Palynology and Stratigraphy of an Upper Cretaceous Sedimentary-Volcanic Sequence, Emma Fiord, Northwest Ellesmere Island, N.W.T, Canada.

By

R. Andrew MacRae

Submitted in partial fufillment of the requirements for the degree of Bacheicr of Science, Honours at Dalhousie University, Halifax, Nova Scotia.

March, 1989

Distribution License

DalSpace requires agreement to this non-exclusive distribution license before your item can appear on DalSpace.

NON-EXCLUSIVE DISTRIBUTION LICENSE

You (the author(s) or copyright owner) grant to Dalhousie University the non-exclusive right to reproduce and distribute your submission worldwide in any medium.

You agree that Dalhousie University may, without changing the content, reformat the submission for the purpose of preservation.

You also agree that Dalhousie University may keep more than one copy of this submission for purposes of security, back-up and preservation.

You agree that the submission is your original work, and that you have the right to grant the rights contained in this license. You also agree that your submission does not, to the best of your knowledge, infringe upon anyone's copyright.

If the submission contains material for which you do not hold copyright, you agree that you have obtained the unrestricted permission of the copyright owner to grant Dalhousie University the rights required by this license, and that such third-party owned material is clearly identified and acknowledged within the text or content of the submission.

If the submission is based upon work that has been sponsored or supported by an agency or organization other than Dalhousie University, you assert that you have fulfilled any right of review or other obligations required by such contract or agreement.

Dalhousie University will clearly identify your name(s) as the author(s) or owner(s) of the submission, and will not make any alteration to the content of the files that you have submitted.

If you have questions regarding this license please contact the repository manager at dalspace@dal.ca.

Grant the distribution license by signing and dating below.

Name of signatory	Date

ORA • ET • LABORA

DALHOUSIE UNIVERSITY
Department of Geology
Halifax, N.S. Canada B3H 3J5 Telephone (902) 424-2358 Telex: 019-21863

DALHOUSIE UNIVERSITY, DEPARTMENT OF GEOLOGY

B.Sc. HONOURS THESIS

Author: R. Andrew MacRae

Title: "Palynology and Stratigraphy of an Upper Cretaceous Sedimentary-Volcanic Sequence, Emma Fiord, Northwest Ellesmere Island, N.W.T., Canada"

Permission is herewith granted to the Department of Geology, Dalhousie University to circulate and have copied for non-commerical purposes, at its discretion, the above title at the request of individuals or institutions. The quotation of data or conclusions in this thesis within 5 years of the date of completion is prohibited without permission of the Department of Geology, Dalhousie University, or the author.

The author reserves other publication rights, and neither the thesis nor extensive extracts from it may be printed or otherwise reproduced without the authors written permission.

Signature of author

Date: May 29, 1989

Palynology and Stratigraphy of an Upper Cretaceous Sedimentary-Volcanic Sequence, Emma Fiord, Northwest Ellesmere Island, N.W.T, Canada.

By

R. Andrew MacRae

Submitted in partial fufillment of the requirements for the degree of Bachelor of Science, Honours at Dalhousie University, Halifax, Nova Scotia.

March, 1989

ACKNOWLEDGEMENTS:

I extend the greatest thanks to Gunter Muecke and Graham Williams who acted as thesis co-supervisors. They led me through the wilds of the Arctic, and the woolly world of palynology, respectively.

Thanks go to Jennifer Bates and Doug Merrett for lively discussion in the field, and to Rob Fensome for helpful discussions about biologic nomenclature. Sedley Barss helped obtain citations from PALYLIT.

I thank Bill MacMillan for preparing palynology slides, Gordon Brown for thin sections, and the staff of Dalhousie Audio Visual for preparing some of the palynology plates. Lewis Billard photographed and printed the plant megafossil plates, and I thank Joe Harvey for provided some reference material on modern plants.

I am indebted to the people at the Polar Continental Shelf Project, Resolute Bay, and the Department of Indian and Northern Affairs for a field expenses grant. Without their support, the fieldwork would not have been possible. Thanks go to the helicopter pilots and the people at Eureka Weather Station for their hospitality.

A special thanks goes to Donna and my parents for caring so much.

CONTENTS:

Page

ABSTRACT:

Terrestrial sedimentary units (lignite and siliclastics) are interbedded with bimodal volcanic units (alkali basalts, silicic volcanics and pyroclastics) on an unnamed peninsula between Audhild Bay and Emma Fiord (81°30'N, 90°W), northwest Ellesmere Island, Canadian Arctic Islands. The complete section is over 300 metres thick, and is complicated by interfingering of the volcanic and sedimentary units. The units were deposited within the Sverdrup Basin during the Late Cretaceous. They correlate lithologically with the lower part of the Eureka Sound Group, and are time-equivalent to the upper Kanguk Formation.

Seven palynology samples display a rich palynomorph assemblage (over 30 species). Forms include the age-diagnostic pollen species *Wodehouseia edmontonicola* Wiggins, 1976 and *Wodehouseia gracile* (Samoilovitch, 1961). Comparing to the biostratigraphic framework of western North America, these indicate an early to middle Maastrichtian age for part of the sequence. Other forms present are *Cranwellia*, *Erdtmanipollis*, and several species of triprojectate (*Aquilapollenites*) pollen. The assemblage has affinities with the western North American and Siberian paleofloral provinces.

Plant megafossils include *Parataxodium*, *Ginkgo*, and undetermined angiosperms.

Whole-rock $^{40}Ar/^{39}Ar$ age dating of the bracketting volcanic units (G.K. Muecke and P. Reynolds, pers. comm.) has yielded dates of 80 Ma ± 2 Ma. This is mid-late Campanian according to the currently accepted time scales.

There is a minimum discrepancy of several million years between the biostratigraphic and radiometric ages. A conservative estimate is a discrepancy of 5 million years. One explanation is that some of the pollen forms (i.e. *Wodehouseia*) were appearing earlier at high latitudes than at more southerly

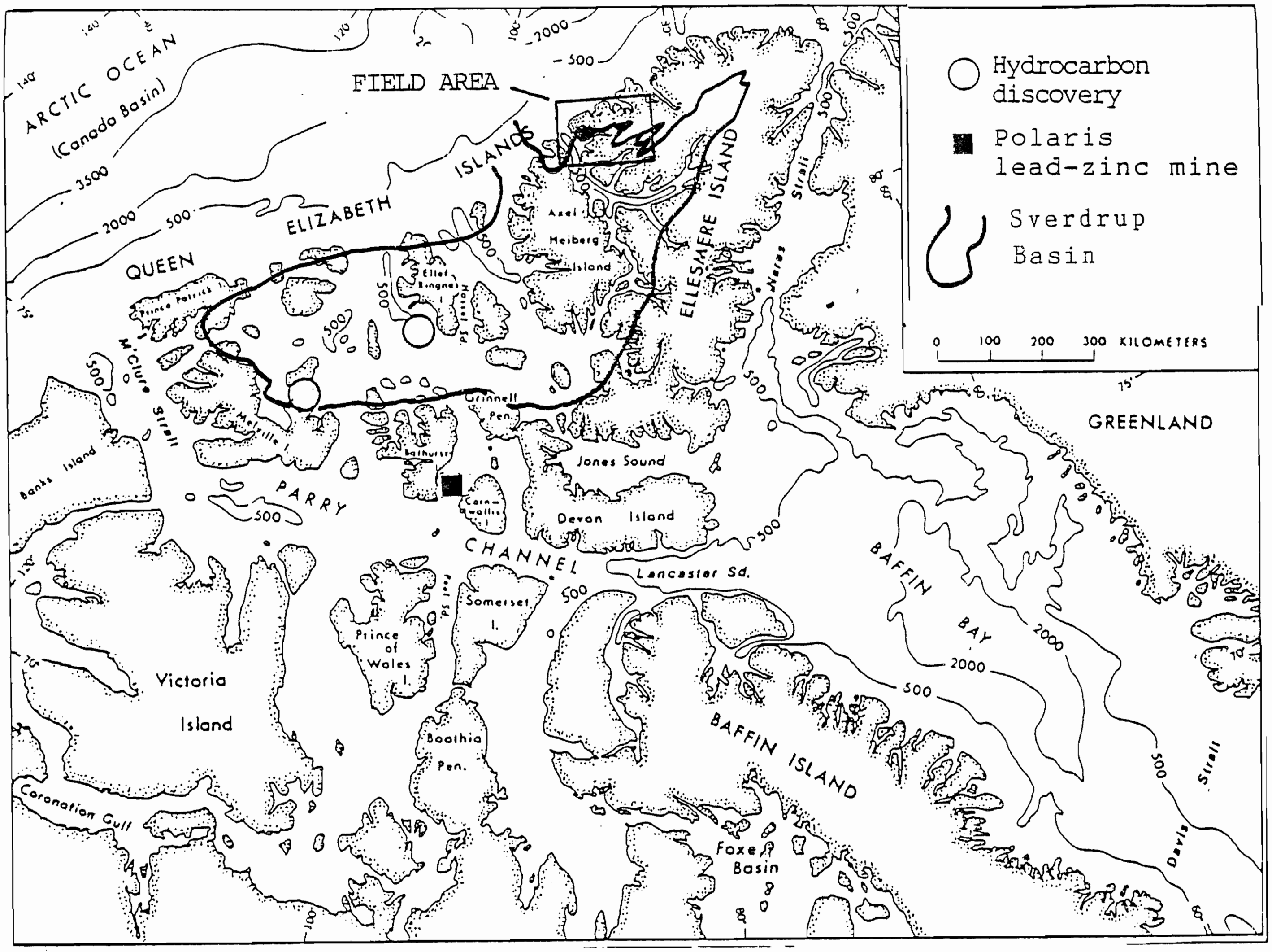
areas (western North America). Another explanation is an error in the currently accepted time scale, or the biostratigraphy in western North America. In light of work by other authors (Nichols and Sweet, in press) indicating heterochronities in the appearence of *Wodehouseia* in western North America, a biotic heterochroneity seems most likely. Examination of other units in the Canadian Arctic Islands may be able to test this hypothesis.

1. INTRODUCTION:

The Sverdrup Basin (text figure 1) of the Canadian Arctic Islands is a frontier of hydrocarbon exploration. Recent study in the extensive Late Mesozoic-Tertiary sediments of the basin has contributed much to an understanding of the later stages of its evolution (e.g., Kerr, 1981; Miall, 1985). The igneous units have, until recently, received limited attention; despite their importance to basin thermal history, tectonics, and stratigraphy in general.

The final stage of deposition in the Sverdrup Basin is represented by the largely terrestrial sediments of the Eureka Sound Group. During the last decade, the Upper Cretaceous-Tertiary Eureka Sound Group has received attention because of its rich fossil flora and fauna (Dawson, et al., 1976; McKenna, M.C., 1980; Estes & Hutchison, 1980; Choi, 1983), and its importance to understanding the late stages of the Eurekan Orogeny (Miall, 1985, 1986). The fossil assemblage includes broad-leafed plants, mammals, turtles, and crocodiles indicating a 'warm' climate (McKenna, 1980, Estes & Hutchison, 1980) - difficult to explain for an area at a high paleolatitude (McKenna, 1980; Wynne, et al., 1988). The fossils show similarities with North American and Asian-European terrestrial biota, suggesting the possibility of a connecting land-bridge via the Arctic (Estes & Hutchison, 1980). At the present time, tectonic reconstructions of the Arctic Ocean are uncertain (Rowley & Lottes, 1988), and paleogeographic information provided by fossils may prove important. The age of the biota is critical to any interpretation. Biotic provincialism can make an accurate date difficult.

Hickey et al. (1983) use paleomagnetic data from the Eureka Sound Group in an attempt to independently date palynomorphs (after Choi, 1983), plant



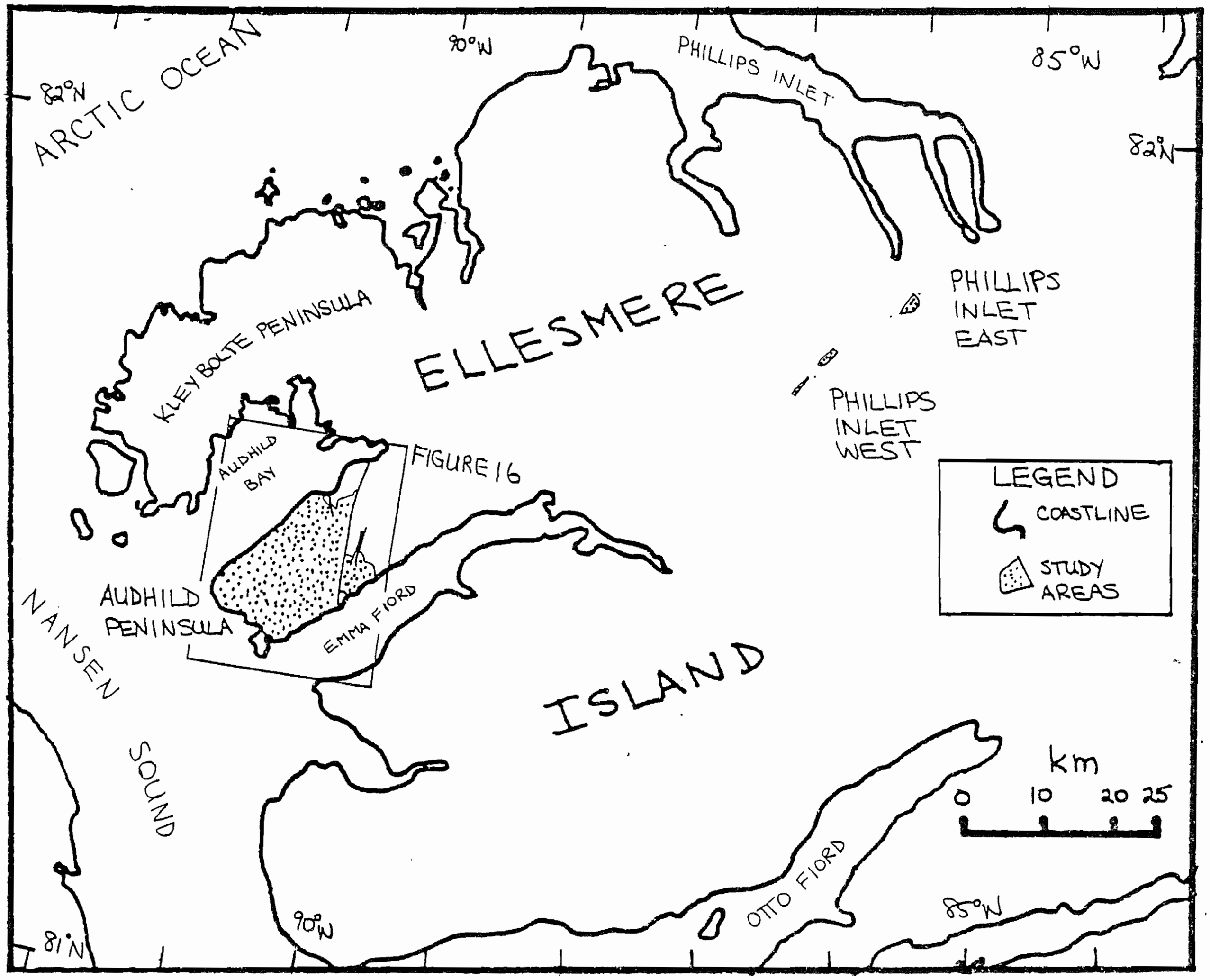
Text Figure 1: ARCTIC ISLAND GEOGRAPHY
Figure shows location of field area, two oil and gas discoveries, and the Polaris lead-zinc mine. Modified after Kerr (1981).

megafossils, and vertebrate material. They conclude that the biostratigraphic age obtained by comparing to lower latitude biotas is as much as 18 million years younger than the paleomagnetic data suggests. For instance, pollen forms present in the Maastrichtian stage of Western North America (Triprojectates, *Wodehouseia*) seem to appear in Early Campanian to Santonian time in the Eureka Sound Group - a large discrepancy. Hickey et al. (1983) explain the biotic heterochroneity by suggesting some elements of the biotia evolved in the Arctic and subsequently migrated southward.

Their work was criticized (Kent, et al., 1984; Norris & Miall, 1984) for the poor quality of their paleomagnetic data, and questionable interpretations of the palynologic data. Tauxe & Clark (1987) have recollected and remeasured paleomagnetic data from the Eureka Sound, and have concluded that no significant discrepancy exists. Spicer et al. (1986) have criticized the interpretation of the palynologic data, citing evidence of reworked dinoflagellates in many of the samples.

Clearly what is needed to resolve the question conclusively is reliable absolute age control of the biostratigraphy. The radiometric age dating of contemporaneous volcanic units is usually the most reliable, but no igneous units have been mapped within the Eureka Sound Group.

The volcanic units on Audhild Peninsula (81° 30' N, 90° W, unofficial name used herein), northwest Ellesmere Island (text figure 1, 2) were originally mapped by Thorsteinsson & Trettin (1972) as possibly Carboniferous because they overlie the Carboniferous age Nansen Formation. A younger age for the volcanics is suggested by Embry and Osadetz (1988). They correlated the sequence at Audhild Peninsula and similar units near Phillips Inlet (fig. 2), with the Late Cretaceous Hansen Point Volcanics (Trettin & Parrish, 1987).



Text Figure 2: LOCATION OF FIELD AREAS

Fieldwork by G.K. Muecke (and party) during the 1986 field season confirmed the excellent preservation of the volcanics, and their suitability for geochemical work, including radiometric age dating. The occurrence of sedimentary units between the volcanic units presents an ideal opportunity to compare biostratigraphic to absolute (radiometric) dates.

Fieldwork during the 1987 field season included mapping and sampling for palynolgy all the sedimentary units at Audhild Peninsula and Phillips Inlet. The present study examines material from Audhild Peninsula. The main objectives are:

1.) To determine the local stratigraphy at Audhild Peninsula
2.) To determine the biostratigraphic age of the sedimentary units from the palynomorph and plant megafossil assemblages.
3.) To correlate the sequences with other units in the Sverdrup Basin and to determine whether the sequence is related to the Eureka Sound Group.
4.) To compare the radiometric age of the volcanics with the biostratigraphic age to shed light on the possibility of the diachronous appearance of Cretaceous-Tertiary biotas at high versus middle latitudes.

Radiometric age dating has been done G.K. Muecke and P. Reynolds, Dalhousie University. An unambiguous answer to the last question may not be within the resolution of the data.

2. BACKGROUND:

2.1 Past Exploration & Regional Setting:

The Canadian Arctic Islands have been an exploration frontier since the 17th century search for a 'Northwest Passage'. Nineteenth century European explorations were largely geographical surveys. Geology at even a regional scale remained unknown until the 20th century. The Canadian Franklin Operation of the 1950's was an attempt by the Canadian government to survey the geography and geology of the Canadian Arctic Islands, and assert its territorial claims to the area. Regional geology mapping in the Ellesmere and Axel Heiberg Island areas was carried out by using dogsleds and fixed-wing aircraft. The Franklin Operation reports (e.g., Fortier, et al., 1963) and maps (e.g., Thorsteinsson & Trettin, 1972) are the starting point for most geologic work in the Arctic Islands.

More recently, exploration has been stimulated by the discovery of economic lead-zinc deposits to the west of Cornwallis Island and on Baffin Island (Kerr, 1977). Oil and gas have been discovered near Melville and Ellef Ringnes Islands (Stuart & Wennekers, 1977) (see text figure 1). Hydrocarbon exploration within the Sverdrup Basin and the Canada Basin has resulted in extensive seismic surveys and drilling.

2.2 Regional Structure:

The Canadian Arctic Islands is a complex continental margin extending from the Canadian Shield to the Arctic Ocean. Balkwill (1978) provides an early comprehensive survey of the regional geology of the Arctic Islands. Kerr (1981) summarizes current knowledge and discusses possible tectonic interpretations - still at an early, somewhat speculative stage. The following summary draws from these two references, unless otherwise cited.

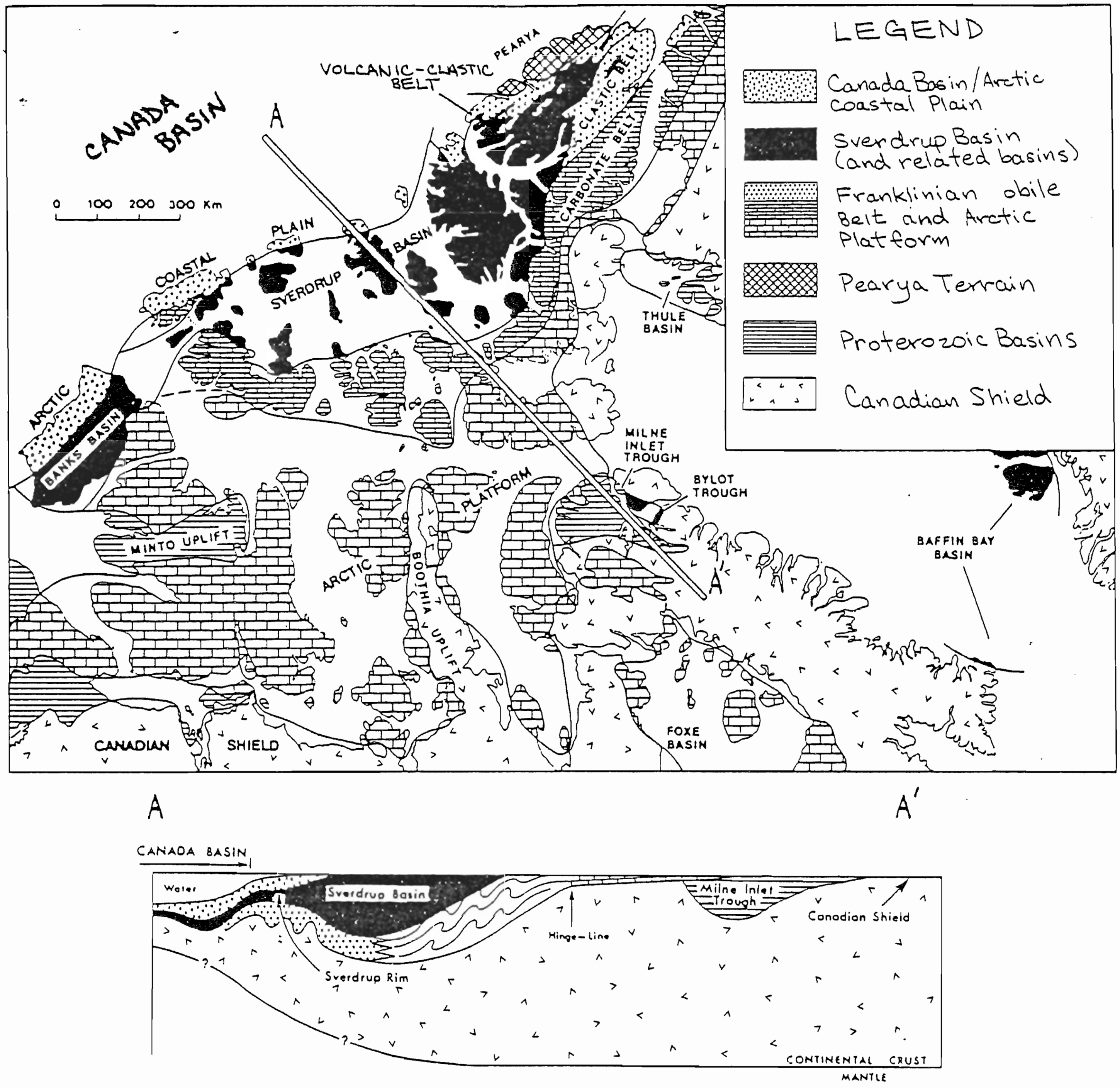
Several phases of compressional and extensional tectonics ranging from Precambrian to Tertiary time have resulted in a complex geology. However, five major structural elements can be recognized (refer to text figure 3 throughout):

1. The Canadian Shield (undifferentiated)- The same Precambrian crystalline basement which underlies the North American craton. It is composed of highly deformed and metamorphosed igneous and sedimentary rocks. It outcrops in the southern areas of the Arctic Islands and on eastern Ellesmere Island. It underlies all younger structures (text fig. 3, cross section). Uplift of portions of the Shield by later tectonic events produced structures such as the Boothia Uplift. The uplifts served as sediment supplies for much of the Paleozoic, and were probably reactivated during the Mesozoic (Miall, 1984a).

2. Proterozoic Sediment Troughs - Late Precambrian sedimentary troughs which escaped intense deformation (e.g., Milne Inlet Trough).

3. The Pearya Terrain (Trettin, 1987) - An area of Proterozoic to Ordovician rocks on the northwest coast of Ellesmere Island (see text fig. 3). It has been interpreted at an accreted terrain with Caledonian affinites (Trettin, 1987). It was probably a sediment source and topographic high during the late Paleozoic-Mesozoic.

4. The Franklinian Mobile Belt (Trettin, 1987) - A Cambrian to Late Devonian 'geosynclinal' structure stretching from northeast Ellesmere to the subsurface in the Banks Island area. It underlies the Sverdrup Basin (text fig. 3, cross



Text Figure 3: ARCTIC ISLAND STRUCTURE
Major structural provinces in the Arctic Islands. A general younging of structures occurs from the southeast to the northwest. The Pearya Terrain is Proterozoic-Ordivician. The Franklinian Mobile Belt and Arctic Platform are Cambrian to Late Devonian. The Sverdrup Basin is Carboniferous-Tertiary, and the Canada Basin/Arctic Coastal Plain is Late Mesozoic-Tertiary. The section from A-A' shows large-scale structure at depth, and is very general. Modified after Kerr (1981).

section). A basinward, deepwater, clastic-volcanic belt ('eugeocline') and a shelf-deposited carbonate belt ('miogeocline') are present. The volcanics are restricted to northwest Ellesmere Island (see text fig. 3). The belt was extensively deformed during the late Devonian-early Mississippian Ellesmerian Orogeny.

5. The Arctic Platform - is the cratonward (stable), lateral continuation of the Franklinian Mobile Belt. It escaped much of the deformation experienced by the Franklinian Mobile Belt. The Arctic Platform is largely shelf deposited carbonate, with some siliclastics in the vicinity of major uplifts (e.g., Boothia Uplift)

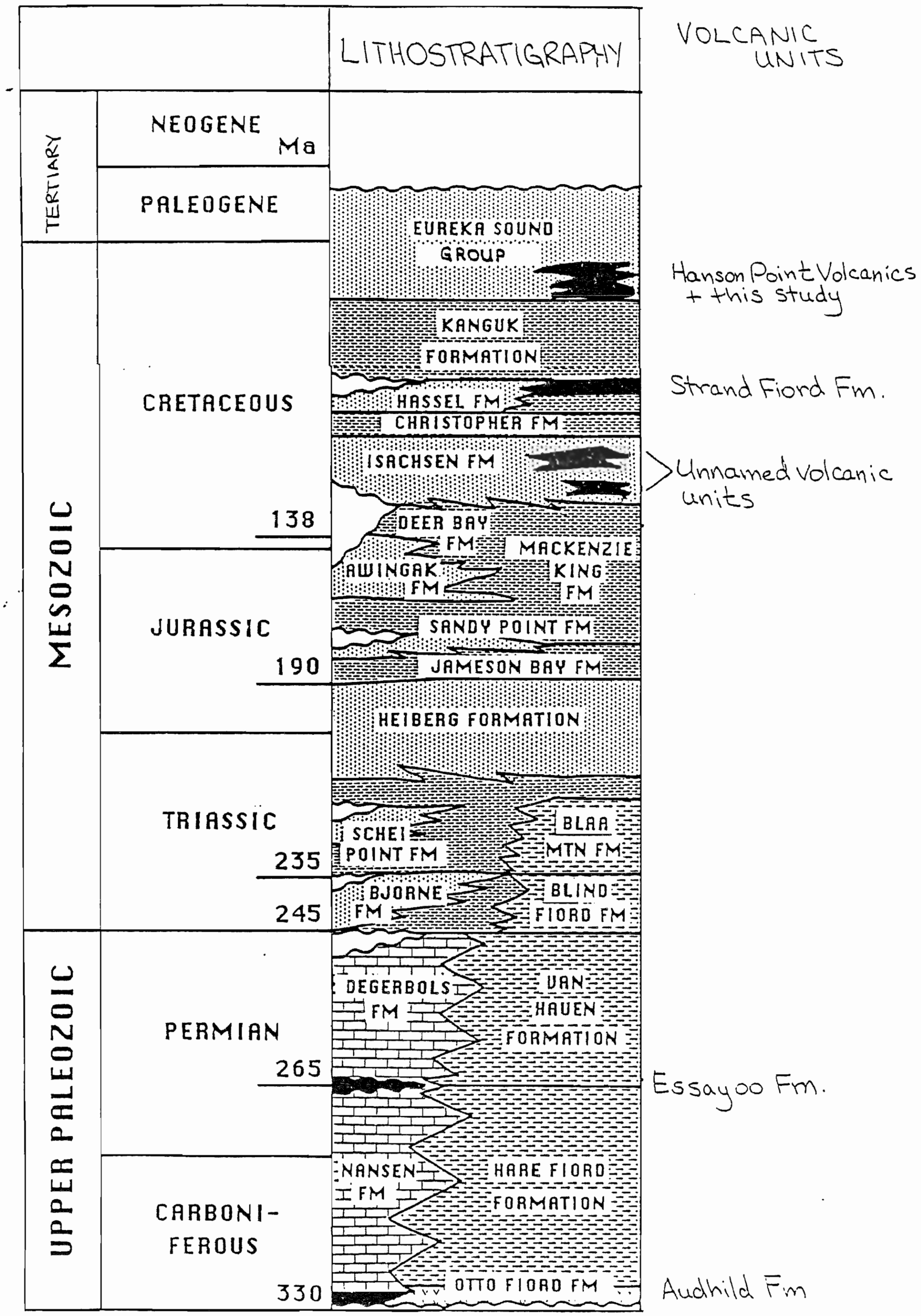
6. The Sverdrup Basin - is a large depositional basin which lies on top of the Franklinian Mobile Belt. It is Late Carboniferous to Oligocene in age and separated from the Canada Basin by a basement high known as the Sverdrup rim. The Banks Basin is a satellite basin. See section 2.3 for further details about the Sverdrup Basin.

7. The Arctic Coastal Plain/Canada Basin - represents the most recent phase of deposition. It forms a sedimentary wedge extending into the Arctic Ocean, and includes mid-Tertiary to present shelf and slope deposits. The sediments are related to the opening of the Canada Basin.

2.3 The Sverdrup Basin: (refer to text fig. 4)

(Text after Kerr, 1981; and Balkwill, 1978)

The Sverdrup Basin is over 300 km long in its longest dimension (NE to SW), and up to 13 km in depth. Deposition occurred in the basin from Late



Text Figure 4: GENERALIZED SVERDRUP BASIN STRATIGRAPHY
The column represents a N-S section in the vicinity of Axel Heiberg and Ellesmere Islands. Volcanic units are shown in black. Dotted and dashed ornament is for coarse (sandstones) and fine (shales) siliclastics respectively. Brick ornament is for carbonate. The Otto Fiord Formation is composed of evaporites.

Carboniferous to Oligocene. Both marine and terrestrial sediments are present within the basin. The initial extensional event occurred in the Carboniferous. Accompanying the initial rifting event are evaporites of the Otto Fiord formation and basaltic volcanics of the Audhild (Ritcey, 1989) and Borup Fiord Formations. The evaporites have formed diapiric structures that serve as structural traps for hydrocarbons in some areas (Smith & Wennekers, 1977). Another early period of basaltic vulcanism - the Permian Essayoo Formation - is probably related to the initial extension (Cameron, 1989).

Marine deposits are most common in the early phases of the basin's development. Towards the end of the Mesozoic, the basin steadily shallowed, and carbonate deposition was replaced by dominantly siliclastic deposition. Several phases of intrusive and extrusive igneous activity in the late Mesozoic (mostly Cretaceous) are probably related to the same tectonic activity that caused changes in basin deposition (Williamson, Muecke, & Clarke, 1987). The tectonic activity was probably related to the opening of nearby oceanic basins, including the Labrador Sea, Baffin Bay, and/or the Arctic Ocean (Canada Basin) (Miall, 1985). Much of the late Mesozoic igneous activity (both intrusive and extrusive) appears to be concentrated in the northeastern Arctic Islands (Osadetz & Embry, 1988; Williamson, 1989).

Four phases of extrusive igneous activity have been recognized in the Cretaceous of Axel Heiberg and Ellesmere Islands. There are two volcanic members in the Isachsen Formation (Valanginian-Aptian). Basaltic units are found at the base and within the Walker Island Member of the Isachsen, at Geodetic Hills and Bunde Fjord (respectively), Axel Heiberg Island (Embry & Osadetz, 1988). The third phase is represented by the Cenomanian-Turonian

(Embry.& Osadetz, 1988) Strand Fjord Formation, which occurs within the marine Kanguk Formation. Extensive outcrops are found at Bunde, Bals, and Strand Fiords on Axel Heiberg Island. The formation is composed of basaltic flows, pyroclastics, and minor sediments up to 789 m thick (Rickets, et al., 1985). The fourth, and youngest, phase of volcanic activity is represented by bimodal volcanic and sedimentary sequences occurring on northwest Ellesmere Island. It includes the Hansen Point Volcanics (Trettin & Parrish, 1987) and probably the Phillips Inlet and Audhild Peninsula (this study) sequences (Embry & Osadetz, 1988). The hypothesis that the volcanics of these areas are related has not been proven. The volcanics of the latest phase occur along the margin of the Arctic Ocean.

Contemporaneous intrusive units, in the form of dykes and sills, are very extensive in the Sverdrup Basin, and appear to be concentrated in the vicinity of central Axel Heiberg and Ellesmere Islands (Jollimore, 1986). The greatest majority of intrusives are of Cretaceous age (Embry.& Osadetz, 1988). In some areas, the intrusives make up a significant volume of the basin, and probably make an important contribution to the thermal history of the basin.

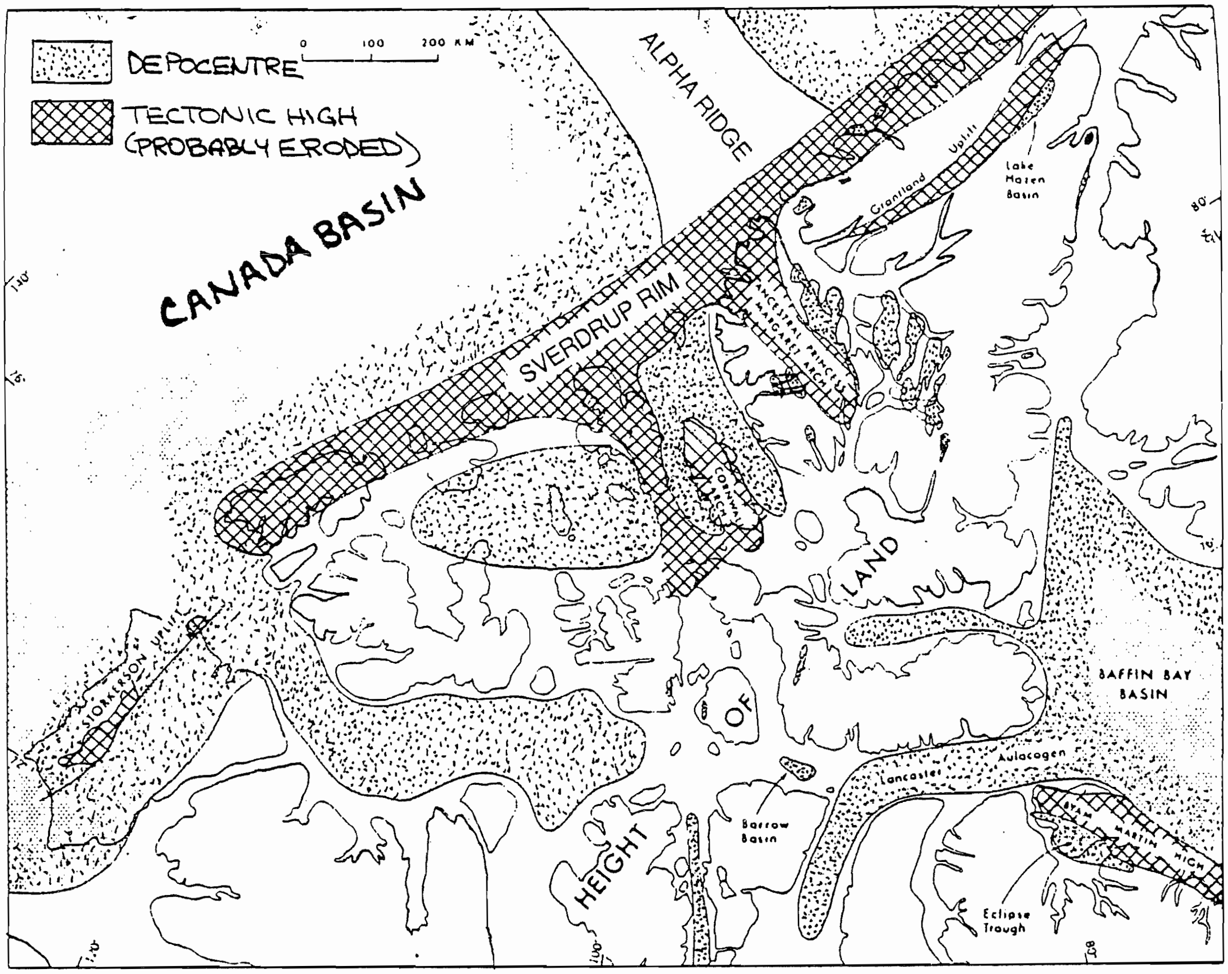
The marine Kanguk Formation, of Turonian to latest Maastrichtian (Wall, 1983; Doerenkamp et al., 1976) represents the last extensive marine incursion. The contact with the overlying (largely) terrestrial Eureka Sound Group is diachronous (Wall, 1983; Doerenkamp, et al. 1976), ranging from Late Campanian (Wall, 1983) to Late Maastrichtian (Doerenkamp, et al., 1976; Plauchut & Jutard, 1976), and reflects the gradual retreat of marine conditions. Terrestrial sedimentation was dominant in the late Maastrichtian-Tertiary. The Eureka Sound Group represents the final phase of deposition in the basin.

2.4 The Eureka Sound Group: (see text figs. 4,5)

The following summary draws mainly from Miall (1986). The stratigraphy of the Eureka Sound Group has been studied extensively (e.g., Bustin, 1982; Miall, 1979, 1984a, 1984b, 1985, 1986; Ricketts, 1986; Ricketts & McIntyre, 1986; Reidiger & Bustin, 1987), because of the extent of the unit (throughout the Arctic Islands), its volume, the presence of interesting fossil biota (Hickey, et al., 1983), and its importance in understanding the last phase of tectonic activity in the Arctic Islands - the Eurekan Orogeny.

The Eurekan Orogeny represents a period of compression within the Sverdrup Basin beginning in the Maastrichtian and climaxing in the Eocene (Miall, 1984a). It was expressed in the development of localized arches of uplift, including a long arch along the Arctic Ocean margin, known as the Sverdrup Rim (see text figure 5). In the opinion of Miall (1986), these arches divided the Sverdrup Basin into several smaller basins (text figure 5) during the whole time of Eureka Sound Group deposition. Each arch shed siliclastic sediment into the 'intermontaine' basins. Ricketts (1988) claims that there is no evidence for separate basins during the early stages of deposition of the Eureka Sound Group, the apparent separation being a the result of post (or syn) depositional tectonics.

The Eureka Sound Group is predominantly fluvio-deltaic (terrestrial) sediments of Maastrichtian and younger age. Some thin marine incursions are present. The basal contact with the underlying marine shales of the Kanguk Formation is sharply erosional to gradational. Where gradational, Ricketts (1986) placed the basal contact of the Eureka Sound Group above the level



Text Figure 5: LATE CRETACEOUS-TERTIARY PALEOGEOGRAPHY (Eureka Sound time) Figure shows major areas of uplift related to the Eurekan Orogeny, and remaining depocentres. Note the occurrence of the raised area called the Sverdrup Rim at the margin of the Canada Basin. The growing Canada and Baffin Bay basins were produced by oceanic spreading. Tectonic highs shed sediment into the basins until the Oligocene, when uplift of the entire area stopped deposition. Modified after Kerr (1981). This model is based on the views of Miall (1986).

where the sandstone/shale ratio exceeds 2/3. As mentioned previously, the contact is diachronous, occurring as early as Campanian, and as late as the Maastrichtian-Paleocene boundary in some areas (Doerenkamp, et al., 1976; Plauchut & Jutard, 1976; Wall, 1983).

There is an ongoing dispute over the definition and nomenclature of the formation-level units within the Eureka Sound Group (Miall, 1988 and Ricketts, 1988).

2.5 Previous Palynologic (miospores only) Work in the Late Cretaceous of Arctic North America:

Early palynologic studies include those of Hills and Wallace (1969) at a single locality of the Eureka Sound Group. They described a new genus of fossil pollen - *Paraalnipollenites*, as well as a small assemblage of triprojectates, *Wodehouseia*, and other species. Tschudy (1969) examined triprojectates (*Aquilapollenites*) from the northern part of Alaska. McIntyre (1974) examined material from Horton River (east of the Mackenzie Delta) and determined the units are Santonian to Maastrichtian. Assemblages reported include several species of triprojectates (*Aquilapollenites*), *Wodehouseia*, and many dinoflagellate taxa. Descriptions are lacking. Doerenkamp et al. (1976) provided an extensive account of palynology and stratigraphy in the Mackenzie Delta, Banks Island, and adjacent areas. Their work includes material from the Isachsen Formation, Kanguk Formation, and Eureka Sound Group from the surface and borehores. It is an important stratigraphic reference. Much of the material compares well with material from the Cretaceous and Tertiary of western North America, but the study lacks descriptions of taxa. The comprehensive taxonomic work of Wiggins (1976) on Oculata pollen (including *Wodehouseia*) used material from the Campanian and Maastrichtian of the North Slope of Alaska and Alaska Peninsula. Felix & Burbidge (1978) describe a Maastrichtian palynoflora with Siberian affinities from the lower part of the Eureka Sound Group on Ellef Rignes Island. Wilson (1978) examined the palynology of sections spanning the late Campanian to Tertiary on the Mackenzie River and Delta.

Choi (1983) studied the palynology of the Eureka Sound Group extensively on central Ellesmere and Axel Heiberg Island, and drew conclusions about the age, and affinities of the flora with Siberia and western North America. This study was used in Hickey _et al._ (1983). Mudie (1985) examined material collected from the subsurface on the Alpha Ridge (see text fig. 5). The assemblage includes Maastrichtian-Tertiary age dinoflagellates, pollen, and spores. The assemblage indicates that the Alpha Ridge must be older than Maastrichtian (if the material is in place). Work by Frederiksen _et al._ (1988) briefly describes an assemblage of pollen, spores, and rare dinoflagellates which span the Cretaceous-Tertiary boundary of the North Slope of Alaska.

Although palynologic data is mentioned in most of the recent work on the Eureka Sound Group (e.g., Miall, 1986, Ricketts, 1986), the detailed data (including figures, descriptions, and ranges) is unpublished.

