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Palynomorph biostratigraphy of Upper Cretaceous to Eocene samples from the Sagavanirktok Formation in its type region, North Slope of Alaska

By

Norman O. Frederiksen[1], Thomas P. Sheehan[1], Thomas A. Ager[2], Timothy S. Collett[2], Thomas D. Fouch[2], Karen J. Franczyk[2], and Mark Johnsson[3]

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[1]Reston, Virginia
[2]Denver, Colorado
[3]Bryn Mawr College

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ABSTRACT

This report discusses the palynomorph (pollen, fungal spore) analysis of 39 outcrop samples from the Sagavanirktok Formation at six localities in its type region on the North Slope of Alaska.[1] The analyses were performed to obtain information mainly about the ages but also about the environments of deposition and provenance of the sediments. Sampling localities and their pollen/fungal spore ages, as determined here, were: Franklin Bluffs (early to middle Eocene), Sagwon Bluffs area (early and late(?) Paleocene), Ivishak River (late Maastrichtian or early Paleocene), Shaviovik anticline area (Paleocene), Kavik River (upper Maastrichtian or early Paleocene), and Toolik River-White Hills (Campanian or Maastrichtian; Paleocene).

The present samples demonstrate well the rise in angiosperm taxon diversity on the North Slope of Alaska from very low at the beginning of the Paleocene to very high in the Eocene.

INTRODUCTION

The Sagavanirktok Formation (Upper Cretaceous and Tertiary) on the North Slope of Alaska is in part correlative with the informally named West Sak and Ugnu sands (see Bird, 1988) that contain enormous accumulations of heavy oil in the Prudhoe Bay area, and the sandstones of the Sagavanirktok Formation themselves are potential petroleum reservoir rocks (Bird and others, 1987). This report concerns the palynological analysis of 39 outcrop samples of the Sagavanirktok Formation from seven localities in its type region on the North Slope of Alaska. A total of 71 outcrop, core, and trench samples were processed for this study, in addition to 11 samples previously processed and examined for pollen by Ager that were re-analyzed (these 11 samples are included in the 39 analyzed samples mentioned before). The samples previously discussed by Frederiksen and others (1994) are also included in the summary of this report.

Angiosperm pollen grains in the samples were analyzed mainly to determine their ages. The presence of dinocysts was noted in order to infer some information about the environments of deposition of the sediments, and the presence of reworked palynomorphs was noted in order to provide information about the provenance of the sediments. Practically nothing is known about the climatic affinities of the Paleocene pollen taxa; therefore, little could be inferred about the nature of the terrestrial paleoclimate as a supplement to the conclusions of Frederiksen and others (1994) about the Eocene climate. Most of the productive samples were collected during the 1994 field season.

Tables of sample locality data list only those samples that were processed for palynomorphs.

PALYNOLOGICAL METHODS

The samples discussed in this paper were processed using normal palynological techniques of HCl; HF; HNO_3; short centrifugation with soapy water to remove fines; and heavy liquid separation using a $ZnCl_2$ liquid of 1.45 s.g. A relatively light heavy liquid was used in order to remove the abundant black woody material in the samples. The residues were stained with Bismark brown. The final step of residue preparation was screening to remove unwanted fine material, using 8 µm or 10 µm sieves. However, some of the residues consisted mainly of bisaccate conifer pollen, and for these samples it was very helpful to use a nest of 8 µm and 40 µm sieves to remove both the fine material and the larger palynomorphs, enriching the final residue in angiosperm pollen. The residues were mounted in glycerine jelly.

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[1]Some samples, for example from Franklin Bluffs, may be assignable to the Mikkelsen Tongue of the Canning Formation.

STRATIGRAPHY AND PREVIOUS AGE DETERMINATIONS

The Sagavanirktok Formation is 3,300-8,800 ft (1,000-2,700 m) thick in northeastern Alaska; in some places, this thickness includes one or more tongues of the Canning Formation (Bird and others, 1987). The Sagavanirktok Formation, named and described by Gryc and others (1951), was divided by Detterman and others (1975) into three members, in ascending order the Sagwon, Franklin Bluffs, and Nuwok Members, as summarized by table 1. Gryc and others (1951) and Detterman and others (1975) considered the Sagavanirktok Formation to be entirely Tertiary in age. However, Late Cretaceous sandy, shallow marine and terrigenous strata are now also included in the formation, which contains microfossils as old as Campanian; the base of the formation becomes younger toward the northeast (Molenaar and others, 1987).

Table 1. Members of the Sagavanirktok Formation (in descending order); these members apparently do not include the Cretaceous rocks placed in the formation by, for example, Molenaar and others (1987).

Member	Lithology	Age
Nuwok Member	Mainly sand, mudrock, and siltstone	Late Tertiary[1]
Franklin Bluffs Member	Laminated mudrock, fine-grained sandstone, silt, and clay, overlain by sand, gravel, and volcanic ash	Eocene,[2,3,4] Oligocene(?),[1] and Miocene(?)[1]
Sagwon Member	Mudrock, sandstone, conglomerate, and coal	Paleocene[4,5] and Eocene[3,4]

[1]Detterman and others (1975)
[2]Ager and others (1986)
[3]Frederiksen and others (1994)
[4]This report
[5]T. A. Ager, in Carey and others (1988) and in Spicer and Parrish (1990)

The type locality of the Sagwon Member is at Sagwon Bluffs (area of sections B1, B2 in figs. 1-3); "the type section starts at VABM Gard and continues south for about 1.6 km (1 mi) along the river bluff, lat 69°23'30" to 69°24'30" N., long 148°39'30" to 148°41' W." (Detterman and others, 1975, p. 37). The type locality of the Franklin Bluffs Member, and of the Sagavanirktok Formation itself, is at Franklin Bluffs (figs. 1 and 4, very close to Section A8 of this report); the type section is "along the stream 1.8 km (1.1 mi) S. 10° W. of VABM Greta, lat 69°49' N., long 148°41' W." (Detterman and others, 1975, p. 37). The upper Tertiary Nuwok Member is not discussed in this report.

Detterman and others (1975, p. 38) defined the Sagwon Member as being "the coal bearing sequence of the Tertiary in northeastern Alaska." Therefore, Frederiksen and others (1994) placed the contact between the Sagwon and Franklin Bluffs Members at the south end of Franklin Bluffs, where coal-bearing strata (Section A1 of this report, assigned to the uppermost part of the Sagwon Member) are overlain by silty and clayey strata of the Franklin Bluffs Member (Section A2 of this report). This contact is probably conformable as surmised by Detterman and others (1975). The Sagwon Member has been dated at its type locality as Paleocene, apparently early Paleocene, on

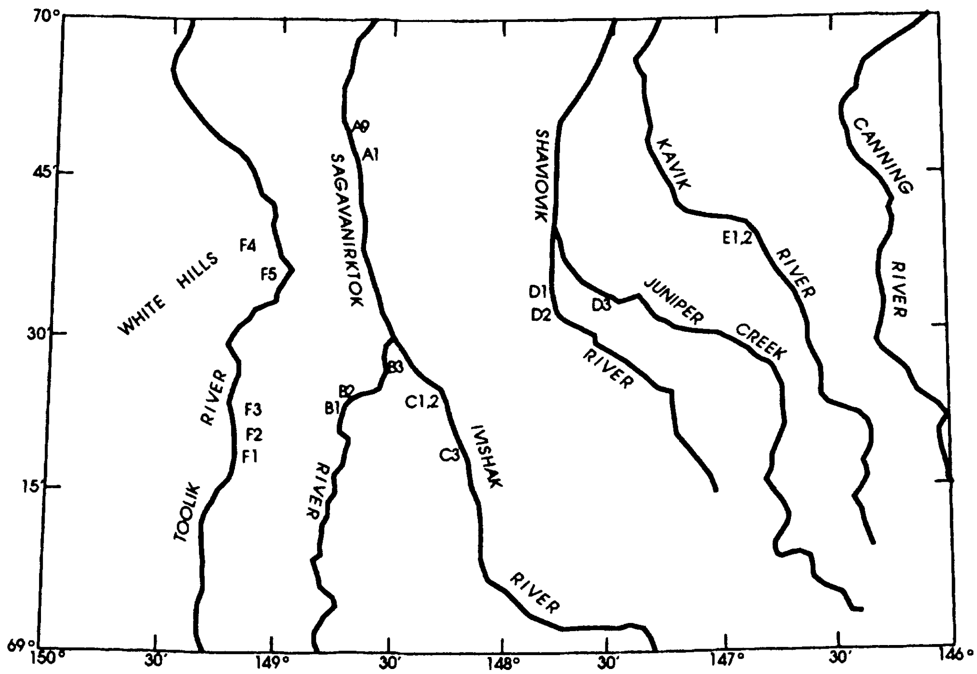

Figure 1. Index map showing locations of sections discussed in this report that were sampled during the 1984, 1992, and 1994 field seasons.

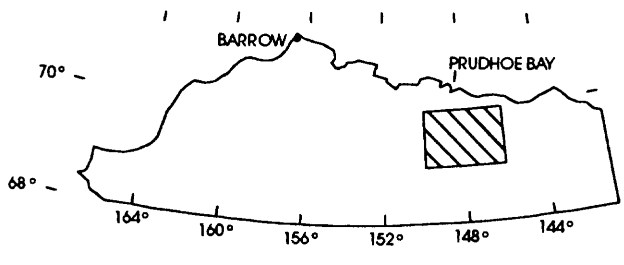

Figure 2. Location of the figure 1 map in northern Alaska.

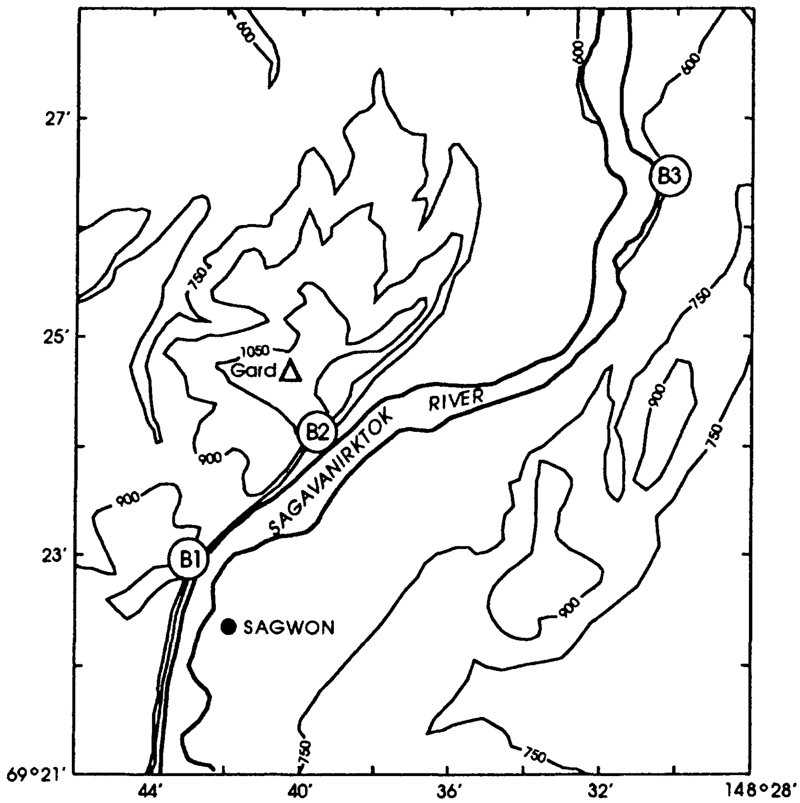

Figure 3. Location of stratigraphic sections in the Sagwon Bluffs area. Sagwon Bluffs are the gently sloping areas west of Sections B1 and B2. Contour interval is 150 ft. Section B1 was sampled in 1984 and 1994, B2 and B3 in 1994. Section B1 includes part of section 19 of Detterman and others (1975); Section B2 includes part of section 23 of Detterman and others (1975) and sample locality B of Roberts and others (1991).

the basis of very low-diversity pollen assemblages (T. A. Ager, in Carey and others, 1988, and in Spicer and Parrish, 1990). Plant megafossils "from the beds in the lower part of the Sagavanirktok formation on the Sagavanirktok River" were dated as early Tertiary by R. W. Brown (unpublished report cited by Keller and others, 1961, p. 208). These plant megafossils had been collected near Sagwon, according to Detterman and others (1975). The top of the Sagwon Member (Section A1 of this report) is very probably early Eocene in age (Frederiksen and others, 1994; this report).

Detterman and others (1975, p. 37, 39) believed that "the beds at Franklin Bluffs are younger than Eocene," but this determination was not based on any fossil evidence. All strata that have been dated from the Franklin Bluffs Member have proved to be early to middle Eocene (Ager and others, 1986; Frederiksen and others, 1994; this report), and, as pointed out by Frederiksen and others (1994), the Eocene mudrock and sandstone sections in the Franklin

Bluffs Member of the Sagavanirktok Formation are temporal equivalents of the Mikkelsen Tongue of the Canning Formation (Molenaar and others, 1987).

