DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Palynological dating of some Upper Cretaceous to Eocene outcrop and well samples from the region extending from the easternmost part of the National Petroleum Reserve in Alaska to the western part of the Arctic National Wildlife Refuge, North Slope of Alaska

By

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Open-File Report 02-405

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ABSTRACT

This report (1) provides palynologically determined ages for some Upper Cretaceous and lower Tertiary North Slope outcrops and (2) reviews consultant and oil company palynological reports on Upper Cretaceous and lower Tertiary rocks in eight North Slope wells.

Dinocyst species in 12 samples from the Rogers Creek and overlying Barrow Trail Members of the Schrader Bluff Formation along the Chandler and Colville Rivers, as well as previous age determinations based on inoceramids and foraminifers, indicate that the Barrow Trail is early Campanian; the uppermost part of the Rogers Creek Member apparently is also early Campanian, but most of the Rogers Creek apparently is Santonian and perhaps partly late Coniacian in age. Pollen biostratigraphy suggests that the top of the Barrow Trail Member is not demonstrably diachronous at least in a north-south direction; therefore, the base of the overlying Sentinel Hill Member may also be only slightly diachronous.

Pollen grains were used to date 13 of 16 outcrop samples collected in 1997 by U. S. Geological Survey geologists on the North Slope between 145° and 148° west longitude. The pollen-bearing samples ranged from Maastrichtian to Paleocene and possibly to Eocene in age.

Consultant and oil company palynological reports are reviewed that deal with ages of Upper Cretaceous to Eocene strata in eight North Slope wells from near the Colville River to near the Canning River. As is usual on the North Slope, the top of the Paleocene is picked at the topmost occurrence or topmost consistent occurrence of *Paraalnipollenites confusus*. In some places, the base of the Eocene and especially the top of the Cretaceous must be picked on the basis of dinoflagellates because angiosperm pollen is rare especially in the Cretaceous. At least the upper part of the preserved Paleocene often lacks dinoflagellates; the lower part often is marine, reflecting the early Paleocene highstand. In the eight wells discussed here and the two wells discussed in a prior open-file report, the uppermost preserved pre-Tertiary rocks vary from undated or pre-Mississippian metasedimentaries to Santonian-Campanian to Maastrichtian. The lowermost preserved Tertiary rocks are mainly Paleocene.

INTRODUCTION

Paleontological age determinations and correlations of sedimentary rocks are of great importance to hydrocarbon exploration on the North Slope of Alaska. This report concerns the area from the easternmost part of the National Petroleum Reserve in Alaska (NPRA) to the western part of the Arctic National Wildlife Refuge (ANWR; fig. 1). The purposes of the report are to provide palynological data on samples from some Upper Cretaceous and Paleocene outcrops and to review consultant and oil company palynological reports on Upper Cretaceous and Tertiary rocks in eight North Slope wells. Tables 1 and 2 list the palynomorph taxa mentioned in this report.

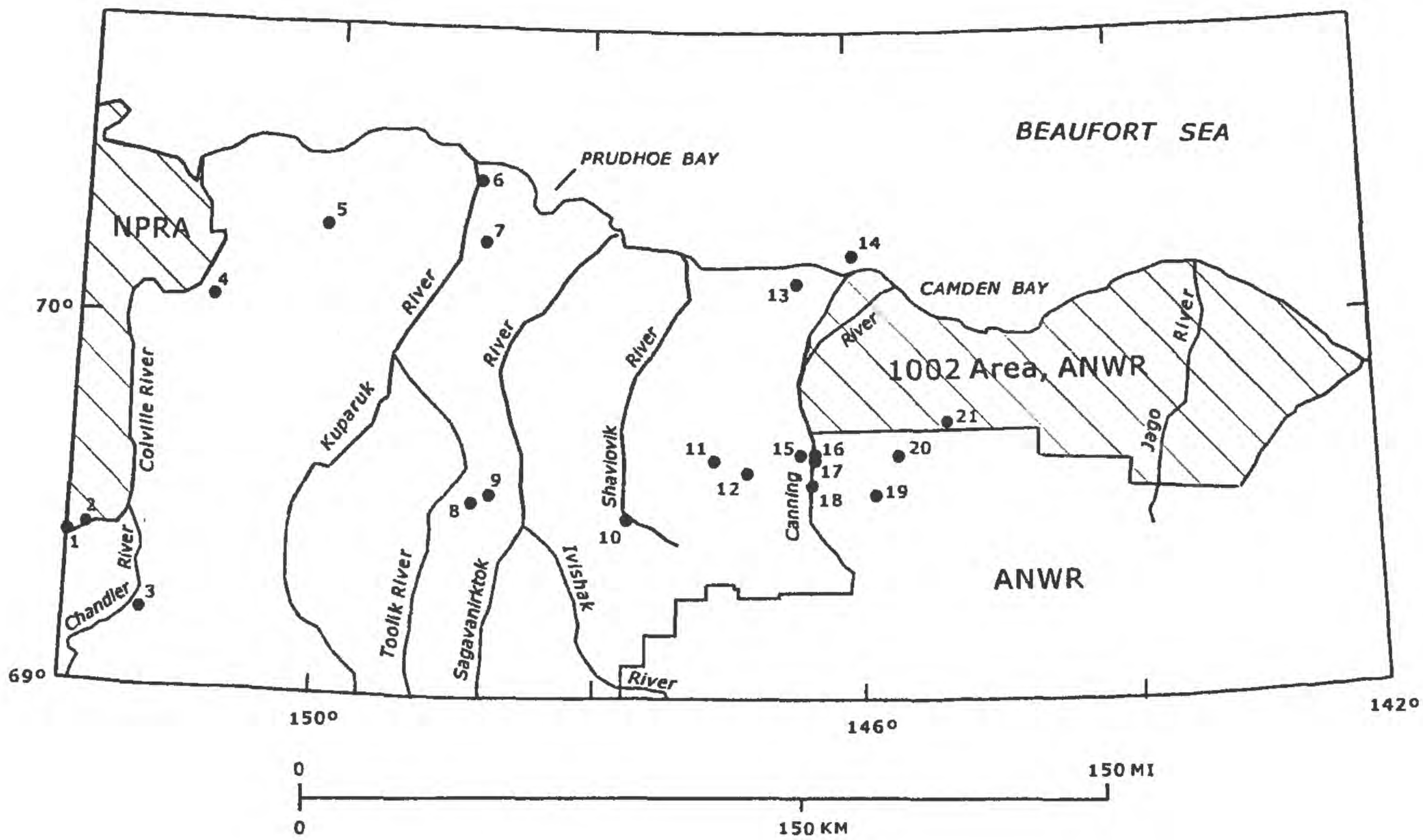

Figure 1. Index map showing locations of outcrop sections and wells on the North Slope of Alaska that are discussed in this report. Localities: 1 and 2, sampled outcrops along the Colville River; 3, sampled outcrops along the Chandler River; 4, Arco Itkillik River #1 well; 5, Arco Ugnu SWPT-1 well in the Kuparuk River oil field, from which detailed pollen occurrence data were obtained from the uppermost Maastrichtian and the lowermost Paleocene (Frederiksen and others, 1998); 6, Sohio Prudhoe Bay Unit R-1 well; 7, Placid et al. State #1 well; 8, Arco Susie Unit #1 well; 9, Arco Nora Federal #1 well; 10, Kadleroshilik River #2 outcrop section; 11, Kavik West outcrop section; 12, Kavik syncline section; 13, Mobil West Staines State #2 well; 14, Exxon Alaska State A-1 well; 15, Exxon Canning River B-1 well; 16, Navy section, outcrop 97-38; 17, Navy section, outcrops 97-23 and 97-24; 18, Kermits Island #2 outcrop section; 19, Hue Creek outcrop section; 20, East Fork of the Tamayariak River outcrop section; 21, East Katakturuk #1 and #2 sections.

PREVIOUS WORK

Many reports have been published or cited concerning pollen biostratigraphy of Upper Cretaceous and Tertiary strata on the North Slope of Alaska (e.g., Tschudy, 1969; Wiggins, 1976, 1981, 1982; Witmer and others, 1981a, b; Molenaar and others, 1984; Ager and others, 1986; Frederiksen and others, 1986, 1988, 1994, 1996, 1998; Frederiksen, 1987, 1991; Frederiksen and Schindler, 1987; Mickey and Haga, 1988; Kimyai, 1992; Fouch and others, 1993; Frederiksen and McIntyre, 2000). Published articles on Late Cretaceous dinocysts from Arctic North America are mainly concerned with Arctic Canada, for example papers by Norford and others (1972), Felix and Burbridge (1973), McIntyre (1974, 1975, 1985), Doerenkamp and others (1976), and Ioannides and McIntyre (1980). Apparently the only published report on Late Cretaceous dinocysts from the North Slope of Alaska was by Kimyai (1992), but dinocyst data from the Alaskan North Slope are also included in the open-file report by Frederiksen and McIntyre (2000).

PALYNOLOGICAL METHODS

Outcrop samples discussed in this report were processed in the U.S. Geological Survey palynological laboratory in Reston, Virginia. These samples underwent the normal palynological techniques of HCl; HF; brief oxidation using 35% HNO_3 followed by treatment with 5% NH_4OH; centrifugation with soapy water to remove fines; and heavy liquid separation using a $ZnCl_2$ liquid of 1.45 s.g. The relatively light heavy liquid of 1.45 s.g. was effective in removing some of the abundant black woody material in the samples. The residues were stained with Bismark brown and then the finest material removed using 10 μm sieves. Residues were mounted in glycerine jelly.

PALYNOMORPH BIOSTRATIGRAPHY OF SOME UPPER CRETACEOUS OUTCROP SAMPLES FROM ALONG THE CHANDLER AND COLVILLE RIVERS

Introduction

This part of the report is concerned with two stratigraphic units of the Colville Group (Upper Cretaceous), in ascending order, the Rogers Creek and Barrow Trail Members of the Schrader Bluff Formation (fig. 2). From these units we document the occurrences and discuss the chronostratigraphic significance of 24 dinocyst species in 12 samples, as well as the presence/absence of the Campanian dinocyst marker *Laciniadinium biconiculum* in 10 additional samples, from along the Chandler and Colville Rivers (fig. 1, localities 1-3; figs. 3-7; table 3). We also document the occurrences and discuss the chronostratigraphic significance of 13 pollen species in 34 samples from the same localities.

This section of the report is a continuation of a palynological study (Frederiksen and McIntyre, 2000) that focused on the mainly marine Sentinel Hill Member of the Schrader Bluff Formation and the mainly nonmarine Kogosukruk Tongue of the Prince Creek Formation (fig. 2),

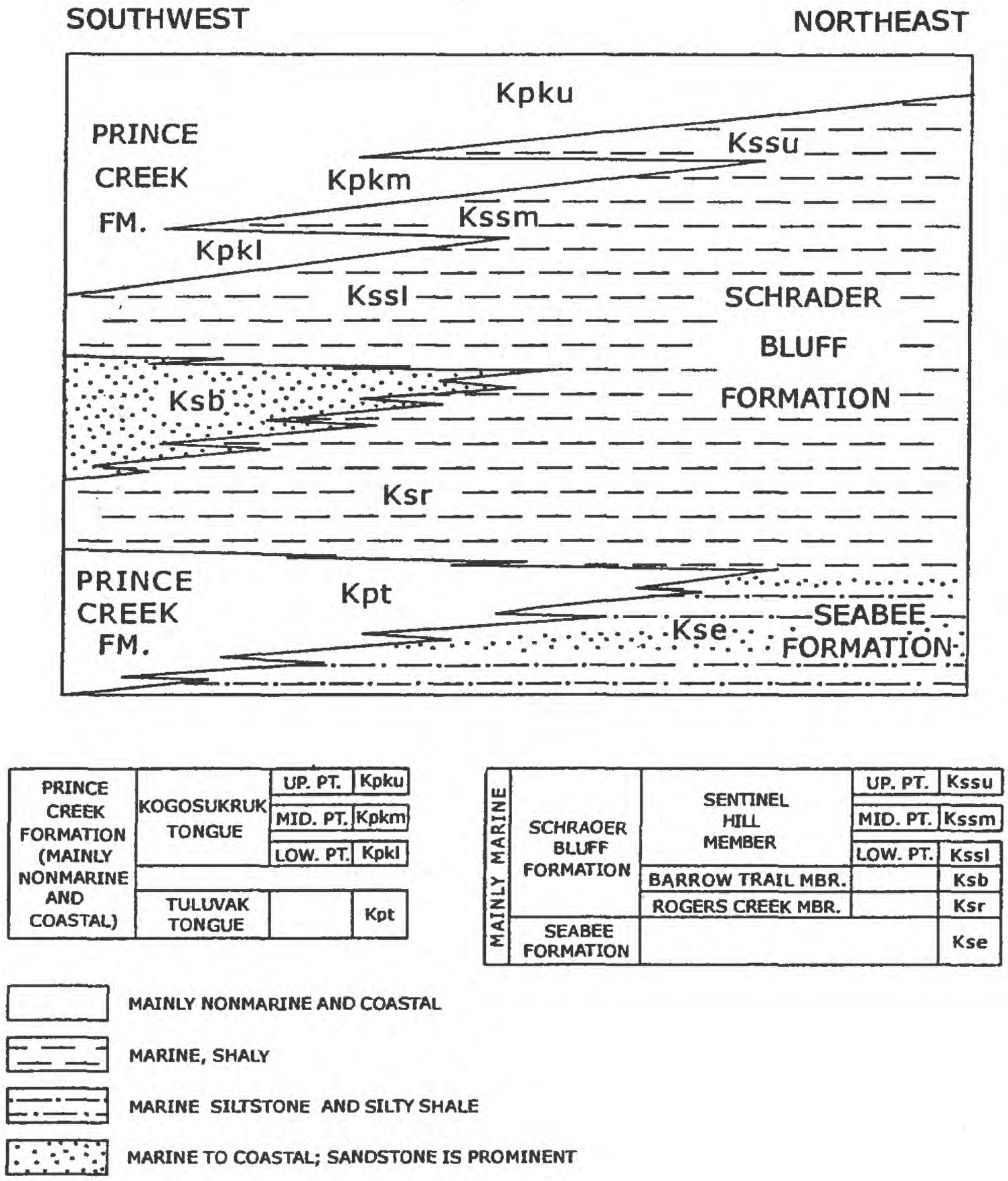

Figure 2. Intertonguing Turonian to Maastrichtian stratigraphic units of the Colville Group along the Chandler and Colville Rivers. The nomenclature is from the Colville River (Brosgé and Whittington, 1966; Frederiksen and McIntyre, 2000); a slightly different nomenclature was used by Detterman and others (1963) for the Chandler River section (see fig. 4 of the present report). Only the upper part of the Seabee Formation is shown. The vertical axis of the diagram represents geologic time but is not to scale. After Gryc and others (1951), Gryc (1956), and K. J. Bird (written commun., 2001).

