c1

PALYNOSTRATIGRAPHIC INVESTIGATION OF UPPER MAASTRICHTIAN AND PALEOCENE STRATA NEAR TATE LAKE, N.W.T..

by

Gerhard Bihl

B.Sc., University of Alberta, 1967
M.Sc., University of Alberta, 1968

A thesis submitted in partial fulfilment of the requirements for the degree of doctor of philosophy

in the Department
of
Geology

We accept this thesis as conforming to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

October , 1973

In presenting this thesis in partial fulfilment of the requirements for an advanced degree at the University of British Columbia, I agree that the Library shall make it freely available for reference and study. I further agree that permission for extensive copying of this thesis for scholarly purposes may be granted by the Head of my Department or by his representatives. It is understood that copying or publication of this thesis for financial gain shall not be allowed without my written permission.

Department of Geology

The University of British Columbia
Vancouver 8, Canada

Date 22/10/1973

ABSTRACT

Sedimentary strata near Tate Lake, south of Norman Wells, N.W.T., were investigated using palynomorph analysis indicating the presence of Upper Maastrichtian and Paleocene beds. The Upper Maastrichtian sections contain two local palynostratigraphic zones correlative with Srivastava's *Wodehousea spinata* and *Mancicorpus gibbus* zones of the Edmonton and Battle Formations of Alberta, and other Maastrichtian formations in western North America. The Paleocene strata compare lithologically and palynologically with the Lower Fort Union Group of Montana and Wyoming, the post-Brazeau beds of the Alberta Foothills, the upper part of the Bonnet Plume Formation, N.W.T., and Tertiary coal deposits in Spitzbergen. A progressive cooling in climate from subtropical to warm temperate during Upper Maastrichtian times is indicated by the decrease in the number of angiosperm species and greater influx of gymnosperms and pteridophytes. A marked change in microflora and lithology at the Cretaceous-Tertiary boundary indicates temperate conditions and increased rates of sedimentation in the Tate Lake area. Major lignite seams characteristic of the Paleocene strata probably were produced in freshwater swamps in one of the subsiding sedimentary basins formed along the east side of the Mackenzie Mountains during the Laramide orogeny. The Tate Lake strata appear to be part of the Hell Creek-Fort Union type formational sequences straddling the Cretaceous-Tertiary boundary indicating that climatic and sedimentary conditions were very similar all along the Rocky Mountains. On this basis corresponding changes are predicted for the Monster, Reindeer and Moose Channel Formations.

TABLE OF CONTENTS

TEXT FIGURES

TEXT FIGURES PAGE

MICROFOSSIL FIGURES

ACKNOWLEDGEMENTS

I am most grateful to Dr. G.E. Rouse, under whose direction this thesis was prepared, and who gave generously of his time for discussions, provided continual encouragement and proved an ever-present source of stimulation. I also wish to extend my thanks to my assistant Mr. Ross Hill for help in the field beyond the call of duty; Dr. F.R. Clarke, P.Gordy, C.Bruce and A.Audretsch of Shell Exploration, Calgary, for organizational support before and during the fieldwork; Drs. C. Yorath and W. Brideaux from the Geological Survey of Canada and Mr. D. McIntyre, Chevron Standard, Calgary, for helpful discussions. Support for the thesis work was provided by National Research Council and Union Oil Company grants plus Shell Exploration field and laboratory assistance. Dr. L. Bayrock and Mr. T. Reimchen assisted editorially.

INTRODUCTION

The purpose of the present study is a palynostratigraphic zonation of a series of interbedded lignites, shales, siltstones, sandstones and chert conglomerates exposed in badlands west of Tate Lake near the headwaters of the East Fork of Little Bear River (Fig.1,2) and to compare the obtained palynomorph assemblages with those of similar age from other regions of western North America. The resultant biostratigraphic framework should assist oil exploration efforts being conducted in the Mackenzie lowlands.

The badlands appear to be part of a series of erosional Tertiary remnants that extend along the eastern flank of the Rockie Mountains from Wyoming to the Mackenzie Delta. Except for a wind-swept treeless dissected plateau at elevations between 800 to 1000 meters above sea level, the area is covered by dense taiga and muskeg, with many lakes poorly drained by small meandering streams. Outcrops between altitudes of 800 to about 600 meters occur only as mudslide scars and cutbanks along the major streams.

In 1768 Alexander Mackenzie observed burning coal seams along the Mackenzie River near Fort Norman, which are very similar to the coal seams exposed in the Tate Lake badlands. J.W. Dawson (1889) correlated plant macrofossils collected from the banks of the Mackenzie south-west of Fort Norman with the Fort Union flora of the Great Plains, and Williams (1922) described in detail the lithologies from which the fossils were collected. Bell (1949) identified the flora as correlative with the post-Brazeau beds of the Coalspur Saunders area, Alberta, assigning to it a Lower Paleocene age. No work was carried out in the Tate Lake area until the Second World War (the Canol project), during which Hart (1944), probably on sedimentologic and stratigraphic evidence assigned the lignites and conglomerates of the badlands to the Tertiary, describing them as resting conformably upon the Upper Cretaceous East Fork Formation.

To obtain palynologic evidence of the age of the Tate Lake deposits, several sections in the badlands were measured and sampled by the writer to ensure as much horizontal and vertical coverage as possible (Fig.3,4). Nearly all shales, siltstones and lignites were sampled to obtain maximum information on the sedimentation and contemporaneous paleoecological conditions. Badland exposures on the east side of Summit Lake were also investigated, and descending the East Fork of Little Bear River by rubber raft more information about the stratigraphic relationships between the Tate Lake beds and underlying strata was obtained.