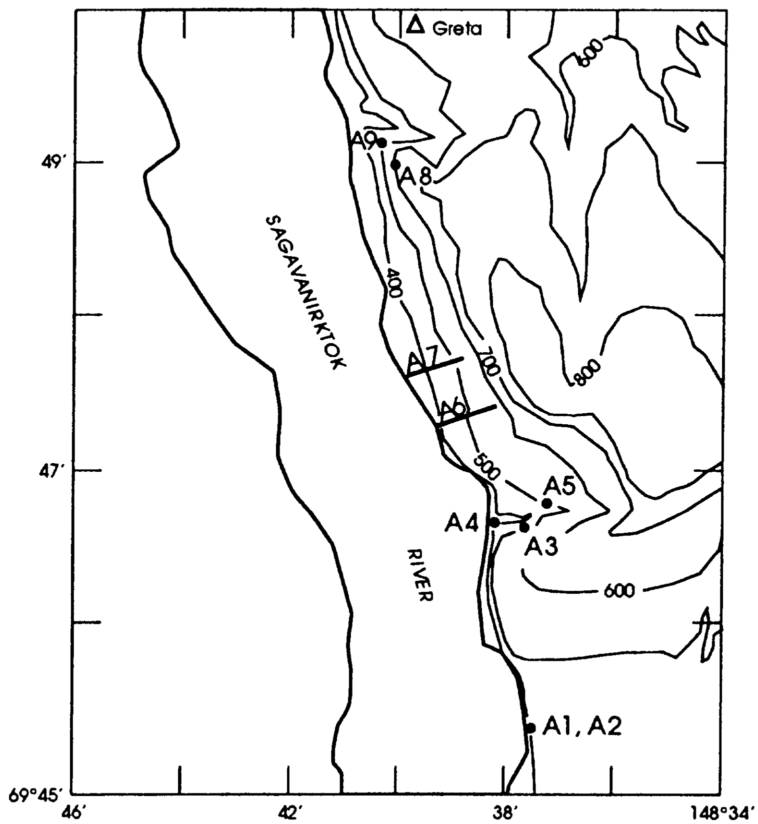

Figure 4. Location of stratigraphic sections at Franklin Bluffs. Contour interval is 100 ft. Section A1 was sampled in 1984 and 1992, A2-A4 in 1992, A5 in 1994, A6 and A7 in 1984, A8 and A9 in 1994.

PALYNOLOGY

Locality A - Franklin Bluffs

Locality A includes nine sections in the Franklin Bluffs, which extend along the east side of the Sagavanirktok River from sec. 17, T. 6 N., R. 14 E., to sec. 27, T. 5 N., R. 14 E., Sagavanirktok (D-3) quadrangle (fig. 4). In figure 4, locations of sections sampled by the 1984 field party are taken from the maps drawn by this party.

Section A1

Section A1 is a coal-bearing interval at the south end of Franklin Bluffs, collected by Ager in 1984. This is probably the same interval that was sampled in 1992 by Frederiksen and others (1994, section 4). The coal bed exposed in 1984 consisted of wood, needles, and cones of *Metasequoia*. The coal bed exposed in 1992 seemed to be composed entirely of slabs of wood with muddy coal or coaly mudrock at the base (sample R4713F of Frederiksen and others, 1994), but at that time the top of the bed was overlain by slumped(?) gravel, and in 1984 more of the coal bed was visible. The location of section 4 of Frederiksen and others (1994) was in the SE$^1/_4$ NW$^1/_4$ SW$^1/_4$ sec. 27, T. 5 N., R. 14 E. (lat. 69°45.39′ N., long. 148°47.42′ W.). As noted previously, Section A1 apparently forms the top of the Sagwon Member of the Sagavanirktok Formation. Analyses of four samples from Section A1 are included in this report (three samples of Ager, listed in table 2, and one sample of Frederiksen and others, 1994); the analyses are given in table 3.

Sections A2, A3, A4

Sections A2, A3, and A4 of this report are sections 5, 2, and 1, respectively, of Frederiksen and others (1994). Section A2 is a thin silty and clayey exposure less than 10 m topographically above Section A1; Sections A3 and A4 are farther north (fig. 4). They are early or middle Eocene in age (Frederiksen and others, 1994) and are not discussed in detail in this report, but a summary of taxon occurrences in these sections is given in table 6.

Section A5

Section A5 (fig. 4) is the same as section 3 of Frederiksen and others (1994; not sampled for palynomorphs in 1992). The location is NE$^1/_4$ NW$^1/_4$ sec. 22, T. 5 N., R. 14 E. (lat. 69°46.94′ N., long. 148°37.09′ W.), in a small gully developed in the south side of a west-flowing unnamed stream that enters the Sagavanirktok River, and is composed mainly of noncalcareous mudrock and very-fine-grained sandstone. During the 1994 field season (July 19), Frederiksen collected one sample from Section A5 (table 2), but the preservation of palynomorphs was poor.

Section A6

Six of the samples Ager collected in 1984 from this locality were re-analyzed for this report (table 4); these samples were from the lower part of the local section.

Section A7

Two of Ager's samples collected in 1984 were re-analyzed for this report (table 5), from near the base of the local section.

Table 2. Samples processed for palynomorphs from Locality A, Franklin Bluffs (excluding those discussed by Frederiksen and others, 1994). In the Pollen Analysis column, A means an analysis was completed, B means the sample was barren of palynomorphs, and P means palynomorphs were present but preservation was too poor for an analysis to be made. Initials of sample collectors are: TAA, Thomas A. Ager; TDF, Thomas D. Fouch; NOF, Norman O. Frederiksen.

Palynology number; collector(s)	Field number	Section	Position	Latitude and longitude	Lithology	Pollen analysis
R3402B TAA	3/8/84, stop 2, sample B	A1	2-inch clay layer below coal bed		Clay	A
R3313 TAA	8/8/84	do.	Below coal bed		Felt-like woody debris	A
R3428 TAA	8/8/84	do.	Within coal bed		Coal	A
R4943 NOF	NF94AK-1	A5	Approximately 20 m above base of section, W. side of cross-gulley in major E-W gulley	69°46.94' 148°37.09'	Mudrock, medium gray, carbonaceous, laminated	P
R3319A TAA	7/8/84, section 1, sample 1	A6	4 m above river level			A
R3319B TAA	7/8/84, section 1, sample 2	do.	5 m above sample 1			A
R3319D TAA	7/8/84, section 1, sample 4	do.	Below log layer			A
R3319E TAA	7/8/84, section 1, sample 5	do.	About 5.5 m above log layer			A

R3319F TAA	7/8/84, section 1, sample 6	do.	About 10 m above log layer		Silt, brown	A
R3319G TAA	7/8/84, section 1, sample 7	do.	About 14 m above log layer		Clay and silt	A
R3401H TAA	3/8/84, section 1, sample H	A7	About 75 ft (22.9 m) below top of section		Silt and clay	A
R3401I TAA	3/8/84, section 1, sample I	do.	8 ft (2.4 m) below sample H		Silt and clay	A
R4945 A TDF, NOF	NF94AK-6	A8	20 cm above TF 7 m	69°49.02'(27) 148°40.77' (base of this part of section)		P
R4945 F TDF	7TF94SIAK	do.	81.6 m	69°48.96'(27) 148°40.51'	Mudrock, gray, contain-ing floating pebbles, deeply weathered	P
R4945 G TDF	8TF94AK	do.	82-83 m	do.	Mudrock, light gray	B
R4945 H TDF	9TF94AK	do.	93.4-9.4? m	69°48.93'(27) 148°40.36'	Mudrock, medium to very light gray, laminated to blocky, with sand lenses	B
R4945 I TDF, NOF	NF94AK-4	do.	Near top of section 6's silt-stone/ mudrock section	do.	Clay, medium gray, weathered	B

R4944 A TDF, NOF	NF94AK-2	A9	15-19 cm above top of massive ash bed	69°49.18' 148°40.52'	Mudrock, medium dark brownish-gray, carbonaceous, with laminae of sandstone, light gray, fine-grained	A

Section A8

Section A8 is at or very near the type locality of the Franklin Bluffs Member of the Sagavanirktok Formation and was part of what the 1994 field party labeled section 6. During the 1994 field season (July 19), Fouch and Frederiksen collected nine samples, and five were processed, but none could be analyzed because these rather deeply weathered rocks were barren or contained only poorly preserved palynomorphs.

Section A9

Section A9 is also in the type area of the Franklin Bluffs Member and was also part of what the 1994 field party labeled section 6. During the 1994 field season (July 19), Fouch and Frederiksen collected two samples, and one of these (R4944A) was processed and analyzed (table 6).

Discussion of Locality A

It is difficult to find significant trends of palynomorph distributions within the individual sections (except for Section A1); thus, for the most part, each section is treated here as a single entity (table 6). Table 6 disregards two sections (A5, A8) which did not yield useable pollen assemblages.

Section A1.--Section A1 differs from the other sections because the palynomorphs here were from coaly strata. Twenty-three pollen and fungal spore taxa were definitely identified, and two additional taxa were questionably identified, in the four samples from Section A1 (table 6; table 3 includes some generalized taxa not shown in table 6), but most of these are long-ranging or their stratigraphic ranges are poorly known. Figure 5 shows ranges of eight pollen taxa that have significant known ranges and two taxa of uncertain stratigraphic range. *Rhoipites angustus* type apparently has not previously been reported from the Arctic, but in the eastern Gulf Coast it is very rare below the uppermost Paleocene and is common throughout the Eocene. Data on the age range of *Aquilapollenites tumanganicus* are given in the Taxonomy section of the paper. The known range of *Diervilla* sp. is from Arctic Canada (Kalkreuth et al. (1993). Specimens similar to *Basopollis obscurocostatus* were illustrated by Doerenkamp et al. (1976, pl. 1, figs. 18-20) under the name *Extratriporopollenites* sp. cf. *E. atumescens* Thomson & Pflug 1953; this species was stated to be unknown below the lower Eocene in the Canadian Arctic. In the eastern Gulf Coast, *B. obscurocostatus* ranges from lower upper Paleocene to lower Eocene (Tschudy, 1975; Frederiksen,

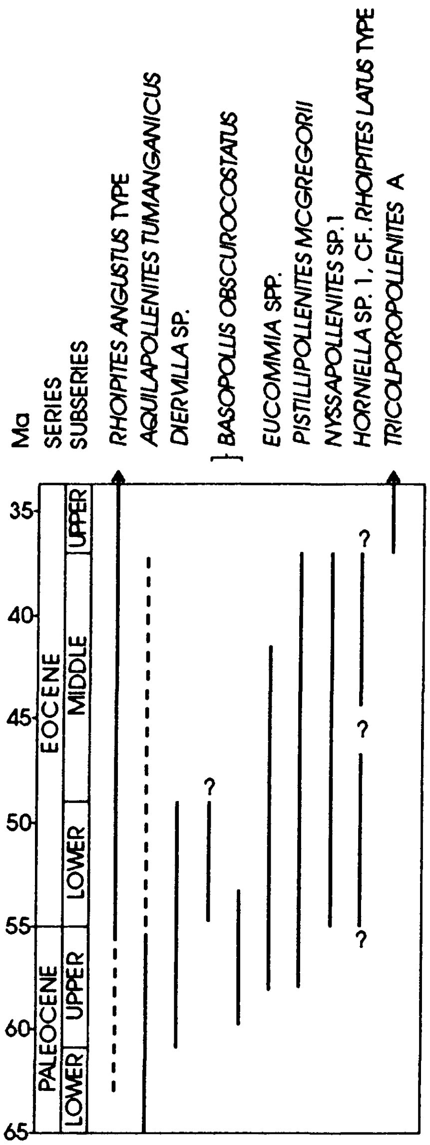

Figure 5. Known ranges of certain pollen taxa in samples from Section A1 at Franklin Bluffs. See text for sources of range information. Data for *Rhoipites angustus* are from the eastern Gulf Coast; for *Aquilapollenites tumanganicus*, from eastern Siberia; for *Diervilla* sp., *Pistillipollenites mcgregorii*, *Nyssapollenites* sp. 1, and *Tricolporopollenites* A, from Arctic Canada; for *Basopollis obscurocostatus*, from the Canadian Arctic (left line) and from the eastern Gulf Coast (right line); and for *Eucommia*, from Wyoming, Montana, and the eastern Gulf Coast. The geochronologic scale is that of Berggren and others (1995).

1991a). The range of *Eucommia* pollen is not well documented in the Arctic, but elsewhere in North America it ranges at least from upper Paleocene (Wyoming, Montana: Pocknall, 1987) to middle Eocene (eastern Gulf Coast: Frederiksen, 1988). The stratigraphic ranges of *Pistillipollenites mcgregorii*, *Nyssapollenites* sp. 1, and *Tricolporopollenites* A in figure 5 are from the Canadian Arctic (Rouse, 1977). The geologic ranges of *Horniella* sp. 1 and cf. *Rhoipites latus* type are unknown, but these species are morphologically closely related to *Rhoipites latus* type of Rouse (1977), which is known in the Arctic only in the lower to middle Eocene.

Ten specimens of the fungal spore species *Pesavis tagluensis* in sample R3313 ranged from 25-40 µm in size with a mean size of 32 µm. Kalgutkar and

Sweet (1988) studied the size distribution of specimens of *Pesavis tagluensis* in the lower to middle Paleocene compared with specimens in the upper Paleocene to Eocene of the Canadian Arctic. A mean size of 32 μm was more typical of the lower to middle Paleocene, and no specimens as small as 25 μm were found in the upper Paleocene to Eocene, but specimens as large as 40 μm were rare in the lower to middle Paleocene and common in the upper Paleocene and Eocene of the Canadian Arctic (Kalgutkar and Sweet, 1988).