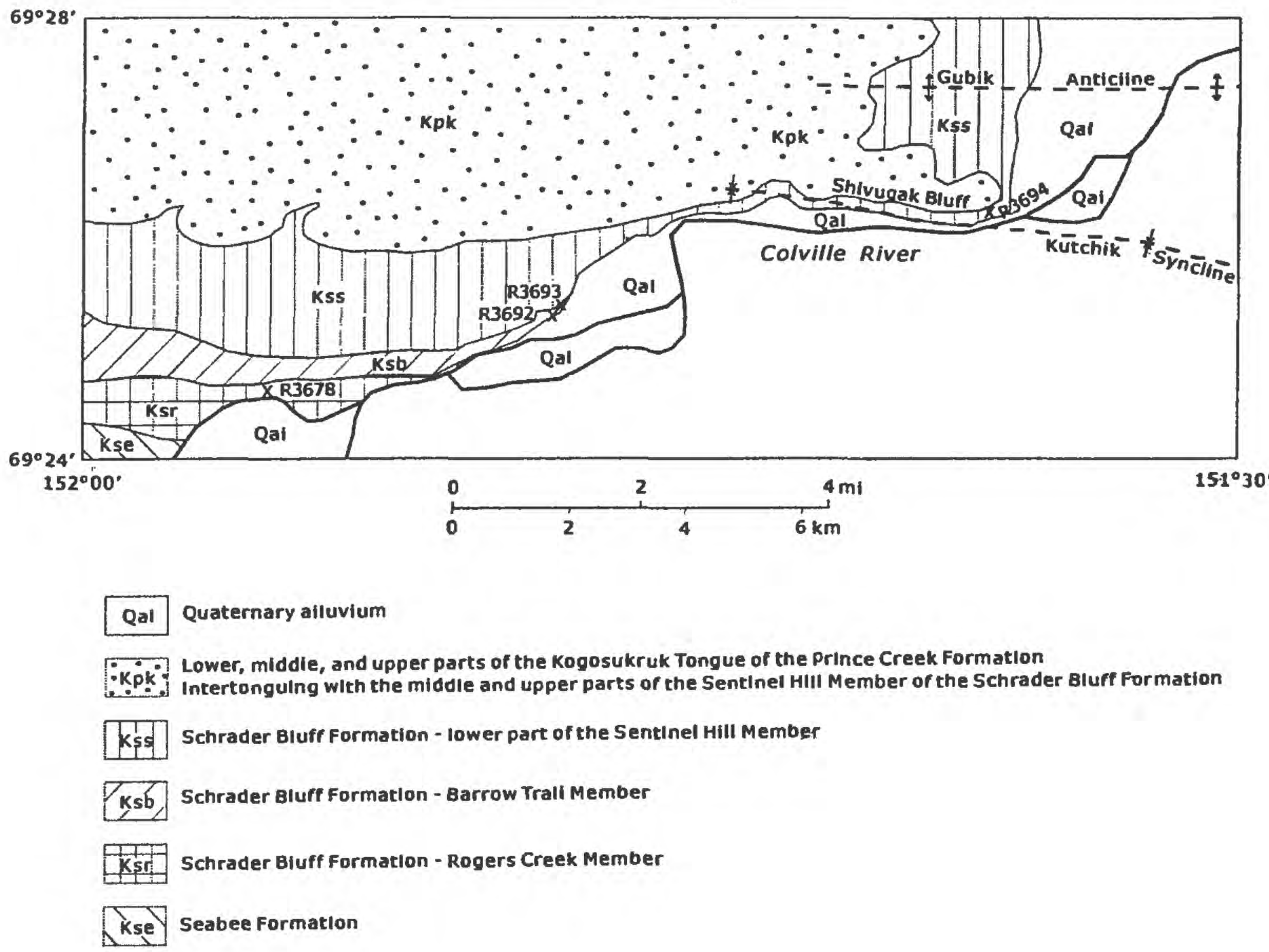

Figure 3. Locations of outcrop sample sets from the Rogers Creek and Barrow Trail Members of the Schrader Bluff Formation and from the lowest samples of the Sentinel Hill Member of the same formation, from along the Colville River. Geology (from Brosgé and Whittington, 1966, pl. 52) is shown only north of the river.

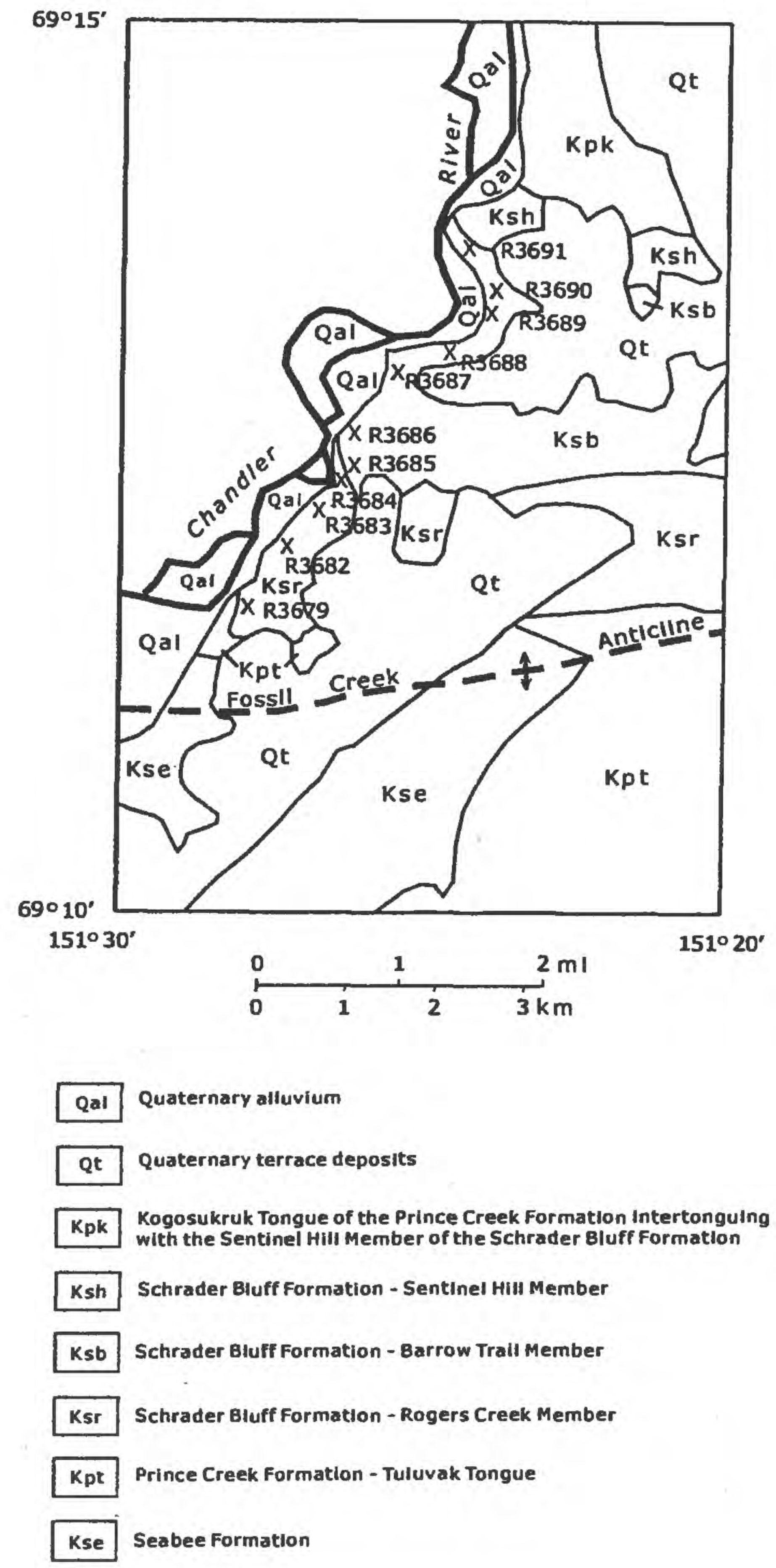

Figure 4. Locations of outcrop sample sets from the Rogers Creek and Barrow Trail Members of the Schrader Bluff Formation from the Tuluvak Bluffs along the Chandler River. Geology (from Detterman and others, 1963, pl. 27) is shown only east of the river.

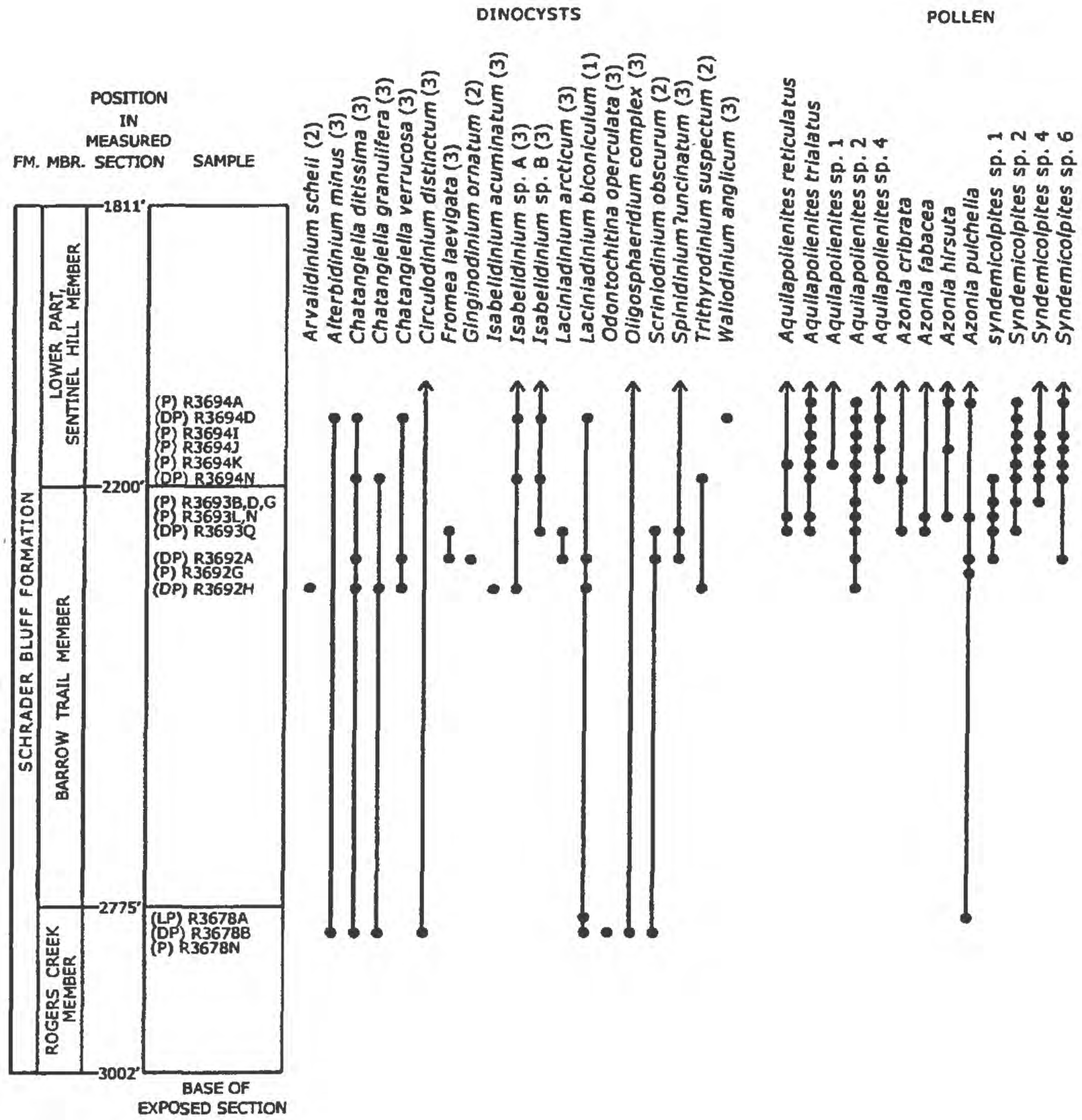

Figure 5. Measured section along the Colville River below Umiat (fig. 3; Brosgé and Whittington, 1966, pl. 54, section 14) showing stratigraphic positions of samples referred to in this report and occurrences of dinocyst and pollen taxa in these samples. Also shown are the lowest palynomorph samples from the Sentinel Hill Member of the Schrader Bluff Formation along the Colville River that were studied by Frederiksen and McIntyre (2000). Only the upper part of the Rogers Creek Member is exposed in this area. DP, studied for both dinocysts and pollen; LP, studied for both dinocysts and pollen, but as regards dinocysts, scanned only for occurrences of *Laciniadinium biconiculum*; P, studied for pollen only. Numbers following dinocyst species names indicate: (1) known only from the Campanian; (2) known only from Campanian and older rocks; (3) long-ranging species. Arrows indicate taxa known to range higher than the lower part of the Sentinel Hill Member along the Colville River (Frederiksen and McIntyre, 2000).