3. METHODS:

3.1 Fieldwork:

Fieldwork was carried out during the 1987 field season for a total of one month during July and August. Fieldwork at Audhild Peninsula was carried out from July 6 to July 8 at the southern camp (Emma Camp #1), and July 11 to July 20th at the northern camp (Emma Camp #2) (see text figure 16).

All mapping was done on foot, using air photos as a topographic reference. A compass is useless in this area because of daily secular variations and high inclination. All strike orientations are estimated by comparing landmarks to air photos and topographic maps. For this reason, strike data is of very limited precision. The detail of mapping was at a scale of tens of metres in some areas (see field notes), but no topographic base maps are available at this scale (closest is 1:250 000). Air photo enlargements will be used to construct a base map when they become available.

Stratigraphic sections were measured using a Jacob staff. The bedding orientation was often difficult to determine in the sedimentary sections because the rocks were (usually) poorly exposed. The orientation of bracketting volcanic units was usually used to estimate bedding. Significant cumulative errors in the stratigraphic sections are possible.

Sample collection was hampered by extensive frost shattering and the occurrence of permafrost just beneath the surface rubble. In many cases, samples were collected from fragmented, but *definitely in place* outcroppings. Many sediments were also poorly consolidated, further hampering sampling efforts. Because of the potential for contamination by modern miospores, great care was taken when sampling.

Sample locations are shown in text figure 20. Starred samples were submitted for palynological preparation. Of thirteen palynological samples submitted, ten were prepared in time for consideration in this study. These are:

Emma Camp #1:

From section 1A:

EL87-115 - grey-brown mudstone

EL87-116 - organic-rich (black) shale

EL87-118 - grey mudstone-shale with lignite fragments

EL87-120 - organic-rich (black) shale

From section 1B:

EL87-106 - fine, light-coloured mudstone with tubular plant fragments

EL87-107 - graded fine wacke-mudstone bed with subvertical lignite fragments

EL87-109B - fine wacke with coal fragments

From Emma Camp #2:

From section 2A:

EL87-204 - bituminous sandy shale w/ coalified plant fragments

EL87-205 - bituminous sandy mudstone

EL87-099 - fine, dark grey volcaniclastic sandstone with lignite fragments; immediately above a leaf-bearing horizon.

3.2 Palynology:

3.2.1 Sample Processing & Slide Preparation:

The basic strategy in preparing palynological samples is to disaggregate the rock using acids which attack the minerals of the rock, but leave the organic material, including the palynomorphs, unharmed. When the rock is disaggregated, the palynomorphs can be concentrated by gravity separation or other methods. Because the processing technique requires the use of dangerous acids, it MUST be performed with proper safety equipment - including gloves, eye protection, acid-resistant clothing, and a well-ventilated fume hood. Safety cannot be stressed enough when hydrofluoric acid (HF) is in use. Palynologic processing must not be attempted without proper equipmen and instruction!

The samples used in this study were prepared in the palynology lab at the Atlantic Geoscience Centre, Bedford Institute of Oceanography. The technique used is described in Barss & Williams (1973), but will be reviewed here (the following summary draws from this reference).

Sample processing begins with the selection of a sediment sample thought to contain palynomorphs. Samples which appear very organic-rich, such as coals, do not necessarily have the best chance of containing palynomorphs. It is often a matter of luck. Fine-grained samples with moderate amounts of organics (e.g., dark grey shale) are often the best. The amount of sample depends upon the organic content - generally 5 to 50 grams is needed. The sample must be carefully washed, in order to remove any adhering 'dirt' which could contain modern pollen or spores. This was especially important for the samples in this study. The sample is crushed into small pieces of 0.5 cm or so.

Care must be taken not to contaminate the sample with fragments from previous sample crushings. The sample is placed in a 500 mL polypropylene beaker. Coals do not require the HCl and HF baths (see below).

The sample is placed in Hydrochloric acid to remove any carbonates which are present. Usually the beaker is not filled more than half way. The concentration of acid used depends upon the amount of carbonate in the sample, but is generally 10% (by volume). If the sample effervesces too strongly, the palynomorphs may be mechanically damaged. For samples with very little carbonate (e.g., bituminous shales) the acid may be heated on a hot plate to speed the reaction. The sample is left for some time (usually a few hours) to react. If the reaction has not stopped after several hours, the acid should be replaced with fresh acid until all reaction ceases. All calcium carbonate must be removed before the next acid bath.

When reaction is complete, the waste acid is carefully decanted off, taking care not to lose any residue. The residue is washed by filling the beaker with distilled water and stirring. It is allowed to sit for at least half an hour to let the residue settle, then the water is decanted. The washing is repeated three times. The washing must remove any dissolved Ca remaining from the HCl bath, or adding hydrofluoric acid in the next step will produce fluorite (CaF) crystals. These are extremely difficult to remove, because of the low Ksp of CaF.

Approximately 250 mL of concentrated hydrofluoric acid (HF) is carefully added to dissolve the silicates present. No glassware can be used. Extreme caution must be used with HF - it is corrosive and toxic. A fume hood designed for HF must be used. The sample is allowed to react for about 24 hours. The sample can be heated (NOT BOILED!) to speed the reaction. The sample should be a mineral and organic slurry after this step. The acid is decanted, and the residue washed at least three times. Coarse fragments can be removed at this time.

Approximately 200 mL of concentrated HCl is added to the residue. It will remove any fine fluorides which precipitated during the last washing steps. The acid is heated on a hot plate for 30 minutes. The acid is decanted and washed as before.

At this stage, the residue is a mixture of partly dissolved mineral grains and organics. The next steps involve the preparation and concentration of the organic fraction. If the organics have undergone thermal alteration, they may become opaque. In an attempt to lighten the colour of the grains, oxidation is performed. The processing of coals begins at this step. Coals must be disaggregated by oxidants, since HCl and HF have little effect. Oxidation of the organic fraction will eventually destroy any palynomorphs. The intensity and duration of the oxidation step depends upon the condition of the palynomorphs - the darker they are, the longer and more intense the oxidation must be. Samples requiring short oxidation are reacted with 10% nitric acid. Longer oxidation requires concentrated nitric acid, or a combination of nitric acid and potassium chlorate, known as Schulze solution. The oxidation is performed on only small parts of the sample at a time, in case it is overdone. The samples are periodically checked under the microscope to see if oxidation is complete. Oxidation times can be as long as half an hour, but are usually less. The presence of pyrite (and other sulphides) in the sample will cause a violent reaction, so caution must be exercised.

When the oxidation is complete, the acid is decanted, the beaker is topped up with distilled water, and allowed to sit for one hour. Then the diluted acid is decanted, and the residue is concentrated in one 50 mL polypropylene centrifuge tube by successively adding residue, centrifuging, and decanting.

5% ammonium hydroxide (NH_4OH) is added to the residue and stirred. It will remove the oxidized organics left in solution from the last step. It is allowed to react for less than 3 minutes, then the tube is centrifuged, and the liquid decanted. The residues are washed 3 times by successive addition of distilled water, centrifuging, and decanting.

Screens are used to separate the coarse fraction, and fine fractions. Screen sizes are varied, but usually a 180μ and 30μ mesh are used. The large mesh removes the largest fragments. The material which remains on the 30μ screen and the material which passes through can contain palynomorphs. Residues should be examined under the microscope to see if further concentration is necessary.

If the sample contains abundant mineral grains, gravity separation is used to remove them from the residue. Water is removed from the residue by centrifuging and decanting the sample. A portion of the sample is placed in zinc bromide ($ZnBr_2$) solution (prepared with water and a bit of HCl) of specific gravity 1.4-2.0, and centrifuged. The mineral portion of the residue will sink, while the organics will remain as a float and/or in suspension. The two fractions are checked to see if separation is sufficient. Some experimentation may be necessary to find the best specific gravity. The palynomorph-containing fraction is washed by diluting with water and centrifuging.

The concentrated residue, of the two size fractions, is mounted on a glass slide, using a plastic mounting medium. The residue is fixed to the surface of the cover slip so that the palynomorphs lie within a single focal plane.

Considerable modification of the procedure may be necessary for some samples, especially in the oxidation and concentration steps. This is a very general description of the procedure.

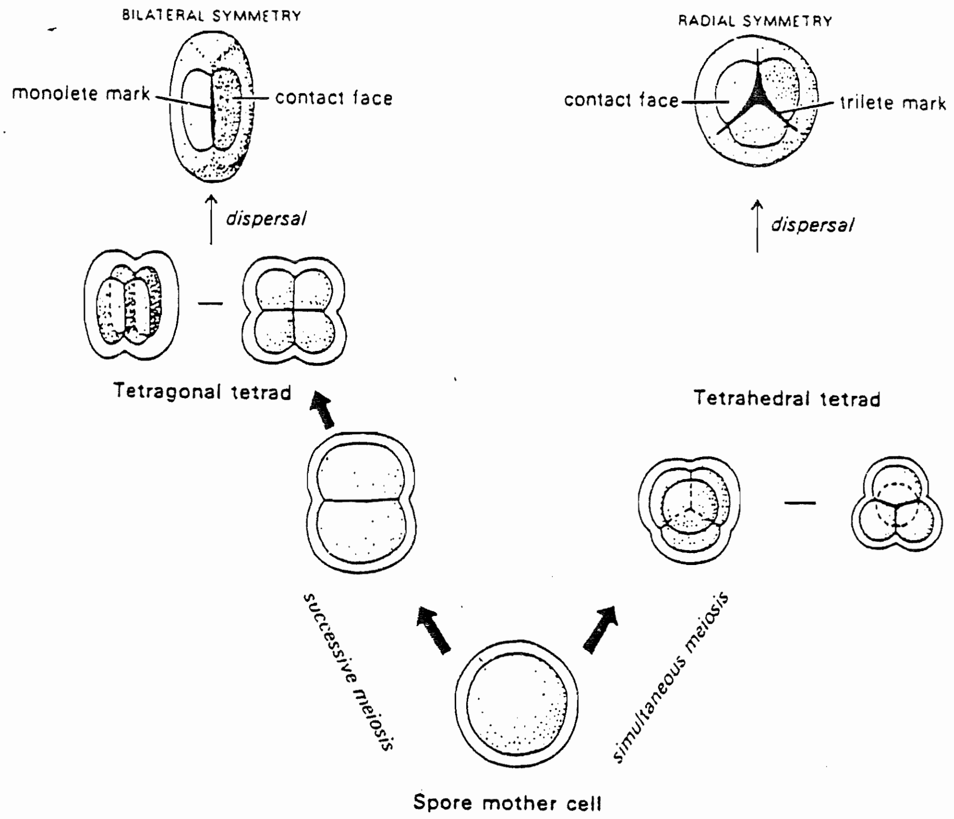
3.2.2 Identification:

The identification of miospores (pollen and spores) is based upon the morphology of the cell wall. The cell wall is composed of a group of complex biopolymers called sporopollenin which is extremely resistant to chemical attack. Variations in geometry, structure, and ornamentation (surface relief) reflect the miospore's development from a living plant, and probably adaptations to a particular style of dispersal or environment.

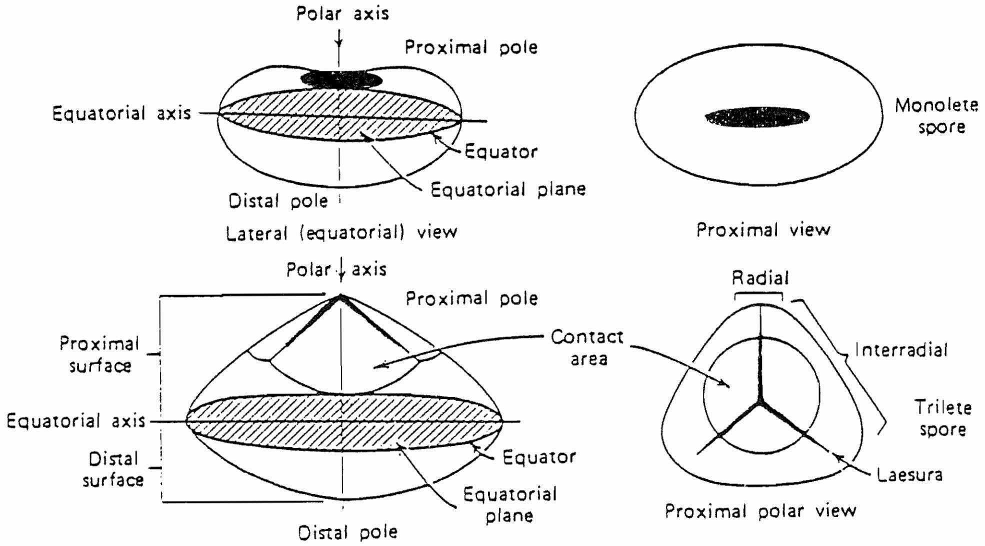
Groups of miospores originate by meiosis of a single mother cell. They usually remain in clusters until mature. Clusters of four are most common (see text figs. 6,8, & 9). The way in which the spore mother cell divides determines the symmetry of the grain - radial if simultaneous meiosis occurs, and bilateral if successive meiosis occurs (see text fig. 6).

An analogy can be drawn between a typical miospore and the geometry of the Earth. Terms like polar, equatorial, latitudinal, and longitudinal have similar geometric meanings on a miospore as on the Earth. The polar axis of the miospore is a line which runs through the grain from the area in the centre of a cluster (proximal) to the area outside the cluster (distal) (see text figs. 7, 8, & 9). The equator divides the two polar areas.

Text Figure 6: GENERATION & SYMMETRY OF SPORES (after Brasier, 1980)



Text Figure 7: PLANT SPORE GEOMETRY & TERMINOLOGY (after Tschudy & Scott, 1969)



The following is a list of morphological characters and descriptive terminology for miospores based largely on Erdtman (1969), (1972), and Tschudy & Scott (1969). It is by no means complete. The summary is organized according to morphologic characters. Refer to text figures 6 to 13 throughout.

1. Symmetry: Refers to the geometric similarities of the grain.

a. Asymmetric:

i. nonfixiform - shape not fixed (variable)

ii. fixiform - consistent shape

b. Symmetric:

i. radial - if a three-fold rotational axis or higher is present

ii. bilateral - a two-fold rotational axis is present

2. Shape: The outline of the grain (see text fig. 11).

a. In equatorial view:

i. radially symmetrical grains:

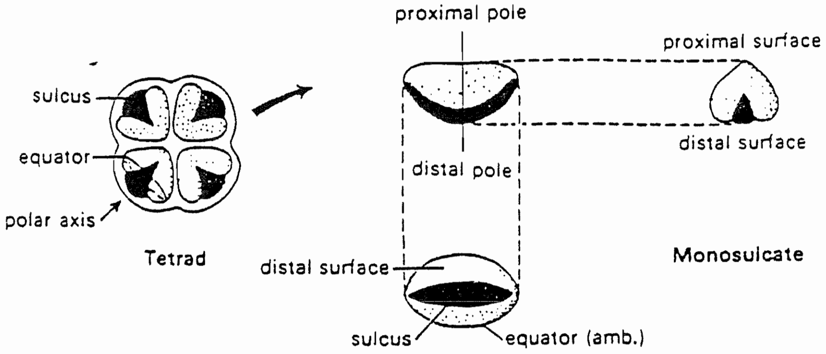
- spherical - circular shaped (in equatorial view)
- prolate - polar dimension longer than equatorial
- oblate - polar dimension shorter than equatorial

ii. bilaterally symmetric grains:

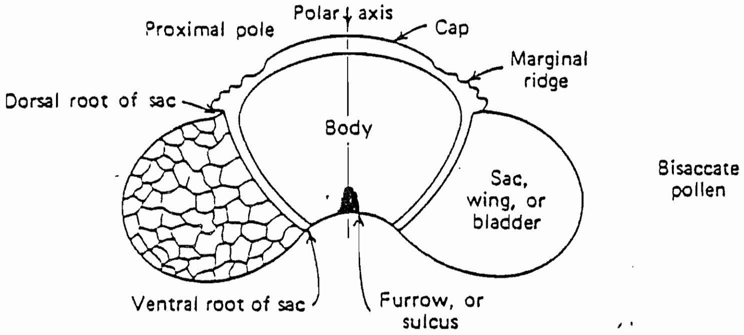
- two sections to consider - same terms apply

iii. Various other terms, like boat-shaped or tripod-shaped, are also used. Other morphological terms automatically imply a certain shape (e.g., bisaccate, see below)

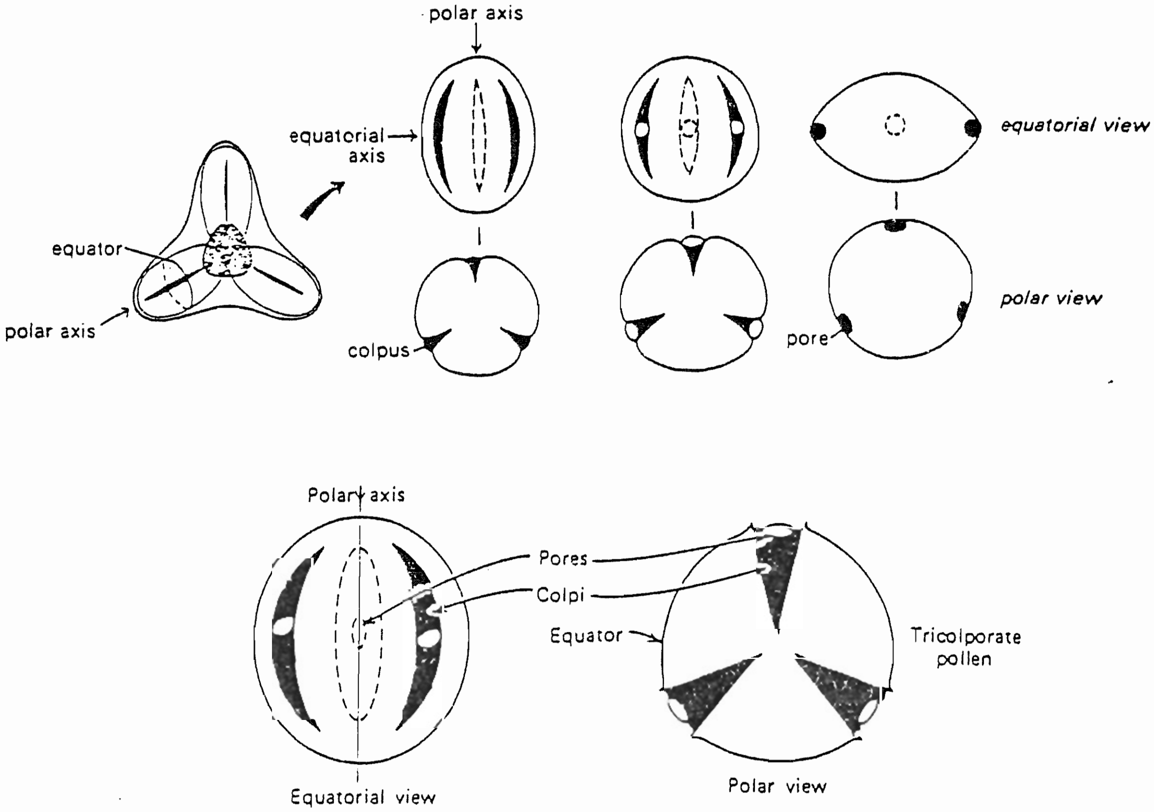
Text Figure 8: GENERATION & TERMINOLOGY OF BILATERALLY SYMMETRIC POLLEN GRAINS (after Brasier, 1980)



Bisaccate pollen grain:



Text Figure 9: GENERATION & TERMINOLOGY OF RADIALLY SYMMETRIC POLLEN GRAINS (after Brasier, 1980)



b. In polar view:

i. terms like circular, triangular, combine with qualifying terms like concave and convex. See text fig. 11. Again, sometimes original descriptive terms are used, and some terms automatically imply a certain shape (e.g., syncolpate, see below).

3. Polarity: Refers to the relative development of the two poles of a pollen grain

- isopolar - poles equally developed
- heteropolar - poles unequally developed
- subisopolar - intermediate development of poles

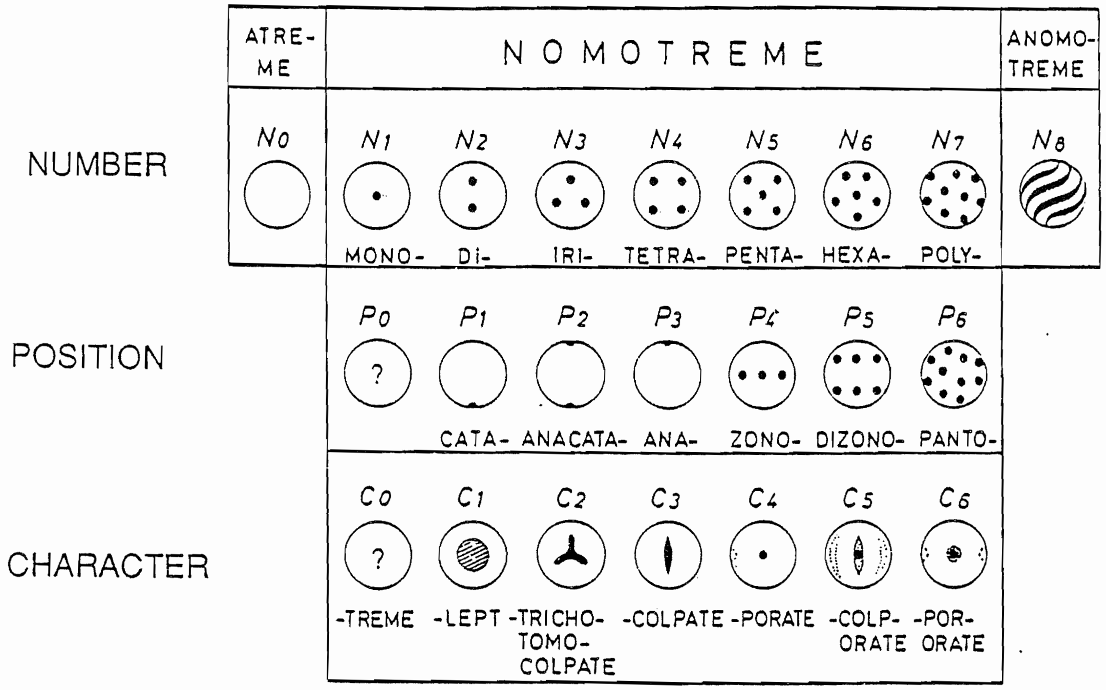
4. Apertures: By far the most important morphological character of a miospore, apertures represent the zone where the grain wall will split when a spore germinates, or a pollen grain develops a pollen tube. Erdtman (1969) designed a classification scheme for apertures which relies on three characters: their number, position, and shape (see text fig. 10). The result of the classification is a single descriptive term formed by adding prefixes and suffixes to a root word. Word segments are enclosed in square brackets ([]).

a. Number: Self explanatory. Standard Greek or Latin prefixes are used to describe the number of pores (e.g., [tri, tetra].). [a] is used if no apertures are present (e.g., alete). See text figure 10.

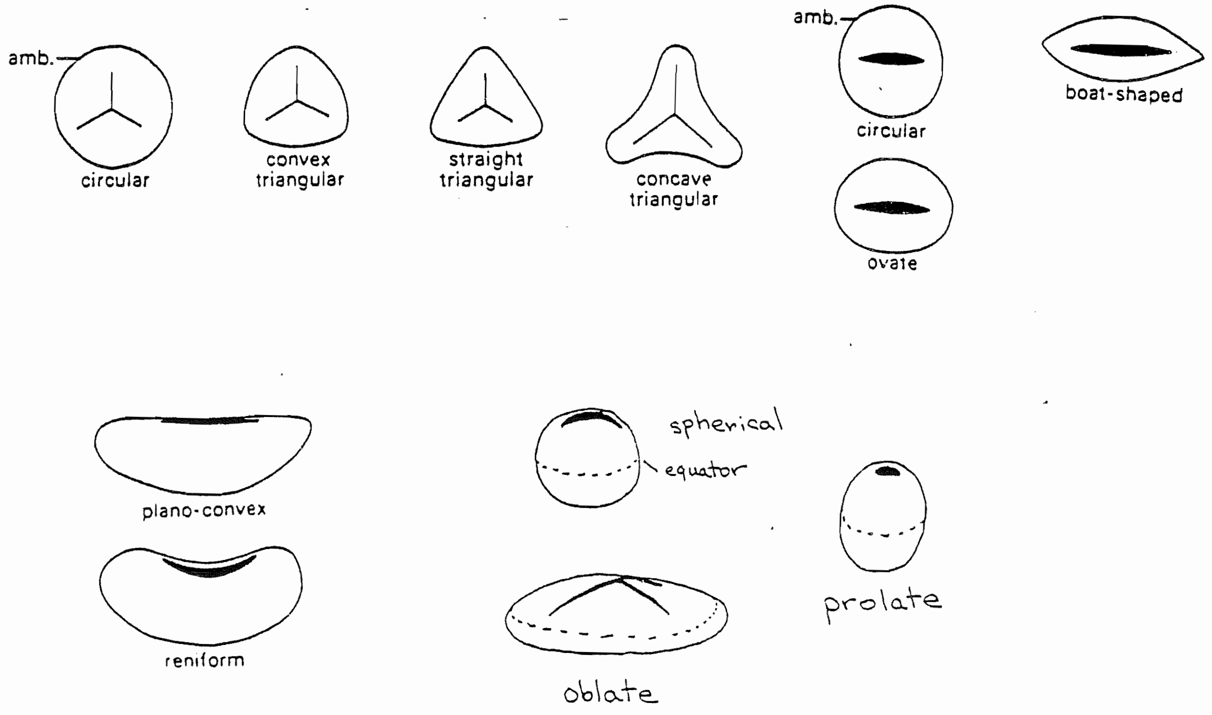
b. Position: Refer to text figure 10 throughout.

i. proximalipolar [cata] - aperture points into the cluster of grains. Proximal

Text Figure 10: APERTURE CLASSIFICATION SCHEME OF ERDTMAN (1969)



Text Figure 11: SOME TYPICAL MIOSPORE SHAPES
(after Brasier, 1980)



apertures are typical of spores. See text figure 10.

ii. distalipolar [ana] - aperture points away from the cluster of grains. Typical of pollen grains. See text figure 10.

iii. bipolar [anacata] - apertures are present at both poles.

iv. latitudinal [zono] - occurring in zones perpendicular to the polar axis. Multiple zones are described by prefixes (e.g., [dizono]).

v. global [panto] - all over the grain in an ordered or random pattern.

<u>c. Character:</u> The shape and orientation of the apertures (refer to text fig. 10 throughout). Terms which end with [lete] apply only to spores.

i. [-treme] - uncertain or not determined

ii. [-lept] - aperture-like, thin area (leptoma)

iii. elongated aperture(s) - furrow

- proximal (on pole): [monolete] spore. Structure is a monolete scar. (text figure 7)
- distal (on pole): [sulcate] pollen. Structure is a sulcus. (text fig. 8)
- not over either pole: structure is a sulculus. Naming depends upon distribution:
    - global distribution - [rugate]
    - equatorial with long axis perpendicular to equator - [colpate].

Structures are colpi (singular: colpus). They are typical only of pollen grains. See text figure 9. Multiple colpi are indicated by prefixes (e.g., tricolpate). If the colpi meet at the poles, the grain is [syncolpate]. A grain with converging pairs of colpi is [rupate].

iv. pores: [porate] Aperture is a pore if it is more or less round. Multiple pores are described with a prefix (e.g., triporate, text fig. 9). Special cases include:

- [hilate] or [cataporate] - proximal pore, indicating a spore. Structure is a hilum
- [ulcate] or [anaporate] - distal pore, probably a pollen grain. Structure is an ulcus.
- [forate] or [pantoporate] - pores with a global distribution, called foramina.

v. three-fold (or greater) apertures:

- distal: [tricotomocolpate] - 3-branched aperture or rarely 4-branched.
  - proximal: usually [trilete] spores (tetralete are also possible).
  - can also be present on both poles (add [di])

vi. compound apertures: different aperture shape at different levels within the wall of the pollen grain results in a combination of aperture forms. They look similar to a mouth, so are called ora [orate]. Ora are found only on pollen grains. Descriptive terms are formed by adding an [or] to other terms:

- [colporate] - colpate grain with ora (text figure 9)
- [pororate] - porate grain with ora (two pores of different size)
- [ruporate], [rugorate], [foraminorate] - similar combination

vii. other aperture forms:

- [spiraperturate] - spiral-shaped apertures
- [anomotreme] - irregular

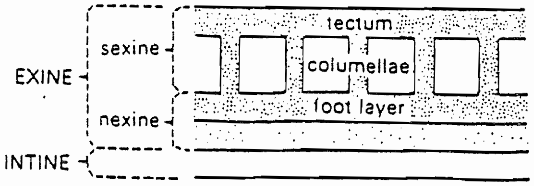
5. Size: Miospores can vary considerably in size, to hundreds of microns (megaspores). Most are in the range of 10 to 80 microns in size.

6. Sporoderm: The cell wall of a miospore. The sporoderm of spores is a single layer of sporopollenin, often with small projections. Pollen sporoderm, called exine, can be considerably more complicated, with multiple layers, connecting columns, and projections (see text figure 12). The projections (either pollen or spore) are known as ornament, and are the second most important diagnostic character of miospores. Text figure 13 illustrates several types of ornamentation:

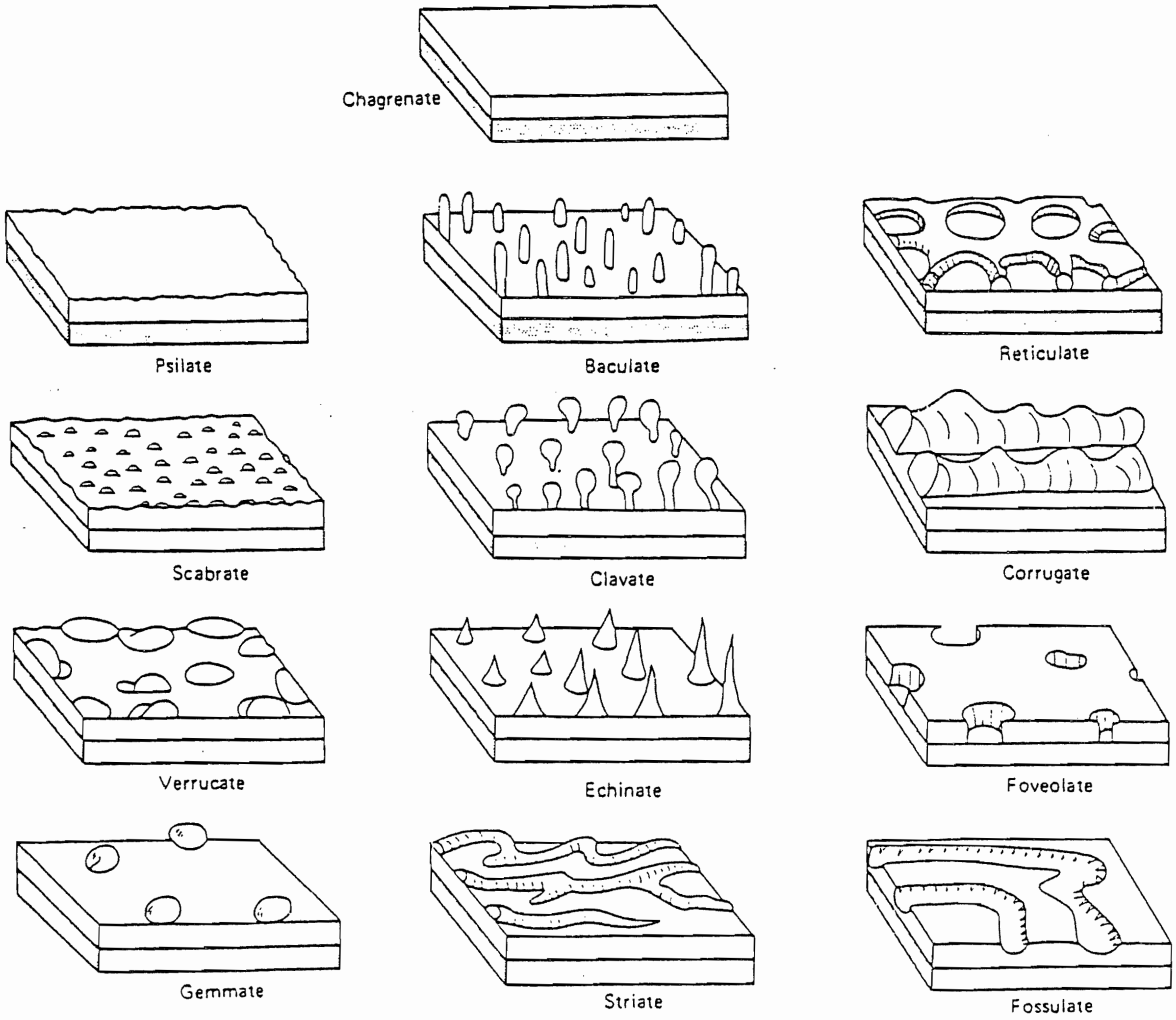
- chagrinate - perfectly smooth (at light microscope resolution)
- psilate - smooth, but with some very small surface irregularities
- scabrate - small bumps
- verrucate - large flattened bumps
- gemmate - ball-like projections
- bacculate - elongated cylindrical projections
- clavate - club-like projections (with enlarged tips)
- echinate - spine-like projections
- striate - raised sub-parallel ridges (with rounded cross-sections)
- corrugate - similar to striate, but height of ridges is variable
- reticulate - sunken, randomly oriented, wall-like structure
- granulate - a very fine reculate ornament
- foveolate - small pores in outer exine layers (much smaller than apertures)
- fossulate - sunken, sub-parallel trenches

Many other terms are commonly used.

Text Figure 12: SIMPLIFIED POLLEN EXINE STRATIFICATION (after Brasier, 1980)



Text Figure 13: SOME COMMON TYPES OF ORNAMENTATION (after Tschudy & Scott, 1969)



7. Other Characteristics: Many other diagnostic properties are unique to certain types of miospores. For instance:

a. Sacci: Sack-shaped, hollow structures used for floatation. Spores or pollen with sacci are saccate. Sacci occur on some types of spores (especially Late Paleozoic spores), but are best known in gymnosperm pollen, especially conifers (see text fig. 8).

b. Flanges or skirts: Flattened extensions of sporoderm which rim the outline of a miospore. Most commonly occur in trilete spores. Also occur in some pollen grains (e.g., *Wodehouseia*).

3.2.3 Taxonomy:

In general, the classification of miospores is artificial, and based on morphology. Early palynologists identified the morphology of fossil miospores with modern plants. They assigned modern names to the fossil forms. This assumes that miospores produced by plants of the past are identical to modern forms. This is not a safe assumption (except for Pleistocene and Recent forms), and mistakenly assigning a fossil form to a certain type of plant would lead to erroneous ecologic interpretations. In the fossil record, it is rare for miospores to be directly associated with the plant which produced them; so palynologists use form-genera. Form-genera do not necessarily have phylogenetic significance. They merely relate miospores which have similar morphologies and which *may* be phylogenetically related. For example a genus like *Triporopollenites* includes undifferentiated triporate pollen grains - a morphologic grouping. A genus like *Wodehouseia* includes pollen grains with a variety of unique morphological characteristics - ellipsoidal shape, two pairs of pores, and an equatorial flange.

A morphologic classification system can cause problems, since there is a tendency to develop a 'pigeon-hole' style of classification, and a profusion of names.

Groupings of miospore genera are often constructed to include form-genera which have a common theme to their morphology. For instance, the Oculata group of pollen include the form genera *Wodehouseia* and *Azonia*. Both these form-genera are flattened ellipsoid-shaped, with 4 elongate pores and often with an equatorial flange. Their similarity probably reflects a genetic relationship.

Synonymy of different form-genera and species is a common problem, especially when a publication has limited distribution and/or occurs in languages not familiar to other authors. The tendency in recent years has been to group similar form-genera and species under a single name. For instance, the species *Laevigatosporites haardti* (Potonié & Venitz, 1934) Thomson & Pflug, 1953 is considered a senior synonym for *Laevigatosporites gracilis* Wilson and Webster , 1946 and *Laevigatosporites ovatus* Wilson and Webster, 1946; according to many authors. The sheer volume of published material makes it difficult for any one author to stay abreast of current taxonomy.

3.2.4 The Trouble with Triprojectates:

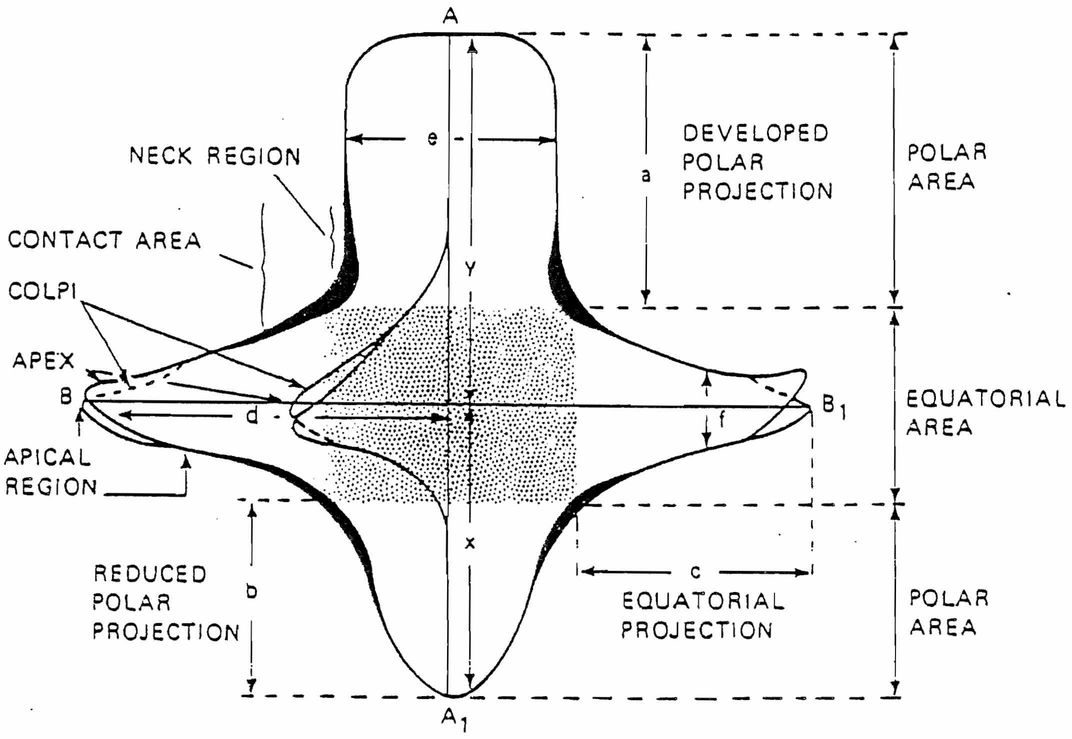
The term Triprojectacites (Mtchedlishvili, 1961) is applied to a group of unique Late Cretaceous pollen. They are characterized by tricolpate apertures, three equatorial projections, and one or two polar projections (see text figure 14). Surface sculpture is highly varied; it may be spinate, reticulate, striate, or some combination. The great degree of morphologic variation in the triprojectate group makes them potentially very useful for stratigraphic work; however, their use is limited by great taxonomic problems.

The trouble centers on two main factors:

1. The great variation within the group has led to the publication of at least 200 taxa since the first described species by Rouse (1957). The differences between the taxa are sometimes very subtle, and of questionable validity.

2. The status of the holotype of *Aquilapollenites quadrilobus* Rouse, 1957 is uncertain (possibly lost).

The type species of Genus*Aquilapollenites*, *Aquilapollenites quadrilobus*, was originally described by Radforth & Rouse, 1954, from the Maastrichtian Brazeau Formation, western Alberta. It was not given a name, and a holotype declared until 1957 (Rouse, 1957, p.370). After its publication, several Russian authors (e.g., Chlonova, 1961; Mtchedlishvili, 1961), described a large number of triprojectate species from the Late Cretaceous of the northern part of the USSR. They placed the taxa into several genera, including *Triprojectus*, *Mancicorpus*, *Integricorpus*, *Projectoporites*, *Parviprojectus*, and an emended *Aquilapollenites*. They grouped the genera together under the name Triprojectacites (Mtchedlishvili, July, 1961). Almost simultaneous with the



Text Figure 14: HETEROPOLAR Aquilapollenites AND SOME TERMINOLOGY (EQUATORIAL VIEW) (after Srivastiva, 1978)

Russian publications were papers by Funkhouser (April, 1961), and Stanley (November, 1961). They described several new species of triprojectates; however, they assigned them all to the genus *Aquilapollenites*.

From 1961 onward, numerous publications on triprojectates appeared. Various authors espoused three points of view: 1. that all triprojectates should remain in the genus *Aquilapollenites*, essentially as described by Funkhouser (1961); 2. they should be placed in several genera (e.g., Stanley, 1970) based on Mtchedlishvili (1961); or 3. the species should be assigned to the genera *Aquilapollenites* and *Mancicorpus* as emended by Srivastava, 1968. Each author tranferred species from other genera into his/her concept of the group. The result is an absolute profusion of names (I estimate over 400) applied to only about 200 taxa. Unfortunately, some species names are not unique. When transferred into other genera, still more new names are generated.

A great problem in all this work is the status of the type species of *Aquilapollenites* - *Aquilapollenites quadrilobus* Rouse, 1957. The various multi-genera classifications require that the type species of *Aquilapollenites* remain in that genus. Some authors (e.g., Tschudy and Leopold, 1971) have contended that the definition of *Aquilapollenites* proposed by Srivastava (1968) and Stanley (1970) would exclude the holotype of *Aquilapollenites quadrilobus*, and therefore is invalid (or least must be emended further). The solution to the problem is to look at the original holotype of *Aquilapollenites quadrilobus*.

The original illustration of the holotype of *Aquilapollenites quadrilobus* (Radforth and Rouse, 1954, pl.1, fig. 14 as designated in Rouse, 1957, p.370) is very poor quality. Its orientation obscures the details of the minor pole, critical to the multi-genera classification. Even more disturbing is the loss of the original slide, as reported by Srivastava and Rouse, 1970. Accordingly, Srivastava and Rouse, 1970 selected a neotype. Their specimen appears to agree with the definition of *Aquilapollenites* in the multi-genera classification.

Tschudy and Leopold (1971) claim to have rediscovered the holotype slide of *Aquilapollenites quadrilobus*. Stanley (1973) relates a personal communication from Wayne Brideaux about the origin of the slide used by Tschudy and Leopold (1971). Apparently, the slide was originally mounted in corn syrup. The material had run off the slide, and into the bottom of the box. The material was remouted and sealed to make the slide used by Tschudy and Leopold (1971). Tschudy and Leopold (1971) figure a specimen VERY similar to the original plate of Rouse, 1954. At the very least, this specimen is from the same material as the original holotype, and therefore must be considered a lectotype. A lectotype takes precidence over the neotype of Srivastava and Rouse (1970) because the lectotype is selected from the original type material (International Code of Botanical Nomenclature, article 7, note 3) (Jansonius and Hills, 1976, card #141-142). Tschudy and Leopold (1971) figure specimens of *Aquilapollenites* from the same slide which they claim are identical to the claimed holotype/lectotype. The specimens are heteropolar, and at least some would be placed in the genus *Mancicorpus* as defined by Srivastava, 1968 and Stanley, 1970. Since *Aquilapollenites quadrilobus* must remain in the genus it was originally described under, Tschudy and Leopold (1971) claim that the multi-genera classification scheme of Srivastava (1968) or Stanley (1970) must be considered invalid (as currently defined). Tschudy and Leopold (1971) place all triprojectate species under the one genus *Aquilapollenites*.

