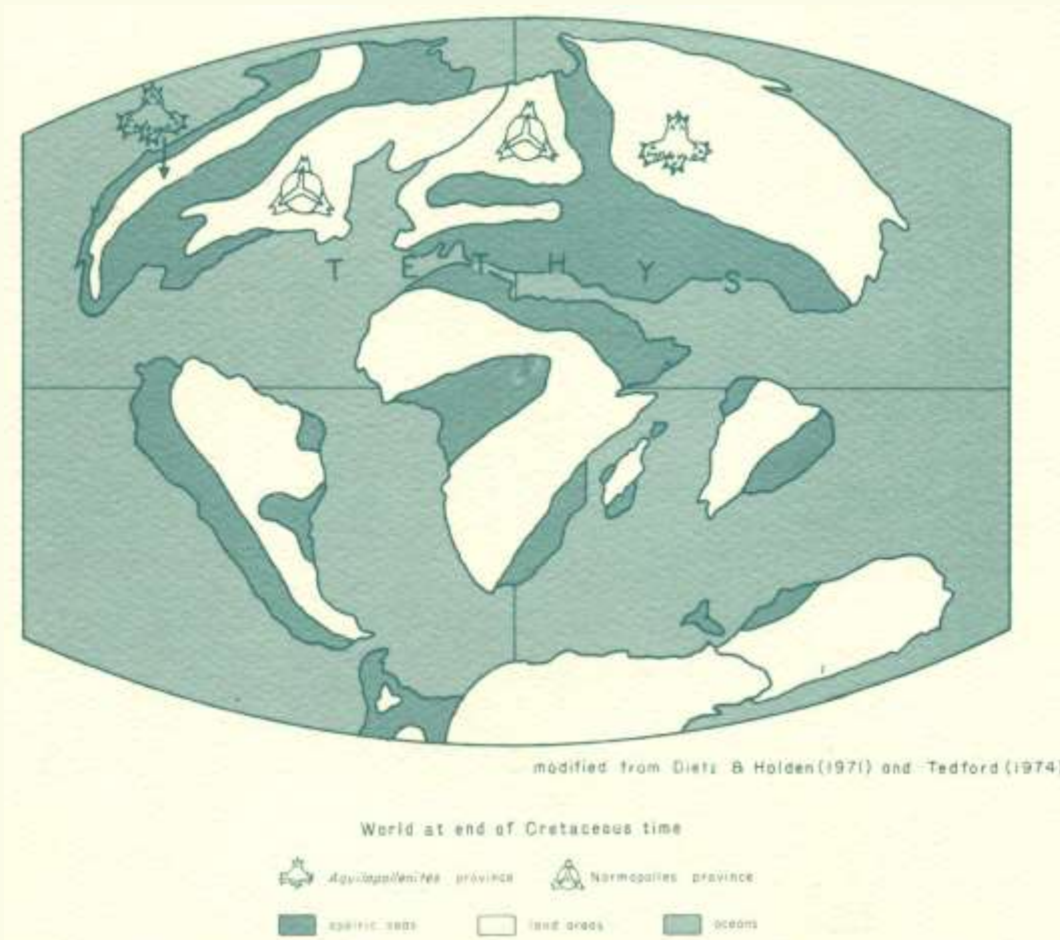
Circular 170 1980

Normapolles pollen from *Aquilapollenites* province, western United States

by Robert H. Tschudy



New Mexico Bureau of Mines & Mineral Resources

A DIVISION OF
NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY

Circular 170

New Mexico Bureau of Mines & Mineral Resources

A DIVISION OF
NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY

Normapolles pollen from *Aquilapollenites* province, western United States

by Robert H. Tschudy

SOCORRO 1980

First Printing, 1980

Published by Authority of State of New Mexico, NMSA 1953 Sec. 63-1-
4 Printed by University of New Mexico Printing Plant, January 1980

Available from New Mexico Bureau of Mines & Mineral Resources, Socorro, NM 87801 Price $2.50

Contents

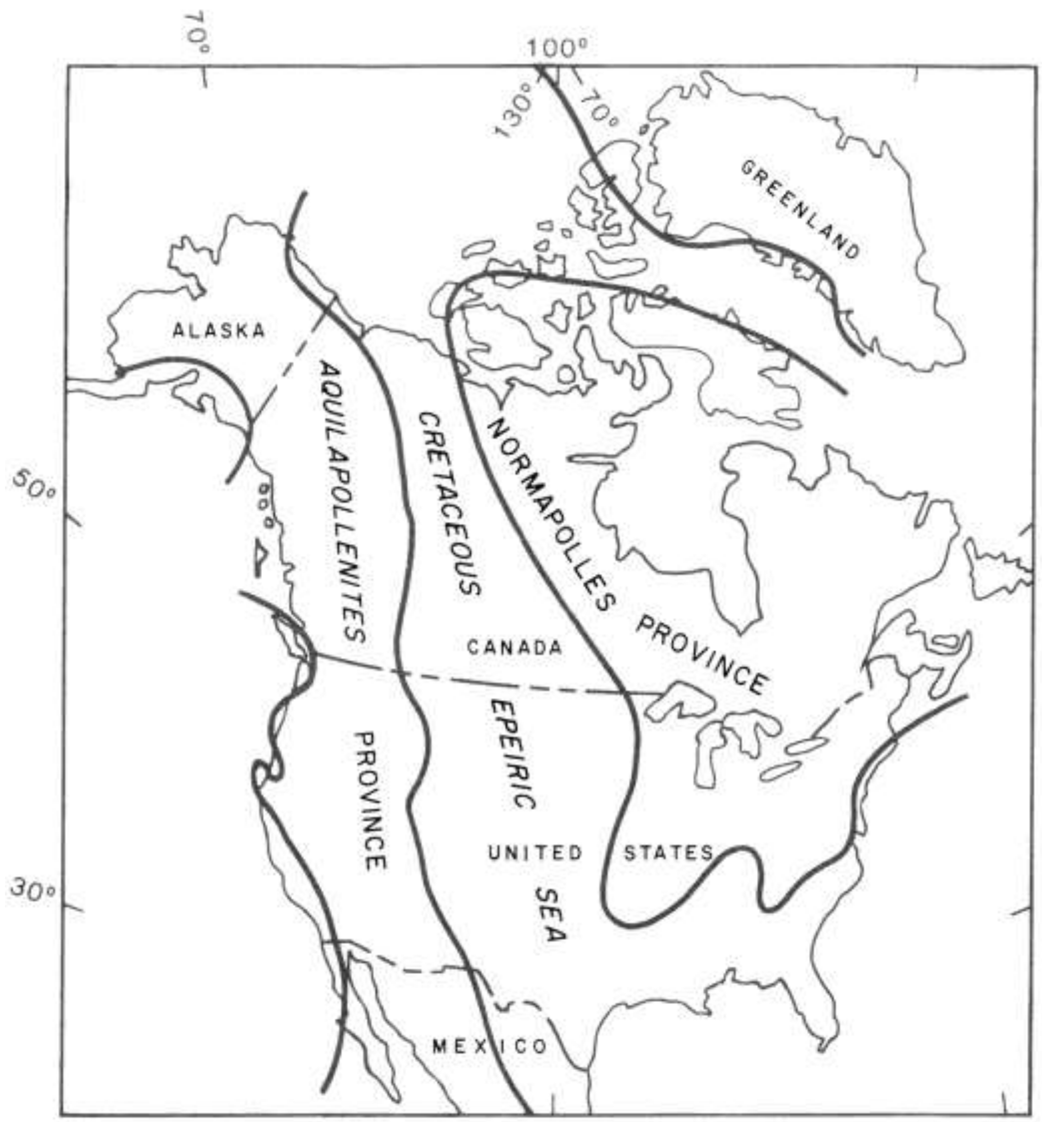


FIGURE 1—Probable distribution of land and sea in North America during Campanian time.

