Pollen Zonation and Correlation of Maastrichtian Marine Beds and Associated Strata, Ocean Point Dinosaur Locality, North Slope, Alaska

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Chapter E

Pollen Zonation and Correlation of Maastrichtian Marine Beds and Associated Strata, Ocean Point Dinosaur Locality, North Slope, Alaska

By NORMAN O. FREDERIKSEN

A multidisciplinary approach to research studies of sedimentary rocks
and their constituents and the evolution of sedimentary basins, both
ancient and modern

U.S. GEOLOGICAL SURVEY BULLETIN 1990

EVOLUTION OF SEDIMENTARY BASINS—NORTH SLOPE BASIN

U.S. DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

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CONTENTS

PLATES

[Plates follow References Cited]

FIGURES

TABLES

Pollen Zonation and Correlation of Maastrichtian Marine Beds and Associated Strata, Ocean Point Dinosaur Locality, North Slope, Alaska

By Norman O. Frederiksen

Abstract

A detailed composite palynostratigraphic section is herein constructed for the Maastrichtian rocks overlying the Ocean Point dinosaur locality using outcrop and seismic shothole samples along and near the lower Colville River, North Slope of Alaska. This composite section includes two Maastrichtian pollen zones—in ascending order, zone A (a new, tentative zone) and the *Wodehouseia spinata* Assemblage Zone of Nichols and others (1982). In the study area, the *Wodehouseia spinata* Zone is divisible into five tentative subzones. Six new pollen species are described from the two zones: *Rousea compta, Azonia strictiparva, Wodehouseia wigginsii, Aquilapollenites alaskensis, Fibulapollis inaequalis,* and *Manicorpus pseudosenonicus.*

A pollen correlation exists between reliably dated Upper Cretaceous sections of the Western Interior and the Brackett basin in the Northwest Territories of Canada. In this paper, a pollen correlation is made between the lower Colville River section and the Brackett basin section. This correlation shows that the study section on the North Slope is "middle" to latest Maastrichtian in age. The Ocean Point marine beds near the Colville River are within the *Wodehouseia spinata* Assemblage Zone and are "middle" Maastrichtian on the basis of pollen correlations.

INTRODUCTION

Few reliable data have been available on ages of uppermost Cretaceous strata on the North Slope of Alaska because these strata generally lack marine fossils. Furthermore, the marine fossils that are present, with the exception of benthic foraminifers, (1) have long geologic ranges, (2) have geologic ranges that seem to be different on the North Slope than in other regions, or (3) are endemics whose geologic ages are very uncertain (Marincovich and others, 1983, 1985, 1986; Brouwers, 1988).

The purposes of this paper are (1) to compile a composite palynostratigraphic section for the lower Colville River region, from west of Ocean Point eastward and northward (upsection) to the top of the Cretaceous sequence in the region, (2) to describe and name new pollen species present in the composite section, and (3) to compare the stratigraphic ranges of important pollen taxa in the composite section with ranges of the taxa in the Western Interior of North America to determine ages of the North Slope samples.

This study is based on occurrences of 64 angiosperm pollen taxa (table 1; fig. 2). These taxa were recovered from 32 seismic-line shothole samples from west and east of the Colville River and from 18 outcrop samples taken along the Colville River, mainly west of Ocean Point (fig. 1; see "Sample Locality Register"). I previously examined approximately 65 pollen-bearing Campanian and Maastrichtian samples downsection from the Ocean Point area (Frederiksen and others, 1988; Frederiksen, 1989); thus, the range bases of pollen taxa mentioned in this paper are well defined, at least compared to most pollen taxa previously studied in northwestern North America.

Palynological Methods

Palynological samples were prepared using standard acid maceration. All samples were separated by heavy liquid ($ZnCl_2$), were sieved on 10-µm nylon screens, and were mounted in glycerine jelly. Preservation of pollen in nearly all samples was excellent.

Slide designations show the sample number with the slide number in parentheses. The coordinates listed in the holotype descriptions and in table 3 locate the specimens on microscope 871956 at the U.S. Geological Survey, Reston, Va. On this microscope, the coordinates for the center point of a standard 25.4×76.2 mm slide are 38.8×102.5 (horizontal × vertical axes); the horizontal coordinates increase toward the right edge of the stage, and the vertical coordinates increase toward the front of the stage. Slides having R prefixes are stored at the U.S. Geological Survey, Reston, Va.; slides having D prefixes are stored at the U.S. Geological Survey, Denver, Colo. Slides having ARCO labels and no prefix (for example, 16410) are stored at Chevron U.S.A.,

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Inc., San Ramon, Calif., except slide 20738(2), which belongs to D.W. Edelman of Edelman, Percival, and Associates, Red Oak, Tex.

A composite palynostratigraphic section is herein constructed for the "middle" and upper Maastrichtian along the lower Colville River. Most upper Maastrichtian samples were collected from shotholes along three seismic lines (fig. 1), and graphic correlation was used (see figs. 3, 4) to position the shothole samples relative to one another in the composite section (fig. 2). The principles and practice of graphic correlation have been described in detail in previous papers (Shaw, 1964; Miller, 1977; Edwards, 1984) and are not discussed here. The concept of graphic boxes to better define likely true positions of range tops and bases (biostratigraphic events) was introduced by Edwards (1984). Each taxon is given an odd-numbered designation (see table 1);

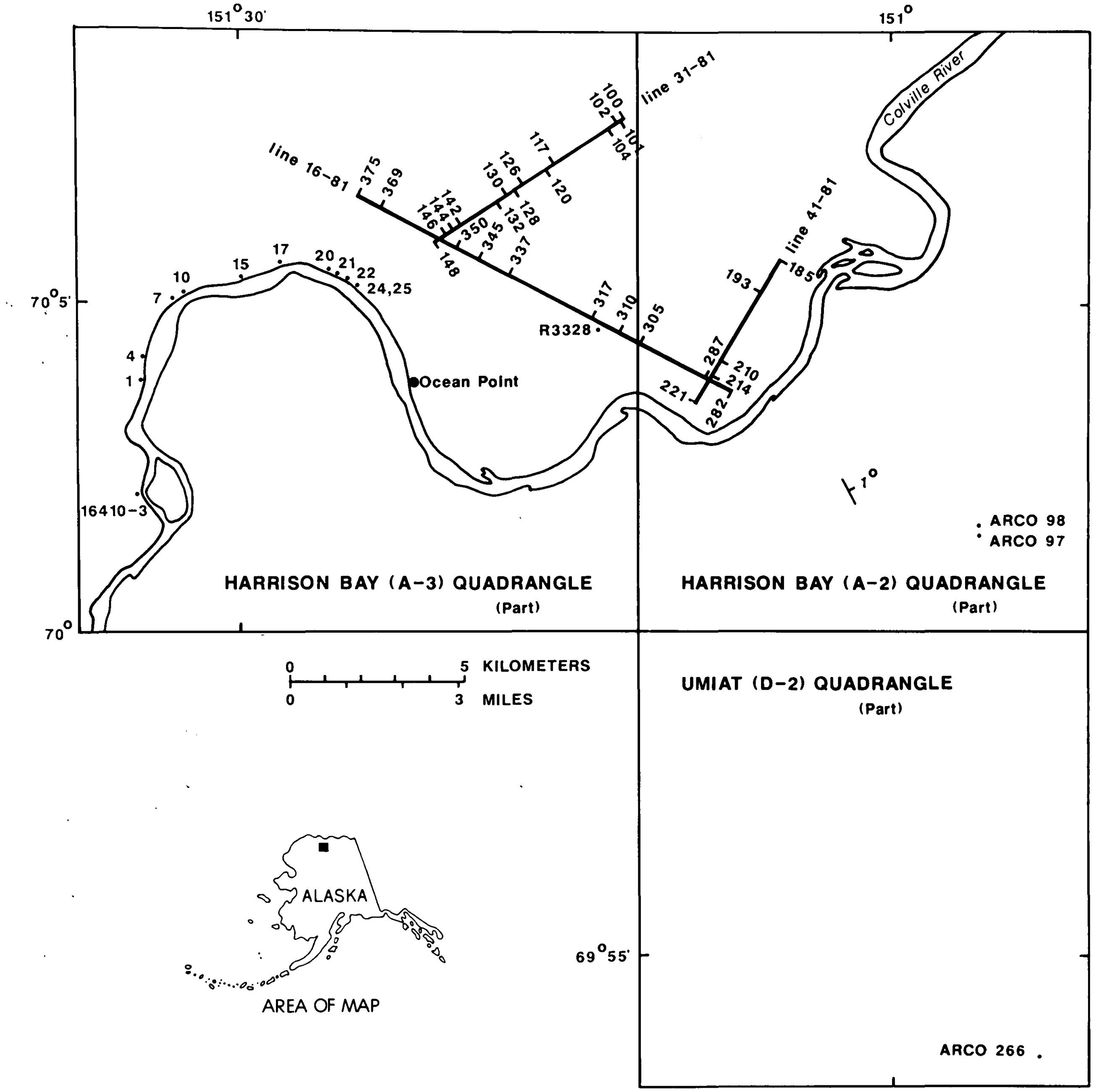


Figure 1. Palynologic sample locations in lower Colville River area, Alaska. Only sampled parts of U.S. Geological Survey seismic lines are shown. Numbered localities along the Colville River upriver from Ocean Point are sections of Phillips (1988). Strike and dip of the Colville Group shown in the A–2 quadrangle.

in the graphic correlation charts (figs. 3, 4), range bases are identified by the taxon number and range tops are identified by the next higher integer than the taxon number. For example, *Orbiculapollis globosa* is taxon 49; the range base of this taxon in any particular section is event 49, and the range top of the taxon is event 50. A range base data point is marked by the symbol "o," a range top data point by "+."

Photographs of many Campanian and Maastrichtian pollen species of the Colville River region have previously been published (Tschudy, 1969; Wiggins, 1976; Frederiksen and others, 1988). Therefore, pollen photographs herein (pls. 1–7) show only species for which photographs of specimens from the study area have not previously been published.

With few exceptions, the year given as part of each taxonomic name refers to the date when the name was published, not to a particular paper. Therefore, the "References Cited" do not include authors and dates that appear only as parts of taxonomic names.

Acknowledgments

I thank the following people for generously providing samples from Campanian and Maastrichtian rocks of the Colville River area: V.D. Wiggins, Chevron U.S.A., Inc.; H.S. Sonneman and J.B. Stough, Exxon Company, U.S.A.; D.W. Edelman, Edelman, Percival and Associates; R.A. Spicer, Oxford University; J.T. Parrish, University of Arizona; and T.A. Ager, K.J. Bird, E.M. Brouwers, and B.D. Tschudy, U.S. Geological Survey.

STRATIGRAPHY

Rocks sampled for this study belong to the Upper Cretaceous Colville Group, which consists of the Seabee, Schrader Bluff, and Prince Creek Formations (Brosgé and Whittington, 1966); the Colville Group is about 1,150 m thick in the study area according to seismic-reflection data (Tetra Tech, Inc., 1982).

The Seabee Formation is at least partly of Turonian age; it is not exposed in the study area. The mainly marine Schrader Bluff Formation and the mainly nonmarine Prince Creek Formation (fig. 2) overlie the Seabee. The Schrader Bluff and Prince Creek Formations consist of shale, sandstone, and bentonitic and tuffaceous strata; the Prince Creek also includes coal beds. The two formations interfinger regionally, but in the section studied, the only rocks assigned to the Schrader Bluff are in the tongue composed of the Ocean Point marine beds (Macbeth and Schmidt, 1973; Wiggins, 1976; Frederiksen and others, 1988), which include the marine strata equivalent to those observed in sections 20–25 of Phillips (1988). These rocks apparently belong to the Sentinel Hill Member of the Schrader Bluff Formation. Prince Creek rocks in the region are tentatively assigned to the Kogosukruk Tongue of the formation (Brosgé and Whittington, 1966). Overlying the Schrader Bluff and Prince Creek Formations are sandy, gravelly, lignitic strata that Carter and Galloway (1985) referred to as the Tertiary Sagavanirktok Formation. Few exposures of Cretaceous and early Tertiary strata are present in the region, except along streams, because these strata are blanketed by the Pliocene and Pleistocene Gubik Formation (Carter and Galloway, 1985).

In the region, the strike of the Colville Group is generally northwest (Tetra Tech, Inc., 1982; T.A. Ager, written commun., 1988). The dip of the uppermost Cretaceous and lowermost Tertiary strata is approximately 1° ENE. This determination is based in part on correlation of strata in seismic shotholes in the study area (T.A. Ager, written commun., 1988), in part on the dip of an Upper Cretaceous seismic reflector in the region (K.J. Bird, oral commun., 1989), and in part on the structure-contour maps of Werner (1987) for the uppermost Cretaceous and lowermost Tertiary strata in the Kuparuk River Unit (KRU) northeast of the study area. Werner's maps show dips of about 1.5° ENE in the eastern part of the KRU, which is about 70 km northeast of Ocean Point, and about 1° ENE in the western part of the KRU, which is about 40 km northeast of Ocean Point.

COMPOSITE PALYNOSTRATIGRAPHIC SECTION

This study is based on examination of (1) 29 seismic-line shothole samples from west of the Colville River, (2) 3 shothole samples from east of the river for which some data had previously been published by Wiggins (1976) but which have been reexamined during this study, (3) 8 outcrop samples, mainly from the Ocean Point marine beds, that had previously been studied (Frederiksen and others, 1988), and (4) 10 new outcrop samples from nonmarine strata within and below the sequence of Ocean Point marine beds (fig. 1). Thus, the composite palynostratigraphic section (fig. 2) includes 50 samples (see "Sample Locality Register") and apparently represents about 239 m of section (see fig. 6). Samples from U.S. Geological Survey (USGS) seismic shothole lines (from west of the Colville River) were extremely useful for this study because very few upper Maastrichtian exposures are known from the lower Colville River area (Frederiksen and others, 1988). The USGS shothole samples were, according to the drillers' notes, taken from depths of 75–90 ft (23–27 m) below the surface.

Seismic Lines 16–81 and 31–81

The process of compiling a composite palynostratigraphic section for the "middle" to upper Maastrichtian

Table 1. "Middle" to late Maastrichtian pollen taxa of the North Slope, Alaska

[A few additional species represented by very rare specimens are shown on the plates but not listed here or shown on the range chart (fig. 2)]

Taxon number	Taxon
	Porate pollen
1	*Alnus* spp.
3	*Anacolosidites* sp.
5	*Betulaepollenites* spp.
7	*Erdtmanipollis* spp.
9	*Jarzenipollis trina* (Stanley 1965) Kedves 1980
11	*Paraalnipollenites confusus* (Zaklinskaya 1963) Hills & Wallace 1969, type H of Frederiksen and others (1988)
13	*Paraalnipollenites confusus* type Z of Frederiksen and others (1988)
15	*Proteacidites thalmannii* Anderson 1960 complex
17	*Triatriopollenites* spp.
21	*Triporopollenites megagranifer* (Potonié 1934) Thomson & Pflug 1953 type of Frederiksen and others (1988)
23	*Triporopollenites mullensis* (Simpson 1961) Rouse & Srivastava 1972
25	*Trivestibulopollenites* spp.
27	*Ulmipollenites krempii* (Anderson 1960) Frederiksen 1979
29	*Ulmipollenites tricostatus* (Anderson 1960) Frederiksen 1980
	Tricolpate and tricolporate pollen
31	*Callistopollenites radiatostriatus* (Mchedlishvili *in* Samoilovich & Mchedlishvili 1961) Srivastava 1969
33	*Callistopollenites tumidoporus* Srivastava 1969
35	*Callistopollenites* sp. of Frederiksen and others (1988)
37	*Cercidiphyllites* sp. of Frederiksen and others (1988)
39	*Cranwellia* + *Striatellipollis*
41	*Kurtzipites annulatus* Norton *in* Norton & Hall 1969
43	*Kurtzipites circularis* (Norton *in* Norton & Hall 1969) Srivastava 1981
45	*Kurtzipites trispissatus* Anderson 1960
47	*Myrtipites scabratus* Norton *in* Norton & Hall 1969
49	*Orbiculapollis globosa* (Chlonova 1957) Chlonova 1961
51	*Porosipollis porosus* (Mchedlishvili *in* Samoilovich & Mchedlishvili 1961) Krutzsch 1969
53	*Rousea compta* n. sp.
55	*Senipites drumhellerensis* Srivastava 1969
57	*Siberiapollis constrictus* (Samoilovich *in* Samoilovich & Mchedlishvili 1961) n. comb.
59	*Siberiapollis* sp. aff. *S. occulatus* (Samoilovich *in* Samoilovich & Mchedlishvili 1961) Tschudy 1971 = *Proteacidites* sp. of Frederiksen and others (1988, pl. 1, fig. 17)
61	*Siberiapollis* sp. aff. *Proteacidites* sp. 1 of McIntyre (1974) = *Proteacidites* sp. 1 of McIntyre (1974) of Frederiksen and others (1988, pl. 1, fig. 18)
	Tricolpate and tricolporate pollen—Continued
65	*Tricolpites* sp. aff. *T. matauraensis* Couper 1953
67	*Trudopollis* spp.
	Oculata pollen
69	*Azonia cribrata* Wiggins 1976
71	*Azonia fabacea* Samoilovich *in* Samoilovich & Mchedlishvili 1961
73	*Azonia hirsuta* (Samoilovich 1965) Wiggins 1976
75	*Azonia* sp. cf. *A. hirsuta*
77	*Azonia pulchella* Felix & Burbridge 1973
79	*Azonia strictiparva* n. sp.
81	*Wodehouseia bella* Wiggins 1976
83	*Wodehouseia edmontonicola* Wiggins 1976
85	*Wodehouseia elegans* (Samoilovich *in* Samoilovich & Mchedlishvili 1961) Wiggins 1976
87	*Wodehouseia gracile* (Samoilovich *in* Samoilovich & Mchedlishvili 1961) Pokrovskaya 1966
89	*Wodehouseia octospina* Wiggins 1976
91	*Wodehouseia quadrispina* Wiggins 1976
93	*Wodehouseia spinata* Stanley 1961 (includes *Wodehouseia stanleyi* Srivastava 1966)
95	*Wodehouseia vestivirgata* Wiggins 1976
97	*Wodehouseia wigginsii* n. sp.
	Triprojectate pollen
99	*Aquilapollenites* sp. aff. *A. abscisus* Chlonova 1961
101	*Aquilapollenites alaskensis* n. sp.
105	*Aquilapollenites* sp. cf. *A. augustus* Srivastava 1969
107	*Aquilapollenites conatus* Norton 1965
109	*Aquilapollenites fusiformis* Tschudy 1969
111	*Aquilapollenites immiser* Sweet 1986
113	*Aquilapollenites quadrilobus* Rouse 1957
115	*Aquilapollenites reticulatus* (Mchedlishvili *in* Samoilovich & Mchedlishvili 1961) Tschudy & Leopold 1971
117	*Aquilapollenites unicus* (Chlonova 1957) Chlonova 1961
119	*Aquilapollenites* sp. A
121	*Bratzevaea amurensis* (Bratzeva 1965) Takahashi *in* Takahashi & Shimono 1982
123	*Fibulapollis inaequalis* n. sp.
125	*Fibulapollis scabratus* Tschudy 1969
127	*Manicorpus delicatus* (Stanley 1961) Bondarenko 1968
129	*Manicorpus notabile* Mchedlishvili *in* Samoilovich & Mchedlishvili 1961
131	*Manicorpus pseudosenonicus* n. sp.
133	*Manicorpus rostratus* Srivastava 1968

of the lower Colville River area (fig. 2) began with seismic lines 16–81 and 31–81 (fig. 1). A complication in arranging samples from line 16–81 into stratigraphic order is that some of the shotholes were spudded on the coastal plain at about 100 ft (30.5 m) elevation, and some were spudded in the Colville River valley floor below, at elevations of 25–45 ft (7.6–13.7 m). Considering the geographic locations of the shotholes in this line, the topography, and the dip of the strata, the samples from this line were ordered stratigraphically as shown on the vertical axis of figure 3, the graphic-correlation diagram for seismic lines 16–81 and 31–81.