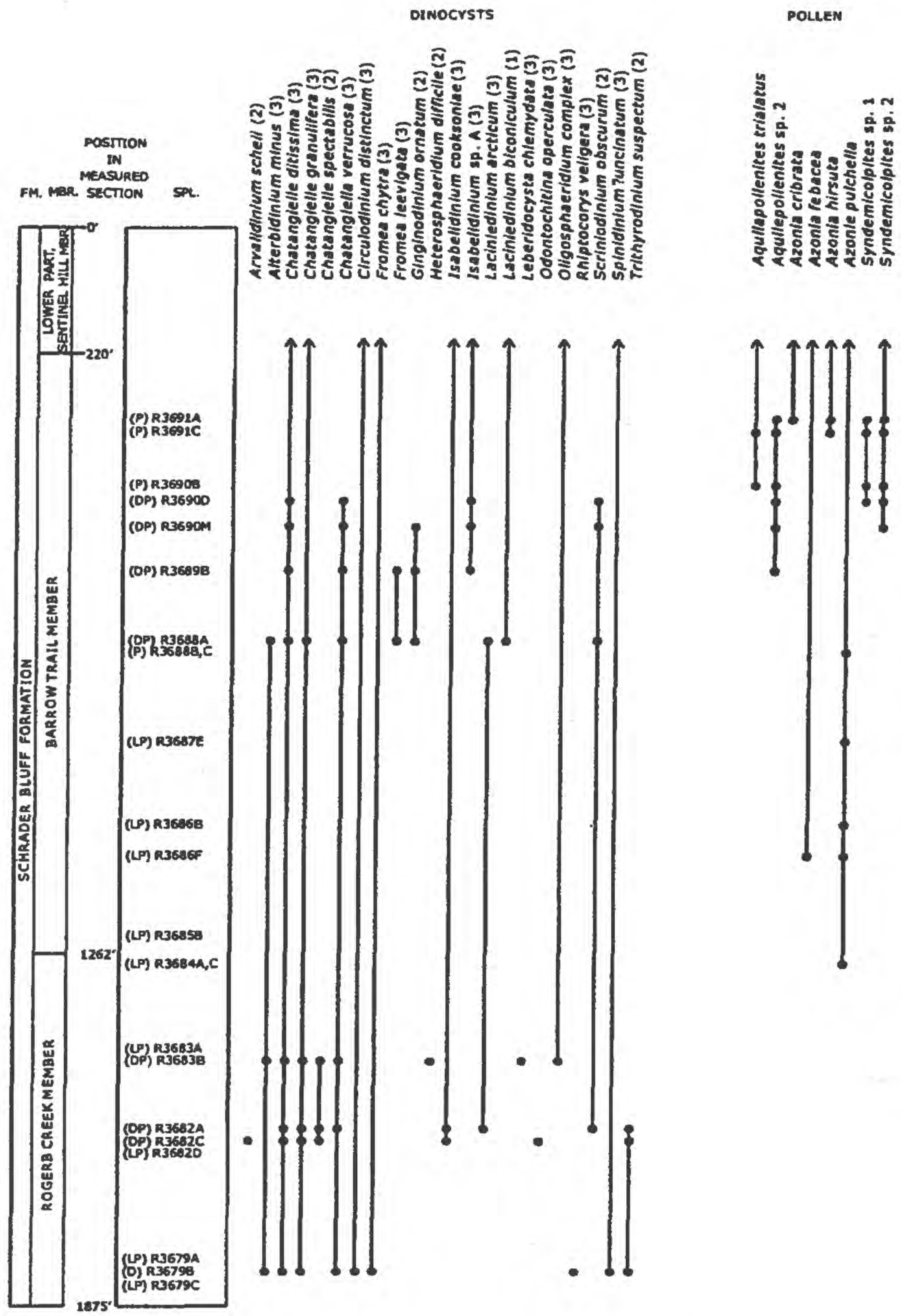

Figure 6. Measured section along the Chandler River (fig. 4; Detterman and others, 1963) showing stratigraphic positions of samples referred to in this report and occurrences of dinocyst and pollen taxa in these samples. Also shown is the lower part of the Sentinel Hill Member of the Schrader Bluff Formation, but no palynomorph samples were available from this unit along the Chandler River. D, studied for dinocysts only; DP, studied for both dinocysts and pollen; LP, studied for both dinocysts and pollen, but as regards dinocysts, scanned only for occurrences of *Laciniadinium biconiculum*; P, studied for pollen only. Numbers following dinocyst species names indicate: (1) known only from the Campanian; (2) known only from Campanian and older rocks; (3) long-ranging species. Arrows indicate taxa known to range higher than the lower part of the Sentinel Hill Member along the Colville River (Frederiksen and McIntyre, 2000).

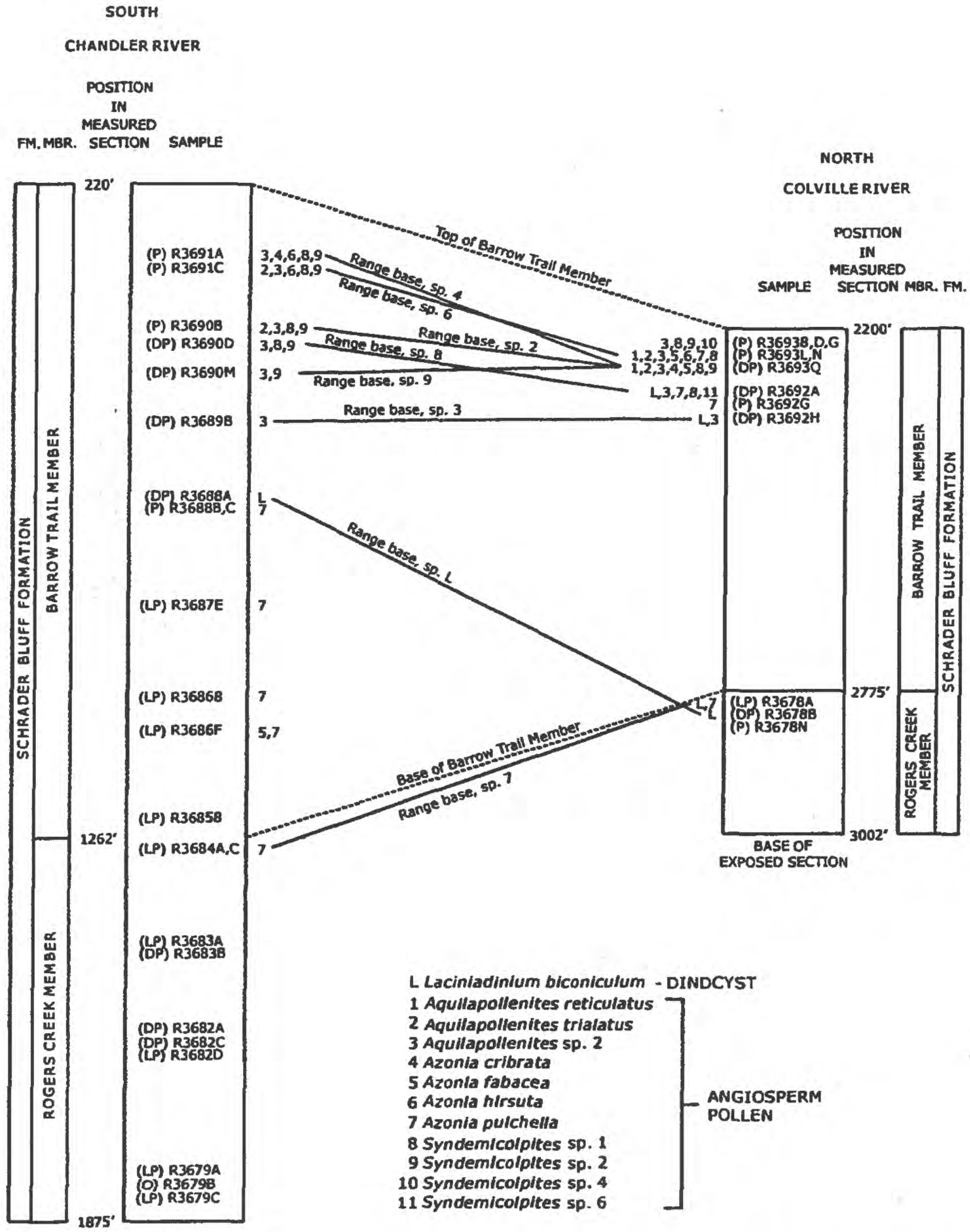

Figure 7. Comparison of angiosperm pollen species occurrences, and the occurrences of the Campanian dinocyst species *Laciniadinium biconiculum*, in the Rogers Creek and Barrow Trail Members of the Schrader Bluff Formation along the Chandler and Colville Rivers, emphasizing the lowermost occurrences of species common to the two sections. The horizontal datum for the two sections is the middle of the Barrow Trail Member. In the Sample columns, D indicates that the sample was scanned for dinocysts only; DP, scanned for both dinocysts and pollen; LP, studied for both dinocysts and pollen, but as regards dinocysts, scanned only for occurrences of *Laciniadinium biconiculum*; P, scanned for pollen only.

which intertongue with each other along the Colville River and form the mid(?)-Campanian to upper Maastrichtian part of the Colville Group. Taking dinocysts and pollen together, we now have detailed palynological occurrence data of one sort or the other from the base of the Rogers Creek Member (probably Coniacian or Santonian) to near the top of the Maastrichtian (near the top of the Prince Creek Formation) in the northeastern part of the NPRA and along the Chandler River (fig. 1). Detailed pollen occurrence data from the uppermost part of the Maastrichtian and the lowermost Paleocene are available from the Kuparuk River oil field (fig. 1, locality 5; Frederiksen and others, 1998).

Stratigraphy

Strata sampled for the present study belong to the Upper Cretaceous Colville Group, which includes the Seabee, Schrader Bluff, and Prince Creek Formations (Brosgé and Whittington, 1966). The formations and their subunits are shown in figure 2; they represent part of the Brookian sequence that prograded from the Brooks Range in a northeasterly direction during much of Mesozoic and Cenozoic time (Bird and Molenaar, 1992). These Brookian units consist of northeastward-thinning nonmarine and sandy marine wedges alternating with southwestward-thinning marine shaly wedges. The nonmarine and sandy marine wedges originated from relatively brief pulses of uplift in the southwest (each lasting less than 5 m.y. according to Decker and others, 1996) and (or) from sea-level fall in the northeast. The marine shaly wedges originated from sea-level rise in the northeast and (or) from downward tectonic flexure of the depositional basin responding to the uplifts of the Brooks Range (Cole and others, 1997).

The global sea-level chart of Haq and others (1988) shows five short-term eustatic sea-level rises and an equal number of sea-level falls during the 12 m.y. span of the Campanian; however, the rises and falls are each thought to have amounted to only about 40-220 ft. Thus, eustatic changes during the Campanian apparently did not have a great influence on the onlap and offlap events displayed in figure 2 as compared with the influence of the short-term uplift/thrusting events in the Brooks Range and the tectonic subsidence episodes in the Colville basin.

Cole and others (1997, p. 20,687) noted that the Late Cretaceous "southern-sourced units are strongly time transgressive, oldest in the southwest and youngest in the northeast." It is difficult to obtain good enough time resolution based on paleontological data to determine the amount of time transgression of the lower and upper surfaces of the relatively small stratigraphic units shown in figure 2, but we do discuss this question in this report.

The Seabee Formation (fig. 2) is mainly or entirely of Turonian age (Jones and Gryc, 1960; Tappan, 1960; Cobban and Gryc, 1961; Lanphere and Tailleur, 1983) and has not been studied for this report. The Schrader Bluff and Prince Creek Formations overlie the Seabee. The mainly marine Schrader Bluff and the mainly nonmarine Prince Creek intertongue with each other in the study area (fig. 2) and consist of shale, sandstone, and bentonitic and tuffaceous strata; the Barrow Trail Member of the Schrader Bluff Formation, and especially the Prince Creek Formation, also include coal beds.