Abstract

During Late Cretaceous time in North America, two distinct land floras were present, one in the Normapolles province in northeastern North America and one in the *Aquilapollenites* province in the western part of the continent. A few fossil pollen grains assignable to Normapolles genera have been found in formations of the Western Interior of the United States. These formations lie within the *Aquilapollenites* pollen province. Pollen types found in Upper Cretaceous and lower Tertiary rocks from the Normapolles province and from the *Aquilapollenites* province generally are distinctly different. During Late Cretaceous time the two provinces were isolated from each other by epeiric seaway barriers to plant migration. The presence of Normapolles-type pollen in rocks of the *Aquilapollenites* province demonstrates that at least a few Normapolles genera were able to surmount this seaway barrier. A record of the presently known occurrences of Normapolles genera in the *Aquilapollenites* province of western North America is presented together with the stratigraphic distribution of these occurrences. Some Normapolles genera from the west have been shown to be of aid in the recognition of specific segments of the stratigraphic column. Others appear to be present only in the northern or southern part of the *Aquilapollenites* province, and still others have been found so infrequently that they are of minor stratigraphic significance.

Introduction

During Late Cretaceous time two distinct and geographically separate land floras were present in the northern hemisphere. The areas containing these floras have been named the Normapolles province and the *Aquilapollenites* province according to the predominant pollen type present (Góczán and others, 1967; Stanley, 1970; R. H. Tschudy, 1970). In North America during the Cretaceous, these two provinces were separated by a great north-south-trending epeiric sea (fig. 1) that apparently provided a barrier to plant migration until its final withdrawal during the early Tertiary. Upper Cretaceous and lower Tertiary rocks from eastern North America east of this seaway have yielded a Normapolles pollen flora, and those west of the seaway have yielded an *Aquilapollenites* pollen flora.

Fossil pollen from the western segment of North America during latest Cretaceous time is characterized by pollen of many species of the genus *Aquilapollenites* and by several other genera, such as *Cranwellia, Scollardia,* and *Wodehouseia,* that are virtually unknown from eastern North American rocks.

Upper Cretaceous rocks of the eastern part of North America are characterized by their content of pollen from numerous genera belonging to the Normapolles group. Most of these genera, such as *Interporopollenites, Pseudoculopollis,* and *Endoinfundibulapollis,* have never been observed in rocks from western North America. The *Aquilapollenites* province extends westward from the Mississippi embayment area through the western United States, Canada, and through Alaska into eastern Asia; the Normapolles province extends eastward from the Mississippi embayment to western Europe. During the Cretaceous, northeastern North America and Europe were apparently joined; the North Atlantic seaway had not yet opened sufficiently to pose a barrier to plant migration (Owen, 1976). In Eurasia, the two provinces were separated by a north-trending arm of the Tethys Sea during much of Cretaceous time; thus, the two provinces were effectively separated by seaway barriers to plant migration.

Pollen specimens assignable to the Normapolles group of genera occasionally have been found in rock samples from the *Aquilapollenites* province of western North America. At first glance, these occurrences appear anomalous. Because of their generally very low representation in pollen assemblages from the *Aquilapollenites* province, and because they appear to be out of place geographically, they have been ignored in some instances. I have seen only occasional isolated pollen grains assignable to Normapolles genera in samples from rocks from the northern part of the Rocky Mountains. In central Rocky Mountain rocks at the latitude of Denver, Colorado, and southwards, Normapolles pollen often appears in higher concentrations. Recent work in northwestern New Mexico (R. H. Tschudy, 1976b) recorded the presence of pollen of Normapolles genera in a frequency as high as 25 percent of the total angiosperm pollen present in some samples. This comparative abundance of Normapolles pollen, totally different from that of most other samples from west of the Mississippi embayment, led to this re-evaluation of the part played by Normapolles genera in the *Aquilapollenites* province. This report compiles the isolated data from our files in the Denver Laboratory and from the literature and presents these data in a stratigraphic framework.

ACKNOWLEDGMENTS-I thank Karl R. Newman and Raymond A. Christopher for suggestions for improving the manuscript and for calling my attention to additional references to Normapolles genera in the *Aquilapollenites* province. Sharon Van Loenen provided invaluable aid in the preparation of the illustrative material.

Previous work

References to Normapolles genera in western North America are scattered, and some of them are difficult to interpret. A significant proportion of the palynologic literature from western North America fails even to mention the occurrence of Normapolles genera. Papers mentioning Normapolles genera in the *Aquilapollenites* province may be segregated into groups that refer to the following general areas: southern Rocky Mountains, northern Rocky Mountains, western Canada, and California.

Southern Rocky Mountains

The first report of the presence of Normapolles pollen from the southern part of the Rocky Mountain area was in Anderson (1960), which discusses Cretaceous-Tertiary palynology of the east side of the San Juan Basin, New Mexico. Of the two specimens he photographed as representatives of the Normapolles genus *Extratriporopollenites,* the specimen from the Lewis Shale undoubtedly belongs to the genus *Trudopollis;* I cannot identify the specimen from the Kirtland Shale from the photograph.

The uppermost and lowermost occurrences of selected angiosperm pollen grains were used by Thompson (1972) to establish correlations between two sections of Mancos Shale in southwestern Colorado. He used representatives of the genera *Vacuopollis, Pseudoplicapollis, Plicapollis, Trudopollis,* and *Extratriporopollenites* (as well as 20 additional angiosperm-pollen types) to establish his correlations. The exact positions in the sections of uppermost and lowermost occurrences of the above taxa were not shown. I have estimated the positions of all the Normapolles taxa mentioned, except *Extratriporopollenites, as* occurring within the Santonian-Coniacian interval. *Extratriporopollenites* was probably limited to the Turonian. No photographs were provided.

Romans (1975) reported the presence of specimens attributable to the genus *Plicapollis* from two formations from Black Mesa, Arizona. He reported that this type of pollen is common in the Toreva Formation and is rare in the Wepo Formation. Unfortunately, the accurate stratigraphic positions of the samples studied were not given.

I reported the presence of the following Normapolles genera in rocks from the San Juan and Raton Basins, New Mexico (R. H. Tschudy, 1973): *Thomsonipollis* in the Ojo Alamo Sandstone and Raton Formation and *Trudopollis* in the Trinidad Sandstone, Vermejo and Fruitland Formations, Lewis Shale, and Pictured Cliffs Sandstone. Góczán and others (1967) noted that specimens of the genus *Thomsonipollis* had been observed in samples of the Laramie (Raton?) Formation, Raton Pass, Alabama. This note certainly refers to Raton Pass on the border between Colorado and New Mexico!