The line of correlation in figure 3 can be placed with considerable accuracy because (1) the two seismic lines cross (dot enclosed by a diamond in fig. 3), and (2) the slope of the line of correlation is known to be about 45° because the vertical and horizontal axes of the diagram have the same thickness scale and because rates of late Maastrichtian deposition in the areas of the two seismic lines are likely to have been very similar. Placement of the line of correlation also agrees with positions of the error boxes for the palynostratigraphic events in figure 3; these events (range bases and tops) are based on tabulated occurrences of taxa in the two sections.

Composite Section 16–81+31–81 and Seismic Line 41–81

A composite section was drawn for lines 16–81 and 31–81 using the line of correlation in figure 3. The upper part of this composite section appears as the vertical axis in figure 4, a graphic-correlation diagram for composite section 16–81+31–81 and line 41–81. The line of correlation (fig. 4) can be accurately placed because a firm tie-point exists between the two sections (dot enclosed by a diamond in fig. 4) and because the slope of the line is known. However, few palynostratigraphic events are recorded in the thin stratigraphic intervals shown in figure 4, and the error boxes for the events are large because few samples were available, particularly from seismic line 41–81. Therefore, it is fortunate that the line of correlation could be based on the locations of the seismic lines and on the inferred rates of sedimentation. Using the line of correlation in figure 4, samples from line 41–81 could be integrated with those of composite section 16–81+31–81 (vertical axis of fig. 5).

Relative Ages of ARCO Shothole Samples

As noted previously, I reexamined three ARCO shothole samples from east of the Colville River (fig. 1) for which some pollen data had been published by Wiggins (1976). Because the dip in the study area appears to be about 1° ENE, the stratigraphic sequence of the samples, in descending order, should be: line 1, shotpoint 98; line 1, shotpoint 97; line 2, shotpoint 266 (abbreviated here as ARCO samples 98, 97, and 266). ARCO samples 98 and 97 can be fitted into the composite palynostratigraphic section because *Myrtipites scabratus*, *Wodehouseia octospina*, *Porosipollis porosus*, and *Wodehouseia quadrispina* are present in these samples; the first two of these species have defining range bases, and the last two species have defining range tops (fig. 5). Furthermore, ARCO 98 also contains the stratigraphically useful species *Aquilapollenites alaskensis* and *A. conatus*. Both samples lack *Manicorpus delicatus* and *Wodehouseia gracile* and therefore appear to be younger than the range tops of these two species. ARCO 97 contains *Senipites drumhellerensis*; this species has the same observed range top as *M. delicatus* and *W. gracile*, but it occurs in fewer samples within the upper part of its range and therefore has a less distinct last occurrence than the other two species. Thus, these two ARCO samples must be in the uppermost part of the sampled Maastrichtian section of the area, and I consider them to lie biostratigraphically between samples R3819 and R3820 of seismic line 31–81.

ARCO sample 266 contains the stratigraphically important species *Manicorpus delicatus*, *Senipites drumhellerensis*, and *Wodehouseia gracile*, which have defining range tops (fig. 5). *Aquilapollenites conatus*, *Ulmipollenites krempii*, and *Wodehouseia wigginsii* were not found in sample 266; therefore, the sample presumably is older than the range bases of *A. conatus* and *U. krempii* but younger than the range top of *W. wigginsii*. ARCO sample 266 also contains *Wodehouseia vestivirgata*, found west of the Colville River only in sample R3828 from seismic line 31–81 (fig. 5). In short, several lines of evidence lead to the conclusion that ARCO sample 266 is slightly older than sample R3828.

Relative Age of Sample R3328

Sample R3328 is the youngest Cretaceous outcrop sample of Frederiksen and others (1988). On the map (fig. 1) this sample is close to seismic line 16–81, shotpoint 315; the sample from shotpoint 315 (not examined in this study) was collected from a depth of between 75 and 90 ft (23–27 m) below the top of the cliff. Sample R3328 was collected in the cliff face at approximately the same depth as shotpoint sample 315. Sample R3328 contains *Manicorpus delicatus*, *Senipites drumhellerensis*, *Ulmipollenites krempii*, and *Wodehouseia quadrispina*; therefore, the sample should lie below the range tops of *M. delicatus* and *S. drumhellerensis* and above the range bases of *U. krempii* and *W. quadrispina*. The stratigraphically important species *Aquilapollenites conatus* was not seen in sample R3328; thus, the sample may lie below the range base of this species. Accordingly, pollen data do not conflict with the approximate correlation of outcrop sample R3328 with sample R3889 (shotpoint sample 317, seismic line 16–81).

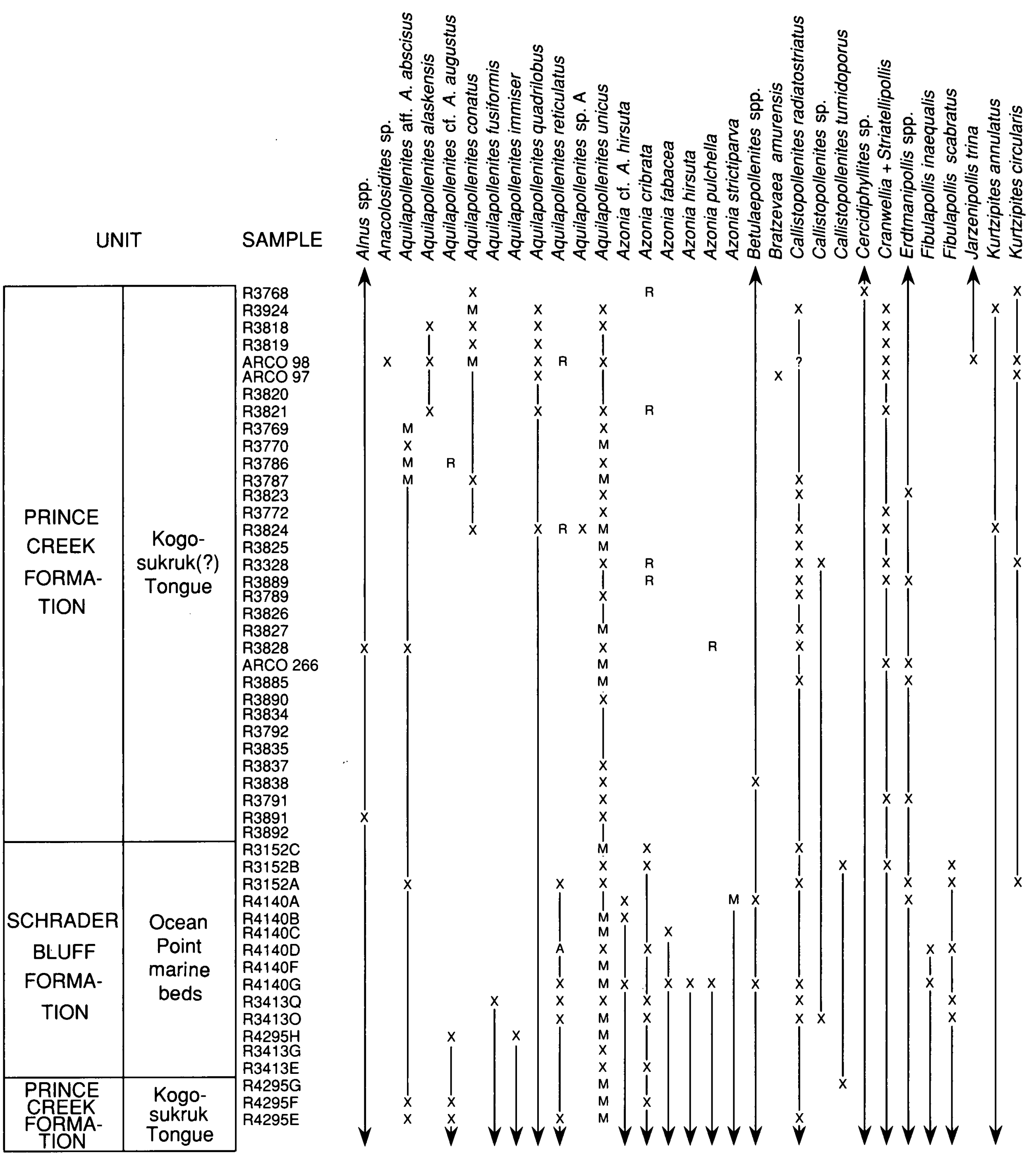


Figure 2. Occurrence and range chart of angiosperm pollen taxa, composite section for zone A and *Wodehouseia spinata* Assemblage Zone of lower Colville River area, North Slope, Alaska. X, present; P, probably present; ?, possibly present; R, interpreted as reworked. Symbol "A" (meaning "affinis") indicates specimens similar to and perhaps conspecific with that species are present. Symbol "M" (meaning "many") indicates that species is most abundant of its group in a sample, provided at least five specimens of species were seen in sample. Groups are: Triprojectate group (*Aquilapollenites* + *Bratzevaea* + *Fibulapollis* + *Manicorpus*) and Oculata group (*Azonia* + *Wodehouseia*). Stratigraphic nomenclature modified from Brosgé and Whittington (1966) and Frederiksen and others (1988). Prince Creek rocks above Ocean Point marine beds were tentatively assigned to Kogosukruk Tongue of formation by Brosgé and Whittington (1966). Spacing of samples not to scale. Obliquely ruled parts of Subzone column denote transitional boundaries. Arrows denote species is present above and (or) below section.

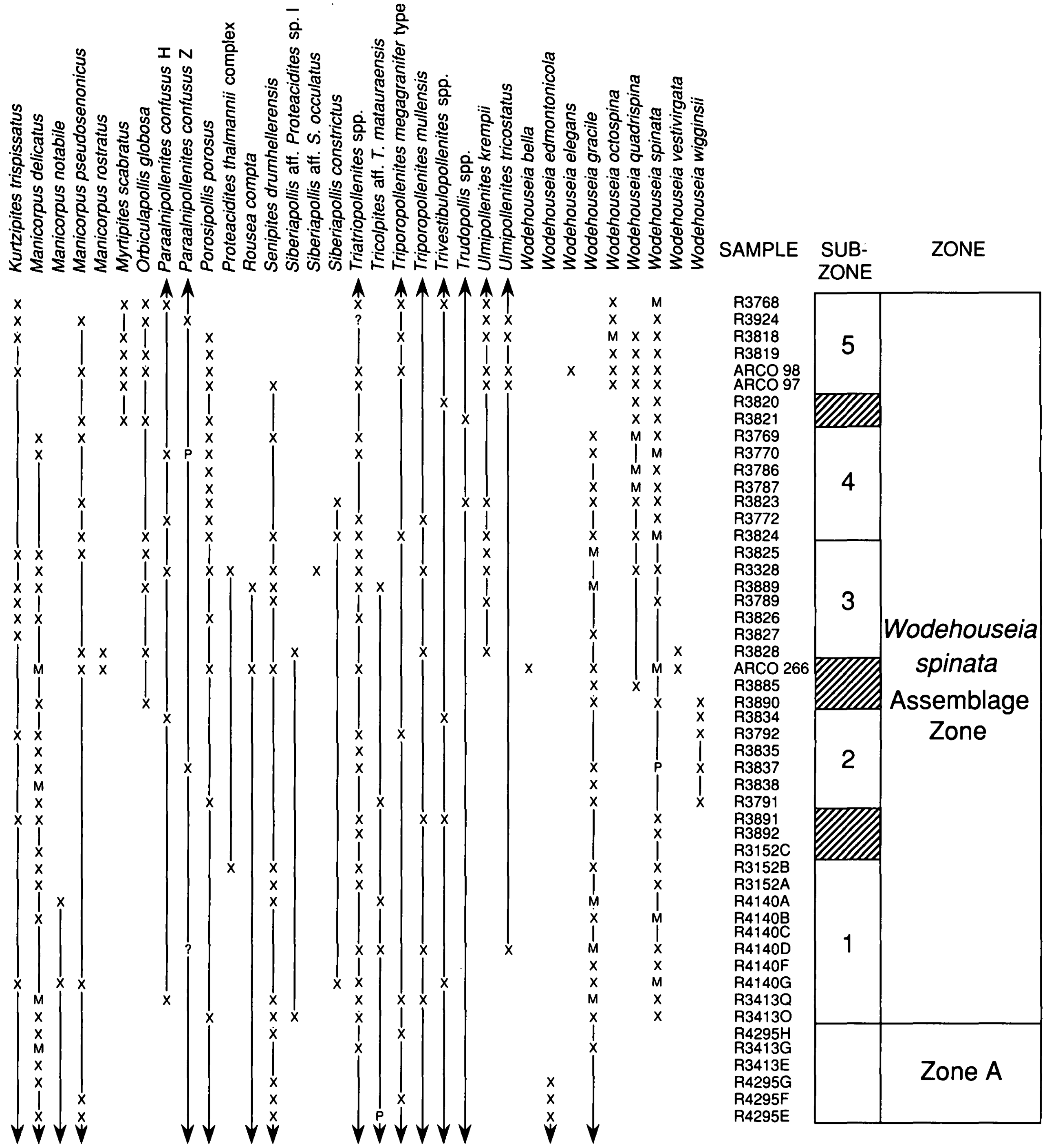


Figure 2.—Continued

Summary of Composite Palynostratigraphic Section

Shothole samples from USGS seismic lines were placed in stratigraphic order using graphic correlation. The three ARCO shothole samples and outcrop sample R3328 were added to the composite palynostratigraphic section for the sake of completeness, but they add little to the knowledge of species ranges except to place in the sequence the occurrences of *Wodehouseia bella* and *W. elegans*. Stratigraphically below the USGS shothole samples are 17 outcrop samples whose positions are well known (Phillips, 1988).

The result of sample compositing is the final composite range chart for 64 pollen taxa in 50 samples (fig. 2) representing the "middle" and upper Maastrichtian in the lower Colville River area. As noted in the following section of the paper, the top of the section in figure 2 is probably within 7 to 21 m of the Cretaceous-Tertiary boundary in the area. The base of the study section is taken as the lowest occurrence of *Aquilapollenites unicus*, which is in section 15 of Phillips (1988, sample 86EB93). The base of the study section is about 14 to 17 m above the highest tephra bed and the highest strata containing vertebrate fossils shown in Phillips' (1988) sections.

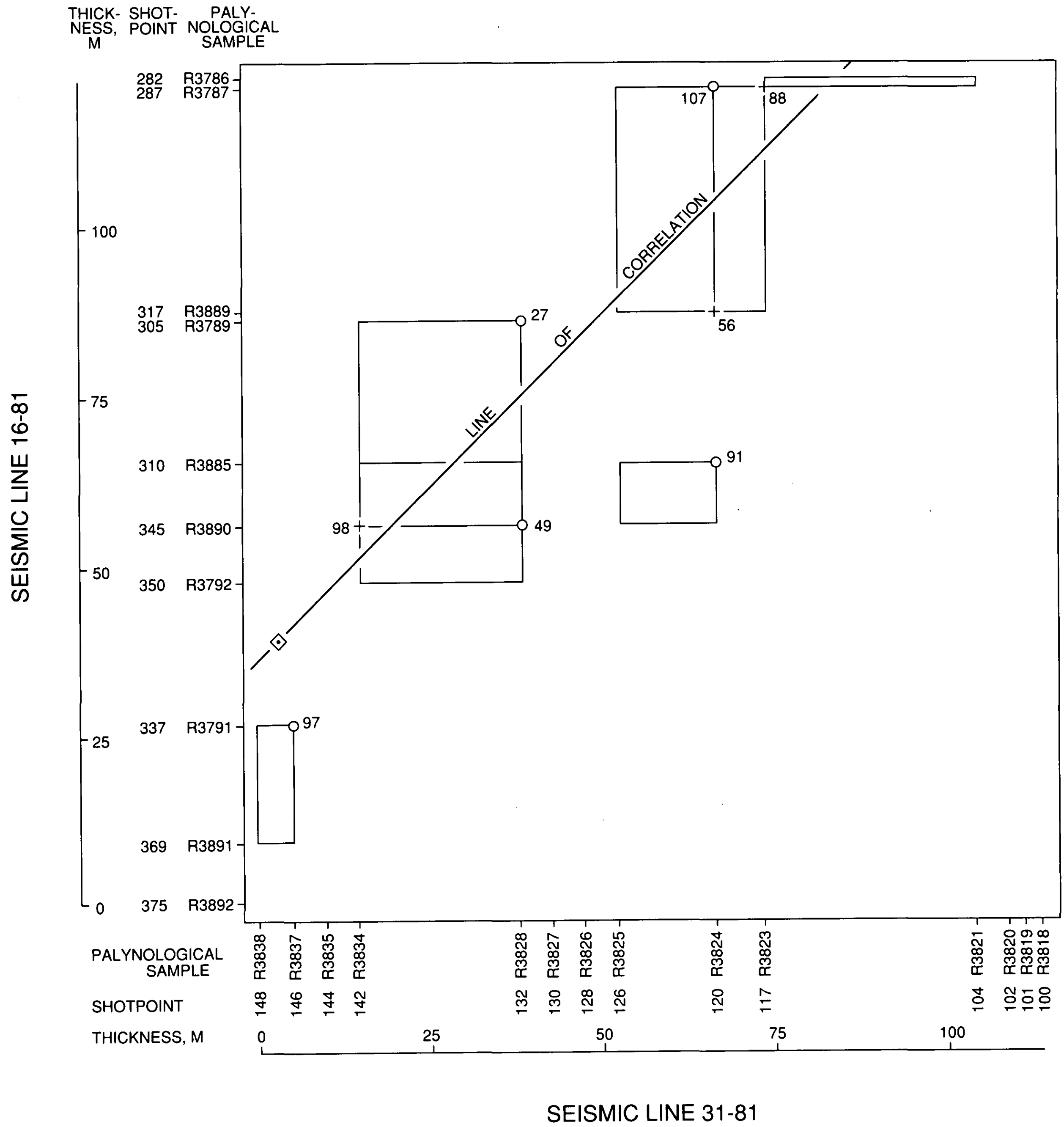


Figure 3. Graphic correlation of stratigraphic sections based on shothole samples from seismic lines 16-81 and 31-81 (see fig. 1 for location of seismic lines). Dot enclosed by diamond is where two seismic lines cross. Data points are events (o, range base; +, range top) accompanied by event numbers.

ZONATION OF COMPOSITE PALYNOSTRATIGRAPHIC SECTION

The composite palynostratigraphic section for the "middle" and upper Maastrichtian of the lower Colville River area has been divided into two pollen zones (table 2; figs. 2, 6). These are zone A and the overlying *Wodehouseia spinata* Assemblage Zone of Nichols and others (1982) and Nichols and Sweet (in press). Correlation of these zones with other regions is discussed in the section "Correlation of Sections in Colville River Region and Northwestern Canada."