In summary, Section A1 is certainly no older than late Paleocene, but it does not contain any taxa confined to the Paleocene. Several taxa are present that are thought to be only Eocene or younger although the samples lack many Eocene taxa that are found to the north; however, this lack may well have been caused by paleoecological factors and not by age. Therefore, Section A1 could be from close to the Paleocene-Eocene boundary, most likely from the Eocene side of the boundary, or it could even be from well up in the lower Eocene; the evidence for a definite age determination is somewhat sparse.

Table 3 presents detailed analyses of three of Ager's samples (R3402B, R3313, R3428) and Frederiksen's sample R4713F from Frederiksen and others (1994). Meaningful counts could not be made of taxa in R4713F because only residues containing the >20 μm fraction were available. The most obvious features of the taxon counts in table 3 are the considerable differences in relative frequencies among samples particularly of pteridophyte spores (mainly fern and *Lycopodium* spores), bisaccate gymnosperms (probably mainly pine), TCT pollen (mainly or entirely *Metasequoia*), *Ulmipollenites undulosus*, and miscellaneous angiosperms (in these samples, these pollen grains are commonly or mainly small, finely reticulate tricolpates and tricolporates). Palynomorphs in the clay sample (R3402B) probably include many allochthononous specimens and perhaps some autochthonous grains produced by plants growing on clay substrates such as pteridophytes, pines and their relatives, and miscellaneous angiosperms. The "miscellaneous angiosperm" pollen came mainly from entomophilous (insect-pollinated) plants, and such plants typically produce relatively small amounts of pollen in contrast to massively produced wind-pollinated pollen of taxa such as pines, *Metasequoia*, and Ulmaceae (elm family, *Ulmipollenites*). Therefore, entomophilous plants were more common in the vegetation of mineral and some coaly substrates than the relative frequencies of their pollen would suggest. Trees and shrubs of Ulmaceae, and herbs(?) producing *Aquilapollenites tumanganicus*, seem to have preferred peaty substrates. A fair number of specimens of *Diervilla* sp. (bush honeysuckle, of the family Caprifoliaceae, the honeysuckle family) occurred in the coal sample (R3428). However, *Diervilla* sp. was also found in two other sections (A6 and A7) in detrital sediments. The fungal spore species *Pesavis tagluensis* was seen only in the sample composed of woody debris.

Sections A2, A3, A4, A6, A7, and A9.--Sections A2, A3, A4, A6, and A7, to the north of A1, are lower to middle Eocene as demonstrated by Ager and others (1986) and Frederiksen and others (1994); data on Section A9 are given here for the first time. Several taxa observed only in Sections A6 to A9 are worth discussing here. *Milfordia hungarica* is a rather rare species known in North America only from the lower Eocene and lower part of the middle Eocene (Frederiksen, 1983, 1988). In the Canadian Arctic, *Carya* >28 μm may be the Eocene species referred to by McIntyre (1994), and specimens of this species were illustrated from rocks thought to be lower Eocene by Doerenkamp and others (1976). In the eastern Gulf Coast, *Carya* >28 μm had its first appearance in the lower part of the middle Eocene (Frederiksen, 1988). *Novemprojectus traversii* was originally described from the Canadian Arctic, from strata attributed to the middle Eocene (Choi, 1984), but McIntyre (1991a) thought these strata were more likely to be lower Eocene and gave a possible range of the species as lower to middle(?) Eocene. In summary, although these Eocene pollen taxa were found only in sections in the northern part of the Franklin Bluffs sampled area, they all seem to range down into the lower Eocene and therefore do not provide firm evidence that these northern sections are younger than those to the south.

Table 3. Distribution of pollen and fungal spore taxa in four samples from Section A1 (Franklin Bluffs). Samples run approximately from oldest on the left to youngest on the right. Numbers are percentages, based on a count of at least 200 spores, pollen grains, and fungal spores. X, <1 percent (or present, in the column for R4713F); A = aff., specimen is similar to and may be the same species as the species listed; ?, identification uncertain.

Taxon	Sample			
	R4713F	R3402B	R3313	R3428
	Coaly mudrock	Clay	Felt-like woody debris	Coal
Pasavis tagluensis			X	
Pteridophyte spores	X	30	5	4
Bisaccate gymnosperms	X	30	X	2
Taxodiaceae-Cupressaceae-Taxaceae (TCT)	X	13	69	27
Triatriopollenites spp.	X	4	X	X
Triporopollenites megagranifer type	A	2		
Triporopollenites mullensis		X		
Paraalnipollenites alterniporus type H			X	X
Paraalnipollenites alterniporus type Z				X
Carya <29 µm	X		X	
Pistillipollenites mcgregorii	X			
Ulmipollenites tricostatus		X	1	2
Ulmipollenites undulosus		5	18	44
Diervilla sp.				X
Alnipollenites verus	X	?		X
Liquidambar type 1		?		
Cercidiphyllum sp.				X
Eucommia sp.		X		
Horniella sp. 1	X	2		
Cf. *Rhoipites latus* type	X			
Rhoipites angustus type	X			
Tricolporopollenites A of Rouse (1977)	X			X
Nyssapollenites sp. 1	X	X	X	X
Nyssapollenites sp. 2		X		
Lanagiopollis spp.			?	
Intratriporopollenites sp. 1				X
Aquilapollenites tumanganicus			1	2
Basopollis obscurocostatus		X		
Ericipites spp.	X	X		
Miscellaneous angiosperms	X	14	5	21

Table 4. Distribution of palynomorphs in samples from Section A6 (Franklin Bluffs). Samples run from oldest on the left to youngest on the right. X, present; ?, identification uncertain.

Taxon	Sample of R3319 series					
	A	B	D	E	F	G
Milfordia hungarica		X				
Triatriopollenites spp.	X	X		X		X
Triporopollenites mullensis	X			X	X	
Paraalnipollenites alterniporus type H	X					X
Paraalnipollenites alterniporus type Z	X					
Trivestibulopollenites spp.		X		X	X	
Momipites coryloides				X		
Carya <29 µm	X	X				X
Carya >28 µm		X			X	
Caryapollenites prodromus group, type 1	X	X			X	X
Caryapollenites prodromus group, type 2	X			X	X	X
Platycaryapollenites swasticoidus		X				
Platycaryapollenites sp.		X				
Pistillipollenites mcgregorii				X		X
Ulmipollenites tricostatus				X		
Ulmipollenites undulosus	X	X	X	X	X	X
Diervilla sp.	X		X			X
Alnipollenites verus	X	X	X	X	X	X
Pterocarya spp.	X	X		X	X	X
Juglans sp.		X				
Liquidambar type 1		X	X	X		X
Cercidiphyllum sp.						X
Quercoidites sp. 1	X		X			
Eucommia spp.	X	X				
Ilexpollenites spp.						X
Tricolpites sp. 1	X		X		X	
Tricolpites aff. *T. asper* of Frederiksen and others (1988)			X			
Rhoipites latus type of Rouse (1977)	X	X	X	X	X	
Rhoipites angustus type		X				X
Tricolporopollenites A of Rouse (1977)	?			X		X
Nyssapollenites sp. 2		X	X			
Bombacacidites paulus type				X	X	X
Bombacacidites nacimientoensis						X
Intratriporopollenites sp. 1	X	X	X		X	
Intratriporopollenites sp. 2		X		X	X	
Intratriporopollenites sp. 3			X	X	X	
Pompeckjoidaepollenites subhercynicus		X				
Basopollis sp.		X				
Novemprojectus sp.		X				
Ericipites spp.					X	
Dinocysts	X	X	X			
Reworked Campanian-Maastrichtian pollen grains	X	X		X	X	X
Reworked Paleozoic or Mesozoic spores and pollen grains		X				

Table 5. Distribution of palynomorphs in samples from Section A7 (Franklin Bluffs). The older sample is on the left. X, present.

Taxon	Sample of R3401 series	
	I	H
Triatriopollenites spp.	X	X
Triporopollenites megagranifer type	X	
Triporopollenites mullensis	X	
Paraalnipollenites alterniporus type H	X	
Trivestibulopollenites spp.	X	
Carya <29 µm	X	X
Carya >28 µm	X	
Caryapollenites prodromus group, type 1	X	X
Caryapollenites prodromus group, type 2	X	
Ulmipollenites tricostatus	X	X
Ulmipollenites undulosus	X	X
Diervilla sp.	X	
Alnipollenites verus	X	X
Pterocarya spp.	X	X
Liquidambar type 1	X	
Rhoipites latus type of Rouse (1977)	X	
Rhoipites angustus type	X	
Tricolporopollenites A of Rouse (1977)	X	
Nyssapollenites sp. 2	X	
Bombacacidites aff. *B. fereparilis*	X	
Bombacacidites nacimientoensis	X	
Bombacacidites paulus type	X	
Intratriporopollenites sp. 1	X	X
Intratriporopollenites sp. 2	X	X
Intratriporopollenites sp. 3	X	X
Pseudoplicapollis sp.	X	
Novemprojectus traversii	X	
Ericipites spp.	X	
Dinocysts	X	
Reworked Campanian-Maastrichtian pollen grains	X	
Reworked Carboniferous spores	X	X

Reworked Paleozoic to Late Cretaceous palynomorphs were found in scattered samples from Sections A2 to A7 (tables 4, 5; Frederiksen and others, 1994). Dinocysts also occur in many samples from Sections A2 to A9, and these (along with Eocene pollen taxa) were the basis for the early to middle Eocene age determination of Ager and others (1986).

Table 6. Summary of pollen and fungal spore taxon distributions in samples from seven sections of Franklin Bluffs. Some data are repeated from Frederiksen and others (1994). In this table, the sections are arranged from south (oldest?) on the left to north (youngest?) on the right. X, present; ?, identification uncertain. Dinocysts and taxa thought to be represented by reworked specimens are not shown.

Taxon	Section						
	A1	A2	A3	A4	A6	A7	A9
Milfordia hungarica					X		
Pandaniidites sp.							X
Triatriopollenites sp. 1			X	X			
Triatriopollenites spp.	X	X	X	X	X	X	X
Triporopollenites megagranifer type	X			X		X	
Triporopollenites mullensis	X	X	X	X	X	X	X
Paraalnipollenites alterniporus type H	X			X	X	X	
Paraalnipollenites alterniporus type Z	X		X	X	X		
Trivestibulopollenites spp.		X	X	X	X	X	
Momipites coryloides					X		
Betulaepollenites spp.			X	X			
Carya <29 µm	X	X	X	X	X	X	X
Carya >28 µm					X	X	
Caryapollenites prodromus group, type 1		X	X	X	X	X	X
Caryapollenites prodromus group, type 2		X	X	X	X	X	
Platycaryapollenites swasticoidus					X		
Platycaryapollenites spp.			X		X		
Plicatopollis sp.				X			
Plicatopollis/Platycaryapollenites sp.		X					
Pistillipollenites mcgregorii	X	X	X	X	X		
Corsinipollenites sp.				X			
Ulmipollenites krempii		X	X				
Ulmipollenites tricostatus	X			X	X	X	
Ulmipollenites undulosus	X	X	X	X	X	X	X
Diervilla sp.	X				X	X	
Alnipollenites verus	X	X	X	X	X	X	?
Pterocarya spp.		X	X	X	X	X	
Juglans sp.					X		
Liquidambar type 1	?		X	X	X	X	X
Liquidambar type 2			X	X			
Cercidiphyllum sp.	X				X		
Quercoidites sp. 1			X		X		
Eucommia spp.	X		X	X	X		
Ilexpollenites spp.		X	X	?	X		
Tricolpites sp. 1			X	X	X		X
Tricolpites sp. 2			X				X
Tricolpites aff. *T. asper* of Frederiksen and others (1988)					X		
Horniella sp. 1	X		X				X
Rhoipites latus type of Rouse (1977)			X	X	X	X	
Cf. *Rhoipites latus* type	X		X	X			
Aesculiidites B of Rouse (1977)			X				
Rhoipites angustus type	X	X	X	X	X	X	X
Tricolporopollenites A of Rouse (1977)	X		X		X	X	
Nyssapollenites sp. 1	X		X	X			
Nyssapollenites sp. 2			X	X	X	X	X
Lanagiopollis spp.	?		X	X			
Bombacacidites aff. *B. fereparilis*						X	

Table 6 (continued)

Taxon	Section						
	A1	A2	A3	A4	A6	A7	A9
Bombacacidites nacimientoensis					X	X	
Bombacacidites paulus type			X	X	X	X	
Intratriporopollenites sp. 1	X	X	X	X	X	X	
Intratriporopollenites sp. 2		X	X	X	X	X	
Intratriporopollenites sp. 3			X		X	X	X
Pompeckjoidaepollenites subhercynicus				X	X		
Aquilapollenites tumanganicus	X		X	X			
Novemprojectus traversii						X	
Novemprojectus sp.					X		
Basopollis obscurocostatus	X						
Basopollis sp.					X		
Pseudoplicapollis sp.			X			X	
Ericipites spp.	X		X	X	X	X	X
Pasavis tagluensis	X			X			

Locality B - Sagwon Bluffs Area

The Sagwon Bluffs area is in the Sagavanirktok (B-3) quadrangle (fig. 3). Detterman and others (1975) provided two measured sections from the Sagwon Member of the Sagavanirktok Formation at Sagwon Bluffs. Their section 19 (Detterman and others, 1975, fig. 11) was at lat 69°23'15" N., long 146°14' to 146°17' W., and included the lowermost part of Section B1 of this report. Their section 23 (Detterman and others, 1975, fig. 13), designated as the type section of the Sagwon Member, was at lat 69°23'30" to 69°24'30" N., long 148°39'30" to 148°41' W., and included Section B2 of this report.