Later, I documented the presence of pollen of the genus *Complexiopollis* in the Gibson and Dilco Coal Members of the Crevasse Canyon Formation of northwestern New Mexico (R. H. Tschudy, 1976b). I also found specimens of the genera *Trudopollis, Pseudoplicapollis,* and *Plicapollis* in the Gibson Coal Member of the Crevasse Canyon Formation as well as specimens of *Plicapollis* in the basal part of the Menefee Formation.

Northern Rocky Mountains

The earliest mention of fossil pollen attributable to Normapolles genera in the Rocky Mountain area was probably that of Sarmiento (1957). He provided photographs of several specimens from the Mancos Shale of Utah (Turonian-Coniacian) that probably represent Normapolles genera. He notes specifically the genera *Extratriporopollenites* and *Oculopollis;* however, it is doubtful that the specimens shown belong to these two genera. Sarmiento's photographs suggest the genera *Plicapollis* and *Pseudoplicapollis.* At the time of publication, 1957, little was known of the characteristics of the Normapolles group, particularly in North America, and the publication of Góczán and others (1967), which clarified the morphological characteristics of the group, had not yet appeared.

The first suggestion of the potential stratigraphic value of several Normapolles genera found in western North American rocks appeared in Newman (1965). He showed tentative stratigraphic ranges and figured specimens of *Sporopollis* (now *Pseudoplicapollis), Conclavipollis* (now *Vacuopollis),* and *Trudopollis.* See Góczán and others (1967) for details of changes in nomenclature. Specimens representing these fossil genera were found in the upper part of the Mancos Shale, in the Iles Formation, and in the basal part of the Williams Fork Formation of western Colorado, all of Campanian age. Later, Newman (1972) compiled the vertical-range zones of selected palynomorph taxa in Montana and incorporated the then known ranges of the above three Normapolles taxa into that scheme.

Lohrengel (1969) figured a specimen that he named *Extratriporopollenites pompeckji* (Potonié) Thomson and Pflug from the Kaiparowits Formation of Utah. The photograph and the name suggest the genus *Trudopollis,* but the photograph is poor, and no description is given. Lohrengel placed the Kaiparowits Formation in the upper Maestrichtian. Later work (Peterson and Kirk, 1977) placed the Kaiparowits Formation in the upper Campanian.

Ryder and Ames (1970) figured a specimen from the upper part of the Beaverhead Formation (Turonian part) of southwestern Montana and east-central Idaho that is probably a specimen of *Pseudoplicapollis.* Orlansky (1971) reported rare specimens of *Pseudoplicapollis* and figured specimens that are probably attributable to the genus *Vacuopollis* from the Straight Cliffs Sandstone (Santonian) of Utah.

A survey of palynomorphs from several coal-bearing horizons in Utah (May, 1972) disclosed the presence of occasional pollen specimens belonging to the Normapolles group. After an examination of May's photographs, I have included on fig. 2 only those forms of unquestionable generic identity. Most of the specimens he attributed to the Normapolles genera *Latipollis* (now *Complexiopollis)* and *Nudopollis* cannot be identified with certainty; consequently, they are omitted. All of May's specimens are from the early Campanian.

Stone (1973) examined about 64 samples from measured reference sections of the Almond Formation in the Rock Springs uplift area of Wyoming. Some idea of the relative sparcity of Normapolles palynomorphs in these rocks can be obtained by an examination of Stone's data. From the 64 samples only 5 specimens of *Vacuopollis,* 3 specimens of *Trudopollis,* 2 of *Plicapollis,* and 1 of *Pseudoplicapollis* were found. In other words, 11 Normapolles specimens were found among 4,664 pollen and spore specimens counted, or among 1,695 angiosperm-pollen grains counted.

I have reported the presence of pollen of the genus *Basopollis* from Eocene rocks of the Powder River Basin (R. H. Tschudy, 1976a), as well as pollen of the genera *Thomsonipollis, Nudopollis,* and *Interpollis microsupplingensis* Krutzsch from the Eocene part of the Dawson Arkose of the Denver Basin (Soister and R. H. Tschudy, 1978).

Western Canada

Six references to Normapolles pollen from western Canadian rocks have come to my attention. Rouse and Srivastava (1972) photographed specimens from the Paleocene Bonnet Plume Formation of northeastern Yukon, Canada, that they attributed to the genera *Latipollis* and *Extratriporopollenites.* Judging from the photographs, I believe that both specimens figured represent the Normapolles genus *Basopollis.*

Hopkins (1973) mentioned that a very few triporate pollen grains referable to the Normapolles group have been observed in the lower part of the Kanguk Formation (probable Turonian age) on Ellef Ringnes and Amund Ringnes Islands, arctic Canada. Hopkins did not specify any particular genera.

McIntyre (1974) recorded and photographed specimens attributable to the genera *Plicapollis, Trudopollis,* and *Extratriporopollenites. Plicapollis* was found in the "Bituminous Zone" of probable Santonian-Campanian age from the Horton River section, Northwest Territories, Canada. *Trudopollis* and *Extratriporopollenites* were found in the "Pale Shale Zone" of probable early Maestrichtian age in the same section.

Three Canadian papers appeared in 1975: Singh (1975) noted that he found a few specimens of *Complexiopollis* in the Morden Member of the Vermilion River Formation (late Turonian) of Alberta. The papers by Norris and others (1975) and Jarzen and Norris (1975) discussed the same rocks but from slightly different viewpoints. These papers mention the rare presence of *Vacuopollis* in the upper Colorado Group (probable Turonian age) from Alberta. *Trudopollis* pollen was found frequently enough to be used to characterize a middle Campanian fossil pollen suite as the *Trudopollis* Suite. This suite was present in the Oldman and Foremost Formations of Alberta.

California

The only other references to Normapolles genera from the western United States that I have found are those of Drugg (1967) and Chmura (1973). Drugg (1967) found specimens of *Nudopollis terminalis* (Thomson and Pflug) Pflug in the upper part of the Dos Palos Member of the Moreno Formation of California. This part of the Dos Palos Member is of Paleocene age. Chmura (1973) found seven specimens of *Trudopollis speciosus* Zaklinskaya from the Moreno Formation of California. This species of *Trudopollis* differs from other *Trudopollis* specimens found in the Western Interior. Most, if not all, of the other specimens can be accommodated in the species circumscription of *Trudopollis meekeri* Newman. The part of the Moreno Formation that yielded *Trudopollis* specimens is of late Campanian and early Maestrichtian age.

TABLE 1—Localities of USGS Normapolles-pollen samples from formations listed in fig. 2. Letters after USGS paleobotany locality numbers indicate multiple samples from separate horizons; these samples are from the same locality and obtained from cores or measured sections.