Schrader Bluff strata studied for this report are assigned to the Rogers Creek and Barrow Trail Members. Along the Chandler River, the shaly Rogers Creek Member is 613 ft thick

(Detterman and others, 1963; fig. 5); it thickens northward (fig. 2) to 700-900 ft in the area of the Colville River (Brosgé and Whittington, 1966). Conversely, the sandy Barrow Trail Member along the Chandler River is 1042 ft thick, but it thins northward to 575-800 ft thick in the area of the Colville River. Along and near the Colville River, strata extending from the Barrow Trail-Sentinel Hill contact to the top of the Cretaceous are estimated to be 3800 ft thick (Frederiksen and McIntyre, 2000).

Sample Localities and Palynomorph Occurrences

The palynomorph biostratigraphy in this study is based on 35 samples from the Rogers Creek and Barrow Trail Members along the Chandler and Colville Rivers (figs. 3-7). These samples were collected in 1984 by H. S. Sonneman of Exxon Company U.S.A. Samples of the Rogers Creek and Barrow Trail along the Colville River are from the north flank of the Umiat Anticline (whose crest is just to the south and west of the map area of fig. 3) and on the south flank of the Kutchik Syncline. Samples of the Rogers Creek and Barrow Trail along the Chandler River are from the north flank of the Fossil Creek Anticline (fig. 4).

Study of the palynology of the Rogers Creek and Barrow Trail Members in this report concentrates on three important questions, (1) whether the stratigraphic location of the Santonian-Campanian boundary can be determined within this section, (2) whether pollen occurrence data can be used to make correlations between the Rogers Creek-Barrow Trail sections along the Chandler and Colville Rivers, and (3) whether palynological data contribute to an understanding of the amount of time transgression of the lower and upper surfaces of the units shown in figure 2.

Dinocyst Data and Interpretations

In the Chandler River section (fig. 6), dinocysts are distinctly less abundant in the lower half of the Barrow Trail Member than in the upper half, which is why no samples from this part of the section were sent to McIntyre for dinocyst analysis. This appears to be a paleoecological effect; in 30 Barrow Trail samples collected for calcareous marine fossils north of the Colville River, it was found that microfossils (mainly foraminifers) were distinctly more common in the upper half of the member, and megafossils were most common in the middle part of the member (Brosgé and Whittington, 1966).

Among the dinocyst species whose occurrences are shown in figures 5-7, chronostratigraphically the key species is *Laciniadinium biconiculum*, which in Arctic North America is known only from the Campanian (Brideaux and Myhr, 1976; Ioannides and McIntyre, 1980; Lentin and Williams, 1980; Bujak and Davies, 1983; McIntyre, 1985). This species has its observed range base in the middle of the Barrow Trail Member in the Chandler River section but in the uppermost part of the underlying Rogers Creek Member in the Colville River section. However, within the observed range of the species in the two sections, it was found in only five of nine samples examined for dinocysts (fig. 7); thus, the resolution of the range data for *L. biconiculum* is not particularly good. However, the lack of this species in all nine samples below the uppermost part of the Rogers Creek Member is probably reasonably good evidence that *L.*

biconiculum did not exist in the region prior to late Rogers Creek time. Whether *L. biconiculum* ranges completely to the base of the Campanian in the North American Arctic is unknown. Therefore, the main importance of the occurrence data for *Laciniadinium biconiculum* is that they demonstrate that the lower part of the Schrader Bluff Formation is Campanian in age at least as far downsection as the uppermost part of the Rogers Creek Member at least along the Colville River. Whether the middle and lower parts of the Rogers Creek are still Campanian or instead are Santonian or even in part Coniacian remains to be determined.

Pollen Data and Interpretations

The effort to use angiosperm pollen to correlate between the Chandler and Colville River sections and to place the Santonian-Campanian boundary in these sections depends on lowest occurrences of pollen species in the important *Aquilapollenites* and *Syndemicolpites* groups and in the genus *Azonia*, which includes the oldest taxa of the important Oculata pollen group. Figure 8 shows data concerning these taxa as reported in the literature and in this study. A problem with comparing the oldest occurrences of these taxa between the Chandler and Colville River sections is that no samples were available from the Barrow Trail Member below its upper part along the Colville River (fig. 7). The lack of samples from the Rogers Creek Member below its upper part along the Colville River is not considered to be very important because no useful palynomorph species appear to be present within the lower and middle parts of the Rogers Creek in the Chandler River section.

Sixty-seven angiosperm pollen species were found within the upper Maastrichtian of the North Slope (uppermost middle part of the Kogosukruk Tongue to the top of the Kogosukruk Tongue, Prince Creek Formation; Frederiksen and McIntyre, 2000). However, the number of species decreases downsection, and at the base of the Sentinel Hill Member, mid(?)-Campanian in age, only 12 species were found (fig. 5; aside from morphologically simple forms of no apparent biostratigraphic use), and below the upper part of the underlying Barrow Trail Member there is a near-lack of biostratigraphically useful angiosperm pollen species (figs. 5, 6). No doubt this is why Mickey and Haga (1988), in their summary of biostratigraphic units within the Devonian-Quaternary sequence in the NPRA, did not show any "spore-pollen zonules" from the lower part of the Schrader Bluff Formation down to the base of the Upper Cretaceous.

The *Aquilapollenites* group (fig. 8) is thought to have originated in western Siberia, from where it migrated to eastern Siberia and Japan and thence to Alaska (Stanley, 1970). The lowest occurrence of the *Aquilapollenites* group in Arctic Canada is reported to be in the upper Santonian or lower Campanian (fig. 8; Núñez-Betelu and Hills, 2001). On the North Slope of Alaska, the lowest occurrence of this group (fig. 7, species 1-3) is in the upper part of the Barrow Trail Member. The occurrence of the Campanian dinocyst marker species *Laciniadinium biconiculum* lower in the section, in the Rogers Creek Member (fig. 7, species L), indicates that on the North Slope of Alaska, and presumably also in Arctic Canada, the oldest known occurrences of the *Aquilapollenites* group are early (but not earliest) or middle Campanian and not late Santonian in age (fig. 8).

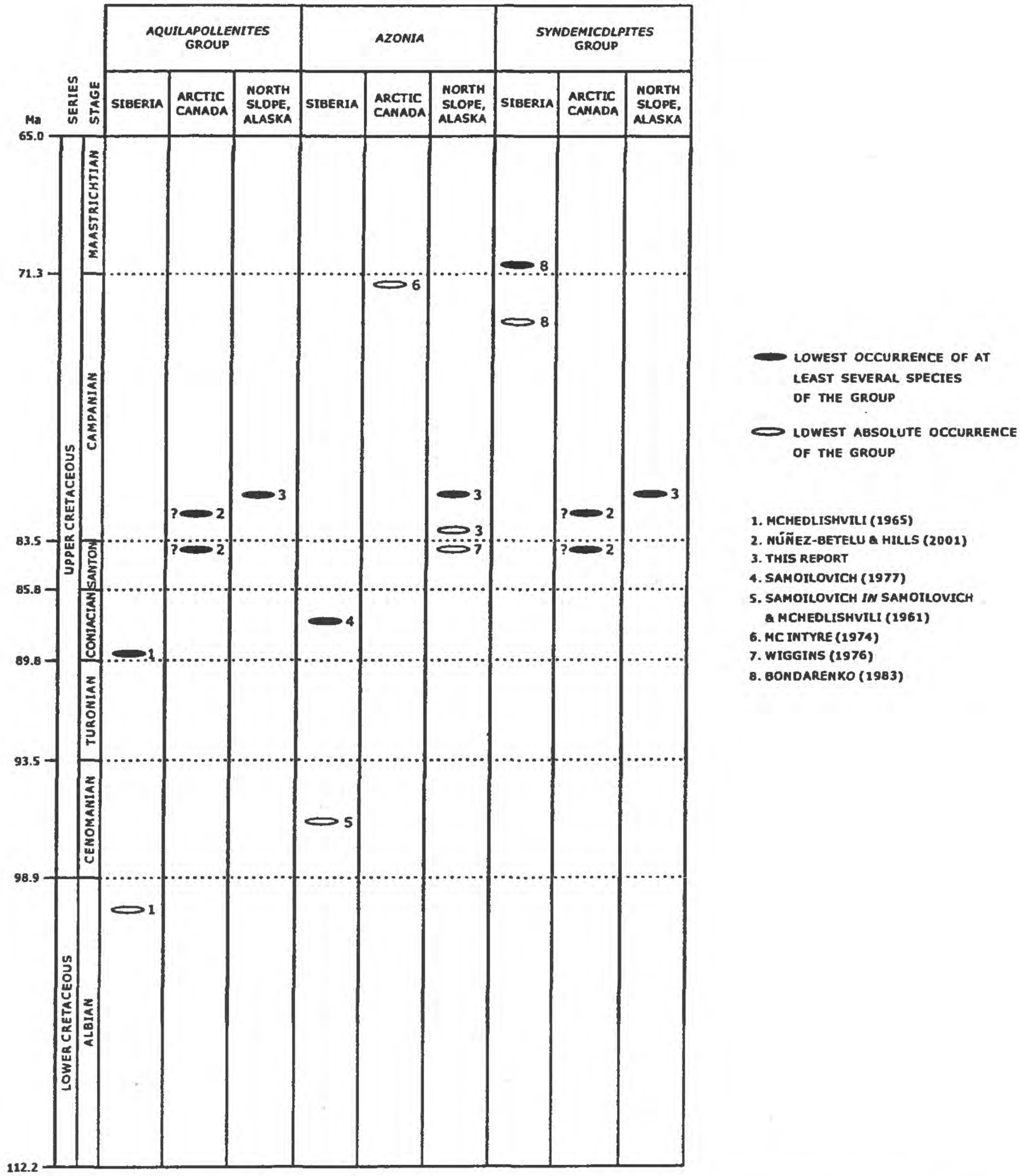

Figure 8. Lowest recorded occurrences of three important genera or generic groups of angiosperm pollen in the Cretaceous of Siberia, Arctic Canada, and the North Slope of Alaska. Little has been published on occurrences of species of the *Aquilapollenites* and *Syndemicolpites* groups on the North Slope, particularly in lower Campanian and older strata. Radiometric ages of stage boundaries are from Gradstein and others (1995).

Like the *Aquilapollenites* group, the genus *Azonia* no doubt originated in Siberia (apparently in the Cenomanian) and later migrated to North America (fig. 8). The oldest published occurrence of *Azonia* in Arctic Canada is from the late Campanian (McIntyre, 1974), but it would seem likely that *Azonia*, like the *Aquilapollenites* group, actually migrated to North America in the late Santonian or early Campanian. On the North Slope of Alaska, the oldest occurrence of *Azonia* was reported to be in the upper Santonian (fig. 8; Wiggins, 1976), but Wiggins did not describe the basis of this age determination. In the present study, the lowest observed occurrence of *Azonia* (fig. 7, species 7) is in the uppermost part of the Rogers Creek Member. It appears at first glance that the range base of *Azonia pulchella* has the same stratigraphic position in both the Chandler and Colville River sections, and that this range base event may be isochronous in the two sections. However, *Azonia pulchella* occurs only sporadically (in 9 of 20 samples within its observed range in the diagram), angiosperm pollen is very rare in the Rogers Creek Member, and no samples were available below the uppermost part of the Rogers Creek Member on the Colville River. Therefore, we do not regard the diagram as presenting good evidence that this range base event is isochronous in the two sections. The observed range base of the genus *Azonia* approximately coincides with the lowest known occurrence of the dinocyst species *Laciniadinium biconiculum* and therefore appears to indicate that in Arctic North America, the genus *Azonia* has its range base in the lowermost Campanian rather than in the upper Santonian as stated by Wiggins (1976). However, for the reasons stated above, we can only state that the minimum age of the range base of *Azonia* is early Campanian; the true range base could be Santonian.

In contrast to the *Aquilapollenites* group and *Azonia*, the *Syndemicolpites* pollen group appears to have originated in Arctic North America and then to have migrated westward to Siberia (fig. 8). Like the *Aquilapollenites* group, the oldest record of the *Syndemicolpites* group in Arctic Canada is in the late Santonian or early Campanian (Núñez-Betelu and Hills, 2001). On the North Slope of Alaska, the four oldest known species of *Syndemicolpites* (fig. 7, species 8-11) have their range bases in the upper part of the Barrow Trail Member, early (but not earliest) or middle Campanian in age.