The base of zone A is the range base of *Aquilapollenites unicus*. As mentioned previously, in the lower Colville River area this palynostratigraphic event occurs in section 15 of Phillips (1988, sample 86EB93; sample R4295E of fig. 2). In the study area, the range base of *A. unicus* is somewhat more distinct than the range base of *Wodehouseia spinata* because *A. unicus* is nearly ubiquitous and is usually the most abundant

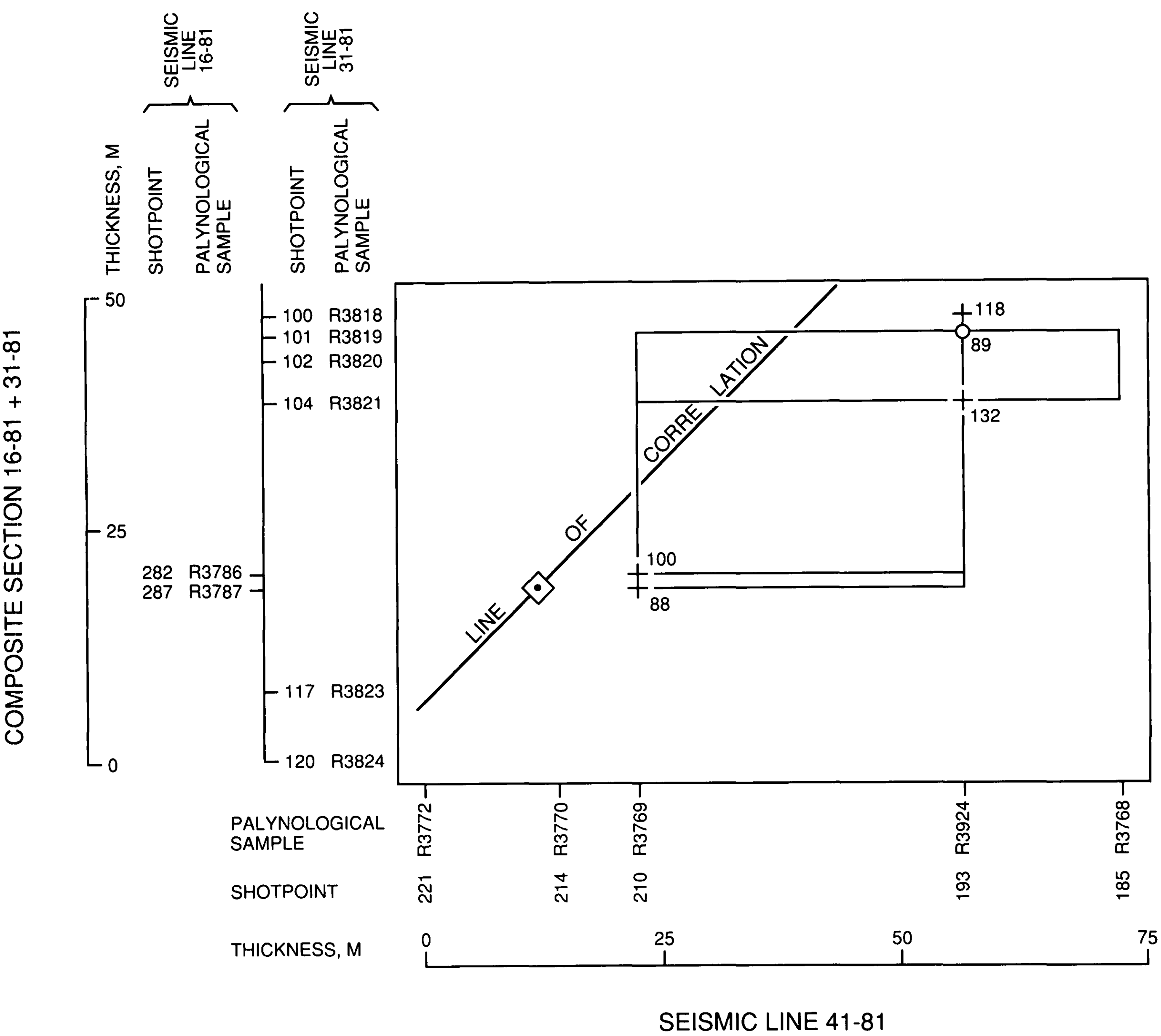


Figure 4. Graphic correlation of a stratigraphic section based on shothole samples from seismic line 41-81 with the composite section based on shothole samples from seismic lines 16-81 and 31-81 (see fig. 1 for location of seismic lines). Dot enclosed by diamond is where seismic lines 41-81 and 16-81 cross. Data points are events (o, range base; +, range top) accompanied by event numbers.

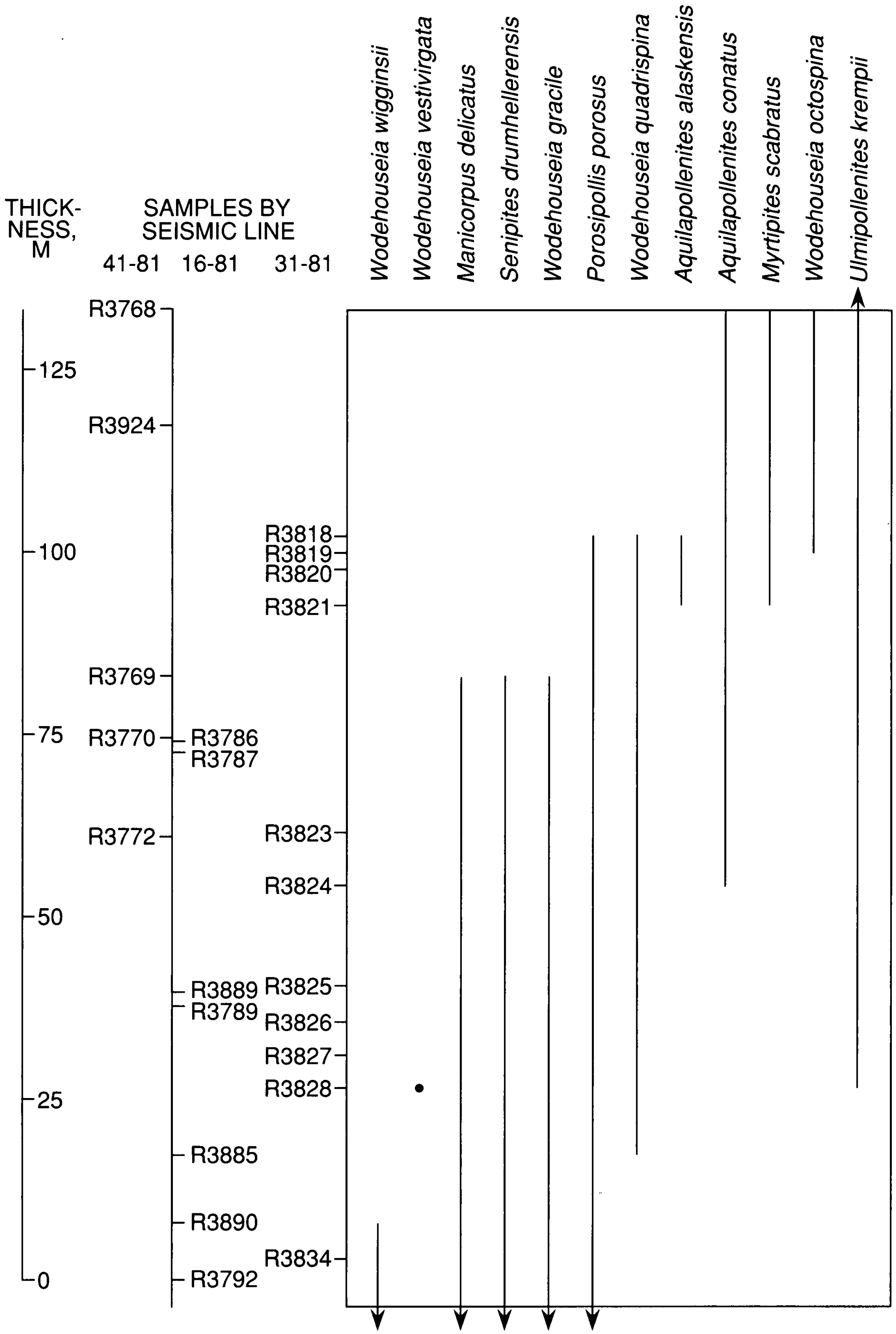


Figure 5. Ranges of some stratigraphically important pollen taxa in samples from composite palynostratigraphic section constructed by graphic correlation of shothole samples from seismic lines 16-81, 31-81, and 41-81. See figures 3 and 4 for graphic correlation and figure 1 for location of seismic lines. Dot indicates species was found in only one sample. Arrows denote species is present above and (or) below section.

Table 2. Definitions of "middle" and upper Maastrichtian pollen zones and tentative subzones, Colville River region, North Slope, Alaska

[Numbers following species names are event numbers, most of which are in figure 8. Ranges of defining species are shown in figure 6]

Zone	Subzone	Datum(s) defining base of zone or subzone
Wodehouseia spinata Assemblage Zone	5	Range bases of *Wodehouseia octospina* (89) and *Myrtipites scabratus* (47); range tops of *Wodehouseia gracile* (88), *Aquilapollenites* sp. aff. *A. abscisus* (100), and *Manicorpus delicatus* (128); occurrence of *Aquilapollenites alaskensis* (101)
	4	Range base of *Aquilapollenites conatus* (107)
	3	Range bases of *Ulmipollenites krempii* (27), *Orbiculapollis globosa* (49), and *Wodehouseia quadrispina* (91); range top of *Wodehouseia wigginsii* (98)
	2	Range base of *Wodehouseia wigginsii* (97)
	1	Range base of *Wodehouseia spinata* (93); approximate markers are the range tops of *Wodehouseia edmontonicola* (84), *Aquilapollenites* sp. cf. *A. augustus* (106), and *Fibulapollis scabratus* (126)
Zone A		Range base of *Aquilapollenites unicus* (117)

species of the triprojectate group throughout the lower part of its range (fig. 2). In the study area, the boundary between zone A and the *Wodehouseia spinata* Assemblage Zone is primarily defined by the lowest occurrence of *Wodehouseia spinata*, but the zone boundary is also marked approximately by the range tops of *Aquilapollenites* sp. cf. *A. augustus* and *Fibulapollis scabratus* and particularly by the stratigraphically important range top of *Wodehouseia edmontonicola*. In this area, zone A is about 36 m thick (fig. 6).

The *Wodehouseia spinata* Assemblage Zone has been intensively studied in North America, as discussed in the section "Pollen Zonation of the Western Interior." In the lower Colville River area, the pollen assemblage in sample R34130 marks the base of this zone (fig. 2), at a level that is near the top of section 22 of Phillips (1988). *W. spinata* has been observed in most but not all samples within the lower part of its range; in these samples, it is sparse to moderately abundant. *W. spinata* is more consistently present in the upper part of the upper Maastrichtian in this area. In the study area, the *W. spinata* Assemblage Zone is slightly more than 200 m thick (fig. 6) and has been divided into five tentative subzones, as shown in table 2. The boundaries of several of these subzones are somewhat transitional (fig. 6) because the range tops and bases defining each subzone boundary are not always at the same horizon. Several species additional to those listed in table 2 might have been used to define subzone boundaries, but these species, for example *Aquilapollenites reticulatus* and *Azonia cribrata*, are so common within their stratigraphic ranges that they are found as reworked specimens higher in the section; thus, the true range tops of these species are not very well known.

The tentative subzones of table 2 and figure 6 are relatively thin—typically about 40 m—and will be difficult to recognize in other places except where detailed sampling is possible. Nevertheless, the subzonation scheme emphasizes that, in the lower Colville River area and presumably throughout the North Slope of Alaska, the *Wodehouseia spinata* Assemblage Zone—representing roughly the latter half of Maastrichtian time—can be subdivided using range tops and bases of important pollen species.

CORRELATION AND AGE OF COMPOSITE SECTION

This part of the paper is (1) a review of previous Maastrichtian pollen work that has been done in the Colville River region and in northwestern Canada, (2) a summary of the late Maastrichtian pollen zonation of the Western Interior of North America, where this zonation has been tied to occurrences of marine fossils and dinosaurs, (3) a summary of previous paleontological conclusions about the age of the section sampled for this paper, and (4) a discussion of pollen correlations from the Colville River study area to the northern Western Interior that aid in determining the age of the strata in the study area.

Previous Palynological Work in Colville River Region and Northwestern Canada

A relatively small number of papers and abstracts have been published on the Campanian and Maastrichtian palynology of the Colville River region, mainly in the past several years (Tschudy, 1969; Wiggins, 1976, 1981, 1982; Frederiksen and others, 1985, 1986, 1988; Frederiksen, 1986, 1989; Brouwers and others, 1987; Frederiksen and Schindler, 1987). What has been lacking for the North Slope of Alaska is detailed knowledge of

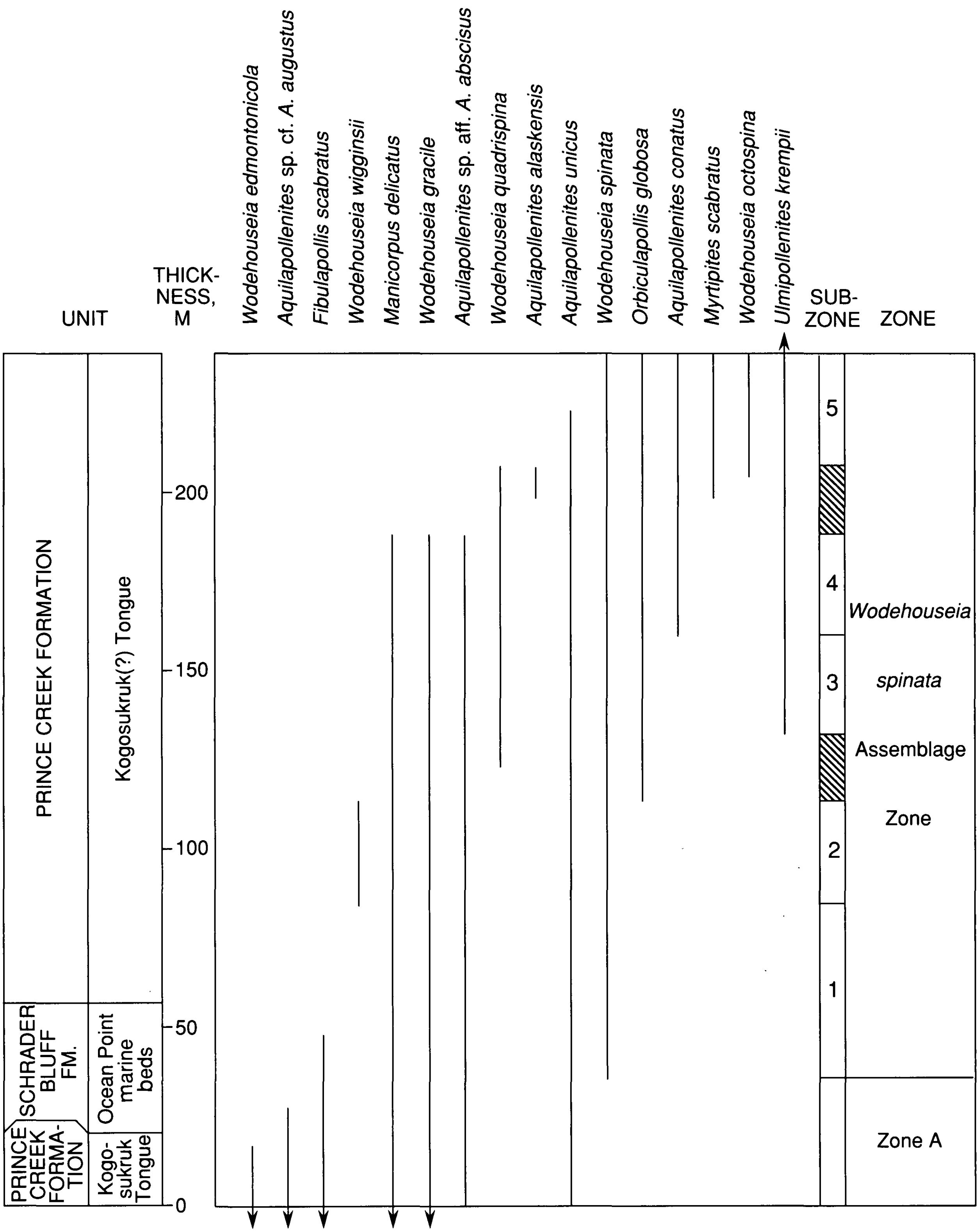


Figure 6. Ranges of pollen taxa used for zonation and subzonation (table 2) of composite palynostratigraphic section for the "middle" and upper Maastrichtian strata in Ocean Point area of lower Colville River (fig. 2). Obliquely ruled portions of Subzone column denote transitional subzone boundaries. Arrows denote species is present above and (or) below section.

the Upper Cretaceous pollen stratigraphy. The most detailed palynostratigraphic papers published thus far are by Wiggins (1976) and Frederiksen and others (1988). Wiggins (1976, table 1) provided Campanian and Maastrichtian pollen ages for several specific localities near Ocean Point and to the south on the Colville River. His age determinations, particularly for the Maastrichtian, were based mainly on pollen correlations with other regions of northern North America and Siberia. Building on Wiggins' work, Frederiksen and others (1988) studied palynomorph assemblages from 8 Cretaceous outcrop samples from the Ocean Point area and 11 Paleocene outcrop samples from localities east and northeast of Ocean Point. Their data helped in determining an approximate position of the Cretaceous-Tertiary boundary in the area.

After completing work that was included in Frederiksen and others (1988), T.A. Ager (written commun., 1988) examined 11 pollen-bearing seismic shothole samples and additional outcrop samples from northeast of the Cretaceous samples studied for this paper. His determination of Paleocene ages for these new samples, based on palynological evidence, means that the stratigraphically highest sample considered in this paper is within 7 to 21 m of the Cretaceous-Tertiary boundary.

The uppermost part of the Cretaceous sequence of the lower Colville River area must be very late Maastrichtian in age because it contains pollen species that elsewhere in the Western Interior are not present below the uppermost Maastrichtian. These are *Ulmipollenites krempii*, *Myrtipites scabratus*, and *Wodehouseia quadrispina*. In western Canada from Alberta to the southwestern Canadian Arctic Islands, the uppermost parts of many Cretaceous sections consist of an interval, 12 cm to 30 m thick, in which the angiosperm component of the pollen flora is of very low diversity (Doerenkamp and others, 1976, zone CVII; Jerzykiewicz and Sweet, 1986; Lerbekmo and others, 1987; Sweet, 1988; Sweet and Braman, 1988). This uppermost Maastrichtian interval may be represented in the study area by the interval of decreased pollen diversity that forms the uppermost 30 m of the lower Colville River composite palynostratigraphic section (Frederiksen, 1989, fig. 3). However, only two samples were examined palynologically from this interval (R3768 and R3924 of figs. 2 and 6); therefore, details are lacking about the diversity decrease at the top of the Cretaceous section.

Maastrichtian pollen species from northwestern Canada have been listed in theses and published papers (fig. 7). The most thorough pollen-stratigraphic work in this region is by Nichols and Sweet (in press) on the Bonnet Plume basin, Yukon Territory (fig. 7, loc. E) and Brackett basin, Northwest Territories (fig. 7, loc. F), by Sweet and others (1989) on the Brackett basin, and by McIntyre (1974), Doerenkamp and others (1976), Sweet (1978), Wilson (1978), and Kalgutkar and Sweet (1988) in the Mackenzie Delta region (fig. 7, loc. D).