USGS Paleobot. Loc. No.	Formation	Sample type[1]	Location[2]	Sec.	T.	R.	County	State
D4861-A,B	Wasatch	O	935' FSL, 2600' FWL	30	9S.	14E.	Big Horn	Wyoming
D5002-C	Wasatch	O	SW¼NE¼	21	43N.	78W.	Johnson	Wyoming
D5095-A,B	Wasatch	C	SW¼SE¼SE¼SE¼	2	47N.	73W.	Campbell	Wyoming
D5504	Dawson Arkose	O	E½NW¼	14	9S.	62W.	Arapahoe	Colorado
D5672	Dawson Arkose	C	NW¼	19	8S.	62W.	Elbert	Colorado
D5781-A	Dawson Arkose	O	Center	17	9S.	61W.	Elbert	Colorado
D5667	Dawson Arkose	C	W½	27	9S.	63W.	Elbert	Colorado
D5668	Denver	C	W½	3	9S.	64W.	Elbert	Colorado
D5669	Denver	C	SW¼	2	9S.	65W.	Elbert	Colorado
D5781-A,B	Denver	O	Near center	17	9S.	61W.	Elbert	Colorado
D5837	Denver	O	NW¼NW¼	33	5S.	63W.	Arapahoe	Colorado
D4665-D	Ojo Alamo	C	1,324' FSL, 1,614' FWL	36	29N.	4W.	Rio Arriba	New Mexico
D4219-J,K,L	Raton	C	SE¼SW¼	17	31N.	19E.	Colfax	New Mexico
D3910-E,H	Raton	C	Center	33	31N.	19E.	Colfax	New Mexico
D4219-G,H,I	Raton	C	SE¼SW¼	17	31N.	19E.	Colfax	New Mexico
D3690-F	Hell Creek	MS	W½	14	141N.	55E.	Dawson	Montana
D3472-J	Hell Creek	MS	SE¼	29	21N.	34E.	Garfield	Montana
D3690-B	Fox Hills, Ss., Colgate Mbr.	MS	SE¼SE¼	27	141N.	55E.	Dawson	Montana
D1331	Fox Hills, Ss.	O	SW¼	14	38N.	62W.	Niobrara	Wyoming
D3673	Fox Hills, Ss.	O	Center	36	7N.	91W.	Moffat	Colorado
D4179-C	Vermejo	MS	NE¼SE¼	1	32N.	17E.	Colfax	New Mexico
D4757-D	Fruitland	O	Center	31	29N.	15W.	San Juan	New Mexico
D4666-A,B,D,E, G,I	Fruitland	C	1324' FSL, 1614' FWL	36	29N.	4W.	Rio Arriba	New Mexico
D3913	Trinidad Ss.	MS	Center	27	31N.	22E.	Colfax	New Mexico
D4178	Trinidad Ss.	O	NW¼NE¼SE¼	1	32N.	17E.	Colfax	New Mexico
D4761-B	Pictured Cliffs Ss.	C	1324' FSL, 1614' FWL	36	29N.	4W.	Rio Arriba	New Mexico
D3739-A	Mesa Verde Teapot, Ss. Mbr.	MS	NW¼SE¼	34	38N.	79W.	Natrona	Wyoming
D4779-A	Lewis Sh.	C	1324' FSL, 1614' FWL	36	29N.	4W.	Rio Arriba	New Mexico
D3725-C	Judith River	O	NW¼	26	24N.	17E.	Blaine	Montana
D3726-D	Judith Riber	O	NW¼	26	24N.	17E.	Blaine	Montana
D3724-B	Claggett Sh.	O	NE¼SW¼	12	22N.	17E.	Fergus	Montana
D3718-A,G,H	Eagle Ss.	O	NW¼NW¼	13	22N.	17E.	Fergus	Montana
D3719	Telegraph Creek	O	NW¼NW¼	13	22N.	17E.	Fergus	Montana
D3324	Maudlow	O	SE¼SE¼	26	4N.	5E.	Gallatin	Montana
D4758-A,B	Menefee	O	Center	5	29N.	16W.	San Juan	New Mexico
D3785-A,F,I,J, K,L,M,N	Niobrara	DH	SE¼NW¼	34	41S.	4E.	Kane	Utah
D4670	Niobrara	MS	SW¼	6	4N.	8E.	Gallatin	Montana
D4878	Niobrara	O	SW¼NW¼	34	46N.	114W.	Teton	Wyoming
D5224-A,B	Crevasse Canyon, Gibson Coal Mbr.	O	NE¼NE¼	20	16N.	12W.	McKinley	New Mexico
D5225-B	Crevasse Canyon, Gibson Coal Mbr.	O	SW¼NW¼	29	17N.	12W.	McKinley	New Mexico
D4879-A,B,G,H	Bacon Ridge Ss.	MS	Center W½	10	44N.	114W.	Teton	Wyoming
D5215-E	Crevasse Canyon, Dilco Coal Mbr.	O	NW¼SW¼	31	16N.	12W.	McKinley	New Mexico