Detterman and others (1963, p. 288) stated that "An over-all eastward gradation into shale and an eastward thinning of the Barrow Trail member are apparent from the columnar sections.... The upper contact [of the Barrow Trail with the overlying Sentinel Hill Member] appears to become lower [from the Barrow Trail's thickest occurrence, along the Chandler River] in an easterly direction; thus, the thinning is largely in the upper part of the member." Thus the upper surface of the Barrow Trail appears, on stratigraphic evidence, to be rather distinctly diachronous, becoming older eastward as would be expected if the Sentinel Hill sea advanced slowly from the northeast. However, it also seems possible that the supply of sediment from the Brooks Range decreased in late Barrow Trail time but sediments, although thinning toward the northeast, continued to be deposited over the whole surface of the Barrow Trail wedge; in this scenario, the upper surface of the Barrow Trail could be fairly isochronous. Pollen correlations (fig. 7) indicate, based on the lowest occurrences of half a dozen species, that the upper part of the Barrow Trail Member appears to be approximately time-equivalent in the Chandler and Colville River sections. We therefore tentatively conclude that the top of the Barrow Trail

Member is not demonstrably diachronous at least in a north-south direction. This may mean that the base of the overlying Sentinel Hill Member is also only slightly diachronous, representing a rapid marine onlap from the north or northeast, caused by rapid sea level rise and (or) rapid depression of the North Slope Basin at the beginning of Sentinel Hill time. In figure 2, the bases of all the shaly marine units are shown as being only slightly diachronous, although evidence seems to exist in this report only for the nature of the Barrow Trail-Sentinel Hill Member contact. As stated previously, palynological correlation of the Rogers Creek-Barrow Trail Member boundary is hampered by the rarity of angiosperm pollen in this part of the section and by the lack of samples from below the uppermost part of the Rogers Creek along the Colville River.

Integrated Chronostratigraphy

Figure 9 summarizes previously proposed age assignments for the Rogers Creek and Barrow Trail Members of the Schrader Bluff Formation and the assignments proposed here on the basis of dinocyst biostratigraphy. The data point in column 3 of figure 9 refers to an ammonite dated as "Santonian(?)" by the Exxon team, which was collected 175 ft below sample R3687E of this report (fig. 7). The Barrow Trail Member can be assigned to the early Campanian. The uppermost part of the Rogers Creek Member is also early Campanian, at least on the Colville River. The remainder of the Rogers Creek Member could be Coniacian, Santonian, or Campanian.

PALYNOLOGY OF SOME MAASTRICHTIAN AND PALEOCENE (TO EOCENE?) OUTCROP SAMPLES FROM BETWEEN 145^{O} AND 148^{O} WEST LONGITUDE ON THE NORTH SLOPE

Introduction

This section of the report concerns the palynological dating of 16 outcrop samples collected in 1997 by C. J. Schenk and D. W. Houseknecht (Schenk and others, 1999). Certain discrepancies exist between the latitudes and longitudes that were recorded by Houseknecht (and cited in this report) and those that were provided by Schenk and others (1999) for the sample localities, because different members of the field party recorded slightly different Global Positioning System (GPS) locations depending on where they were working in the outcrop area.

Kermits Island #2 section

Two samples were examined from the Canning Formation in the Kermits Island #2 section, lat 69.58045° N, long 146.30683° W (Schenk and others, 1999, locality 97-18; fig. 1, locality 18), collected August 5, 1997:

Field no. DH97-16, palynology sample R5375A; mudstone, medium dark brownish-gray, just below a discontinuity (sequence boundary?). DH97-16 contained only rare palynomorphs

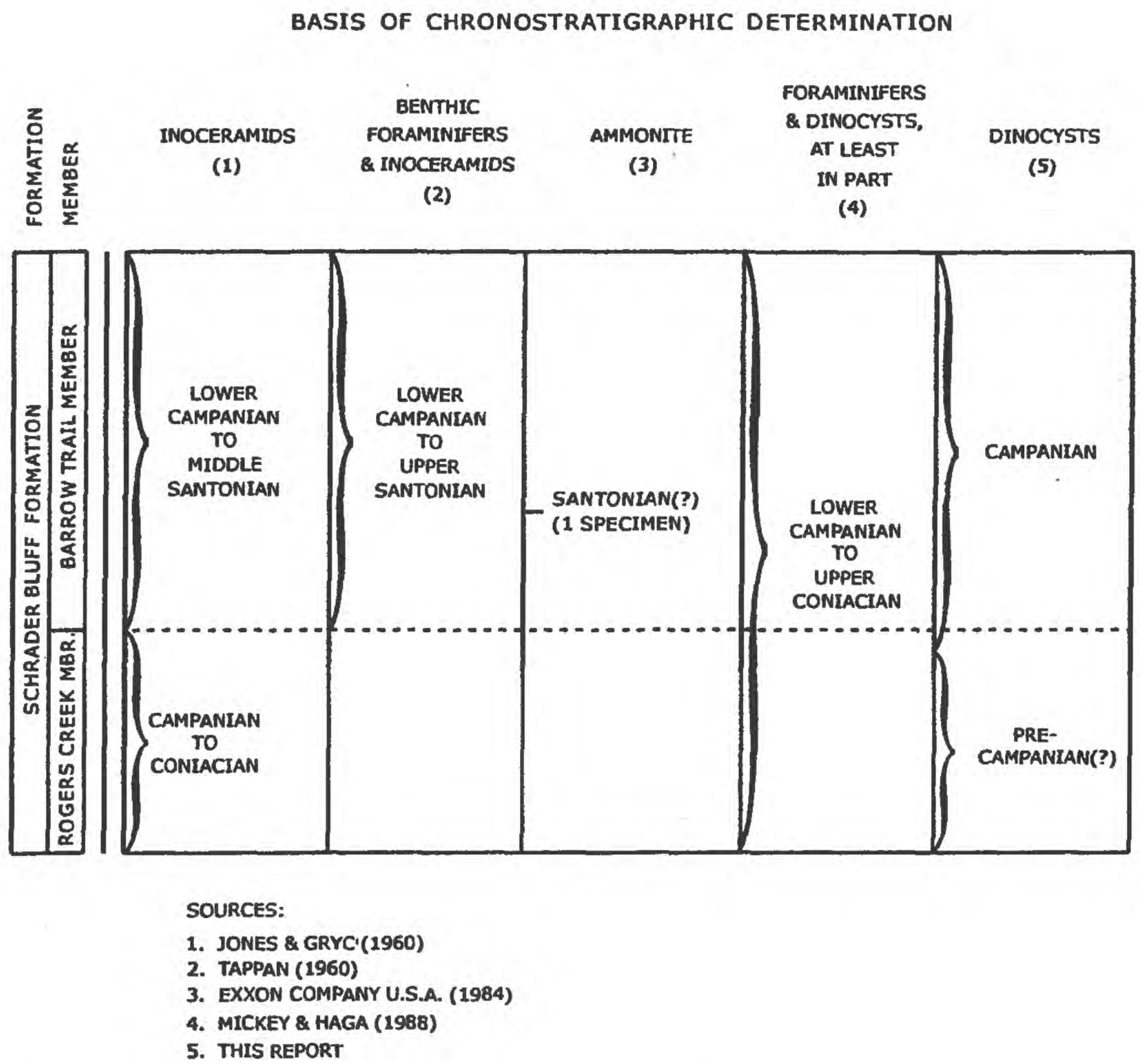

Figure 9. Chronostratigraphic assignments for Coniacian(?) to lower Campanian strata along the Chandler and Colville Rivers, based on several kinds of fossils. In column 5, it is assumed that the observed range base of *Laciniadinium biconiculum* is at the base of the Campanian Stage, but although this species is known from the lower Campanian, in fact there does not seem to be definitive evidence that this species ranges all the way to the base of that stage.

of any kind, including no useful angiosperms. However, several dinocysts were found, reasonably well preserved and indicating marine or marginal-marine conditions (unless they were reworked specimens) but nondescript for purposes of age determination.

Field no. DH97-17, palynology sample R5375B; mudstone, medium dark brownish-gray, weathered, just above the discontinuity (sequence boundary?). DH97-17 contained mostly a large quantity of presumably reworked dark-brown plant material, but no useful palynomorphs have been seen.

Navy section

Four samples were examined from the Sagavanirktok Formation in the Navy section:

Field no. DH97-26, palynology sample R5370A, lat 69.65332° N, long 146.23958° W (Schenk and others, 1999, locality 97-23; fig. 1, locality 17); from unit B, collected August 6, 1997; mudstone, coaly.

Field no. DH97-33A, palynology sample R5370B, lat 69.65332° N, long 146.23958° W; collected August 7, 1997 (Schenk and others, 1999, locality 97-24; fig. 1, locality 17); mudstone, medium brownish-gray, carbonaceous, in second parasequence above big hummocky stratification.

Field no. DH97-33B, palynology sample R5370C, lat 69.65332° N, long 146.23958° W (Schenk and others, 1999, locality 97-24; fig. 1, locality 17); collected August 7, 1997; mudstone, medium dark brownish-gray, carbonaceous, in second parasequence above big hummocky stratification.

Field no. DH97-81, palynology sample R5370D, lat 69.66234° N, long 146.23854° W (Schenk and others, 1999, locality 97-38; fig. 1, locality 16); collected August 10, 1997, from big sand unit at top of section (fluvial?); coal.

The following taxa were found (numbers = numbers of specimens seen; P = probable; Q = possible):

	97-26	97-33A	97-33B	97-81
Alnus	P	1		
Aquilapollenites sp. aff. *A. fusiformis*		1		
Aquilapollenites reticulatus	2			
Aquilapollenites unicus	Q			
Aquilapollenites sp.			1	
Caryapollenites imparalis		1		
Momipites wyomingensis				2
Paraalnipollenites alterniporus type H				3
Triatriopollenites sp.				1
Triporopollenites mullensis	5-6	1		13
Ulmipollenites tricostatus	1			
Ulmipollenites krempii or U. tricostatus			1	
Dinocysts		P		1
Acritarchs	1	1		

Angiosperm pollen was rare in all these samples; dinocysts were seen in one or two samples; and one acritarch was seen in each of two samples (possibly representing marine organisms although the biological affinity of acritarchs is unknown). The specimens of *Aquilapollenites* are Cretaceous, mainly or entirely Maastrichtian, but since they are less frequent than porate specimens (which make up all the taxa listed except the *Aquilapollenites* ones, and even though most of the porate taxa do range down into the Maastrichtian), it is reasonable to believe that all these samples are Paleocene in age and that the specimens of *Aquilapollenites* are reworked. It is interesting that in DH97-81, a coal sample, no *Aquilapollenites* was observed, in contrast with the detrital samples; coal samples do not normally contain reworked specimens. The range bases of *Caryapollenites imparalis* and *Momipites wyomingensis* are in the middle Paleocene; thus, the ages at least of samples DH97-33A and DH97-81 are middle Paleocene or younger.

Kavik syncline section

Field no. DH97-43, palynology sample R5371, lat 69.60704° N, long 146.77675° W (Schenk and others, 1999, locality 97-26; fig. 1, locality 12); collected August 8, 1997, Kavik syncline, Sagavanirktok Formation, coal just below hummocky stratification at the top of the section. This sample was nearly barren of palynomorphs. One specimen each was seen of *Pterocarya* and *Triatriopollenites.* The known range base of *Pterocarya* is not clearly established on the North Slope of Alaska or Arctic Canada: it is not known from the Cretaceous, it was not seen in the many lowermost Paleocene core samples from the Arco Ugnu SWPT-1 well in the Kuparuk River oil field (Frederiksen and others, 1998), and it is only questionably known from other lower Paleocene samples. It is definitely present in the upper Paleocene. Therefore, from the very small amount of information available from this sample, it appears to be middle Paleocene or younger.

East Katakturuk #1 and #2 sections

Two samples were examined from the Canning Formation(?) in the East Katakturuk #1 and #2 sections, lat 69.75433° N, long 145.32400° W; collected August 10, 1997. These sections were collectively termed the Katakturuk confluence section in Houseknecht's field notes.

Field no. DH97-69 (Schenk and others, 1999, locality 97-33; fig. 1, locality 21), palynology sample R5376A, just below lowest sand; mudstone, medium brown, weathered. Sample DH97-69 contained (a) mostly a large quantity of presumably reworked dark-brown plant material, possibly including some palynomorphs, but preservation was very poor, in addition to (b) sparse light-colored plant material—presumably indigenous—that included rare palynomorphs: one specimen each of *Aquilapollenites* sp. cf. *A. sentus* (late Maastrichtian) and *Aquilapollenites* sp. (Late Cretaceous), and one or two specimens of *Triporopollenites mullensis* (Maastrichtian to Eocene). The specimens of *Aquilapollenites* could be reworked. Therefore, the age is late Maastrichtian or younger.

Field no. DH97-72 (Schenk and others, 1999, locality 97-34; fig. 1, locality 21), palynology sample R5376B; sandstone, fine- to medium-grained, with small coal clasts. Sample DH97-72 contained well preserved but rare pollen including *Aquilapollenites reticulatus*, *Caryapollenites imparalis*, and *Triporopollenites mullensis*. The range base of *Caryapollenites imparalis* is in the middle Paleocene, so the age is middle Paleocene or younger, and the *Aquilapollenites* (Maastrichtian) is reworked.

East Fork of the Tamayariak River

Two samples were examined from the Canning Formation, East Fork of the Tamayariak River, lat 69.65912° N, long 145.65104° W (Schenk and others, 1999, locality 97-37; fig. 1, locality 20); collected August 10, 1997:

Field no. DH97-76, palynology sample R5374A, near base of section at creek level; mudstone, medium dark gray.
Field no. DH97-80, palynology sample R5374B, top of section, down creek from bluff; mudstone, medium dark gray.