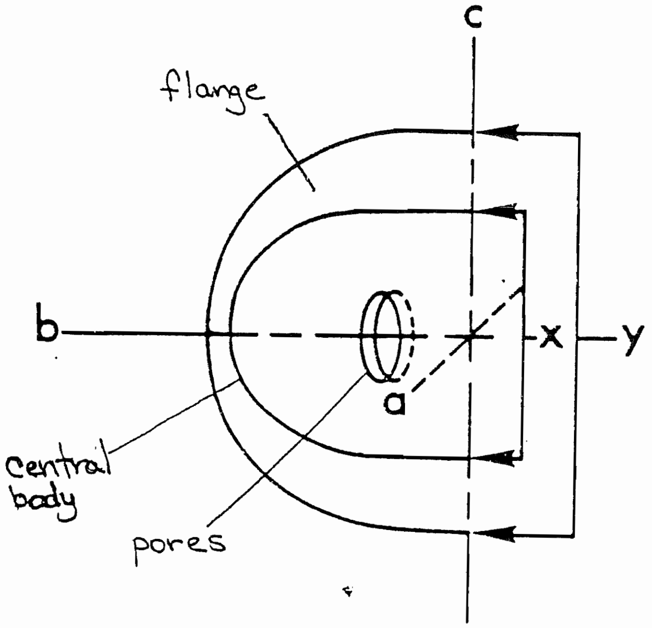
In this author's opinion, the specimen figured by Tschudy and Leopold (1971) is a valid lectotype. There does seem to be some basis for the division of the group into multiple genera (e.g., the genus *Integricorpus* is quite distinct), however, there will always be species whose position is debatable. Given the considerable number of names applied to the triprojectate group, it is probably simplest to place all triprojectates in the single genus *Aquilapollenites*. This convention will be used throughout this thesis, but proper citations will be given to any species not originally described under *Aquilapollenites*.

3.2.5 *Wodehouseia* and the "oculata" group:

Genus *Wodehouseia* is the name applied to an unusual Late Cretaceous pollen grain with an ellipsoidal shape, two pairs of pores, and a flange or skirt (see text figure 15). It is a member of the "oculata" group (Chlonova, 1962) of pollen, all of which share the ellipsoidal outline and two pairs of pores. Members of the Oculata group arose in the Santonian (Wiggins, 1976) (*Azonia*, Samoilovitch, 1961), diversified in the Maastrichtian (*Wodehouseia*, Stanley, 1961), and became extinct shortly after the Cretaceous-Tertiary boundary. The group has no modern analogues.

Wodehoueia is distinct from the remainder of the group in possessing a thin flange around the perimeter of the grain. In some species the flange can be quite large (e.g., *Wodehouseia fimbriata* Stanley, 1961). A fine reticulum and/or short spines are common types of ornamentation. *Wodehouseia* is characteristic of Maastrichtian palynofloras from western North America, Arctic Canada, Siberia, and northeast Asia.

The orientation of the features of *Wodehouseia* is uncertain. Because of its



Text Figure 15: STRUCTURE AND ORIENTATION OF *Wodehouseia*
Figure represents half of a complete pollen grain. X is the width of the central body, and y includes the width of the flange. Using the notation of Wiggins, 1976; a is the minor equatorial axis, and c is the polar axis. The notation adopted herein is: b is the polar axis, a is the minor equatorial axis, and c is the major equatorial axis. Figure modified after Wiggins, 1976.

unusual structure and lack of modern analogues, it is not clear where the polar axis or equator of the grain is. There are no published accounts of clusters of *Wodehouseia* showing their orientation in a tetrad. Wiggins (1976) interprets the plane of the longest axis and the shortest axis as the equatorial plane (see text fig. 15). The intermediate-length axis is the polar axis. In this interpretation the flange is equatorial, and the pores are arranged around the equator. I have observed rare clusters of *Wodehouseia* in sample EL87-106 (see plate 22, fig. 84). In all cases the longest axis is oriented towards the centre of the cluster. If the clusters represent the original orientation of the pollen grains durring formation, the longest axis is the polar axis (see text figure ##). This notation is adopted in the descriptions.

There is much confusion in the literature about the distinction between two species of *Wodehouseia*: *Wodehouseia edmontonicola* Wiggins, 1976, and *Wodehouseia gracile* (Samoilovitch, 1961) Pokrovaskaya, 1966. According to Wiggins (1976), the main distinguishing features between *Wodehouseia edmontonicola* and *Wodehouseia gracile* are the shape of the pores, the size of surface spines, the distribution of surface ornament, and the polar thinings. According to Wiggins (1976), *Wodehouseia gracile* has "extremely small colpi [pores]". The specimens of *Wodehouseia gracile* figured by Wiggins (1976) have rounded (low length/width) pores, while the specimens of *Wodehouseia edmontonicola* have elongate (high length/width). The holotype of *Wodehouseia edmontonicola* is in Srivastava, 1969, pl.1, fig. 6 (Designated by Wiggins, 1976, p.65). It also has elongate pores. The holotype of *Wodehouseia gracile* is in Samoilovitch, 1961 (IN: Samoilovitch and Mtchedlishvili, 1961), pl. 76, fig. 1a-c. Although a poor illustration, it appears to have relatively rounded pores, with length/width <1.5. A possible refiguring of the holotype of *Wodehouseia gracile* is in Samoilovitch, 1967, pl.2, fig. 6, although it is not indicated as such. It has the same features.

Another differentiation is in surface ornamentation. *Wodehouseia edmontonicola* generally has finer surface ornamentation, and it does not occur in the polar areas. The holotype (Srivastava, 1969, pl. 1, fig.6) of *Wodehouseia edmontonicola* has small (<1µm) spines. The spines are absent from the polar areas. Wiggins, 1976 places other specimens described in Srivastava, 1969 (pl. 1, figs. 4, 7 and 9) in synonomy with *Wodehouseia edmontonicola*. Some of these other specimens are almost completely devoid of spines. In contrast, the holotype (Samoilovitch, 1961, pl. 76, fig. 1a-c) of *Wodehouseia gracile* is covered with larger (>1µm?) spines distributed over the entire surface of the central body.

A final distinction is a zone of thinner exine in the polar areas of *Wodehouseia edmontonicola*. Under the microscope, the thin zones appear lighter. The thin zones are present in the holotype (Srivastava, 1969, pl. 1, fig. 6) of *Wodehouseia edmontonicola*, as well as the figures in Wiggins, 1976. Polar zones of exine thinning are not observed on the holotype of *Wodehouseia gracile*, instead the exine is approximately the same thickness over the central body.

The following table summarizes the characteristics used to distinguish *Wodehouseia edmontonicola* and *Wodehouseia gracile* in this thesis:

	Wodehouseia edmontonicola	***W. gracile***
Pores	elongated, high length/width	more rounded, low length/width (usually ≤1.5)
Ornamentation	small (≤1µm) spines to granulate or psilate (spines absent)	large (≥1µm) common spines, often >30µm; rarely a fine reticulum
Distribution of spines	no spines in polar areas	randomly distributed
Exine thickness	thinner at poles	approx. even thickness

4. RESULTS:

4.1 Geology & Stratigraphy: (see text figures 16-20)

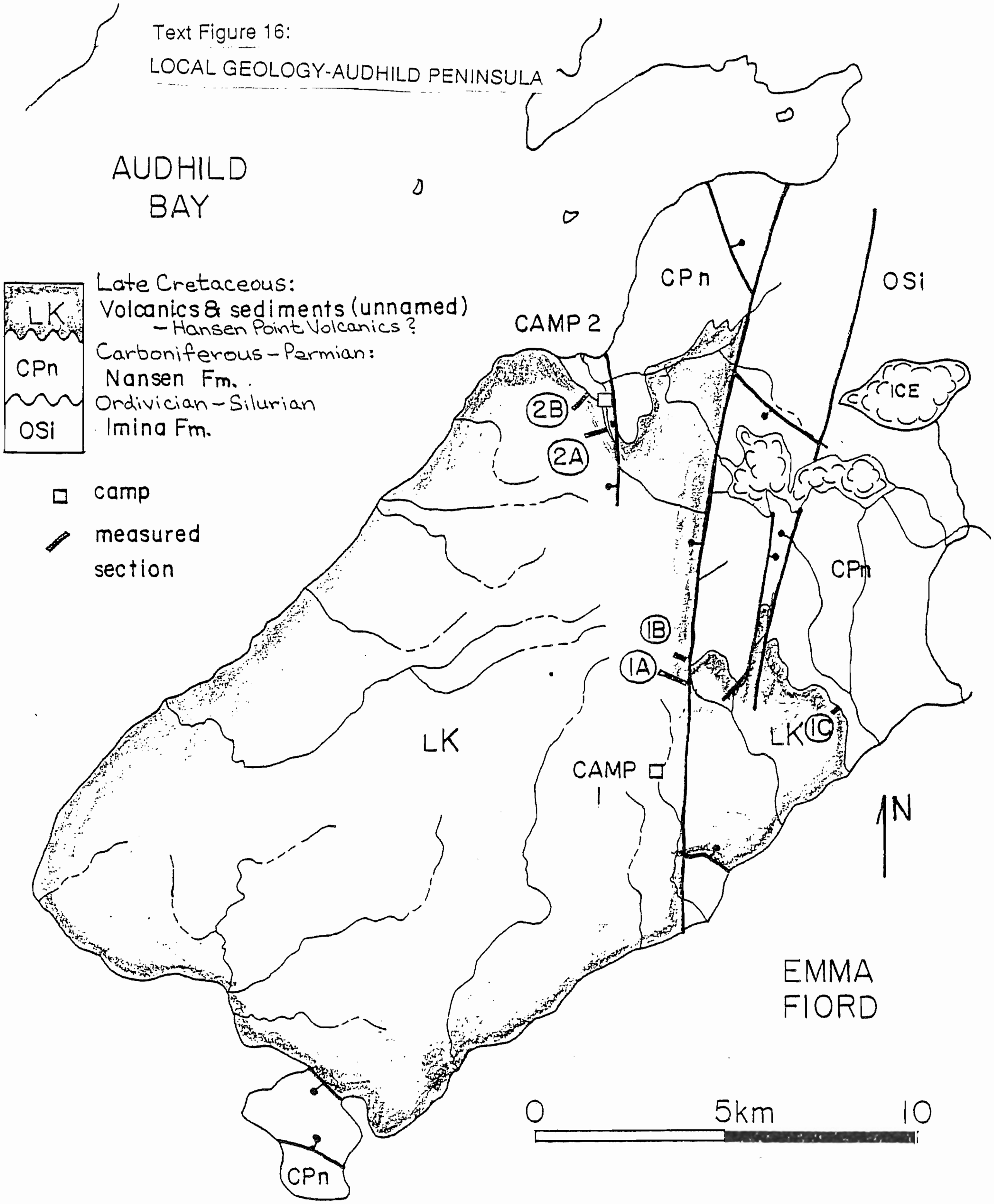
The Audhild Peninsula sequences unconformably overlie the Carboniferous (Thorsteinsson & Trettin, 1972) carbonates of the Nansen Formation. The unconformity is sharply erosional. An orange-coloured dissolution breccia several metres thick marks the basal contact at sections in both outcrop areas. At the northern sections (2A & 2B) (just upstream from Emma Camp #2), the Nansen Formation shows dissolution cavities and orange-brown limonitic deposits in the top 8 metres or so of the outcrop. The Nansen surface has relief of several metres, suggesting a karstic topography.

The overlying Mesozoic sequences are sub-horizontal over most of the outcrop area, except in the vicinity of major faults. Over much of the peninsula, the only outcrops are resistant basalt mesas, and material between the basalts cannot be observed. The topography is notably flat compared to surrounding mountainous areas. At the northeast end of the peninsula, the basal contact of the sequence is exposed in stream outcrop and the topography becomes higher. In these areas, outcrops of less resistant sediments and pyroclastics are observed. Their outcrop is relatively poor compared to the resistant basaltic outcrop. The poorly consolidated sediments and pyroclastics occur as low banks, while the basalt flow units make tall cliffs (up to 25 m high) (text figs. 17 and 18). The northerly field area (Emma Camp #2, see text fig. 16) has the most complete sections, although the southern field area (Emma Camp #1) has better exposure of sedimentary facies.

The sequences are cut by a series of N-S trending high-angle faults (see text

Text Figure 16:

LOCAL GEOLOGY-AUDHILD PENINSULA



Modified from:

Thorsteinsson & Trettin (1972)

fig. 16). The throw of the faults is revealed by the relative displacement of the basal unconformity. At the site of sections 1A & 1B, the displacement appears to be at least 20 metres. To the east of sections 2A & 2B, the basal surface is displaced by as much as 40 metres in places. The volcanic-sedimentary sequences are usually preserved on the downthrown blocks. The dip of the sequences increases rapidly from nearly flat-lying to >40° as the faults are approached, thus forming a local monocline. The strike of the sequences are usually sub-parallel the faults in their vicinity. The monoclinal structure was probably produced by fault drag. It invariably occurs in the same sense as would be expected from the observed displacement of the basal contact (see text figs. 16 and 20).

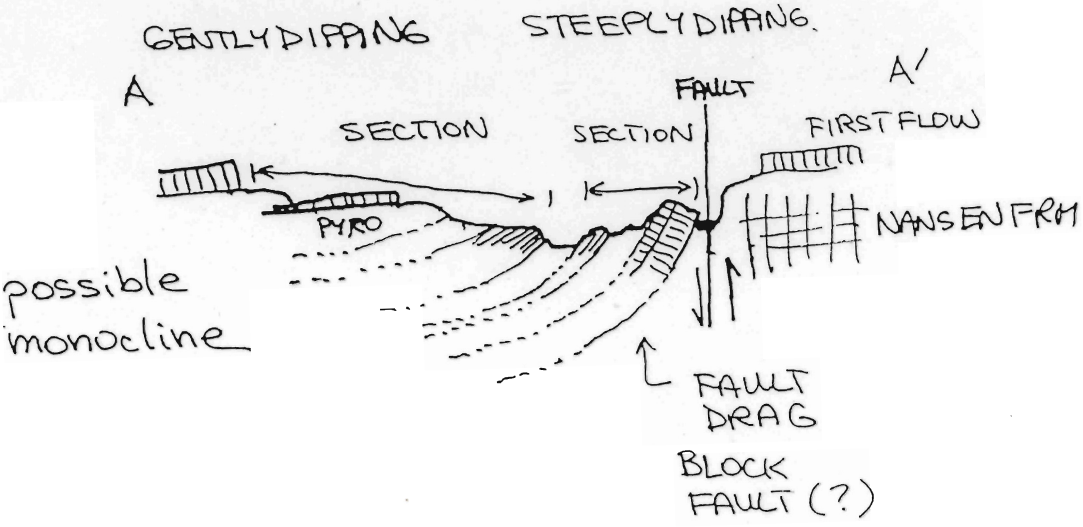
Stratigraphy of the area is represented by five sections (see text fig. 19). The sequences at Audhild Peninsula display a general alternation of sedimentary and volcanic units on the scale of tens to hundreds of metres (see text fig. 20). Sometimes the volcanic units are observed to intertongue with the sedimentary units, but usually lateral continuity of most of the basaltic units is good. Facies changes are most drastic in the sedimentary units. Basaltic units are usually a dark grey to black colour, usually finely feldspar phyric or aphyric. Rarely are they coarsely feldspar phyric or coarsely clinopyroxene and olivine phyric.

4.1.1. Emma Camp #1 Sections:

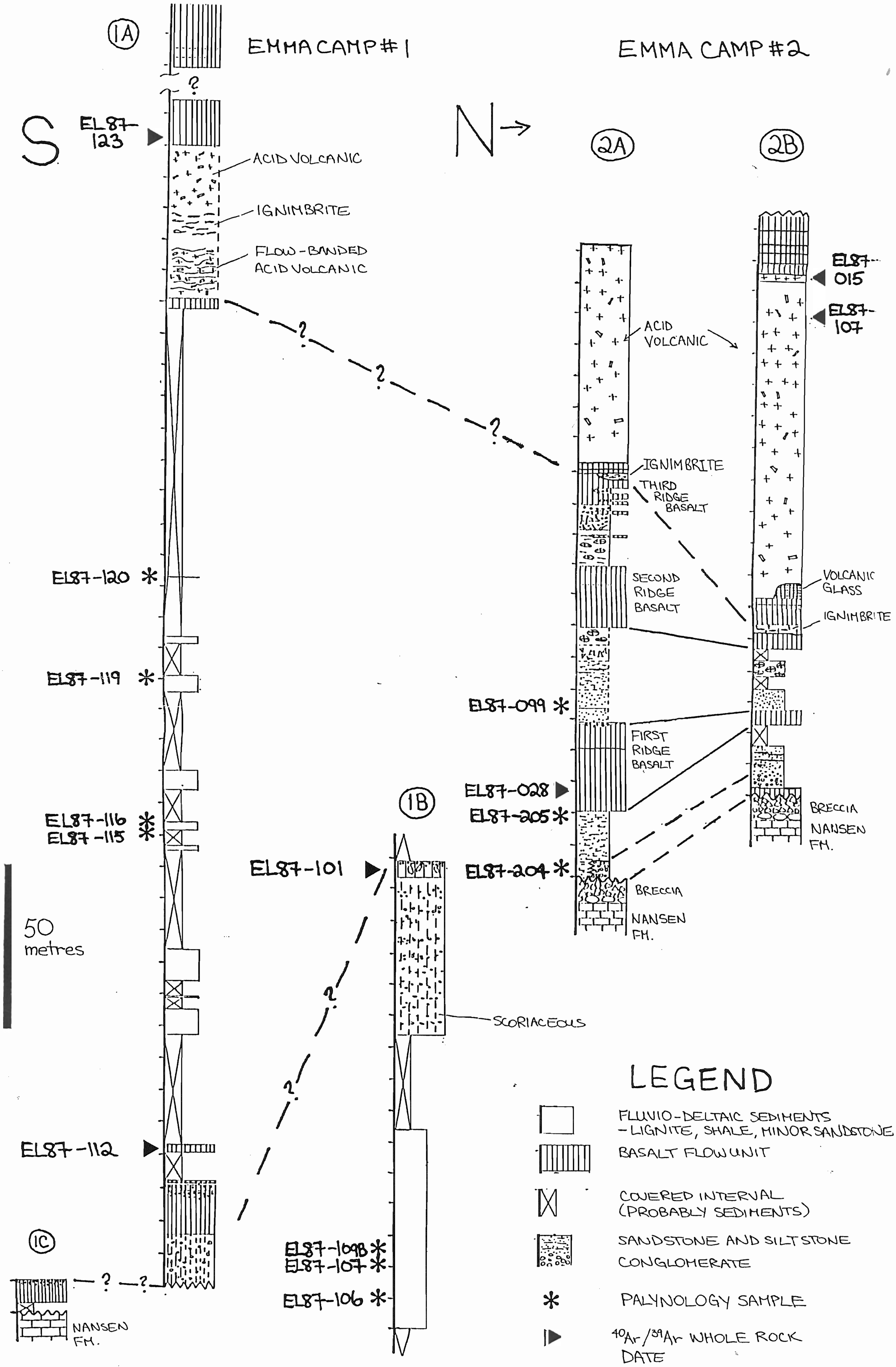
At Emma #1, the amount of outcrop is limited, but sediments are better exposed than the Emma #2 outcrops. Two main sections were measured. Sections 1A and 1B occur along tributary streams running NW-SE, and occur to the west of a major N-S running fault (see text figure 16). The strata strike approximately NNE-SSW, and dip at angles from 5° (to the west) to 80° (section

Text Figure 17: FIELD PHOTOGRAPH: EMMA CAMP#2
A view of the northern (Emma Camp #2) field area looking towards the west to southwest from outcrops of the Nansen Formation (foreground). Prominent ridges are packages of basalt flows. The closest ones are about 25 to 30 metres in height. Poor outcrop of sediments and pyroclastics occurs between the ridges. The basal unconformity is difficult to observe, but runs about 40 metres below the lowest basalt package. Orange discolourations mark the contact in some areas. The large, rounded hill of light coloured material at the top of the sections to the right is a feldspar-phyric acidic volcanic flow unit. It is 80 or more metres thick. Lateral variations in the thickness of units is obvious in some areas. Tents appear in the lower right corner for scale. July, 1987.

Text Figure 18: OUTCROP AT SECTION #1A
Outcrop of lignite and shale at section #1A, Emma Camp #1. Beds are dipping at about 35º to the left. Jacob staff is scaled in feet. July, 1987.



Text Figure 19: CROSS SECTION, SECTION #1A
Figure reproduced from field notes showing interpretation of the changes in dip at section #1A, Emma Camp #1. Section is drawn in the plane of section #1A - about NW-SE. Not to scale.



Text Figure 20: GENERAL STRATIGRAPHY AND SAMPLE LOCATIONS

1B, and closer to the fault).

The base of section 1A occurs at the fault. It is not clear whether the fault has cut off a major part of the section here. On the east side of the fault, a single basaltic flow unit occurs on top of the Nansen Formation, below section 1A. The flow unit was measured at section 1C, further to the east. The bottom 30 to 40 metres of section 1A consists of basaltic flow units, one of which is dated radiometrically (EL87-112); followed by more than 200 metres of coal-rich sediments. This is the interval from which palynology samples EL87-115, 116, 118, and 120 come. After a 50+ metre gap, the sediments are followed by more volcanics. A thin basalt occurs, beneath rubbly subcrop of flow-banded and massive, feldspar-phyric acid volcanics; and a green-coloured ignimbrite. The thin basaltic unit (EL87-123) is also dated radiometrically. Above the acid volcanics are a series of nearly flat-lying basalt mesas, one of which is coarsely feldspar phyric. Radiometric ge dates are being carried out on the youngest basalt mesas (EL87-130, EL87-109A).

Section 1B is less complete. Its basal contact is not observed, and begins with lignite-rich sediments similar to section 1A. Initially it appeared the sections could be correlated by tracing low outcrop ridges along strike between them. However, this section is at a slightly different strike and much steeper dip (near vertical), suggesting some structural complications. Palynology samples EL87-106, 107, and 109B come from this section. The lignite-rich sediments outcrop over 60 metres, and are overlain (with a gap of 30 metres) by scoriaceous basaltic units, and a distinctive coarsely clinopyroxene, feldspar-phyric basalt flow unit (EL87-101). This unit is radiometrically dated.

The sedimentary rocks of both sections are mostly black, fissile, amber-bearing bituminous shale. Fragments of coalified wood, some complete branches a few centimetres in diameter and <10 cm long, occur throughout the shale. Occasionally the coal fragments become common enough that it is difficult to decide whether the rock is lignite or shale. In the field, the two were differentiated by their fracture habit - if fracture was blocky, and extremely brittle; the rock was considered lignite, if fracture was fissile, the rock was considered shale. Lignite beds usually contained abundant yellow-orange amber blobs, up to 5 mm size. Most of the coals and shales have mm-size white, siliceous fragments, and rounded, soft, white clasts to 5 mm size making up to a few percent of the rock (<5%). In thin section, these are revealed to be a variety of volcanically derived fragments, including pumice fragments, and euhedral feldspar grains (some are Sanidine, determined optically). The occurrence of such large clasts in fine sediments is unusual. At one locality (the 50 metre mark of section 1B), upright coalified tree segments up to 10 cm in diameter, and 60 cm long occur in a lignite bed.

Coarser facies include the occasional orange-coloured wacke cemented by siderite. Coalified wood is sometimes present. Coarse clasts, sometimes volcanically derived, occur at the base, but the coarsest clasts are less than 1 cm in size. Basal contacts of the wacke beds are usually sharp, while upper contacts are gradational, often into finer siliclastics like siltstone, and mudstone. The mudstone is usually grey, and often has small, tubular, subvertical plant fragments (possibly a root horizon). The mudstone usually grades into bituminous shale or lignite. The typical siliclastic package is less than 2 metres thick (excluding the bituminous shales), and occur on an approximate 10 metre cycle. Lateral continuity of the wacke beds is low. Thickness can vary considerably over a few metres.

Also present at random intervals are thin (about 10 cm) mudstone layers with good lateral continuity over 5 metres or more. They are dark grey on a fresh surface, but weather to a distinctive white. They could be ash fall horizons. Thin sections were attempted, but the material disaggregates completely when immersed in water, and resin impregnation was not successful.

Bituminous (organic-rich) shale makes up about 70 % of the thickness of both sections.

4.1.2 Emma Camp #2 sections:

Sections at Emma #2 are considerably more complex. The sections shown in text figure 20 are composite sections from several sites distributed laterally over a kilometre or more.

The basaltic units form distinctive ridges over 20 metres tall formed of several flow units (usually 3 or 4). They usually display well-developed columnar jointing, sharp basal contacts, and blocky and/or amygdaloidal flow tops. They can be traced laterally for several kilometres, and have been used for correlating the sections. Three main basaltic packages are present, they are (informally) named the 'First', 'Second', and 'Third Ridge' basalts in order of their occurrence. A single thin flow unit at the base of section 2B was not observed in more southerly areas, and must pinch out. The 'Third Ridge' basalt occurs as a continuous unit only in the southern section (2A). In the northern section (2B), the 'Third Ridge' basalts occur as approximately 14 thin flows which intertongue in a *very* complex manner with each other and coarse volcaniclastics. The 'Second Ridge' basalts become difficult to differentiate from the 'Third Ridge' in section 2B because of the multitude of flows. A spectacular example of a ponded basalt flow with columnar jointing occur in the 'Third Ridge' basalts at section 2A.

A consistent marker near the top of the 'Third Ridge' basalts is an ignimbrite flow unit. The ignimbrite is usually green coloured. It has dark green, sometimes glassy, fillamaé up to 3 cm in diameter, and a light green, feldspar and biotite (?) phyric matrix. The ignimbrite weathers to a yellow or orangey colour. Frost action has produced a sickly green, clayey mud from the glass at some points. The ignimbrite varies considerably in thickness, but averages about 2 metres. It can be traced near the top of the 'Third Ridge' basalts from section 2A to 2B over about 500 metres. It does not occur further south, because the top of the sections have been eroded.

Above the ignimbrite more thin basaltic units are found, and above these, a very thick (80+ metres) mountain of massive, light beige coloured, feldspar-phyric, acid volcanic occurs (see text figure 17). At some points, (section 2B) a lenticular volcanic glass unit occurs beneath the acid volcanic unit. The glass is feldspar-phyric, and flow banded. Scoriaceous basaltic (?) clasts to 3 cm size occur sporadically in the unit.

The sediments of the Emma #2 sections have a decidedly coarser character than the sections at Emma #1. Coals make up only a very small part of the sediments, and conglomeritic facies are common. Because many of the sediments are poorly consolidated, outcrop is poorer than the sections at Emma #1 (sections 1A & 1B). Section 2B has the best representation of sediments.

The base of the sediments at section 2B and 2A is marked by a chert pebble conglomerate several metres thick. Further to the south, the base of section 2A is marked by a dark grey (organic-rich) sandy shale or siltstone (palynology samples EL87-204, 205). On top of the conglomerate in section 2B is a fine, well-sorted, planar-bedded white sandstone with occasional thin (10 cm) lignite and shale horizons. A silicified tree segment with bark was found within these sediments. A general fining of facies from north to south is indicated. The lowest sediment package is about 20-25 metres thick in total.

Above the 'First Ridge' basalts, the second sediment package is about 30 metres thick. It has siliclastic sediments at the base (immediately on top of the 'First Ridge' basalts), and a coarse volcaniclastic near the top (beneath the 'Second Ridge'). The sediments are displayed best in section 2A. A leaf bed occurs about 4m above the 'First Ridge' basalts in the vicinity of section 2A (see map for location; palynology sample EL87-099 comes from just above the leaf bed). Because of poor outcrop, only a sequence of strata can be determined:

1. White, planar-bedded sandstone - well-sorted, with occasional low angle cross-stratification. The same material which occurs within the first sediment package, section 2B.

2. Bituminous shale, mudstone, and lignite - viewed only in subcrop. Associated with numerous calcified wood fragments.

3. Light green pyroclastic (?) - Fragmental rock with light-coloured siliceous fragments, and occasional light-coloured, feldspar-phyric volcanic clasts. Grain size varies from silt to conglomerate. Graded beds common. Well cemented. Small (3 mm) lignite fragments present in some samples. Some samples are breccia, with dark brown matrix. Observed only in subcrop.

4. Coarse, matrix-supported volcaniclastic - Clasts are light-coloured, feldspar-phyric, volcanic. Usually rounded. As large as 20 cm. Matrix is unconsolidated mauve and green clay. Clasts are about 50% of the volume. A

sharp contact with the overlying 'Second Ridge' basalts is observable.

The third sediment package intertongues with the 'Third Ridge' basalts in a complex fashion in section 2B. In section 2A, where the distinction between the 'Second' and 'Third Ridge' basalts is clear, there is an area of excellent exposure (see map). Two sedimentary units are present. The lower is a green, matrix-supported volcaniclastic conglomerate similar to the one which occurs in the second sediment package; it is about 10 metres thick. Clasts tend to be smaller (2-4 cm), more angular (subrounded), and of more varied volcanic composition than the volcaniclastic unit beneath the 'Second Ridge' basalts. Flattened clasts (pumice ???) are also present. The matrix is a light green clay, with a significant proportion of sand-sized grains.

The upper unit is a red-brown coloured (hematite coated), clast-supported conglomerate. Clasts are a grey, fine-grained, feldspar-phyric acid volcanic up to 5 cm in diameter. It is about 8 metres thick (at one outcrop). A sharp contact with the overlying 'Third Ridge' basalts is observable.

In general, the sediment packages and the volcanic units thicken from north to south. Sedimentary facies fine from north to south in the Emma #2 sections, and between Emma #2 and Emma #1.

A basin-shaped outcrop area to the east of Emma Camp #2 (called 'The Other Side' in field notes) is structurally complicated. The contact with the underlying Nansen Formation is observable in stream outcrop in the west. Bedding generally dips gently towards the east, in the direction of a major fault. Near the fault, the dip shallows, and the outcrop is badly sheared. Alternating basaltic and sedimentary units occur within the basin, but it was impossible to measure a stratigraphic section. An ignimbrite unit similar to the one observed in section

2A & 2B was noted towards the top. A single outcrop of volcanic glass occurs above basalts and ignimbrite near the NE corner of the basin. Isolated outcrops of acid volcanics were also noted in some areas.

4.2 Paleontology:

4.2.1 Macrofossils:

Plant macrofossils are found at most of the sediment sections. They occur as wood and foliage.

A: Plant Wood

Wood is found in several preservational states. At the southern (Emma #1) sections, lignite contains abundant coalified tree segments up to 10 cm in diameter, and tens of centimetres long. Most have fossil resin (amber) embedded in their tissues. Growth rings are still obvious, but no diagnostic features are present. At some locations, the tree segments were upright in the lignite. A tree segment partly replaced by siderite was found at a stream section just to the south of section 1A.

At Emma Camp #2 sections, well preserved wood was found within the first sediment package. At section 2B, a tree segment 15 cm in diameter, and 40 cm long was found (plate 1, figs. 1-2). The bark is preserved, and thin sections revealed well preserved growth rings. Tracheid pit structures suggest Taxodiale affinites for the tree. The tree was about 46 seasons old when it died. The original woody material is only slightly coalified, and the pore space is infilled with silica. A second tree segment was found at section 2A with similar preservation. It is 25 cm in diameter, and was greater than 60 seasons old when it died. The growth rings display considerable variation in width.

Calcified wood fragments to 5 cm size were found within the second sediment package.

B: Plant Foliage

Remains of identifiable plant foliage were found at one locality. It is located 4 metres above the 'First Ridge' basalts, upstream (south) from Emma Camp #2. The foliage occurs at the top of a single 3-4 cm graded bed which subcrops on the slope above the basalts. The bed grades from a coarse sandstone to a very fine shale. The basal 2 cm contains abundant white or beige, angular, very fine-grained silicic fragments to 1 cm size. They are probably volcanically derived. Polycrystalline quartz fragments, and feldspar grains occur throughout. Dewatering structures are common, suggesting rapid deposition. Plant material, mostly leaves, is preserved in the top 1 cm of the bed as black, carbonaceous films. Anatomical details are well preserved in some specimens.

Approximately 100 fragments of the bed were collected from subcrop during parts of two field days. Most of the material was reassembled into three large slabs - EL87-060.001, EL87-097.001, and EL87-097.002 (see plate 2, figs. 3-4).

Some consideration was given to identifying the plant remains to species level, but time and reference limitations made this impossible.

In general, taxodioid foliage is the most common part of the assemblage, making up perhaps 80 % of the forms present. The remainder of the forms are several species of angiosperms, cupressoid foliage, a conifer cone, and a ginkgo, in order of abundance. Several seeds are also present. As evidenced by studies of recent leaf occurrences (Spicer & Wolfe, 1987), the relative abundance of leaf species must be interpreted carefully. The relative abundances of a fossil sample may not represent the relative abundances of the living plants because of two independent variables - 1.) the relative proportions of species in a depositional basin, and 2.) the proximity of the species to the depositional area. The relative proportions in a sample will usually represent the assemblage in the immediate area (of deposition). More distant forms represent a small proportion of the assemblage, no matter what their relative abundance in these areas. The dominance of Taxodiales in the assemblage suggests they were a large component of the local plant life. The occurrence of silicified Taxodiale tree segments with preserved bark (suggesting short transport distance) confirms this is likely.

The following is a general description of the leaf forms present:

(Classification after Taylor, 1981)

Division: Ginkgophyta

cf. *Ginkgo*

plate 3, figure 5

Distinguished by 'fan-shaped' leaf outline and parallel dicotomising veination. Veins occur at mm intervals. They branch several times near base of the leaf, rarely away from base. Leaf margin not well preserved, but probably split into several wide segments.

1 specimen observed (EL87-060.002 A&B, part & counterpart). Base of fan is about 7 cm.

The ginkgo is native to central China (Phillips, 1978). Live specimens are common in gardens around the world (e.g., Public Gardens, Halifax, N.S.) because of their unique appearance.

Division: Coniferophyta
Class: Coniferopsida
Order: Coniferales
Family: Taxodiaceae
cf. *Parataxodium*(?)
plate3, figure6; plate 4, figures 7-8

Distinguished by pinnate, deciduous shoots with elongated, flat needles oriented in a horizontal plane (see plate 3, figure 6). Needles have a rounded tip, a single midvein, and are arranged in a semi-alternate pattern along the shoot. The alternate arrangement of the needles distinguishes this form from *Metasequoia*. Bases of the needles are only slightly twisted. Taxodioid foliage is most common, but some cupressoid foliage is present as well (e.g., plate 4, figure 8). A single compressed cone, possibly of this genus, is associated with foliage on specimen EL87-060.001 (plate 7, figure 8). One specimen showing structures interpreted as male (pollen) cones was also found (see plate 4, figure 7). They are attached to the base of a leaf shoot, and are made up of small overlapping scales.

The female cone is approximately 2 cm in diameter. The male cones are about .75 cm in length. Typical complete shoots are 10 cm in length, and needles can reach 2-3 cm. Examples of foliage are found on all specimens.

Modern *Taxodium* is found in backswamp environments in the southeastern United States (Phillips, 1978), but can survive at more northerly climates (e.g., Public Gardens, Halifax, N.S. - but this specimen does not reproduce). In its native habitat, its roots are often immersed in water.

Division: Anthophyta (Angiosperms)

Unfortunately, no general reference on fossil angiosperm leaf morphology exists, so it was not possible to identify the angiosperm leaves. Descriptions are very limited as well.

undet. angiosperm sp. A

plate 5, figure 9

Plate 5, figures 9 (left individual) shows a multilobed symmetric, round (? if complete) leaf form with perfect, reticulate, basal actinodromous veination. Primary veins continue to leaf margin. Secondary veins are arranged in an alternate pattern along the midvein. Lobes are short and round. Description incomplete. Somewhat similar to *Cercidiphyllum*.

Specimen located on EL87-060.001. Part and counterpart preserved. About 4 cm in length.

undet. angiosperm sp. B

plate 5, figure 9-10; plate 6, figure 11

Plate 5, figure 9 (right individual), figure 10 (counterpart of 15), and plate 6, figure 11. Multilobed leaf form with complex, reticulate, basal actinodromous veination. Lobed outline more pronounced than sp. A (between lobe areas are deeply recessed). Description incomplete.

Specimen in plate 5, figs. 9 & 10 is rolled up. Specimen in plate 6, fig.11 is incomplete, but shows acute base, and the unfolded margin of the leaf.

About 3.5-5 cm in length.

undet. angiosperm sp. C.

plate 6, figure 12

Unusual heart-shaped leaf form with perfect basal reticulate actinodromous veination. The 1° mid-vein is unbranching, and reaches the leaf margin. The two lateral 1° veins branch once, and do not reach the leaf margin. Two detached marginal veins are present in the basal half of the leaf. Outline is triangular. Basal angle acute. Apex is reentrant (emarginate). Two broad lateral lobes form the triangular outline. At the mid-distal point of the leaf, two small, irregular-shaped lobes suggest pathological damage. Leaf is damaged at the left margin (see plate 6, figure 12). Description incomplete.

Leaf length about 4.5 cm.

Specimen located on EL87-097.001-A, B (part and counterpart).

A variety of undertermined seeds were also found:

undet. seed sp. A

plate 7, figure 13

Ellipsoidal, oblate. Surface without sculpture, but bumpy (see figure). Sediment infilling with some carbonaceous material remaining. About 1 cm in diameter.

undet. seed sp. B

plate 7, figure 14

Teardrop-shaped seed with triangular, longitudinal projections and striated surface sculpture. Preserved as a mould. About 0.6 cm in length.

undet. seed sp. C

plate 7, figure 15

Bilobed seed with striated surface sculpture. About 1.1 cm in length.

The apparent diversity of the angiosperm flora may be a result of improper distinctions between species. The specimens have been sent to Kirk Johnson of Yale for specific identification.

4.2.2 Palynology:

A: Condition of palynomorphs:

Ten samples were processed in time to be considered in this study (see methods for lithologies). Of these, seven samples were productive enough for palynological analysis:

<u>Emma Camp #1</u>

Section 1A:

EL87-106
EL87-107 } Abundant palynomorphs
EL87-109B

Section 1B:

EL87-115
EL87-116 } Abundant palynomorphs
EL87-118
EL87-120

<u>Emma Camp #2:</u>

Section 2A:

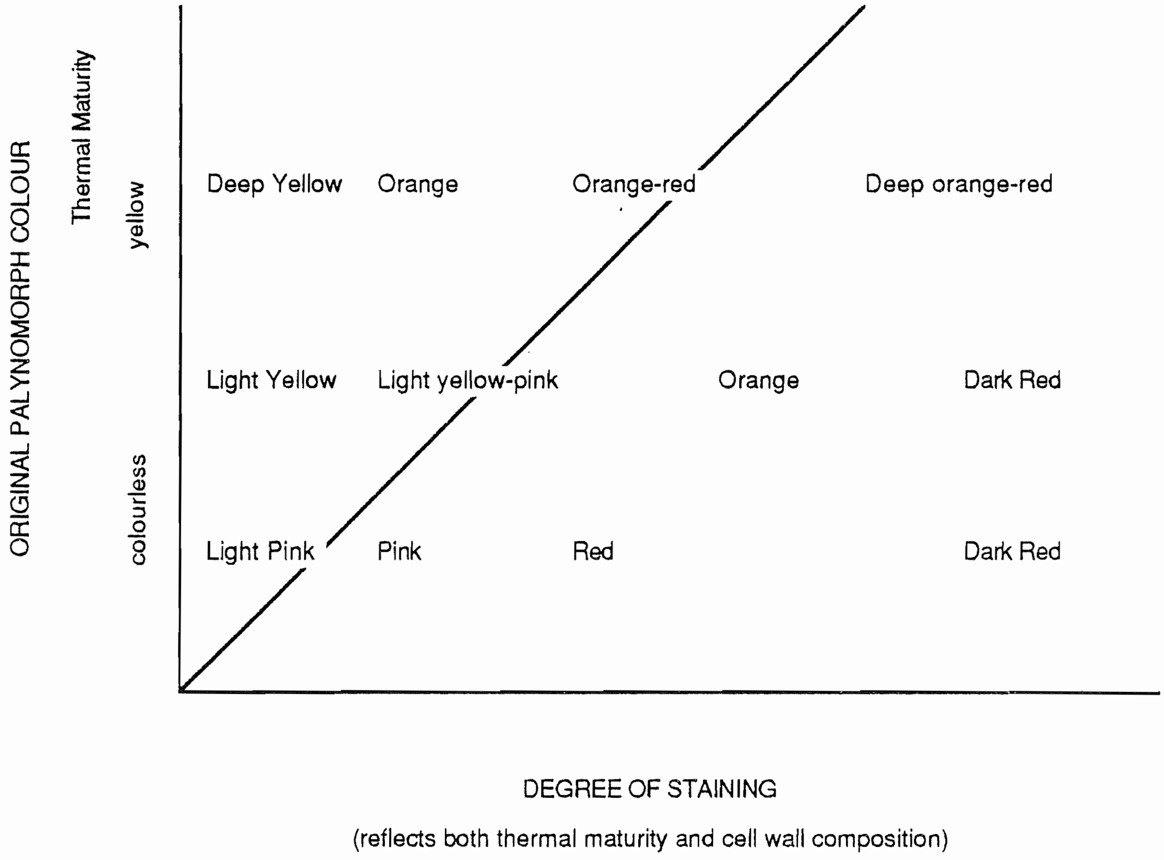
EL87-204 - barren, organic material oxidized
EL87-205 - very rare fungal spores, organic material oxidized
EL87-099 - barren, organic material oxidized

The fact that EL87-204, 205, and 099 (Emma Camp #2) are nearly barren may be explainaed by their occurrence near the base of the section, where thermal effects could be greater. Sample EL87-205 may have been baked by the overlying 'First Ridge' basalt unit, only about 2 metres above.

Palynomorphs in samples EL87-106, 107,109B, 115, 116, 118, and 120 (all from Emma Camp #1) are abundant and well preserved. Most palynomorphs do not show evidence of excessive abrasion. Bisaccate pollen grains were often damaged, probably because of their larger size.

The samples were stained with Safarin Red. The stain has been taken up differentially by some species of miospores. The colour observed reflects the original (unstained) colour of the miospore + the degree of staining. The colour and staining of miospores are generally indicative of their thermal maturity, and are significant to recognizing reworking problems (Wilkins, 1969).

