grains.

Pollen concentration diagrams[1] were prepared: the method used is based on the addition of exotic pollen of known amounts into the preparation. The changes in pollen concentration (grains/gram dry weight = gr gdw^{-1}) provide insights into the variations in the rates of sedimentation and in the accumulation of pollen (as grains per square centimeter per year). Exotic pollen of pine and spruce are counted by scanning one to three slides at low magnification (Nichols, 1975).

Modern Pollen Rain

Nelson (1978, 1979) has published some modern pollen rain data from the North Slope. In addition, W. N. Mode (pers. comm., 1980) has counted modern pollen in surface moss polsters collected along the pipeline haul road. The surface samples of certain of our peat sections also record the modern pollen rain. A feature of Nelson's relative pollen spectra from the region of Prudhoe Bay is the high percentages of *Picea* (19 to 26%). Interestingly, percentages fall off both to the east and west. Other significant taxa include *Alnus, Betula, Salix,* Cyperaceae, and Gramineae (Nelson, 1978, 1979). The first two taxa occur with values of 8 to 30% despite being north of these shrub limits (Figure 1). Mode's data show, on the basis of two polsters from near Prudhoe, only 1 to 2% *Picea,* 5 to 10% *Betula,* 14 to 21% *Alnus,* and about 21% *Salix.* The spectra were dominated by sedge.

Kuparuk River Section

The section sampled for pollen comes from between 208 and 120 cm and dates from 3470 ± 100 BP and to somewhat older than 2300 BP (Figure 6). In view of the sandy nature of the sediments above 120 cm, we estimate the 120-cm level to be close to 2500 BP. Thus the average sedimentation rate for the peat section is 7.8 ± cm 100 yr^{-1}. The pollen was counted at 5-cm intervals which represents, on average, 63 yr.

The relative diagram (Figure 8) indicates the dominance of Cyperaceae. There are, however, significant percentages of various exotic pollens (*Betula, Alnus, Pinus,* and *Picea*) that are presumably wind-blown into the area. *Alnus* often occurs in larger percentages than *Betula* even though dwarf birch grows 70 km to the south. The right-hand side of the diagram shows a simple three-fold growth-form division and indicates that herbs are ranked first in abundance, followed by shrub, and then tree pollen. There are no clear trends in the diagram that might be ascribed to changes in local environments or to regional climatic variations. However, diversity and the percent of tree pollen are below average between 175 and 150 cm and again between 135 to 120 cm. The primary *Pinus* peak occurs near the base of the diagram, whereas the largest percentage of *Picea* is located at 145 cm.

The "absolute" diagram presents a contrast, especially when the curves of *Alnus,* Gramineae, and Cyperaceae are compared. This diagram shows a major peak of "absolute" pollen between 145 and 185 cm. In this interval, maximum "absolute" values of *Alnus, Betula, Picea, Salix,* Gramineae, and Cyperaceae occur. The *Pinus* curve drops off and becomes erratic above 150 cm. A comparison of the high "absolute" peaks against the stratigraphy (Figure 6) indicates little correlation. Therefore, we believe that the peak in pollen accumulation does not represent purely site-specific conditions, but rather a regional environmental change starting at ~2700 BP and terminating at ~2300 BP.

Examination of the data on pollen concentrations indicates that total pollen accumulation throughout the diagram varies from 508 to 6728 gr gdw^{-1}.

Putuligayuk River Section

This is an important section because it represents a continuous span of the late Holocene which includes within it the time of deposition of both the Kuparuk and Sagavanirktok sections. It is essentially coeval with the Atigun section.

The relative diagram (Figure 9) registers the dominance of Cyperaceae pollen at virtually all levels. There are significant percentages at most levels of *Alnus, Betula, Picea, Pinus, Salix, Artemisia,* and Gramineae. The relative diagram records a grass episode at 55 cm at a time when *Alnus* was low and *Picea* and *Pinus* pollen were not entering the area.

The "absolute" diagram tends to mirror the relative diagram. However, the Gramineae

[1]These are not included here due to generally low pollen sums; those interested in this data may contact the authors.