Pollen Zonation of the Western Interior

Nichols and others (1982) provided a palynomorph zonation for the Cretaceous rocks of the central and northern Rocky Mountains region of the United States. They defined the *Wodehouseia spinata* Assemblage Zone to include rocks between the range base of the nominate species and the range tops of many latest Cretaceous species, range tops that were demonstrated to coincide with the Cretaceous-Tertiary boundary. The *Wodehouseia spinata* Assemblage Zone is considered to be late Maastrichtian; because marine fossils and dinosaurs are present in the rocks assigned to this pollen zone in the Rocky Mountains, the zone is believed "to be equivalent to the zone of the ammonite *Hoploscaphites nicolleti* and stratigraphically overlying biozones, including the nonmarine biozone of the dinosaur genus *Triceratops*" (Nichols and others, 1982, p. 729). In the Western Interior (except in Alberta), the base of the *Wodehouseia spinata* Assemblage Zone is thought to approximate the boundary between the lower and upper Maastrichtian (Nichols and Sweet, in press). This boundary is estimated to have an age between 71 and 70 Ma, and the age of the Cretaceous-Tertiary boundary is about 66.5 Ma (Haq and others, 1987). Thus, the *W. spinata* Assemblage Zone probably represents approximately 4 m.y. of time (Nichols and others, 1982). It must be pointed out that the *Wodehouseia spinata* Assemblage Zone of Nichols and others (1982) (and Nichols and Sweet, in press) differs from the *Wodehouseia spinata* Zone of Srivastava (1970), which includes lowermost Paleocene strata (Lerbekmo and others, 1987).

Nichols and Sweet (in press) conducted an extensive review of geologic and geographic ranges of pollen species in the Upper Cretaceous rocks from New Mexico to northwestern mainland Canada. They showed that *Wodehouseia spinata* appears to have an approximately isochronous range base nearly throughout the Western Interior; the only area where the range base of the species is known to be a different age is in Alberta, where the first appearance of *W. spinata* is younger than elsewhere.

Regional pollen zonations for parts of northwestern Canada have also been proposed, and these will be discussed herein.

Previous Conclusions About Age of Sampled Section

Most of the strata studied for this paper lack marine fossils; thus, at present, pollen grains are the most important

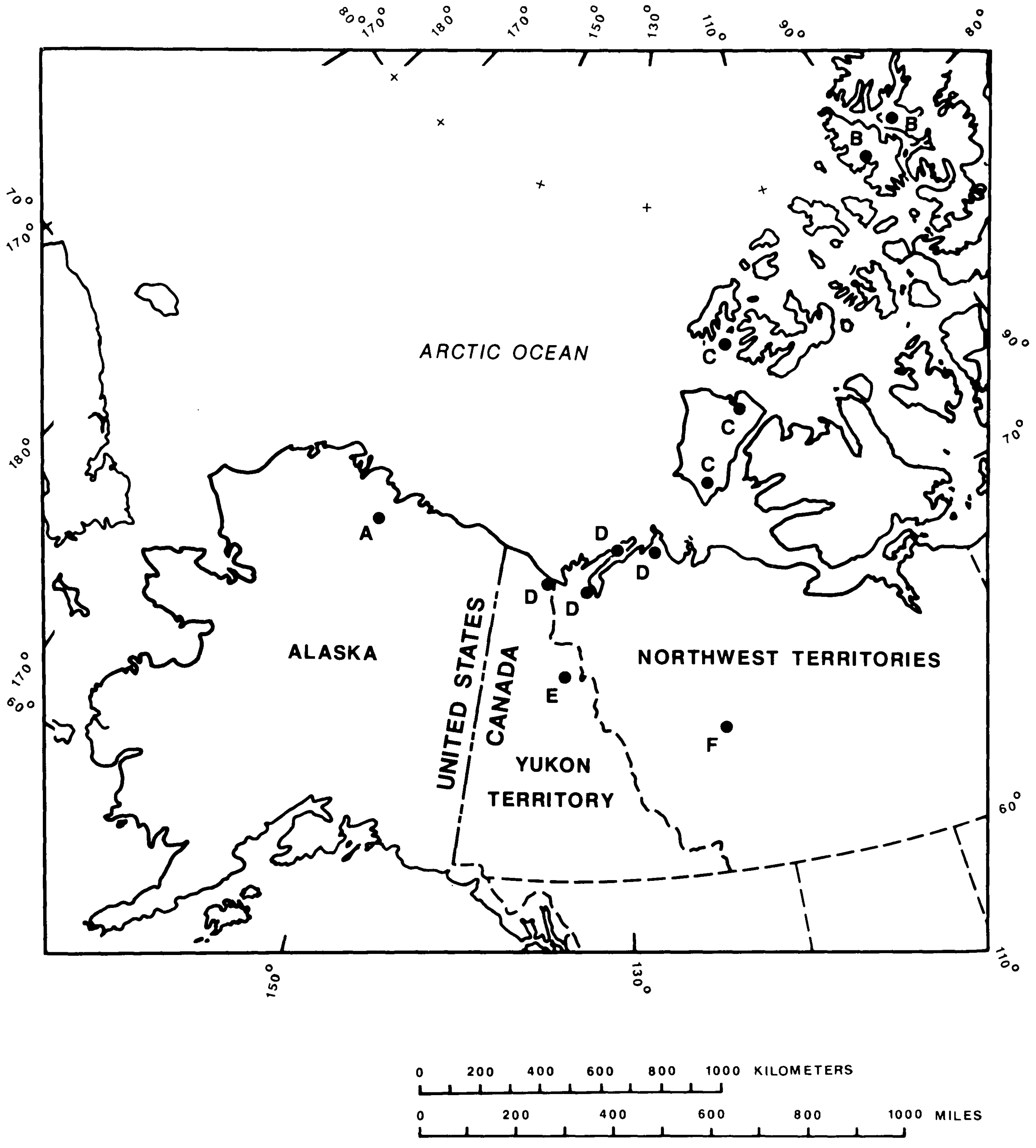


Figure 7. Map of northern North America showing localities from which Maastrichtian pollen has been described. Locality A is Colville River study area; other localities are from the following papers and theses: B—Choi (1983); C—Doerenkamp and others (1976); D (Mackenzie Delta region)—McIntyre (1974), Doerenkamp and others (1976), Sweet (1978), Wilson (1978), Kalgutkar and Sweet (1988); E (Bonnet Plume basin)—Rouse and Srivastava (1972), Kalgutkar and Sweet (1988), Nichols and Sweet (in press); F (Brackett basin)—Bihl (1973), Wilson (1978), Sweet and others (1989), Nichols and Sweet (in press).

fossils for dating the bulk of the sequence. A variety of marine fossils (mainly mollusks, ostracodes, benthic foraminifers, and dinoflagellate cysts) have been studied from the Ocean Point marine beds (fig. 6), but the interpretation of some of these marine fossils is controversial.

Using mollusk and ostracode evidence, Marincovich and others (1985, 1986) and Brouwers (1988) suggested that the Ocean Point marine beds are early Tertiary in age. However, most species of mollusks and ostracodes in these beds are endemic to the North Slope; thus, the ages of these fossils are uncertain. On the basis of benthic foraminifers, the Ocean Point marine beds were originally thought to be late Campanian in age (Macbeth and Schmidt, 1973) but are now considered to be early Maastrichtian (McDougall, 1987) or late Maastrichtian (W.V. Sliter, oral commun., 1989). Dinoflagellate cyst evidence suggests that the Ocean Point marine beds are late Campanian or Maastrichtian in age (Frederiksen and others, 1988).

On the basis of pollen data that were explained only in part, Wiggins (1976, fig. 2 and table 1) showed the Ocean Point marine beds as approximately mid-Maastrichtian, and he dated several samples from seismic shotholes lying southeast of Ocean Point as late Maastrichtian in age. Also on the basis of pollen evidence, but without making detailed correlations with other regions, Frederiksen and others (1988) considered the Ocean Point marine beds to be mid-Maastrichtian in age and placed the Cretaceous-Tertiary boundary about 7.5 km northeast (upsection) of Ocean Point.

Marincovich and others (1985, 1986) suggested that the Cretaceous palynomorphs in the Ocean Point beds may be redeposited specimens. However, the occurrence of late Maastrichtian pollen taxa (for example, *Wodehouseia quadrispina*, *W. octospina*, *Aquilapollenites conatus*) above but not in or below the Ocean Point beds (fig. 2) indicates that the Ocean Point marine beds underlie upper Maastrichtian strata and therefore are Late Cretaceous in age. Furthermore, the order in which particular pollen events (range bases and tops) occur is the same in all three seismic-line sections west of the Colville (figs. 3, 4); this similarity of event ordering in different parts of the area strongly suggests that the observed sequence of range bases and tops reflects evolution, extinction, immigration, and emigration and is not due to reworking.

Correlation of Sections in Colville River Region and Northwestern Canada

Three zonations based at least partly on pollen have been proposed for Upper Cretaceous stratigraphic sequences in northwestern Canada. Doerenkamp and others (1976) established a pollen and dinoflagellate zonation for the Mackenzie Delta region (fig. 7, loc. D) and the southwestern region of the Canadian Arctic Islands (fig. 7, loc. C). Their zones CVIc and CVII are equivalent to the *Wodehouseia spinata* Assemblage Zone of the Western Interior. However, Doerenkamp and others (1976) did not provide detailed range data for Maastrichtian pollen species in their study region. Sweet and others (1989) proposed a tentative pollen zonation for the Brackett basin, Northwest Territories (fig. 7, loc. F); this zonation used pollen species names as zone identifiers (fig. 8). Finally, Sweet (in Nichols and Sweet, in press) created an additional tentative zonation that applied to a composite palynostratigraphic section for the Brackett basin, Northwest Territories, and Bonnet Plume basin, Yukon Territory (fig. 7, loc. E); this zonation used numerals as identifiers, and the zones were termed assemblages (fig. 8). Independent age assignments are generally lacking for the Maastrichtian sequences in the Bonnet Plume and Brackett basins; thus, ages of the zones and assemblages were mainly determined by correlating them with pollen assemblages in Alberta, Montana, and Wyoming that were independently dated on the basis of marine and vertebrate fossils. Nichols and Sweet considered their assemblage 9 to be "early late Maastrichtian" and assemblage 10 to be "latest Maastrichtian" on the basis of these correlations; ages assigned to the zones of Sweet and others (1989) are shown in figure 8.

A graphic-correlation diagram (fig. 8) was constructed by comparing pollen range bases and tops on the North Slope of Alaska (fig. 2) with those in coeval rocks of the Brackett basin in northwestern Canada (Nichols and Sweet, in press, table 1 and fig. 5; Sweet and others, 1989; Sweet, written commun., 1989). In Maastrichtian time, the North Slope (fig. 7, loc. A) was at a latitude of approximately 79°, and the Brackett and Bonnet Plume basins (fig. 7, locs. F, E) were at a latitude of approximately 71° (calculated on the basis of maps 19 and 23 of Smith and others, 1981).

It is easy to make generalized pollen correlations of "middle" to late Maastrichtian rocks between the North Slope of Alaska and northwestern Canada, but it is difficult to make very detailed correlations between the two regions, for several reasons. First, some stratigraphically important species found in northwestern Canada were not observed in the North Slope samples, for example *Aquilapollenites attenuatus* Funkhouser 1961, *A. reductus* Norton 1965, *A. parallelus* Tschudy 1969, *A. delicatus* Stanley 1961 var. *collaris* Tschudy & Leopold 1971, and *Manicorpus gibbus* Srivastava 1968; all of these species except *Aquilapollenites parallelus* occur as far south as the Wyoming-Montana-Alberta region, but the ranges of the producing plants may not have extended as far north as the North Slope. Conversely, some species found on the North Slope have not been recorded from northwestern Canada, apparently because their ranges did not extend that far south; examples are *Aquilapollenites alaskensis*, *Fibulapollis* *inaequalis*, *F. scabratus*, *Wodehouseia vestivirgata*, and *W. wigginsii*. A second difficulty in using pollen for detailed correlations between sections in the North Slope and northwestern Canada is that some species common

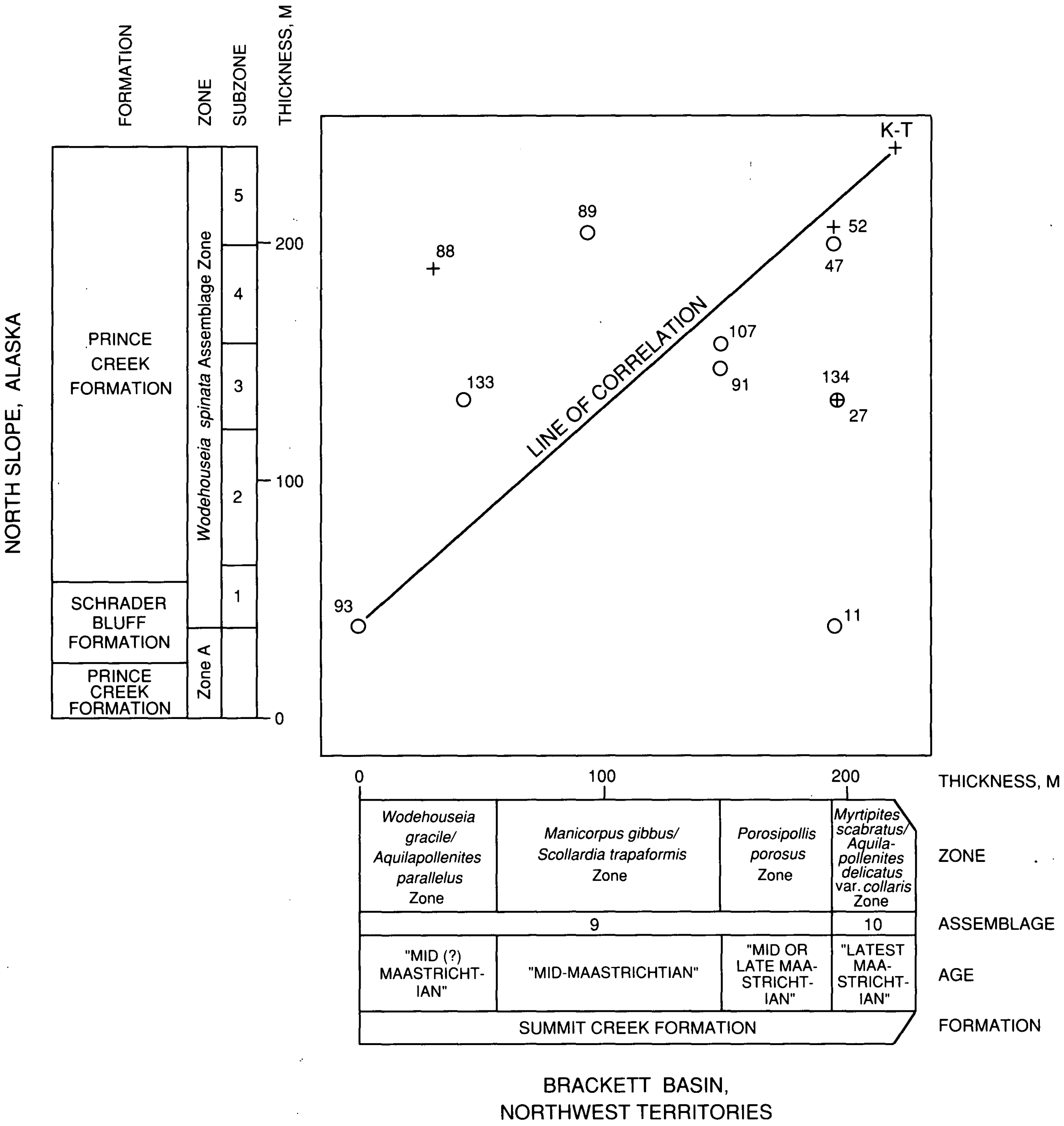


Figure 8. Graphic correlation of North Slope composite section (fig. 7, loc. A) with coeval rocks of Brackett basin, Northwest Territories (fig. 7, loc. F). Data points are events (o, range base; +, range top) accompanied by event numbers. Range top event labeled K-T is Cretaceous-Tertiary boundary defined by range tops of several Maastrichtian pollen species (see text). On horizontal axis, the thickness, zone, age, and formation columns are from Brackett basin (Sweet and others, 1989, p. 89–98); assemblages pertain to both Brackett and Bonnet Plume basins and are from Nichols and Sweet (in press). Base of section shown for Brackett basin is base of assemblage 9 and base of the *Wodehouseia gracile*/*Aquilapollenites parallelus* Zone.

to the two regions appear to have diachronous range tops and (or) range bases within northern North America, as shown by the distance of these event points from the line of correlation in figure 8. Examples of apparently diachronous events are 88 (range top of *Wodehouseia gracile*), 89 (range base of *W. octospina*), 27 (range base of *Ulmipollenites krempii*), and 11 (range base of *Paraalnipollenites confusus* type H).

The upper end of the line of correlation in figure 8 is at the Cretaceous-Tertiary boundary on the North Slope and in the Brackett basin. Not shown on the diagram are individual range tops of many species that are at or slightly below the Cretaceous-Tertiary boundary in both regions (for example, range tops of *Aquilapollenites conatus*, *Wodehouseia spinata*, *W. octospina*, and *Myrtipites scabratus*); these range tops in the North Slope section are shown in figures 2 and 6.

Nichols and Sweet (in press) concluded that the range base of *Wodehouseia spinata* (event 93) in the Brackett and Bonnet Plume basins of northwestern Canada was approximately isochronous with the same event in the Western Interior of the United States. However, Sweet (written commun., 1989) believes that the range base of the species may be slightly older in northwestern Canada than in the Wyoming-Montana-Alberta region. In any case, it seems reasonable to assume that the range base of *W. spinata* is approximately the same age on the North Slope of Alaska as in northwestern Canada, and for this reason event 93 is used to anchor the lower end of the line of correlation in figure 8. The range base of *W. spinata* is by definition the base of the *Wodehouseia spinata* Assemblage Zone of Nichols and others (1982) and Nichols and Sweet (in press), the base of the *Wodehouseia gracile/Aquilapollenites parallelus* Zone of Sweet and others (1989), and the base of Assemblage 9 of Nichols and Sweet (in press).

In contrast to the probably isochronous range base of *Wodehouseia spinata*, the range base of *Aquilapollenites unicus* (not shown in fig. 8) is apparently highly diachronous in northwestern North America. On the North Slope, the latter event marks the base of zone A but is stratigraphically only about 36 m below the range base of *Wodehouseia spinata* (event 93). In the Bonnet Plume basin, the range base of *A. unicus* is within assemblage 8, in rocks thought to be "middle" Maastrichtian in age (Nichols and Sweet, in press), but apparently it is stratigraphically well below the range base of *W. spinata* in that basin. In the Brackett basin, the range base of *A. unicus* may be late Campanian according to Sweet and others (1989) and therefore much older than the same event on the North Slope or in the Bonnet Plume basin.

As noted previously, the range base of *Paraalnipollenites confusus* type H (event 11) is well below the line of correlation; its position suggests this event is much older on the North Slope of Alaska than in the Brackett basin. However, specimens of *P. confusus* type H are rare in the Maastrichtian of the Bonnet Plume and Brackett basins (A.R. Sweet, written commun., 1988), and only scattered occurrences of the species are noted in the Maastrichtian of the North Slope (fig. 2); thus, the true range bases of *P. confusus* type H are probably not very well known in different regions of northern North America. Events 133 and 134 are the range base and range top, respectively, of *Manicorpus rostratus*; this species has a much longer stratigraphic range in the Brackett basin than on the North Slope.