Where typical colour of a palynomorph is stated in the descriptions, a qualitative colour scheme is used. It is figured below:



B: Descriptions of Palynomorphs:

Time did not permit a complete survey of all pertinent reference material. For this reason, taxonomic descriptions do not include a synonymy for most species. Many forms have been identified only to a genus level. Identification of some forms (e.g., many unornamented trilete spores) to species level has been avoided because of uncertainties about diagnostic features. Descriptions of palynomorphs are minimal for most specimens (sufficient to distinguish between each other), but ones which are significant to the age determination (e.g., the triprojectates and *Wodehouseia*) have received detailed descriptions, and the greatest attention in literature searches.

Coordinates of specimens are refered to by England Finder coordinates. Slide lodgement is indicated in appendix A.

Fungal Spores:

Polyporisporites sp.

plate 8, figures 26-27

Description: Chagrenate, monocellate, multiporate (?) fungal spore. Roughly circular to elliptical in shape. Multiple openings (germinal pores ?) are simple, and concentrated at one end of the spore (an end along the major axis if the spore is elliptical). Brown coloured. Spore wall is about 1 μ, diameter about 20μ.

Occurrence: Present in samples EL87-106, 107, 109B, 115, 116, 118, and 120.

Examples: Slide EL87-109B-01, H22/2; Slide EL87-107-02, R22/2.

Genus *Fusiformisporites* (Rouse, 1962) Elsik, 1968

Type species: *Fusiformisporites crabbii* Rouse, 1962

Fusiformisporites sp. A

plate 8, figure 17

Description: Chagrenate, rarely longitudinally striate, inaperturate (?), pentacellate fungal spore. Fusiform in outline. Axis curved. Septal pores are simple. Two irregular latitudinal septa are present. Brown coloured. About 20 μ long and 15 μ wide. Septal walls are about 1 μ thick, outer spore wall is thinner.

Remarks: Only one specimen with striate ornament was observed. It is figured.

Occurrence: Sample EL87-109B, EL87-115.

Example: Slide EL87-109B-01, E15/3.

Multicellaesporites sp.

plate 8, figures 18-19

Description: Psilate, multicellate (7 cells +), uniseriate,multiseptate spore with simple septal pores. Septa are entire or often forming septal flaps. It is unclear how many germinal pores are developed (most specimens are incomplete), but they are simple, and occur at one or both terminations of the spore. Outline is generally elongated elliptical, and often tapers asymmetrically. Specimens from EL87-205 are brown. Specimens from other samples are dark red. Individuals are as long as 60 μ, as wide as 15 μ. L/W usually >4.

Remarks: Several species may be present, but were not distinguished.

Occurrence: Only identifiable palynomorphs in EL87-205. Also present in EL87-106, 107, 109B, 115, 116, 118, and 120.

Examples: Slide EL87-107-01, S10/4; slide EL87-205-01, J19/0

Scutate fruiting body sp. A

plate 8, figure 20

Description: Scutate (disc-shaped) fruiting body lacking an ostiole. Observed as fragments with numerous thick-walled cells arranged in a radially symmetric pattern. Usually 1 cell layer thick. Dark red colour. Estimate about 80 μ radius. Individual cells on scale of 4 μ.

Occurrence: Rare in sample EL87-107.

Example: Slide EL-107-01, Q40/2.

fungal hyphae sp. A

plate 9, figure 21

Description: Bifurcate, tubular fungal hyphae fragment with simple porate septal walls and verrucate surface ornamentation. Light brown colour. Width about 4 µ. Fragment in figure is 44 µ long, and branches once.

Remarks: Many structures resembling fungal hyphae were noted in samples EL87-106, 107, 109B, 115, 116, 118, and 120, but they generally lack convincing fungal features (e.g., septa).

Occurrence: One specimen, sample EL87-106.

Example: Slide EL87-106-01, W41/0.

Plant Spores:

undet. trilete spore sp. A

plate 9, figure 22

Description: Large trilete spore. Amb (outline in polar view) convex triangular. laesurae at least two thirds of spore radius. They are straight, have negative relief (sunk below surrounding surface), and taper towards the spore margin. Spore surface is faintly ornamented in interradial areas (appears as a slight darkening). Remaining spore surface is chagrenate (smooth). Spore is a dark yellow colour. Spore wall is about 1-2 µ thick. Spore diameter is about 100 µ.

Remarks: The dark colour of this specimen suggests that it is reworked.

Occurrence: One specimen, sample EL87-109B.

Example: Slide EL87-109B-01, K45/1.

undet. trilete spore sp. B

plate 9, fig. 23

Description: Trilete spore with chagrinate ornamentation, concave triangular amb, and laesurae with postive relief. About 40-45 μ in diameter.

Occurrence: Very rare, samples EL87-106, 107; rare in sampes EL87-115, 116, 118, and 120.

Genus *Stereisporites* Pflug IN: Thomson and Pflug, 1953

Type species: *Stereisporites stereoides* (Potonie and Venitz, 1934) Pflug IN: Thomson and Pflug, 1953

Stereisporites antiquasporites (Wilson & Webster, 1946, p. 273, fig. 2)

Dettman, 1963, p. 25, pl. 2, figs. 20-21

plate 9, figure 24

Description: Trilete spore. Amb convex triangular. Spore wall thickened on distal surface, producing a rim-like structure at the equator (in polar view). Rim may be several microns wide. Spore is oblate in equatorial view. Laesurae extend to about half the spore radius, are straight, tapering, and have negative relief. Surface of spore is chagrenate, except for very fine ornament at the most central part of the interradial areas. The ornament produces a slight darkening in the areas between the laesurae. Diameter averages about 25 μ. Polar thickening is 1-2 μ.

Remarks: Related to the modern *Sphagnum* - a moss.

Occurrence: Present in samples EL87-106, 107, 109B, 115, 116, 118, and 120.

Example: Slide EL87-107-01, N20/2.

Steriesporites sp. undet.

plate 9, figure 25

Description: Trilete spore. Amb circular with slight concavities at the radial and mid-interradial areas (indented one tenth of spore radius). Thickened distal surface produces a rim-like equatorial zone. Spore is oblate in lateral view. Laesurae dichotomize towards the spore margin, and extend about two thirds to three quarters of spore radius. Surface of spore is chagrenate. Interlaesural areas are darker due to faint ornamentation. Dark pink in colour. Diameter about 20-25 µ.

Remarks: Distinguished from *S. antiquasporites* by dichotomizing laesurae and circular (with small concavities) outline. Variation within *S. antiquasporites* may include this form.

Occurrence: Samples EL87-106, 107.

Example: EL87-106-01, M20/2.

undet. trilete spore sp. C

plate 9, figure 26

Description: Trilete spore. Amb circular. Laesurae extend almost to the equator of the grain. Laesurae are thin, straight, and have positive relief (are raised above spore surface). Spore surface is unornamented (chagrenate). Spore wall is very thin. Light yellow in colour. Diameter approximately 30 µ.

Occurrence: Present in samples EL87-107, 109B, 115, 116, 118, and 120.

Example: Slide EL87-109B-01, N50/0.

undet. trilete spore sp. D

plate 9, figure 27

Description: Trilete spore. Amb straight triangular (with rounded angles). Equatorial shape is flattened. Laesurae extend four-fifths of spore diameter. They are thin, untapering, straight, and have positive relief. Margin (equator) of spore is partially enrolled towards the proximal surface, giving the impression of a slightly thickened equatorial rim a micron or more in width. Spore surface is psilate except for a faint, raised dendritic pattern radiating from the spore margin towards the centre of the spore. The ornament is most obvious in phase contrast illumination. Spore colour is light pink. Spore diameter is approximately 35 µ.

Remarks: Partially enrolled margin could mean the spore is (was) not yet mature.

Occurrence: One specimen, EL87-106.

Example: Slide EL87-106-01, Q49/3.

undet. trilete spore sp. E

plate 10, figure 28

Description: Trilete spore. Amb convex triangular. Laesurae extend to spore margin (in polar view). Laesurae are thin, untapering, straight, and have positive relief. Thin (<1μ) equatorial thickening is present. Surface is verrucate (1μ size projections) with low relief. Colour is light orange. Diameter is approximately 25μ.

Remarks: Distinguished by scabrate ornament, convex triangular amb, and small size. Some similarities with *Stereisporites regius* (Drozhastchich).

Occurrence: Present in samples EL87-106, 107, 109B.

Example: Slide EL87-106-01, S43/4.

undet. trilete spore sp. F

plate 10, figure 29

Description: Trilete spore with short, negative laesurae, and thickened distal surface with verrucate ornament.

Occurrence: Rare in samples EL87-115 and 118.

undet. trilete spore sp. F

plate 10, figure 30

Description: Very thick (4 μ) walled trilete spore covered with long, curved spines (up to 15 μ long and 4 μ wide at base). Dark yellow-brown coloured.

Remarks: Probably a reworked Paleozoic spore.

Occurrence: Rare in sample EL87-115.

Genus *Retitriletes* Pierce, 1961

Type species: *Retitriletes globosus* Pierce, 1961

Retitriletes sp.

plate 10, figures 31-32, plate 11, figure 33

Description: Trilete spore with distinctive reticulate ornamentation on distal surface. Ornament is polygonal. Individual polygons range in size to about 5 μ. Relief is to 2 μ. Proximal surface is marked by three planar contact surfaces with psilate ornament, and a simple trilete scar. Laesurae and contact surfaces extend approximately three quarters of the spore radius. Spore is roughly spherical. Spore is red to yellow coloured. Diameter is approximately 35 μ.

Remarks: *Retitriletes* is related to the modern lycopods (club mosses).

Occurrence: Present in samples EL87-106, 107, 109B, 115, 116, 118, and 120.

Example: Slide EL87-106-01, W35/4.

Genus *Baculatisporites* Pflug and Thomson IN: Thomson and Pflug, 1953

Type species: *Baculatisporites primarius* (Wolff, 1934) Pflug and Thomson IN: Thomson and Pflug, 1953

Baculatisporites sp.

plate 11, figures 33-34

Description: Trilete spore. Spore is oblate, at least 0.5 polar/equatorial ratio. Laesurae extend approximately two thirds to three quarters of spore radius. They are thin, straight, taper slowly, and have positive relief. Spore surface is covered by baculate ornamentation. Sometimes there are density differences between proximal and distal surfaces. Individual bacculae are 1.0-1.5 μ tall and typically have a height/diameter ratio 1-2. Density of bacculae between individual spores varies from about 40% of surface area to nearly 80%. Smaller spores tend to have denser ornamentation. There is a smooth gradation of spore sizes and ornament density. Spore wall about 1 μ thick. Colour is usually red. Spore diameter (equatorial) varies from 25-60 μ.

Remarks: Similar to the modern fern spore *Osmundia*. The size/ornament variations could represent different degrees of spore maturity.

Occurrence: Present in samples EL87-106, 107, 109B, 115, 116, 118, and 120. Common in sample EL87-106.

Examples: Slide EL87-106-01, R36/3 (small form); S41/0 (larger form).

Hamulatisporites amplus Stanley, 1965, p. 242, pl. 29, figs. 1-6

plate 11, figure 35

Description: Large (100 µ) trilite spore with wavey or folded ornamentation (hamulate ornament).

Occurrence: Very rare in samples EL87-115, 118, and 120.

undet. ditrilete spore sp. A

plate 12, figure 36

Description: Ditrilete spore with verrucate ornamentation. Amb convex triangular. A trilete scar is present on both polar surfaces. Trilete scars are not coincident (one is rotated about the polar axis 60° from the other). Laesurae extend almost to the equator of the spore. Surface of grain is verrucate. Projections are about 1 µ in diameter and height. Density is about 30%. Spore colour is red. Spore wall is relatively thick (1.5 µ). Spore diameter averages 25-35 µ.

Occurrence: Present in samples EL87-106, 107, 115.

Examples: Slide EL87-106-01, V50/3; slide EL87-107-01, G11/4.

Genus *Obtusisporites* (Krutzsh, 1959) Pocock, 1970

Type species: *Obtusisporites obtusangulus* (Potonie, 1934)

Obtusisporites sp.

plate 12, figures 37-38

Description: Trilete, immature spore. Amb concave triangular with bulbose radial projections. Trilete scar not fully developed, but its trace is revealed by a deep, trilete furrow in the proximal surface of the spore. The furrow extends to about two thirds of the spore radius. Spore surface has coarse canaliculate to fossulate ornamentation. Usually the ornament has higher relief near the trilete scar, and tends to radiate away from it orthogonally. Ornament often disappears on the distal surface. Spore wall is thick. Colour is invariably dark yellow. Spore diameter approximately 30 μ.

Remarks: *Obtusisporites* is a form-genus for immature spores. The thick spore wall, and fossulate ornament are a result of the 'rolling up' and folding of the interradial spore margins towards the proximal surface. As the spore matures, it 'unrolls'.

Occurrence: Present in samples EL87-106, 107, 109B, 115, 116, 118, and 120.

Examples: Slide EL87-106-01,T41/2.

Genus *Laevigatosporites* (Ibrahim, 1933, emend. Schopf, Wilson, & Bentall, 1944)

Type species: *Laevigatosporites vulgaris* (Ibrahim) Ibrahim, 1933

Laevigatosporites haardti (Potonie and Venitz, 1934, p. 13, pl.1, fig. 13)
Thomson and Pflug, 1953, p. 59, pl. 3, figs. 27-38
plate 12, figures 39-40

Description: Reniform ('Bean-shaped') to plano-convex to elliptical monolete spore. Spore is often compressed into other shapes. The polar axis is perpendicular to the major (longest) axis. The convex polar surface of the spore is distal; proximal surface is concave or planar, and bears a simple monolete scar. Scar is lens-shaped, about eight times as long as wide, and extends approximately one half to three quarters of spore length. Very fine (submicron) echinate ornamentation is present in the vicinity of the scar. It appears as a darkened region near the scar in low magnification. An additional lens-shaped fold or contact surface is often present. The remainder of the spore surface has chagrenate ornamentation. Spore wall is usually thick (1-1.5 μ), but occasional thin-walled specimens were noted . The spores are often folded (compressed). Spore colour is usually dark yellow, but occasionally it is yellow-pink, pink, or orange. Pinker specimens usually have thinner walls. Spores are generally large, and average from 30 to 60 μ in size (longest dimension).

Remarks: Variations within the Audhild Peninsula assemblage of this speicies are completely gradational and seem as large as the variations between species described by some authors.

Occurrence: Common in samples EL87-106, 109B, and 115. Uncommon in samples EL87-107, 116, 118, and 120.

Examples: Slide EL87-107-01, C39/3; Slide EL87-106-01, O47/3.

Genus *Polypodiisporites* Potonie, 1931 IN: Potonie and Gelletich 1933 ex Potonie, 1956

Type species: *Polypodiisporites favus* (Potonie, 1931) ex Potonie, 1956

Polypodiisporites sp.

plate 13, figures 41-42

Description: Reniform to plano-convex monolete spore. Rarely shape is nearly elliptical or circular (usually a result of compression). A lenticular monolete scar with negative relief occurs on the proximal (concave or planar) surface. A thin, raised lip <1 μ wide occurs at the edge of the scar. Scar extends about three quarters of spore length (longest dimension). On different individuals, surface ornament varies from verrucate to low relief reticulate. Ornament structures are typically 2-3 μ scale, relief 0.5 μ or less. The relief is usually much higher on the distal surface. Colour is usually dark yellow or orange. Spore length (longest dimension) varies from 30-45 μ.

Remarks: A complete gradation was observed between forms with reticulate and forms with verrucate ornamentation, so forms were grouped under the same species.

Occurrence: Present in samples EL87-106, 107, 109B, 115, 116, 118, and 120.

Examples: Slide EL87-106-01. P48/1 (reticulate form); T34/3 (reticulate form); K48/4 (verrucate form, equatorial view).

Pollen:

Genus *Abietineapollenites* Potonie ex Delcourt and Sprumont, 1955

Type species: *Abietineapollenites microalatus* (Potonie, 1958) Delcourt and Sprumont, 1955

Abietineaepollenites sp.

plate 13, figures 43-44

Description: Bisaccate pollen grain. Central body circular to elliptical in shape (polar view). Sacci hemispherical, approximately same size as central body, although somewhat variable. Sacci narrow slightly at base, and are distally pendant. Angle between axes of sacci and centre of central body is about 120°. Sulcus is not distinct. Surface of central body has a complex, fine reticulum. Sacci bear similar, but coarser, reticulum. Colour is pink-orange. Exine of central body about 1 µ thick. Sacci exine thicker, perhaps 2 µ thick. Grain length (longest dimension = sacci to sacci) approximately 80 µ. Central body about 40 µ.

Occurrence: Present in samples EL87-106, 107, 109B, 115, 116, 118, and 120.

Examples: Slide EL87-109B-01, T39/2; J17/2.

Genus *Podocarpidites* Cookson ex Couper, 1953

Type species: *Podocarpidites ellipticus* Cookson ex Couper, 1953

Podocarpidites sp.

plate 14, figure 45

Description: Bisaccate pollen grain. Central body roughly circular (polar view). Sacci elongated ellipsoids approximately 1.5 X size of central body. Sacci elongated parallel furrow, and narrow considerably at base. Many details of structure are not preserved. Surface ornament is very finely reticulate. Pollen grain is approximately 50 µ in size (longest dimension).

Occurrence: EL87-109B, 115, 116, 118, and 120

Examples: Slide EL87-109B-01, G8/1.

Genus *Alisporites* Daugherty, 1941

Type species: *Alisporites opii* Daugherty, 1941

Alisporites sp.

plate 14, figure 46

Description: Bisaccate pollen grain. Central body elliptical in shape (polar view). Elongated parallel furrow. Sacci hemispherical, radius slightly larger than central body. Sacci have slightly pointed tips (furthest away from central body). They are flush with central body, giving the entire grain an elliptical outline. The sacci are distally pendant. Angle between axes of sacci approaches 180^{o} (axes are nearly aligned). Surface of central body is very fine reticulum, sacci are slightly coarser. Exine of central body approximately 1 µ thick. Sacci are slightly thicker. Colour is red. Grain length approximately 58 μ.

Remarks: Description based on single specimen.

Occurrence: Present in samples EL87-107, 109B, 115, 116, 118, and 120.

Example: Slide EL87-107-01, T45/1.

Genus *Taxodiaceapollenites* (Potonie) Kremp, 1949

Type species: *Taxodiaceapollenites hiatus* (Potonie, 1931) Kremp, 1949

Taxodiaceaepollenites hiatus (Potonie, 1931, p.5, fig. 27) Kremp, 1949, p. 59, figs. 31, 37, 38

plate 14, figure 47

Description: Inaperturate pollen grain. Spheroidal in shape. Usually split along half of a great circle passing through the centre of the grain. Surface is covered with very fine scabrate ornamentation (submicron scale). Surface is often folded. Colour is red or pink. Diameter between 25 and 35 μ.

Remarks: Related to modern Taxodiaceae, probably *Taxodium*.

Occurrence: Present in samples EL87-106, 107, 109B, 115, 116, 118, and 120

Common in samples EL87-106 and 107.

Example: Slide EL87-106-01, N71/0.

Genus *Sequoiapollenites* Thiergart, 1938

Type species: *Sequoiapollenites polyformosus* Thiergart, 1938

Sequoiapollenites sp.

plate 14, figure 48

Description: Inaperturate pollen grain. Circular in polar view, elliptical in equatorial view (oblate). Several folds are often present. Ligula present, about 5 μ long, 3 μ wide at tip, widens towards base. Tip is blunt and sometimes slightly hooked. Surface has very fine scabrate or psilate ornamentation. Colour red. Exine about 1 μ thick. Diameter about 25 μ.

Remarks: Related to modern Taxodiales, probably *Sequoia* or *Metasequoia*.

Occurrence: Present in samples EL87-106, 107, 109B, 115, 116, 118, and 120.

Examples: Slide EL87-107-01, X14/3.

Genus *Monosulcites* Cookson, 1947 ex Couper, 1953

Type species: *Monosulcites minimus* Cookson, 1947 ex Couper, 1953

Monosulcites sp.

plate 15, figure 49

Description: Monosulcate pollen grain. Elongated elliptical shape (polar view). Sulcus partly open, narrowing towards the centre of the grain. Sulcus extends about nine tenths of length of grain. Surface psilate, with slightly thickened exine near margin of sulcus. Colour light pink. Length (longest dimension) about 20 μ.

Remarks: Possible affinities are cycads or *Ginkgo*.

Occurrence: Single specimen, sample EL87-106, 107, 109B, 115, 116, 118, and 120.

Example: Slide EL87-109B-01, R11/3.

Genus *Cycadopites* Wodehouse, 1933

Type species: *Cycadopites follicularis* Wilson and Webster, 1946

Cycadopites sp. A

plate 15, figure 50

Description: Monosulcate pollen grain. Elliptical to lenticular shape (polar view). Polar axis is shortest dimension of grain. Sulcus open to closed. For open specimens, sulcus is widest at distal pole, narrowing towards extremities. Occasional specimens showing closed sulcus display untapering, straight furrow, or overlapping sulcus margins. Surface psilate to chagrinate. Colour pink or light pink. Exine thin (0.5 μ). Size (longest dimension) about 25-35 μ.

Remarks: May be several undistinguished species present.

Occurrence: Present in samples EL87-106, 107, 109B, 115, 116, 118, and 120.

Example: Slide EL87-107-02, S20/0.

Cycadopites sp. B

plate 15, fig. 51

Description: Elongated monosulcate grain with granulate ornament. Sulcus usually open.

Occurrence: Samples EL87-109B, 115, 116, 118, and 120.

Genus *Liliacidites* Couper, 1953

Type species: *Liliacidites kaitangatensis* Couper, 1953

Liliacidites sp. (?)

plate 15, figures 52-54

Description: Monosulcate pollen grain. Elliptical to lenticular shape (polar view). Sulcus closed, open, or sometimes overlapping. If closed, sulcus is straight. If open, sulcus is narrowest at distal pole, and widens towards extremities. Sulcus extends full length of grain. Surface covered with polygonal reticulum. Muri are half to one quarter the size of lumina. Colour is light pink. Exine tectate, about 1 μ thick. Grain length about 15-30 μ.

Remarks: Often occurs as clusters of as many as 5 individuals (see plate 15, figure 54). Very similar to forms figured by Choi, 1983 from the Eureka Sound Group.

Occurrence: Present in samples EL87-106, 107, 109B, 115, 116, 118, and 120.

Examples: Slide EL87-106-02, T5/0 (closed sulcus); EL87-107-01, K5/1 (group of 5 individuals); Y23/2 (open sulcus).

undet. tricolpate pollen sp. A

plate 16, figure 55

Description: Isopolar, tricolpate pollen grain. In polar view, colpii extend 0.2 of the distance to the poles. Polar outline is circular to convex triangular. Surface of grain is covered with a fine reticulum. Lumina are up to 1 μ diameter. Colour is light pink. Equatorial diameter about 20 μ.

Occurrence: Samples EL87-115, 118, and 120.

Genus *Cranwellia* (Srivastava, 1966) emend. Srivastava, 1969

Type species: *Cranwellia striata* (Couper, 1953) Strivastava, 1966

Cranwellia striata (Couper, 1953, p.51, pl.6, fig. 85) Srivastava, 1966, p. 537-538, pl. 9, figs. 1,4.

plate 16, figures 56, 57

Description: Isopolar, angul-aperturate, tricolpate pollen. Amb triangular, sides straight or slightly convex (?). Equatorial view oblate (elliptical or rounded rhombic). Colpi are triangular and extend within 4 μ of the poles on most specimens. They are approximately 1 to 5 μ wide, depending upon how "opened" they are. Distinctive subparallel striations <1 μ wide with very low relief are present in mesocolpia areas. In equatorial view, they radiate from the equator towards the colpi, bending so they make a right angle with them. Equatorial diameter about 20-30 μ, polar about 15-20 μ (one specimen).

Occurrence: Present in low abundances (rare or very rare) in samples EL87-106, 107, 109B, 115, 118 and 120.

Example: Slide EL87-106-02, O21/3.

Genus *Aquilapollenites* (Rouse, 1957, p.370-371) Funkhouser, 1961 (April), p. 193-194.

Type species: *Aquilapollenites quadrilobus*, Rouse, 1957, Canadian Journal of Botany, v.35, p.370; designate N2, Radforth & Rouse, 1954, Canadian Journal of Botany, v.32, p.195, pl.1, fig. 14 as the holotype.

Tschudy and Leopold (1971) place the following genera in synonomy with

Aquilapollenites:

Triprojectus Mtchedlishvili, IN: Samoilovitch and Mtchedlishvili, 1961 (July), p.204-205

Aquilapollenites (Rouse, 1957) IN: Samoilovitch and Mtchedlishvili, 1961 (July), p. 209

Integricorpus Mtchedlishvili IN: Samoilovitch and Mtchedlishvili, 1961 (July), p. 217

Mancicorpus Mtchedlishvili IN: Samoilovitch and Mtchedlishvili, 1961 (July), p.218-219

Parviprojectus Mtchedlishvili IN: Samoilovitch and Mtchedlishvili, 1961 (July), p.225

Projectoporites Mtchedlishvili IN: Samoilovitch and Mtchedlishvili, 1961 (July), p. 227

Tricerapollis Chlonova, 1961 (August), p.85

Taurocephalus Simpson, 1961 (December), p.440

Aquilapollenites (Rouse, 1957, p.370) Funkhouser, 1961, p.193-194, restr. Srivastava, 1968, p.668-670

Mancicorpus (Mtchedlishvili IN: Samoilovitch and Mtchedlishvili, 1961 (July), p.218-219) Srivastava, 1968, p.695-697

[Note: Genera in square brackets [] indicate the genus that a species was originally described under. Because of limited time, a complete synonomy could not be provided with each species.]

Aquilapollenites [*Mancicorpus*] *senonicus* (Mtchedlishvili IN: Samoilovitch and Mtchedlishvili, 1961 (July), p. 224-225, pl. 72, figs. 2a-3) Tschudy and Leopold, 1961, p. 131-132.

plate 17, figures 58-60

Description: Heteropolar, tricolpate, angulaperturate pollen grains with three equatorial projections. In equatorial view, polar axis averages 30-35 µ in length. Major polar projection is about half the polar axis length (15-20 µ). Its cross section is elliptical (probably compressed), and broadly rounded. Minor polar projection is reduced to a broad cusp-like bump about 2 µ high. On rare specimens, the minor projection is absent, and the minor pole of the grain is flat. Equatorial projections are approximately the same length as the major polar projection (about 15-20 µ), and also have broadly rounded tips. There is considerable variation in the absolute size of the major polar and equatorial projections, but their ratio is always within .15 of 1. Equatorial projections are often tilted towards the minor pole with respect to the polar axis. Angle can range from 0-10°. Equatorial projections and minor projection form a planar base to the grain (minor pole). In polar view, grain is triangular with concave sides. Equatorial projections are paddle-shaped, with planes parallel the polar axis. Colpi extend along edge of equatorial projections, from base of neck of major polar projection to within 2 µ of the minor polar projection (see figure 77). Colpi are thin (0.5 µ), straight, and sometimes bear short scabrae within a 1 µ marginal zone. In some specimens, colpi are open at tips of the equatorial projections (about 1 µ wide). Surface ornamentation is reticulate at the neck of the major polar axis. Lumina are up to 1 µ diameter, muri <0.5 µ. Tip of major polar projection is unornamented. Fine reticulum is present in axial areas, at base of the equatorial projections, and the minor pole. Equatorial projections may possess a very fine reticulum. Spines are absent from the polar and equatorial projections. Exine about about 0.5 µ thick at tips of projections. Sausage-shaped endexinal costae (thickened endexine) 2 µ thick are present at base of equatorial projections. They extend to the base of the polar projections. Polar length ranges from 25-35 µ, equatorial radius from 15-25 µ.

Remarks: Originally described under the genus *Mancicorpus*, *Aquilapollenites senonicus* is very similar to *A.delicatus* Stanley, 1961 var. *delicatus* Tschudy and Leopold, 1971 15 µ in being strongly heteropolar, having equatorial and major polar projections about the same length, and a coarser reticulum at the neck of the major polar projection. *Aquilapollenites delicatus* var. *delicatus* can be distinguished by conical spines on its major polar and equatorial projections. *Aquilapollenites. senonicum* has no prominent spines. This is a subtle distinction, and has caused considerable confusion in the literature. It is impossible to say whether the variation truly represents inter or intra-specific variation. In the Audhild Peninsula samples, most heteropolar Triprojectates fit the description of *Aquilapollenites senonicus.*

Occurrence: Present in samples EL87-106, 107, 109B, 115, 116, 117, and 120. Relatively common in EL87-109B,120.

Examples: Slide EL87-109B-01, V31/4; U47/1; EL87-109B-02, Q9/2.

Aquilapollenites [*Mancicorpus*] *trapeziforme* (Mtchedlishvili IN: Samoilovitch
and Mtchedlishvili, 1961 (July), p. 221-222, pl. 71, figs. 3a-d) comb. nov.
plate 17, figures 61-62

Differential description: Similar to *Aquilapollenites senonicus*, in being a heteropolar pollen grain with three equatorial projections, and possessing reticulate ornament on the major polar projection. Distinguished by the lack of a minor polar projection, and an angle between the polar axis and the equatorial projections greater than 20°.

Occurrence: Very rare to rare in samples EL87-109B, 115, 116, 118, and 120.

Aquilapollenites [*Mancicorpus*] *notabile* (Mtchedlishvili IN: Samoilovitch and
Mtchedlishvili, 1961 (July), p. 220-221, pl. 71, figs. 1a-c, 2a-b) comb. nov.
plate 18, figures 63-64

Differential description: Heteropolar triprojectate with very small (1μ) spines covering surface. Distinguished from *Aquilapollenites senonicus*and *Aquilapollenites trapeziforme* by the lack of reticulate ornament at the base of the major polar projection. Very similar to *Aquilapollenites calvus* Tschudy and Leopold, 1971, p.138-140. According to Tschudy and Leopold, 1971, p.140, *Aquilapollenites calvus* is distinct from *Aquilapollenites notabile* in possessing large verrucae and/or baculae on the exine surface. Judging by the figure of the holotype of *Aquilapollenites notabile* (plate 71, figs. 1a-c, in Mtchedlishvili, 1961), the distinction is very slight, and may not be justified.

Occurrence: Very rare in samples EL87-118, 120.

Aquilapollenites sp. A.

plate 18, figures 65-66

Description: Iso to subisopolar angulaperturate pollen grains with three equatorial projections. In equatorial view, grain is an oblate, rounded rhomboid shape. Polar axis is shorter than equatorial diameter (ratio usually 0.70-0.80). Polar projections are rounded or stub-like; typically 4-6 μ high, and 10 μ wide at the base. Usually there is a 10-25% difference in size between the two polar projections. Polar projections usually densely covered with coarse, conical spinae (0.5-1.5 μ high) directed towards the poles. Equatorial projections are broad, rounded lobes, and much larger than the polar projections. They are approximately 1.5X as long as wide (typically 15 μ long). A 5 μ wide zone of 0.5μ conical spinae extends along the equator of the grain. Spinae are normal to the surface. In polar view, grain is straight to concave triangular with rounded, truncated corners. Colpi extend along edge of equatorial projections to the base of the polar projections. They are thin (0.5 μ), simple, and often have 0.5 μ high bacci within a 1 μ marginal zone. The bacci are obvious in equatorial view as short projections along the margins of the equatorial projections. Besides spinae and bacci, the surface of the grain bears an extremely fine reticulum (<0.5 μ lumina) which is only observable in phase contrast illumination. Sausage-shaped endexinous thickenings 2 μ thick are located in the basal half of equatorial projections. Colour is usually light pink, pink, or red. Polar axis typically 20-35 μ. Equatorial diameter 20-40 μ.

Remarks: Similar to *"Triprojectus" unicus* (Chlonova, 1957) as figured by Felix

& Burbidge from the Maastrichtian part of the Eureka Sound Group, although their assignment to *"T." unicus* is questionable. Also similar to *Aquilapollenites. turbidens* Tschudy & Leopold, 1971 in possessing relatively large equatorial projections and numerous spinae, but Audhild Peninsula specimens have more spinae on polar projections, and longer, thinner endexinous thickenings.

Occurrence: Samples EL87-106, 107, 109B.

Example: Slide EL87-109B-01, T44/0.

Aquilapollenites bertillonites Funkhouser, 1961 (April), p. 196, pl. 2, figs. 5a-c.

plate 18, figures 67-68

[*Aquilapollenites murus* Stanley, 1961b (November), p.347, pl. 5, figs. 1-8, pl. 6, figs. 1-9 is a junior synonym for *Aquilapollenites bertillonites* Funkhouser, 1961, according to Tschudy and Leopold, 1971, p. 160]

Description: Subisopolar to isopolar, triprojectate (tricolpate) pollen grain. In polar view, outline is triangular, concave triangular, or slightly convex triangular. In equatorial view, grain is isopolar to slightly heteropolar. Equatorial projections are conical, with pointed tips, and merge gradually with the central body. Polar projections are broad, rounded humps. Usually the polar length is slightly less than the equatorial diameter. Colpi extend from the tips of the equatorial projections to half the equatorial radius. Usually the colpii are open within 8-10 μ of the tips with a slight, 2-3 μ wide gap. In some compressed specimens, the colpii have been torn open, giving an almost syncolpate appearance. Exine is thin (<0.5 μ) (lighter coloured) within about 10 μ of the tips of the equatorial projections. Exine is more typically 2-3 μ thick. The most distinctive feature of the grains is the bertillonate (hairy) ornamentation. It is composed of very fine (0.5 μ) striations most evident in phase contrast illumination. Some of the raised striations appear to be detatached from the grain at one end, giving the 'hairy' appearance. The bertillonate ornament appears to be oriented away from the equatorial plane of the grain. Polar length typically 30-40μ, equatorial diameter typically 40-45μ.

Discussion: *Aquilapollenites fusiformis* Tschudy, 1969, p.A8-A9, pl. 8, figs. 1-12 is similar to *Aquilapollenites bertillonites* in possessing a finely striated (bertillonate) ornament. However, *Aquilapollenites fusiformis* possesses striate to reticulate surface sculpture, and larger polar projections (relative to the equatorial projections).

Occurrence: Very rare in sample EL87-118, common in sample EL87-120.

Aquilapollenites dentatus Tschudy, 1969, p. A9, pl. 9, figs. 1-12, pl. 10, fig. 1 (?)

plate 19, figure 69

Description: Isopolar, spinose triprojectate with large endexinous thickenings at the base of the equatorial projections.

Discussion: Another possible identification is *Aquilapollenites attenuatus* Funkhouser, 1961, p.194, 196, pl. ; but the endexinous thickenings of *Aquilapollenites attenuatus* are not as pronounced, while on this species they are quite thick (4 μ +).

Occurrence: Very rare to rare in samples EL87-115, 118, and 120.

Aquilapollenites [*Triporina*] *unicus* (Chlonova, 1957, p.44, pl. 1, figs. 1-3 pro parte: Mtchedlishvili IN: Samoilovitch and Mtchedlishvili, 1961 (July), p.206-207, pl. 66, figs. 1a-c [*Triprojectus*]) Stanley, 1970, p. 28

plate 19, figures 70-71

Description: Isopolar to subisopolar, tricolpate pollen grain with 3 equatorial projections. In polar view, grain is concave triangular. Equatorial projections are paddle-shaped (flattened parallel the polar axis) and are up to two thirds of the equatorial diameter of the grain. Colpi occur on the tips of the equatorial projections and extend one third of their length. In equatorial view, the pollen grain is isopolar to slightly heteropolar. The polar and equatorial projections are about the same length, but the equatorial projections are about one half the width of the polar projections. The equatorial projetions are typically 20-25 μ in length and about 10-15 μ in width. The polar projections are 20-25 μ in length and 20-25 μ wide. Elongate, tapered endexinous thickenings about 2-4 μ thick occur at the base of the equatorial projections. They extend from the base of the polar projections to within about 6 μ of the tips of the equatorial projections. The tips of the equatorial projections are rounded to slightly rectangular. The polar projections are usually rounded. The tips of the equatorial projections are ornamented with 6 to 8 1-1.5μ recurved spinae, and short (0.5μ), stubby spinae at the edges of the colpi. The surface of the central body and polar projections also bears 20-30 short (1μ) spinae. They are more common at the tips of the polar projections. The entire pollen grain surface has a very fine surface reticulum (lumina <0.5μ). It is most obvious on the central body and the polar projections. It is almost absent on the equatorial projections. The reticulum is barely visible under normal illumination at 1000x, but it is easily visible under phase contrast illumination. Exine is typically 1-1.5μ thick. Polar length typically 50-65μ, equatorial diameter typically 55-65μ.

Example: Slide EL87-115-01, R45/4.

Occurrence: Common in EL87-115, uncommon in EL87-116, 118, and 120.

Aquilapollenites [*Integricorpus*] sp. 1 of Samoilovitch, 1967, p.131, pl.3, fig. 16

plate 20, figure 72

Description: Isopolar tricolpate pollen grain with enlarged polar projections and very coarse surface reticulum. In polar view, outline is triangular. The grain is angulaperturate. In equatorial view, polar projections are very large, while the equatorial projections are very small. The equatorial projections are short (5-8μ long, 10μ wide at their base), pyramidal in shape, and bear deeply incised colpi from their tips to their base. They are composed of greatly thickened exine (about 4μ thick). The equatorial projections bear a very finely striate ornament. The base of the three equatorial projections forms a striate-ornamented equatorial zone about 10μ wide that contasts sharply with the ornament of the polar projections. The polar projections are large (20-25μ long, 30-35μ wide), rounded, and possess a coarse, polygonal reticulum. Lumina are typically 1-4μ wide (on a single grain). The dissepiments of the reticulum are polygonal, about 1μ wide, and taper upwards in cross section. Exine in the polar areas is about 2-3μ thick, and double-layered. The upper layer is the reticulum. The lower layer is solid, and about 1-1.5μ thick. On rare, generally smaller (immature?) specimens, the ends of the equatorial projections bear a thin-walled (<0.5μ), conical projection longer than the remainder of the equatorial projection. It is possible that this "extra" projection is broken off in mature specimens. Polar length is typically 55-70μ. Equatorial diameter is typically 35-40μ. Some flattened specimens have smaller equatorial diameters.

Discussion: This species has not been formally described, although it is a common and distinctive part of assemblages from the Arctic (e.g., Samoilovitch, 1967, Doerenkamp et al., 1976).

Example: Slide EL87-120-01, P45/1 (equatorial view).

Occurrrence: Very rare in sample EL87-115; common in samples EL87-118 and 120.

Aquilapollenites colvillensis Tschudy, 1969, p.A9-A10, pl.11, figs. 1-18.

plate 20, figure 73

Description: Small (25-40 μ) isopolar triprojectate pollen grain. Equatorial projections are rectangular in outline, and bear 15 or more large (2-3 μ) recurved spinae at the tips. Smaller (0.5 μ) conical spinae cover the polar projections and body of the grain.

Occurrence: Common in sample EL87-115; rare in samples EL87-116, 118, and 120.

Genus *Tricolporopollenites* Pflug and Thomson, 1953

Type species: *Tricolporopollenites dolium* (Potonie) Thomson and Pflug, 1953

undet. tricolporate pollen sp. A

plate 20, figures 74-75

Description: Isopolar, tricolporate pollen grains. In polar view, amb is concave triangular. Corners of the triangular outline are rounded. In equatorial view, the outline is oblate and rounded rectangular in shape. The general 3-dimensional shape of the grain is analogous to a triangular-shaped pill box. The colpii occur at the corners of the triangular outline and extend along longitudinal edges of the grain. At the ends of the three colpii the ektexine thins to form pore-like ova (six in total). Ektexine is finely granular (submicron relief). Exine is about 1.5 µ thick. Equatorial diameter is typically 45-50 µ and polar length is about 25 µ. Colpii are about 25 µ long and are usually <0.5 µ wide. Ova are typically 1-2 µ in diameter.

Occurrence: Uncommon in sample EL87-120.

Examples: Strew slide EL87-120-01; S50/1 - equatorial view, K50/4 - polar view; Single-grain mount EL87-120-SG03 - subpolar view; Single-grain mount EL87-120-SG10 - polar view.

Genus *Tricolporopollenites* Pflug and Thomson, 1953

Type species: *Tricolporopollenites dolium* (Potonie) Thomson and Pflug, 1953

Tricolporopollenites sp.

plate 21, figures 76-77

Description: Isopolar, tricolporate pollen grains. In polar view circular, colpi slightly indented (?). In equatorial view, slightly prolate, elliptical in outline. Colpi extend almost from pole to pole (about four fifths). Colpi about 1.0 μ maximum width, with a 0.5 μ wide, 0.5 μ high marginal flange present in the polar areas. Flange is formed of thickened ektexine, and is absent in a broad equatorial zone about 6 μ width. Flange is replaced by a low, indistinct, marginal scabrae zone about 0.5 μ wide. Surface of remainder of grain is psilate. Exine is about 0.5-1.5 μ thick. Polar length about 14 μ. Equatorial diameter about 12 μ (one specimen).

Remarks: Description based on one specimen in equatorial view.

Occurrence: Very rare EL87-109B and 118.

Example: Slide EL87-109B-01, S11/2.

Genus *Triporopollenites* Pflug and Thomson in Thomson and Pflug, 1953

Type species: *Triporopollenites coryloides* Pflug in Thomson and Pflug, 1953

Triporopollenites sp. A

pl. 21, figure 78

Description: Triporate pollen grain. In polar view, convex triangular outline, angulaperturate. Oblate in equatorial view (?). Pores are simple openings. Exine thickens slightly and curves slightly outward within 2-4 μ of pores. Pollen grain surface psilate. Exine two layered, atectate, about 1.5 μ thick. Colour is red. Diameter about 25-30μ.

Occurrence: Very rare EL87-106, 109B, and 115; uncommon in 116, 118, and 120.

Example: Slide EL87-107-02, M22/0.

Triporopollenites sp. B

plate 21, figures 79-80

Description: Triporate pollen grain. In polar view, convex triangular outline, angulaperturate. Oblate in equatorial view (?). Pores are surrounded by circular, rounded ektexinous thickenings about 2 μ wide and 2 μ high. Pores are covered by a thin membrane. Surface of grain is psilate and folded. Exine is about 0.5 μ thick away from pores. Colour is light pink. Diameter about 25-30μ .

Occurrence: Very rare , samples EL87-106, 107, 109B, 115, and 116; uncommon in samples EL87-118, and 120.

Example: Slide EL87-106-02, Q22/1.

Genus *Paraalnipollenites* Hills and Wallace, 1969

Type species *Paraalnipollenites confusus* (Zaklinskaia, 1963) Hills and Wallace, 1969

Paraalnipollenites sp.

plate 22, figure 81

Description: Triporate pollen grain, hexagonal in outline with pores on every alternate corner. Exine thickenings occur in vicinity of pores, within 4 μ of grain margin, and in a three-fold structure in the centre of the grain.

Occurrence: One specimen in EL87-106 (figured); rare in sample EL87-118 and uncommon in sample EL87-120.

Genus *Wodehouseia* Stanley, 1961a

Type species: *Wodehouseia spinata* Stanley, 1961a, p. 157, pl. 1, figs. 1-12.