Standard palynological techniques using HF, HNO_3, and K_2CO_3 were employed to prepare the organic residue from the rock matrices; the mounting medium is glycerin jelly. Photomicrographs were obtained with a Leitz Orthomat on Leitz Ortholux microscope # 634136.

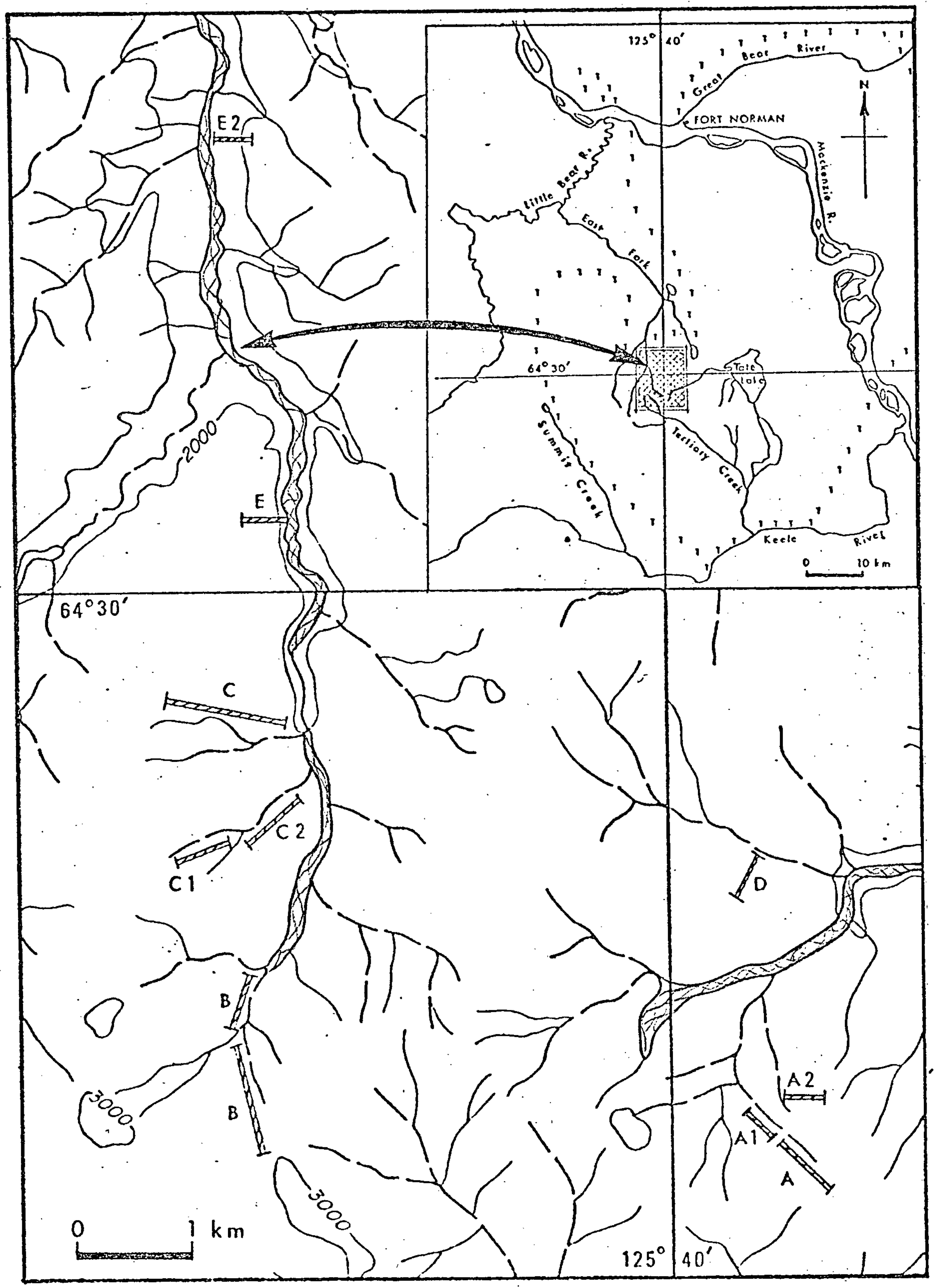


Fig.1. Map of Tate Lake area. Letters A–E denote sections in the cross-hatched area. T denotes probable extent of Tertiary strata.

Fig. 2a. Badlands developed in Lower Paleocene sediments near Tate Lake, N.W.T.. View from the B-section due east towards the A-section indicated by an arrow.

Fig. 2b. Volcanic ash marker surrounding charred tree (? *Metasequoia*) above a massive lignite seam, B-section. The measuring stick to the right of the tree stump is 5 feet long.

Fig. 2a

Fig. 2b

STRATIGRAPHY

Two distinct lithological units were recognized in the Tate Lake badlands. The lower unit consists of soft grey and brown shales with minor beds of fine grained sandstone. The upper unit is characterized by thick conglomerates and series of closely spaced lignites interbedded with siltstones, shales, many volcanic ash layers and minor sandstones.