[1]O=outcrop
MS=measured section
DH=drill hole
C=core

[2]FSL=from south line
FWL=from west line

Stratigraphic framework

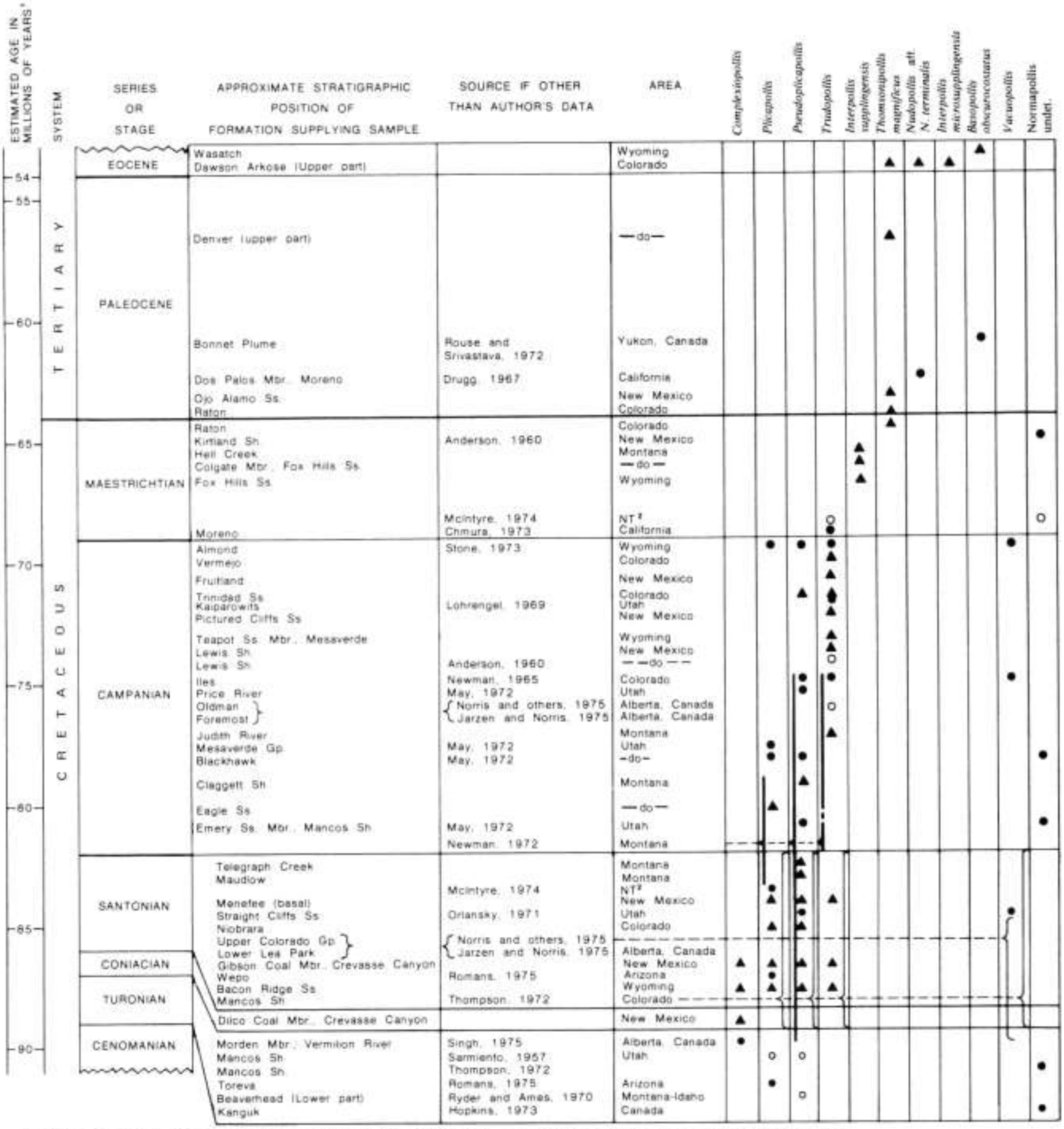
Records of western occurrences of Normapolles pollen from the files of the USGS Denver palynology laboratory as well as those derived from a literature survey have been assembled in table 1 and fig. 2. Table 1 gives USGS sample localities; fig. 2 shows the approximate stratigraphic positions of more than 40 formations in the *Aquilapollenites* province that have yielded pollen grains assignable to Normapolles genera. These formations range in age from Turonian to early Eocene. All of the records from the USGS Denver palynology laboratory involve more than single specimens, although the frequency of occurrence is usually well below 0.01 percent of palynomorphs in the sample.

A single specimen of *Choanopollenites transitus* R. Tschudy was recorded from the Judith River Formation of Montana, and a single specimen of *Choanopollenites consanguineus* R. Tschudy was found in the Gibson Coal Member of the Crevasse Canyon Formation in New Mexico. These two isolated specimens have not been included in fig. 2. Two new Normapolles genera, *Siberiapollis* and *Montanapollis*, were described by B. D. Tschudy (1971) from upper Campanian rocks of Montana. These genera have not been found in the Normapolles province of the eastern United States or elsewhere. Because the occurrences of these two genera are limited to rocks of the *Aquilapollenites* province, they too have been omitted from fig. 2. Several specimens tentatively identified as belonging to the genus *Minorpollis* were recorded from Santonian samples, and one specimen was recorded from the Campanian. The specimens were not abundant enough to eliminate the possibility that they might represent specimens of *Pseudoplicapollis* that failed to show the characteristic plicae. Because the generic determination is questionable, I have chosen to omit these possible occurrences from fig. 2.

I have not found Normapolles pollen specimens in Western Interior rocks of Turonian or Cenomanian age. I have not examined many Turonian samples, but I have studied a large number of Cenomanian samples, mostly from the Dakota Sandstone.

The stratigraphic coverage represented by the U.S. Geological Survey samples is not uniform, primarily due to two factors: 1) the coverage represents mainly those areas of specific interest to the field geologists who have submitted many of the samples for analysis; and 2) the relative proportion of marine and continental rocks present in the Western Interior of the United States is not uniform. Samples from the marine intervals generally have not been submitted for pollen and spore evaluation.

Many samples have been examined from some of the formations listed in fig. 2; however, particularly in the northern part of the area, pollen grains belonging to Normapolles genera were observed in only a few of the samples (for example, *Interpollis supplingensis* (Pflug) Krutzsch from the Hell Creek and Fox Hills Formations). The plants that produced these pollen grains must have been a very minor constituent of the total land flora. On the other hand, some genera— particularly in the central and southern parts of the area— are consistently present in most samples from the studied interval (for example, *Thomsonipollis magnificus* (Thomson and Pflug) Krutzsch in the Dawson Arkose and in the Raton and Denver Formations).



[1]Estimated age modified from Obradovich and Cobban (1975) for Cretaceous, and Geological Society of London (1964) for Tertiary.
[2]Northwest Territories, Canada

EXPLANATION

Occurrences of pollen from

▲ U.S. Geological Survey Denver Palynology Laboratory records

● Records from cited literature

○ Interpreted taxa determinations

---┫ Approximate stratigraphic ranges cited by Newman (1972)

---{ Approximate occurrence interval where sample position not stated

FIGURE 2—OCCURRENCES OF NORMAPOLLES POLLEN FROM THE *AQUILAPOLLENITES* PROVINCE OF WESTERN NORTH AMERICA.

Discussion of Normapolles genera

Complexiopollis

fig. *3a-c*

I have found representatives of this genus in only three formations, all from the Santonian-Coniacian interval. Singh (1975) reported specimens of *Complexiopollis* from the Morden Creek Member of the Vermilion River Formation of Alberta. In Europe and eastern North America, this genus first appeared in the Cenomanian. Its later appearance in western North America suggests the time that the genus was able to migrate across the Cretaceous midcontinental epeiric sea. Additional specimens may have been found; but, because of identification difficulties, they have not been recorded. It is often difficult to place many Normapolles specimens into appropriate species categories unless a sufficient number of specimens is on hand for a detailed morphologic evaluation. Often, samples from the Western Interior do not yield sufficient specimens for a reliable species determination. At times this difficulty may also apply at the generic level.

Plicapollis

fig. *3d-g*

Representatives of this genus have been observed consistently from formations representing the Santonian and basal Campanian intervals. Stone (1973) figured a specimen from the Almond Formation (upper Campanian), and Romans (1975) reported pollen of this genus from upper Turonian rocks. May (1972) figured specimens from the Mesaverde and Blackhawk Formations. The pollen of the Normapolles group recorded by Sarmiento (1957) may pertain to the genera *Plicapollis* and *Pseudoplicapollis.* However, Sarmiento did not provide descriptions; therefore, reliance must be placed upon his photographs. It is certain that pollen of triporate genera was found by Sarmiento, but the accurate determination of the genera he found awaits further investigation. Some of the *Plicapollis* specimens may represent new species, but others may have an affinity to *Plicapollis rusticus* R. Tschudy.

Pseudoplicapollis

fig. *3h-j*

Pollen of *Pseudoplicapollis*, formerly referred to as *Sporopollis* (Góczán and others, 1967) is found in some Western Interior formations ranging in age from Turonian to late Campanian. The species represented by most published and unpublished records is *Pseudoplicapollis endocuspis* R. Tschudy. Specimens are relatively common in some Santonian samples but are absent or sparse in most of those of Campanian age.