Wodehouseia edmontonicola Wiggins, 1976

plate 22, figures 82-84

Synonomy:

1969: Wodehouseia gracile (Samoilovitch, IN: Samoilovitch and Mtchedlishvili, 1961) Pokrovaskaya, 1966: Srivastava, 1969, p. 1309, pl.1, fig. 6-7.

1969: Wodehouseia jacutense (Samoilovitch, IN: Samoilovitch and Mtchedlishvili, 1961) Samoilovitch, 1967: Srivastava, 1969, p. 1309, pl.1, figs.4,9

1976: Wodehouseia edmontonicola Wiggins, p.65, pl.3, figs. 7-8

[Holotype: Wiggins, 1976 designates Wodehouseia gracile in Srivastava, 1969, p.1309, pl.1, fig 6.]

Description: Binigemmate (Wiggins, 1976), flange-bearing angiosperm pollen. Central body ellipsoidal in shape, with three unequal axes. Longest axis is herein considered the polar axis. In minor equatorial view (looking along shortest equatorial axis), grain is prolate. Central body length/width 1.7-2.6, averaging about 2.5. A thin, bilayer flange extends longitudinally from pole to pole in the plane of the polar and major equatorial axes. The flange usually narrows and disappears within 5 μ of the poles. The flange is a lighter colour than the central body (thinner, composed only of ektexine) and has a wavy appearence caused by internal ektexinous thickenings (spine-like). Margin of flange is sometimes rough, but does not bear spinae. Apertures are two pairs of latitudinally elongated pores, usually about 5-6 μ long, and 1.5-2 μ wide. The pairs occur approximately one third of the distance from either pole. They have negative relief, and are covered by a thin membrane. In major equatorial view (looking at flange edgewise), grain is highly prolate; length/width 2.5-3.5. Surface of central body is psilate, and covered with a few randomly distributed, very short (<0.5 μ), stubby spines. Exine within about 10 μ of the poles is devoid of spines, and is thinner (lighter coloured). Exine of central body is thin, about 0.5 μ or less. Colour is dark pink, pink-orange, or red. Typical polar length is 25-40 μ. Rarely occurs in clusters of 2 or 3 individuals with longest axis (polar axis) directed radially from centre of the cluster.

Remarks: See discussion in Methods, section 3.2.4 on the characteristics of used to distinguish this species from *Wodehouseia gracile.* The occurrence of clusters of grains with the longest axis appearing directed towards the centre of the cluster (plate 22, figure 84) suggests the longest axis is the polar axis.

Occurrence: Present in samples EL87-106, 107, 109B and 115. Very common in sample EL87-106.

Examples: Slide EL87-106-01, S44/1; EL87-106-02, T13/0 (elongated form); S46/0 (cluster of 3 individuals).

Wodehouseia gracile (Samoilovitch, IN: Samoilovitch and Mtchedlishvili, 1961) Pokrovaskaya, 1966

plate 22, figures 85-86; plate 23, figures 87-89

Synonomy:

1961: Kryshtofoviana gracile Samoilovitch IN: Samoilovitch and Mtchedlishvili, 1961, p. 237, pl. 76, fig. 1a-c.

1966: Wodehouseia gracilis (Samoilovitch IN: Samoilovitch and Mtchedlishvili, 1961) Pokrovaskaya, 1966, p.308, pl.97, fig. 7, 7a.

1967: Wodehouseia gracile (Samoilovitch IN: Samoilovitch and Mtchedlishvili, 1961) Samoilovitch, 1967, p.132, pl.2, fig.6 [appears to be a re-illustration of the holotype figured in Samoilovitch IN: Samoilovitch and Mtchedlishvili, 1961, pl. 76, fig. 1a; but not indicated as such]

1976: Wodehouseia gracile (Samoilovitch IN: Samoilovitch and Mtchedlishvili, 1961) Pokrovaskaya, 1966: Wiggins, 1976, p. 65, pl. 3, figs. 3-4.

Description: Binigeminate (Wiggins, 1976), flange-bearing angiosperm pollen. Central body ellipsoidal in shape, with three unequal axes. The longest axis is herein considered the polar axis. In minor equatorial view (looking down the shortest equatorial axis), grain is prolate. Central body (the portion of the grain without the flange) length/width ratio is 1.2-3.0, averaging about 2.3. In major equatorial view, (looking at flange edgewise), grain is highly prolate, length/width ratio is 2.5-3.5. A thin, bilayer flange extends longitudinally from pole to pole in the plane of the polar and major equatorial axes. The flange narrows as it approaches the poles, and often disappears within 5 um of the pole. The flange is usually between 3 and 6 μ wide at its widest point. In rare specimens, the flange narrows considerably, but does not disappear entirely at the poles. The flange is typically a lighter colour than the central body (thinner, composed only of ektexine). In some specimens, the flange is somewhat indistinct from the central body. The flange has a wavy to ridged appearance caused by internal spine-like ektexinous thickenings up to 1 μ wide. In this species, the spines tend to be very pronounced, but do not usually penetrate beyond the margin of the flange. The flange spines of some specimens (many specimens in sample EL87-120) curve away from the equatorial plane (see plate 23 , figs. 87-89). Apertures are two pairs of latitudinally elongated pores, usually 2-4 μ long and 1-1.5 μ wide. Pore length/width ratio is typically low, usually about 1.5 Some specimens have ratios as high as 2.5 or as low as 1. The pores typically occur at greater than one third the polar length from each pole (i.e. the length between the pores is less than the length from the pores to the poles). The surface of the central body is psilate to granulate to finely reticulate. If reticulate, lumina are < 0.5 μ in diameter. The entire central body has usually in excess of 30 randomly distributed stubby to conical spines 1-1.5 μ in diameter and up to 2 μ in length. The spines are more typically 1μ in length. Exine of the central body is typically 0.5 μ thick or less. There is no apparent change in thickness towards the poles. Typical polar length is 25-35 μ.

Discussion: Specimens were placed in this species if they displayed 3 or more of the characteristics of Wodehoueia gracile (see Methods section 3.2.5). Some of the specimens in sample EL87-120 (e.g., plate 23 , figs. 87-89) look similar to Wodehouseia avita Wiggins, 1976, p. 67, pl. 4, figs. 1-6, but the mid portion of the central body is not constricted like the specimens figured by Wiggins, 1976, and the flange on the Audhild Peninsula samples extends around the poles.

Within the samples, a complete continuum of morphologic characteristics were observed between the end members *Wodehouseia edmontonicola* and *Wodehouseia gracile*. Subjective judgement is involved in most of the characteristics. A definate assignment to a species is sometimes very difficult. Examples: Strew slide EL87-115-01, P32/3 - minor equatorial view of specimen with rounded pores and large spines; strew slide EL87-120-01, L19/4 - minor equatorial view of specimen with very small, rounded pores and an equatorial flange with curved spines

Wodehouseia cf. *Wodehouseia stanleyi* Srivastava, 1966

plate 24, figures 90-91

Synonomy:

1966: Wodehouseia stanleyi Srivastava, p. 548-549, pl. 11, figs. 12, 15.

1976: Wodehouseia stanleyi Srivastava, p. 548-549, pl. 11, figs. 12, 15: Wiggins, 1976 p.64-65, pl. 3, figs. 1-2.

Description: According to the description of Srivastava, 1966, *Wodehouseia stanleyi* Srivastava is distinguished from *Wodehouseia gracile*(Samoilovitch) by having a flange that appears to merge with the central body. The flange also has thicker internal spines. Some of the specimens observed in the Audhild Peninsula sequences appear to fit this description.
Occurrence: Very rare, sample EL87-118; rare, sample EL87-120.

Genus *Erdtmanipollis* Krutzsch, 1962

Type species *Erdtmanipollis pachysandroides* Krutzsch, 1962, p.281, pl. 8, figs. 1-4, txt. fig. 11.

Erdtmanipollis procumbentiformis (Samoilovitch IN: Samoilovitch and Mtchedlishivli, 1961, p. 199, pl. 64, fig. 1a-d) Krutzsch, 1966, p. 29

plate 24, figures 92-93

Description: Periporate pollen grain. Circular to ellipsoidal in outline. Pores are 1-2 μ diameter, some with a thin marginal flange 0.5 μ wide. Pores pass through endexine 1.5-2 μ thick. Pores are surrounded by raised wedge-shaped ektexinal elements 0.5-2.0 μ in size, and 2 μ height. In some specimens wedges are large equilateral triangles, and fit in a closely interlocking pattern around pores. Other specimens have smaller, flattened triangular elements forming a radiating pattern around the pores. Ektexinal elements are often partly "peeled off" grains. Colour yellow-orange. Diameter typically 30-40 μ.

Occurrence: Present in samples EL87-106, 107, 109B, 115, 116, 118, and 120.

Examples: Slide EL87-106-01, S50/0 (large equilateral triangle ornament form); slide EL87-107-01, M38/4.

Plant remains:

Miscellaneous plant remains

plate 24 figure 94

Fragments of leaf cuticle and wood are abundant in all samples, and show considerable variety. Several varieties of tracheid structures were observed, including circular bordered pits and scaliform pits. Fragments over 100 μ in size are common.

Occurrence: Present in all samples.

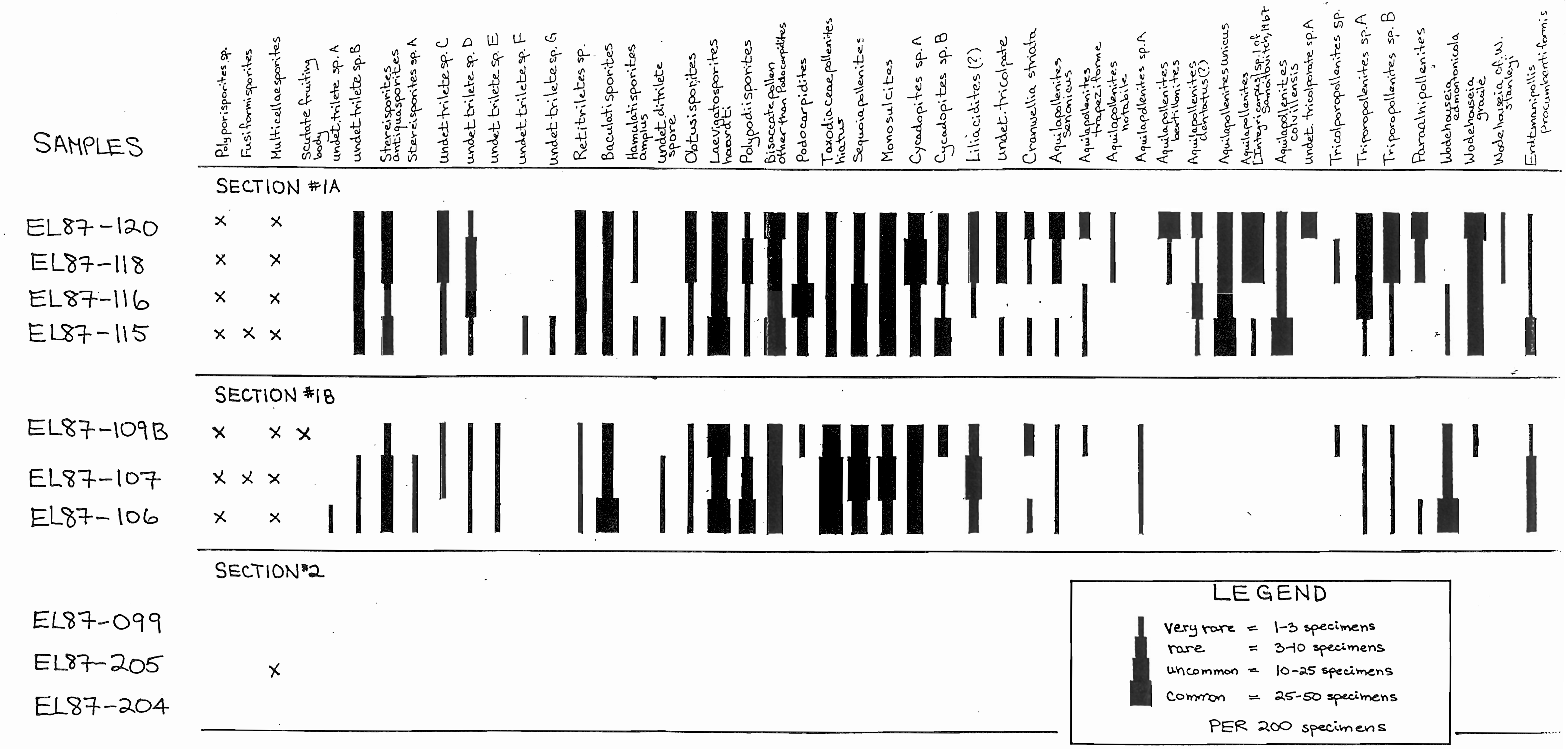
Examples: Slide EL87-109B-01, S44/4 (circular bordered pits); EL87-106-01, S33/2 (cuticle fragment).

C Relative Abundances and Ranges of Palynomorphs:

Counts of approximately 200 miospores were made for each productive sample by scanning the strew slides systematically. There is strong reason to believe the relative proportions of palynomorph species has been biased by the processing and slide-making procedure. Slides from the same sample often show different relative abundances. Even if the slides were prepared in a fashion to reduce the bias, the relative abundance data would be of limited use because at least three independent variables control the abundances: 1) the abundance of the plants in the area of deposition and basin-wide; 2) the amount of pollen produced by the plants and how it is dispersed; and 3) the proximity of the plants to the site of deposition. Other events may bias the sample after deposition. Interpretation of palynomorph abundance data must be done very cautiously.

Although counts of only 200 individuals are not statistically significant for samples with high diversity, the counts give a qualitative idea of the relative proportions of the palynomorph species.

The occurrence and relative abundance of the described taxa are illustrated in text figure 21.



Text Figure 21: RELATIVE ABUNDANCES OF PALYNOMORPHS
Relative abundances of palynomorph taxa are indicated by the width of the bars (see legend). The vertical position of the samples in the diagram is the same at their stratigraphic order in each section. The stratigraphic position of the samples is indicated in text figure 20. Samples EL87-099 and EL87-204 were barren, but are included for completeness.

The only identifiable palynomorphs in sample EL87-205 (Emma Camp #2) are *Multicellaesporites*, a multicellate fungal spore.

Fungal spores are found in all the remaining productive samples.

Of the non-angiospermous miospores, *Laevigatosporites haardti*, *Stereisporites*, *Baculatisporites*, *Retriletes*, bisaccate pollen, *Taxodiaceaepollenites*, *Sequoieapollenites*, *Monosulcites*, and *Cycadopites* sp. A are consistent components of the palynoflora of the productive samples (except EL87-205).

Of the angiospermous pollen, *Aquilapollenites senonicus*, *Triporopollenites sp. A* and *sp. B*, and *Erdtmanipollis* are found in all the productive samples (except EL87-205). *Cranwellia striata* is found in most of the productive samples (except sample EL87-205 - section 2A, 107 - section 1B, and 116 - section 1A)

Of the more abundant triprojectate taxa, *Aquilapollenites* [*Triprojectus*] *unicus* is common in sample EL87-115 from section 1A (Emma Camp #1), and uncommon in the remainder of the samples from section 1A. *Aquilapollenites* [*Integricorpus*] *sp. 1* of Samoilovitch, 1967 is common in samples EL87-118 and 120 from section 1A, and very rare in sample EL87-115. *Aquilapollenites colvillensis* is common in sample EL87-115, but rare in the remainder of the samples from section 1A. *Aquilapollenites bertillonites* is common in sample EL87-120, and very rare in sample EL87-118 from section 1A. See text figure 21 for the distribution of the remainder of the triprojectate taxa. In general, the diversity of the triprojectates increases significantly between section 1B (two species) and 1A (9 species) (both at Emma Camp #1).

Wodehouseia is found in all the productive samples (except EL87-205). The total number of *Wodehouseia* (all species) varies considerably from sample to sample.

In the samples from Section 1B (Emma Camp #1), *Wodehouseia edmontonicola* is the dominant species of *Wodehouseia.* It is very common in sample EL87-106 at the base of the section. It is rare in samples EL87-107 and 109B. The first appearance of *Wodehouseia gracile* is in sample EL87-109B as just a few specimens. In the samples from section 1A, *Wodehouseia gracile* is the dominant species of *Wodehouseia. Wodehouseia edmontonicola* is seen only in sample EL87-115 and 116 at the base of the section. *Wodehouseia gracile* is uncommon in samples EL87-115, 116, and 117, and common in sample EL87-120.

In any one sample, specimens of *Wodehouseia* can be found which are morphologically between the end-member *Wodehouseia edmontonicola* and *Wodehouseia gracile* morphologies. There appears to be a consistent trend up-section; from a population with characteristics of *Wodehouseia edmontonicola* to a population with more characteristics of *Wodehouseia gracile*. Subtle changes in the characteristics of *Wodehouseia gracile* were noted in the samples from section 1A. Since *Wodehouseia* is abundant in these samples, these samples could be a good subject for quantitative analysis of the changes in morphology.

See figure 21 for the ranges of remainder of the palynomorph taxa. In general, the diversity of taxa increases up both sections, and between section 1B and 1A.

The probable reworked taxon undet. trilete spore sp. F occurs only in sample EL87-115 (Section 1A). Other undescribed, reworked Paleozoic spores also occur rarely in sample EL87-115, and can be distinguished by their dark yellow-brown colour, and very different morphologies (generally very thick-walled). Very rare (1 or 2 on each slide) reworked spores occur in the other samples as well. These forms may be derived from the erosion of the underlying Nansen Formation (Carboniferous).

Taxodiaceous pollen-producing plants (Taxodiales), monolete spore-producing plants (ferns), monosulcate pollen-producing plants (e.g., cycads, *Ginkgo*, some angiosperms, etc.), *Wodehouseia*producing, and triprojectate-producing plants were probably a major components of the plant life somewhere in the basin. It is important to emphasize that these plant forms could occur anywhere within the basin (or other nearby areas), and may not be associated with the depositional environment indicated by the enclosing sediments or each other. The occurrence of Taxodiod foliage and wood, *Ginkgo*, and angiosperm leaves in the macrofossil assemblages suggests that at least some of the miospores are locally derived.

4.2.3 Radiometric Dates:

Whole-rock $^{40}Ar/^{39}Ar$ dating has been carried out by G.K. Muecke and P. Reynolds, Dalhousie University, for six samples. Measurements have been standardized to the international standard MMHb-1. The location of the samples in the measured sections is indicated in text figure 20. The results of the dating procedure are listed in table 1.

The age spectra have good to excellent plateaus. Detailed analysis of the spectra is beyond the scope of this thesis, so the dates have been calculated using a simplified method. The dates were calculated using all temperature steps above or equal to the 550-600°C step, in order to remove the early, usually anomalous steps. The values for each temperature step were weighted by the proportion of gas released. The dates obtained by this method are approximately the same as the plateau age. The dates fall in the range of 77 to 82 million years. They agree reasonably considering their different stratigraphic positions, suggesting they are probably accurate. Estimated analytical errors are indicated in table 1. These range from a low of ± 1 million years to ± 3 million years. Analytical errors in the dates are approximately proportional to the amount of radiogenic gas released, which is generally proportional to the amount of potassium (K) in the rock. The lowest analytical errors are associated with samples EL86-107 and EL86-015, both of which are silicic acid volcanic units (high K). The remainder of the samples are basaltic composition (lower K), which probably accounts for the higher analytical errors. Excess argon or argon loss from the samples is very unlikely, because the samples have a wide range of potassium contents and agree well. Petrologically, the samples are very well preserved. For example, sample EL87-101 has unaltered olivine and clinopyroxene phenocrysts.

Realistic uncertainties in the dates are hard to judge, but it is very unlikely that any of the samples can be younger than 75 million years, or older than 85 million years.

On a local scale, the samples from the sections at Emma Camp #1 yield dates between 79 and 82 million years. Within expected uncertainties, it is unlikely that any of the samples can be younger than 76 million years, or older than 85 million years. The best-guess combined age for the samples is 80 ± 2 milion years.

Dates of samples from Emma Camp #2 range from 77 to 79 million years. Within expected uncertainties, it is unlikely that any of the samples can be younger than 75 million years, or older than 81 million years. The best-guess combined age for the sections at Emma Camp #2 is 78 ± 1 million years

Table 1: Whole-rock 40Ar/39Ar dates from Audhild Penninsula

Sample	Composition	Date*	Estimated Analytical Error**
Emma Camp #2, Section 2A:			
EL86-015	acid volcanic	77	±1
EL86-107	acid volcanic	79	±1
EL86-028	basalt	78	±3
Emma Camp #1, Section 1A:			
EL87-123	basalt	82	±3
EL87-112	basalt	79	±3
Emma Camp #1, Section 1B:			
EL87-101	basalt	81	±3

*Dates calculated using 550-600°C and above temperature steps, weighted for proportion of gas released. Values have been rounded to the closest integer date.

**Analytical errors have been rounded UP to the closest integer value.

5. INTERPRETATIONS & DISCUSSION:

5.1 Depositional Environment of the Sediments:

Because of the generally poor outcrop of the sedimentary units, only limited conclusions can be drawn about the depositional envrionment. No post-Nansen Formation marine facies were noted in any of the sections. Terrestrial sedimentation appears to have been dominant.

The graded cycles of siliclastics and coal in the southern (Emma #1) sections are suggestive of typical fluvio-deltaic sedimentation. The cycles are produced by meandering river channels on a floodplain or delta. The high proportion of bituminous shale and lignite in the sections suggests that a backswamp environment is the most likely environment of deposition for most of the sections. River channels were probably small, and meandered slowly, as suggested by the thin and laterally discontinuous channel facies.

Interpretation of the northern sections (Emma #2) is limited by the poorer outcrop, but the domination of coarser siliclastics (including thick conglomerates) over lignite suggests a higher energy, fluvial style of deposition; perhaps alluvial fan.Some plants must have existed in this area (or higher levels within the basin) because of the occurrence of leaves and wood.

Coarser facies in the north (Emma #2) suggests that area may have been closer to the source area of the sediments; although the very limited outcrop and likelyhood of sudden facies changes in a volcanic terrain make it impossible to say with certainty.

It is clear from the presence of volcanic-derived fragments (polycrystalline quartz & euhedral feldspar) in most of the sediments (even the lignites) that sedimentary deposition was associated in time and space with the vulcanism in the area.

Matrix-supported volcanic conglomerates, which are probably gravity flows (lahars ?), suggest proximity to the volcanic source. The increase in the proportion of volcanic units from Emma #1 to Emma #2 suggests Emma #2 was closer to the source for the volcanics. The thinning of basaltic units in the Emma #2 sections from south to north may be a result of localized topography.

5.2 Correlation of Sections:

Correlation of the Emma #1 and #2 sections is based on the occurrence of the distinctive green ignimbrite unit and acidic volcanics at the top of the Emma #1 and Emma #2 sections (see text figure 20). This is done with reasonable confidence because in all the sections, only one horizon of ignimbrite was observed, and it occurs at approximately the same stratigraphic horizon (towards the top). It was observed to have good lateral continuity in the Emma #2 sections (within outcrop area).

There is a drastic change in the thickness, facies, and proportion of sediments from the Emma #2 to Emma #1 sections. This makes direct correlation difficult. It is impossible to say how the sediments of Emma #1 relate to the sediments of Emma #2, except that they are possibly synchronous over at least part of their thickness.

The increase in proportion and thickness of sedimentary units from Emma #2 to Emma #1 has two possible explanations. 1.) Some volcanic units may pinch out completely from the Emma #2 to Emma #1 sections. 2.) Alternatively, the volcanic units could continue to the Emma #1 area, but are cut off the base of section 1A by the major N-S fault (see text figure 20).

5.3 Palynology:

5.3.1 Paleofloras and climatic implications:

Interpretation of the climate at the time of deposition of the Audhild Peninsula sequences is limited by the fact that many of the miospores in the assemblages have no modern analogues. Interpretation of forms with modern analogues should be done very cautiously, as there is no guarantee that a particular miospore or associated plant lives in the same environment now as in the past.

The rich palynofloral assemblage (in terms of species and numbers) suggests that plant life during the deposition of the Audhild sequences was fairly diverse. Some components of the flora included forms now associated with warmer, temperate climates. The occurrence of thick lignite sections at Emma Camp #1 suggests that the total growth was fairly substantial.

The plant megafossils and pollen suggest that Taxodiales and other conifers were a significant component of the local flora. Modern *Taxodium* inhabits swampy areas of the southeastern United States (Phillips, 1978). It is possible these forms were living in the swampy environment suggested by the lignite-rich sediments of the Emma #1 sections.

The abundance of *Cycadopites* and *Monosulcites* in many of the samples and the occurrence of *Ginkgo* in the plant megafossil assemblage suggests that *Ginkgo* may have been a significant component of the basin flora as well. Other primitive gymnosperms (e.g., cycads) were probably also present.

Angiospermous pollen besides triprojectates and Oculata is present in all the productive samples, and angiosperm leaves occur in the megafossil assemblages as well.

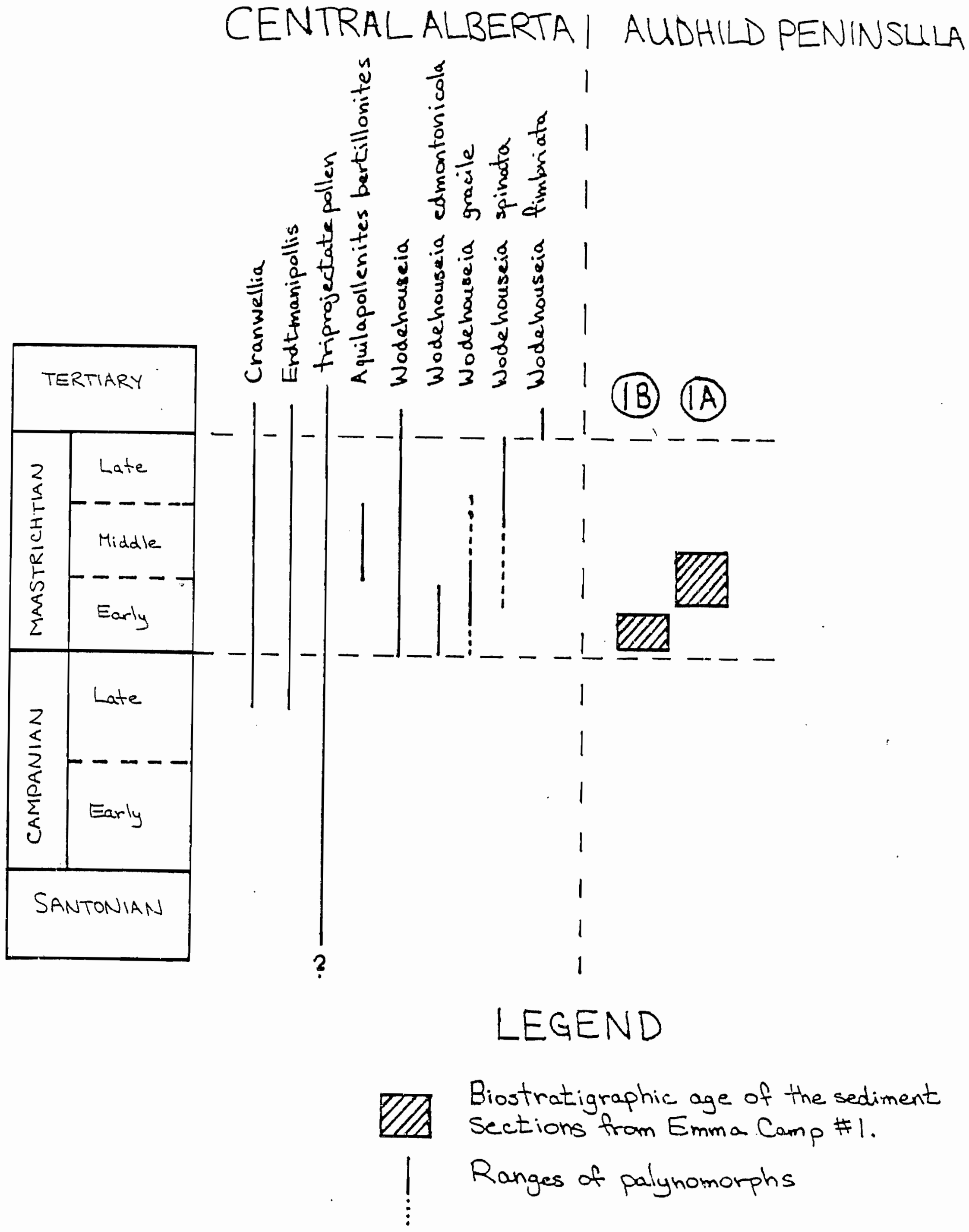
The climatic significance of *Wodehouseia* and triprojectate pollen is unknown, although it does appear the plants producing them were adapted to the Late Cretaceous climate at high latitudes (as suggested by their polar distribution).

In summary, the plant life at Audhild Peninsula was growing in a climate that was at probably at least temperate. Many of the plants living at these latitudes were also found further south in central Alberta and the western United States. The thermal gradient from southerly latitudes to northerly must have been much lower than the present day.

5.3.2 Biostratigraphic Age:

The palynoflora of the Audhiild Peninsula sequences compares best with Late Cretaceous assemblages from Siberia and western North America. The stratigraphic ranges of palynomorphs in the Late Cretaceous of western North America, especially Alberta, are fairly well known with respect to known biostratigraphic boundaries. Much has been contributed because of recent interest in the events occurring at the Cretaceous-Tertiary boundary.

An important consideration with any biostratigraphic work is how the stratigraphic framework of an area is constructed. In the case of the Late Cretaceous, the type sections of the individual ages are in Europe. Correlations between the European type sections and western North America are made



Text Figure 22: ACCEPTED STRATIGRAPHIC RANGES OF SELECTED LATE CRETACEOUS TAXA, WESTERN NORTH AMERICA
The ranges of selected taxa in central Alberta and the western United states is indicated by the vertical lines. Note that these are the *accepted* ranges. References for the ranges are as follows:
Cranwellia, *Erdtmanipollis* - Jerzykiewicz & Sweet, 1988; triprojectates - Srivastava, 1978; *Aquilapollenites bertillonites* - Tschudy & Leopold, 1971; Farabee & Canright, 1986; *Wodehouseia* - Wiggins, 1976; *Wodehouseia edmontonicola*, *Wodehouseia gracile* - Wiggins, 1976, Srivastava, 1969, 1970; *Wodehouseia spinata* - Srivastava, 1969, 1970; Wiggins, 1976; *Wodehouseia fimbriata* - Tschudy & Tschudy, 1986; Wiggins, 1976; Snead, 1969.

difficult because many of the faunas found in the Late Cretaceous of Europe are in chalk facies, and do not occur in western North America (Birkelund, et al., 1984). Recent attempts at correlating the two areas have hinged on the matching of European stratigraphy to the detailed ammonite zones used in western North America. Most of the work has matched foraminiferal zones (Caldwell, et al., 1978; Caldwell & North, 1984) with the ammonite zones. Correlation of other groups of fossil, such as palynomorphs (Norris, et al., 1973), bivalves (Reiskind, 1975) and diatoms and radiolaria (Wall, 1975), are pegged with respect to the ammonite zones.

Figure 22 shows the known ranges of several miospore species, compared to the current stratigraphic framework in the Late Cretaceous of Alberta (after Caldwell, et al., 1978; Caldwell & North, 1984) and their distribution at Audhild Peninsula.

The presence of *Erdtmanipollis* and *Cranwellia striata* indicate a Campanian or Maastrichtian age (Jerzykiewicz and Sweet, 1988).

The presence of triprojectates also indicates a Campanian or Maastrictian age.

Aquilapollenites bertillonites occurs only in the upper part of section #1B (samples EL87-118 and 120) at Audhild Peninsula. Its age is restricted to the middle part of the Maastrichtian according to Tschudy and Leopold (1971) and Farabee and Canright (1986). The occurrence of the distinctive *Aquilapollenites* [*Integricorpus*] sp. 1 of Samoilovitch, 1967 is restricted to three samples from section #1B (EL87-115, 118, 120). Its known range is uncertain, but in the sections described by Doerenkamp (et al., 1976) and McIntyre (1974), it appears somewhere above the base of the Maastrichtian.

The most age diagnostic species are of *Wodehouseia*, which are restricted to basal Maastrichtian to lowermost Paleocene according to many authors ((Srivastava, 1969, 1970; Snead, 1969; Wiggins, 1976; Jerzykiewicz and Sweet, 1988; Nichols and Sweet, in press; and others). Some authors (e.g., Wiggins, 1976; Jerzykiewicz and Sweet, 1988), have placed the Campanian/Maastrichtian boundary at the first occurrence of *Wodehouseia* in the absence of other biostratigraphic data. This could artificially limit the apparent range of *Wodehouseia* due to circular reasoning. In any case, the *accepted* first occurrence of *Wodehouseia* is at the base of the Maastrichtian. The presence of *Wodehouseia* in all the productive samples from sections #1A and #1B indicates that they are Maastrichtian.

A succession of *Wodehouseia* species is observed within the Maastrichtian to Early Paleocene (Wiggins, 1976; Srivastava, 1969, 1970; Tschudy & Tschudy, 1986; Nichols and Sweet, in press) which allows considerable stratigraphic resolution. However, taxonomic resolution is a problem.

W. edmontonicola Wiggins, 1976 occurs in all the samples of section #1A. Srivastava (1969, 1970) reports *W. edmontonicola* (reported as *W. gracile* and *W. jacutense*) from a restricted zone (Zone III, Srivastava, 1970) towards the bottom of the Edmonton Group in central Alberta. According to local stratigraphy, the lower boundary of the Edmonton Group with the Bearpaw Shale is above the Campanian-Maastrichtian boundary (Caldwell, et al., 1978; Caldwell & North, 1984), placing the *W. edmontonicola* zone within the Lower Maastrichtian. Other authors (e.g., Wiggins, 1976) also observe *W. edmontonicola* in the Lower Maastrichtian. This suggests that section #1A is Lower Maastrichtian in age, somewhere above the Campanian-Maastrichtian boundary.

The next species of *Wodehouseia* to appear in the Edmonton Group of Alberta is *W. gracile* (Samoilovitch, 1961) Pokrovaskaya, 1966. This form is similar to *W. edmontonicola*, but bears more spines and has a slightly different shape. It succeeds *W. edmontonicola* in the Edmonton Group. It is probably Lower-Middle Maastrichtian age, and overlaps the distribution of *W. edmontonicola*.

Wodehouseia cf. W. stanleyi Srivastava, 1966 and *Wodehoueia gracile*forms with some features of*W. avita* Wiggins, 1976 occur in the the younger samples of section #1B. *W. stanleyi* is reported from the middle portion of the Edmonton Group (Srivastava, 1966), and is probably Middle Maastrichtian. *W. avita* is reported as Early Maastrichtian in Alaska (Wiggins, 1976), although this data is not independently dated.

In conclusion, the species of *Wodehouseia* and the occurrence of *Aquilapollenites bertillonites* support an Early to possibly Middle Maastrichtian age for sediment sections #1A and #1B at Emma camp #1. Other palynomorphs of the assemblage are less age-diagnostic, but do not conflict with a Maastrichtian age. It also appears that section #1A is older than section #1B, because section #1B contains younger palynomorph species. This was not obvious in the field, although structural complications were suspected.

Note that because of the possibility of reworking, Early to Middle Maastrichtian is a maximum age.

5.3.3 Local (Arctic Islands) Correlation of the Audhild Peninsula Sequences:

The assemblage from Audhild Peninsula compares closely with an assemblage described by Dorenkamp, et al. (1976) from the upper part of the Kanguk Formation of the Banks Island area. Their Zone CVIc includes *Wodehouseia edmontonicola* (as figured, the specimens are *W. edmontonicola*, but they were reported as *W. gracile*; their specimens probably include this species as well), triprojectate pollen including the distinctive *Aquilapollenites* [*Integricorpus*] sp. 1 of Samoilovitch, 1967, *Aquilapollenites* [*Triprojectus*] *unicus*, *Erdtmanipollis*, *Cranwellia striata*, simple triporate pollen, and other forms found at Audhild Peninsula. The presence of *W. edmontonicola/gracile* is diagnostic. The absence of comparable dinoflagellates at Audhild Peninsula could reflect non-marine deposition. In all areas they examined, Dorenkamp et.al. (1976) found Zone CVIc occurred within the Kanguk Formation, usually a few tens of metres beneath the Kanguk Formation - Eureka Sound Group contact, and beneath the Cretaceous/Tertiary boundary.

Palynomorph assemblages from the Eureka Sound Group have been described by Dorenkamp et.al. (1976) from the Banks Island area, by Felix & Burbidge (1973) from Ellef Ringnes Island, and by Choi (1983) from the Axel Heiberg and central Ellesmere Island areas. In all cases, there is limited similarity with the Audhild Peninsula assemblage. The Eureka Sound Group assemblages usually contain slightly younger (Late Maastrichtian or Tertiary) palynomorphs, and *W. edmontonicola/gracile* is absent. The work of Wall (1983) and unpublished palynologic data refered to in Miall (1986) and Ricketts

(1986) imply that the Eureka Sound Group extends down to the base of the Maastrichtian in some areas. It is likely that these areas would have similar assemblages to those at Audhild Peninsula, but the data is unavailable.

Choi (1983) figures a specimen identified as *Mancicorpus senonicus* (Mchedlishvili) (Choi, 1983, plate 41, figure 303) - a form which does occur in the Audhild Peninsula assemblage.

Mudie (1985) reports a Maastrichtian age for part of a core located on Alpha Ridge (see text figure 3). One zone (palynology Zone 2, Mudie, 1985) contains abundant *Wodehouseia gracile*, and other forms similar to the Audhild Peninsula assemblage (e.g., *Triporopollenites bituitus*, *Taxodium sp.*) The sediments of this part of the core are biosiliceous ooze, and represent pelagic deposition in the young Arctic Ocean (Mudie & Blasco, 1985). There are two volcanic ash beds above the the zone containing W.gracile (Mudie & Blasco, 1985). If the core and Audhild Peninsula sequences are correlatable, the ash beds could be related to the explosive (pyroclastic) vulcanism occurring at the top of the Audhild Peninsula or Phillips Inlet sequences - only about 500 km away. This could have important implications for dating ash markers within the sediments of the Canada Basin.

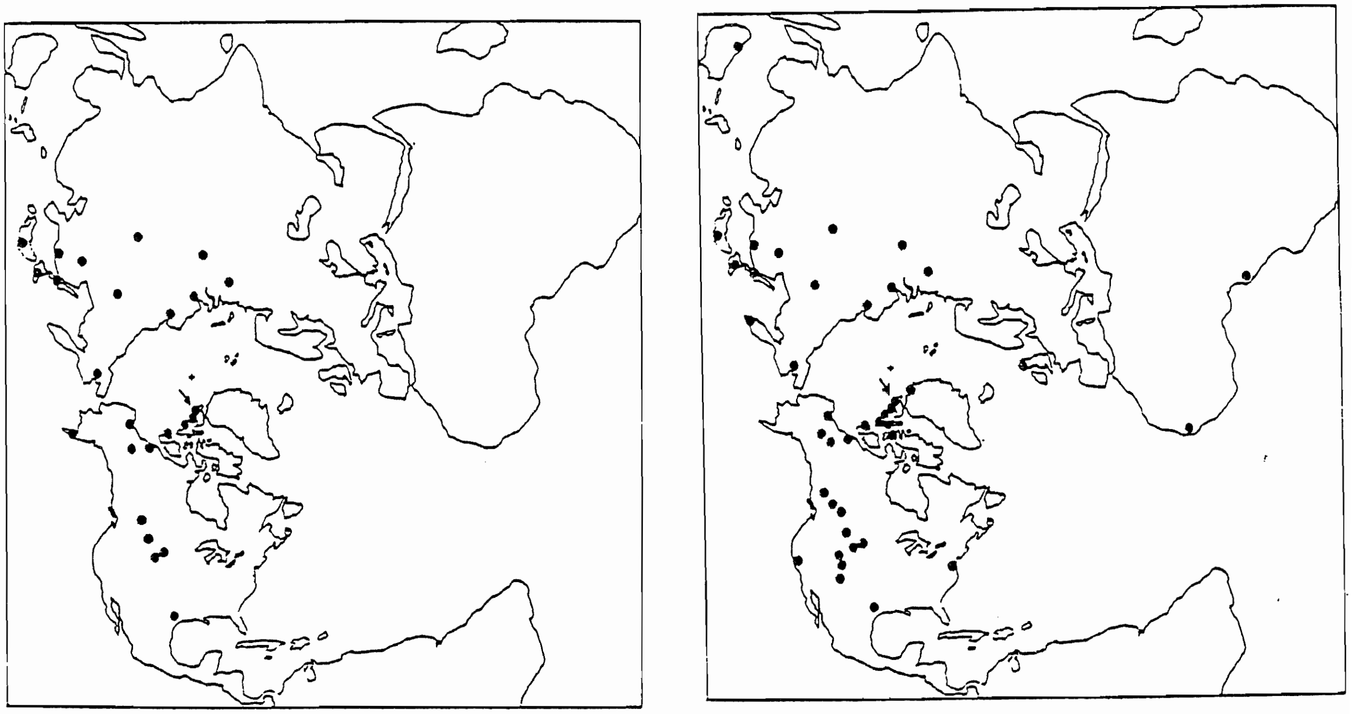
In conclusion, the Audhild Peninsula assemblage correlates best (of the published work) with the Kanguk Formation in the Banks Island area (Doerenkamp, et al., 1976), and the marine pelagic sediments from Alpha Ridge (Mudie, 1985). The Audhild Peninsula assemblage is slightly older than the *published* assemblages from the Eureka Sound Group. Until more palynologic data becomes available from the Eureka Sound Group, a direct correlation is not possible.

Since the Audhild Peninsula sequences appear to be non-marine facies, they probably should be considered correlatable to the Eureka Sound Group. The commencement of terrestrial Eureka Sound Group deposition at Audhild Peninsula earlier than other areas (where Kanguk deposition was continuing) may be related to uplift associated with the vulcanism in the area.