From the contact with the upper unit at the headwaters of the East Fork River, no major lithological changes were recognized by the writer when descending the River to the junction with the Little Bear River. Near this junction (N 64°47'; W 126°02') is the type section of the East Fork Formation currently being redefined by Dr. C. Yorath of the Geological Survey (pers.comm.) which is Late Campanian to Early Maastrichtian in age. Since there appears to be a uniform lithology between the type section and the contact with the overlying conglomerates at the headwaters of the East Fork River the lower unit is here tentatively referred to the East Fork Formation. Palynoassemblages recovered reach from Upper Campanian-Lower Maastrichtian to Upper Maastrichtian which makes the East Fork Formation correlative with the Edmonton Formation. If sedimentation throughout the Maastrichtian was continuous in this area palynostratigraphic zones similar to those described by Srivastava from Alberta can be expected.

The upper unit is described in Hume (1954):

> "On the Little Bear River and tributaries, Hart (10) reports 1,600 feet (484.8 meters) of Tertiary beds. These consist of coarse, carbonaceous sands, gravels, conglomerrates, shales and lignites. At the headwaters of the East Fork River there are lignites 8 to 10 feet thick. For 18 miles along the East Fork River, near its headwaters, the high hills on both sides are made up of Tertiary beds with a measured thickness of over 1,200 feet (363.6 meters)".

This entire unit is characterized by rapid lateral change in lithofacies. For purposes of correlation with time equivalent rock units in the N.W.T. and adjacent areas of western North America the approximately 400 meters of Tertiary strata covering close to 1200 spuare kilometers are here informally designated the Tate Lake conglomerates. The Tate Lake conglomerates extend from near Red Dog Mountain on the Keele River in the south (N 64°15'; W 125°30') along the upper Summit Creek to the vincinity of the junction of Ration Creek and the Little Bear River (N 64°35'; W 126°10'). Eastward the Tate Lake conglomerates can be traced to the headwaters of the East Fork River and Tate Lake (approx. N 64°35'; W 125°10') and from there south along Steward Lake to the Keele River. The Tate Lake conglomerates may be continuous with the Tertiary strata on both sides of MacKay Mountains and around Fort Norman from where they extend about 50 kilometers up the Big Bear River to the Franklin Range and up the Mackenzie River beyond old Fort Point (Williams 1922, Hart 1944, Hume 1954, Yorath pers. comm.). Good outcrops occur around Tate Lake, Summit Lake and the MacKay Mountains. However most of the surface overlying the Tate Lake conglomerates is muskeg and exact boundary relationships are uncertain. In general the Tertiary strata are bounded by Cretaceous rocks to the north and south, and by Devonian rocks to the east and west. Where observed the Tate Lake conglomerates overlie conformably the East Fork Formation (Hart 1944, Bihl this report) and are overlain by glacial drift (Tassonyi 1969). The sampled sections are located at the headwaters of the East Fork River, in a treeless badland terrain between about 670 and 1170 meters above sea level (Fig. 1). The general lithology (Fig. 3 and 4) from the contact with the East Fork Formation is approximately 33 meters of rusty weathering conglomerates with sand and coal stringers and one major coal seam near the bottom; this is followed by 177 meters of grey weathering chert conglomerate with sand, siltstone and shale stringers; then 126 meters of interbedded lignites (seams up to 2.6 meters thick), shales, siltstones and numerous volcanic ash beds of which very few exceed 30 centimeters; and on the top there are about 40 meters of chert conglomerate and conglomeratic sandstones with minor shales and occasional coal stringers. As a result of local lignite combustion the surrounding shales and siltstones are baked a brick red and associated volcanic ash layers are fused to a grey or jasper coloured "glass" occasionally filled with leaf impressions of Metasequoia occidentalis (Rouse pers. comm.).