Roberts and others (1991, sample localities B and C) illustrated two measured sections from the type locality of the Sagwon Member; however, their sample locality B appears to have been mislocated and should have been shown as south, not north, of sample locality C. Sample locality B of Roberts and others (1991) is the same as site 5 or 6 of Collett (1988), and their sample locality C is the same as site 6 of Collett (1988).

Locality B of this report includes three sections within the Sagwon Member in its type area, including an outcrop on the east side of the river (section B3 of this report; table 7). Beside the samples listed in table 7, 13 core and trench samples collected by M. A. Carey and S. B. Roberts were processed, but all were barren of angiosperm pollen or nearly so. These samples were from the lower, middle, and upper coal beds and adjacent detrital strata of Roberts and others (1991, sample locality B).

Section B1

Section B1 exposes the oldest strata in the Sagwon area; it corresponds to site 1 of Collett (1988). Ager's samples from the Sagwon Member, containing very low-diversity pollen assemblages, which he dated as Paleocene, apparently early Paleocene, were from this locality (Ager, in Carey and others, 1988, and in Spicer and Parrish, 1990). During the 1994 field season (July 20 and 21), Frederiksen and Johnsson collected six samples from this section, three were processed, and two of these yielded reasonably well preserved palynomorph assemblages (table 8).

Sample R4946F was from the lowermost strata at Sagwon Bluffs and appeared to be from the unit that Detterman and others (1975, p. 35; fig. 11, section 19) placed at the top of the Kogosukruk Tongue of the Prince Creek Formation and considered to be "the uppermost unit of the Upper Cretaceous, primarily because it is more indurated and darker than the overlying rocks." This sample contained no angiosperm pollen and therefore could not be dated. If fragmented dinocysts in the sample were indigenous (not reworked), then the sample represented deposition in a marine or brackish-water environment, distinctly different from the overlying coal-bearing rocks.

Sample R4946E, within the coal-bearing interval of Section B1, contained several typical Paleocene taxa (*Alnus* and *Triporopollenites mullensis*), but the range bases of these taxa are in the upper Campanian and lower Maastrichtian, respectively. *Aquilapollenites trialatus* and *A. unicus* are Late Cretaceous species; the range top of *A. trialatus* is apparently in the lower Maastrichtian (but possibly in the upper Maastrichtian), whereas *A. unicus* is known only from the upper Maastrichtian. Thus, looking strictly at the geologic ranges of the taxa in the sample, it cannot be determined whether the sample was Maastrichtian, or whether it was Paleocene with reworked Late Cretaceous pollen. However, *Triporopollenites mullensis* was by far the most common species in the assemblage, and this abundance probably indicates that the sample is Paleocene. This sample is typical of some from the Sagavanirktok Formation that were examined for this study in that these samples seem to have come from close to the Cretaceous-Tertiary boundary: reworked Late Cretaceous pollen is common, and most of the abundantly represented Tertiary taxa (mainly wind-pollinated porate types) have their range bases within the Maastrichtian; therefore, it is difficult to tell whether a given sample is lower Paleocene or Maastrichtian. In these cases, the best criterion seems to be the ratio of anemophilous (wind-pollinated) porate pollen to pollen species known only from the Cretaceous; there is a distinct increase in this ratio across the boundary from the uppermost Cretaceous into the lower Paleocene (Frederiksen and others, 1988, fig. 5).

Section B2

Section B2 is at the same locality as Collett's (1988) site 6. However, samples R4947 D and A (table 8) lie below the strata included in Collett's measured section; these samples were from the interval of the 0.7 m thick coal near the base of sample locality B of Roberts and others (1991) and were probably near the base of section 23 of Detterman and others (1975, fig. 13). Sample R4948B lies immediately below the base of the interval of Collett's (1988) coal 3, which is the same as coal SB-2 of Roberts and others (1991, sample locality B) and lies in the middle part of section 23 of Detterman and others (1975, fig. 13). Sample R4948G was from above Collett's (1988) coal 4, which is the same as coal SB-1 of Roberts and others (1991) and lies in the upper part of section 23 of Detterman and others (1975, fig. 13). The palynomorph samples from Section B2 were collected on July 22, 1994.

The four samples from Section B2, like sample R4946E from Section B1, contained several Late Cretaceous species of *Aquilapollenites* in addition to several porate pollen types that have range bases in the Maastrichtian but range up into the Tertiary. However, these assemblages again were dominated by *Triporopollenites mullensis*, and this indicates that the samples were Paleocene and probably lower Paleocene.

Table 7. Samples processed for palynomorphs from Locality B (Sagwon Bluffs area). In the Pollen Analysis column, A means an analysis was completed, and P means palynomorphs were present but preservation was too poor for an analysis to be made. Initials of sample collectors are: KJF, Karen J. Franczyk; NOF, Norman O. Frederiksen; MJ, Mark Johnsson.

Paly-nology number; collector(s)	Field number	Section	Position	Latitude and longitude	Lithology	Pollen analysis
R4946 F NOF, MJ	MJ94AK10	B1	Base of outcrop at N. corner of section	69°22'59"(27) 148°42'38"	Silt-stone, medium gray, carbona-ceous	P
R4946 A NOF, MJ	NF94AK-10	do.	do., 1.2 m below base of thick coal/ carb. shale	do.	Silt-stone, medium dark gray, carbona-ceous	P
R4946 E NOF, MJ	NF94AK-14	do.	63-72 cm below lower of 2 very thin coals 35 cm apart	do.	Clay-stone, medium dark gray, silty, calcare-ous	A
R4947 A NOF	NF94AK-16	B2	17-cm-thick clay over-lying coaly shale, at top of exposure		Clay, medium dark gray, carbona-ceous and coaly	P
R4947 D NOF	NF94AK-19	do.	Base of outcrop; clay unit 30-75 cm below coaly shale		Clay, dark brownish-gray, carbona-ceous	A

R4948 B NOF	NF94AK-21	do.	Clay underlying Fouch's 21 m mark; directly below the base of coaly shales of Collett's (1988) coal interval 3		Clay, medium dark gray, silty, carbonaceous	A
R4948 D NOF	NF94AK-23	do.	Float at 26 m = limestone bed of Roberts and others (1991)?		Siltstone concretion, siliceous (noncalcareous), medium gray	P
R4948 G NOF	NF94AK-26	do.	Float above the no. 4 coal		Siltstone concretion, not tested for calcite, light gray, slightly carbonaceous	A
R4949 B KJF, MJ	MJ94AK16	B3	34 m	69°26'23"(27) 148°30'54"	Mudrock, medium dark gray, carbonaceous	A
R4949 E KJF, MJ	MJ94AK21	do.	89 m	69°26'31"(27) 148°30'58"	Clay, black, slightly silty	A

Table 8. Distribution of palynomorphs in samples from Locality B (Sagwon Bluffs area). Within each section, samples run from oldest on the left to youngest on the right. X, present, but could be reworked; ?, identification uncertain.

Taxon	Section -->	B1		B2				B3	
	Sample -->	R4946F	R4946E	R4947D	R4947A	R4948B	R4948G	R4949B	R4949E
Alnus			X			X		X	
Aquilapollenites rectus								X	
Aquilapollenites reticulatus								?	
Aquilapollenites sp. cf. *A. reticulatus*						X			
Aquilapollenites scabridus								X	
Aquilapollenites trialatus			X			X		X	
Aquilapollenites unicus			X					X	
Expressipollis types								X	
Paraalnipollenites alterniporus type H				?		X	X	X	
Pesavis tagluensis								X	
Pterocarya			?						
Triporopollenites mullensis			X	X	X	X	X	X	X
Wodehouseia spinata								X	
Paleozoic spores		X	X			X			
Dinocysts		X						?	

Section B3

Section B3 lies on the east side of the Sagavanirktok River across from and northeast of Sagwon Bluffs; there do not appear to be any references to this outcrop in the literature. Palynomorph samples were collected by Franczyk and Johnsson on July 22, 1994; they designated this outcrop as their section 9.

Samples R4949 B and E were examined from this section (table 7), and R4949B turned out to contain a diverse assemblage of palynomorphs (table 8). Among the pollen taxa were some (*Aquilapollenites*, *Expressipollis* types, *Wodehouseia*) typical of the Campanian and Maastrichtian, in addition to porate taxa (*Alnus*, *Paraalnipollenites alterniporus* type H, *Triporopollenites mullensis*) that range from the Campanian or Maastrichtian up into the Tertiary. The two sample assemblages from Section B3 were dominated by *Triporopollenites mullensis*, indicating a Paleocene age. However, the most important palynomorph observed was the fungal spore species *Pesavis tagluensis*. One specimen was found, measuring 47 µm in diameter; such large specimens are known in the Arctic only from the upper Paleocene and Eocene (Kalgutkar and Sweet, 1988).

Locality C - Ivishak River

Several authors have provided measured sections of rocks along the Ivishak River; locations of these are shown in figure 6. Molenaar and others (1984) described two non-coal-bearing sections from the Ivishak River. The first of these (Molenaar and others, 1984, section 5), from the upper Ivishak River in C S 1/2 sec. 5, T. 3 S., R. 17 E., Sagavanirktok (A-2) quadrangle, was dated as Late Cretaceous on the basis of palynomorphs; this locality was mapped by Keller and others (1961) as belonging to the upper member of the Ignek Formation (considered by them to be Upper Cretaceous, ?Turonian to ?Maastrichtian). The second Ivishak River section of Molenaar and others (1984, section 3), from the lower Ivishak River in the NE 1/4 sec. 2, T. 2 S., R. 16 E. to SW 1/4 sec. 35, T. 1 S., R. 16 E., Sagavanirktok (B-2) quadrangle, was dated as Campanian to Maastrichtian on the basis of palynomorphs and foraminifers; this locality was slightly west of the area mapped by Keller and others (1961) but would probably have been assigned by them to undifferentiated Ignek Formation (considered by them to be ?Albian to ?Maastrichtian). Roberts and others (1991, sample locality D) measured a coal-bearing section along the Ivishak River, in E 1/2 sec. 9, T. 1 S., R. 16 E., Sagavanirktok (B-3) quadrangle, west of the area mapped by Keller and others (1961).

Section C1

This is Ivishak River section 1 of the 1994 field party, collected July 25, immediately northeast of VABM Hak and to the north of sample locality D of Roberts and others (1991) in Sagavanirktok (B-2) quadrangle (fig. 6). One sample was processed from this section (table 9), but the preservation of palynomorphs was poor.

Section C2

This is Ivishak River section 2 of the 1994 field party, collected July 25, 27, and 28, beginning immediately south of VABM Hak and extending southward through sample locality D of Roberts and others (1991) in Sagavanirktok (B-2) quadrangle. Ten samples from this section were processed (table 9), and three contained enough well preserved pollen to make an analysis (table 10). All three contained typical late Maastrichtian pollen. In the Colville River region (Frederiksen, 1991b), *Wodehouseia spinata*, *Wodehouseia octospina*, and *Aquilapollenites unicus* are not known to range below the *Wodehouseia spinata* Assemblage Zone, the highest pollen zone in the Cretaceous; in that region, *Wodehouseia octospina* was limited to the uppermost part of the *W. spinata* Assemblage Zone, that is, directly below the Cretaceous-Tertiary boundary. However, all three samples examined from Section C2 contained roughly equal amounts of (1) pollen limited to the Upper Cretaceous (*Aquilapollenites*, *Cranwellia* etc.) and (2) Late Cretaceous to Tertiary porate pollen; therefore, it is difficult to determine whether the Late Cretaceous pollen is reworked, that is, whether these samples are latest Maastrichtian or early Paleocene in age. Sample R4951D contained several well-preserved dinocysts, indicating (unless they were reworked) deposition in brackish-water or marine environments.

Section C3

This is Ivishak River section 3 of the 1994 field party, collected July 27, and is the same as part of section 3 of Molenaar and others (1984), in sec. 2, T. 2 S., R. 16 E., Sagavanirktok (B-2) quadrangle. Four samples were processed from this section, but all were either barren or had only poorly preserved pollen (table 9).