Preservation in both samples was fair to poor. The following taxa were found (X = present; P = probable):

	97-76	97-80
Alnus	P	
Aquilapollenites reticulatus	X	
Aquilapollenites sp. aff. *A. reticulatus*	X	X
Aquilapollenites unicus	X	X
Aquilapollenites sp.	X	
Mancicorpus pseudosenonicus	X	
Triporopollenites mullensis	X	X
Campanian pollen	P	
Dinocysts	X	

Pollen grains of taxa restricted to the Maastrichtian were more abundant than those of *Triporopollenites mullensis* (Maastrichtian to Eocene). Therefore, these are probably late Maastrichtian pollen assemblages unless the Cretaceous pollen grains are reworked, in which case the assemblage would be early Paleocene in age because late Paleocene species are lacking. The presence of dinocysts indicates a marine to marginal-marine environment of deposition (unless they are reworked).

Kadleroshilik River #2 section

Field no. DH97-98, palynology sample R5369, lat 69.47650° N, long 147.74033° W (Schenk and others, 1999, locality 97-42; fig. 1, locality 10); Kadleroshilik River #2 section (termed Seismic River Stop #3 in Houseknecht's field notes), Sagavanirktok Formation, collected August 11, 1997; coal. This sample contained a very low-diversity angiosperm pollen assemblage consisting mostly of *Triporopollenites mullensis* and one specimen each of *Triatriopollenites* and *Pterocarya*. Most low-diversity samples that contain mainly *T. mullensis* are lower Paleocene, although it is also true that coals typically contain considerably lower-diversity assemblages than do adjacent detrital rock samples. As stated previously, the range base of *Pterocarya* is probably middle or upper Paleocene, which establishes the maximum age of the sample.

Hue Creek

Two samples were examined from the Canning Formation along Hue Creek (Schenk and others, 1999, locality 97-44; fig. 1, locality 19), collected August 12, 1997. Both samples contained sparse palynomorphs that are very poorly preserved.

Field no. DH97-103, palynology sample R5373A, lat 69.56118° N, long 145.82083° W; lower Canning Formation 100-200 ft above the Hue Shale; mudstone, medium brownish-gray, weathered. No definite angiosperm pollen was seen; one dinocyst was found, a simple spined chorate type useless for age determination but presumably indicating marine or marginal marine conditions, unless the specimen is reworked.

Field no. DH97-104, palynology sample R5373B, lat 69.56024° N, long 145.82750° W; base of Canning Formation just above the Hue Shale; mudstone, medium brownish-gray, weathered. Two specimens of *Triporopollenites mullensis* (Maastrichtian to Eocene) and one specimen of *Wodehouseia* sp., probably a late Maastrichtian form, but possibly reworked, were found. Thus, the sample is probably late Maastrichtian or Paleocene.

Kavik West section

Two samples were examined from the Sagavanirktok Formation of the Kavik West section (termed Over-the-Hill section in field notes of Houseknecht), lat 69.64394° N, long 147.04120° W (Schenk and others, 1999, locality 97-45; fig. 1, locality 11); collected August 12, 1997:

Field no. DH97-105, palynology sample R5372A (creek west of Kavik); shale, coaly.

Field no. DH97-106, palynology sample R5372B (west of Kavik); thick coal bed.

The following taxa were found:

	97-105	97-106
Caryapollenites imparalis	X	X
Caryapollenites wodehousei		X
Momipites wyomingensis	X	X
Paraalnipollenites alterniporus type H	X	X
Striate tricolpate pollen grain	X	
Triatriopollenites sp.		X
Triporopollenites mullensis	X	X
Ulmipollenites tricostatus	X	
Ulmipollenites undulosus	X	X

Sample DH97-105 contained especially abundant spores and pollen grains. In the Canadian Arctic, the range bases of *Caryapollenites imparalis* and *Momipites wyomingensis* are in the middle Paleocene. These are typical middle Paleocene to lower upper Paleocene assemblages; they lack the many typical uppermost Paleocene and Eocene species.

REVIEW OF CONSULTANT AND OIL COMPANY PALYNOLOGICAL REPORTS ON UPPER CRETACEOUS TO EOCENE STRATA IN EIGHT NORTH SLOPE WELLS

Introduction

Previously (Frederiksen and others, 1998), consultants' palynological reports were reviewed that concerned the Arco West Sak River #23 (= Kuparuk River Unit 3A-9) well and the Mobil West Staines State #1 (= West Staines State 18-9-23) well on the North Slope, and additional data were provided on part of the section in the West Staines State #1. The eight consultants' and oil company palynologists' reports that are reviewed here are:

Arco Itkillik River #1
Sohio Prudhoe Bay Unit R-1
Placid et al. State #1
Arco Nora Federal #1
Arco Susie Unit #1
Exxon Alaska State A-1
Mobil West Staines State #2
Exxon Canning River B-1

These wells range in location from near the Colville River to near the Canning River (fig. 1). All of the samples examined by the palynologists were from cuttings, not cores.

Arco Itkillik River #1

Location: Section 10, T8N, R5E; lat 70.06593° N, long 150.85309° W (fig. 1, locality 4).

Reference: Haga (1975). A palynological occurrence chart for this well was not available; therefore, the following remarks are based only on the text of the report.

The interval 80-250 ft was considered to be "Tertiary" and had a very low pollen diversity and pollen taxa that were useless for age determinations.

The sample from 250-340 ft contained a mixture of Eocene and Late Cretaceous species; therefore, it was considered to represent either an interval crossing the Cretaceous-Tertiary boundary or to be entirely Tertiary, containing reworked Cretaceous pollen. No definite Paleocene rocks were found; *Paraalnipollenites confusus* (=*P. alterniporus* of some reports, the principal pollen marker for the Paleocene) was not observed. An interesting aspect of this sample assemblage is that it includes *Aquilapollenites conatus*, which is now known to be restricted to the upper half of the Maastrichtian (species 23 of Frederiksen and McIntyre, 2000, fig. 5).

The interval from 340-790 ft was considered to be Maastrichtian and contains several species now known to be upper Maastrichtian markers.

The interval from 790-2,140 ft was considered to be Campanian because it contained *Aquilapollenites trialatus*. Specimens of *Aquilapollenites magnus* (=*A. unicus* of some reports) in the sample, of late Maastrichtian age, were considered to represent cavings.

Sohio Prudhoe Bay Unit R-1

Location: Sec. 32, T12N, R13E; lat 70.34532° N, long 148.90828° W (fig. 1, locality 6).

Reference: Mickey and Haga (1984a). A palynological occurrence chart was included.

The top of the Eocene was picked at 2,280 ft on the basis of both pollen (*Tiliaepollenites*) and dinocyst information. The top of the Paleocene was picked at 4,140 ft based on the uppermost occurrence of *Paraalnipollenites confusus* as is customary on the North Slope, and this species is rather consistently present within its range in this well. In recent years, as summarized by Norris (1997), *Paraalnipollenites confusus* (=*P. alterniporus*) has been found to have its actual range top in the middle(?) part of the lower Eocene, so that the top of the Paleocene cannot be accurately picked using this species, although the uppermost *consistent* occurrence of the species may be an approximate marker for the top of the Paleocene. Dinocysts were "essentially absent" in the Paleocene rocks, and foraminifers were present only in the lowermost part of the Paleocene interval. "Betulaceae" pollen was recorded from most Paleocene samples but was not differentiated into species; also, *Caryapollenites* was found in two samples but was not identified to species level. Thus, it is not possible to distinguish between upper and lower Paleocene based on the taxon identifications given. It is to be noted that a very detailed description and biostratigraphy of Paleocene species of *Momipites* (no doubt included in the report of Mickey and Haga within "Betulaceae") and *Caryapollenites* in the Western Interior (Wyoming) was given by Nichols and Ott in 1978, and this biostratigraphy at the species level has been heavily relied upon by Canadian palynologists to subdivide the Paleocene in the Arctic.

The top of the Campanian-Maastrichtian interval was picked at 5,850 ft on the absence of the mainly Paleocene species *P. confusus* and on the presence of Cretaceous dinoflagellates in some samples. The important Upper Cretaceous pollen genera *Wodehouseia* and *Aquilapollenites* were found in only a few samples from the Campanian-Maastrichtian interval, and specimens of these genera were very rare.

Placid et al. State #1

Location: Section 3, T10N, R13E; lat 60.90209° N, long 151.39293° W (fig. 1, locality 7).

References: Waanders and Haga (1979); Mickey and Haga (1984b). The 1979 report includes a palynological occurrence chart.

In the 1979 report, the interval of 3,640-5,700 ft was taken to be "Late Cretaceous to Paleocene (undifferentiated)" because there was practically no angiosperm pollen at all in this interval but rare Cretaceous dinoflagellates were present. The top of the Santonian-Campanian at 5,700 ft was picked at the occurrence tops of various dinoflagellates.

In the 1984 report, the interval from 3,580?-5,700 ft was taken to be "probable Paleocene" because of the almost complete absence of dinoflagellates in this interval.

Arco Nora Federal #1

Location: Sec. 5, T2N, R14E; lat 69.55206° N, long 148.75232° W (fig. 1, locality 9).

Reference: Mickey and Haga (1983a). A palynological occurrence chart was included.

The highest samples examined from the well by the consultants, including data from both foraminifers and palynomorphs, began at 2,720 ft and were Cretaceous in age. However, Molenaar and others (1987, fig. 7) show the uppermost part of this well section as being Paleocene in age. In the Maastrichtian samples from 2,720-5,960 ft, the palynology report lists the following "significant pollen" species: *Aquilapollenites magnus* (= *A. unicus*), *Orbiculapollis globosus*, and *Wodehouseia spinata*. Since then, these species have been found to be confined to the upper half of the Maastrichtian. By contrast, the Campanian was identified by the rarity or absence of the above species and by the presence of *Aquilapollenites trialatus*, which is mainly pre-Maastrichtian in age. It was also found that the Maastrichtian had few dinoflagellates, but these fossils were common and much more diverse in the Campanian.

Arco Susie Unit #1

Location: Sec. 22, T2N, R13E; lat 69.51873° N, long 148.92475° W (fig. 1, locality 8).

Reference: Guennel (1971). Only a genus-level palynological occurrence chart was included.

The individual ditch samples examined were hundreds of feet apart; thus, as Guennel noted, this report was based on "rather cursory" data. Conventional cores had been taken at 1,328-1,348 ft and at 2,608-2,635 ft (in addition to some lower in the hole), but no core samples were examined palynologically by Guennel.

Two samples, from 500 and 1,000 ft, were considered to be Eocene(?) and Eocene, respectively, based on an inferred warm-temperate climate; at 1,000 ft there were a number of typical Eocene angiosperm pollen taxa, namely *Myrica* (wax myrtle), *Nyssa* (black gum), *Carya* (hickory), *Ulmus* (elm), *Fagus* (beech), and *Juglans* (walnut). Two samples, from 1,500 and 1,750 ft, were considered to be Paleocene, based on gymnosperm pollen data; remarkably, no angiosperm pollen taxa were listed at all from these samples even though "spores" (in Guennel's usage meaning both spores and pollen grains) were abundant and preservation was good. Two samples, from 2,300 and 2,750 ft, were considered to be Maastrichtian, based on angiosperms such as *Wodehouseia spinata* and several species of *Aquilapollenites*; *W. spinata* is now known to be confined to the upper half of the Maastrichtian. No dinoflagellates, which would indicate a marine to marginal-marine environment, were found in the Maastrichtian to Eocene interval. This seems especially remarkable for the Eocene samples since in our (admittedly limited) experience, Eocene samples from the North Slope are usually marine.

Exxon Alaska State A-1

Location: Sec. 27, T10N, R24E; lat 70.18918° N, long 146.01185° W (fig. 1, locality 14).

Reference: Bujak Davies Group (1985). Instead of an occurrence chart, Bujak and Davies give a first occurrence (= range top) chart.

The top of the Paleocene at 12,300 ft was picked by the top of consistent *Paraalnipollenites confusus*. They say that "other palynological markers for this [*P. confusus*] zone were not observed." The Paleocene rests on metasedimentary rocks in this well.

Mobil West Staines State #2

Location: Section 25, T9N, R22E; lat 70.11053° N, long 146.41637° W (fig. 1, locality 13).

Reference: Mickey and Haga (1984c). A palynological occurrence chart was provided.

The Paleocene-Eocene boundary was picked on the basis of the "approximate lower limit of [an Eocene] dinoflagellate assemblage and the [range] top of *Paraalnipollenites confusus*." The latter species occurred in most samples assigned to the Paleocene and only in these rocks, which are nearly 4,000 ft thick in this well. "Betulaceae" pollen occurred in many samples throughout the Tertiary, but no useful information can be gained from the presence of this broad taxon because it was not subdivided to species level; similarly, *Caryapollenites* was fairly common in the Eocene and the upper half of the Paleocene, but useful information was lost because this genus was not broken down to species level.

Within the "Santonian-Maastrichtian?" interval, practically the only palynomorphs found were dinoflagellates; useful pollen taxa such as species of *Aquilapollenites* were very rare within this interval. *Aquilapollenites magnus* (= *A. unicus*), a marker for the upper half of the Maastrichtian, was found in a few Tertiary samples and in one sample in the upper part of the Santonian-Maastrichtian(?) interval, so that the latter interval presumably includes the upper part of the Maastrichtian. Molenaar and others (1987) considered the uppermost Cretaceous strata in this well to be "probably" Maastrichtian.