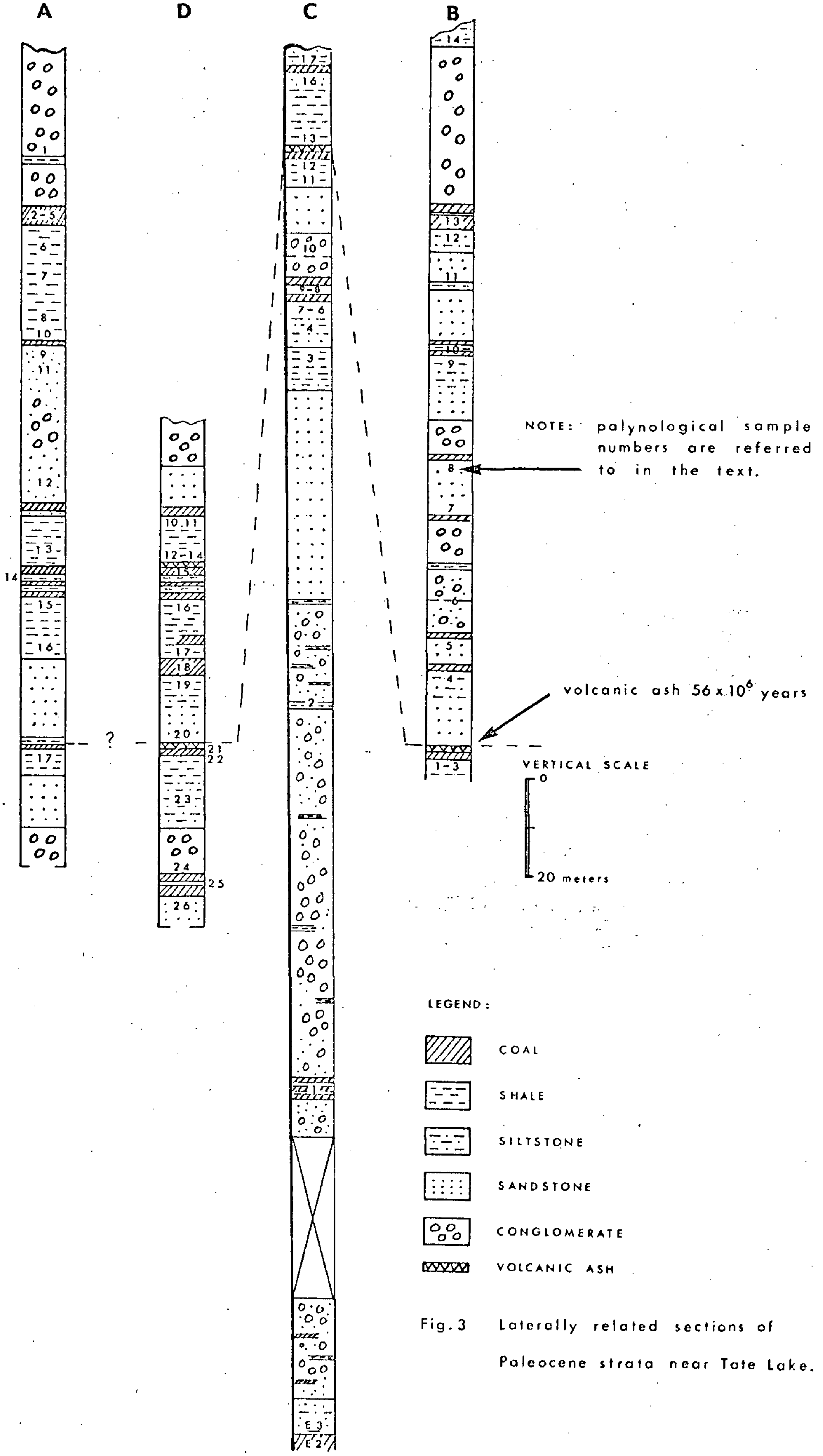


Fig. 3 Laterally related sections of Paleocene strata near Tate Lake.