On the North Slope of Alaska, the range base of consistently occurring *Wodehouseia quadrispina* (event 91) is stratigraphically below the range base of *W. octospina* (event 89), but in the Brackett basin the reverse is true (Sweet, written commun., 1989). However, in both regions the presence of these two species is a useful marker for approximately the upper fourth of the Maastrichtian Stage (assuming that in these regions the range base of *Wodehouseia spinata* is mid-Maastrichtian or late early Maastrichtian in age). The range bases of *Aquilapollenites conatus* (event 107) and *Myrtipites scabratus* (event 47) and the range top of *Porosipollis porosus* (event 52) seem to be approximately isochronous in the Brackett basin and on the North Slope.

Nichols and Sweet (in press) noted that in the Bonnet Plume and Brackett basins, the ranges of *Wodehouseia gracile* and *W. spinata* only slightly overlap; this is shown in figure 8 by the range top of *Wodehouseia gracile* (event 88) lying stratigraphically above the range base of *W. spinata* (event 93), but both events are in the lower part of assemblage 9. Conversely, Nichols and Sweet noted that farther north, in the Mackenzie Delta region (fig. 7, loc. D), there is a greater overlap of ranges for *Wodehouseia gracile* and *W. spinata*. An even greater interval of overlap of the two species exists on the North Slope of Alaska, where event 88 is stratigraphically far above event 93. In short, *W. gracile* apparently died out earlier in the south than in the north. The stratigraphically high occurrences of *W. gracile* on the North Slope are not likely to consist of reworked specimens, because *W. gracile* is found in many samples throughout its stratigraphic range, and it is the most abundant species of the Oculata group (*Azonia* + *Wodehouseia*) in some samples as high as subzone 3 of the *Wodehouseia spinata* Assemblage Zone (fig. 2).

CONCLUSIONS

1. The first detailed palynostratigraphic section is published for rocks on the North Slope of Alaska; it shows ranges of 64 angiosperm pollen taxa in 50 outcrop and seismic shothole samples from the "middle" and upper Maastrichtian. Six of the species are new.

2. The composite study section consists of two pollen zones. These are, in ascending order, zone A (a new, tentative zone) and the *Wodehouseia spinata* Assemblage Zone of Nichols and others (1982). In the study area, the *Wodehouseia spinata* Zone is divisible into five tentative subzones that will make detailed correlations in the region more reliable than was previously possible.

3. The study section for the lower Colville River is correlated on the basis of pollen with "middle" to upper Maastrichtian strata of the Brackett basin, Northwest Territories of Canada. The Brackett basin had previously been correlated, also on the basis of pollen, with Upper Cretaceous sequences of the Western Interior that were reliably dated with ammonites, dinosaurs, and the iridium anomaly marking the Cretaceous-Tertiary boundary. Pollen correlation shows that the top of the Cretaceous section along the lower Colville River is latest Maastrichtian in age.

4. The Ocean Point marine beds on the Colville River are within the *Wodehouseia spinata* Assemblage Zone. These marine beds are "middle" Maastrichtian, as determined by pollen correlations.

TAXONOMY

The following six new species are herein formally named, illustrated, and described:

Rousea compta
Azonia strictiparva
Wodehouseia wigginsii
Aquilapollenites alaskensis
Fibulapollis inaequalis
Manicorpus pseudosenonicus

Two additional new species, *Aquilapollenites* sp. cf. *A. augustus* and *Aquilapollenites* sp. A, are also illustrated and described. In addition, two new combinations (*Siberiapollis constrictus* and *Aquilapollenites magnus*) are proposed, the morphology of *Azonia hirsuta* is discussed, and evidence as to the range top of *Aquilapollenites unicus* is reviewed. Details on sample locations are given in the "Sample Locality Register."

Rousea compta n. sp. (taxon 53)
Plate 1, figures 21–26; plate 2, figures 1–3

Holotype.—Slide 16408-4(B), coordinates 38.1×109.0; pl. 1, figs. 21–23; west bank of Colville River, Umiat D-3 quadrangle, lower Maastrichtian.

Description.—Prolate to subprolate tricolpate pollen grains. Polar axis 25–39 μm; equatorial axis 17–29 μm (10 measured specimens); holotype 30×19 μm. Poles moderately to rather broadly rounded. Colpi extend ¾–⅘ length of polar axis; margins of colpi not thickened. Exine 1–2 μm thick; ektosexine, endosexine, and nexine about the same thickness. Most of exine is rather coarsely reticulate, maximum diameter of brochi in different specimens is 1–2 μm. However, the brochi are much smaller at the poles, mainly <0.5 μm.

Remarks.—This species is characterized by the distinct difference in size of brochi between the poles and most of the remainder of the grain (*compta*, Latin for "ornamented").

Distribution.—Lower Maastrichtian to upper Maastrichtian (to subzone 3 of the *Wodehouseia spinata* Assemblage Zone) of the Colville River area.

Siberiapollis constrictus (Samoilovich _in_ Samoilovich & Mchedlishvili 1961) n. comb. (taxon 57)
Plate 2, figures 4, 5

Basionym.—*Proteacidites constrictus* Samoilovich *in* Samoilovich and Mchedlishvili, 1961, p. 182, pl. 57, figs. 3–4.

Remarks.—*Proteacidites* is triporate, but this species is distinctly brevitricolporate.

Azonia hirsuta (Samoilovich 1965) Wiggins 1976 (taxon 73)
Plate 2, figures 8, 9, 12

Jacutiana hirsuta Samoilovich, 1965, p. 131–132, fig. 11a, b; pl. 4, figs. 1a–g, 2a–g.
Ocellipollis munitus Chlonova, 1966, p. 66–67, pl. 1, figs. 1–4.
Azonia hirsuta (Samoilovich) Wiggins, 1976, p. 61.

Remarks.—The two specimens of *Jacutiana hirsuta* illustrated by Samoilovich (1965) do not have obvious apertures, but the outlines of the specimens have weakly expressed indentations where apertures would be if the grains lay in equatorial view. The holotype of *Ocellipollis munitus* is almost identical to the holotype of *Jacutiana hirsuta* except that the holotype of *O. munitus* has distinct slit-like apertures; therefore, Wiggins (1976) was justified in considering the two species to be conspecific. The other specimens of *O. munitus* illustrated by Chlonova (1966) have considerably thicker exines than the holotype and may represent a different species.

Azonia strictiparva n. sp. (taxon 79)
Plate 2, figures 13–15

Azonia cf. _A. parva_ Wiggins 1976. Frederiksen and others, 1988, pl. 1, figs. 24–25.

Holotype.—Slide R4140A(3), coordinates 54.1×99.9; pl. 2, fig. 13; nonmarine beds within the sequence of Ocean Point marine beds near Ocean Point, "middle" Maastrichtian.

Description.—Isopolar pollen grains with bilateral symmetry. Short axis of grain 16–21 μm; long axis 20–25 μm (8 measured specimens). Dimensions of holotype 19×22 μm. Apertures 2-geminicolpate, colpi 6–10 μm long, slitlike or slightly open, with rough margins. Exine 1–1.5 μm thick at sides of grain and 0.8–1 μm thick at the ends. Sexine tectate; columellae distinct; endosexine generally thicker than nexine or ektosexine. Design of sexine finely reticulate to granulate.

Remarks.—Grains in this species are symmetrical (*stricti-*, Latin for "straight"), whereas grains in *Azonia parva* Wiggins 1976 are fabiform. Grains of *A. strictiparva* are also considerably smaller than those of *A. parva.*

Distribution.—Lower Maastrichtian to "middle" Maastrichtian (to subzone 1 of the *Wodehouseia spinata* Assemblage Zone) of the Colville River area.

Wodehouseia wigginsii **n. sp. (taxon 97)**

Plate 3, figures 1–4

Holotype.—Slide R3837(2), coordinates 25.4×101.4; pl. 3, figs. 1, 2; from U.S. Geological Survey seismic line 31-81, shotpoint 146, upper Maastrichtian.

Description.—Isopolar pollen grains with bilateral symmetry. Overall dimensions of grain 29–37×32–51 µm (9 measured specimens); holotype 35×48 µm. Apertures 2-geminicolpate, colpi oval to boat shaped, 4–5 µm long, with smooth margins; centers of colpi 8–11 µm apart. Nexine of body and sexine of carinate flange each about 1 µm thick. Width of flange, 5–6 µm along sides of grain and 0.8–1.5 µm at ends of grain. Sexine of body tectate; design of sexine over body finely reticulate. The only spines on the body are scattered short spines at ends of grain; flange has radiating long spines, some of which project beyond edge of flange.

Remarks.—This species is characterized by lacking spines on the body except at the ends of the grain. The species is named after Virgil D. Wiggins of Chevron U.S.A., Inc.

Distribution.—Upper Maastrichtian (subzone 2 of the *Wodehouseia spinata* Assemblage Zone) of the Colville River area.

Aquilapollenites alaskensis **n. sp. (taxon 101)**

Plate 3, figures 5–9

Holotype.—Slide ARCO 98(B), coordinates 48.6×105.8; pl. 3, figs. 7, 8; sample from ARCO seismic line 1, shotpoint 98, east of Colville River, upper Maastrichtian.

Description.—Tricolpate, isopolar pollen grains with three equatorial projections. Polar axis 41–57 µm; equatorial axis including projections 48–65 µm (13 measured specimens). Width of body (between bases of projections) 14–21 µm; width of equatorial projections at their midpoint 9–11 µm. Dimensions of holotype: polar axis 55 µm; equatorial axis approximately 62 µm. Poles of body and tips of equatorial projections broadly rounded; attachment areas of equatorial projections to body sharply concave. The body tends to decrease in width in the equatorial area ("wasp-waisted"). Colpi rather obscure, apparently extending only from the tips to the bases of the equatorial projections. Exine about 1 µm thick in most areas, 0.5 µm thick at tips of projections. Nexinal costae 1.5–2 µm thick, extending about two-thirds the length of the equatorial projections but barely extending onto body of grain. Sexine tectate; columellae indistinct at high power. Sexine punctate and finely conate; coni closer together on equatorial projections than on body.

Remarks.—This species is distinguished by its straight-sided to "wasp-waisted" body and finely conate sexine. The body has a greater length to width ratio than in *Aquilapollenites unicus* (Chlonova 1957) Chlonova 1961 and *A. magnus* (Mchedlishvili *in* Samoilovich & Mchedlishvili 1961) n. comb.; furthermore, in *A. alaskensis,* the lengths of the nexinal costae on the equatorial projections and the body are different than in *A. unicus* and *A. magnus. A. alaskensis* has longer equatorial projections and more distinct nexinal costae than in *Projectoporites spinulosus* Mchedlishvili *in* Samoilovich & Mchedlishvili 1961.

Distribution.—Found only in the upper part of the upper Maastrichtian (subzone 5 of the *Wodehouseia spinata* Assemblage Zone) of the Colville River area.

Aquilapollenites unicus **(Chlonova 1957) Chlonova 1961 (taxon 117)**

Plate 7, figure 4

Discussion.—*Aquilapollenites unicus* is very similar to *Aquilapollenites magnus* (Mchedlishvili) n. comb. (basionym: *Projectoporites magnus* Mchedlishvili *in* Samoilovich & Mchedlishvili, 1961, p. 227, pl. 74, figs. 1a–e). The two species are somewhat difficult to compare because the original description of *A. unicus* by Chlonova (1957) was based on a partial misunderstanding of its morphology and because only two specimens of *A. magnus* were found by Mchedlishvili. However, the main differences between the two species seem to be that *A. unicus* has a thicker exine and has endexinal costae that extend far out onto the equatorial projections, whereas *A. magnus* has a thinner exine and shorter endexinal costae.

The *A. unicus-A. magnus* complex has been found in Maastrichtian rocks in east-central and coastal Yukon Territory (Rouse and Srivastava, 1972; Kalgutkar and Sweet, 1988; Nichols and Sweet, in press), in various parts of the Northwest Territories (McIntyre, 1974; Doerenkamp and others, 1976; Wilson, 1978; Sweet and others, 1989; Nichols and Sweet, in press), and on the North Slope of Alaska (Frederiksen and others, 1988, pl. 2, fig. 10; this paper, fig. 2). This pollen complex was also found in Paleocene rocks in west-central Northwest Territories (Wilson, 1978) and on the North Slope of Alaska (Frederiksen and others, 1988), and a similar species, *Aquilapollenites* sp. of Staplin and others (1976, pl. 2, fig. 25), was found in the lower Tertiary of the Mackenzie Delta region and the Canadian Arctic Islands (Staplin and others, 1976; Head, 1986). In Siberia, *A.*

unicus ranges to the top of the Cretaceous and, as rare specimens, into the Danian (Chlonova, 1980, fig. 8). Frederiksen and others (1988, fig. 4) considered Paleocene specimens of the *A. unicus-A. magnus* complex to be reworked, but the true range top of this species complex may be in the Paleocene because this complex may be ancestral to the genus *Novemprojectus* in the Paleocene-Eocene boundary interval of northern Alaska (Ager and others, 1986) and in the Eocene of the Canadian Arctic (Choi, 1984). Therefore, the true range top of the *A. unicus-A. magnus* complex is somewhat uncertain.

***Aquilapollenites* sp. cf. *A. augustus* Srivastava 1969 (taxon 105)**

Plate 7, figures 5–10

Description.—Tricolpate, isopolar to subisopolar pollen grains with three equatorial projections; polar areas of body much larger than equatorial projections. Polar axis 38–56 µm; equatorial axis including projections 38–68 µm (10 measured specimens). Width of body (between bases of projections) 16–48 µm; width of equatorial projections at their midpoint 10–17 µm. In subisopolar specimens, one pole is longer, broader, and (or) more broadly rounded than the other. Poles of body and tips of equatorial projections broadly rounded; attachment areas of equatorial projections to body distinctly concave. Colpi obscure; in specimens lying in oblique view, no colpi are seen on the body. Thus, the colpi apparently are confined to the equatorial projections. Exine about 1–1.5 µm thick in most areas, 0.5 µm thick at tips of projections. Nexinal costae as thick as 3.5 µm, extending about ½–¾ the length of the equatorial projections and extending a moderate distance onto body of grain. Sexine tectate; columellae distinct. Sexine distinctly punctate, with somewhat scattered small spines. The spines cover most or all of the body as well as the tips of the equatorial projections.

Remarks.—This species is composed of a somewhat heterogeneous group of specimens that are intermediate between *Aquilapollenites augustus* Srivastava 1969 and *A. unicus* (Chlonova 1957) Chlonova 1961. The body is broadly rounded at the poles as in *A. augustus* and not as rectangular as in *A. unicus*. The equatorial projections are broader than in *A. unicus*, and they are smaller than in *A. augustus*. The equatorial axis including projections is usually slightly greater than the polar axis.

Distribution.—Lower Maastrichtian of the Colville River area.

***Aquilapollenites* sp. A (taxon 119)**

Plate 4, figures 2–5

Description.—Tricolpate, isopolar pollen grains with three rudimentary equatorial projections. Polar axis 30–35 µm; equatorial axis including projections 21–24 µm (7 measured specimens). In equatorial view, poles moderately to broadly rounded; equatorial projections conical in shape; attachment areas of equatorial projections to body gently concave. Colpi extend nearly full length of grain. Exine about 1 µm thick in most areas, thinning in some specimens to 0.5 µm at tips of projections. Nexinal costae only on body, thickest in attachment area (3–5 µm thick) and about 10 m long, thinning toward poles. Sexine tectate; columellae distinct at high power. Design of sexine distinctly punctate.

Remarks.—This species is characterized by its very small equatorial projections.

Distribution.—Found only in sample R3824, U.S. Geological Survey seismic line 31-81, shotpoint 120, upper Maastrichtian (subzone 4 of the *Wodehouseia spinata* Assemblage Zone).

***Fibulapollis inaequalis* n. sp. (taxon 123)**

Plate 4, figures 7–12; plate 5, figures 1–3

Holotype.—Slide R4140G(2), coordinates 65.5×110.6; pl. 4, figs. 7, 8; nonmarine beds within the interval of the Ocean Point marine beds near Ocean Point, "middle" Maastrichtian.

Description.—Tricolpate, heteropolar pollen grains with three equatorial projections. Polar axis 19–32 µm; equatorial axis including projections 21–42 µm (14 measured specimens). Dimensions of holotype: polar axis 32 µm; equatorial axis 35 µm. In equatorial view: One polar projection considerably larger than the other; equatorial projections longer but narrower than major polar projection. Polar projections very broadly rounded; tips of equatorial projections moderately rounded; attachment areas of equatorial projections to body generally only slightly concave. Colpi extend from tips of equatorial projections probably only to the bases, or not quite to the bases, of these projections. Exine 0.8–1 µm thick in most areas, slightly thinner at tips of equatorial projections. Nexinal costae only slightly bow shaped (as seen in equatorial view), 1.5–3.5 µm thick and 5–11 µm long. Sexine tectate; columellae indistinct to fairly distinct at high power. Entire sexine distinctly punctate and rather finely conate.

Remarks.—This species is characterized by being distinctly heteropolar (*inaequalis*, Latin for "unequal, different," referring to the poles). The species is similar to *Manicorpus* sp. of Kalishevich and others (1981, pl. 29, fig. 2). Previously described species of *Fibulapollis* are isopolar to sub(?)isopolar. *Fibulapollis scabratus* Tschudy 1969 has straighter sides and more narrowly rounded poles. *Aquilapollenites minutus* Srivastava 1966 of Bihl (1970, pl. 3, fig. 7) has slightly concave sides but is isopolar. *Aquilapollenites aptus* Srivastava 1969 is similar to *Fibulapollis inaequalis*, but *A. aptus* has a more prominently developed minor pole; Srivastava described the species as being subisopolar.

Distribution.—Base of the Maastrichtian to "middle" Maastrichtian (to subzone 1 of the *Wodehouseia spinata* Assemblage Zone) of the Colville River area.

Manicorpus pseudosenonicus **n. sp. (taxon 131)**
Plate 5, figures 11–15; plate 6, figures 1–3

Manicorpus trapeziforme **Mchedlishvili *in* Samoilovich & Mchedlishvili 1961 of McIntyre, 1974, pl. 20, figs. 5–6.**

Holotype.—Slide R3824(1), coordinates 27.7×110.1; pl. 5, figs. 11–12; sample from U.S. Geological Survey seismic line 31-81, shotpoint 120, west of Colville River, upper Maastrichtian.

Description.—Tricolpate, heteropolar pollen grains with three equatorial projections; a major pole is well developed, but a minor pole is very small or typically lacking altogether. Polar axis 18–47 µm; equatorial axis including projections 35–64 µm (13 measured specimens). Dimensions of holotype: polar axis 21 µm; equatorial axis 37 µm. In equatorial view: pole and tips of equatorial projections broadly to somewhat narrowly rounded; attachment areas of equatorial projections to body distinctly concave. In polar view: shape triangular, sides gently concave, corners narrowly rounded. Colpi extend from tips of equatorial projections probably only to the bases of these projections. Exine about 1.5–2 µm thick at the pole, consisting mostly of endosexine; sexine thickens slightly toward attachment areas, then thins to 0.5–1 µm thick at tips of equatorial projections. Nexinal costae (in specimens where present) bow shaped (as seen in equatorial view), as much as 4.5 µm thick and 15 µm long, extending equally as far on the body as on the equatorial projections. Sexine tectate. Body distinctly and finely reticulate; however, the polar region is typically more finely reticulate than elsewhere and may be punctate to nearly psilate. Equatorial projections punctate and finely but distinctly conate. Equatorial projections may be pendent or nearly perpendicular to polar axis.