Trudopollis

fig. *3k-m*

Newman (1965) proposed a new species of *Trudopollis, T. meekeri.* He found this pollen type in samples from the Iles and basal Williams Fork Formations of western Colorado. Most of the specimens of *Trudopollis* recorded from the Western Interior, with the exception of *Trudopollis speciosus* Zaklinskaya reported by Chmura (1973) from California, probably are of this species. This genus has been found in Santonian to upper Campanian rocks. McIntyre (1974) reported the presence of this genus in basal Maestrichtian rocks from arctic Canada. Apparently, plants of this genus became extinct in the Western Interior during latest Campanian or early Maestrichtian time.

Interpollis supplingensis (Pflug) Krutzsch

fig. *3n-o*

This species has not been reported in the Western Interior palynological literature. I have found specimens in only the Fox Hills Sandstone undifferentiated, the Colgate Member of the Fox Hills, and the Hell Creek (or Lance) Formation of Wyoming and Montana. K. R. Newman (oral communication, 1978) has found specimens in the Laramie Formation of the Golden, Colorado, area. This species has been observed in a frequency of only 2-3 specimens per slide. Each of these slides contains perhaps 5,000-10,000 additional non-Normapolles palynomorphs. This species of *Interpollis is* readily recognizable but is extremely sparse.

Thomsonipollis magnificus (Thomson and Pflug) Krutzsch

fig. *3p-q*

Pollen of this genus has been found in Western Interior rocks of latest Maestrichtian to early Eocene age. *T. magnificus* is a common constituent of many assemblages of this age range from Colorado and New Mexico. Specimens of *Thomsonipollis* have not been observed from any samples north of the approximate latitude of Denver, Colorado, although a great many Maestrichtian and Paleocene samples from this area have been studied. Specimens from the Western Interior have a thinner wall than does the holotype of *T. magnificus* and more closely resemble the species *T. magnificoides* Krutzsch. Both Elsik (1968) and Srivastava (1972) have noted that gradational forms prevent the clear separation of the two species *Thomsonipollis magnificus* and *T. magnificoides;* consequently, they have included a wide range of morphological forms within the species circumscription of *T. magnificus.*

Nudopollis aff. N. terminalis (Thomson and Pflug) Pflug

fig. *3r-s*

Specimens belonging to this genus have been reported by Drugg (1967) from the Paleocene part of the Moreno

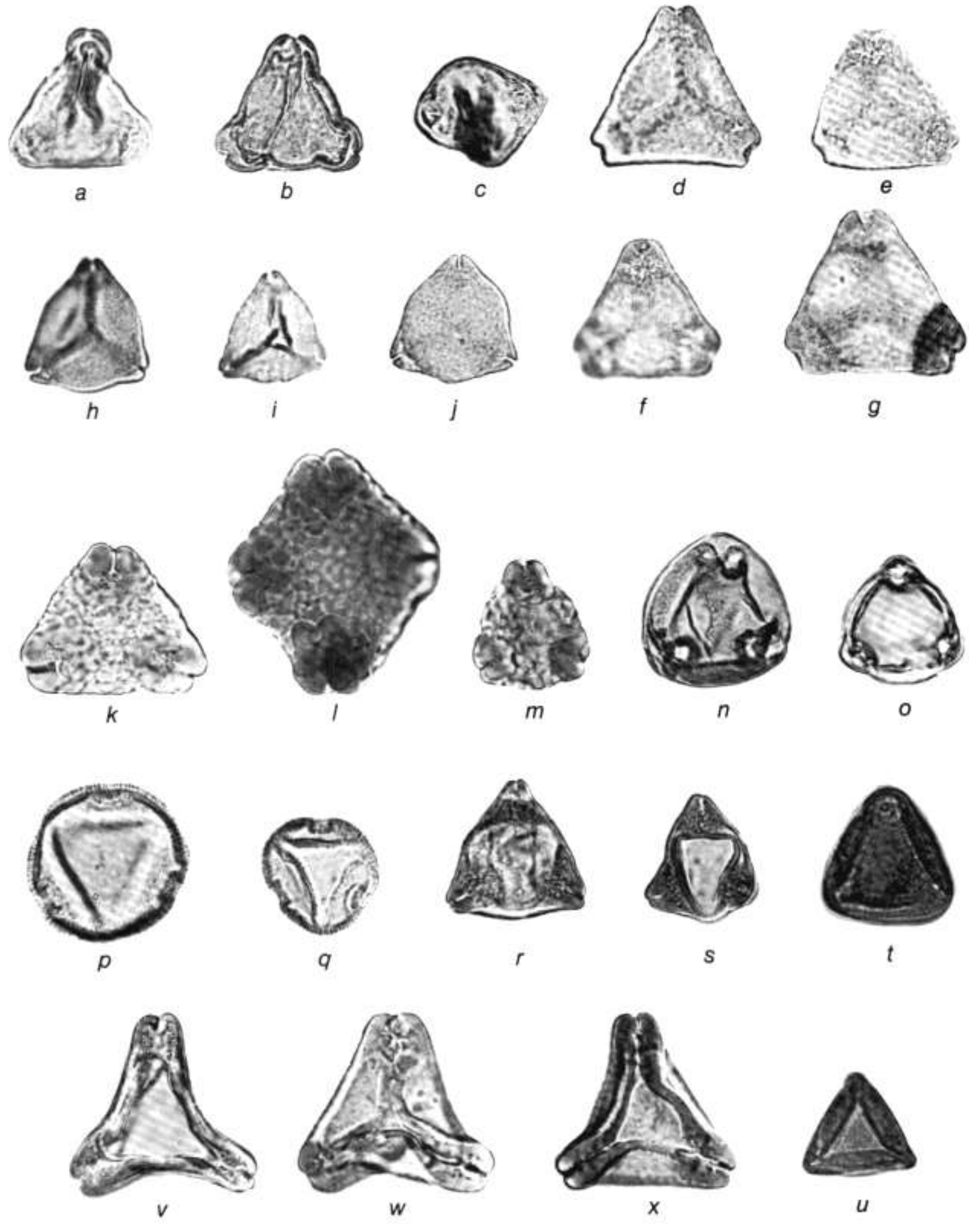


FIGURE 3—NORMAPOLLES POLLEN, ×1000: **a,b**—*Complexiopollis,* polar view, Dilco Coal Member, Crevasse Canyon Formation, New Mexico; **c**—equatorial view of same; **d,e**—*Plicapollis,* Gibson Coal Member, Crevasse Canyon Formation, New Mexico; **f**—*Plicapollis,* Eagle Sandstone, Montana; **g**—*Plicapollis,* Straight Cliffs Sandstone, Colorado; **h**—*Pseudoplicapollis,* Red Bird Silty Member, Pierre Shale, Wyoming; **i**—*Pseudoplicapollis,* Fruitland Formation, New Mexico; **j**—*Pseudoplicapollis,* Gibson Coal Member, Crevasse Canyon Formation, New Mexico; **k**—*Trudopollis* from same; **l**—*Trudopollis,* Trinidad Sandstone, New Mexico; **m**—*Trudopollis,* Teapot Sandstone Member, Mesaverde Formation, Wyoming; **n**—*Interpollis supplingensis* (Pflug) Krutzsch, Hell Creek Formation, Montana; **o**—*I. supplingensis* from Fox Hills Sandstone, Wyoming; **p**—*Thomsonipollis magnificus* (Thomson and Pflug) Krutzsch, Dawson Arkose, Colorado; **q**—*T. magnificus,* Raton Formation, New Mexico; **r,s**—*Nudopollis* aff. *N. terminalis* (Thomson and Pflug) Pflug, Dawson Arkose, Colorado; **t,u**—*Interpollis microsupplingensis* Krutzsch from same; **v,x**—*Basopollis* aff. *B. obscurocostatus* R. Tschudy, Wasatch Formation, Wyoming.