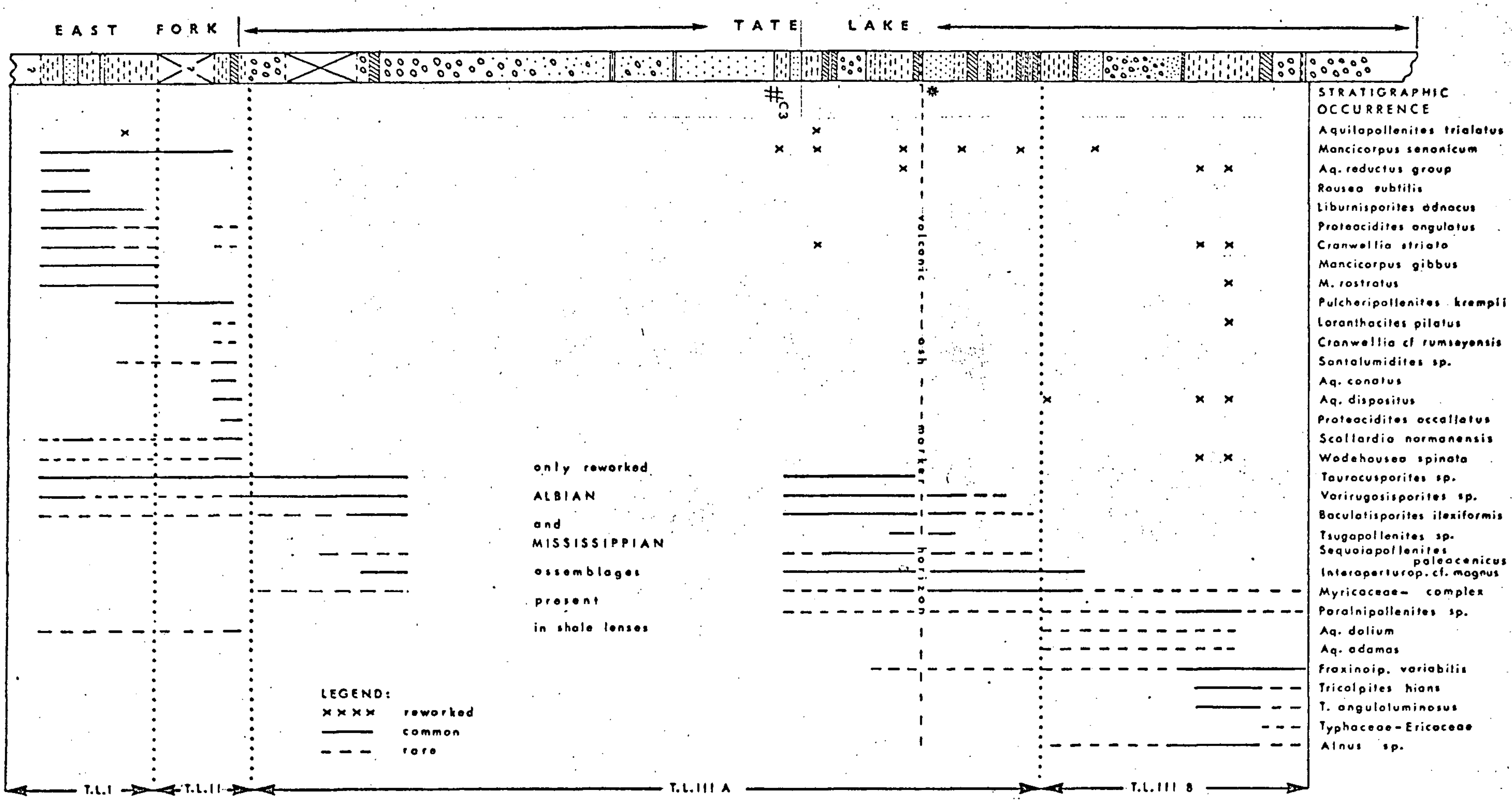


Fig. 4. TATE LAKE COMPOSITE SECTION WITH LOCAL STRATIGRAPHIC RANGES OF CHARACTERISTIC INDEX PALYNOMORPHS.

RESULTS

For correlation purposes a composite section was compiled to encompass both the Paleocene and Maastrichtian beds (Fig.4). The Paleocene sediments, dominated by poorly sorted coarse clastics, showed good recovery of palynomorphs from siltstones and shales interbedded with the lignites. The lignites themselves are generally very woody with low palynomorph content. Shale stringers in the conglomerates usually yielded a high proportion of Lower Cretaceous and Mississippian palynomorphs. The best recovery from the underlying Maastrichtian beds was obtained from dark grey shales.

Assemblages and Zonation: Analyses of samples show three well-defined palynomorph assemblage zones present in the composite Tate Lake section. The characteristic index species only are listed here. Complete listings of palynomorphs for the three assemblage zones are given in Appendix II. The zones denoted T.L.I and T.L.II are Maastrichtian in age while T.L.III is of Paleocene age.

The lowest zone (T.L.I) shows the greatest species diversity and is characterized by the following (see Plate I):

Mancicorpus gibbus Srivastava

M. rostratus Srivastava

M. pulcher (Funkhouser) Srivastava

Aquilapollenites reductus Norton

A. reticulatus Norton

Proteacidites angulatus Samoilovitch

P. crispus Samoilovitch

P. cf thalmannii Anderson

Callistopollenites radiostriatus Mtchedlishvili

Rousea subtilis Srivastava

Liburnisporites adnacus Srivastava

This zone strongly resembles the Mancicorpus gibbus subzone of the Scollardia trapaformis zone of the Edmonton Formation and Battle Formation of Alberta (Srivastava 1970).

The middle zone (T.L.II) is the equivalent of the Wodehousea spinata zone of the Edmonton Formation (Srivastava 1970), with the following characteristic palynomorphs (see Plate II & III):

Wodehousea spinata Stanley

Aquilapollenites conatus Norton

A. dispositus Mtchedlishvili

Scollardia normanensis n.sp.

Cranwellia cf C. rumseyensis Srivastava

Proteacidites occalatus Samoilovitch

Pulcheripollenites krempii Srivastava

Loranthacites cf L. pilatus Mtchedlishvili

Santalumidites sp.

The upper zone (T.L.III) is Paleocene in age, generally correlative with early Tertiary palynomorph assemblages from the Great Plains, Spitzbergen and Siberia. There appear to be two sub-assemblages in this zone. The following are characteristic and/or dominant of the lower part of zone T.L.III:

a/ Lower sub-assemblage:

Interaperturopollenites cf I. magnus (Potonie) Thomson & Pflug

Sequoiapollenites paleocenicus Stanley cf Metasequoia occidentalis

Tsugaepollenites sp.

Triporopollenites mullensis (Simpson) Rouse & Srivastava

Myricipites dubius Wodehouse

Baculatisporites comauensis (Cookson) Potonie

B. ilexiformis n.sp.

Taurocusporites segmentatus Stover

Varirugosisporites cf V. tolmanensis Srivastava

Palynomorphs that are common or restricted to the upper part of zone T.L.III are:

b/ Upper sub-assemblage:

Fraxinoipollenites variabilis Stanley

Tricolpites hians Stanley

T. lillei Couper

T. anguloluminosus Anderson

Aquillapolenites dolium (Samoilovitch) Srivastava

A. adamas n.sp.

Caprifoliipites sp.

Alnipollenites sp.

Betulaceoipollenites infrequens (Stanley) Rouse & Srivastava

Taxodiaceaepollenites hiatus - cf Glyptostrobus sp.

Piceapollenites sp.

Pinuspollenites sp.

<u>Reworked Palynoassemblages</u>: Perhaps the greatest source of error in palynostratigraphical work is introduced by the reworking of older microfloras. In a rapidly shifting sedimentary environment this may even lead to the mixing of contemporaneous floras and obliterate facies differences. Stanley (1969) states that

> "These secondary grains usually are present in larger number in both marine and non-marine sediments than most workers would like to admit. Any attempt at climatic interpretation necessitates subtraction of the reworked grains in order to reach accurate conclusions."

Palynomorphs of Mississippian, Permian and Albian age were noted throughout the composite Tate Lake section (Plate V). The following is a list of samples showing the type of mixed assemblages; the letter-numeral designates refer to sections and samples as shown in Figure 3:

purely Mississippian-Albian assemblages: A19;B12,14;C2,3,11;D23
mixed Miss.-Alb. & Paleocene " : B1,11;C5,6,9;D17-20
mixed Maastricht & Paleocene " : A10;B9,11;C13,16;D14
purely Paleocene ass.: A3-5,13,15-17;B3,10,13;C7;D10,11,24,25.