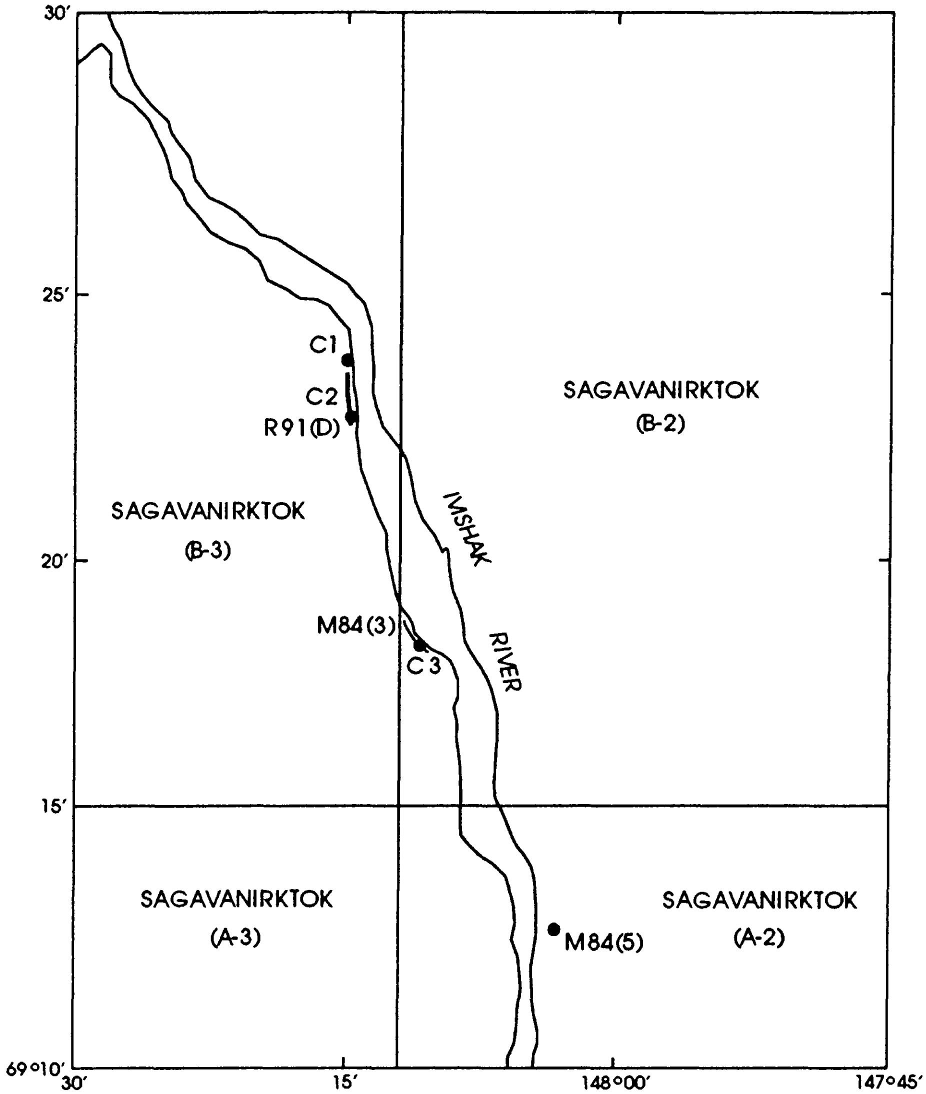

Figure 6. Location of stratigraphic sections along the Ivishak River. Sections C1-C3 were sampled by us in 1994. M84(3) and M84(5) are sections 3 and 5, respectively, of Molenaar and others (1984); R91(D) is sample locality D of Roberts and others (1991). VABM Hak is located so close to Section C1 that no separate symbol marking the VABM could be shown.

Table 9. Samples processed for palynomorphs from Locality C (Ivishak River). In the Pollen Analysis column, A means an analysis was completed, B means the sample was barren of palynomorphs, and P means palynomorphs were present but preservation was too poor for an analysis to be made. Initials of sample collectors are: TSC, Timothy S. Collett; TDF, Thomas D. Fouch; KJF, Karen J. Franczyk; NOF, Norman O. Frederiksen; MJ, Mark Johnsson.

Palynology number; collector(s)	Field number	Section	Position	Latitude and longitude	Lithology	Pollen analysis
R4950 A TSC, TDF	NF94AK-I-1-1	C1	1 m in measured section	69°23.35′(27) 148°15.16′	Siltstone, medium gray, carbonaceous	P
R4951 A TDF, NOF	NF94AK-28	C2	First beds exposed south of saddle = 130 m in measured section	69°23.31′(27) 148°15.18′ (base of section)	Sandstone, medium dark gray, fine-grained, muddy, carbonaceous	B
R4951 C TDF, NOF	NF94AK-30	do.	4.5 m south of spl. 29, north of saddle	69°23.31′(27) 148°15.18′	Mudrock, medium dark gray, sandy	P
R4951 D TDF, NOF	NF94AK-31	do.	9.6 m south of spl. 30, north of saddle	69°23.31′(27) 148°15.18′	Sandstone, medium dark gray, fine-grained, carbonaceous	A
R4951 I TDF, NOF	NF94AK-36	do.	432 m, float	69°22.46′ 148°15.40′	Sandstone, medium dark gray, fine- to medium-grained	P
R4951 L TDF, NOF	NF94AK-40	do.	660 m		Mudrock, medium dark gray	P

R4951 O TDF, NOF	NF94AK-43	do.	873 m		Mudrock, medium dark gray, carbona-ceous	P
R4951 S TDF, NOF	NF94AK-47	do.	1101 m, under-lies coal		Clay, medium gray, coaly	A
R4951 T TDF, NOF	NF94AK-48	do.	1121 m	69°22.22' 148°16.87'	Clay, medium gray, sandy, carbona-ceous	P
R4951 X TDF, NOF	NF94AK-52	do.	1348 m		Clay, medium gray, carbona-ceous	A
R4951 Z TDF, NOF	NF94AK-54	do.	Approx. 1526.5 m, finer material in or below coal, with some clay		Coal and clay	P
R4952 A KJF, MJ	MJ94AK32	C3	560 m	69°18'24"(27) 148°11'32"	Silt-stone, dark gray	B
R4952 B KJF, MJ	MJ94AK35	do.	490 m	69°18'24"(27) 148°11'35"	Silt-stone, dark gray, carbona-ceous	P
R4952 C KJF, MJ	MJ94AK39	do.	40 m	69°18'45"(27) 148°11'53"	Mudrock, medium dark gray to black, coaly	B
R4952 D KJF, MJ	MJ94AK43	do.	700 m	69°18'18"(27) 148°11'29"	Silt-stone, medium dark gray, carbona-ceous	P

Table 10. Distribution of palynomorphs in samples from Section C2. Samples run from oldest on the left to youngest on the right. X, present; R, Campanian taxa interpreted as being reworked. However, it may well be that the Cretaceous species of *Aquilapollenites*, *Cranwellia*, *Manicorpus*, and *Wodehouseia* are also reworked (see text).

Taxon	Sample of R4951 series		
	D	S	X
Alnus sp.			X
Aquilapollenites sp. cf. *A. augustus*			X
Aquilapollenites unicus	X		X
Aquilapollenites reticulatus	X	X	X
Aquilapollenites sp. cf. *A. reticulatus*			X
Cranwellia striata			X
Expressipollis types	R	R	R
Manicorpus sp.			X
Paraalnipollenites alterniporus type H		X	X
Triporopollenites mullensis	X	X	X
Wodehouseia octospina			X
Wodehouseia spinata	X		X
Dinocysts	X		

Locality D - Shaviovik Anticline Area

Many measured sections and dated samples exist for the Shaviovik anticline area, as shown in figure 7. Molenaar and others (1984, p. 13, sections 9 and 10) described two sections from the lower Shaviovik River. Their section 9 (same as D1 of our fig. 7) was unfossiliferous, but this locality was mapped by Keller and others (1961) as being near the contact between the upper member of the Ignek Formation and the Sagavanirktok Formation, a contact that they considered to coincide with the Cretaceous-Tertiary boundary. Section 10 of Molenaar and others (1984) (same as D2 of our fig. 7) was dated as "probably Paleocene" on the basis of palynomorphs, and this locality had been mapped by Keller and others (1961) as belonging to the Sagavanirktok Formation (which they considered to be Tertiary). Keller and others (1961) described an undated section from the south flank of the Shaviovik anticline. Molenaar and others (1984, section 11 = D3 of our fig. 7) showed a section from the west bank of Juniper Creek which was Campanian or Maastrichtian (from palynomorphs) and Senonian (from foraminifers) in the lower part of the section and Tertiary (from palynomorphs) in the middle and upper parts of the section. These may be the same samples "from the lower part of the deltaic unit on the Shaviovik anticline" that contained Maastrichtian and Paleocene palynomorphs and foraminifers according to an unpublished report by Anderson Worldwide Associates, Inc., cited by Molenaar (1983, p. 1077). Seismic shothole samples from the Sagavanirktok Formation or the anticline were dated by H. R. Bergquist as Late Cretaceous based on foraminifers and radiolarians (Keller and others, 1961, p. 208-209, pl. 24: line 6, shotpoints 2 and 3; line 6, shotpoints 19 and 20; line 3, shotpoint 3; abbreviated K6(2-3), K6(19-20), and K3(3), respectively, in our fig. 7). SOCAL 60U2X3 in figure 7 is a shotpoint sample in sec. 35, T. 2 N., R. 19 E.,

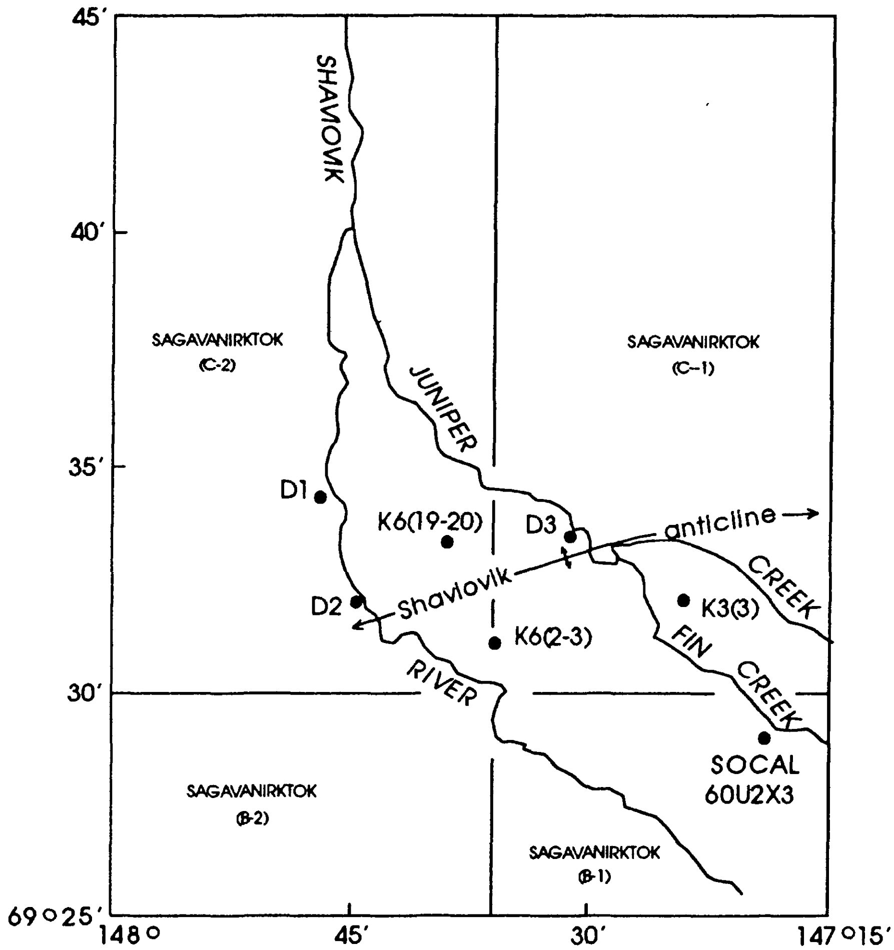

Figure 7. Location of stratigraphic sections and isolated samples in the Shaviovik anticline area. Sections D1-D3 were sampled by us in 1994. D1, D2, and D3 are the same as sections 9, 10, and 11, respectively, of Molenaar and others (1984). K3(3) is line 3, shotpoint 3; K6(19-20) is line 6, shotpoints 19 and 20; and K6(2-3) is line 6, shotpoints 2 and 3; all of these were dated by H. R. Bergquist in Keller and others (1961, p. 208-209, pl. 24). SOCAL 60U2X3 is a shotpoint sample dated by Wiggins (1976).

Sagavanirktok (B-1) quadrangle, which Wiggins (1976, table 1) dated as early to middle Paleocene based on palynomorphs.

Section D1

Section D1 of this report is Shaviovik River section 1 of the 1994 field party (collected on July 28 and 29) and is the same as section 9 of Molenaar and others (1984) and sample locality E of Roberts and others (1991), located on the west side of the Shaviovik River in W 1/2 secs. 29 and 32, T. 3 N., R. 18 E., Sagavanirktok (C-2) quadrangle, west of the area mapped by Keller and others (1961). As stated previously, section 9 of Molenaar and others (1984)

Table 11. Samples processed for palynomorphs from Locality D (Shaviovik anticline area). In the Pollen Analysis column, A means an analysis was completed, and P means palynomorphs were present but preservation was too poor for an analysis to be made. Initials of sample collectors are: TDF, Thomas D. Fouch; KJF, Karen J. Franczyk; NOF, Norman O. Frederiksen; MJ, Mark Johnsson. Stratigraphic positions of samples in Section D3 are from Molenaar and others (1984, section 11).