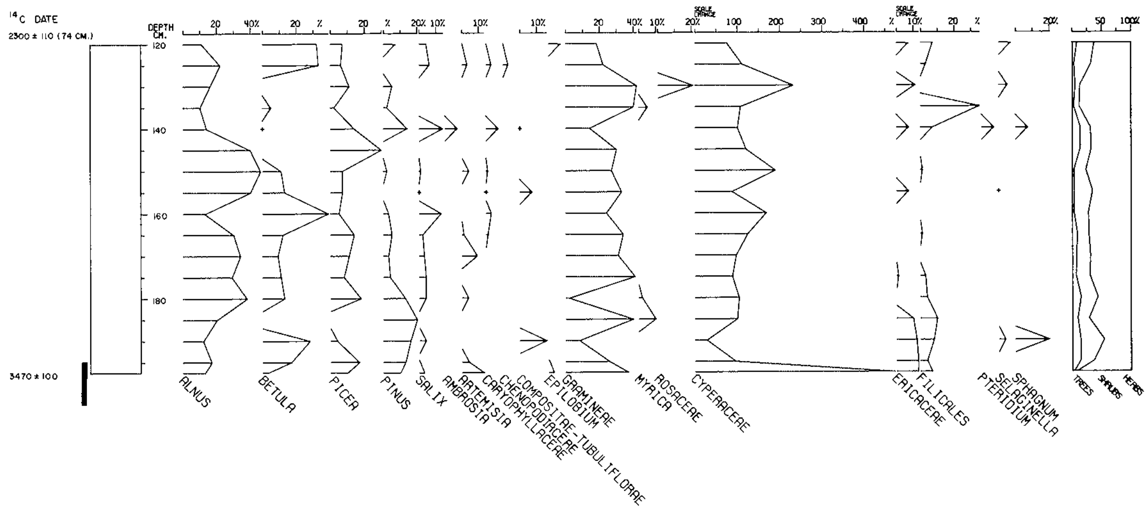

FIGURE 8. Kuparuk River site relative pollen diagram (pollen sum excludes Cyperaceae, Ericaceae, and *Sphagnum*).

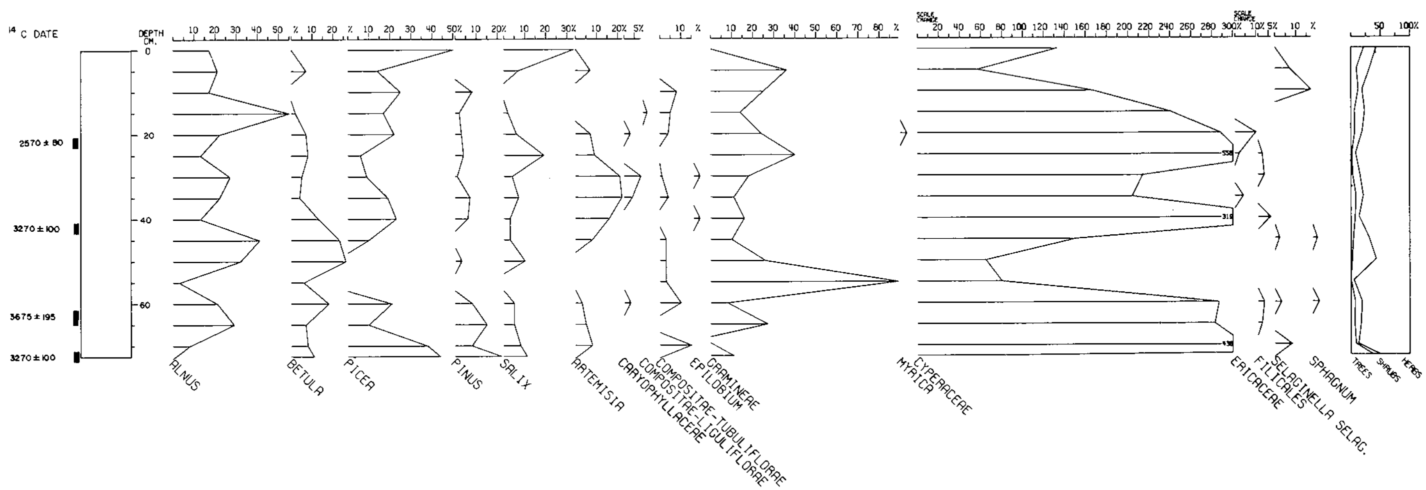

FIGURE 9. Putuligayuk River site relative pollen diagram (pollen sum excludes Cyperaceae, Ericaceae, and *Sphagnum*).