It is interesting to compare this described biostratigraphic section with that from the Mobil West Staines State #1 (= West Staines State 18-9-23) well only a few miles away. In the latter well (Bujak Davies Group, 1985; Frederiksen and others, 1998), the presence of upper Paleocene strata could be established based on the presence of *Insulapollenites rugulatus*, and a fair variety of Eocene (and upper Paleocene?) taxa were found in the "Paleocene" (that is, within the interval containing consistent *Paraalnipollenites confusus*). Neither *Insulapollenites rugulatus* nor most of the Eocene (and upper Paleocene?) taxa were reported by Haga in 1984 (Mickey and Haga, 1984c) from the thick Paleocene section in the Mobil West Staines State #2. It is to be noted that Rouse's excellent and well-illustrated summary paper on pollen taxa and their stratigraphic ranges in the lower Tertiary of the Canadian Arctic had already been published in 1977. Perhaps Haga's sample processing was not good enough to yield sufficient species for him to make a better analysis.

Exxon Canning River B-1

Location: Sec. 32, T4N, R34E; lat 69.66385° N, long 146.27528° W (fig. 1, locality 15).

Reference: Mickey and Haga (1983b). A palynological occurrence chart was provided.

The Paleocene was picked by the "fairly consistent" occurrence of *Paraalnipollenites confusus* in the interval. Reworked Late Cretaceous pollen was found in a fair number of samples from the Paleocene and post(?)-Paleocene strata.

The Campanian-Maastrichtian interval had very low-diversity pollen assemblages and was identified on the basis of dinoflagellates.

Table 1. List of dinocyst species mentioned in this report.

Alterbidinium minus (Alberti) Lentin & Williams
Arvalidinium scheii (Manum) Lentin & Vozzhennikova
Chatangiella ditissima (McIntyre) Lentin & Williams
Chatangiella granulifera (Manum) Lentin & Williams
Chatangiella spectabilis (Alberti) Lentin & Williams
Chatangiella verrucosa (Manum) Lentin & Williams
Circulodinium distinctum (Deflandre & Cookson) Jansonius
Fromea chytra (Drugg) Stover & Evitt
Fromea laevigata (Drugg) Stover & Evitt
Ginginodinium ornatum (Felix & Burbridge) Lentin & Williams
Heterosphaeridium difficile (Manum & Cookson) Ioannides
Isabelidinium acuminatum (Cookson & Eisenack) Stover & Evitt
Isabelidinium cooksoniae (Alberti) Lentin & Williams
Isabelidinium sp. A
Isabelidinium sp. B
Laciniadinium arcticum (Manum & Cookson) Lentin & Williams
Laciniadinium biconiculum McIntyre
Leberidocysta chlamydata (Cookson & Eisenack) Stover & Evitt
Odontochitina operculata (O. Wetzel) Deflandre & Cookson
Oligosphaeridium complex (White) Davey & Williams
Rhiptocorys veligera (Deflandre) Lejeune-Carpentier & Sarjeant
Scriniodinium obscurum Manum & Cookson
Spinidinium ?uncinatum May
Trithyrodinium suspectum (Manum & Cookson) Davey

Table 2. List of pollen species mentioned in this report.

Aquilapollenites conatus Norton 1965
Aquilapollenites sp. aff. *A. fusiliformis* B. D. Tschudy 1969
Aquilapollenites magnus (Mchedlishvili in Samoilovich & Mchedlishvili 1961) Frederiksen 1991
Aquilapollenites reticulatus (Mchedlishvili in Samoilovich & Mchedlishvili 1961) B. D. Tschudy & Leopold 1971
Aquilapollenites sp. aff. *A. reticulatus*
Aquilapollenites sp. cf. *A. sentus* Srivastava 1969
Aquilapollenites trialatus Rouse 1957
Aquilapollenites unicus (Chlonova 1957) Chlonova 1961
Aquilapollenites sp. 1 of Frederiksen and McIntyre (2000)
Aquilapollenites sp. 2 of Frederiksen and McIntyre (2000)
Aquilapollenites sp. 4 of Frederiksen and McIntyre (2000)
Azonia cribrata Wiggins 1976
Azonia fabacea Samoilovich in Samoilovich & Mchedlishvili 1961
Azonia hirsuta (Samoilovich 1965) Wiggins 1976
Azonia pulchella Felix & Burbridge 1973
Caryapollenites imparalis Nichols & Ott 1978
Caryapollenites wodehousei Nichols & Ott 1978
Insulapollenites rugulatus Leffingwell 1970
Mancicorpus pseudosenonicus Frederiksen 1991
*Momipites wyomingens*is Nichols & Ott 1978
Orbiculapollis globosus (Chlonova 1957) Chlonova 1961
Paraalnipollenites alterniporus (Simpson 1961) Srivastava 1975, type H of Frederiksen and others (1988)
Paraalnipollenites confusus (Zaklinskaya 1963) Hills & Wallace 1969G
Syndemicolpites sp. 1 of Frederiksen and McIntyre (2000)
Syndemicolpites sp. 2 of Frederiksen and McIntyre (2000)
Syndemicolpites sp. 4 of Frederiksen and McIntyre (2000)
Syndemicolpites sp. 6 of Frederiksen and McIntyre (2000)
Triporopollenites mullensis (Simpson 1961) Rouse & Srivastava 1972
Ulmipollenites krempii (Anderson 1960) Frederiksen 1979
Ulmipollenites tricostatus (Anderson 1960) Frederiksen 1980
Ulmipollenites undulosus Wolff 1934
Wodehouseia spinata Stanley 1961 (includes *Wodehouseia stanleyi* Srivastava 1966)

Table 3. Palynomorph samples from the Rogers Creek and Barrow Trail Members of the Sentinel Hill Formation. At each location, samples are listed proceeding down-section.

USGS Palynology Series No.	Exxon Company Locality No.	Location	Member
R3693	84 SH I	Colville River	Barrow Trail
R3692	84 SH II	do.	do.
R3678	84 RC I	do.	Rogers Creek
R3691	84 TB I A-D	Chandler River	Barrow Trail
R3690	84 TB II	do.	do.
R3689	84 TB II A,B	do.	do.
R3688	84 TB III A-C	do.	do.
R3687	84 TB IV	do.	do.
R3686	84 TB V	do.	do.
R3685	84 TB V A,B	do.	do.
R3684	84 TB VI A-D	do.	Rogers Creek
R3683	84 TB VII A-D	do.	do.
R3682	84 TB VIII	do.	do.
R3679	84 TB IX	do.	do.

SUMMARY AND CONCLUSIONS

Palynomorph Biostratigraphy of Some Upper Cretaceous Outcrop Samples From Along the Chandler and Colville Rivers

The effort to use pollen species to correlate between the Chandler and Colville River sections and to place the Santonian-Campanian boundary in these sections depends on lowest occurrences of pollen species in the important *Aquilapollenites* and *Syndemicolpites* groups and in the genus *Azonia*, which includes the oldest taxa of the important Oculata pollen group. Pollen biostratigraphy suggests that the top of the Barrow Trail Member is not demonstrably diachronous at least in a north-south direction; therefore, the base of the overlying Sentinel Hill Member may also be only slightly diachronous.

Occurrences are documented of 24 dinocyst species in 12 samples from the Rogers Creek and Barrow Trail Members of the Schrader Bluff Formation along the Chandler and Colville Rivers. Dinocyst chronostratigraphy, together with previous age determinations based on inoceramids and foraminifers, indicates that the Barrow Trail is early Campanian; the uppermost part of the underlying Rogers Creek Member apparently is also early Campanian, but most of the Rogers Creek is apparently Santonian and perhaps partly late Coniacian in age. This study thus extends our detailed palynological chronostratigraphy for the North Slope from the top of the Maastrichtian down to the Santonian and perhaps into the Coniacian.

Palynology of Some Maastrichtian and Paleocene (to Eocene?) Outcrop Samples From Between 145° and 148° West Longitude on the North Slope

This section of the report concerns the palynological dating of 16 outcrop samples, from eight stratigraphic sections, that were collected in 1997 by C. J. Schenk and D. W. Houseknecht. Three of the samples were nearly barren of palynomorphs; two samples were Maastrichtian; one sample was Maastrichtian or Paleocene; one sample could only be dated as Maastrichtian or younger; six samples were Paleocene; and three samples were Paleocene or Eocene.

Review of Consultant and Oil Company Palynological Reports on Upper Cretaceous to Eocene Strata in Eight North Slope Wells

Bujak and Davies give their raw data in the form of a highest occurrence chart (that is, they only show the depth where the topmost occurrence of each taxon was observed), whereas Hideyo Haga gives his raw data in the form of occurrence charts, which appear to be preferable because then one can see in how many samples a particular taxon occurs, and whether the topmost occurrence is likely to be a reworked specimen.

As is usual on the North Slope, the approximate top of the Paleocene is picked in these reports at the topmost occurrence or topmost consistent occurrence of *Paraalnipollenites confusus*. Sometimes the occurrences of this species are really the only way to identify the Paleocene interval.

Sometimes, the base of the Eocene and especially the top of the Cretaceous have to be picked on the basis of dinoflagellates because angiosperm pollen is rare especially in the Cretaceous.

At least the upper part of the preserved Paleocene often lacks dinoflagellates; the lower part often is marine, reflecting the early Paleocene highstand.

Upper Maastrichtian marker pollen species were found in at least some of the wells, but there is not enough species information given (were the species missing or were they merely not reported at species level?) to determine whether or not the upper Maastrichtian is really missing in most of the other wells. The question arises because Wiggins (1976, p. 53) stated that "a significant subsurface unconformity is present at the [Cretaceous-Tertiary] boundary in the Prudhoe Bay area," and Robertson (1986, p. 257) reported that "in the western portion of the Prudhoe Bay Field* ... the Late Cretaceous unconformity is diachronous," presumably meaning that the age of uppermost preserved Cretaceous rocks varies from place to place in the region.

The following table summarizes the Cenozoic/preCenozoic boundary in these wells and in the two wells previously reviewed:

Arco West Sak River #23	Paleocene/Maastrichtian
Arco Itkillik River #1	Eocene(?)/Maastrichtian
Sohio Prudhoe Bay Unit R-1	Paleocene/Campanian-Maastrichtian
Placid et al. State #1	Probable Paleocene/Santonian-Campanian
Arco Nora Federal #1	Paleocene/Maastrichtian
Arco Susie Unit #1	Paleocene(?)/Maastrichtian
Exxon Alaska State A-1	Paleocene/metasedimentary rocks
Mobil West Staines State #1	Paleocene/Santonian-Campanian
Mobil West Staines State #2	Paleocene/Maastrichtian
Exxon Canning River B-1	Paleocene/Campanian-Maastrichtian

The data certainly show that the Cretaceous-Tertiary boundary in these wells is diachronous. Paleocene rocks are generally present above the boundary, but it is difficult from the data given, and because of contamination from uphole, to determine whether the lowermost preserved Paleocene rocks are actually early Paleocene in age. Upper Maastrichtian rocks are sometimes present below the boundary, but the data are not good enough to show whether these include uppermost Maastrichtian rocks, and in at least two of the wells where Upper Cretaceous strata exist, it appears that Maastrichtian rocks are not present at all. By comparison, in the Arco Ugnu SWPT-1 well in the Kuparuk River oil field, in which the Cretaceous-Tertiary boundary was investigated in great detail (Frederiksen and others, 1998), there was very little or no unconformity at the Cretaceous-Tertiary boundary.

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* The wells Robertson (1986) examined were the Beechey Point #1, Term C-1, Hurl #1, Kuparuk State #1, and West Kuparuk #1.

It is possible that the sample processing was better in some laboratories than in others, which might account for more detailed results by some workers than by others. Other difficulties in age determinations may have been caused by sample quality—the presence of abundant cavings in some samples, and some apparently missing intervals may have been relatively thin and (or) composed of sediments not conducive to palynomorph preservation in particular wells.

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REFERENCES CITED

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.

Bird, K. J., and Molenaar, C. M., 1992, The North Slope foreland basin, *in* Macqueen, R. W., and Leckie, D. A., eds., Foreland basins and foldbelts: American Association of Petroleum Geologists Memoir 55, p. 363-393.

Bondarenko, N. M., 1983, Novyye rody pyl'tsy iz verkhnego mela Arktiki [New pollen genera from the Upper Cretaceous of the Arctic]: Paleontologicheskii Zhurnal, no. 2 (for 1983), p. 97-104. (Translation in Paleontological Journal, 1983, no. 4, p. 98-105).

Brideaux, W. W., and Myhr, D. W., 1976, Lithostratigraphy and dinoflagellate cyst succession in the Gulf Mobil Parsons N-10 Well, District of Mackenzie, *in* Report of Activities, Part B: Geological Survey of Canada Paper 76-1B, p.235-249.

Brosgé, W. P., and Whittington, C. L., 1966, Geology of the Umiat-Maybe Creek region, Alaska: U.S. Geological Survey Professional Paper 303-H, p. 501-638.