Palynology number; collector(s)	Field number	Section	Position	Latitude and longitude	Lithology	Pollen analysis
R4956 B TDF, NOF	NF94AK-56	D1	1 m below coal SH-4		Mudrock, medium dark brownish-gray	A
R4956 D TDF, NOF	NF94AK-58	do.	Between the 1.4 ft and 1.2 ft coals (below SH-3) of Roberts and others (1991)		Shale, dark brownish-gray, coaly	A
R4956 F TDF, NOF	NF94AK-60	do.	Immediately above coal SH-3		Mudrock, medium gray, carbonaceous	A
R4956 H TDF, NOF	NF94AK-62	do.	2 ft below 12 ft coal		Mudrock, medium dark brownish-gray, carbonaceous	A
R4956 I TDF, NOF	NF94AK-63	do.	Lower part of coal interval SH-2		Clay, dark brown, mixed with abundant coal chips	A

R4957 C TDF, NOF	NF94AK-67	D2	Approx. 350 ft; just below thick sand-stone		Shale, medium dark brownish-gray	A
R4957 D TDF, NOF	NF94AK-68	do	Approx. 190 ft		Silt-stone, medium dark gray	A
R4953 A KJF, MJ	MJ94AK45	D3	720 m	69°33'38"(27) 147°31'51"	Clay, black, and coal	A
R4953 D KJF, MJ	MJ94AK50		520 m	69°33'27"(27) 147°31'32"	Clay, medium dark gray, carbona-ceous, and subordi-nate shale, dark gray, carbona-ceous	A
R4953 E KJF, MJ	MJ94AK53		90 m	69°33'13"(27) 147°31'13"	Silt-stone, dark gray, carbona-ceous	P

was unfossiliferous. Five samples were processed from Section D1 (table 11), and all were analyzed (table 12). The assemblages contain Late Cretaceous pollen species (of the genera *Aquilapollenites* and *Wodehouseia*), but most pollen grains are of *Triporopollenites mullensis*, and *Ulmipollenites undulosus* is fairly common. Unlike *T. mullensis*, *U. undulosus* has not been reported from the Cretaceous. The most age-diagnostic species appears to be *Caryapollenites inelegans*, which has its range base in the Canadian Arctic in the middle or upper Paleocene (McIntyre, 1994). In short, the samples are Paleocene, and at least R4956F is middle or upper Paleocene. Two of the samples contained well preserved dinocysts; thus (unless these are reworked specimens), the strata were deposited in marine or brackish-water environments.

Beside the samples listed in table 11, five trenched coal samples collected by M. A. Carey and S. B. Roberts were processed, but all were barren of angiosperm pollen or nearly so. These samples were from sample locality E of Roberts and others (1991).

Table 12. Distribution of palynomorphs in samples from Section D1 (Shaviovik River). Samples run from oldest on the left to youngest on the right. X, present; R, interpreted as being reworked; ?, identification uncertain.

Taxon	Sample of R4956 series				
	B	D	F	H	I
Alnus sp.	X			X	X
Aquilapollenites colvillensis			R		
Aquilapollenites trialatus			R	R	
Aquilapollenites unicus			R		
Aquilapollenites reticulatus	R		R	R	
Caryapollenites inelegans			X		
Paraalnipollenites alterniporus type H	X	X	X	X	X
Triatriopollenites spp.	X		X	X	
Triporopollenites megagranifer	X	?			
Triporopollenites mullensis	X	X	X	X	X
Trivestibulopollenites spp.				X	
Ulmipollenites krempii					X
Ulmipollenites tricostatus	X			X	X
Ulmipollenites undulosus	X	X	X	X	X
Wodehouseia spinata	R				
Dinocysts			X	X	

Section D2

Section D2 of this report, on the west side of the Shaviovik River, was sampled for palynomorphs on July 29, 1994, and is the same as section 10 of Molenaar and others (1984, p. 13, NW 1/4 sec. 16, T. 2 N., R. 18 E., Sagavanirktok (C-2) quadrangle), which, as noted above, was dated as "probably Paleocene" on the basis of palynomorphs. Two samples were processed from this section (table 11), and both were analyzed (table 13). Preservation was rather poor in sample R4957D. In sample R4957C, it was observed that the triporate pollen grains (*Paraalnipollenites alterniporus* type H, *Triporopollenites mullensis*) were distinctly lighter in color and much better preserved than pollen grains of the taxa restricted to the Upper Cretaceous (*Aquilapollenites* spp., *Expressipollis* types); thus, this sample, at least, is undoubtedly Paleocene.

Section D3

Section D3 is on the west side of Juniper Creek and is the same as section 11 of Molenaar and others (1984) and sample locality F of Roberts and others (1991), which were both stated to be in C sec. 5, T. 2 N., R. 19 E., Sagavanirktok (C-1) quadrangle. As stated previously, section 11 of Molenaar and others (1984) was dated as Campanian or Maastrichtian in the lower part and Tertiary in the middle and upper parts. Section D3 was mapped by Keller and others (1961) as being near the contact between the upper member of the Ignek Formation (considered by them to be Upper Cretaceous, ?Turonian to ?Maastrichtian) and the Sagavanirktok Formation (considered to be Tertiary). Franczyk and Johnsson collected samples from this locality on July 28.

Three samples were processed from this section (table 11), and two of these were analyzed (table 14). Sample R4953A contained a very low-diversity pollen assemblage, consisting nearly entirely of *Triporopollenites mullensis* and *Paraalnipollenites alterniporus* type H. It appears to be early Paleocene in age. Sample R4953D has a richer pollen assemblage, and the presence of

Caryapollenites inelegans and *C. wodehousei* indicates a late Paleocene age (McIntyre, 1994). It is not clear why the sample from 520 m in the Juniper Creek measured section should appear younger than the sample from 720 m; apparently, the very low-diversity pollen assemblage from the higher sample is caused by some paleoecological effect, which gives cause to be cautious in interpreting other very low-diversity assemblages in this study.

Table 13. Distribution of palynomorphs in samples from Section D2 (Shaviovik River). The younger of the two samples is on the right. X, present; P, probably present; ?, identification uncertain; R, interpreted as being reworked.

Taxon	Sample of R4957 series	
	D	C
Aquilapollenites trialatus	R	P(R)
Aquilapollenites reticulatus	R	R
Expressipollis types		?(R)
Paraalnipollenites alterniporus type H	?	X
Triporopollenites mullensis		X
Dinocysts		X

Table 14. Distribution of palynomorphs in samples from Section D3 (Juniper Creek). Samples run from older on the left to younger on the right. X, present; P, probably present; R, interpreted as being reworked.

Taxon	Sample of R4953 series	
	D	A
Alnus sp.	X	
Aquilapollenites reticulatus	R	
Aquilapollenites trialatus	R	
Aquilapollenites unicus	R	
Caryapollenites inelegans	X	
Caryapollenites wodehousei	X	
Expressipollis types	R	
Paraalnipollenites alterniporus type H	X	X
Pterocarya sp.	P	
Triporopollenites mullensis	X	X
Dinocysts	X	

Locality E - Kavik River

Keller and others (1961) and Roberts and others (1991, sample locality G, S 1/2 sec. 36, T. 4 N., R. 21 E., Mt. Michelson (C-5) quadrangle) described sections within the Sagavanirktok Formation on the west side of the Kavik River. Apparently, no paleontological data were available from these sections, but Keller and others (1961) mapped the area along the Kavik in the area sampled by Roberts and others (1991) and our 1994 field party (fig. 1) as belonging to the upper member of the Ignek Formation (considered by Keller and others to be Upper Cretaceous, ?Turonian to ?Maastrichtian). Samples from the Sagavanirktok Formation on the Kavik River that were dated by Anderson Worldwide Associates, Inc. (unpublished report cited by Molenaar, 1983, p. 1077) contained Maastrichtian and Paleocene palynomorphs and foraminifers. The relative stratigraphic positions of our samples from the Kavik River were difficult to describe because the sections are structurally complicated.

Table 15. Samples processed for palynomorphs from Locality E (Kavik River). In the Pollen Analysis column, A means an analysis was completed, and P means palynomorphs were present but preservation was too poor for an analysis to be made. Initials of sample collectors are: KJF, Karen J. Franczyk; MJ, Mark Johnsson.

Palynology number; collector(s)	Field number	Section	Position	Latitude and longitude	Lithology	Pollen analysis
R4954 B KJF, MJ	MJ94AK58	E1		69°37'44"(27) 146°48'28"	Siltstone, dark gray, carbonaceous	P
R4955 B KJF, MJ	MJ94AK64	E2		69°39'10"(27) 146°50'41"	Mudrock, dark gray, carbonaceous	P
R4955 D KJF, MJ	MJ94AK68	do.		69°39'18"(27) 146°51'18"	do.	A

Section E1

This is section Kavik-1 of the 1994 field party; samples were collected by Franczyk and Johnsson on July 30. This section is the same as the upper half of sample locality G of Roberts and others (1991). Only one sample was processed from this section (table 15), and this sample contained only poorly preserved palynomorphs.

Section E2

This is section Kavik-2 of the 1994 field party; samples were collected by Franczyk and Johnsson on July 30. This section is the same as the lower half of sample locality G of Roberts and others (1991). One of the two samples processed from this section (table 15) contained adequately preserved palynomorphs, and the assemblage from this sample (R4955D) included *Aquilapollenites trialatus* (probable), *Aquilapollenites unicus*, *Aquilapollenites* sp. cf. *A. unicus*, *Expressipollis* type, *Paraalnipollenites alterniporus* type H, *Triporopollenites mullensis*, *Wodehouseia spinata*, and *Wodehouseia gracile* (probable). Because of the fairly high frequency of Upper Cretaceous pollen grains relative to *Triporopollenites mullensis*, this sample is perhaps more likely to be upper Maastrichtian than lower Paleocene, but the data cannot be interpreted definitively, particularly because at least some of the Cretaceous pollen grains are most likely reworked from the lower Maastrichtian or Campanian (*Aquilapollenites trialatus*, *Expressipollis* type).

Locality F - Toolik River-White Hills

Locations of stratigraphic sequences described along the Toolik River and in the White Hills are shown in figure 8. Molenaar and others (1984, section 1) described a section from the Toolik River in NE 1/4 sec. 19, T. 2 S., R. 12 E., Sagavanirktok (B-4) quadrangle. These sandstones and siltstones were dated as Campanian (from palynomorphs) and Senonian (from foraminifers). Roberts and others (1991, sample locality A) described a section at the eastern end of the White Hills; although they did not provide an age determination for these rocks, their stratigraphic diagram (their fig. 3) showed the White Hills as including both Upper Cretaceous and lowermost Tertiary strata. SOCAL 16854-12 in figure 8 is an outcrop sample of Wiggins (1976, table 1), in sec. 25, T. 1 S., R. 12 E., Sagavanirktok (B-4) quadrangle, which was dated as late Maastrichtian. SOCAL 17129-48 is a shotpoint sample of Wiggins (1976, table 1), in sec. 32, T. 1 S., R. 12 E., Sagavanirktok (B-4) quadrangle, dated as early Paleocene.

For this report, eight samples were processed from five sections along the Toolik River and in the White Hills (fig. 8; table 16), and a total of six samples were analyzed from four of the sections (table 17).

Section F1

This is section 1 of the 1994 field party, from the east bank of the Toolik River in sec. 2, T. 2 S., R. 12 E., Sagavanirktok (B-4) quadrangle (fig. 8), and samples were collected by Fouch, Collett, and Frederiksen on August 1. Palynomorphs in sample R4958C (table 17) were generally poorly preserved, and only Campanian to Maastrichtian taxa were observed. However, abundant specimens were found in sample R5958B, again only of Campanian to Maastrichtian age.

Section F2

This is section 2 of the 1994 field party, from the east bank of the Toolik River in sec. 24, T. 1 S., R. 12 E., through sec. 19, T. 1 S., R. 13 E., Sagavanirktok (B-4) quadrangle (fig. 8), and samples were collected by Franczyk, Johnsson, and Frederiksen on August 1. The pollen assemblage from sample R4959C (table 17) consisted mainly of specimens of *Paraalnipollenites alterniporus* type H and *Triporopollenites mullensis*, in addition to several Late Cretaceous taxa (*Aquilapollenites* spp.). The sample is Paleocene, probably lower Paleocene. Sample R4959B had few specimens and taxa, consisting of both Cretaceous (reworked?) and Cretaceous to Paleocene types.

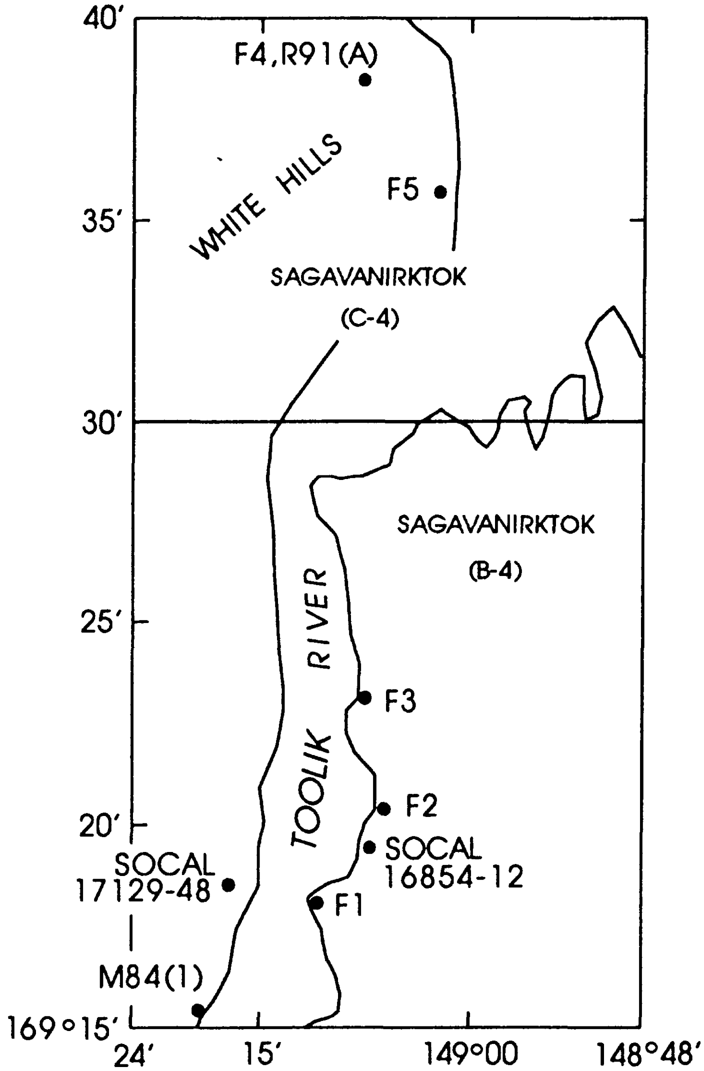

Figure 8. Location of stratigraphic sections along the Toolik River and in the White Hills. Sections F1-F5 were sampled by us in 1994. M84(1) is section 1 of Molenaar and others (1984); R91(A) is sample locality A of Roberts and others (1991). SOCAL samples are from Wiggins (1976, table 1).