Formation of California. I have found *Nudopollis* aff. *N. terminalis* in samples from the early Eocene part of the Dawson Arkose of the Denver Basin. Westward dispersal of plants that produced this pollen occurred after the withdrawal of the Cretaceous epeiric sea.

Interpollis microsupplingensis Krutzsch

fig. *3t-u*

Pollen of this species has been reported from the eastern margin of the Mississippi embayment (R. H. Tschudy, 1975) and is a common constituent of Eocene assemblages from the bauxite area of Arkansas, on the western border of the embayment. I recently found this species in the early Eocene part of the Dawson Arkose of the Denver Basin.

Basopollis aff. *B. obscurocostatus* R. Tschudy

fig. 3v-x

Representatives of this taxon were found in formations from the basal Eocene part of the Wilcox Group of the Mississippi embayment (R. H. Tschudy, 1975). In the Western Interior this pollen type has been observed only in lower Eocene rocks of the Powder River Basin of Wyoming and southern Montana and in Paleocene rocks of Yukon, Canada (Rouse and Srivastava, 1972). Plants that produced pollen of *Basopollis* aff. *B. obscurocostatus* R. Tschudy, like those of *Nudopollis terminalis* (Thomson & Pflug) Pflug and *Interporopollenites microsupplingensis* Krutzsch, could have migrated westward from the Normapolles province after the withdrawal of the Cretaceous epeiric sea. Furthermore, *Basopollis* has not been observed in rocks younger than early Eocene in either region, suggesting that this taxon became extinct at approximately that time.

Vacuopollis

Newman (1965) reported the presence of specimens of *Conclavipollis* (now *Vacuopollis)* from the upper Man-cos, Iles, and lower Williams Fork Formations (Campanian) of western Colorado. This genus has been reported also by Stone (1973) from the Almond Formation (Campanian) of Wyoming, by Orlansky (1971) from the Straight Cliffs Sandstone of Utah (Santonian), and by Norris and others (1975) and Jarzen and Norris (1975) from the interval occupied by the upper Colorado Group and lower Lea Park Formation (late Turonian to Santonian) of Alberta, Canada. I have not seen specimens of this pollen type in any Western Interior sample.

Significance of Normapolles genera in Western Interior

Many of the occurrences of Normapolles genera in the *Aquilapollenites* province are probably of little practical significance because of their extremely low frequency. However, some Normapolles genera appear to be limited to specific segments of the stratigraphic column and also are present in numbers sufficient to provide useful biostratigraphic information. At present *Complexiopollis* pollen has been found too infrequently to be of great value; it has been found only in a few samples of late Turonian to early Santonian age, but not in younger samples. On the other hand, *Plicapollis* pollen is present in significant numbers in many Santonian samples, and when present, this taxon helps to identify this segment of the stratigraphic column. Similar significance can be attributed to the presence of *Pseudoplicapollis* and *Trudopollis. Interpollis supplingensis* has been observed only in Maestrichtian samples from the northern part of the *Aquilapollenites* province, and *Thomsonipollis magnificus* has been observed only from the southern part of the province in rocks of latest Maestrichtian to early Eocene age.

Nudopollis, Interpollis microsupplingensis Krutzsch, and *Vacuopollis* have been found too infrequently to be of much significance. *Basopollis obscurocostatus* R. Tschudy has been found consistently but in low frequency in many samples from the lower Eocene Wasatch Formation of the Powder River Basin. *Basopollis* is one of the taxa of value in identifying the early Eocene in this basin (R. H. Tschudy, 1976a).

Some of the plants that produced Normapolles-type pollen evidently were able to cross the Cretaceous epeiric sea barrier and become established in the *Aquilapollenites* province. A few others migrated westward after the withdrawal of the sea, before they became extinct in North America. Limited quantitative evidence also suggests that some of these migrants were better able to survive and multiply in the more southerly parts of the province than in the north. Representatives of Normapolles genera are found occasionally in the Canadian part of the *Aquilapollenites* province, and my own observations indicate that Normapolles pollen occurrences are less frequent in formations in the northwestern United States than they are in the south.

Some genera in some parts of the Western Interior have already demonstrated their value for biostratigraphy. Further observations will probably confirm or modify the ranges of the taxa reported here and will record occurrences in additional formations. The observed occurrences of pollen belonging to Normapolles genera in the Western Interior indicate that more attention should be given to these genera, even though they sometimes may be very sparse.

References

Anderson, R. Y., 1960, Cretaceous-Tertiary palynology, eastern side of the San Juan Basin, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Mem. 6, 58 p.

Chmura, C. A., 1973, Upper Cretaceous (Campanian-Maastrichtian) angiosperm pollen from the western San Joaquin Valley, California: Palaeontographica, ser. B, v. 141, nos. 3-6, p. 89-171

Dietz, R. S., and Holden, J. C., 1971, The breakup of Pangaea, *in* Continents adrift: Readings from Scientific American, p. 102-113

Drugg, W. S., 1967, Palynology of the Upper Moreno Formation (Late Cretaceous-Paleocene) Escarpado Canyon, California: Palaeontographica, ser. B, v. 120, nos. 1-4, p. 1-71

Elsik, W. C., 1968, Palynology of a Paleocene Rockdale lignite, Milam County, Texas, [pt.] 11, Morphology and taxonomy (end): Pollen et Spores, v. 10, no. 3, p. 599-664

Geological Society of London, 1964, Summary of the Phanerozoic time scale-the Geological Society Phanerozoic time-scale 1964, *in* The Phanerozoic time scale-a symposium, W. B. Harland and others, eds.: Geological Society of London, Quarterly Journal, v. 120s, p. 260-262

Gill, J. R., and Cobban, W. A., 1966, The Red Bird section of the Upper Cretaceous Pierre Shale in Wyoming, with a section on a new echinoid from the Cretaceous Pierre Shale of eastern Wyoming, by P. M. Kier: U.S. Geological Survey, Prof. Paper 393-A, p. Al -A73

Góczán, F., Groot, J. J., Krutzsch, W., and Pacltová, B., 1967, Die Gattungen des "Stemma Normapolles Pflug, 1953B" (Angiospermae). Neubeschreibungen and Revision Europäischer Formen (Oberkreide bis Eozän): Paläontologische Abhandlungen, ser. B, v. 2, no. 3, p. 427-633