Remarks.—This species has conate equatorial projections like *Manicorpus delicatus* (Stanley 1961) Bondarenko 1968, but *M. delicatus* has a distinctly ornamented pole. *Manicorpus pseudosenonicus* has a polar area of thinner exine and finer reticulation like *M. senonicus* Mchedlishvili *in* Samoilovich & Mchedlishvili 1961 and *Manicorpus trapeziforme* Mchedlishvili *in* Samoilovich & Mchedlishvili 1961, but *M. senonicus* and *M. trapeziforme* have reticulate rather than conate equatorial projections. *Manicorpus trapeziforme* Mchedlishvili *in* Samoilovich & Mchedlishvili 1961 of Doerenkamp and others (1976, pl. 3, fig. 2) may also belong to *Manicorpus pseudosenonicus*.

Distribution.—Lower Maastrichtian to upper Maastrichtian (to subzone 5 of the *Wodehouseia spinata* Assemblage Zone) of the Colville River area; also found in the Mackenzie Delta region of northwestern Canada (as *Manicorpus trapeziforme*: McIntyre, 1974).

SAMPLE LOCALITY REGISTER

Quadrangle locations given only for samples not shown in figure 1. Relative positions of R3413 and R3152 series of samples, from sections 21/22 and 25, respectively, of Phillips (1988), were provided by E.M. Brouwers (written commun., 1990). Sample designations followed by (P) are included in the list only because photomicrographs of specimens from these samples are included in the plates.

Sample	Locality
16408–4(P)	Sec. 25, T. 5 N., R. 2 E., Umiat (D-3) quadrangle
16410–3(P)	Sec. 26/27, T. 8 N., R. 2 E., Harrison Bay A-3 quadrangle
20738(P)	Smiley (1969) sample 52, Umiat (B-3) quadrangle
ARCO 97	ARCO line 1, shotpoint 97, sec. 29, T. 8 N., R. 5 E. (Wiggins, 1976)
ARCO 98	ARCO line 1, shotpoint 98, sec. 20, T. 8 N., R. 5 E. (Wiggins, 1976)
ARCO 266	ARCO line 2, shotpoint 266, sec. 9, T. 6 N., R. 5 E. (Wiggins, 1976)
D3124A(P)	Lat 69° 40' N., long 151° 25' W., T. 4 N., R. 2 E., Umiat (C-3) quadrangle (Tschudy, 1969)
D4036–80A(P)	U.S. Geological Survey Sentinel Hill core test 1, depth of sample 899–909 ft; lat 69° 36' 57" N., long 151° 27' 11" W., Umiat (C-3) quadrangle (Robinson and Collins, 1959)
R3152A	Field no. 83EB130, section 25 of Phillips (1988), about 7.2 m below iron-stained bed
R3152B	Field no. 83EB133, section 25 of Phillips (1988), about 3.7 m below iron-stained bed
R3152C	Field no. 83EB136, section 25 of Phillips (1988), from the iron-stained bed
R3317A(P)	Field no. 84–TA–AUG 5 stop 1 sample A, near section 4 of Phillips (1988), 1.2 m below base of freshwater limestone bed, Harrison Bay (A-3) quadrangle
R3328	Field no. 84–TA–JUL 29/4/1, C S½ N½ sec. 6, T. 8 N., R. 4 E.
R3413E	Field no. 84EB29, section 21/22 of Phillips (1988), at about the same level as sample 87LP 15, 20 of section 21
R3413G	Field no. 84EB31, section 21/22 of Phillips (1988), about 0.46 m above sample R3413E

R3413O	Field no. 84EB39, section 21/22 of Phillips (1988), at a level just above sample 87LP 47, 48, 49 of section 22
R3413Q	Field no. 84EB41, section 21/22 of Phillips (1988), about 1.8 m above sample R3413O and slightly higher than the top of section 22 (Phillips, 1988)
R3694A(P)	Field no. 84SH–III–10, NE¼ NE¼ SW¼ sec. 22, T. 1 N., R. 2 E., Umiat (B-3) quadrangle
R3695B(P)	Field no. 84PC–I–10, C SE¼ sec. 6, T. 3 N., R. 3 E., Umiat (C-3) quadrangle
R3768	USGS seismic line 41-81, shotpoint 185
R3924	USGS seismic line 41-81, shotpoint 193
R3769	USGS seismic line 41-81, shotpoint 210
R3770	USGS seismic line 41-81, shotpoint 214
R3772	USGS seismic line 41-81, shotpoint 221
R3786	USGS seismic line 16-81, shotpoint 282
R3787	USGS seismic line 16-81, shotpoint 287
R3789	USGS seismic line 16-81, shotpoint 305
R3791	USGS seismic line 16-81, shotpoint 337
R3792	USGS seismic line 16-81, shotpoint 350
R3818	USGS seismic line 31-81, shotpoint 100
R3819	USGS seismic line 31-81, shotpoint 101
R3820	USGS seismic line 31-81, shotpoint 102
R3821	USGS seismic line 31-81, shotpoint 104
R3823	USGS seismic line 31-81, shotpoint 117
R3824	USGS seismic line 31-81, shotpoint 120
R3825	USGS seismic line 31-81, shotpoint 126
R3826	USGS seismic line 31-81, shotpoint 128
R3827	USGS seismic line 31-81, shotpoint 130
R3828	USGS seismic line 31-81, shotpoint 132
R3834	USGS seismic line 31-81, shotpoint 142
R3835	USGS seismic line 31-81, shotpoint 144
R3837	USGS seismic line 31-81, shotpoint 146
R3838	USGS seismic line 31-81, shotpoint 148
R3885	USGS seismic line 16-81, shotpoint 310
R3889	USGS seismic line 16-81, shotpoint 317
R3890	USGS seismic line 16-81, shotpoint 345
R3891	USGS seismic line 16-81, shotpoint 369
R3892	USGS seismic line 16-81, shotpoint 375
R3946P(P)	Field no. 86EB16, section 7 of Phillips (1988), Harrison Bay (A-3) quadrangle
R3946Q(P)	Same locality as above, field no. 86EB17
R3947D(P)	Field no. 86EB167, section 1 of Phillips (1988), Harrison Bay (A-3) quadrangle
R3947J(P)	Field no. 86EB173, same locality as R3947D
R4140A	Field no. 86EB73, section 24 of Phillips (1988), nonmarine strata within the sequence of the Ocean Point marine beds
R4140B	Field no. 86EB121, same locality as R4140A
R4140C	Field no. 86EB72, same locality as R4140A
R4140D	Field no. 86EB122, same locality as R4140A
R4140F	Field no. 86EB124, same locality as R4140A
R4140G	Field no. 86EB125, same locality as R4140A
R4295B(P)	Field no. 86EB65, section 10 of Phillips (1988), Harrison Bay (A–3) quadrangle
R4295E	Field no. 86EB93, section 15 of Phillips (1988)
R4295F	Field no. 86EB103, section 17 of Phillips (1988)
R4295G	Field no. 86EB99, section 17 of Phillips (1988)
R4295H	Field no. 86EB114, section 20 of Phillips (1988)

REFERENCES CITED

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

Bihl, G., 1970, New evidence on the age of the Sheerness badlands, east-central Alberta: Bulletin of Canadian Petroleum Geology, v. 18, p. 216–226.

———1973, Palynostratigraphic investigation of upper Maastrichtian and Paleocene strata near Tate Lake, N.W.T.: Vancouver, B.C., University of British Columbia, unpub. Ph.D. dissertation, 51 p.

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.

Brouwers, E.M., 1988, Late Maastrichtian and Danian faunas from northern Alaska: Reconstructions of environment and biogeography [abs.]: Geological Society of America Abstracts with Programs, v. 20, p. A371.

Brouwers, E.M., Clemens, W.A., Spicer, R.A., Ager, T.A., Carter, L.D., and Sliter, W.V., 1987, Dinosaurs on the North Slope, Alaska: High latitude, latest Cretaceous environments: Science, v. 237, p. 1608–1610.

Carter, L.D., and Galloway, J.P., 1985, Engineering-geologic maps of northern Alaska, Harrison Bay quadrangle: U.S. Geological Survey Open-File Report 85–256, 47 p.

Chlonova, A.F., 1957, O vydelenii rukovodiashchikh vidov pri opredelenii vozrasta otlozhenii po sporovo-pyl'tsevomy analizu [On differentiation of the leading species for determination of the age of strata by spore-pollen analysis]: Novosibirsk, Akademiia Nauk SSSR, Izvestiia Vostochnykh Filialov Akademii Nauk SSSR, no. 2, p. 43–46.

———1966, Novye vidy pyl'tsy morfologicheskogo tipa "oculata" [New species of the morphological type "oculata"], *in* Palinologiia Sibiri, k II Mezhdunarodnoi

Palinologicheskoi Konferentsii (Utrekht, Niderlandy, 1966) [Palynology of Siberia, for the 2nd International Conference on Palynology (Utrecht, Netherlands, 1966)]: Akademiia Nauk SSSR, Sibirskoe Otdelenie, p. 66–69.

———1980, Floristicheskie provintsii Mela SSSR i prilegaiushchikh raionov vostochnoi Azii po palinologicheskim dannym [Cretaceous floristic provinces of the USSR and adjacent regions of eastern Asia according to palynological data], *in* Paleopalinologiia Sibiri: Stat'i sovetskikh palinologov k V Mezhdunarodnoi palinologicheskoi konferentsii (Kembridzh, Angliia, 1980) [Paleopalynology of Siberia: Articles of Soviet palynologists for the 5th International Palynological Conference (Cambridge, England, 1980)]: Moscow, Izdatel'stvo "Nauka," p. 39–64.

Choi, D.K., 1983, Paleopalynology of the Upper Cretaceous-Paleogene Eureka Sound Formation of Ellesmere and Axel Heiberg Islands, Canadian Arctic Archipelago: University Park, Pa., Pennsylvania State University, unpub. Ph.D. dissertation, 580 p.

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

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.

Edwards, L.E., 1984, Insights on why graphic correlation (Shaw's method) works: Journal of Geology, v. 92, no. 5, p. 583–597.

Frederiksen, N.O., 1986, Reconnaissance biostratigraphy of the *Expressipollis* and Oculata pollen groups in Campanian and Maastrichtian rocks of the North Slope, Alaska [abs.]: Palynology, v. 11, p. 227–228.

———1989, Changes in floral diversities, floral turnover rates, and climates in Campanian and Maastrichtian time, North Slope of Alaska: Cretaceous Research, v. 10, p. 249–266.

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., Ager, T.A., Oftedahl, O.G., and Edwards, L.E., 1985, Palynological samples near the Cretaceous/Tertiary boundary, North Slope of Alaska [abs.]: Society of Economic Paleontologists and Mineralogists, Annual Midyear Meeting, Abstracts, v. 2, p. 31.

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

Haq, B.U., Hardenbol, J., and Vail, P.R., 1987, Chronology of fluctuating sea levels since the Triassic: Science, v. 235, p. 1156–1167.

Head, M.J., 1986, Latest Cretaceous-Paleogene palynology of Ellesmere and Axel Heiberg Islands, East Canadian Arctic [abs.]: Geological Association of Canada, Mineralogical Association of Canada, and Canadian Geophysical Union, Joint Annual Meeting, Program with Abstracts, v. 11, p. 79.

Jerzykiewicz, T., and Sweet, A.R., 1986, The Cretaceous-Tertiary boundary in the central Alberta Foothills. I: Stratigraphy: Canadian Journal of Earth Sciences, v. 23, p. 1356–1374.

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.

Kalishevich, T.G., Zaklinskaya, E.D., and Serova, M.Ia., 1981, Razvitie organicheskogo mira tikxookeanskogo poyasa na rubejhe mezozoia i kainozoia [Development of the organic world of the Pacific Ring at the Mesozoic-Cenozoic boundary]: Moscow, Izdatel'stvo "Nauka", 149 p.

Lerbekmo, J.F., Sweet, A.R., and St. Louis, R.M., 1987, The relationship between the iridium anomaly and palynological floral events at three Cretaceous-Tertiary boundary localities in western Canada: Geological Society of America Bulletin, v. 99, p. 325–330.

Macbeth, J.I., and Schmidt, R.A.M., 1973, Upper Cretaceous foraminifera from Ocean Point, northern Alaska: Journal of Paleontology, v. 47, p. 1047–1061.

Marincovich, L., Jr., Brouwers, E.M., and Carter, L.D., 1985, Early Tertiary marine fossils from northern Alaska: Implications for Arctic Ocean paleogeography and faunal evolution: Geology, v. 13, p. 770–773.

———1986, Reply *to* the comment by Frederiksen, Ager, and Edwards on "Early Tertiary marine fossils from northern Alaska: Implications for Arctic Ocean paleogeography and faunal evolution": Geology, v. 14, p. 803–804.

Marincovich, L., Jr., Brouwers, E.M., and Hopkins, D.M., 1983, Paleogeographic affinities and endemism of Cretaceous and Paleocene marine faunas in the Arctic [abs.], in U.S. Geological Survey Polar Research Symposium—Abstracts with Program: U.S. Geological Survey Circular 911, p. 45–46.

McDougall, K., 1987, Maestrichtian benthic foraminifers from Ocean Point, Alaska: Journal of Foraminiferal Research, v. 17, p. 344–366.

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.

Miller, F.X., 1977, The graphic correlation method in biostratigraphy, *in* Kauffman, E.G., and Hazel, J.E., eds., Concepts and methods of biostratigraphy: Stroudsburg, Pa., Dowden, Hutchinson and Ross, p. 165–186.

Nichols, D.J., Jacobson, S.R., and Tschudy, R.H., 1982, Cretaceous palynomorph biozones for the central and northern Rocky Mountain region of the United States, *in* Powers, R.B., ed., Geologic studies of the Cordilleran thrust belt: Denver, Rocky Mountain Association of Geologists, v. 2, p. 721–733.

Nichols, D.J., and Sweet, A.R., in press, Biostratigraphy of Upper Cretaceous nonmarine palynofloras in a north-south transect of the Western Interior Basin, *in* Evolution of the Western Interior Basin: Geological Association of Canada Special Paper.

Phillips, R.L., 1988, Measured sections, paleoenvironments, and sample locations near Ocean Point, Alaska: U.S. Geological Survey Open-File Report 88–40, 1 sheet.

Robinson, F.M., and Collins, F.R., 1959, Core test, Sentinel Hill area and test well, Fish Creek area, Alaska: U.S. Geological Survey Professional Paper 305–I, p. 485–521.

Rouse, G.E., and Srivastava, S.K., 1972, Palynological zonation of Cretaceous and Early Tertiary rocks of the Bonnet Plume Formation, northeastern Yukon, Canada: Canadian Journal of Earth Sciences, v. 9, p. 1163–1179.

Samoilovich, S.R., 1965, Pyl'tsa novykh vidov verkhnemelovykh pokrytosemennykh rastenii Iakytii [Pollen of new species of Upper Cretaceous angiosperm plants of Yakutia], *in* Paleofitologicheskii Sbornik [Paleophytological Collection]: Vsesoiuznyi Heftianoi Nauchno-Issledovatel'skii Geologorazvedochnyi Institut (VNIGRI), Trudy, v. 239, p. 121–141.

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.

Shaw, A.B., 1964, Time in stratigraphy: New York, McGraw-Hill, 365 p.

Smiley, C.J., 1969, Cretaceous floras of the Chandler-Colville region, Alaska—stratigraphy and preliminary floristics: American Association of Petroleum Geologists Bulletin, v. 53, p. 482–502.

Smith, A.G., Hurley, A.M., and Briden, J.C., 1981, Phanerozoic paleocontinental world maps: Cambridge, Cambridge University Press, 102 p.

Srivastava, S.K., 1970, Pollen biostratigraphy and paleoecology of the Edmonton Formation (Maastrichtian), Alberta, Canada: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 7, p. 221–276.

Staplin, F.L., ed., 1976, Tertiary biostratigraphy, Mackenzie Delta region, Canada: Bulletin of Canadian Petroleum Geology, v. 24, p. 117–136.

Sweet, A.R., 1978, Palynology of the lower part, type section, Tent Island Formation, Yukon Territory, *in* Current Research, Part B: Geological Survey of Canada Paper 78–1B, p. 31–37.

———1988, A regional perspective on the palynofloral response to K-T boundary event(s) with emphasis on variations imposed by the effects of sedimentary facies and latitude [abs.], *in* Global catastrophes in Earth history: An interdisciplinary conference on impacts, volcanism, and mass mortality, Snowbird, Utah, October 20–23, 1988, Abstracts: Houston, Lunar and Planetary Institute Contribution 673, p. 190–191.

Sweet, A.R., and Braman, D.R., 1988, Floral changes within the interval containing the Cretaceous-Tertiary boundary in western Canada: A stratigraphic, palaeogeographic and palaeoenvironmental perspective [abs.]: 7th International Palynological Congress, Brisbane, Australia, Abstracts, p. 161.

Sweet, A.R., Ricketts, B.D., Cameron, A.R., and Norris, D.K., 1989, An integrated analysis of the Brackett coal basin, Northwest Territories, *in* Current Research, Part G: Geological Survey of Canada Paper 89–1G, p. 85–99.

Tetra Tech, Inc., 1982, Petroleum exploration of NPRA, 1974–1981, final report: Houston, Tetra Tech, Inc., I, II, III, Report 8200, 183 p.

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.

Werner, M.R., 1987, Tertiary and Upper Cretaceous heavy-oil sands, Kuparuk River Unit area, Alaskan North Slope, *in* Meyer, R.F., ed., Exploration for heavy crude oil and natural bitumen: American Association of Petroleum Geologists Studies in Geology, no. 23, p. 537–547.

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.

Wilson, M.A., 1978, Palynology of three sections across the uppermost Cretaceous/Paleocene boundary in the Yukon Territory and District of Mackenzie, Canada: Palaeontographica, Abt. B, v. 166, p. 99–183.