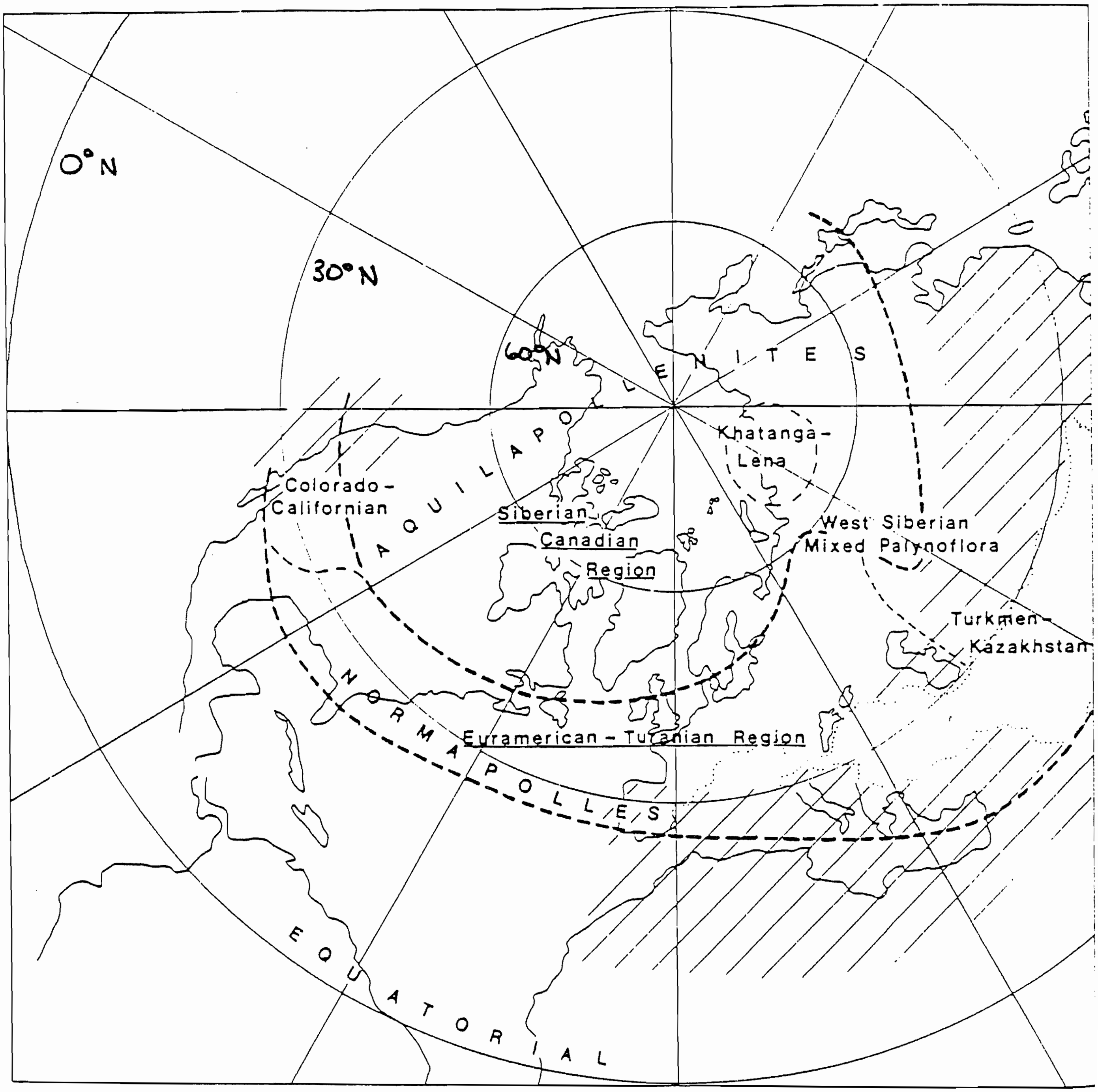
5.3.4 Paleofloral Provincialism: (refer to text figures 23 & 24)

Text figure 23 shows the geographic occurrence of fossil Oculata pollen (including *Wodehouseia* and *Azonia*) and triprojectate pollen (*Aquilapollenites*) in Upper Cretaceous (mostly Maastrichtian) sediments. The presence of *Wodehouseia* and the Triprojectate group in the Audhild Peninsula assemblage suggests affinites with western North American and Siberian paleofloras (see text figure 23).

The groups have a distinct geographic *zone* of occurrence. Other pollen groups show their own zones of occurrence (e.g., the Normapolles group of pollen). It is generally agreed that the zones reflect paleogeographic variations in the terrestrial floras. Several authors (Samoilovitch, 1977; Srivastava, 1978; Herngreen & Chlonova, 1981; Batten, 1984; Frederiksen, 1987) have proposed paleofloral provinces based on the pollen assemblages. When the pollen provinces are plotted on a tectonic reconstruction of plate positions (text figure 24), they are seen to occupy broadly latitudinal bands. It is believed that the bands are a result of variations in paleoclimate , complicated by sea barriers to plant dispersal (Batten, 1984). Because land plants cannot easily disperse across sea barriers, there must have been a land bridge or chain of islands



Text Figure 23: GEOGRAPHIC DISTRIBUTION OF Oculata (left), AND Triprojectates (right) . Modified after Choi (1983). Point added for this study (arrowed). Point also added for Triprojectates from the Kap Washington Group (Batten, 1982).



Text Figure 24: MAASTRICHTIAN AGE PALEOFLORAL PROVINCES (after Batten, 1984) Plotted on a version of Smith and Briden's (1977) paleogeographic reconstruction for the Santonian. Dashed lines are approximate boundaries of the zonations. Pollen forms from one province can occasionally be found in the other. Similar zonations occur in the southern hemisphere. The zonations probably reflect both climatic conditions and geographic isolation (by intervening oceans). Note the possibility of an Arctic land bridge in the vicinity of Greenland and Scandanavia, and at the Bering Straits, suggested by the circum-polar distribution of the *Aquilapollenites* province.

between continental areas with the same paleoflora.

The assemblage at Audhild Peninsula lies within the *Aquilapollenites* paleofloral province (Batten, 1984; after Samoilovitch, 1977) (see text figure 24). It extends over Siberia, Arctic Canada, and western North America. A connection between the areas must have existed at some time. This conclusion is supported by other terrestrial biotas (Estes & Hutchison, 1980). A land bridge is possible through the Arctic Canada-Greenland-Svalbard route, and/or the Bering Straits. A Greenland connection seems more likely in light of the occurrence of the distinctive form-genus *Expressipollis* (Chlonova, 1961) in eastern Siberia and Ellef Ringnes Island (Canadian Arctic Islands) (Felix & Burbidge, 1973). Some tectonic reconstructions make this feasible (e.g., Soper, et.al., 1982, Rowley & Lottes, 1988).

Judging by the rapid changes in pollen form (in the Oculata and Triprojectate groups), and the occurrence of many of the forms in both areas, the migration of some plants must have occurred consistently throughout the Campanian and Maastrichtian.

The question of how plant forms migrated (North America to Siberia, vice versa, or both) has not been settled. Tschudy (1971) reports *Aquilapollenites quadrilobus* (Rouse) as having an Albian to end Cretaceous range in Siberia, while North American occurrences are only as early as Santonian. This would suggest a Siberian origin. However, Sravistava (1978) claims the Albian age is a misquote, and no significant time difference exists. I tend to believe this is so.

Stanley (1970) states that the Triprojectate group had its origin during Turonian time in western Siberia, and subsequently migrated across an assumed Bering land bridge to western North America by the Turonian-

Santonian (according to Norris, et.al., 1973). A Greenland land bridge is just as likely.

The area of origin of the genus *Wodehouseia* (Oculata group) is not clear. The genus first occurs at the Campanian-Maastrichtian boundary in Alaska and western North America (Wiggins, 1976). The Campanian precursors of the genus (certain species of *Azonia*) are restricted to the more polar areas of Siberia, Arctic Canada, and Alaska (Wiggins, 1976). *Wodehouseia* appears continuously throughout the Maastrichtian in these areas, and is more diverse in the Arctic as well. At more southerly locations (e.g., Alberta and Montana), it is less common (e.g., Srivastava, 1970; Norton (1969), and its stratigraphic distribution is sporadic (e.g., Srivastava, 1970). It seems possible that *Wodehouseia* originated in the arctic, and migrated southward during the Maastrichtian. The sporadic occurrence of *Wodehouseia* in western North America can be explained as the influx of new species from the north. Migration of plant forms between Siberia and North America probably also occurred, because identical forms are present in both areas.

Recent studies on the distribution of triprojectates, *Wodehouseia*, and other groups by Nichols and Sweet (in press) in the Late Cretaceous of western North America suggest that species of triprojectates and *Wodehouseia* were appearing earlier in the north (Yukon and Alaska) than at southern localities (Central Alberta and western United States). Species also persisted longer in the north when a species became extinct in the more southern localities.

5.4 Radiometric Dates:

80±2 Ma is the mean date for the volcanic units bracketting the palynology samples from sections #1A and #1B (Emma Camp #1).

The DNAG time scale (Palmer, 1983) is widely accepted. It suggests a 74.5±4 Ma age for the Campanian/Maastrichtian boundary, and 84±3 Ma for the base of the Campanian. Within the age uncertainties, this suggests a mid-Campanian age for the sediment sections at Emma Camp #1. Time scales suggested by other authors (e.g., Hallam, et al., 1985) place the Campanian / Maastrichtian boundary at or younger than 74.5 Ma.

5.5 Comparison of Biostratigraphic & Radiometric Dates:

Text figure 25 summarizes the absolute and biostratigraphic framework of the present study.

If one accepts the DNAG time scale (Palmer,1983) Campanian/Maastrichtian boundary of 74.5±4 Ma, there is a significant discrepancy between the mid-Campanian age suggested by the radiometric dates (80±2 Ma), and the Lower-Middle Maastrichtian date suggested by the palynologic data (≤74.5 ± 4 Ma). Although the large uncertainty of ± 4 Ma in the Campanian/Maastrichtian boundary allows some leeway, it is unlikely that the two dates can be reconciled. A conservative estimate of the discrepancy would be 5 million years. This assumes that the biostratigraphic age is basal Maastrichtian.

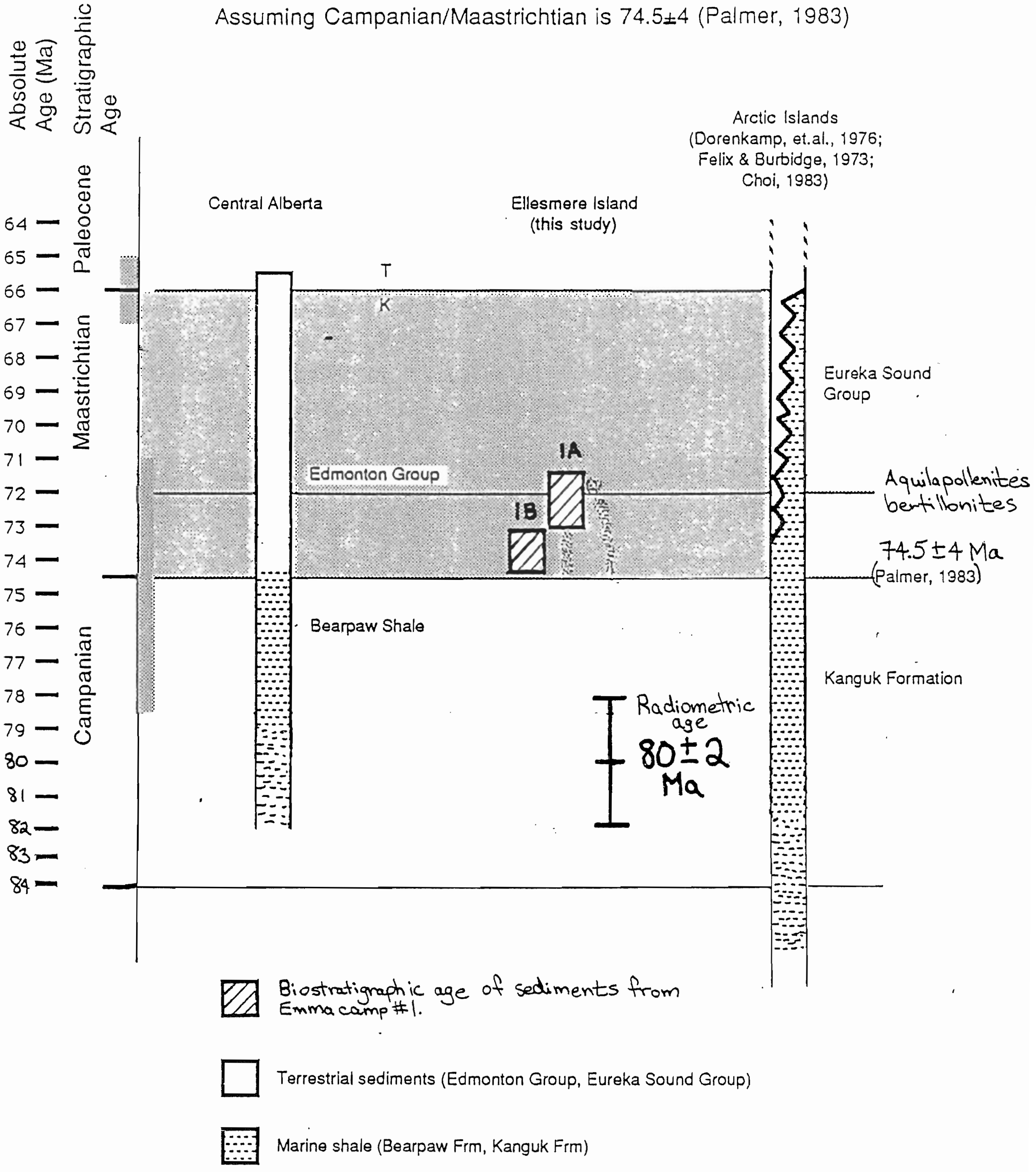
If the discrepancy is real, there are several possible explanations:

There could be an error in the collection of the biostratigraphic, radiometric, or stratigraphic data.

The biostratigraphic age is well fixed because of the occurrence of *Wodehouseia* and *Aquilapollenites bertillonites*. Considering the accepted

Absolute-Biostratigraphic Time-Space Diagram

Assuming Campanian/Maastrichtian is 74.5±4 (Palmer, 1983)



Text Figure 25: RADIOMETRIC-BIOSTRATIGRAPHIC AGE COMPARISON
Figure uses 74.5±4 Ma Campanian/Maastrichtian boundary of Palmer (1983).
See text for discussion.

range of just the genus *Wodehouseia* (base of Maastrichtian to Early Paleocene) yields a maximum age of basal Maastrichtian. It is important to point out that this is based on the *accepted* age range of *Wodehouseia*. The range could be wrong.

Reworking of palynomorphs does not help the situation, because it would mean the biostratigraphic age is even younger.

The radiometric date should be considered reliable because of the excellent preservation of the volcanic units, the relatively high K content of the volcanic units (alkali basalts), and the consistency of the dates. The analytical technique used has been checked thoroughly against international standards for many years (Muecke, pers. comm.). Any error which does exist must be systematic.

An error in the placement of the volcanic units stratigraphically above and below the sediment sections is very unlikely.

If the current data is assumed to be correct, and an age discrepancy exists, there could be two explanations:

1.) An error in the currently accepted time scale: Of the surveyed time scales, the Palmer (1983) Campanian/Maastrichtian boundary of 74.5±4 Ma is most likely to be correct, but is still too young. It could be in error. Improvements in the geochronologic framework in the type areas (Europe) may shed some light on this possibility. Recent work in Cretaceous biostratigraphy (Birkelund, et.al., 1984) has led to better standardization of index fossils, and will hopefully work its way into geochronologic work. If techniques applied recently to the dating of the Cretaceous/Tertiary boundary (Baadsgaard, et al., 1988) were applied to the Campanian/Maastrichtian boundary, the geochronology of this interval would be much better constrained.

2.) Biotic heterochroneity: The possibility of Arctic biotic heterochroneity was originally supported by Hickey et.al. (1983). They used paleomagnetic data from the sediments of the Eureka Sound Group as an absolute age control. An absolute chronology based on the paleomagnetics of sedimentary facies is tricky in the best of situations. Their work has since been disputed by several authors (Kent, et. al., 1984; Norris & Miall, 1984; Spicer, et. al., 1986; Tauxe & Clark 1987) on the basis of poor data and questionable interpretations. Hickey et.al. (1983) suggest an age discrepancy as large as 18 Ma between arctic and lower latitude biotas. A discrepancy this large is not supported by the present study, but a smaller discrepancy of 5 million years is suggested.

An important qualification to the idea of a biotic heterochroneity is the organisms involved. Hickey et al. (1983) suggested a wide range of biotas (both plants and animals) were appearing at anomalously early times. In the present study, the accepted (western North America) biostratigraphic age is well constrained for *Wodehouseia* and *Aquilapollenites bertillonites*, so only these taxa can be suggested as appearing earlier at Audhild Peninsula. The behavior of the other taxa is not resolvable.

A combination of 1) and 2) is also a possibility.

If a biotic heterochroneity does exist, one possible explanation could be the migration of *some* terrestrial plant types (i.e., Triprojectates, Oculata) from Siberia to western North America via a Svalbard-Greenland-Canadian Arctic Islands land bridge. It is unclear whether migration of plant species could take geologically significant amounts of time , but it could explain the age discrepancy. There is evidence for an exchange of plant forms between Siberia and North America via some route (see section 5.3.4). It makes sense that the migration of plant forms could take some time to complete. Another possibility is the origin of these forms somewhere in the polar area (not necessarily the Canadian Arctic, though), and subsequent migration to more southern areas. This idea was the idea suggested by Hickey et.al. (1983). Only the plants producing triprojectate and Oculata pollen need be involved, unlike the ideas of Hickey (et al., 1983). The time taken for the migration could be controlled by geographic distance or obstacles, and the slow adaptation of the plant forms to the 'unfamiliar' climates. Of all fossil groups, terrestrial plants are probably the most likely to display heterochroneities because of their relatively slow dispersal rates compared to marine and other biotas.

The existence of a biotic heterochroneity would have great implications for arctic stratigraphy, and stratigraphy in general. Age determinations based on the occurrence of *Wodehoueia* and triprojectates would vary significantly from low to higher latitudes.

Future study will concentrate on developing better constraints on the biostratigraphic and radiometric ages at Audhild Peninsula and the Canadian Arctic Islands, and finding a better biostratigraphic/absolute framework at lower latitudes. Research will include more radiometric dates from Audhild Peninsula, as well as radiometric and palynologic work at the nearby Phillips Inlet sections. Until the geochronology and biostratigraphy in the Arctic Islands and lower latitudes is better constrained, the cause of the age discrepancy cannot be resolved conclusively.

6. CONCLUSIONS:

1. Local stratigraphy:

a) The sequences at Audhild Peninsula are marked by complex intertonguing relationships between the volcanic and sedimentary units.

b) The volcanic units are bimodal, with basalts dominant. Acid volcanics, glassy ignimbrite, and flow-banded porphyritic glass make up a minor proportion. The volcanics are very well preserved.

c) The sedimentary units include coarse siliclastics in the northern sections, and thick lignite-rich fluvio-deltaic sediments in the south. Identification of sedimentary structures is hampered by poor outcrop between the volcanic units.

d) Volcanic-derived clastic units include a matrix-supported volcaniclastic conglomerate, interpreted as a debris flow (lahar?); and a crystal-bearing ash fall tuff.

e) Correlation between the northern (Emma #1) and southern (Emma #2) sections is based on the occurrence of acidic volcanics and ignimbrite near the top of both sections. This correlation may not be reliable.

e) Lateral changes of sedimentary facies over several kilometres suggest the northern area was closer to the source of the sediments.

f) The occurrence of euhedral feldspar, pumice, and other volcanically derived clasts within most sedimentary units (even the lignite) suggests proximity to active vulcanism during the deposition of the sediments.

2. Paleontology and biostratigraphy:

a) Palynomorphs (spores and pollen) are exclusively terrestrial.

b) Comparison of palynomorphs with the Edmonton Group of Alberta suggests an Early to Middle Maastrichtian age is most likely, based on the presence of *Wodehouseia* and some of the triprojectates. Early Maastrichtian is the *oldest* age possible for the sequences using accepted biostratigraphy..

c) The presence of Oculata (*Wodehouseia*) and Triprojectate pollen indicates affinities with western North America and Siberian floras. The flora lies within the Maastrichtian *Aquilapollenites* floral province of Batten (1984, after Samoilovitch, 1977)

d) Plant megafossils suggest local floras included Taxodiales, *Ginkgo*, and angiosperms.

3. Correlation:

a) The miospore assemblage is most similar to the terrestrial palynomorphs of the Kanguk Formation at Banks Island (Doerennkamp, et.al., 1976) and part of a CESAR core from Alpha Ridge (Mudie, 1985), suggesting that terrestrial deposition at Audhild Peninsula was synchronous with Kanguk Formation marine deposition in other areas.

b) The Maastrichtian age indicates the sedimentary sequences are correlatable with the lower portion of the Eureka Sound Group; however, the assemblage is slightly older than the Eureka Sound Group in most areas (based on published palynology).

4. Radiometric age & biotic heterochroneity:

a) $^{40}Ar/^{39}Ar$ whole rock age for bracketting volcanics at the Emma #1 sections is 80±2 Ma - mid Campanian according to the time scale of Palmer (1983) (Campanian/Maastrichtian boundary at 74.5 ±4 Ma).

b) Assuming there are no other errors, there is an age discrepancy between the radiometric age and the biostratigraphic age of about 5 million years.

c) If a discrepancy does exist, and represents biotic heterochroneity, it is suggested it could represent the time taken for migration of Oculata and Triprojectate forms from an origin in Asia (Siberia) or the arctic to western North America.

d) Errors in the currently accepted time scale and/or the currently accepted ranges of palynomorphs are possible as well.

Appendix A: Storage of samples

Palynological slides and field samples are stored in the collections of Dalhousie University. Information on their location can be obtained by refering the thesis title, author, and sample/slide number to the curator of the Geology Departement collections. Slides are numbered according to sample number (the field sample which the slide was prepared from) and the number of slides prepared from each sample. See table for slide numbers.

The palynological preparations were done at the Atlantic Geoscience Centre, Dartmouth, Nova Scotia. Any remaining wet sample is stored there.

Coordinates of palynomorphs were obtained on a Zeiss Universal microscope using an England Finder.

TABLE OF SLIDES USED IN STUDY.

Stored in Department of Geology collections, Dalhousie University, Halifax, N.S.

STREW SLIDES:
Emma Camp #1, section #1A
EL87-115-01
EL87-115-02
EL87-116-01
EL87-116-02
EL87-118-01
EL87-118-02
EL87-120-01
EL87-120-02
Emma Camp #1, section #1B
EL87-106-01
EL87-106-02
EL87-107-01
EL87-107-02
EL87-109B-01
EL87-109B-02
Emma Camp #2, section #2A
EL87-204-01
EL87-204-02
EL87-205-01
EL87-205-02
EL87-099-01
EL87-099-02

SINGLE GRAIN MOUNTS:
EL87-120-SG1 to EL87-120-SG25

BIBLIOGRAPHY:

Baadsgaard, H.; Lerbekmo, J.F.; & McDougall, I. (1988)
A radiometric age for the Cretaceous-Tertiary boundary based on K-Ar, Rb-Sr, and U-Pb ages of bentonites from Alberta, Saskatchewan, and Montana. Canadian Journal of Earth Sciences **25**:1088-1097.

Balkwill, H.R. (1978)
Evolution of the Sverdrup Basin, Arctic Canada. American Association of Petroleum Geologists, Bulletin **62**:1004-1028.

Barss, M.S. & Williams, G.L. (1973)
Palynology and nannofossil processing techniques. Geological Survey of Canada Paper **73-26**:25pp.

Batten, D.J. (1982)
Palynology of shales associated with the Kap Washington Group volcanics, central North Greenland. Grønlands geol. Unders. **108**:15-23.

Batten, D.J. (1984)
Palynology, climate and the development of Late Cretaceous floral provinces in the Northern Hemisphere; a review. Fossils & Climate :127-164.

Birkelund, T.; Hancock, M.B.; Hart, M.B.; Rawson, P.F.; Remane, J.; Robaszynski, F.; Schmid, F.; & Surlyk, F. (1984)
Cretaceous stage boundaries - Proposals. Bulletin of the Geological Society of Denmark **33**:3-20.

Brasier, M.D. (1980)
Micropaleontology. Billings & Sons - London.

Bustin, R,M. (1982)
Beaufort Formation, eastern Axel Heiberg Island, Canadian Arctic Archipelago. Bulletin of Canadian Petroleum Geology **30**:140:149.

Caldwell, W.G.E.; North, B.R.; Stelck, C.R.; & Wall, J.H. (1978)
A foraminiferal zonal scheme for the Cretaceous system in the Interior Plains of Canada - IN: Stelck, C.R. & Chatterton, B.D.E. (eds.) Western and Arctic Canadian Biostratigraphy. Geological Association of Canada Special Paper **18**:495-575.

Caldwell, W.G.E. & North, B.R. (1984)
Cretaceous stage boundaries in the southern Interior Plains of Canada. Bulletin of the Geological Society of Denmark **33**:57-69.

Cameron, B. (1989)
Petrochemistry and origin of the Permian volcanics of the Essayoo Formation, Sverdrup Basin, High Canadian Arctic. Unpublished M.Sc. thesis, Dalhousie University, Halifax, Nova Scotia.

Choi, D.K. (1983)
Paleopalynology of the Upper Cretaceous-Paleogene Eureka Sound Formation of Ellesmere and Axel Heiberg Islands, Canadian Arctic Archipelago. Unpublished Ph.D. thesis, Pennsylvania State University, Harrisburg, Pennsylvania. 581pp.

Chlonova, A.F. (1957)
Distinguishing of index species in age determination of deposits according to spore-pollen analysis. Izvestiya Vostochnogo Filiala AN SSSR **2**:43-46 (In Russian).

Chlonova, A.F. (1961)
Spores and pollen of the upper half of Upper Cretaceous of the the eastern part of the west Siberian lowland. Trudy Inst. Geol. Geophy. SOAN SSSR, Novosibirisk, **7**:1-139 (In Russian).

Chlonova, A.F. (1962)
Some morphological types of spores and pollen grains from Upper Cretaceous of eastern part of Siberian Lowland. Pollen et Spores **4**:297-309.

Dawson, M.R.; West, R.M.; Langston, W.; & Hutchison, J.H. (1976)
Paleogene terrestrial vertebrates: Northernmost occurrence, Ellesmere Island, Canada. Science **192**:781-782.

Doerenkamp, A.; Jardine, S.; & Moreau, P. (1976)
Cretaceous and Tertiary palynomorph assemblages from Banks Island and adjacent areas (N.W.T.). Bull. Can. Pet. Geol. **24**:372-417.

Elsik, W.C.; et al (1983)
Annotated glossary of fungal palynomorphs. AASP Contributions **11**: 35pp.

Embry, A.F. and Osadetz, K.G. (1988)
Stratigraphy and tectonic significance of Cretaceous volcanism in the Queen Elizabeth Islands, Canadian Arctic Archipelago. Canadian Journal of Earth Sciences **25**:1209-1219.

Erdtman, G. (1969)
Handbook of palynology - An introduction to the study of pollen grains and spores. Hafner Publishing - New York. 486 pp.

Erdtman, G. (1972)
Pollen morphology and plant taxonomy - Angiosperms. Hafner Publishing - New York. 553pp.

Estes, R. & Hutchison, J.H. (1980)
Eocene lower vertebrates from Ellesmere Island, Canadian Arctic Archipelago. Paleogeography, Paleoclimatology, Paleoecology **30**:325-347.

Farabee, M.J. & Canright, J.E. (1986)
Stratigraphic palynology of the lower part of the Lance Formation (Maestrichtian) of Wyoming. Palaeontographica Abt.B **199**:1-89.

Felix, C.J. & Burbridge, P.P. (1973)
A Maestrichtian age microflora from Arctic Canada. Geoscience & Man **7**:1-29.

Fensome, R.A. (1983)
Miospores from the Jurassic-Cretaceous boundary beds of the Aklavik Range, N.W.T., Canada. PART 1. Unpublished Ph.D. Thesis, U. of Saskatchewan.

Fortier, Y.O.; Blackadar, R.G.; Glenister, B.F.; Greiner, H.R.; McLarin, D.J.; McMillan, N.J.; Norris, A.W.; Roots, E.F.; Souther, J.G.; Thorsteinsson, R.; & Tozer, E.T. (1963)
Geology of the north-central part of the Arctic Archeipelago, Northwest Territories (Operation Franklin). Geological Survey of Canada Memoir **320**.

Frederiksen, N.O. (1987)
Tectonic and paleogeographic setting of a new latest Cretaceous floristic province in North America. Palaios **2**:533-542.

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

Funkhouser, J.W. (April, 1961)
Pollen of the genus Aquilapollenites. Micropaleontology **7**:193-198.

Hallam, A.; Hancock, J.M.; LaBrecque, J.L.; Lowrie, W.; & Channel, J.E. (1985)
Jurassic to Paleogene: Part I - Jurassic and Cretaceous geochronology and Jurassic to Paleogene magnetostratigraphy. IN: The Chronology of the Geological Record. Snelling, N.J. (ed.). British Geological Survey Memoir **10**:118-132.

Herngreen, G.F.W. & Chlonova, A.F. (1981)
Cretaceous microfloral provinces. Pollen et Spores **23**:441-554.

Hickey, L.J. (1977)
Stratigraphy and paleobotany of the Golden Valley Formation (Early Tertiary) of Western North Dakota. Geol. Soc. Am. Memoir **150**:1-181.

Hickey, L.J.; West, R.M.; Dawson, M.R.; & Choi, D.K. (1983)
Arctic terrestrial biota: Paleomagnetic evidence of age disparity with mid-northern latitudes during the Late Cretaceous and Early Tertiary. Science **221**:1153-1156.

Hills, L.V. & Wallace, S. (1969)
Paraalnipollenites, a new form genus from uppermost Cretaceous and Paleocene rocks of Arctic Canada and Russia. IN: Contributions to Canadian Paleonotolgy. GSC Bulletin **182**:139-145.

Hopkins, W.S. (1971)
Palynology of the Lower Cretaceous Isachsen Formation on Melville Island, District of Franklin. Geol. Surv. Can. Bull. **197**:109-132.

Hopkins, W.S. & Balkwill, H.R. (1973)
Description, palynology, and paleoecology of the Hassel Formation (Cretaceous) on eastern Ellef Ringes Island, District of Franklin. Geol. Surv. Can. Paper **72-37**.

Jansonius, J. & Hills, L.V. (1976)
Genera file of fossil spores and pollen. Special Publication, Dept. of Geology, University of Calgary, Canada; annual supplements.

Jerzykiewicz, T. & Sweet, A.R. (1988)
Sedimentological and palynological evidence of regional climatic changes in the Campanian to Paleocene sediments of the Rocky Mountain Foothills, Canada. Sedimentary Geology, **59**:29-76.

Jeletzky, J.A. (1971)
Marine biotic provinces and paleogeography of western Arctic Canada illustrated by a detailed study of ammonites. Geol. Surv. Can. Paper **70-22**.

Jollimore, W. (1986)
Analysis of dyke swarms within the Sverdrup Basin, Queen Elizabeth Islands. Unpublished B.Sc. thesis, Dalhousie University, Halifax, Nova Scoita. 54pp.

Kauffman, E.G. (1984)
Paleobiogeography and evolutionary response dynamic in the Cretaceous western interior seaway of North America - IN: Jurassic-Cretaceous biochronology and paleogeography of North America. Westermann, G.E.G. (ed.). Geol. Ass. Canada Special Pap **27**:285-301.

Kent, D.V.; McKenna, M.C.; Opdyke, N.D.; Flynn, J.J.; & MacFadden, B.J. (1984)
Arctic biostratigraphic heterochroneity: Letters. Science **224**:173-174.

Kerr, J. W. (1977)
Cornwallis Lead-Zinc District - Mississippi Valley-type deposits controlled by

stratigraphy & tectonics. Can. J. Earth Sci. **14**:1402-1426.

Kerr, J.W. (1981)
Evolution of the Canadian Arctic Islands: A transition between the Atlantic and Arctic Oceans - In: Nairn, A.E.M.; Churkin, M.; & Stehl, F.G. (eds.) - The ocean basins and margins 5: The Arctic Ocean. pp. 105-199. Plenum Press, New York & London.

Krutzsch, W. (1962)
Stratigraphisch bzw. botanisch wichtige neue Sporen- und Pollenformen aus dem deutschen Tertiar. Geologie, Jahrgang **11**:265-307.

Krutzsch, W. (1966)
Zur kenntnis der praquartaren periporaten Pollenformen. Geologie, Jahrgang **15**:16-71

Lerbekmo, J.F.; Chaitanya, S.; Jarzen, D.M.; and Russel, D.A. (1979)
The Cretaceous-Tertiary boundary in south-central Alberta - a revisions based on additional dinosaurian and microfloral evidence. Can. J. Earth Sci. **16**:1866-1869.

Lerbekmo, J.F. & St. Louis, R.M. (1986)
The terminal Cretaceous iridium anomaly in the Red Deer Valley, Alberta, Canada. Can. J. Earth Sci. **23**:120-124.

McIntyre, D.J. (1974)
Palynology of an upper Cretaceous section, Horton River, District of McKenzie, N.W.T. GSC Paper **74-14**:1-7

McKenna, M.C. (1980)
Eocene paleolatitude, climate, and mammals of Ellesmere Island. Paleogeography, Paleoclimatology, Paleoecology **30**:349-362.

Merrett, D.C. (1989)
The magmatic evolution of tfe Phillips Inlet Volcanics, northwest Ellesmere Island, N.W.T. Unpublished M.Sc. thesis, Dalhousie University, Halifax, N.S.

Miall, A.D. (1979)
Tertiary fluvial sediments in the Lake Hazen Intermontane Basin, Ellesmere Island, Arctic Canada. Geol. Surv. Can. Paper **79-9**:1-25.

Miall, A.D. (1984a)
Sedimentation and tectonics of a diffuse plate boundary: The Canadian Arctic Islands from 80 Ma B.P. to the present. Tectonophysics **107**:261-277.

Miall, A.D. (1984b)
Variations in fluvial style in the Lower Cenozoic synorogenic sediments of the Canadian Arctic Islands. Sedimentary Geology **38**:499-523.

Miall, A.D. (1985)
Stratigraphic and structural predictions from a plate-tectonic model of an oblique-slip orogen: The Eureka Sound Formation (Campanian-Oligocene), northeast Canadian Arctic Islands. Soc. Econ. Paleonologists & Mineralogists. 361-374.

Miall, A.D. (1986)
The Eureka Sound Group (Upper Cretaceous-Oligocene), Canadian Arctic Islands. Bull. Can. Pet. Geol **34**:240-270.

Miall, A.D. (1988)
The Eureka Sound Group: alternative interpretations of the stratigraphy and paleogeographic evolution - Discussion. IN: Current Research, Part D. GSC Paper **88-1D**:143-147.

Mtchedlishvili, M.D. (1961)
Triprojectacites IN: Samoilovitch and Mtchedlishvili (eds.) (see this reference), p.203-229.

Mudie, P.J. (1985)
Palynology of the Cesar cores, Alpha Ridge. Geological Survey of Canada Paper **84-22**:149-174.

Mudie, P.J. & Blasco, S.M. (1985)
Lithostratigraphy of the CESAR cores. Geological Survey of Canada Paper **84-22**:59-99.

Nichols, D.J. & Sweet, A.R. (1989 in press)
Biostratigraphy of Upper Cretaceous nonmarine palynofloras in a north-south transect of the Western Interior Basin. Review of Paleobotany and

Palynology.

Norton, N.J. and Hall (1969)
Palynology of the upper Cretaceous and lower Tertiary in the type locality of the Hell Creek Formation, Montana, U.S.A. Paleontographica Abt. B **125**:1-64.

Norris, G.; Jarzen, D.M.; Awai-Thorne, B.V. (1973)
Evolution of the Cretaceous terrestrial palynoflora in western Canada. IN: Caldwell, W.G.E. (ed.) The Cretaceous system in the western interior of North America. Geol. Ass. Canada Special Paper **13**:

Norris, G. & Miall, A.D. (1984)
Arctic biostratigraphic heterochroneity: Letters. Science **224**:174-175.

North, B.R. & Caldwell, W.G.E. (1973)
Foraminiferal faunas in the Cretaceous system of Saskatchewan. IN: Caldwell, W.G.E. (ed.) The Cretaceous system in the western interior of North America. Geol. Ass. Canada Special Paper **13**:

Palmer, (1983)
The Decade of North American Geology Time Scale. Geology **11**:503-504.

Phillips, R. (1978)
Trees of North America and Europe. Pan Books-London. 224pp.

Plauchut, B.P. & Jutard, G.G. (1976)
Cretaceous and Tertiary stratigraphy, Banks and Eglinton Islands and Anderson Plain (N.W.T.). Bull. Canadian Pet. Geol. **24**:321-371.

Pokrovskaya, I.M. (1966)
Pollen of angiospermae of unestablished systematic position. IN: Pokrovskaya, I.M. (ed.) Paleopalynology, methods of paleopalynologic investigations, and morphology of some fossil spores, pollen, and other plant microfossils. Trudy Vses. Nauchn.-Issled. Geol. Inst., **141**:301-321. (In Russian)

Radforth, N.W. & Rouse, G.E. (1954)
The classification of recently discovered Cretaceous plant microfossils of potential importance to the stratigraphy of western Canadian coals.

Canadian Journal of Botany **32**:187-201.

Reidiger, C.L. & Bustin, R.M. (1987)
The Eureka Sound Formation, southern Ellesmere Island. Bull. Can. Pet. Geol. **35**:123-142.

Reiskind, J. (1975)
Marine concretionary faunas of the uppermost Bearpaw Shale (Maestrichtian) in eastern Montana and southwestern Saskatchewan. IN: Caldwell, W.G.E. (ed.) The Cretaceous system in the western interior of North America. Geol. Ass. Canada Special Paper **13**:

Ricketts, B.D. (1986)
New formations in the Eureka Sound Group, Canadian Arctic Islands. In: Current Research, Part B, Geol. Surv. Can. Paper **86-1B**:363-374.

Ricketts, B.D. (1988)
The Eureka Sound Group: alternative interpretations of the stratigraphy and paleogeographic evolution - Reply. In: Current Research, Part D. GSC Paper **88-1D**:149-152.

Rickets, B.D. & McIntyre, D.J. (1986)
The Eureka Sound Group of eastern Axel Heiberg Island: new data on the Eurekan Orogeny. In: Current Research, Part B, Geol. Surv. Can. Paper **86-1B**:405-410.

Rickets, B.D.; Osadetz, K.G.; Embry, A.F. (1987)
Volcanic style in the Strand Fiord Formation (Upper Cretaceous), Axel Heiberg Island, Canadian Arctic Archipelago. Polar Research **3**:107-122.

Ritcey, D. (1989)
A chemical study of the Carboniferous Audhild Volcanics, Northwestern Ellesmere Island, Arctic Canada: Initial vulcanism in the Sverdrup Basin. Unpublished B.Sc. thesis, Dalhousie University, Halifax, N.S.

Rouse, G.E. (1957)
The application of a new nomenclatural approach to upper Cretaceous plant microfossils from western Canada. Canadian Journal of Botany **35**:349-375.

Rowley, D.B. & Lottes, A.L. (1988)
Plate-kinematic reconstructions of the North Atlantic and Arctic: Late Jurassic to Present. Tectonophysics **155**:73-120.

Samoilovitch, S.R. (1967)
Tentative botanico-geographical subdivision of northern Asia in late Cretaceous time. Review of Palaeobotany and Palynology **2**:127-139.

Samoilovitch, S.R. (1977)
A new outline of the floristic zoning of the Northern Hemisphere in the late Senonian. Paleont. J. **3**:366-372.

Samoilovitch, S.R. & Mtchedlishvili, N.D. (1961)
Pyl'tsa i spory zapadnoi Sibiri, Yura-Paleotsen. [Pollen and spores from western Siberia, Jurassic-Paleocene.] Trudy VNIGRI **177**:342.

Simpson, J.B. (1961)
The Tertiary pollen-flora of Mull and Ardnamurchan. Transactions of the Royal Society of Edinburgh, 64:421-468.Stuart Smith, J.H. & Wennekers, J.H.N. (1977)
Geology and hydrocarbon discoveries of the Canadian Arctic Islands. Bull. Am. Assoc. Petrol. Geol. **61**:1-27.

Snead, R.G. (1969)
Microfloral diagnosis of the Cretaceous-Tertiary boundary, central Alberta. Research Council of Alberta, Bulletin **25**:1-143.

Soper, N.J.; Dawes, P.R.; & Higgins, A.K. (1982)
Cretaceous-Tertiary magmatic and tectonic events in North Greenland and the history of adjacent ocean basins. IN: Dawes, P.R. & Kerr, J.W. (eds.), Nares Strait and the drift of Greenland: a conflict in plate tectonics. Meddr. Gronland, Geoscience **8**:205-220.

Spicer, R.A. & Parrish, J.T. (1986)
Paleobotanical evidence for cool north polar climates in the middle Cretaceous (Albian-Cenomanian) time. Geology **14**:703-706

Spicer, R.A. & Wolfe, J.A. (1987)

Plant taphonomy of late Holocene deposits in Trinity (Clair Engle) Lake, northern California. Paleobiology **13**:227-245.

Spicer, R.A.; Wolfe, J.A.; & Nichols, D.J. (1987)
Alaskan Cretaceous-Tertiary floras and Arctic origins. Paleobiology **13**:73-83.

Srivastava, S.K. (1966)
Upper Cretaceous microflora (Maestrichtian) from Scollard, Alberta, Canada. Pollen et Spores **3**:498-552.

Srivastava, S.K. (1968)
Reticulate species of *Aquilapollenites* and an emendation of genus *Mancicorpus* Mtchedlishvili. Pollen et Spores **10**:665-697.

Srivastava, S.K. (1969)
Pollen genus *Wodehouseia* and its stratigraphic significance in the Edomonton Formation (Maastrichtian), Alberta, Canada. Can. J. Earth Sci. **6**:1307-1311.

Srivastava, S.K. (1969b)
New spinulose Aquilapollenites spp. from the Edmonton Formation (Maestrichtian), Alberta, Canada. Canadian Journal of Earth Sciences, **6**:133-144.

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

Srivastava, S.K.(1970b)
Systematic revision of *Aquilapollenites* Rouse, 1957. Canadian Journal of Botany **48**:1591-1601.

Srivastava, S.K. (1972)
Pollen Genus Erdtmanipollis Krutzsch 1962. Pollen et Spores, **14**:309-322.

Srivastava, S.K. (1978)
Cretaceous spore-pollen floras: a global evaluation. Biological Memoirs **3**:1-130.

Srivastava, S.K. and Rouse, G.E. (1970)
Systematic revision of *Aquilapollenites* Rouse, 1957. Canadian Journal of Botany, **48**:1591-1601.

Stanley, 1961a
A new sporomorph genus from South Dakota. Pollen et Spores, **3**:155-162.

Stanley, E.A. (November, 1961b)
The fossil pollen genus *Aquilapollenites*. Pollen et Spores **3**:329-352.

Stanley, E.A. (1970)
The stratigraphical, biogeographical, paleoautecological and evolutionary significance of the fossil pollen group Triprojectacites. Bull. Georgia Acad. Sci. **28**:1-44.

Stanley, E.A. (January, 1973)
Some taxonomic problems concerning the late Cretaceous plant microfossil group Triprojectacites Mchedlishvili and the genus *Aquilapollenites* Rouse. Bull. Georgia Acad. Sci. **31**:31-36.

Sweet, A.R. (1986)
The Cretaceous-Tertiary boundary in the central Alberta Foothills. II: Miospore and pollen taxonomy. Can. J. Earth Sci. **23**:1375-1388.