The purely Mississippian-Albian assemblage was also encountered in Albian rocks by Rouse (pers. comm.) in the Peel River area, Audretsch (pers. comm.) in the Mt. Goodenough section of the Richardson Mountains, and by the writer in oilwell cuttings from the Eagle Plains and the Mackenzie Delta. It is quite possible that uplift and erosion during Albian times produced the mixture of mainly lower Mississippian spores and Middle Albian dinoflagellates. These were then reworked together in Maastrichtian and Paleocene times. This interpretation appears more likely than deriving Mississippian and Albian palynomorphs from separate outcrops, because of the areal extent of the mixing throughout the lower Mackenzie valley and eastern Yukon. An 83 meter interval of conglomerates and sandstones in the lower C-section contained some shale lenses yielding only Mississippian-Albian assemblages (Fig. 4). Similar assemblages were also recovered from the extensive outcrop of rusty and crossbedded white sandstone on the east side of Summit Lake, which is barren except for a few stringers of coaly shale no more than 1 to 5 centimeters thick (showing up as moist springlines on the hillsides). From their stratigraphic position and lithological appearance these sandstones are most likely Tertiary (Hart 1944, Hume 1954, Yorath 1970).

Reworked Maastrichtian palynomorphs affects the dating of rock units based on index markers e.g. based on their occurrence in the Tate Lake conglomerate, the ranges of the Maastrichtian *Wodehousea spinata*, *Mancicorpus rostratus*, *M. senonicum*, *Aquilapollenites dispositus*, *A. reticulatus* and *Cranwellia striata* would extend into the Paleocene. The rare occurrence of the mainly Santonian-Campanian *A. trialatus* in both Upper Maastrichtian and Lower Paleocene sediments seems to indicate that the above species is reworked in the Tate Lake conglomerates rather than part of the contemporaneous Paleocene microflora. State of preservation is usually not a good criterion in the interpretation since many samples in the Tate Lake conglomerates yielded also poorly preserved Paleocene palynomorphs. However the reworked specimens of *Wodehousea spinata* can be quite clearly distinguished from the excellently preserved and abundant specimens of T.L.II zone in the Upper East Fork Formation.

Only the smaller Maastrichtian species of Aquilapollenites are well preserved in the Tate Lake conglomerates. Aquilapollenites dolium and A. adamas were found in excellent condition and are probably part of the contemporaneous Paleocene microflora. Taurocusporites sp. considered by Eliuk (1969) to be a contaminant in his Lower Paleocene assemblage is herein considered to be a Paleocene contemporary on the basis of consistent occurrence and good preservation in all four sections of the Tate Lake locality. Taurocusporites segmentatus ranges together with Baculatisporites comauensis, Varirugosisporites cf. V. tomanensis, Erdtmanipollis procumbentiformis and other forms from the Maastrichtian into the Paleocene. As more data become available it will be possible to eliminate reworked species on a statistical basis as well as to extend the ranges of species that do carry on into the Tertiary.

The fact that most thick conglomerates and sandstones with thin shale stringers in the Tate Lake sections contained a very high percentage of reworked palynomorphs, while thick siltstones and shales contained only a small percentage, might be worthwhile to investigate in neighbouring areas. If the relationship between percentage of reworked palynomorphs and coarseness of sediment can be proven to be consistent in other areas of the N.W.T. e.g. the Mackenzie Delta, then the percentage of reworked microflora might be useful in the interpretation of interrelationships of subsurface strata penetrated by oilwells to complete the data inferred from well-logs.

PALYNOSTRATIGRAPHIC CORRELATION

Of the three local assemblage zones established in the study area the lowest one T.L.I (Fig. 4) is correlative with the *Mancicorpus gibbus* subzone of the *Scollardia trapaformis* zone established by Srivastava (1968, 1970) in the Red Deer and Cypress Hills areas of Alberta. Srivastava's argument that this assemblage zone is of stratigraphic significance is supported by the 1500 kilometer distance separating Tate Lake and the Red Deer Valley. The T.L.I is also characterized by the presence of *Mancicorpus rostratus* and the abundant occurrence of small reticulate aquiloid grains e.g. *Aquilapollenites reductus*, and *Liburnisporites adnacus*. The latter has been described by Srivastava (1972) but its stratigraphic occurrence within the Edmonton Formation is not specified. Another palynomorph assemblage that appears to be correlative with the *M. gibbus* subzone and T.L.I is the one described by Eliuk (1969) from Hardisty Creek, western Alberta. Eliuk features *Proteacidites thalmannii* which is rare in the T.L.I. In comparison with the good yields and excellent preservation obtained by Srivastava (1968) both the Hardisty Creek and Tate Lake localities yielded smaller numbers of formspecies and a somewhat poorer preservation which may be indicative of higher energy sedimentary environment closer to the Rocky mountains.

Local assemblage zone T.L.II, characterized by *Wodehousea spinata*, *Aquilapollenites conatus*, *A. dispositus* and *Scollardia normanensis*, is equivalent to Srivastava's *W. spinata* zone and zone 2 of the Bonnet Plume Formation (Rouse & Srivastava 1972).