Location of photographed specimens

[Stratigraphic and geographic data for samples are given in the plate explanations and in "Sample Locality Register." All specimens are from the Colville River region, and all are Maastrichtian in age except those on pl. 2, figs. 8, 9, and 12, which are Campanian in age]

Figure	Slide	Coordinates
	Plate 1	
1	ARCO 98(B)	25.5×96.0
2	R3824(1)	25.6×100.6
3–4	ARCO 98(B)	46.9×108.3
5	R3924(1)	27.5×99.1
6	R3824(1)	25.6×108.8
7	R3819(1)	31.2×100.5
8	R3890(1)	26.2×101.9
9	R3768(1)	28.0×103.4
10	16410–3(A)	29.5×97.7
11	R3695B(1)	37.2×94.8
12	R3819(1)	25.0×95.5
13	ARCO 98(B)	56.2×106.7
14	R3789(2)	27.0×100.2
15	ARCO 98(B)	49.0×94.5
16	16410–3(A)	30.2×96.5
17–18	16410–3(A)	28.5×107.3
19	16410–3(A)	34.6×103.2
20	D3124A(3)	18.7×98.2
21–23	16408–4(B)	38.1×109.0
24–25	16408–4(B)	39.5×103.1
26	16410–3(A)	31.2×100.0
	Plate 2	
1–3	16408–4(B)	38.6×100.0
4	R3824(1)	26.4×110.0
5	R3823(2)	31.7×107.7
6–7	R3838(2)	28.7×93.5
8	R3694A(2)	42.0×98.4
9	D4036–80A(1)	31.0×97.8
10	R4140A(3)	46.1×97.5
11	R4140A(3)	54.8×99.1
12	20738(2)	44.7×110.0
13	R4140A(3)	54.1×99.9
14	16408–4(B)	47.0×99.2
15	16410–3(A)	31.1×109.5
	Plate 3	
1–2	R3837(2)	25.4×101.4
3–4	R3834(2)	29.6×92.5
5	ARCO 97(B)	45.3×93.7
6	ARCO 98(B)	25.5×95.8
7–8	ARCO 98(B)	48.6×105.8
9	ARCO 98(B)	48.4×103.0
10	R3924(1)	29.8×103.0
	Plate 4	
1	R3924(1)	40.2×103.9
2–3	R3824(1)	25.0×95.7
4–5	R3824(1)	25.0×97.6
6	ARCO 98(B)	52.2×98.2
7–8	R4140G(2)	65.5×110.6
9–10	R4140G(2)	55.3×110.4
11–12	R3317A(2)	37.8×109.4
13–14	ARCO 97(B)	53.4×104.8
	Plate 5	
1–2	R3947J(1)	40.3×95.8
3	R3695B(1)	36.0×108.8
4	R3947D(1)	46.9×98.0
5–6	R3825(1)	25.9×102.2
7	16408–4(B)	30.1×104.6
8	16408–4(B)	30.0×106.3
9–10	R3828(1)	28.0×103.8
11–12	R3824(1)	27.7×110.1
13–14	ARCO 98(B)	29.0×109.8
15	ARCO 98(B)	47.1×107.5
	Plate 6	
1	R3824(1)	26.3×98.5
2–3	ARCO 98(B)	32.5×100.0
4–5	16408–4(B)	30.1×98.4
6	ARCO 266(1)	43.0×98.3
7–8	R3791(2)	28.8×97.2
	Plate 7	
1	R4295H(2)	56.5×102.8
2	R4295B(2)	51.5×98.6
3	R3946P(1)	44.7×97.4
4	R4295E(2)	47.1×95.0
5	R4295E(2)	41.7×100.6
6	16410–3(A)	34.4×99.2
7–8	R3946Q(2)	42.5×101.3
9–10	R3786(2)	29.9×103.4
11–12	R4295H(2)	53.1×99.8

PLATES 1–7

[Contact photographs of the plates in this report are available from the U.S. Geological Survey Library, Federal Center, Denver, Colorado 80225]

PLATE 1

Porate, colpate, and colporate pollen

[Magnification × 1,000. All specimens Maastrichtian in age. Specimens photographed with bright field illumination, unless otherwise noted]

FIGURES 1, 2. *Triporopollenites megagranifer* (Potonié 1934) Thomson & Pflug 1953 type.

3, 4. *Anacolosidites* sp.; interference contrast.

5. *Kurtzipites annulatus* Norton *in* Norton & Hall 1969.

6–8. *Orbiculapollis globosa* (Chlonova 1957) Chlonova 1961. 7, interference contrast.

9–11. *Kurtzipites trispissatus* Anderson 1960. 10, interference contrast, overmacerated specimen from which nexine is missing.

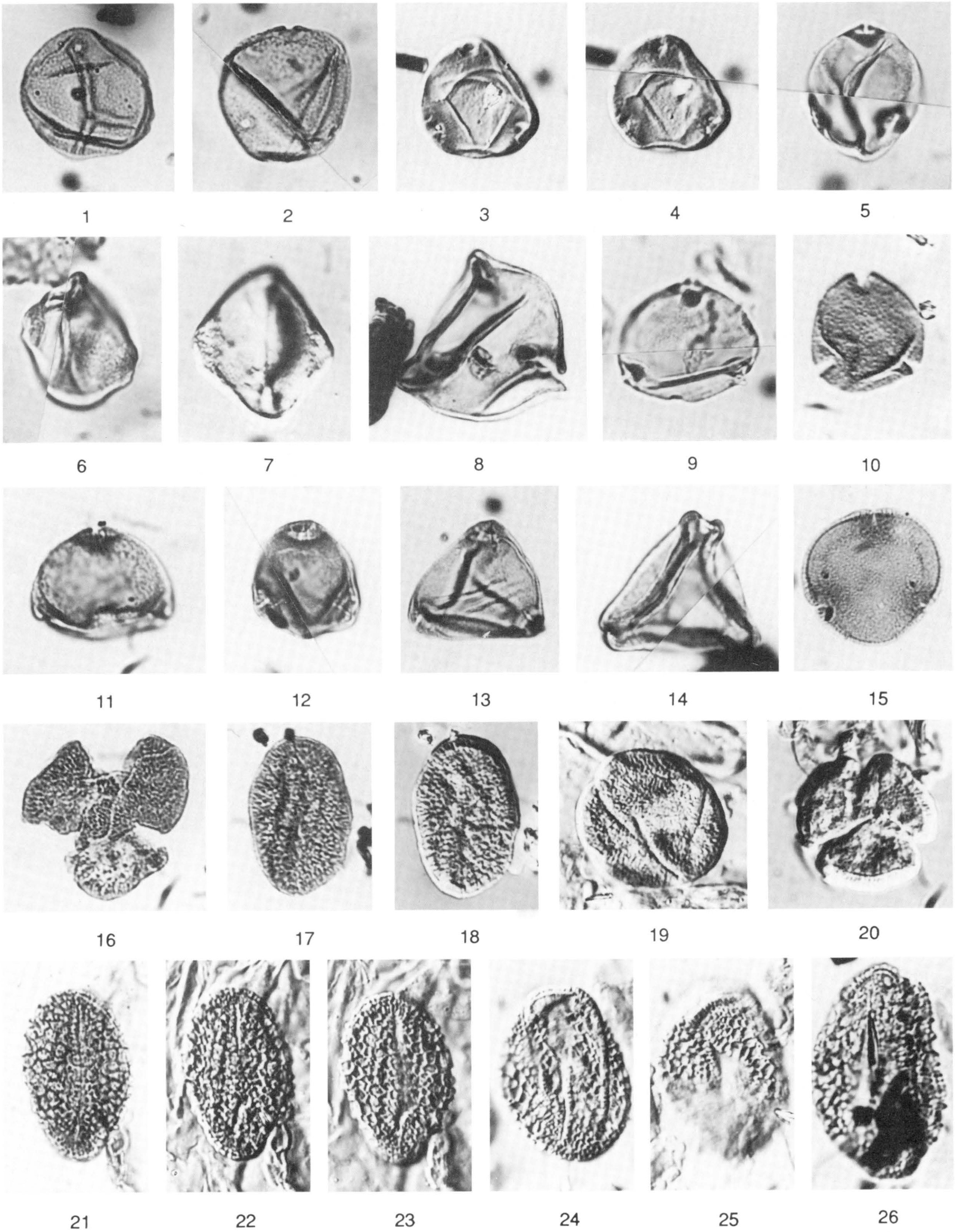
12, 13. *Myrtipites scabratus* Norton *in* Norton & Hall 1969.

14. *Betulaepollenites*(?) sp.

15. *Bombacacipites* sp. aff. *B*. sp. of Nichols and Sweet (in press, pl. 3, fig. 13).

16–20. *Tricolpites* sp. aff. *T. matauraensis* Couper 1953. 18–20, interference contrast.

21–26. *Rousea compta* n. sp. 21–23, holotype. 22–25, interference contrast.



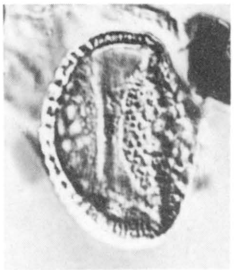
TRIPOROPOLLENITES, ANACOLOSIDITES, KURTZIPITES, ORBICULAPOLLIS, MYRTIPITES, BETULAEPOLLENITES, BOMBACACIPITES, TRICOLPITES, ROUSEA

PLATE 2

Porate, colpate, and colporate pollen

[Magnification × 1,000. All specimens Maastrichtian in age except those in figures 8, 9, and 12. Specimens photographed with bright field illumination, unless otherwise noted]

FIGURES 1–3. *Rousea compta* n. sp.; interference contrast.
4, 5. *Siberiapollis constrictus* (Samoilovich *in* Samoilovich & Mchedlishvili 1961) n. comb.
6, 7. *Proteacidites* sp.
8, 9, 12. *Azonia hirsuta* (Samoilovich 1965) Wiggins 1976; all three specimens are Campanian in age.
10, 11. *Azonia* sp. cf. *A. hirsuta.*
13–15. *Azonia strictiparva* n. sp. 13, holotype. 14, 15, interference contrast.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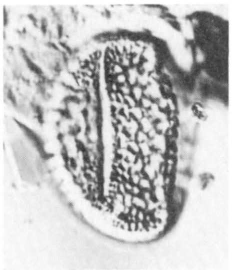
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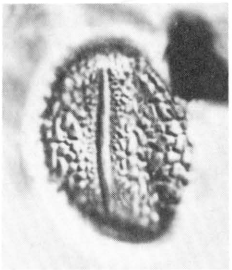
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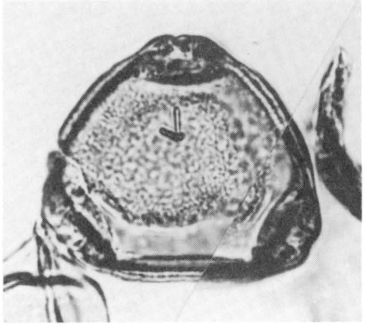
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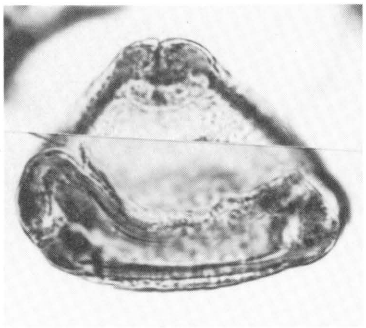
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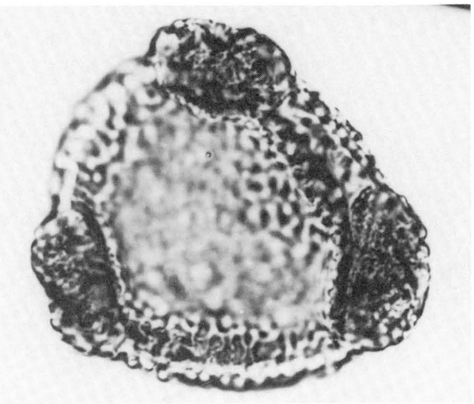
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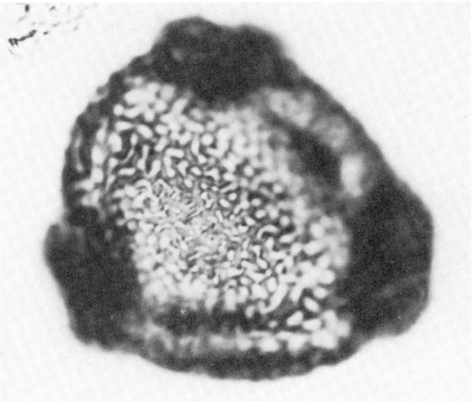
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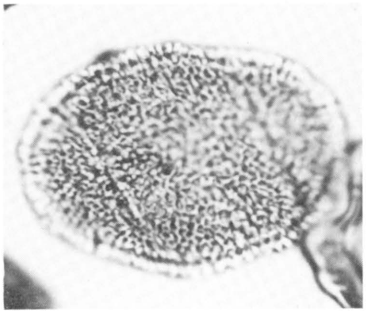
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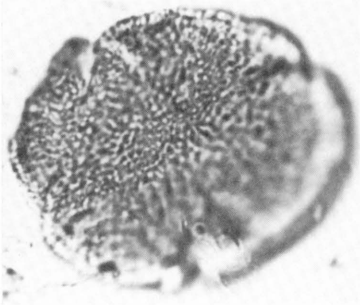
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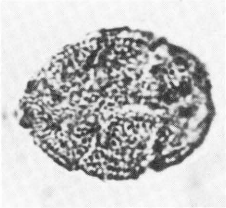
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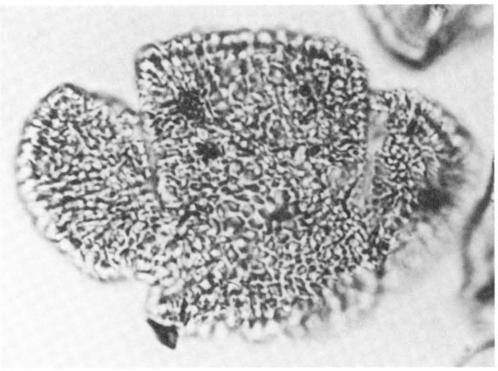
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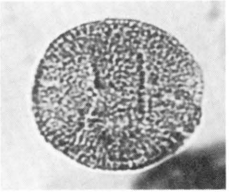
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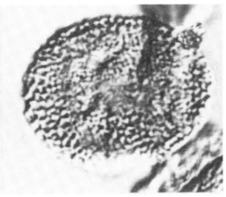
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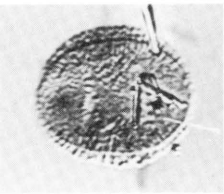
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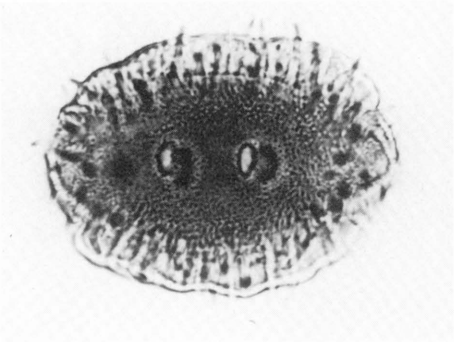
ROUSEA, SIBERIAPOLLIS, PROTEACIDITES, AZONIA

PLATE 3

Colpate pollen

[Magnification × 1,000. All specimens Maastrichtian in age. Specimens photographed with bright field illumination, unless otherwise noted]

FIGURES 1–4. *Wodehouseia wigginsii* n. sp. 1, 2, holotype. 2–4, interference contrast.
5–9. *Aquilapollenites alaskensis* n. sp. 7, 8, holotype. 8, interference contrast.
10. *Aquilapollenites conatus* Norton 1965.



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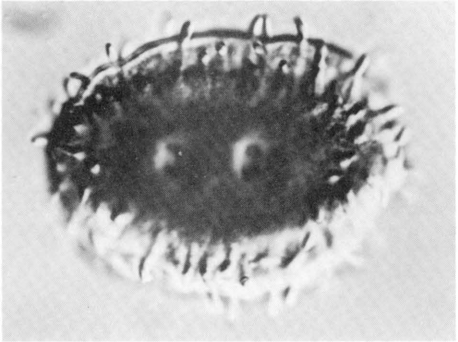

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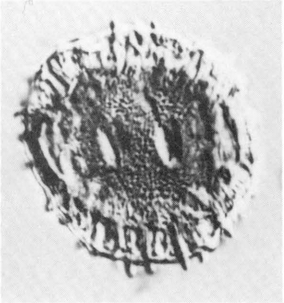

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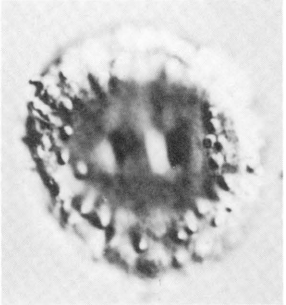

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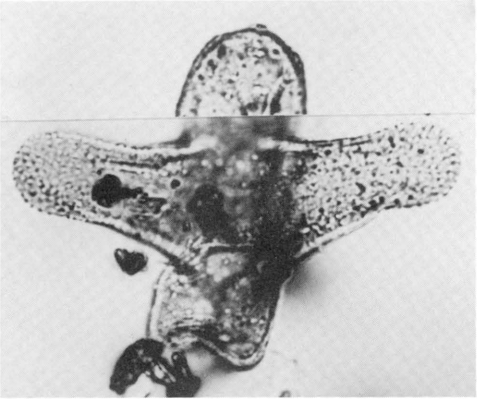

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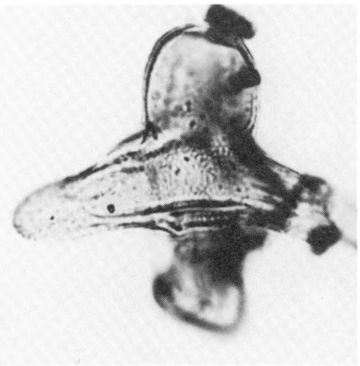

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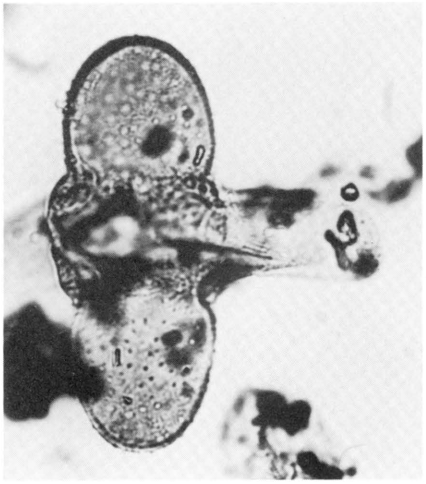

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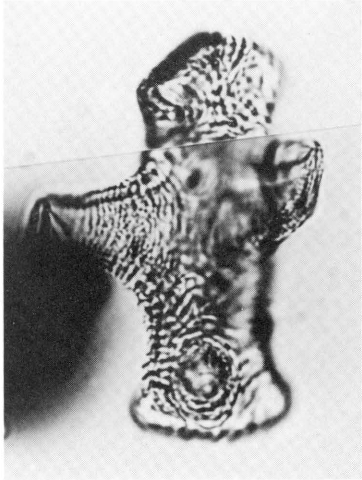

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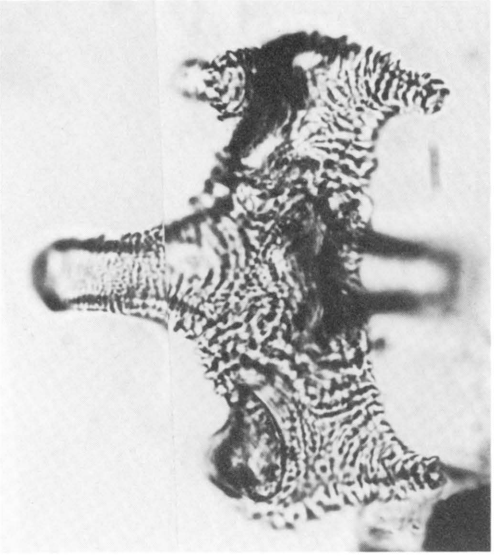
WODEHOUSEIA, AQUILAPOLLENITES

PLATE 4

Colpate pollen

[Magnification × 1,000. All specimens Maastrichtian in age. Specimens photographed with bright field illumination, unless otherwise note]