Tauxe, L. & Clark, D.R. (1987)
New paleomagnetic results from the Eureka Sound Group: Implications for the age of early Tertiary Arctic biota. Geo. Soc. Am. Bull. **99**:739-747.

Thorsteinsson, R (1974)
Carboniferous and Permian stratigraphy of Axel Heiberg Island and western Ellesmere Island, Canadian Arctic Archipelago. GSC Bulletin **224**:1-

Thorsteinsson, R. & Trettin, H.P. (1972)
Geology Map 1305A: Cape Stalworthy Map Area, District of Franklin. GSC Surveys and Mapping Branch.

Trettin, H.P. (1987)

Pearya: a composite terrane with Caledonian affinites in northern Ellesmere Island. Can. J. Earth Sci. **24**:224-245.

Trettin, H.P. & Parrish, R. (1987)
Late Cretaceous bimodal magmatism, northern Ellesmere Island: isotopic age and origin. Can. J. Earth Sci. **24**:257-265.

Tschudy, R.H. (1969)
Species of *Aquilapollenites* and *Fibulapollis* from two upper Cretaceous localities in Alaska. U.S. Geological Survey Prof. Paper **643-A**:A1-A17.

Tschudy, R.H. (1971)
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. Kosanke, R.M. & Cross, A.T. (eds.) Geol. Soc. Am. Special Paper **127**:65-111.

Tschudy, R.H. & Leopold, E.B. (1971)
Aquilapollenites (Rouse) Funkhouser - Selected Rocky Mountain taxa and their stratigraphic ranges. IN: Symposium on palynology of the late Cretaceous and early Tertiary. Kosanke, R.M. & Cross, A.T. (eds.) Geol. Soc. Am. Special Paper **127**:113-167.

Tschudy, R.H. & Scott, R.A. ; eds. (1969)
Aspects of palynology. John Wiley & Sons - New York. 510pp.

Tschudy, R.H. & Tschudy, B.D. (1986)
Extinction and survival of plant life following the Cretaceous/Tertiary boundary event, Western Interior, North America. Geology **14**:667-670.

Wall, J.H. (1975)
Diatoms and radiolarians from the Cretaceous system of Alberta - a preliminary report. IN: Caldwell, W.G.E. (ed.) The Cretaceous system in the western interior of North America. Geological Association of Canada Special Paper **13**:394-

Wall, J.H. (1983)
Jurassic and Cretaceous foraminiferal biostratigraphy in the eastern Sverdrup Basin, Canadian Arctic Archipelago. Bull: Can. Petroleum Geology **31**:246-281.

Wiggins, V.D. (1976)
Fossil Oculata pollen from Alaska. Geoscience & Man **25**:51-76.

Williamson, M.-C. (1988)
The Cretaceous igneous province of the Sverdrup Basin, Canadian Arctic: Field relations and petrochemical studies. Unpublished Ph.D. thesis, Dalhousie University, Halifax, Nova Scotia, p.1-417.

Wilson, L.R. (1964)
Recycling, stratigraphic leakage, and faultly techiniques in palynology. Grana Palynologica **5**:425-436.

Wilson, M.A. (1978)
Palynology of three sections across the uppermost Cretaceous/Paleocene boundary in the Yukon Territory and District of McKenzie, Canada. Palaeontographica Abt. B **166**:99-183.

Wolfe, J.A. (1987)
Late Cretaceous-Cenozoic history of deciduousness and the terminal Cretaceous event. Paleobiology **13**:215-226.

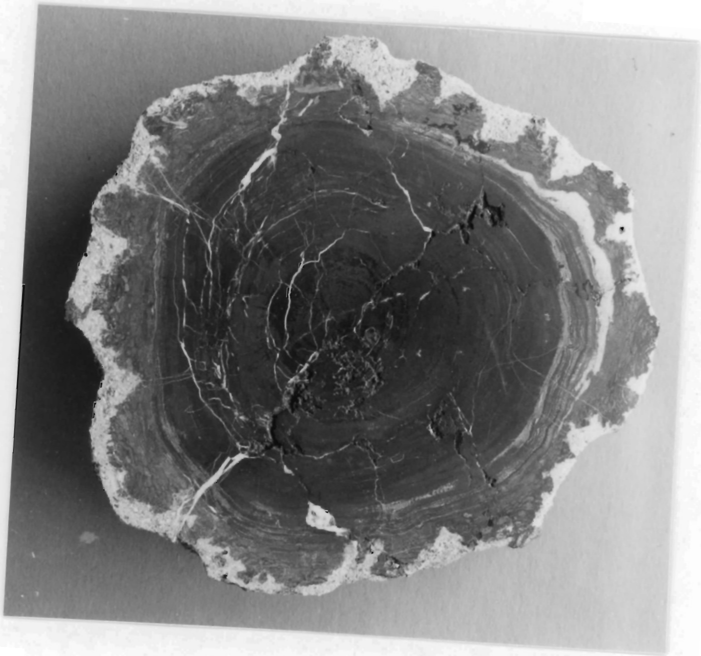
Wynne, P.J.; Irving, E.; and Osadetz, K.G. (1988)
Paleomagnetism of Cretaceous volcanic rocks of the Sverdrup Basin - magnetostratigraphy, paleolatitudes, and rotations. Canadian Journal of Earth Sciences **25**:1220-1239.

Plate 1

Figure 1: Taxodiale wood (silicified) with preserved bark. Sample EL87-027. Diameter is about 15 cm.

Figure 2: Section of Taxodiale wood (silicified). Sample EL87-027 (thin section)

1



2

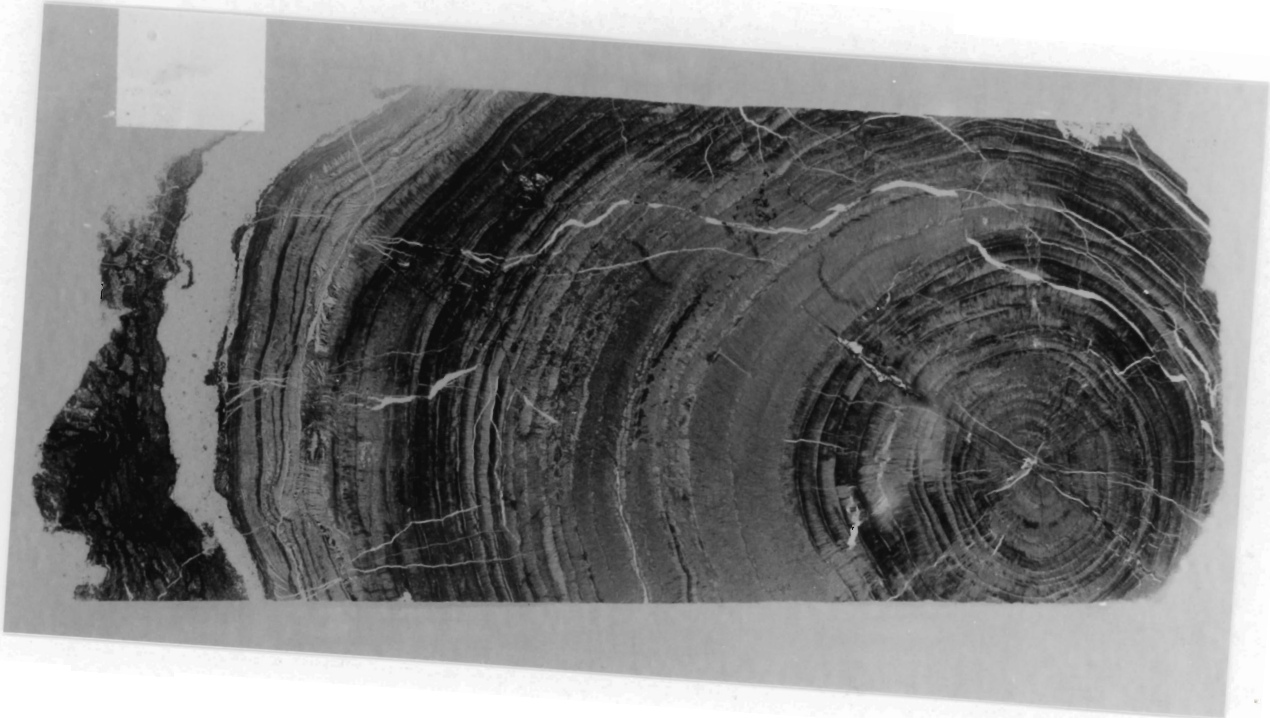


Plate 2

Figure 3: Slab with foliage. Approximately 50 cm in longest dimension. Sample EL87-060.001.

Figure 4: Slab with foliage. Approximately 50 cm in longest dimension. Sample EL87-097.001

3

4

Plate 3

Figure 5: cf. *Ginkgo*. Approximately life size. Specimen EL87-060.002A

Figure 6: *Parataxodium sp.* taxodiod foliage. Approximately 1.1 x life size. Sample EL87-060.001A

5

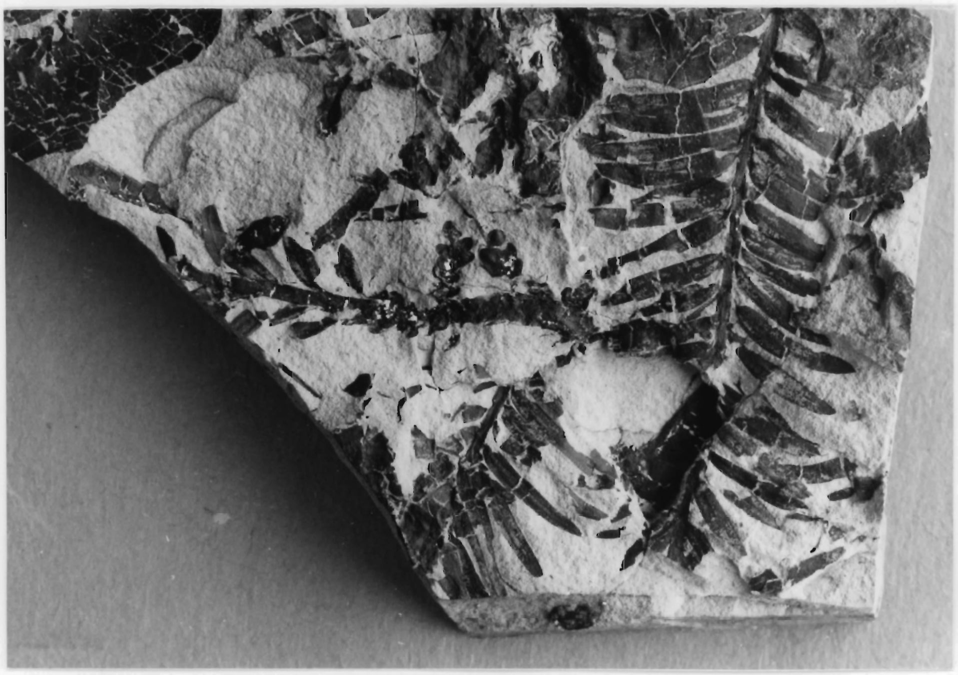
6

Plate 4

Figure 7: *Parataxodium sp*. Possible male cones (pollen bearing) at base of taxodiod shoot. Approximately 1.5x. Sample EL87-060.

Figure 8: *Parataxodium sp*. Cupressoid foliage and a female cone (upper right). Approximately 1.8x. Sample EL87-060.001A

7



8

Plate 5

Figure 9: Undet. angiosperm sp. A (left) and undet. angiosperm sp. B (right). Approximately 1.5x. Sample EL87-060.001A

Figure 10: Undet. angiosperm sp. B. Counterpart to right individual in figure 9. Leaf is enrolled. Approximately 4x. Sample EL87-060.001

9

10

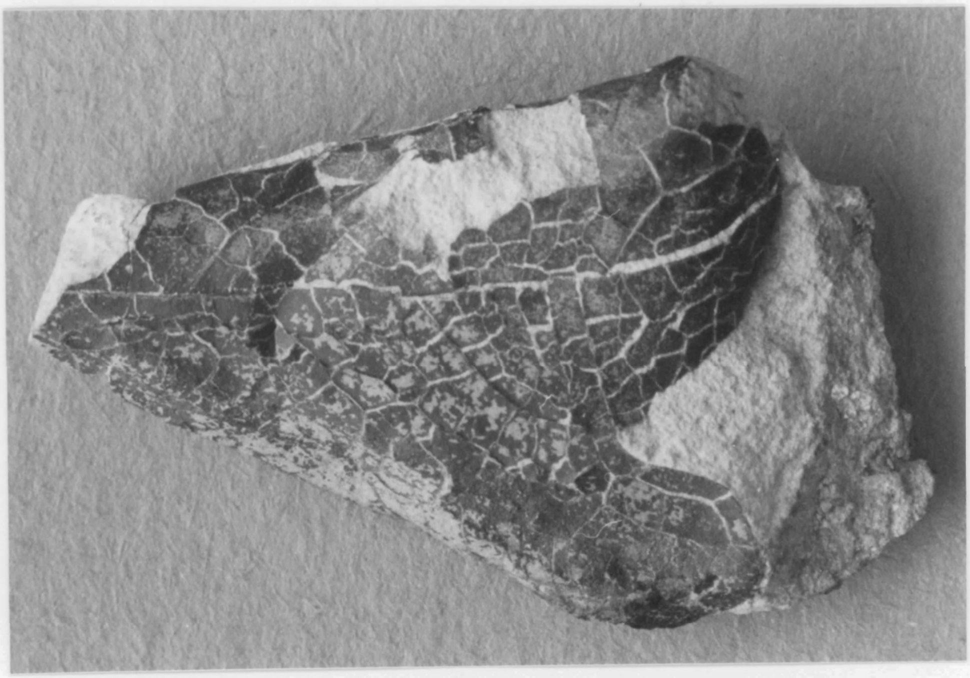
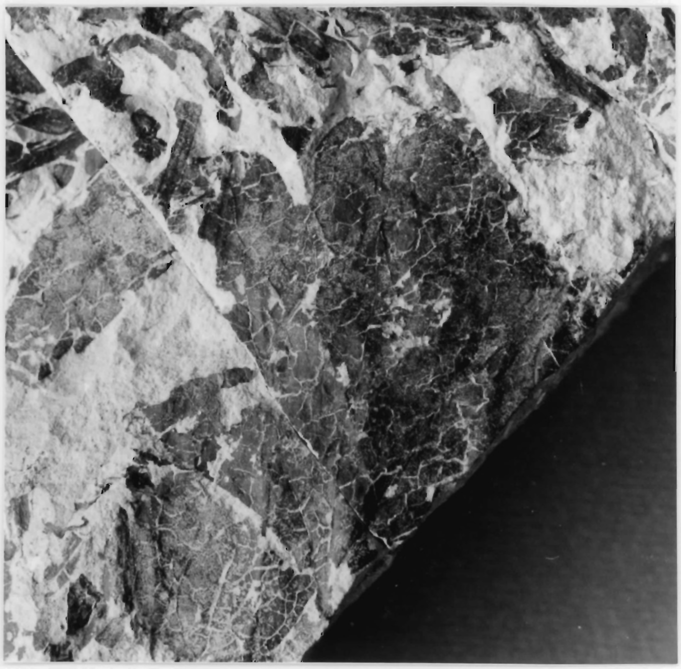


Plate 6

Figure 11: Undet. angiosperm sp. B. Approximately 1.5x. Sample EL87-097.001.

Figure 12: Undet. angiosperm sp. C. Approximately 2x. Sample EL87-097.001.

11



12

Plate 7

Figure 13: Undet. seed sp. A. Approximately 10x. Sample EL87-060

Figure 14: Undet. seed sp. B. Approximately 5x. Sample EL87-097.001.

Figure 15: Undet. seed sp. C. Approximately 5x. Sample EL87-097.001.

13

14

15

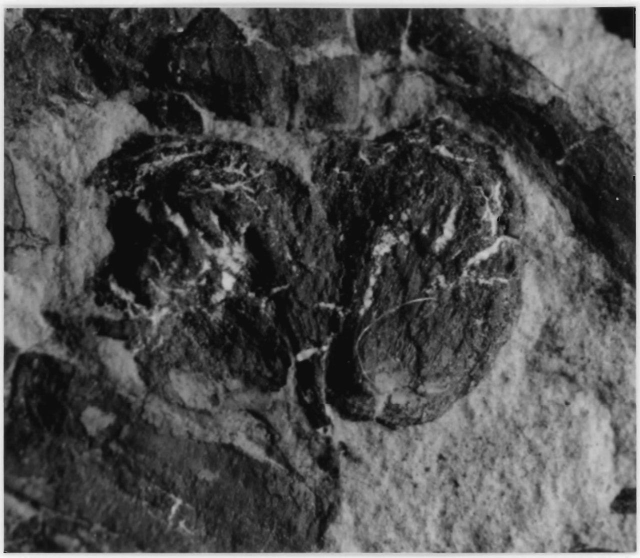


Plate 8

Figure 16: *Polyporisporites sp.* Approximately 25 µm in diameter. Strew slide EL87-109B-01; H22/2.

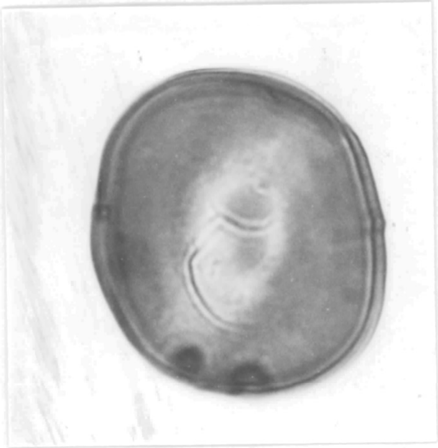
Figure 17: *Fusiformisporites sp.* Approximately 25 µm long. Strew slide EL87-109B-01; E15/3.

Figure 18: *Multicellaesporites sp.* Approximately 52 µm long. Strew slide EL87-205-01; J19/0.

Figure 19: *Multicellaesporites sp.* Approximately 38 µm long. Strew slide EL87-107-01; S10/4.

Figure 20: scutate fruiting body. Approximately 100 µm long. Strew slide EL87-107-01; Q40/2.

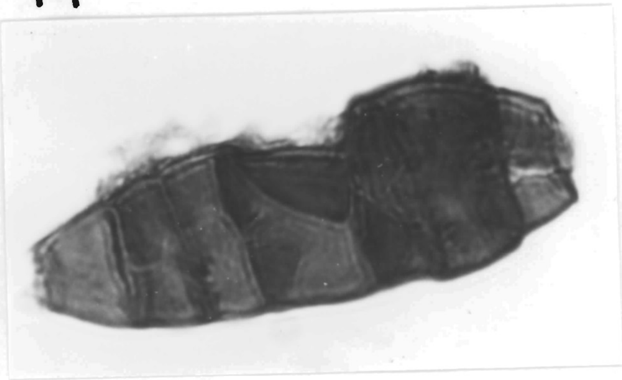
16



18

17

19



20

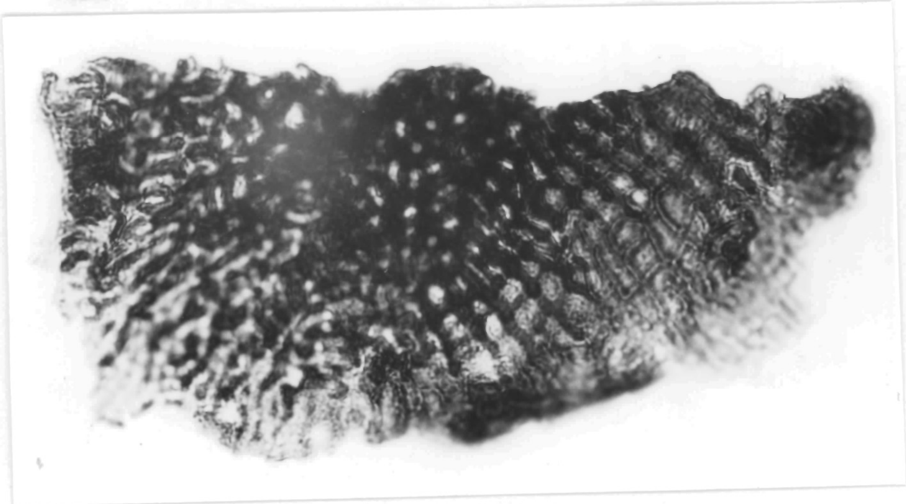


Plate 9

Figure 21: Fungal hyphae sp. A. Approximately 44 µm long. Phase contrast illumination. Strew slide EL87-106-01; W41/0.

Figure 22: undet. trilete spore sp. A. Approximately 100 µm in diameter. Normal illumination. Strew slide EL87-109B-01; K45/0.

Figure 23: undet. trilete spore sp. B. Approximately 40 µm in diameter. Normal illumination. Single grain mount EL87-120-SG11.

Figure 24: *Stereisporites antiquasporites* (Wilson & Webster, 1946) Dettmann, 1963. Approximately 26 µm in diameter. Normal illumination. Strew slide EL87-107-01; N20/2.

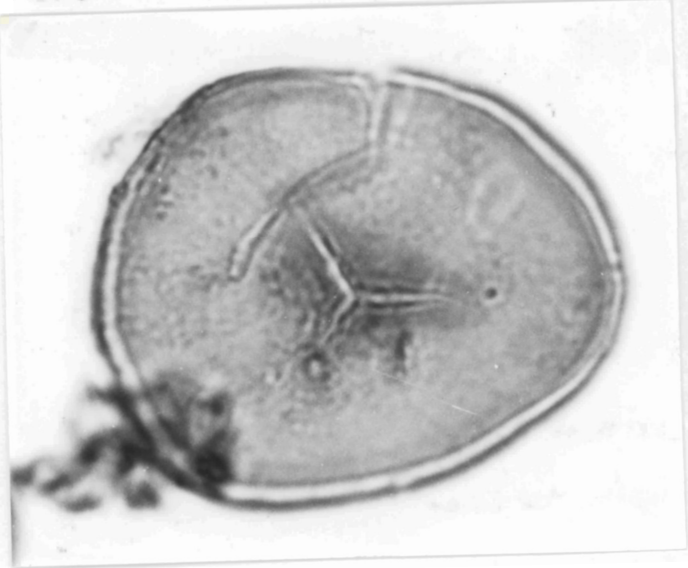
Figure 25: *Stereisporites* sp. A. Approximately 20 µm in diameter. Normal illumination. Strew slide EL87-106-01; M20/2.

Figure 26: undet. trilete spore sp. C. Approximately 35 µm in diameter. Normal illumination. Strew slide EL87-109B-01; N50/0.

21

22

24



25

26

23

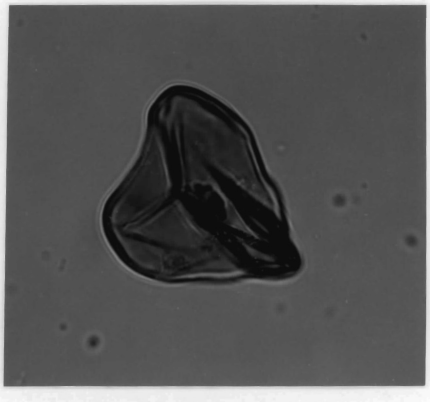


Plate 10:

Figure 27: undet. trilete spore sp. D. Approximately 30 µm in diameter. Normal illumination. Strew slide EL87-106-01; Q49/3.

Figure 28: undet. trilete spore sp. E. Approximately 22 µm in diameter. Normal illumination. Strew slide EL87-106-01; S43/4.

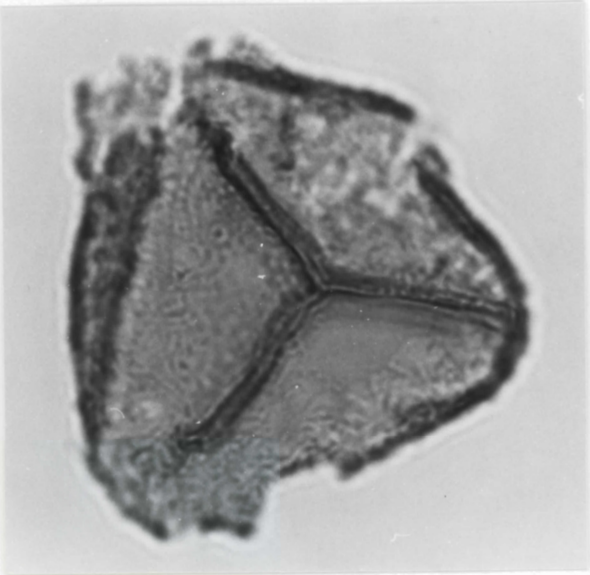
Figure 29: undet. trilete spore sp. F. Approximately 28 µm in diameter. Normal illumination. Strew slide EL87-106-02; S33/4.

Figure 30: undet. trilete spore sp. G. Central body about 30 µm in diameter. With spines, 45 µm diameter. Normal illumination. Strew slide EL87-115-02; S23/4.

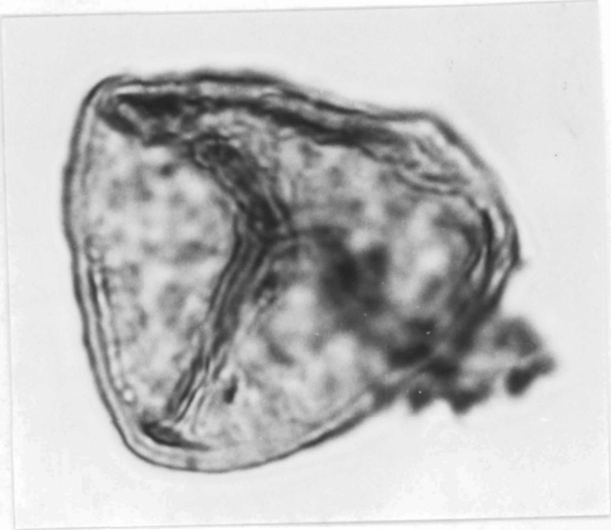
Figure 31: *Retitriletes sp.*; distal polar view. Approximately 36 µm in diameter. Normal illumination. Strew slide EL87-107-01; 031/3.

Figure 32: *Retitriletes sp.*; equatorial view. Approximately 34 µm in diameter. Normal illumination. Strew slide EL87-106-01; W35/4.

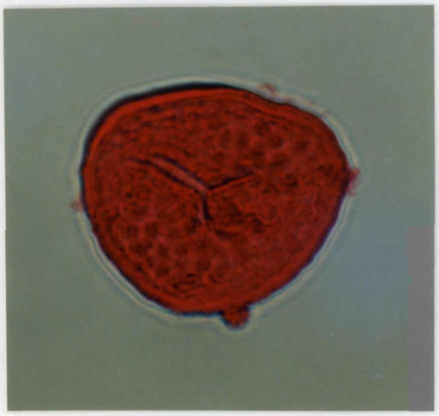
27



28

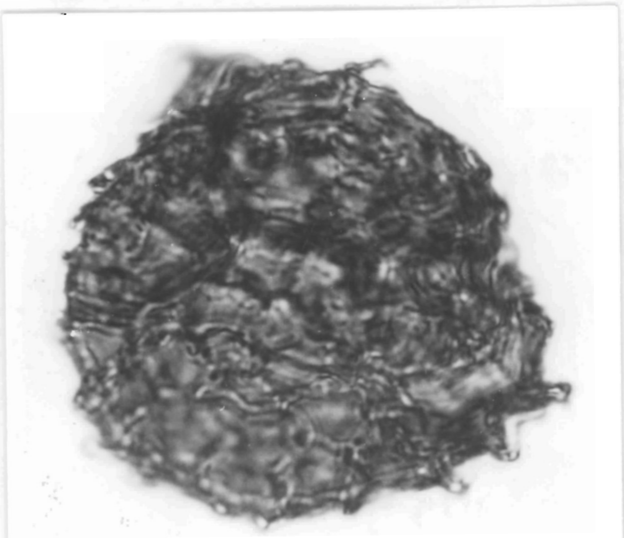


29



30

31



32

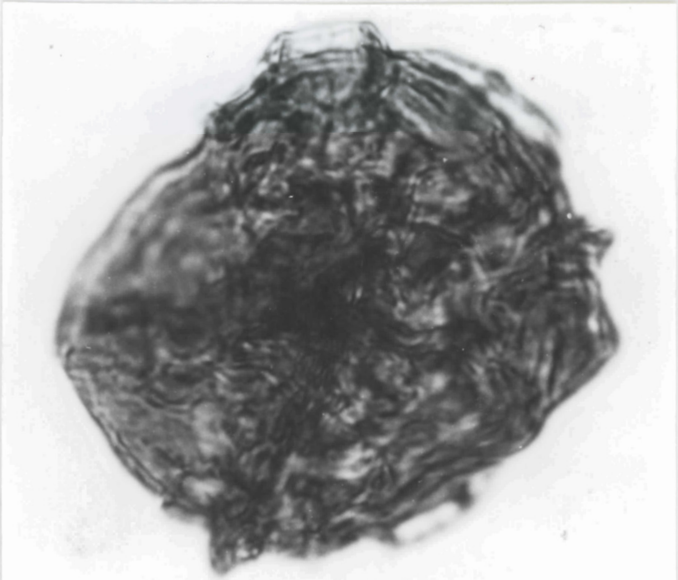


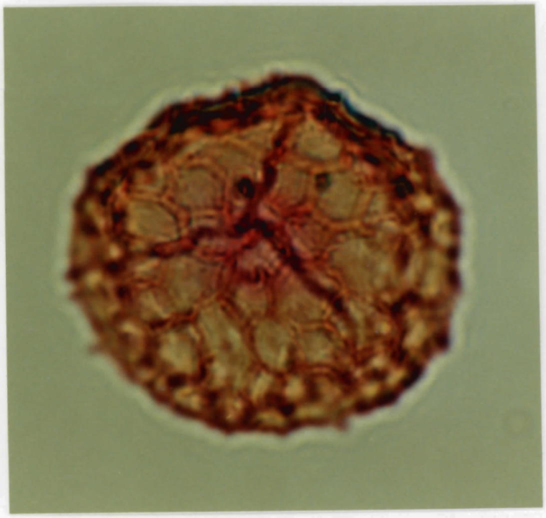
Plate 11

Figure 33: *Retitriletes sp.*; proximal polar view. Approximately 35 µm in diameter. Note lack of reticulum on contact surfaces. Normal illumination. Strew slide EL87-115-02; G39/3.

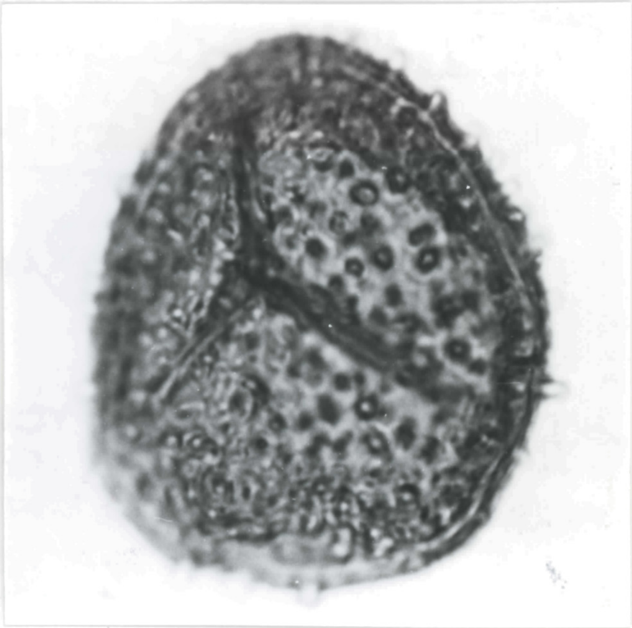
Figure 34: *Baculatisporites sp.*; polar proximal view. Approximately 32 µm in diameter. Normal illumination. Strew slide EL87-106-01; S41/0.

Figure 35: *Hamulatisporites amplus* Stanley, 1965; polar distal view. Approximately 100 µm in diameter. Normal illumination. Strew slide EL87-120-02; R39/4.

33



34



35

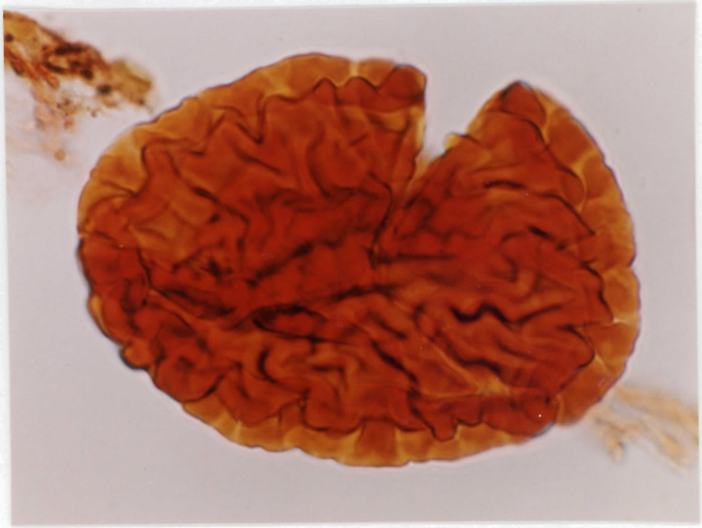


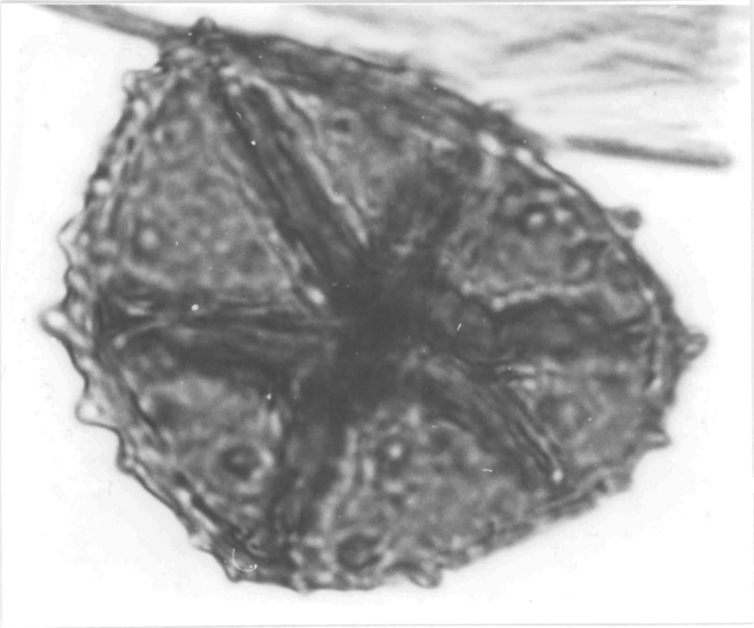
Plate 12

Figure 36: Undet. ditrilete spore; polar view. Approximately 26 µm in diameter. Normal illumination. Strew slide EL87-106-01; V50/3.

Figures 37-38: *Obtusisporites sp.*; polar view. Approximately 30 µm in diameter. Normal (figure 37) and phase contrast (figure 38) illumination. Strew slide EL87-106-01; T41/2.

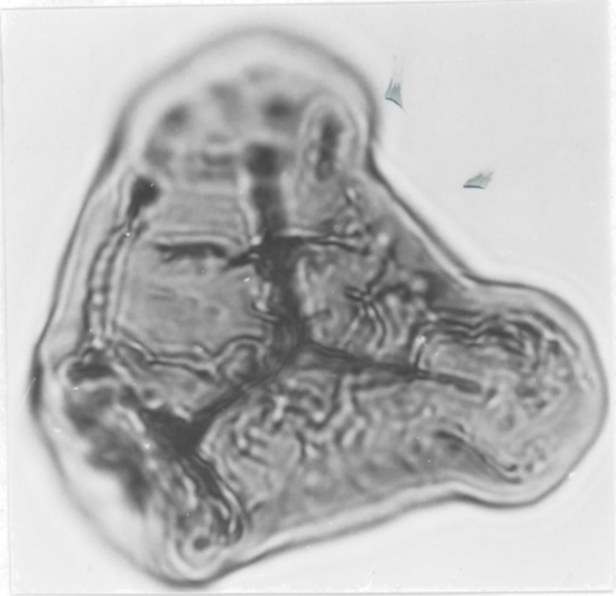
Figures 39-40: *Laevigatosporites haardti* (Potonie & Venitz, 1934) Thomson & Pflug, 1953; proximal polar view. Approximately 54 µm in length. Normal (figure 39) and phase contrast (40) illumination. Strew slide EL87-107-01; C39/3.

36

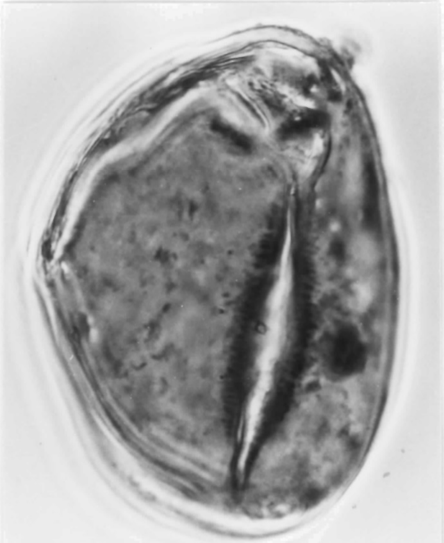


39

37



40



38

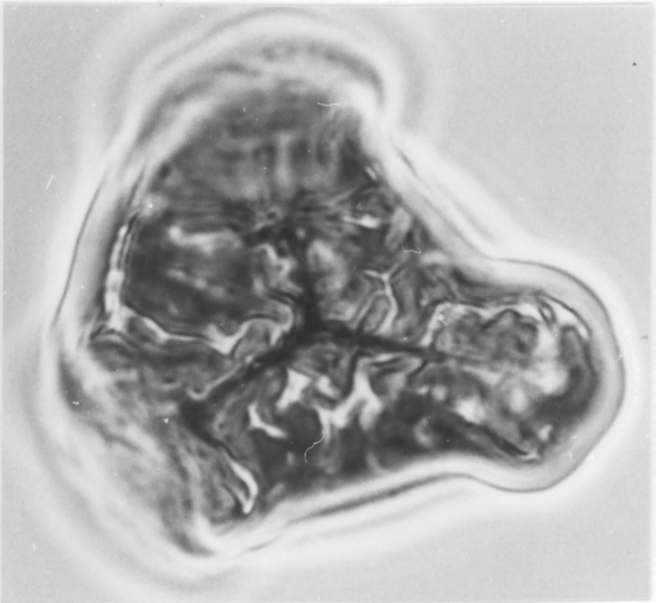


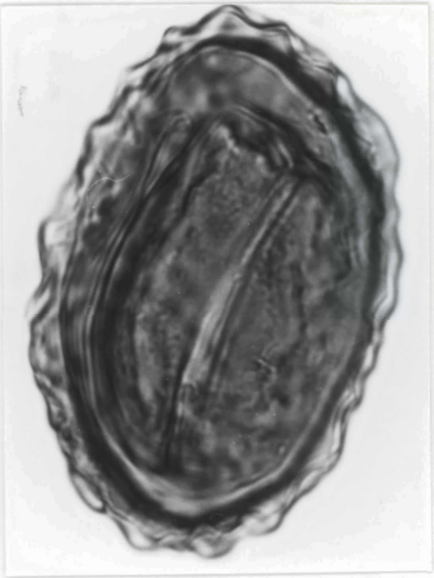
Plate 13

Figure 41: *Polypodiisporites sp.*; polar view. Approximately 46 µm in length. Normal illumination. Strew slide EL87-106-01; P48/1.

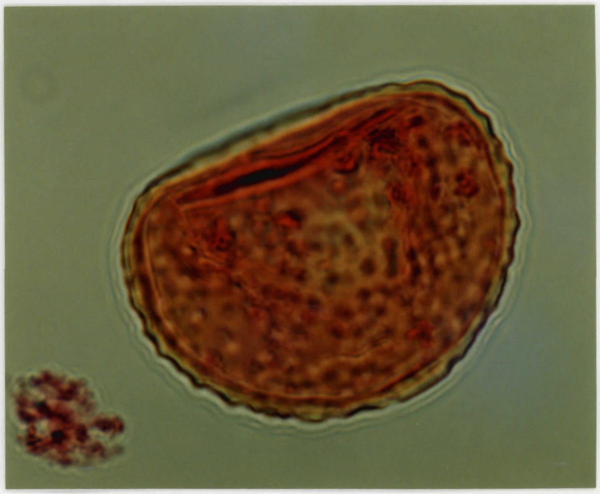
Figure 42: *Polypodiisporites sp.*; equatorial view. Approximately 40 µm long. Normal illumination. Strew slide EL87-109B-02; V23/3.

Figure 43-44: *Abietineaepollenites sp.*, polar distal view. Approximately 80 µm in longest dimension. Normal (figure 43) and phase contrast (figure 44) illumination. Strew slide EL87-109B-01; J17/2.

41



42



43

44

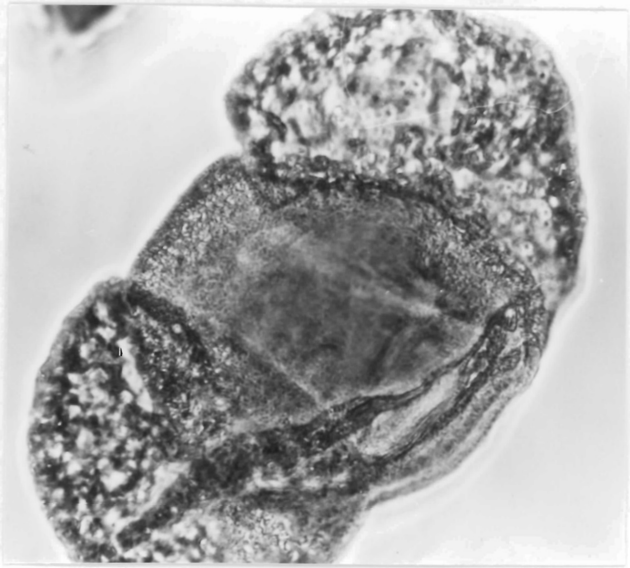


Plate 14

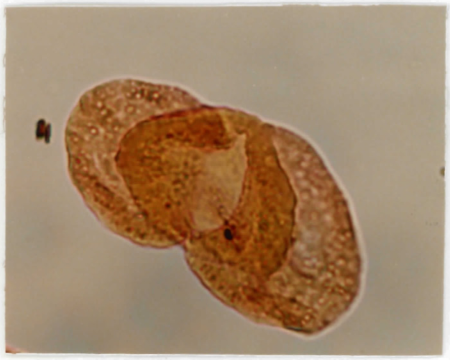
Figure 45: *Podocarpidites sp.*; polar view. Approximately 50 µm in longest dimension. Normal illumination. Strew slide EL87-109B-01; G8/1.

Figure 46: *Alisporites sp.*; polar view. Approximately 58 µm in longest dimension. Normal illumination. Strew slide EL87-107-01; T45/1.