Bujak, J. P., and Davies, E. H., 1983, Modern and fossil Peridiniineae: American Association of Stratigraphic Palynologists, Contributions Series, v.13, 202 p.

Bujak Davies Group, 1985, Palynology of Mobil West Staines [State] #1 and Exxon Alaska State A-1, Alaska North Slope: Unpublished, 49 p.

Cobban, W. A., and Gryc, G., 1961, Ammonites from the Seabee Formation (Cretaceous) of northern Alaska: Journal of Paleontology, v. 35, p. 176-190.

Cole, F., Bird, K. J., Toro, J., Roure, F., O'Sullivan, P. B., Pawlewicz, M., and Howell, D. G., 1997, An integrated model for the tectonic development of the frontal Brooks Range and Colville Basin 250 km west of the Trans-Alaska Crustal Transect: Journal of Geophysical Research, v. 102, no. B9, p. 20,685-20,708.

Decker, J., Corrigan, J., and Bergman, S., 1996, Brookian maturation and erosion framework of North Alaska: American Association of Petroleum Geologists Annual Meeting Abstracts, v. 5, p. 34.

Detterman, R. L., Bickel, R. S., and Gryc, G., 1963, Geology of the Chandler River region, Alaska: U.S. Geological Survey Professional Paper 303-E, p. 224-324.

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.

Exxon Company U.S.A., 1984, unpublished report.

Felix, C. J., and Burbridge, P. P., 1973, A Maestrichtian age microflora from Arctic Canada: Geoscience and Man, v. 7, p.1-29.

Fouch, T. D., Collett, T., Bird, K. J., Carter, L. D., and Frederiksen, N. O., 1993, The Cretaceous and Tertiary Sagavanirktok Formation, a major exploration target under the North Slope of Alaska and adjacent Beaufort Sea: Preliminary evaluation of exposures at Franklin Bluffs: Rocky Mountain Section SEPM, Newsletter, v. 18, no. 2, p. 1-2.

Frederiksen, N. O., 1987, Reconnaissance biostratigraphy of the *Expressipollis* and Oculata pollen groups in Campanian and Maastrichtian rocks of the North Slope, Alaska: Palynology, v. 11, p. 227-228.

----1991, 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., and McIntyre, D. J., 2000, Palynomorph biostratigraphy of mid(?)-Campanian to upper Maastrichtian strata along the Colville River, North Slope of Alaska: U.S. Geological Survey Open-file Report 00-493, 36 p.

Frederiksen, N. O., and Schindler, K. S., 1987, Campanian to Maastrichtian pollen biostratigraphy and floral turnover rates, Colville River region, North Slope, Alaska: American Association of Petroleum Geologists Bulletin, v. 71, p. 558.

Frederiksen, N. O., Ager, T. A., and Edwards, L. E., 1986, Comment on "Early Tertiary marine fossils from northern Alaska: Implications for Arctic Ocean paleogeography and faunal evolution": Geology, v. 14, p. 802-803.

----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., Andrle, V. A. S., Sheehan, T. P., Ager, T. A., Collett, T. S., Fouch, T. D., Franczyk, K. J., and Johnsson, Mark, 1998, Palynological dating of Upper Cretaceous to middle Eocene strata in the Sagavanirktok and Canning Formations, North Slope of Alaska: U.S. Geological Survey Open-File Report 98-471, 51 p.

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.

Frederiksen, N. O., Sheehan, T. P., Ager, T. A., Collett, T. S., Fouch, T. D., Franczyk, K. J., and Johnsson, Mark, 1996, Palynomorph biostratigraphy of Upper Cretaceous to Eocene samples from the Sagavanirktok Formation in its type region, North Slope of Alaska: U.S. Geological Survey Open-File Report 96-84, 44 p.

Gradstein, F. M., Agterberg, F. P., Ogg, J. G., Hardenbol, Jan, Van Veen, Paul, Thierry, Jacques, and Huang, Zehui, 1995, a Triassic, Jurassic and Cretaceous time scale, *in* Berggren, W. A., Kent, D. V., and Hardenbol, Jan, eds., Geochronology, time scales and global stratigraphic correlation: SEPM (Society for Sedimentary Geology) Special Publication 54, p. 95-126.

Gryc, G., 1956, Introduction and summary, *in* Gryc, G., and others, Mesozoic sequence in Colville River region, northern Alaska: American Association of Petroleum Geologists Bulletin, v. 40, p. 209-213.

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.

Guennel, G. K., 1971, Palynology of the Susie Unit #1 well, North Slope, Alaska: Marathon Oil Company, unpublished, 13 p., 2 pls.

Haga, Hideyo, 1975, Arco Itkillik #1, North Slope, Alaska, palynology report: Anderson, Warren & Associates, Inc., unpublished, 6 p.

Haq, B. U., Hardenbol, J., and Vail, P. R., 1988, Mesozoic and Cenozoic chronostratigraphy and cycles of sea-level change, *in* Sea-level changes—An integrated approach: SEPM Special Publication 42, p. 71-108.

Ioannides, N. S., and McIntyre, D. J., 1980, A preliminary palynological study of the Caribou Hills outcrop section along the Mackenzie River, District of Mackenzie: Geological Survey of Canada, Paper 80-1A, p.197-208.

Jones, D. L., and Gryc, G., 1960, Upper Cretaceous pelecypods of the genus *Inoceramus* from northern Alaska: U.S. Geological Survey Professional Paper 334-E, p. 149-165.

Kimyai, A., 1992, Palynological assemblages of the Cretaceous sediments in the Fish Creek test well no. 1, North Slope, Alaska: Revista Española de Micropaleontologia, v. 24, no. 3, p. 27-42.

Lanphere, M. A., and Tailleur, I. L., 1983, K-Ar ages of bentonites in the Seabee Formation, northern Alaska: A Late Cretaceous (Turonian) time-scale point: Cretaceous Research, v. 4, p. 361-370.

Lentin, J. K., and Williams, G. L., 1980, Dinoflagellate provincialism with emphasis on Campanian peridiniaceans: American Association of Stratigraphic Palynologists, Contributions Series, v. 7, 47 p.

McIntyre, D. J., 1974, Palynology of an Upper Cretaceous section, Horton River, District of Mackenzie, N.W.T.: Geological Survey of Canada Paper 74-14, 57 p.

----1975, Morphologic changes in *Deflandrea* from a Campanian section, District of Mackenzie, N. W. T., Canada: Geoscience and Man, v.11, p.61-76.

----1985, Palynology, *in* Geology, biostratigraphy and organic geochemistry of Jurassic to Pleistocene strata, Beaufort-Mackenzie area, northwest Canada; course notes: Canadian Society of Petroleum Geologists, Calgary, p. 39-49.

Mchedlishvili, N. D., 1965, Znachenie pokrytosemennykh rastenii dlya stratigrafii verkhnemelovykh otlozhenii [The significance of angiospermous plants for the stratigraphy of Upper Cretaceous sediments], in Samoilovich, S. R., ed., Paleofitologicheskii Sbornik [Paleophytological Collection]: Vsesoiuznyi Heftianoi Nauchno-Issledovatel'skii Geologorazvedochnyi Institut (VNIGRI), Trudy, v. 239, p. 5-34.

Mickey, M. B., and Haga, Hideyo, 1983a, BioStratigraphic analysis, ARCO Nora Federal #1, North Slope, Alaska: BioStratigraphics Consulting Micropaleontology, unpublished, 29 p.

----1983b, BioStratigraphic analysis, EXXON Canning River B-1, North Slope, Alaska: BioStratigraphics Consulting Micropaleontology, unpublished, 20 p.

----1984a, U.S. Geological Survey/Sohio Prudhoe Bay Unit R-1, sec. 32, T12N/R13E UBM, API #50-029-20353, North Slope Alaska: Micropaleo Consultants, Inc., unpublished, 19 p.

----1984b, Revised biostratigraphic analysis, Placid et al. State #1, North Slope, Alaska: Micropaleo Consultants, Inc., unpublished, 11 p.

----1984c, Biostratigraphic analysis, Mobil West Staines State No. 2, North Slope, Alaska: Micropaleo Consultants, Inc., unpublished, 18 p.

----1988, Distribution of large-scale depositionally related biostratigraphic units, National Petroleum Reserve in Alaska, *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. 657-665.

Molenaar, C. M., Bird, K. J., and Kirk, A. R., 1987, Cretaceous and Tertiary stratigraphy of northeastern Alaska, *in* Tailleur, Irv, and Weimer, Paul, eds., Alaskan North Slope geology: Pacific Section, Society of Economic Paleontologists and Mineralogists, and Alaska Geological Society, Book 50, v. 1, 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: United States Geological Survey, Open-File Report 84-695, 19 p.

Nichols, D. J., and Ott, H. L., 1978, Biostratigraphy and evolution of the *Momipites-Caryapollenites* lineage in the early Tertiary in the Wind River Basin, Wyoming: Palynology, v. 2, p. 93-112.

Norford, B. S., Brideaux, W. W., Chamney, T. P., Copeland, M. J., Frebold, H., Hopkins, W. S., Jr., Jeletzky, J. A., Johnson, B., McGregor, D. C., Norris, A. W., Pedder, A. E. H., Tozer, E. T., and Uyeno, T. T., 1972, Biostratigraphic determinations of fossils from the subsurface of the Yukon Territory and the districts of Franklin, Keewatin and Mackenzie: Geological Survey of Canada Paper, 72-38, 29 p.

Norris, G., 1997, Paleocene-Pliocene deltaic to inner shelf palynostratigraphic zonation, depositional environments and paleoclimates in the Imperial Adgo F-28 well, Beaufort-Mackenzie Basin: Geological Survey of Canada Bulletin 523, 71 p.

Núñez-Betelu, K., and Hills, L. V., 2001, Sedimentology, palynology, and Rock-Eval pyrolysis of the Upper Cretaceous Kanguk Formation, Canadian Arctic, *in* Goodman, D. K., and Clarke, R. T. (eds.), Proceedings of the IX International Palynological Congress, Houston, Texas, U.S.A., 1996: American Association of Stratigraphic Palynologists Foundation, p. 181-189.

Robertson, E. B., 1986, The Tertiary palynology of the Prudhoe Bay Field, North Slope, Alaska: Palynology, v. 10, p. 257.

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 5A, p. 48-65.

Samoilovich, S. R., 1977, Palinologicheskaya kharakteristika verkhnemelovykh otlozheniy Zapadnoy Yakutii [Palynological characteristics of Upper Cretaceous deposits of West Yakutia], *in* Samoilovich, S. R. and Timoshina, N. A., (eds.) Voprosy fitostratigrafii [Questions of phytostratigraphy]: Vsesoiuznyi Heftianoi Nauchno-Issledovatel'skii Geologorazvedochnyi Institut (VNIGRI), Trudy, v. 398, p. 40-69.

Samoilovich, S. R., and Mchedlishvili, N. D., eds., 1961, Pyl'tsa i spory zapadnoi Sibiri, Iura-Paleotsen [Pollen and spores of western Siberia, Jurassic-Paleocene]: Vsesoiuznyi Heftianoi Nauchno-Issledovatel'skii Geologorazvedochnyi Institut (VNIGRI), Trudy, v. 177, 657 p.

Schenk, C. J., Houseknecht, D. W., and Burruss, R. C., 1999, USGS Arctic National Wildlife Refuge field summary, 1995-1997, Chapter FS *in* The oil and gas resource potential of the 1002 area, Arctic National Wildlife Refuge, Alaska: U.S. Geological Survey Open-File Report 98-34, 98 p.

Stanley, E. A., 1970, The stratigraphical, biogeographical, paleoautecological and evolutionary significance of the fossil pollen group Triprojectacites: Georgia Academy of Science Bulletin, v. 28, p. 1-44.

Tappan, H. N., 1960, Cretaceous biostratigraphy of northern Alaska: American Association of Petroleum Geologists Bulletin, v. 44, p. 273-297.

Tschudy, B. D., 1969, Species of *Aquilapollenites* and *Fibulapollis* from two Upper Cretaceous localities in Alaska: U.S. Geological Survey Professional Paper 643-A, p. A1-A17.

Waanders, G. L., and Haga, Hideyo, 1979, Placid [et al.] State #1 (Prudhoe Bay), sec. 3, 10N/13E, North Slope, Alaska: Anderson, Warren & Associates, Inc., unpublished, 10 p.

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

----1981, *Noctuipollis*; a new Upper Cretaceous (Campanian) pollen genus from Arctic Alaska: Grana, v. 20, p. 37-41.

----1982, *Expressipollis striatus* n.sp. to *Anacolosidites striatus* n.sp.: An Upper Cretaceous example of suggested pollen aperture evolution: Grana, v. 21, p. 39-49.

Witmer, R. J., Haga, Hideyo, and Mickey, M. B., 1981a, Biostratigraphic report of thirty-three wells drilled from 1975 to 1981 in National Petroleum Reserve in Alaska: U.S. Geological Survey Open-File Report 81-1166, 47 p.

Witmer, R. J., Mickey, M. B., and Haga, Hideyo, 1981b, Biostratigraphic correlations of selected test wells of National Petroleum Reserve in Alaska: U.S. Geological Survey Open-File Report 81-1165, 89 p.