Section F3

Section F3 was north of the August 1 localities, on the east bank of the Toolik River in sec. 1, T. 1 S., R. 12 E., Sagavanirktok (B-4) quadrangle (fig. 8), and was sampled on August 2. One sample was processed (table 16), but it contained only poorly preserved palynomorphs.

Section F4

This is locality 005 of the 1994 field party, from the easternmost White Hills, in sec. 11, T. 3 N., R. 12 E., Sagavanirktok (C-4) quadrangle (fig. 8), and was sampled on August 2. Section F4 was slightly south of sample locality A of Roberts and others (1991), which was located in SE 1/4 sec. 2, T. 3 N., R 12 E. Sample R4961D contained a diverse assemblage consisting mainly of porate pollen (table 17). No species confined to the Cretaceous were observed; thus, the sample is Paleocene, and because of the presence of *Caryapollenites imparalis*, it should be middle or upper Paleocene (McIntyre, 1994).

Section F5

This is locality 006 of the 1994 field party, from the easternmost White Hills, in secs. 19 and 30, T. 3 N., R. 13 E., Sagavanirktok (C-4) quadrangle (fig. 8), and was sampled on August 2. Sample R4962A contained a diverse, well preserved pollen assemblage mainly of porate pollen in addition to a few Cretaceous pollen grains (*Aquilapollenites* spp., *Expressipollis* type) considered to be reworked (table 17). The most interesting species was *Diervilla* sp., previously seen on the North Slope of Alaska only in Eocene samples from Franklin Bluffs and especially in the coal bed (probably lower Eocene) at the top of the Sagwon Member at the south end of Franklin Bluffs. The same species was also reported from coals of late Paleocene to early Eocene age on Ellesmere Island (Kalkreuth and others, 1993). Therefore, sample R4962A is probably upper Paleocene or lower Eocene; however, it lacks the many tricolpate and tricolporate species found in the Eocene, and thus it is probably upper Paleocene.

Table 16. Samples processed for palynomorphs from Locality F (Toolik River-White Hills). In the Pollen Analysis column, A means an analysis was completed, B means the sample was barren of palynomorphs, and P means palynomorphs were present but preservation was too poor for an analysis to be made. Initials of sample collectors are: TSC, Timothy S. Collett; TDF, Thomas D. Fouch; KJF, Karen J. Franczyk; NOF, Norman O. Frederiksen; MJ, Mark Johnsson.

Palynology number; collector(s)	Field number	Section	Position	Latitude and longitude	Lithology	Pollen analysis
R4958 B TSC, TDF, NOF	NF94AK-70	F1	12 ft above base of section		Shale, medium gray, soft	A
R4958 C TSC, TDF, NOF	NF94AK-71	do.	13 ft above base of section		Shale, medium dark gray, hard	A

R4958 F TSC, TDF, NOF	NF94AK-74	do.	77 m, within interval with shells		Sand-stone, medium gray, very fine-grained	B
R4959 B KJF, NOF, MJ	NF94AK-76	F2	2.5 ft below coal at top of first slope	69°20'16" 149°4'54"	Clay, medium gray	A
R4959 C KJF, NOF, MJ	NF94AK-77	do.	Directly above coal at top of first slope	do.	Shale, medium dark gray	A
R4960 D KJF, NOF, MJ	NF94AK-84	F3	Slump 2/3 of the way down slope	69°22.67' 149°08.29'	Mudrock, medium dark gray	P
R4961 D TDF, NOF	NF94AK-88	F4	Parting in basal part of coal bed		Clay, medium dark gray	A
R4962 A TDF, NOF	NF94AK-89	F5	Directly over-lying coal bed		Silt-stone, medium dark gray, lami-nated, carbona-ceous	A

Table 17. Distribution of palynomorphs in samples from Locality F (Toolik River-White Hills). X, present, but could be reworked; P, probably present; ?, identification uncertain.

Taxon	F1	F1	F2	F2	F4	F5
Section -->	F1	F1	F2	F2	F4	F5
Sample -->	R4958B		R4959B		R4961D	
Sample -->		R4958C		R4959C		R4962A
Alnus sp.				?	X	X
Aquilapollenites colvillensis				X		
Aquilapollenites reticulatus	X	P	X	X		X
Aquilapollenites trialatus	X	X				X
Betulaepollenites spp.					X	
Caryapollenites imparalis					X	
Cranwellia sp.			P			
Diervilla sp.						X
Ericaceae						X
Expressipollis types	X	X				X
Kurtzipites trispissatus	X					
Momipites coryloides				?		
Paraalnipollenites alterniporus type H			X	X	X	X
Paraalnipollenites alterniporus type Z						X
Pterocarya sp.						P
Retitrescolpites sp. aff. *R. anguloluminosus*					X	
Triatriopollenites spp.				?	X	X
Triporopollenites megagranifer				X	X	X
Triporopollenites mullensis			X	X	X	X
Trivestibulopollenites spp.					X	
Ulmipollenites krempii					X	X
Ulmipollenites tricostatus					X	X
Ulmipollenites undulosus					?	X
Dinocysts	X		X			

COMPARISON AND SUMMARY

Age Determinations

Table 18 summarizes the palynomorph ages of the six localities examined for this report, and these ages, in addition to those provided by other workers referred to in this report, are shown in figure 9. Most of the samples are early Tertiary. However, reworked Cretaceous pollen is common, and most of the abundantly represented Paleocene pollen taxa (mainly wind-pollinated porates) have their range bases within the Maastrichtian, so that it was sometimes difficult to determine whether a given sample was early Paleocene or Campanian/Maastrichtian.

Table 18. Summary of palynomorph ages at the six localities examined for this report.

Locality	Location	Age
A	Franklin Bluffs	Early to middle Eocene
B	Sagwon Bluffs area	Early Paleocene; late(?) Paleocene
C	Ivishak River	Late Maastrichtian or early Paleocene
D	Shaviovik anticline area	Paleocene; middle or late Paleocene; late Paleocene
E	Kavik River	Late Maastrichtian or early Paleocene
F	Toolik River-White Hills	Campanian or Maastrichtian(?); early Paleocene; middle or late Paleocene; late Paleocene

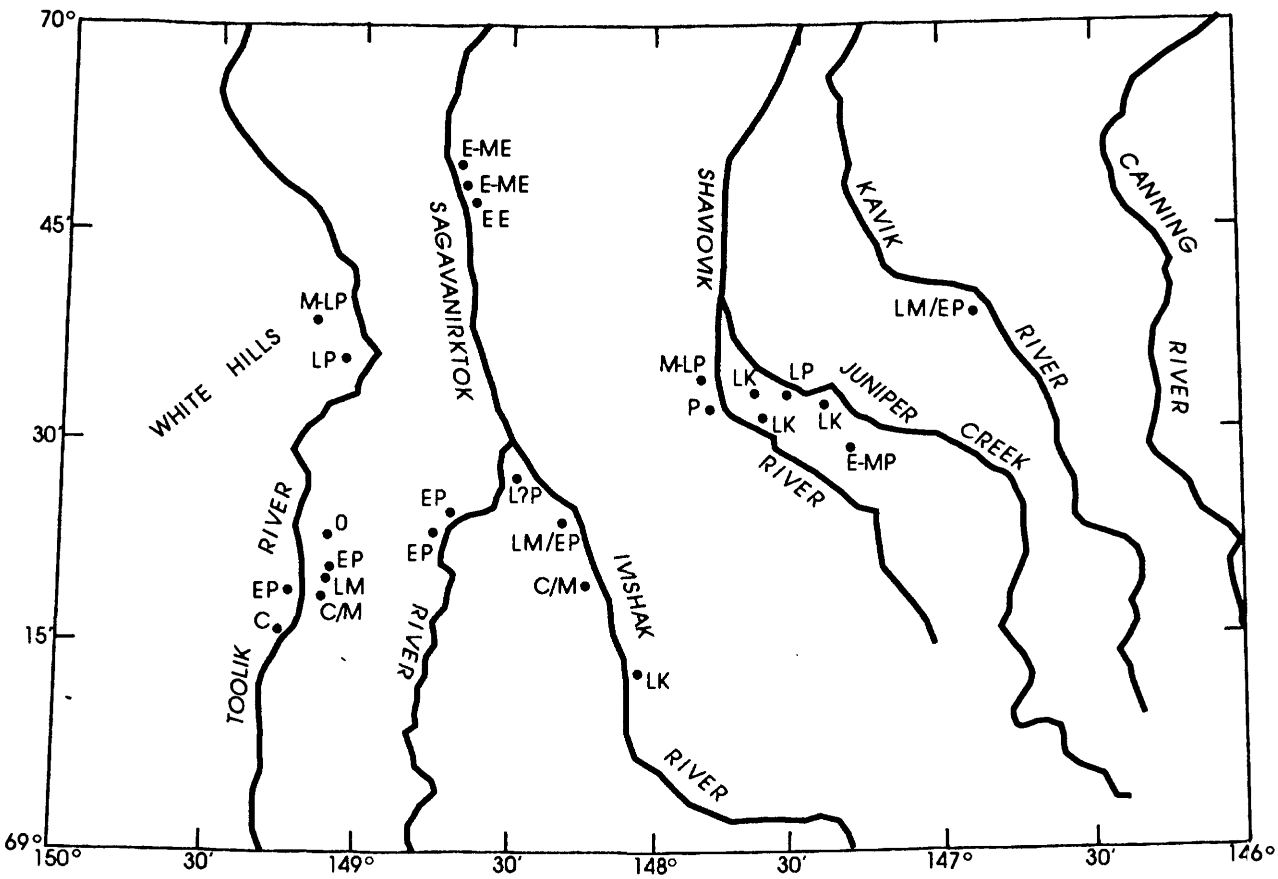

Figure 9. Map showing inferred ages of samples discussed in this report. E, early; M, middle, L, late. C, Campanian; E, Eocene; K, Cretaceous; M, Maastrichtian; O, barren sample; P, Paleocene.

As expected, the overall pattern of ages in figure 9 (except for the Shaviovik anticline area) is from older (Late Cretaceous) in the south to younger (Paleocene, then Eocene) to the north. The additional samples examined from Franklin Bluffs support the previous age determinations of Ager and others (1986) and Frederiksen and others (1994) that the sampled section is probably entirely early to middle Eocene. Similarly, the new samples examined from the lower part of the Sagwon Bluffs section support the previous early Paleocene age determination for those rocks by Ager (in Carey and others, 1988, and in Spicer and Parrish, 1990). However, preservation of palynomorphs was not good enough to make possible an age determination of the lowermost rocks at Sagwon Bluffs that had been considered to be Upper Cretaceous by Detterman and others (1975). Collett (in Spicer and others, 1994, p. 165), thought that the "uppermost part of the [Sagwon Bluffs] section may be early Eocene based on the projection of subsurface stratigraphy." However, the youngest rocks examined for this report from the Sagwon Bluffs area were in Section B3, on the east side of the Sagavanirktok River, to the northeast of Sections B1 and B2, and were probably late Paleocene. Little has been published about ages of rocks along Juniper Creek; thus, a probable late Paleocene age for one sample from this area is of interest, and this seems to be the youngest age yet determined for rocks in the Shaviovik anticline area. However, it is curious that samples near the axis of the Shaviovik anticline (D2, D3) appear to be younger (Paleocene) than those on the flanks dated by Bergquist (in Keller and others, 1961; LK samples in fig. 9). The one sample examined from the Kavik River could not be dated with any certainty. The new data, combined with previous reports, show a nice progression of ages northward along the Toolik River and in the eastern White Hills.

The samples available were not adequate to affirm or dispute Molenaar's (1983, p. 1077) idea of "the regional pattern of the base of the [Sagavanirktok Formation] becoming younger to the northeast."