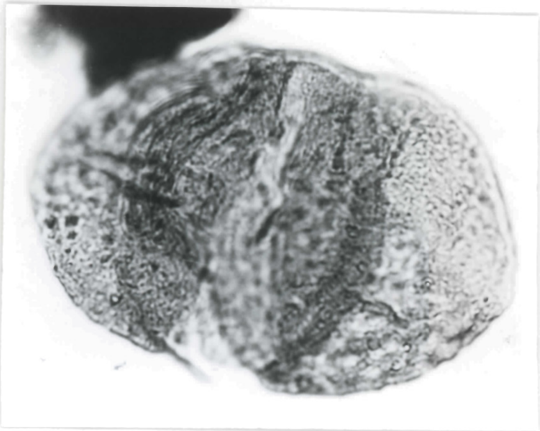
Figure 47: *Taxodiaceaepollenites hiatus* (Potonie, 1931) Kremp, 1949. Approximately 36 µm in diameter. Normal illumination. STrew slide EL87-106-02; N7/0.

Figure 48: *Sequoiapollenites sp.* Approximately 24 µm in diameter. Note the ligule. Normal illumination. Strew slide EL87-107-01; X14/3.

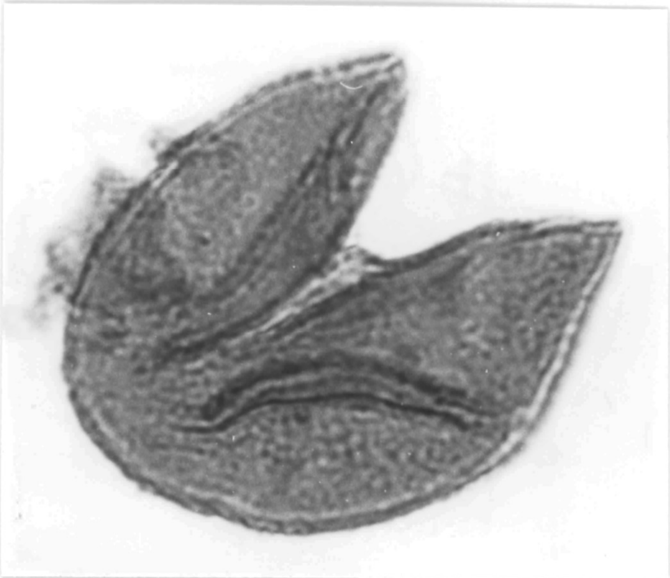
45



46



47



48

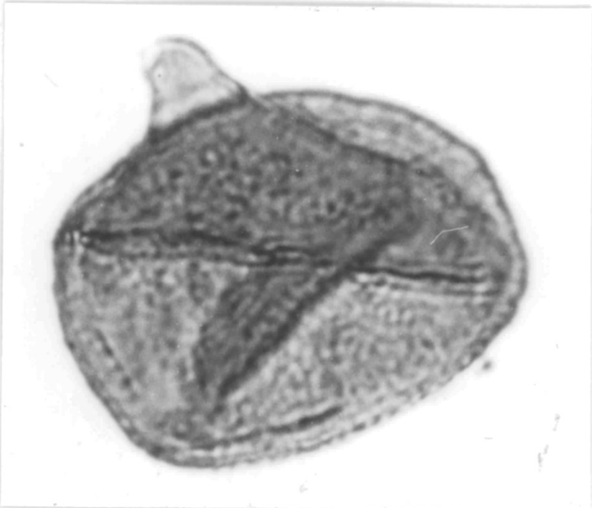


Plate 15

Figure 49: *Monosulcites sp.* Approximately 28 µm in length. Normal illumination. Strew slide EL87-109B-01; O21/2.

Figure 50: *Cycadopites* sp. A. Approximately 42 µm in length. Normal illumination. Strew slide EL87-120-01; P13/3.

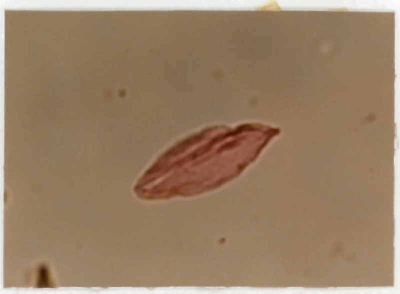
Figure 51: *Cycadopites* sp. B. Approximately 35 µm in length. Normal illumination. Strew slide EL87-115-02; T43/2.

Figures 52-53: *Liliacidites sp.*; polar proximal view. Approximately 21 µm in length. Normal (figure 52) and phase contrast (figure 53) illumination. Strew slide EL87-107-01; Y23/2.

Figure 54: *Liliacidites sp.*; cluster of 5 individuals. Approximately 34 µm in length. Normal illumination. Strew slide EL87-107-01; K5/1.

49

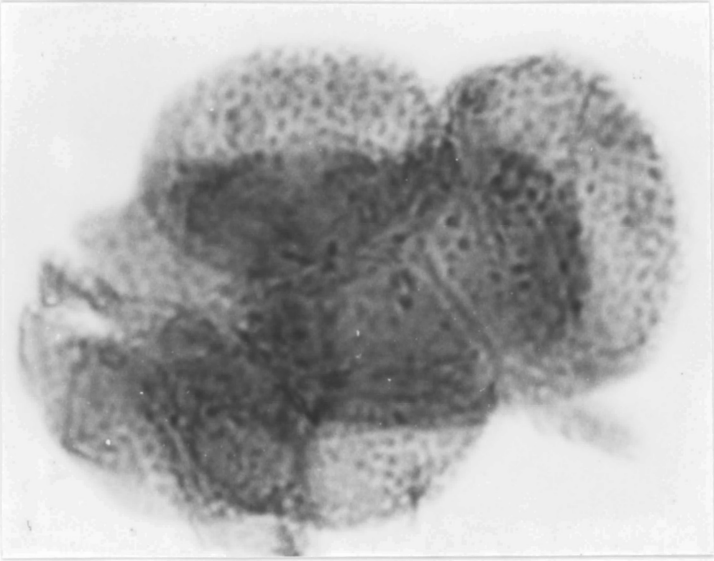
50



51

52

54



53

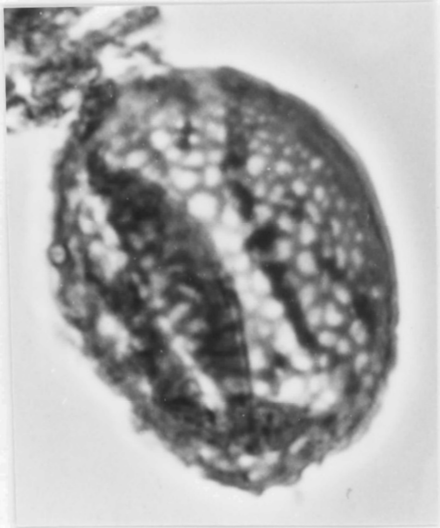
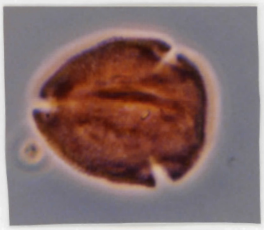


Plate 16

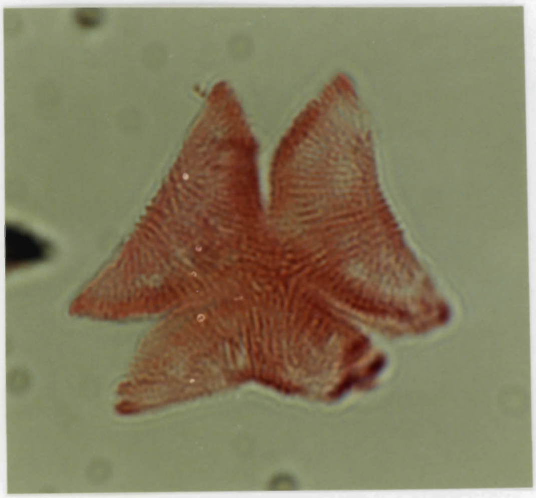
Figure 55: undet. tricolpate sp. A. Note the fine surface reticulum. Approximately 22 µm in diameter. Phase contrast illumination. Strew slide EL87-120-01; S27/2.

Figure 56-57: *Cranwellia striata* (Couper, 1953) Srivastava, 1966; polar view. Approximately 25 µm diameter. Normal (figure 56) and phase contrast (figure 57) illumination. Strew slide EL87-115-02; R15/1.

55



56



57

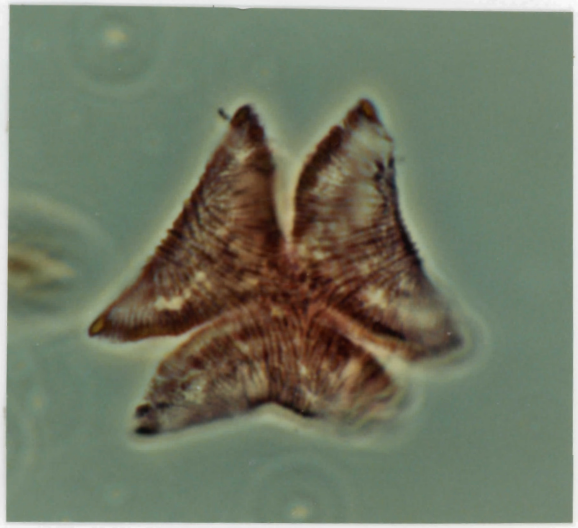


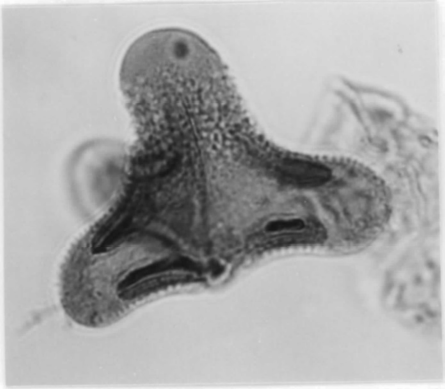
Plate 17

Figures 58-59: *Aquilapollenites* [*Mancicorpus*] *senonicus* (Mtchedlishvili, 1961) Tschudy & Leopold, 1971; equatorial view. Approximately 40 µm wide at equatorial projections. Normal (figure 58) and phase contrast (figure 59) illumination. Strew slide EL87-109B-01; V31/4.

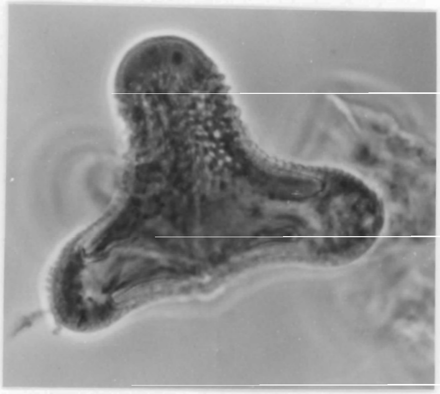
Figure 60: *Aquilapollenites* [*Mancicorpus*] *senonicus* (Mtchedlishvili, 1961) Tschudy & Leopold, 1971; minor pole view. Approximately 38 µm in diamter. Normal illumination. Strew slide EL87-109B-01; U47/1.

Figures 61-62: *Aquilapollenites* [*Mancicorpus*] *trapeziforme* (Mtchedlishvili, 1961) comb. nov.; equatorial view. Length across equatorial projections is approximately 40 µm. Normal (figure 61) and phase contrast (62) illumination. Strew slide EL87-120-02; T47/3.

58

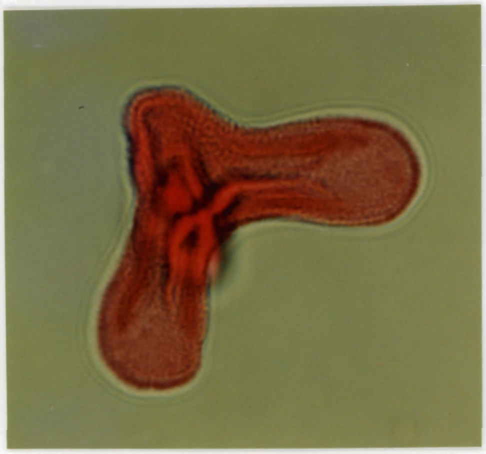


59



60

61



62

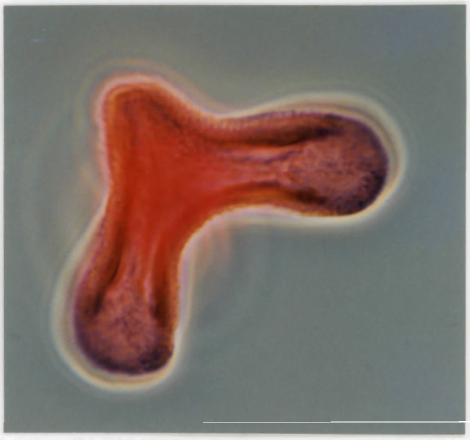


Plate 18

Figures 63-64: *Aquilapollenites* [*Mancicorpus*] *notabile* (Mtchedlishvili, 1961) comb. nov.; equatorial view. Equatorial diameter about 38 µm. Normal (figure 63) and phase contrast (figure 64) illumination. Strew slide EL87-120-02; T50/0.

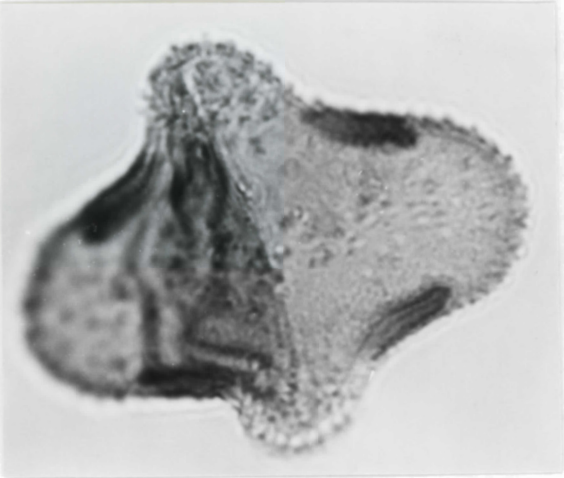
Figures 65-66: *Aquilapollenites* sp. A; equatorial view. Equatorial diameter about 37 µm. Normal (figure 65) and phase contrast (figure 66) illumination. Strew slide EL87-109B-01 T44/0.

Figures 67-68: *Aquilapollenites bertillonites* Funkhouser, 1961; sub-polar view. Equatorial diameter is about 35 µm. Normal (figure 67) and phase contrast (figure 68) illumination. Strew slide EL87-120-01; F39/4.

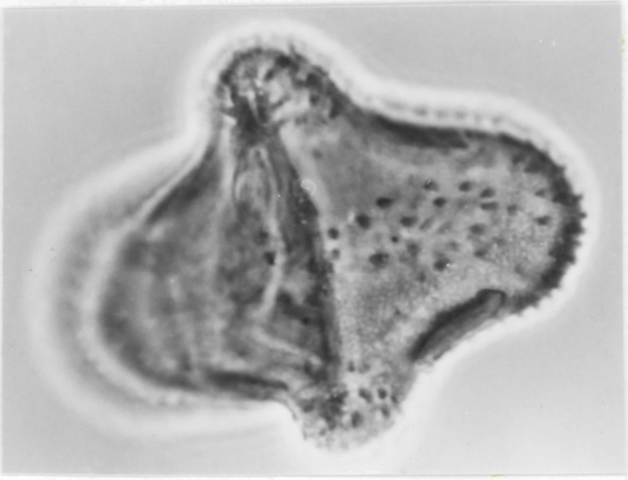
63

64

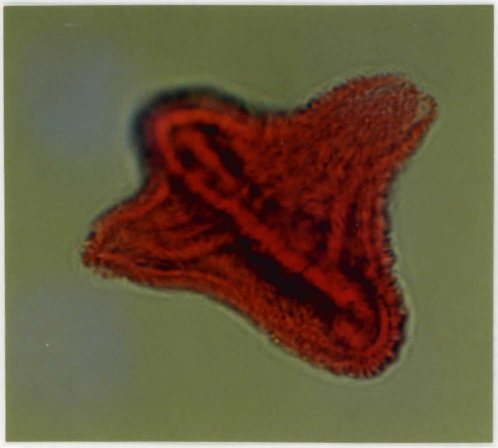
65



66



67



68

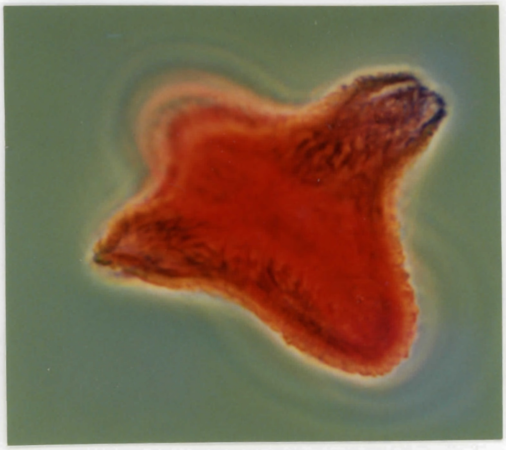
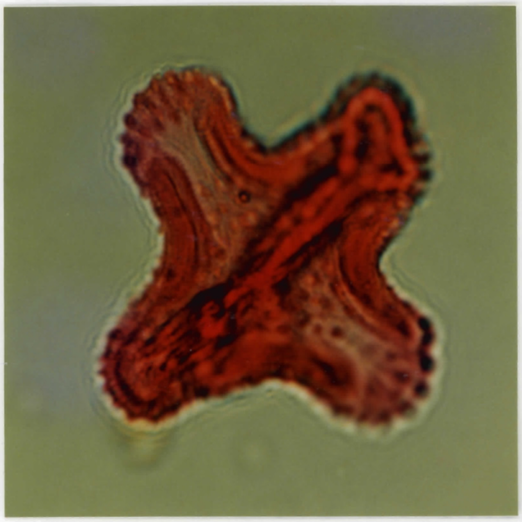


Plate 19

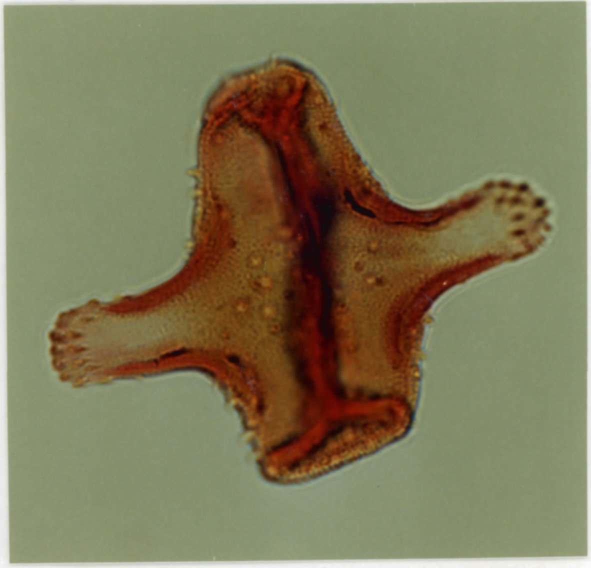
Figure 69: *Aquilapollenites dentatus* ? Tschudy, 1969; equatorial view. Approximately 35 µm equatorial diameter. Normal illumination. Strew slide EL87-120-01; Q47/0.

Figures 70-71: *Aquilapollenites* [*Triporina/Triprojectus*] *unicus* (Chlonova, 1957) Mtchedlishvili, 1961; equatorial view Polar length approximately 60 µm. Normal (figure 70) and phase contrast (figure 71) illumination. Strew slide EL87-115-02; Q23/3.

69



70



71

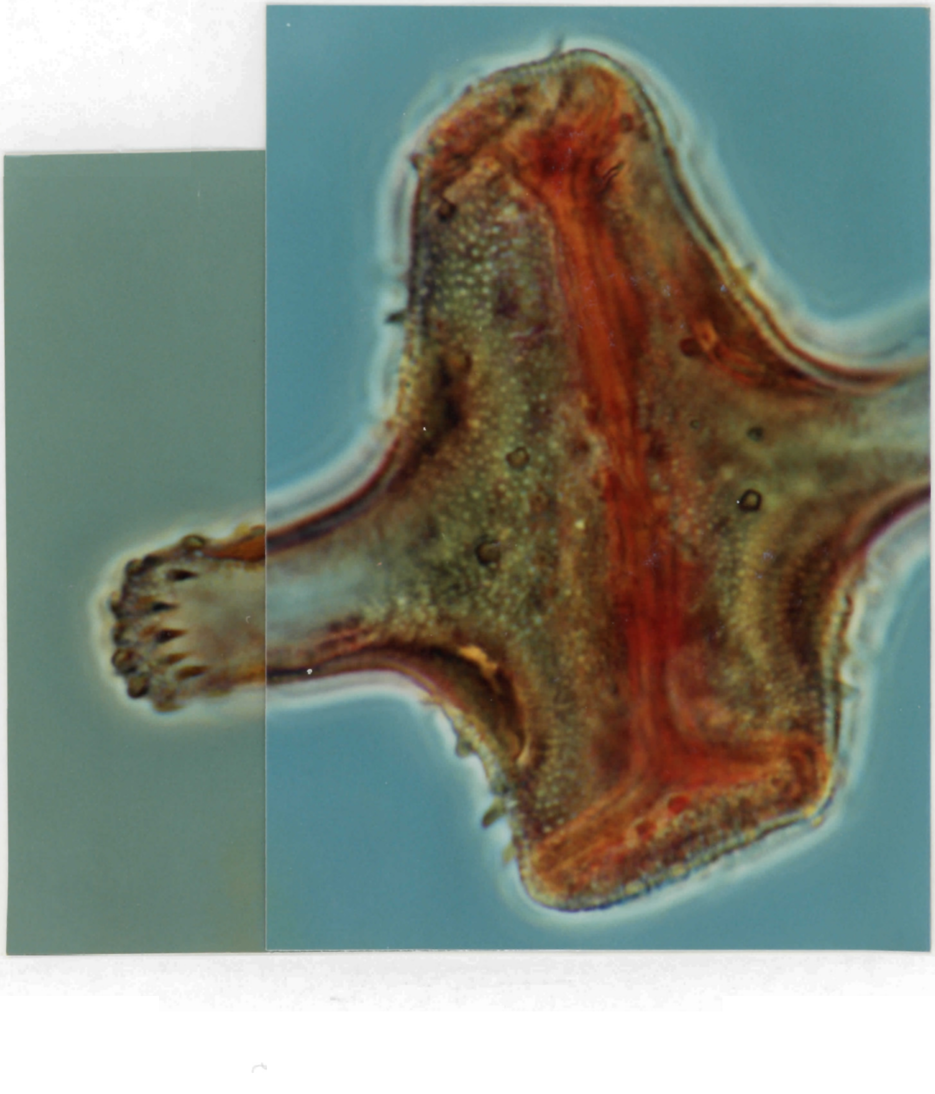


Plate 20

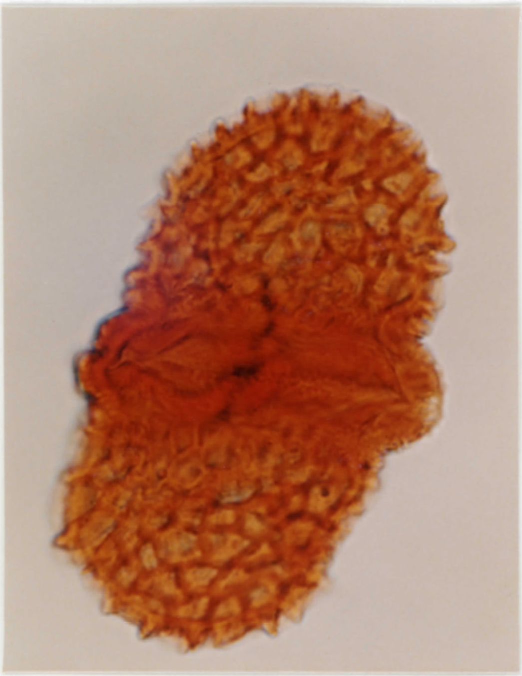
Figure 72: *Aquilapollenites* [*Integricorpus*] sp. 1 of Samoilovitch, 1967; equatorial view. Polar length approximately 70 µm. Normal illumination. Strew slide EL87-120-01; P45/1.

Figure 73: *Aquilapollenites colvillensis* Tschudy, 1969; equatorial view. Equatorial diameter about 35 µm. Normal illumination. Strew slide EL87-115-01; G34/4.

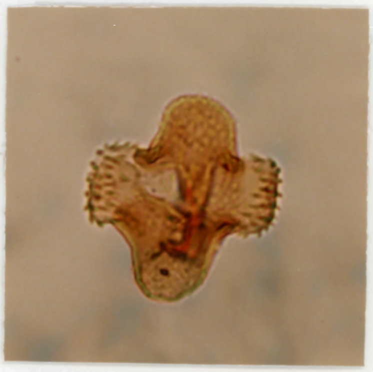
Figure 74: undet. tricolporate sp. A; polar view. Approximately 40 µm in diameter. Normal illumination. Single grain mount EL87-120-SG10.

Figure 75: undet. tricolporate sp. A; sub-equatorial view. Approximately 38 µm in diameter. Normal illumination. Single grain mount EL87-120-SG07.

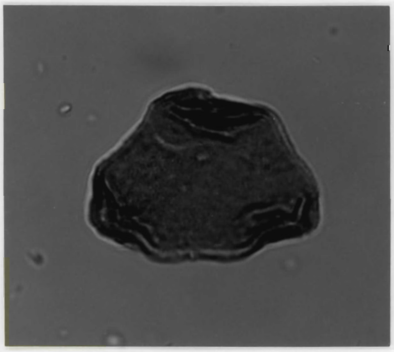
72



73



74



75

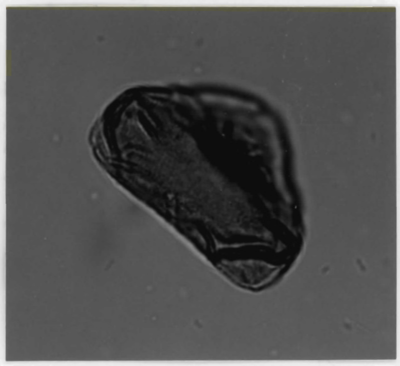


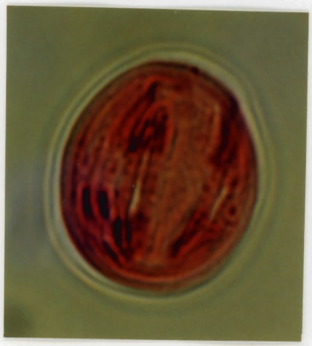
Plate 21

Figures 76-77: *Tricolporopollenites sp.*; equatorial view. Approximately 12 µm length. Normal (figure 76) and phase contrast (figure 77) illumination. Strew slide EL87-109B-01; S11/2.

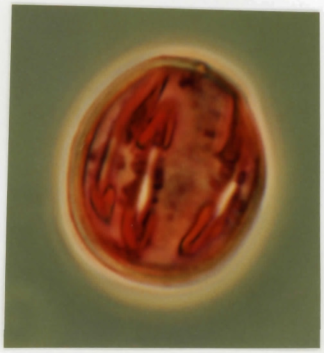
Figure 78: *Triporopollenites* sp. A; polar view. Approximately 15 µm diamter. Normal illumination. Strew slide EL87-107-01; N18/0.

Figures 79-80: *Triporopollenites* sp. B.; polar view. Approximately 15 µm in diameter. Normal (figure 79) and phase constrast (figure 80) illumination. Strew slide EL87-106-02; Q22/1.

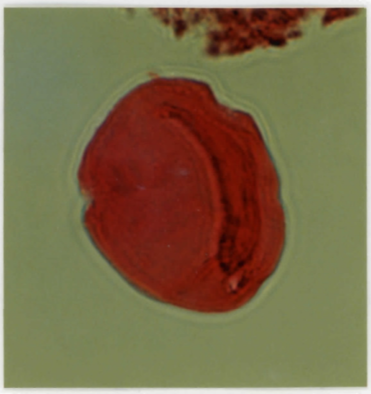
76



77



78



79

80

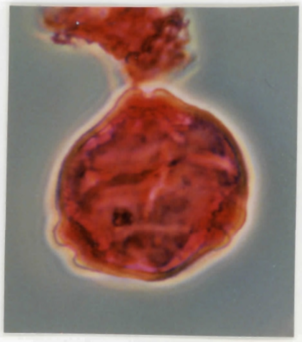


Plate 22

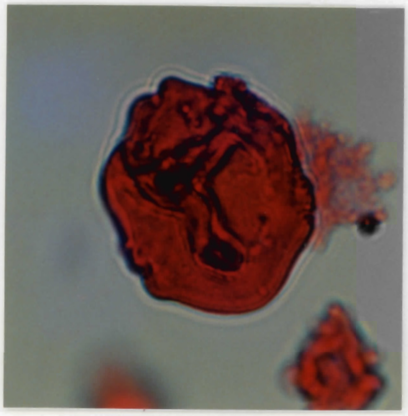
Figure 81: *Paraalnipollentes sp.*; polar view. Approximately 20 µm in diameter. Normal illumination. Strew slide EL87-106-02; Q19/3.

Figure 82-83: *Wodehouseia edmontonicola* Wiggins, 1976; minor equatorial axis view. Approximately 37 µm long. Central body about 17 µm wide. Flange about 3 µm wide. Normal (figure 82) and phase contrast (83) illumination. Strew slide EL87-106-01; S44/1.

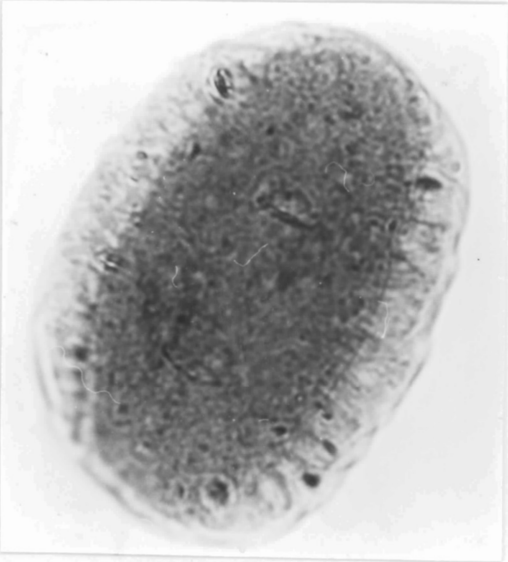
Figure, 84: *Wodehouseia edmontonicola* Wiggins, 1976; cluster of 3 individuals. Longest axis is directed towards the centre of the cluster. Approximately 50 µm across. Normal illumination. Strew slide EL87-106-01; S46/0.

Figures 85-86: *Wodehouseia gracile* (Samoilovitch, 1961) Pokrovaskaya, 1966; minor equatorial axis view. Approximately 40 µm long, central body about 20 µm wide. Flange about 4 µm at its widest. Spines to 1-3 µm diameter. Normal (figure 85) and phase contrast (figure 86) illumination. Strew slide EL87-115-01; P32/3.

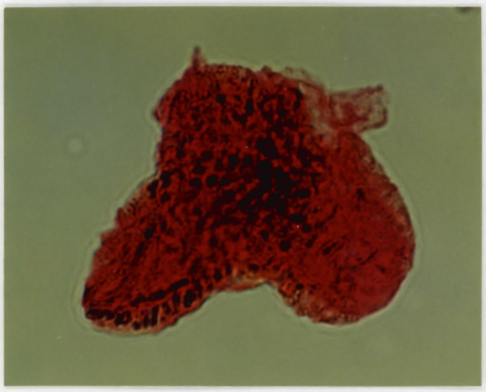
81



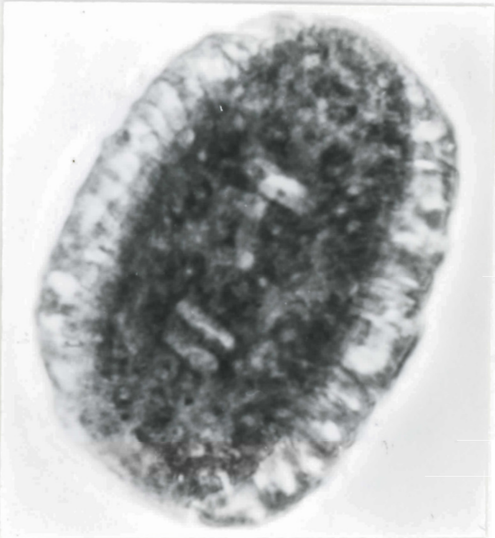
82



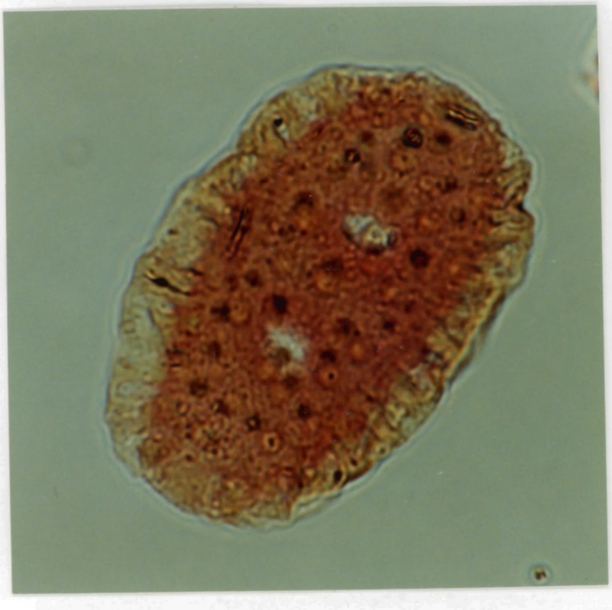
84



83



85



86

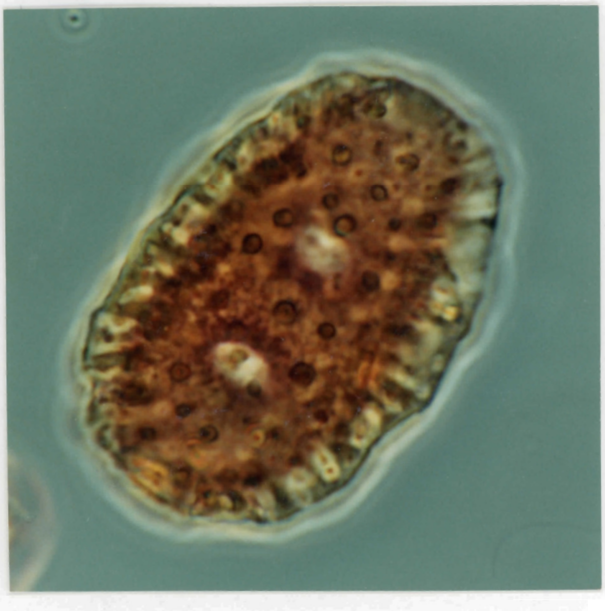
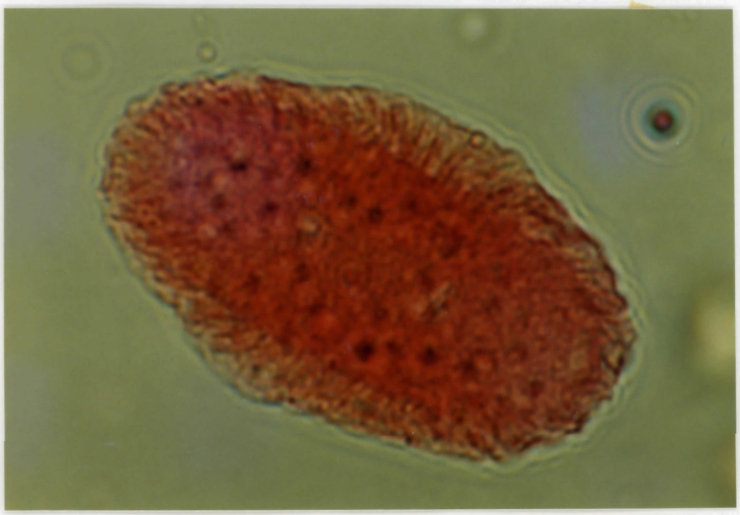


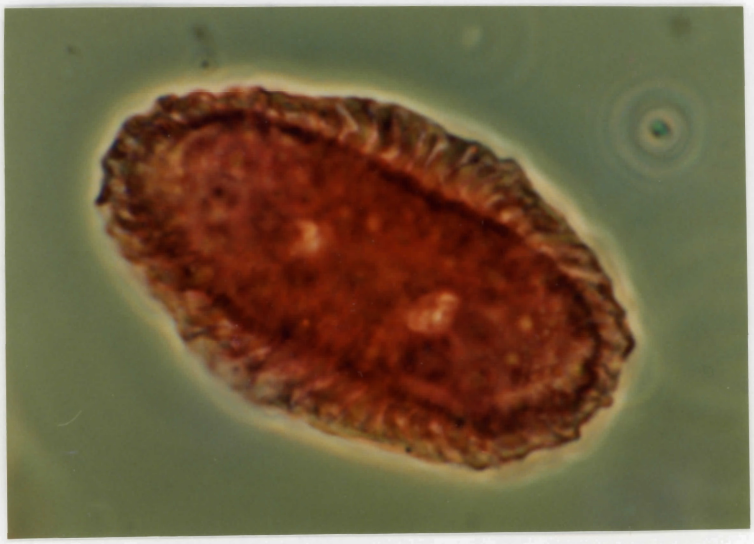
Plate 23

Figures 87-89: *Wodehouseia gracile* (Samoilovitch, 1961) Pokrovaskaya, 1966, with some characteristics of *Wodehouseia avita*, Wiggins, 1976, including curved flange spines and a more elongate body. Approximately 35 µm long. Spines are as large as 2 µm in length. Normal (figure 87) and phase contrast (figures 88 and 89) illumination. Figure 88 focuses on the pores, whereas figure 89 focuses on the spines. Strew slide EL87-120-01; L19/4.

87



88



89

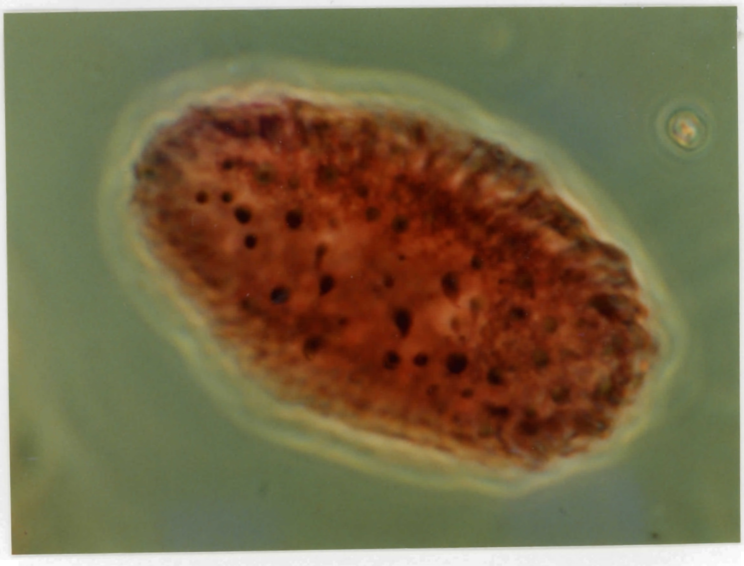


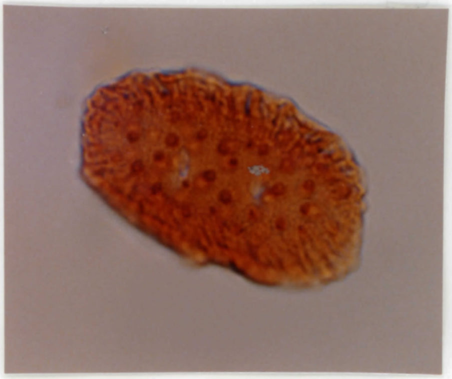
Plate 24

Figures 90-91: *Wodehouseia* cf. *Wodehouseia stanleyi* Strivastava, 1966; minor equatorial view. Approximately 32 µm long. Normal (figure 90) and phase contrast (figure 91) illumination. Strew slide EL87-118-02; R24/1.

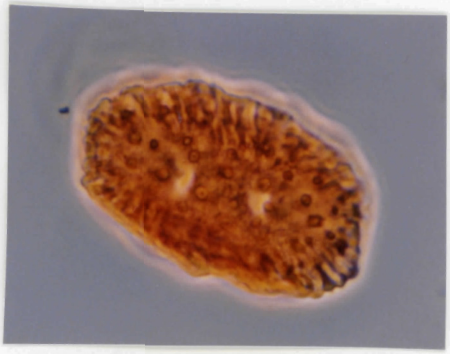
Figures 92-93: *Erdtmanipollis procumbentiformis* (Samoilovitch, 1961) Krutzsch, 1966. Approximately 40 µm in diameter. Normal (figure 92) and phase contrast (figure 93) illumination. Strew slide EL87-118-01; S23/3.

Figure 94: Leaf cuticle fragment. Approximately 112 µm long. Normal illumination. Strew slide EL87-106-01; S33/2.

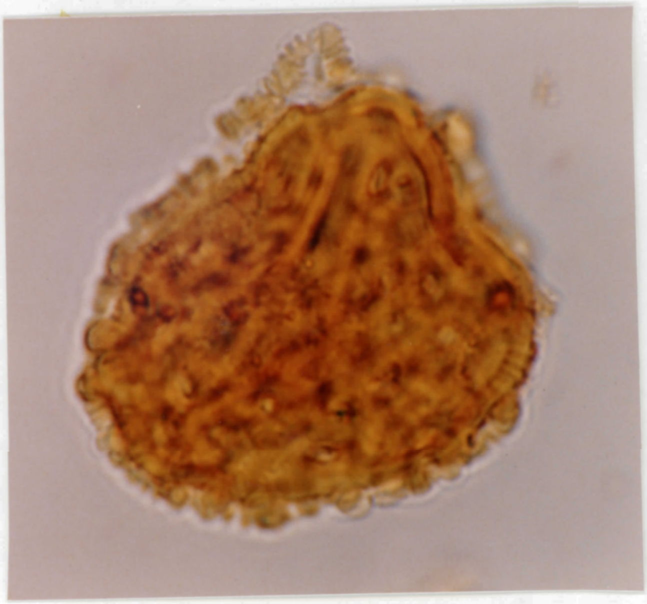
90



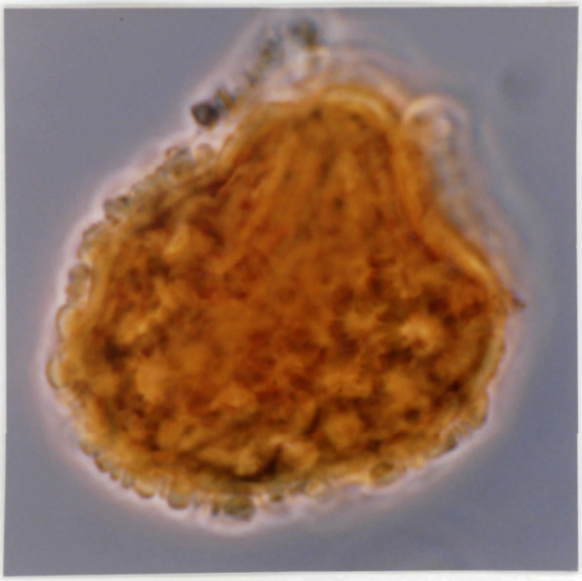
91



92



93



94