FIGURES 1. *Aquilapollenites conatus* Norton 1965.
2–5. *Aquilapollenites* sp. A.
6. *Aquilapollenites quadrilobus* Rouse 1957; interference contrast.
7–12. *Fibulapollis inaequalis* n. sp. 7, 8, holotype.
13–14. *Bratzevaea amurensis* (Bratzeva 1965) Takahashi *in* Takahashi & Shimono 1982; interference contrast.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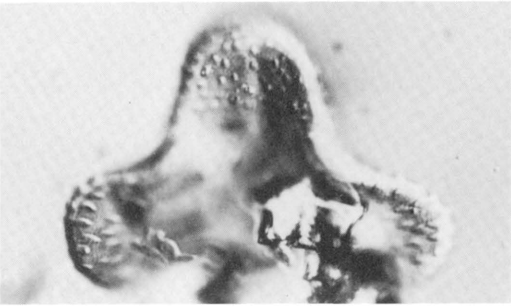
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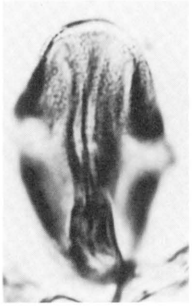
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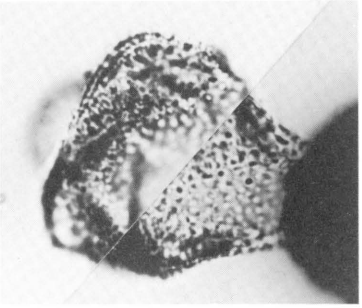
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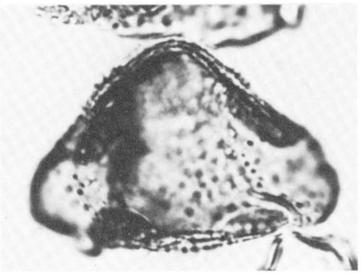
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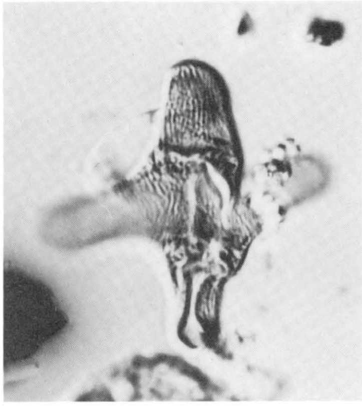
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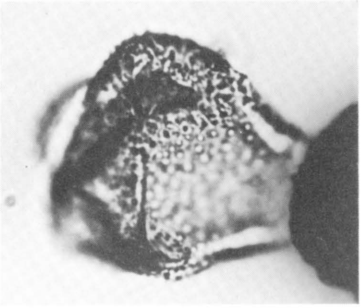
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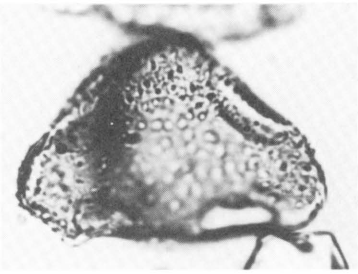
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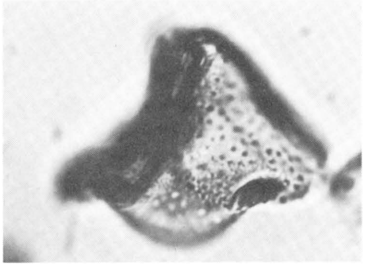
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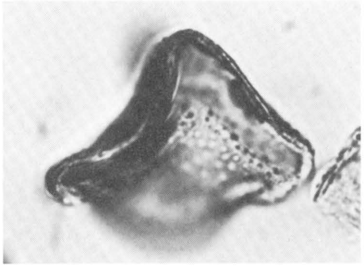
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14

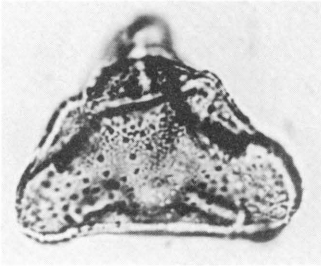
AQUILAPOLLENITES, FIBULAPOLLIS, BRATZEVAEA

PLATE 5

Colpate pollen

[Magnification × 1,000. All specimens Maastrichtian in age. Specimens photographed with bright field illumination, unless otherwise noted]

FIGURES	
1–3.	*Fibulapollis inaequalis* n. sp.
4.	*Fibulapollis* sp. aff. *F. inaequalis.*
5, 6.	*Fibulapollis* sp. Poles finely reticulate and conate; body and equatorial projections punctate and conate. 6, interference contrast.
7, 8.	*Manicorpus notabile* Mchedlishvili *in* Samoilovich & Mchedlishvili 1961; interference contrast.
9, 10.	*Manicorpus rostratus* Srivastava 1968.
11–15.	*Manicorpus pseudosenonicus* n. sp. 11, 12, holotype. 14, 15, interference contrast.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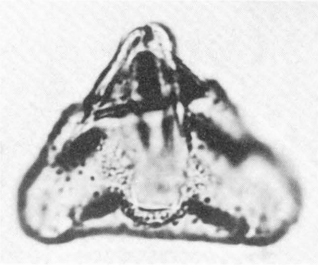
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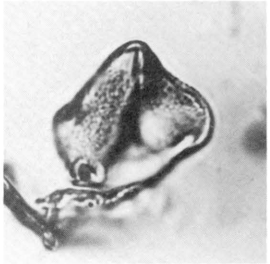
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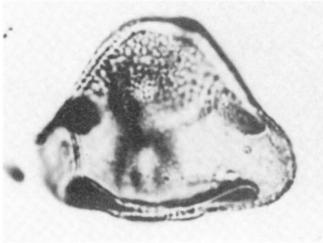
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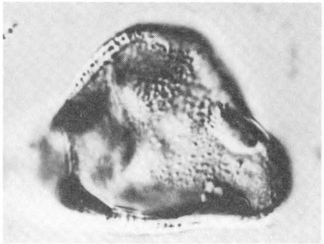
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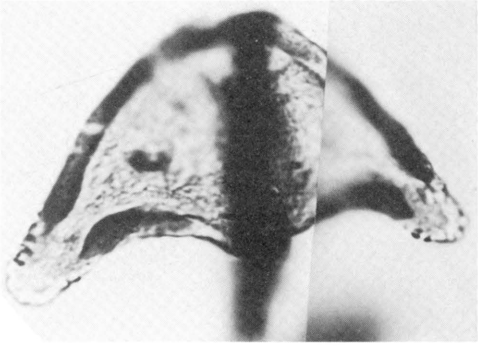
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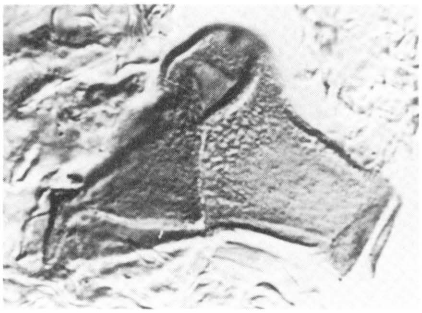
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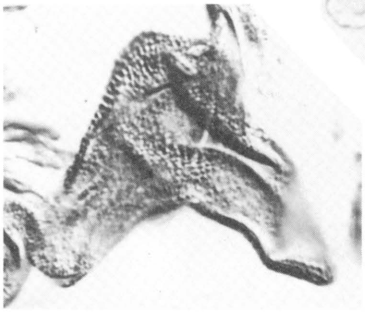
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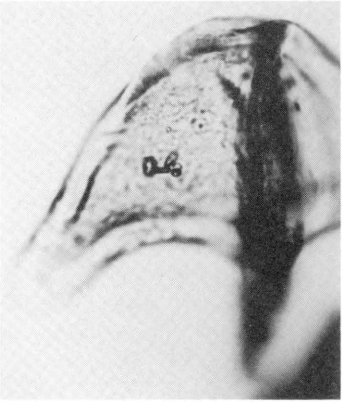
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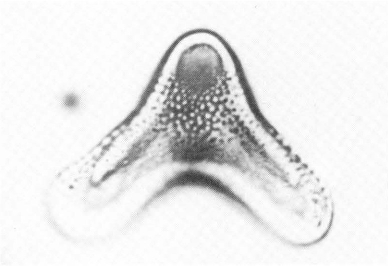
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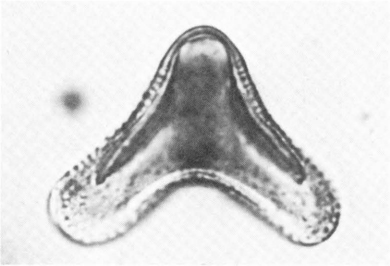
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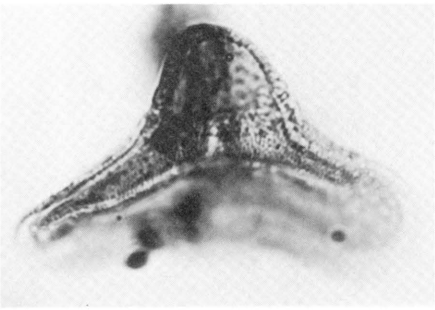
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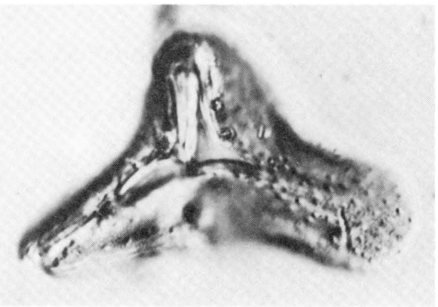
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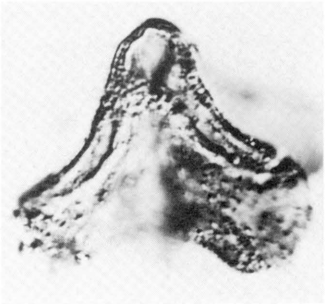
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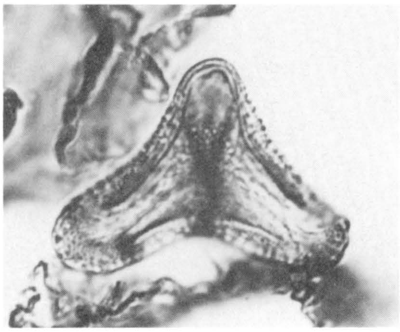
FIBULAPOLLIS, MANICORPUS

PLATE 6

Colpate pollen

[Magnification × 1,000. All specimens Maastrichtian in age. Specimens photographed with bright field illumination, unless otherwise noted]

FIGURES 1–3. *Manicorpus pseudosenonicus* n. sp. 2, 3, interference contrast.
4, 5. *Manicorpus* sp. cf. *M. pseudosenonicus* n. sp.
6. *Manicorpus rostratus* Srivastava 1968.
7–8. *Manicorpus* sp.



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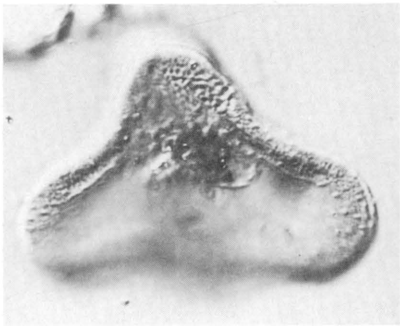

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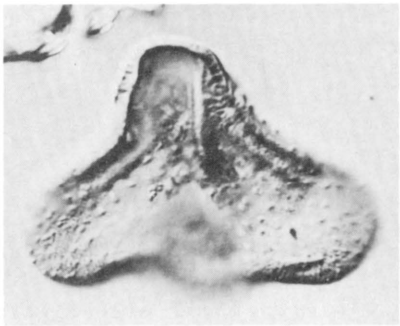

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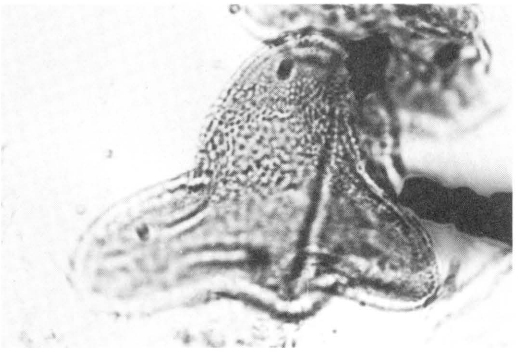

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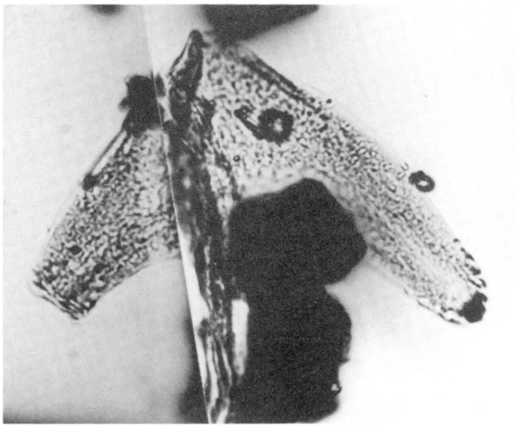

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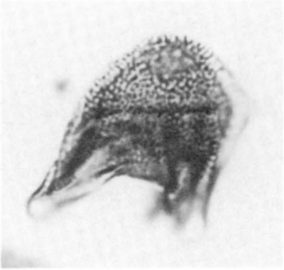

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MANICORPUS

PLATE 7

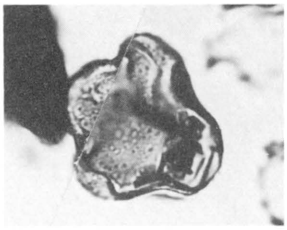
Colpate pollen

[Magnification × 1,000. All specimens Maastrichtian in age. Specimens photographed with bright field illumination, unless otherwise noted]

FIGURES 1–3. *Aquilapollenites immiser* Sweet 1986.

4. *Aquilapollenites unicus* (Chlonova 1957) Chlonova 1961.

5–10. *Aquilapollenites* sp. cf. *A. augustus* Srivastava 1969. 6, interference contrast; note that in this specimen, the left equatorial projection is folded over the body.



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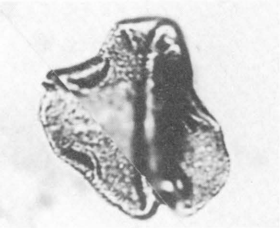

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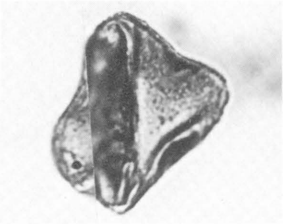

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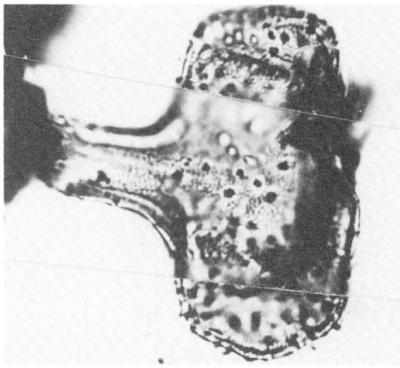

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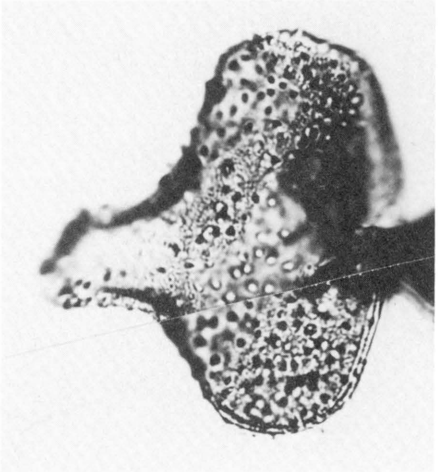

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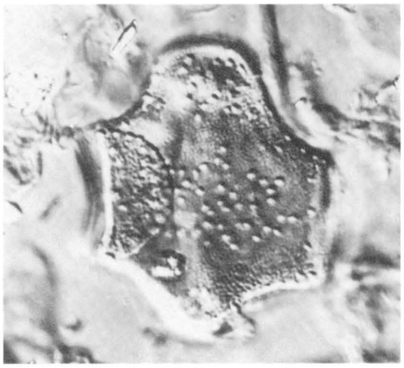

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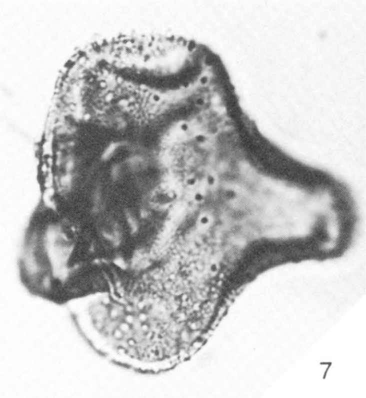

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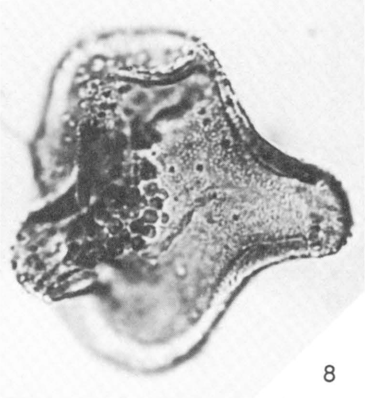

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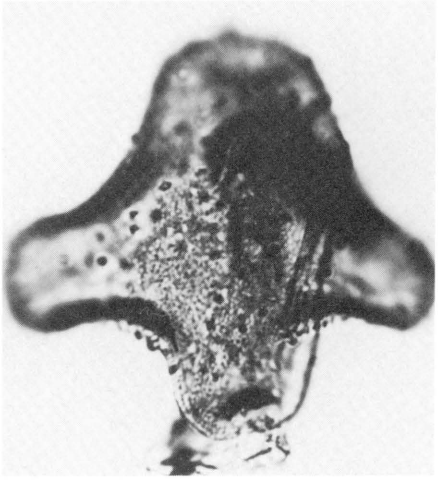

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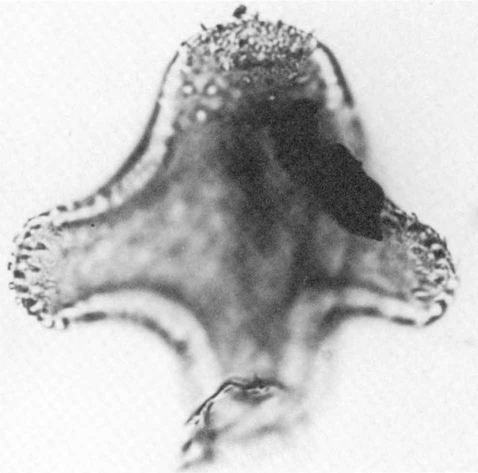

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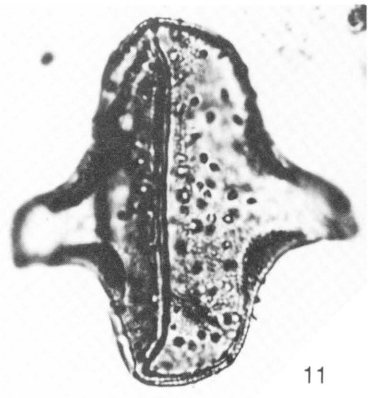

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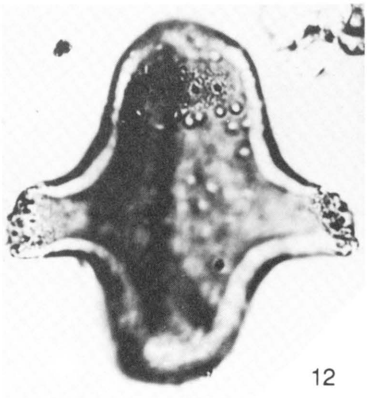

12

AQUILAPOLLENITES

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