Floral and Vegetational Analysis

The 39 samples analyzed for this report, in addition to those analyzed by Frederiksen and others (1994), provide a good record of the rise in angiosperm taxon diversity on the North Slope of Alaska from very low at the beginning of the Paleocene (following the Terminal Cretaceous Extinction Event) to very high in the lower and middle Eocene (promoted by the climatic thermal maximum for the Tertiary in the latest Paleocene and Eocene). In the lower Paleocene of the Sagavanirktok Formation, most pollen grains were of the anemophilous (wind-pollinated) triporate species *Paraalnipollenites alterniporus* and *Triporopollenites mullensis*, which intergrade morphologically. This low pollen diversity corresponds well with the fact that at Sagwon Bluffs, fossil leaves are mainly of the species *Corylus beringiana* (Spicer and others, 1994), which probably were borne by plants producing the two dominant triporate pollen species found at the same locality. The pollen diversity in the middle and upper Paleocene (northeastern Sagwon Bluffs area, Juniper Creek, Toolik River-White Hills) is somewhat higher than in the lower Paleocene, but if the pollen assemblages had been better preserved (as they are in the Franklin Bluffs material), then the observed diversities particularly in the upper Paleocene might well have been considerably higher. The high angiosperm diversity in the early and middle Eocene at approximately 78° N. latitude (Scotese and Golonka, 1993) is striking and strongly supports previous evidence as to the warmth of climate in the Arctic during that time. This Eocene angiosperm flora from Franklin Bluffs appears to have a higher diversity than the flora of probable middle Eocene age from Axel Heiberg Island (McIntyre, 1991b) which is now far to the north of northern Alaska but in the Eocene apparently was only slightly farther north (Scotese and Golonka, 1993).

ACKNOWLEDGMENTS

K. J. Bird reviewed several drafts of this report and made helpful comments for its improvement.

TAXONOMY

Most Tertiary taxa listed in this report are the same as those in Frederiksen and others (1994). Cretaceous species from northern Alaska are illustrated by Frederiksen and others (1988) and Frederiksen (1991b) and other references therein. Additional Tertiary taxa are as follows:

Milfordia hungarica (Kedves) Krutzsch & Vanhoorne in Krutzsch 1970.

Momipites coryloides Wodehouse 1933.

Carya >28 µm of Frederiksen (1988).

Caryapollenites inelegans Nichols & Ott 1978.

Caryapollenites wodehousei Nichols & Ott 1978.

Platycaryapollenites swasticoidus (Elsik) Frederiksen & Christopher 1978.

The name *Paraalnipollenites alterniporus* (Simpson) Srivastava 1975 is a replacement for *P. confusus* (Zaklinskaya) Hills & Wallace 1969, the name used by Frederiksen and others (1994).

Diervilla sp. = *Diervilla* sp. of Kalkreuth and others (1993, pl. 2, fig. 27). *Diervilla echinata* Piel 1971 is more nearly circular and has smaller annuli.

Quercoidites sp. 1. Prolate, tricolpate, granulate, with distinct margines.

Tricolpites sp. 1. Similar to *Tricolporopollenites kruschii sensu* Elsik 1968 of Rouse (1977, pl. 2, fig. 38) but more coarsely reticulate. Tricolporate?

Tricolpites sp. 2. Similar to *Tricolporopollenites kruschii sensu* Elsik 1968 of Rouse (1977, pl. 2, fig. 38) but with deeper colpi and no indication of ora.

Tricolpites aff. *T. asper* of Frederiksen and others (1988).

Aesculiidites B of Rouse (1977, pl. 1, fig. 23).

Retitrescolpites aff. *R. anguloluminosus* (Anderson) Frederiksen 1979.

Bombacacidites aff. *B. fereparilis* Frederiksen 1983.

Bombacacidites nacimientoensis (Anderson) Elsik 1968.

Basopollis obscurocostatus Tschudy 1975.

Aquilapollenites tumanganicus Bolotnikova 1973. All specimens of *A. tumanganicus* illustrated by Bolotnikova (1973, pl. 25, fig. 1; 1979, pl. 3, figs. 30, 31, 36) have polar regions that flare (are wider than the body midway between equator and pole) in a trilobate fashion; thus, Bolotnikova's specimens fit the definition of *Novemprojectus*, and they appear to be identical with the specimens from the North Slope of Alaska. *A. tumanganicus* of this report is a different species from *A. tumanganicus* of McIntyre (1994; McIntyre and Ricketts, 1989; Kalkreuth and others, 1993) because the latter species does not have the pinched-in waist and trilobate flaring poles of Bolotnikova's specimens or of the Alaskan North Slope specimens. *A. tumanganicus* of this report is distinctly different from *Novemprojectus traversii* Choi 1984, because the latter species has polar lobes that are much more pronounced than in *A. tumanganicus*. *Novemprojectus* sp. in Sections 1 and 2 of Frederiksen and others (1994) is *Aquilapollenites tumanganicus* of this report.

The range chart of Bolotnikova (1979, fig. 6) shows *Aquilapollenites tumanganicus* in eastern Siberia (western coast of the Sea of Japan) as ranging throughout the Paleocene and being sparsely present in the lower to middle Eocene. However, on the North Slope of Alaska, this species is not known from strata below Section A1 of this report (probably lower Eocene).

Novemprojectus traversii Choi 1984.

Novemprojectus sp. (not the same species as *Novemprojectus* sp. in Sections 1 and 2 of Frederiksen and others, 1994). Very similar to *N. traversii* but has long spines.

REFERENCES CITED

These references do not include papers cited only because the authors' names were part of a taxon name.

Ager, T. A., Edwards, L. E., and Oftedahl, O., 1986, Eocene palynomorphs from the Franklin Bluffs, Arctic Slope, northeast Alaska: Palynology, v. 10, p. 243.

Berggren, W. A., Kent, D. V., Swisher, C. C. III, and Aubry, M.-P., 1995, A revised Cenozoic geochronology and chronostratigraphy, *in* Berggren, W. A., Kent, D. V., Aubry, M.-P., and Hardenbol, Jan, eds., Geochronology, time scales and global stratigraphic correlation: SEPM Special Publication 54, p. 129-212.

Bird, K. J., 1988, Alaskan North Slope stratigraphic nomenclature and data summary for Government-drilled wells, *in* Gryc, George, ed., Geology and exploration of the National Petroleum Reserve in Alaska, 1974 to 1982: U.S. Geological Survey Professional Paper 1399, p. 317-336.

Bird, K. J., Griscom, S. B., Bartsch-Winkler, Susan, and Giovannetti, D. M., 1987, Petroleum reservoir rocks, *in* Bird, K. J., and Magoon, L. B., eds., Petroleum geology of the northern part of the Arctic National Wildlife Refuge, northeastern Alaska: U.S. Geological Survey Bulletin 1778, p. 79-99.

Bolotnikova, M. D., 1973, *Aquilapollenites* Rouse pollen grains from the Paleocene deposits of the western coast of the Sea of Japan, *in* Fossil floras and phytostratigraphy of the Far East: U.S.S.R. Academy of Sciences, Vladivostok, p. 98-104 (in Russian).

______1979, Spore-pollen complexes of Tertiary deposits of the western coast of the Sea of Japan: Moscow, "Science" Publishing House, 194 p. (in Russian).

Carey, M. A., Roberts, S. B., and Clark, A. C., 1988, Chemical analyses for nine coal samples from the Sagwon Member (Tertiary) of the Sagavanirktok Formation, North Slope, Alaska: U. S. Geological Survey Open-file Report 88-678, 17 p.

Choi, D. K., 1984, A new Eocene triprojectate pollen genus from the Canadian Arctic, *Novemprojectus*: Review of Palaeobotany and Palynology, v. 43, p. 337-341.

Collett, T. S., 1988, Unpublished measured sections at Sagwon Bluffs.

Detterman, R. L., Reiser, H. N., Brosgé, W. P., and Dutro, J. T., Jr., 1975, Post-Carboniferous stratigraphy, northeastern Alaska: U. S. Geological Survey Professional Paper 886, 46 p.

Doerenkamp, A., Jardiné, S., and Moreau, P., 1976, Cretaceous and Tertiary palynomorph assemblages from Banks Island and adjacent areas (N.W.T.): Bulletin of Canadian Petroleum Geology, v. 24, p. 372-417.

Frederiksen, N. O., 1983, Angiosperm pollen and miscellanea, *in* Middle Eocene palynomorphs from San Diego, California: American Association of Stratigraphic Palynologists Contributions Series, v. 12, p. 32-109, 124-155.

______1988, Sporomorph biostratigraphy, floral changes, and paleoclimatology, Eocene and earliest Oligocene of the eastern Gulf Coast: U.S. Geological Survey Professional Paper 1448, 68 p.

______1991a, Midwayan (Paleocene) pollen correlations in the eastern United States: Micropaleontology, v. 37, p. 101-123.

______1991b, Pollen zonation and correlation of Maastrichtian marine beds and associated strata, Ocean Point dinosaur locality, North Slope, Alaska: U.S. Geological Survey Bulletin 1990-E, 24 p.

Frederiksen, N. O., Ager, T. A., and Edwards, L. E., 1988, Palynology of Maastrichtian and Paleocene rocks, lower Colville River region, North Slope of Alaska: Canadian Journal of Earth Sciences, v. 25, p. 512-527.

Frederiksen, N. O., Edwards, L. E., Fouch, T. D., Carter, L. D., and Collett, T. S., 1994, Palynomorph biostratigraphy of Eocene samples from the Sagavanirktok Formation at Franklin Bluffs, North Slope of Alaska: U.S. Geological Survey Open-File Report 94-653, 32 p.

Gryc, G., Patton, W. W., Jr., and Payne, T. G., 1951, Present Cretaceous stratigraphic nomenclature of northern Alaska: Journal of the Washington Academy of Sciences, v. 41, p. 159-167.

Kalgutkar, R. M., and Sweet, A. R., 1988, Morphology, taxonomy and phylogeny of the fossil fungal genus *Pesavis* from northwestern Canada: Geological Survey of Canada Bulletin 379, p. 117-133.

Kalkreuth, W. D., McIntyre, D. J., and Richardson, R. J. H., 1993, The geology, petrography and palynology of Tertiary coals from the Eureka Sound Group at Strathcona Fiord and Bache Peninsula, Ellesmere Island, Arctic Canada: International Journal of Coal Geology, v. 24, p. 75-111.

Keller, A. S., Morris, R. H., and Detterman, R. L., 1961, Geology of the Shaviovik and Sagavanirktok Rivers region, Alaska: U.S. Geological Survey Professional Paper 303-D, p. 169-222.

McIntyre, D. J., 1991a, Appendix 3, palynology, *in* Ricketts, B. D., Delta evolution in the Eureka Sound Group, western Axel Heiberg Island: the transition from wave-dominated to fluvial-dominated deltas: Geological Survey of Canada Bulletin 402, p. 66-72.

_____1991b, Pollen and spore flora of an Eocene forest, eastern Axel Heiberg Island, N.W.T.: Geological Survey of Canada Bulletin 403, p. 83-97.

_____1994, Appendix 1, palynology, in Ricketts, B. D., Basin analysis, Eureka Sound Group, Axel Heiberg and Ellesmere Islands, Canadian Arctic Archipelago: Geological Survey of Canada Memoir 439, p. 85-101.

McIntyre, D. J., and Ricketts, B. D., 1989, New palynological data from Cornwall Arch, Cornwall and Amund Ringnes Islands, District of Franklin, N.W.T., *in* Current Research, Part G: Geological Survey of Canada Paper 89-1G, p. 199-202.

Molenaar, C. M., 1983, Depositional relations of Cretaceous and lower Tertiary rocks, northeastern Alaska: American Association of Petroleum Geologists Bulletin, v. 67, p. 1066-1080.

Molenaar, C. M., Bird, K. J., and Kirk, A. R., 1987, Cretaceous and Tertiary stratigraphy of northeastern Alaska, *in* Tailleur, I. L., and Weimer, Paul, eds., Alaskan North Slope geology: Pacific Section, Society of Economic Paleontologists and Mineralogists, Field Trip Guidebook 50, p. 513-528.

Molenaar, C. M., Kirk, A. R., Magoon, L. B., and Huffman, A. C., 1984, Twenty-two measured sections of Cretaceous-lower Tertiary rocks, eastern North Slope, Alaska: U.S. Geological Survey Open-File Report 84-695, 23 p.

Pocknall, D. T., 1987, Palynomorph biozones for the Fort Union and Wasatch Formations (upper Paleocene-lower Eocene), Powder River Basin, Wyoming and Montana, U.S.A.: Palynology, v. 11, p. 23-35.

Roberts, S. B., Stricker, G. D., and Affolter, R. H., 1991, Stratigraphy and chemical analyses of coal beds in the Upper Cretaceous and Tertiary Sagavanirktok Formation, east-central North Slope, Alaska: U.S. Geological Survey Coal Investigations Map C-139-B, 1 sheet.

Rouse, G. E., 1977, Paleogene palynomorph ranges in western and northern Canada, *in* Elsik, W. C., ed., Contributions of stratigraphic palynology (with emphasis on North America), v. 1, Cenozoic palynology: American Association of Stratigraphic Palynologists Contributions Series, v. 5A, p. 48-65.

Scotese, C. R., and Golonka, J., 1993, PALEOMAP Paleogeographic Atlas, PALEOMAP Progress Report 20: Arlington, University of Texas at Arlington, Department of Geology, 34 p.

Spicer, R. A., Davies, K. S., and Herman, A. B., 1994, Circum-Arctic plant fossils and the Cretaceous-Tertiary transition, *in* Boulter, M. C., and Fisher, H. C., eds., Cenozoic plants and climates of the Arctic: Berlin, Springer-Verlag, p. 161-174.

Spicer, R. A., and Parrish, J. T., 1990, Late Cretaceous-early Tertiary palaeoclimates of northern high latitudes: a quantitative view: Journal of the Geological Society of London, v. 147, p. 329-341.

Tschudy, R. H., 1975. Normapolles pollen from the Mississippi embayment: U.S. Geological Survey Professional Paper 865, 42 p.

Wiggins, V. D., 1976, Fossil oculata pollen from Alaska: Geoscience and Man, v. 15, p. 51-76.