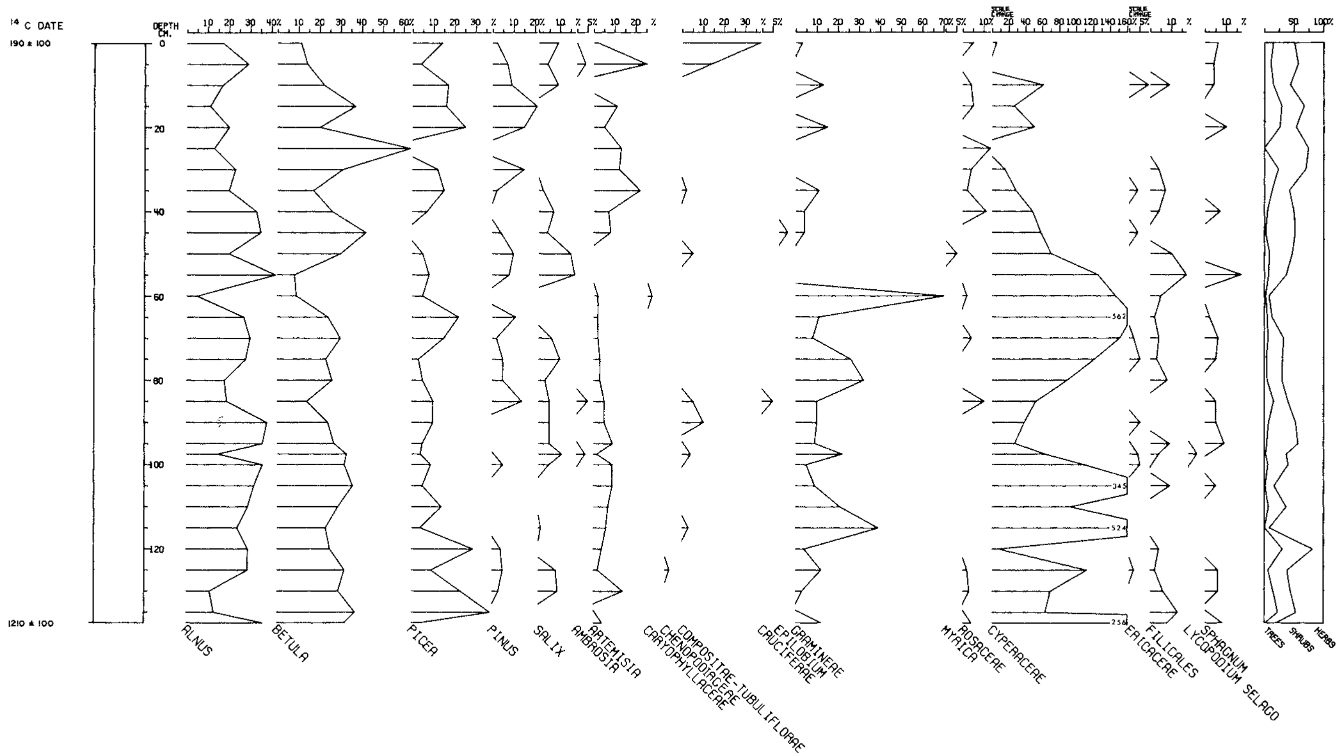

FIGURE 10. Sagavanirktok River site relative pollen diagram (pollen sum excludes Cyperaceae, Ericaceae, and *Sphagnum*).

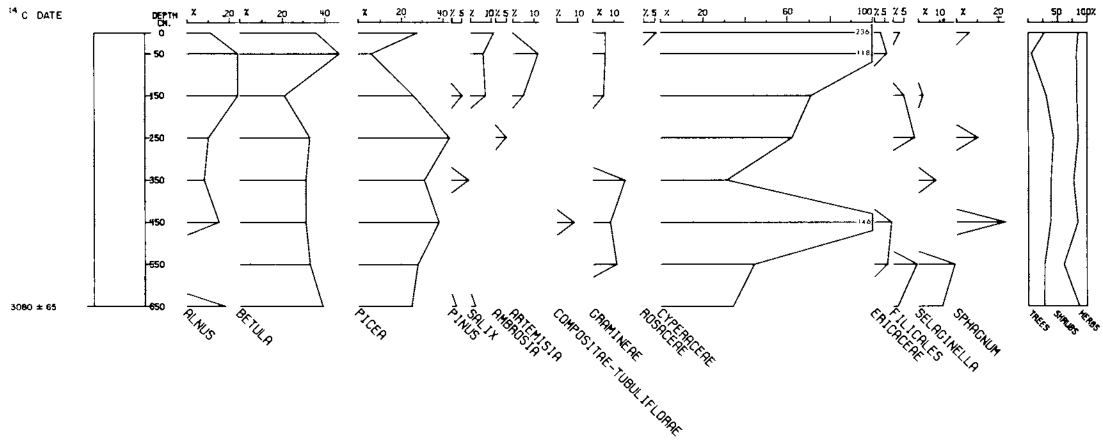

FIGURE 11. Atigun River site relative pollen diagram (pollen sum excludes Cyperaceae, Ericaceae, and *Sphagnum*).

peak described above now is correlated with a secondary Cyperaceae maxima; tree pollen numbers again register minimum values here. The grouping of the taxa into growth forms indicates the strong tree components in these diagrams. "Absolute" pollen numbers vary by an order of magnitude between 464 and 14,161 gr gdw^{-1}. In this diagram the surface pollen represents average present conditions for the last several years. The eolian deposition, which starts at 19 cm, leads the decline in "absolute" pollen values which troughs at 10 cm.