Hopkins, W. S., Jr., 1973, Some preliminary palynological conclusions on the Albian and Upper Cretaceous strata of Amund and Ellef Ringnes Islands, District of Franklin *in* Report of activities, pt. B: Canada Geological Survey, Paper 73-1, pt. B, p. 179-180

Jarzen, D. M., and Norris, Geoffrey, 1975, Evolutionary significance and botanical relationships of Cretaceous Angiosperm pollen in the western Canadian Interior: Geoscience and Man, v. 11, p. 47-60

Lohrengel, C. F., 2nd, 1969, Palynology of the Kaiparowits Formation, Garfield County, Utah: Brigham Young University, Geology Studies, v. 16, pt. 3, p. 61-180 [1970]

May, F. E., 1972, A survey of palynomorphs from several coal-bearing horizons of Utah, *in* Central Utah coal fields by H. H. Doelling: Utah Geological and Mineralogical Survey, Mon. Ser. no. 3, p. 497-542

McIntyre, D. J., 1974, Palynology of an Upper Cretaceous section, Horton River, District of Mackenzie, N.W.T. [Northwest Territories]: Canada Geological Survey, Paper 74-14, 56 p.

Newman, K. R., 1965, Upper Cretaceous-Paleocene guide palynomorphs from northwestern Colorado: University of Colorado, Studies, Series in Earth Sciences, no. 2, 21 p.

, 1972, A review of Jurassic, Cretaceous and Paleocene stratigraphic palynology in Montana: Montana Geological Society, Guidebook 21st annual geological conference, Crazy Mountains Basin, p. 81-84

Norris, Geoffrey, Jarzen, D. M., and Awai-Thorne, B. V., 1975, Evolution of the Cretaceous terrestrial palynoflora in western Canada, *in* The Cretaceous System in the Western Interior of North America, by W. G. E. Caldwell: Canada Geological Association, Spec. Paper 13, p. 333-364

Obradovich, J. D., and Cobban, W. A., 1975, A time scale for the Late Cretaceous of the Western Interior of North America, *in* The Cretaceous System in the Western Interior of North America, by W. G. E. Caldwell: Canada Geological Society, Spec. Paper 13, p. 31-54

Orlansky, Ralph, 1971, Palynology of the Upper Cretaceous Straight Cliffs Sandstone, Garfield County, Utah: Utah Geological and Mineralogical Survey, Bull. 89, 57 p.

Owen, H. G., 1976, Continental displacement and expansion of the earth during the Mesozoic and Cenozoic: Royal Society of London, Philosophical Trans., A., Mathematical and Physical Sciences, v. 281, no. 1303, p. 223-291

Peterson, Fred, and Kirk, A. R., 1977, Correlation of the Cretaceous rocks in the San Juan, Black Mesa, Kaiparowits and Henry Basins, southern Colorado Plateau: New Mexico Geological Society, Guidebook 28th field conference, p. 167-178

Romans, R. C., 1975, Palynology of some Upper Cretaceous coals of Black Mesa, Arizona: Pollen et Spores, v. 17, no. 2, p. 273-329

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, no. 9, p. 1163-1179

Ryder, R. T., and Ames, H. T., 1970, Palynology and age of Beaverhead Formation and their paleotectonic implications in Lima region, Montana-Idaho: American Association of Petroleum Geologists, Bull., v. 54, no. 7, p. 1155-1171

Sarmiento, Roberto, 1957, Microfossil zonation of Mancos Group [Utah]: American Association of Petroleum Geologists, Bull., v. 41, no. 8, p. 1683-1693

Singh, Chaitanya, 1975, Stratigraphic significance of early angiosperm pollen in the mid-Cretaceous strata of Alberta, *in* The Cretaceous System in the Western Interior of North America by W. G. E. Caldwell: Canada Geological Society, Spec. Paper 13, p. 365-389

Soister, P. E., and Tschudy, R. H., 1978, Evidence for Eocene rocks in Denver Basin: Rocky Mountain Association of Geologists, Symposium on energy resources of the Denver Basin, Colorado Springs, Colorado, guidebook, p. 231-235

Srivastava, S. K., 1972, Some spores and pollen from the Paleocene Oak Hill Member of the Naheola Formation, Alabama (U.S.A.): Review of Palaeobotany and Palynology, v. 14, nos. 3-4, p. 217-285

Stanley, E. A., 1970, The stratigraphical, biogeographical, paleoautecological, and evolutionary significance of the fossil pollen group Triprojectacites: Georgia Academy of Science, Bull., v. 28, no. 1, p. 1-44

Stone, J. F., 1973, Palynology of the Almond Formation (Upper Cretaceous), Rock Springs Uplift, Wyoming: American Paleontology, Bull., v. 64, no. 278, 135 p.

Tedford, R. H., 1974, Marsupials and the new paleogeography, *in* Paleogeographic provinces and provinciality, C. H. Ross, ed.: Society of Economic Paleontologists and Mineralogists, Spec. Pub. no. 21, p. 109-126

Thompson, G. G., 1972, Palynologic correlation and environmental analysis within the marine Mancos Shale of southwestern Colorado: Journal of Sedimentary Petrology, v. 42, no. 2, p. 287-300

Tschudy, B. D., 1971, Two new fossil pollen genera from upper Campanian (Cretaceous) rocks of Montana: U.S. Geological Survey, Prof. Paper 750-B, p. B53-B61

Tschudy, R. H., 1970, Palynology of the Cretaceous-Tertiary boundary in the northern Rocky Mountain and Mississippi Embayment regions, *in* Symposium on palynology of the Late Cretaceous and early Tertiary, R. M. Kosanke and A. T. Cross, eds.: Geological Society of America, Spec. Paper 127, p. 65-111 [1971]

, 1973, The Gasbuggy Core-a palynological appraisal, *in* Cretaceous and Tertiary rocks of the southern Colorado Plateu, J. E. Fassett, ed.: Four Corners Geological Society, Cretaceous-Tertiary Mem., p. 131-143

, 1975, Normapolles pollen from the Mississippi Embayment: U.S. Geological Survey, Prof. Paper 865, 42 p.

, 1976a, Pollen changes near the Fort Union-Wasatch boundary, Powder River Basin, *in* Geology and energy resources of the Powder River, R. B. Landon, ed.: Wyoming Geological Association, Guidebook 28th annual field conference, Casper, Wyoming, p. 73-81

, 1976b, Palynology of Crevasse Canyon and Menefee Formations of San Juan Basin, New Mexico, *in* Guidebook to coal geology of northwest New Mexico, J. W. Shomaker, and W. J. Stone, eds.: New Mexico Bureau of Mines and Mineral Resources, Circ. 154, p. 48-58

Typefaces:	Text in 10-pt. English Times, leaded two points References in 8-pt. English Times, leaded one point Display heads in 24-pt. English Times bold
Table:	Camera-ready copy furnished by NM Bureau of Mines & Mineral Resources
Presswork:	Miehle Single Color Offset Harris Single Color Offset
Binding:	Saddlestitched with softbound cover
Paper:	Cover on 65-lb. ivory Carnival text Text on 70-lb. Quintessence Dull
Ink:	Cover—PMS 329 Text—PMS Black
Press run:	750