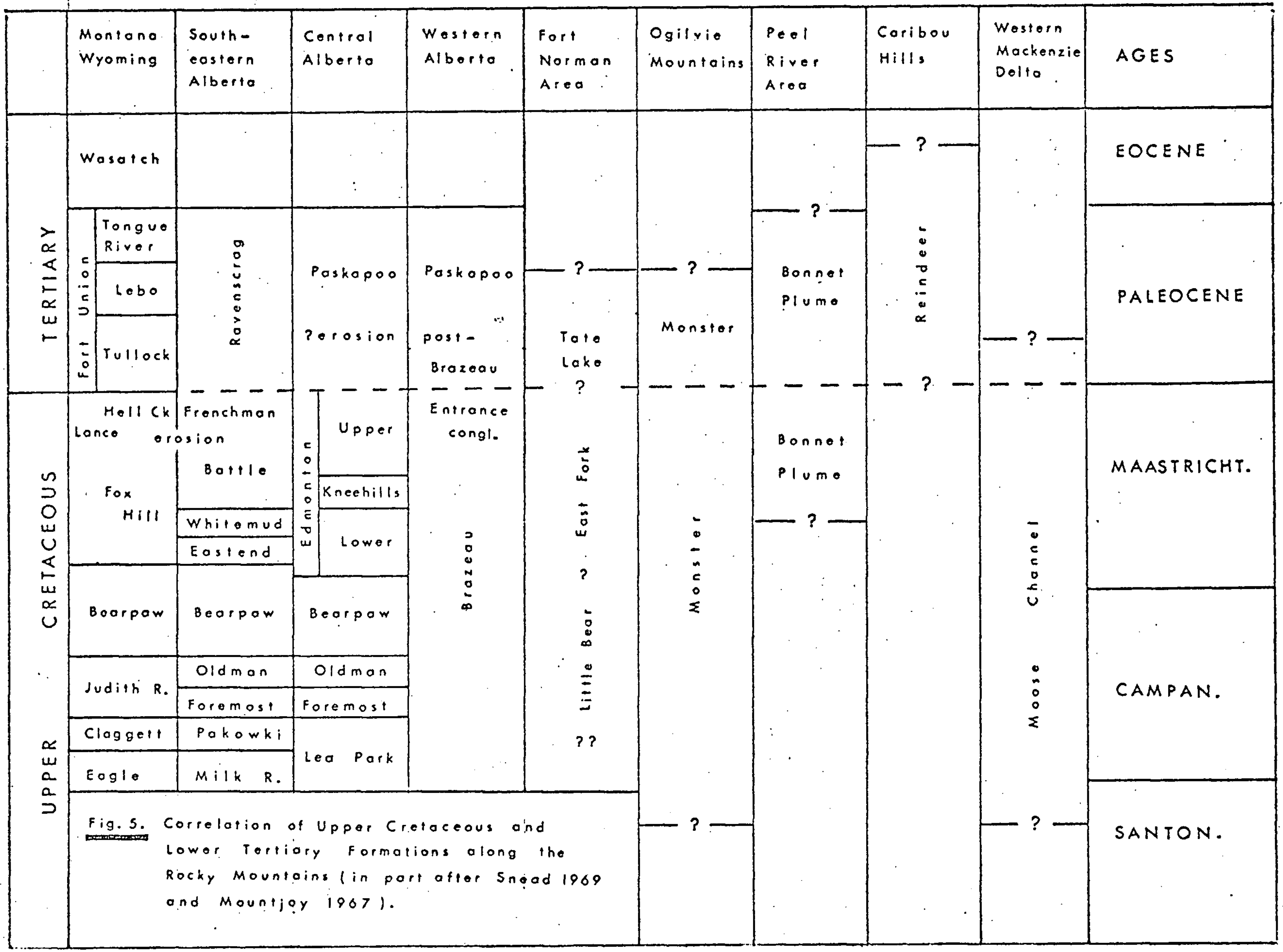


Fig. 5. Correlation of Upper Cretaceous and Lower Tertiary Formations along the Rocky Mountains (in part after Snead 1969 and Mountjoy 1967).

Most species of this assemblage have been reported by Leffingwell (1966), Norton & Hall (1969), Srivastava (1970), Stanley (1965), and Tschudy (1966) as being restricted to the uppermost Cretaceous. Wodehouse fimbriata which may be indicative of a transition zone straddling the Cretaceous-Tertiary boundary (Srivastava 1970), was not found in the Tate Lake succession, neither was its presence recorded by Leffingwell (1966), Tschudy (1966), Snead (1968), Eliuk (1969) nor Rouse & Srivastava (1972) from essentially contemporaneous strata. However, the writer recovered Polycolpites pocockii, Tetracolpites reticulatus, Cardioangulina diaphana, Leptolepidites tenuis and other palynomorphs that have been recorded in association with W. fimbriata by Stanley (1965), Norton & Hall (1969), and Srivastava (1970). These are from the L-section (N 64°38'; W 125°54') on a tributary of the East Fork River to the north of the E-section.

The change in the microflora from T.L.II to T.L.III substantiates the observation of Tschudy (1966) that:

> "...... a marked palynological change occurs at the level of the first definite lignite."