Sagavanirktok River Section

This section was sampled at 5-cm intervals which represents, on average, one sample every 36 yr (Figure 10). Considerable difficulties were experienced in counting pollen from this section. Even counting an entire slide frequently resulted in 50 grains and less. The recovery estimates of the added exotic tablets were also consistently low. The low pollen numbers are easily explained as much of the section (Table 4) is largely inorganic, and hence the number of pollen grains per gram dry weight will be low compared to the pollen accumulation onto a surface that is primarily organic. However, the low counts are such that we are cautious in interpreting any changes in "absolute" pollen numbers.

The relative diagram (Figure 10) differs from the previous two sites by the presence of higher *Betula* percentages; thus the proportion of shrub pollen is higher in this diagram. Cyperaceae pollen is still the major constituent of the diagram, but it varies between 0 and 160% and thus is less important than in the other diagrams. The Cyperaceae curve declines toward low values in the upper 50 cm of the section, roughly over the last 500 or 600 yr (assuming sedimentation rate of 14 cm 100 yr^{-1}). This is accompanied by an increase in *Artemisia* and Rosaceae which could be indicative of a sand dune environment, dominated by Gramineae, *Artemisia,* and *Dryas*.

The "absolute" diagram verifies the low absolute numbers of Cyperaceae pollen and in the upper part of the diagram both Cyperaceae and Gramineae pollen decline to very low "absolute" numbers. Exotic tree pollens of *Picea* and *Pinus,* particularly *Picea,* are quite evident with a maximum *Picea* value of 700 gr gdw^{-1} near the base of the section.

Atigun Road Cut Section

The Atigun section lies well inland of the three sites from the Coastal Plain (Figure 1). It is a basin-fill type deposit and hence some reworking and redeposition of the pollen is probable. The section is 6.5 m thick and covers about 3000 yr of record. Because of the thickness of the section, samples were taken at 100- and 50-cm intervals. These levels thus represent, respectively, a sampling interval of about 500 or 250 yr on average.

The relative diagram (Figure 11) is similar to those from Prudhoe Bay with 30 to 40% *Betula* and 10 to 20% *Alnus*. Cyperaceae pollen occasionally reaches high percentages but in this diagram is more commonly less than 60%. Gramineae is present but in low percentages. Tree pollen is dominated by *Picea*. *Pinus* is only present at some levels.

The "absolute" diagram suggests a very general three-fold division of the data. At the base, the accumulation of *Picea*, *Alnus*, and *Betula* pollen was relatively high. Between 5.5 and 2.5 m Cyperaceae pollen is present in moderate quantities, but at 1.5 m and thereafter the diagram is dominated by Cyperaceae.

Coastal Peat

A buried peat is dated at 6480 ± 130 BP (Table 3). This site is on the coast and hence in the zone of depressed summer temperatures. The pollen spectrum is dominated by Cyperaceae (311%) but *Betula* is the next most important taxa and makes up 41% of the count inside the sum. Other important pollens are *Picea* (11%), *Alnus* (11%), and *Pinus* (6%). This sample appears to have a larger proportion of Low Arctic shrub pollen and exotic tree pollen than the profiles noted above which date ≤3500 BP.

DISCUSSION

Rarely have pollen diagrams been presented for tundra areas that are as well known vegetationally as the Prudhoe Bay-Atigun River area. Pollen diagrams from the region only partly mirror the present vegetation. We are impressed by the evidence of widespread and consistent influx of exotic pollen into the tundra. Exotic *Pinus* and *Picea* pollen entering the coastal region may come from south of the Brooks Range. The nearest white spruce (*Picea glauca*) occurs about 300 km to the south across the divide of the Brooks Range (Viereck, 1979). However, because of the prevailing easterly winds it is probable that significant pollen may be carried into the area from the vicinity of the Mackenzie River delta, Canada, where the treeline runs close to the coast (Ritchie, 1974). The closest spruce east of Prudhoe Bay are in the Firth River drainage (Drew and Shanks, 1965). The nearest species of pine are *Pinus contorta*, which occurs west of Dawson, Yukon Territory, about 800 km southeast of Prudhoe Bay, and *Pinus banksiana*, which occurs in the Nahanni Mountains, 1400 km south-southeast of Prudhoe Bay (Hultén, 1968). The high amounts of spruce and pine are a feature of the diagrams presented here and this was also noted by Nelson (1978, 1979) in polsters from nearby sites. Such high percentages contrast with the lower percentages recorded at Chandler Lake (Livingstone, 1957) and at sites on the North Slope (Nelson, 1978, 1979). *Betula* and *Alnus* pollen also are consistently high in the region although the plants do not occur locally.

Several aspects of the local tundra are underrepresented in the pollen profiles. All the diagrams contain rather low percentages of *Salix* pollen, especially when compared to the consistently high values of *Betula* and *Alnus* pollen. *Betula* and *Alnus* are lacking in the present-day vegetation of the Prudhoe Bay area, but *Salix* is important in streamside and tundra communities. This can be explained by the fact that *Salix* is largely insect-pollinated; *Betula* and *Alnus*, on the other hand, are wind-pollinated and release large amounts of pollen. The mosses are also underrepresented in the profiles. Although they account for up to 50% of the relative cover of plants, they do not appear in the pollen diagrams, except for *Sphagnum* which is locally an exotic moss. Moss spores are not distinguishable with usual palynological techniques; however, it is also known that most of the common mosses in the region, e.g., *Tomenthypnum*, *Drepanocladus*, and *Scorpidium*, do not produce sporophytes in this environment. *Dryas* is another important component of the local vegetation that is underrepresented in the pollen diagrams. The plant does flower abundantly locally, but it also is an entomophilous plant, and the pollen is not dispersed by the wind. Other unrepresented families include the Saxifragaceae, Leguminosae, Papaveraceae, and Scorphulariaceae. Ritchie (1977) has called these unrepresented groups "palynologically silent elements," and has noted the difficulty of interpreting tundra vegetation from pollen records since these groups are often dominant in the vegetation.

It is difficult at present to recognize any consistent changes in the pollen profiles that are indicative of changes in the local vegetation patterns. The influx of exotic pollen apparently masks the small-scale changes in the tundra mosaic, and some mixing and redistribution of sediments in thaw lake cycles may redistribute pollen. The general stratigraphies and macrofossil assemblages (for example, sedge and moss fragments, *Salix* twigs, and loess layers) of the peat profiles appear to reflect the local changes in a more interpretable manner. In the Prudhoe Bay region the pollen record is not a faithful recorder of local vegetation conditions because (1) many of the important local aspects of the flora are underrepresented or not recognized, and (2) significant amounts of the pollen are far-traveled, and thus the local tundra mosaic is effectively filtered and not available for reconstruction. However, the broad changes in amount of sedge pollen and in the amount of exotic shrub or tree pollen may possibly reflect regional changes in climate. The similarity between the Prudhoe Bay and the Atigun River profiles suggests that caution needs to be used in applying Livingstone's (1955, 1957) zonation scheme too freely.

The importance of grasses and *Artemisia* in the present-day dune vegetation at Prudhoe Bay leads to interesting speculation about the nature of the "steppe-tundra" landscape. Several authors (Colvinaux, 1964; Hopkins, 1967) have suggested that a vast grassland covered Beringia during the late Pleistocene; this is supported by faunal interpretations (Guthrie, 1968) and the existence of steppe communities in the Siberian arctic (Yurtsev, 1972). The lack of present-day northern Alaskan analogs to the Siberian steppe-tundra (Matthews, 1976; Young, 1976; Cwynar and Ritchie, 1980), and the existence of present-day *Artemisia*-Gramineae dune communities at Prudhoe Bay points to the possibility of a very different type of arctic grassland in the Alaskan portion of Beringia than those described by Yurtsev in present-day Siberia. Just how extensive the fluvial and nonfluvial dune landscapes were and what the composition of the associated plant communities was is difficult to deduce from the present-day environment. The ongoing work of Komárková, who is studying the vegetation of the sand region of northwestern Alaska (Komárková and Webber, 1980; Komárková, pers. comm., 1980), and phytosociological studies along the Brooks Range to Arctic Coast transect (Brown and Berg, 1980; Walker, 1981) will certainly aid in future discussions regarding both present and past Alaskan tundra environments. The recent work of Cwynar and Ritchie (1980) in northwest Canada further suggests that the so-called steppe-tundra may have been simply an expansion of existing dry tundra types and that we may not have to resort to recently "extinct biomes" to explain the palynological data. To improve on the pioneering work of Livingstone (1955, 1957) and Ritchie (1974, 1977), we need more fossil profiles, more information on local modern pollen rain, and better dating control before we can develop a sound and consistent system of pollen zones.

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