In the Maastrichtian East Fork Formation no coal seams exceeding one foot in thickness were seen by Dr. C. Yorath (pers. comm.). In the E-section the only coal noted was a 1.5 meter seam with shale partings above which the change in palynomorph assemblage takes place. Here most of the aquiloid and all of the proteaceaeous species disappear together with the bulk of the Maastrichtian assemblage. However, most fern spores and gymnospermous pollen continue. *Taurocusporites segmentatus*, *Baculatisporites comauensis*, *B. ilexiformis*, *Osmundacidites wellmanii* and *Varirugosisporites* cf *V. tolmanensis* locally abundant in the Upper East Fork Formation are common throughout the lower Tate Lake conglomerates and disappear above a diagnostic ash horizon (Fig. 4). *Sequoiapollenites paleocenicus*, *S. polyformus*, *Interaperturopollenites* cf. *I. magnus*, and *Taxodiaceaepollenites hiatus*, which make their first appearance above the coal also disappear together with this characteristic fern assemblabe. The increase in bisaccate gymnosperm pollen is noticable from T.L.I to T.L.II, also documented by Srivastava (1970), but very striking between T.L.II and T.L.III. Norton & Hall (1969) state:

> "The abundance of vesciculate types such as *Abietineaepollenites microalatus* forma *microalatus* and *Podocarpus otagoensis* is in direct contrast to the situation in the Upper Cretaceous assemblage where these types are virtually absent."

The bisaccate pollen are dominant in the upper part of the Tate Lake conglomerates where they are in common association with *Paraalnipollenites confusus*, *Betulaceoipollenites* & *Alnipollenites* spp., *Tricolpites lillei* and *T. hians*. Pollen tetrads of probably typhaceaeous-ericaceaeous affinity occur here for the first time, which seems comparable to the microfloral changes in the Upper Tullock Formation (Fort Union Group) recorded by Leffingwell (1966).

The T.L.III assemblage zone seems most correlative with the assemblages of the Tullock Formation (Leffingwell 1966, Tschudy 1966, Norton & Hall 1969), the post-Brazeau beds (Eliuk 1969), zone 3 of the Bonnet Plume Formation (Rouse & Srivastava 1972) and

Tertiary deposits of Spitzbergen reported by Manum (1962). The closest palynomorph correlation is noted with Manum's Spitzbergen assemblage derived from beds containing leaf impressions identical to those described by Dawson (1889) from the Mackenzie River exposures near Fort Norman, which Bell (1949) compares with his post-Brazeau leaves from Alberta:

> "Those (species) identified comprise: Cladophlebis groenlandica, Elatocladus (Taxites?) olriki, Trochodendroides arctica, Pterospermites whitei, Acer arcticum, Nordenskioldia borealis. Two of these species, namely Cladophlebis groenlandica and Elatocladus olriki are present in the Paleocene post-Brazeau beds of central Alberta. Pterospermites whitei and Acer arcticum are both members of the Fort Union flora and Nordenskioldia borealis occurs in the Arctic Tertiary. The flora, accordingly, is considered definitely Paleocene, although it may be somewhat older than the Paskapoo flora."

Closely related to, and possibly synonymous with Pterospermites whitei is Pterospermites spectabilis reported from the Mackenzie leaf flora by Dawson (1889) also cited by Manum (1962) from Spitzbergen and described as Credneria spectabilis by Koch (1963) from the Lower Paleocene of Greenland. Dawson (1889) and Manum (1962) also list Glyptostrobus ungeri, Sequoites langsdorffi and Taxodium distichum cf Metasequoia occidentalis to which the palynomorph species Taxodiaceaepollenites hiatus, Sequoiapollenites polyformus and S. paleocenicus are related. Metasequoia occidentalis leaves occur abundantly in the Tate Lake conglomerates and the palynomorph assemblage is correlative with the assemblage from the leafbearing strata near Fort Norman (Rouse & Brideaux pers. comm.).and the Spitzbergen assemblage (Manum 1962); particularly with the latter in that tiliaceous, juglandaceous and ulmaceous pollen are absent, Metasequoia and taxodiaceaeous pollen are very common, and spores locally exceedingly abundant. An influx of juglandaceous, ulmaceous and ericeceous pollen is recorded by Leffingwell (1966) and Norton & Hall (1969) from the upper part of the Fort Union Group. If there is a continuous sedimentary record as the persistence of the Taurocusporites-Baculatisporites-Varirugosisporites assemblage from the T.L.II into the T.L.III seems to indicate then the equivalent to the Upper Fort Union in the Tate Lake conglomerates probably has been removed by erosion. Manum argues that Tsugaepollenites sp., occurring at Forlandsundet but not in the main Tertiary basin of Spitzbergen 80 kilometers away, indicates a difference in age between the two rock series. In the Tate Lake locality, Tsugaepollenites sp. occurs only in the C-section (Fig.3), but is absent in the other sections all within a radius of 5 kilometers, which in this particular case at least suggests a facies variation rather than any marked difference in geological age.

PALEOECOLOGY

Any assessment of the paleoecology of the Tate Lake strata is dependent on the recognition of the main climatic, physiographic, and water-to-land ratio factors that prevailed during the time of their emplacement. The separation of the continents in Lower Cretaceous time is well documented by paleomagnetic data and sedimentological evidence (Smith 1971). If during the greater part of the Cretaceous three or more isolated continental blocks were present, then three or more floral groups could have evolved independently of each other. Relative to this, Krutzsch (1967) has suggested that after the Laramide and early Alpine-Himalayan orogenies re-established landbridges at the end of the Cretaceous, there were three broad floral groups in Europe in a state of competitive interaction during the early Tertiary (Fig.7):

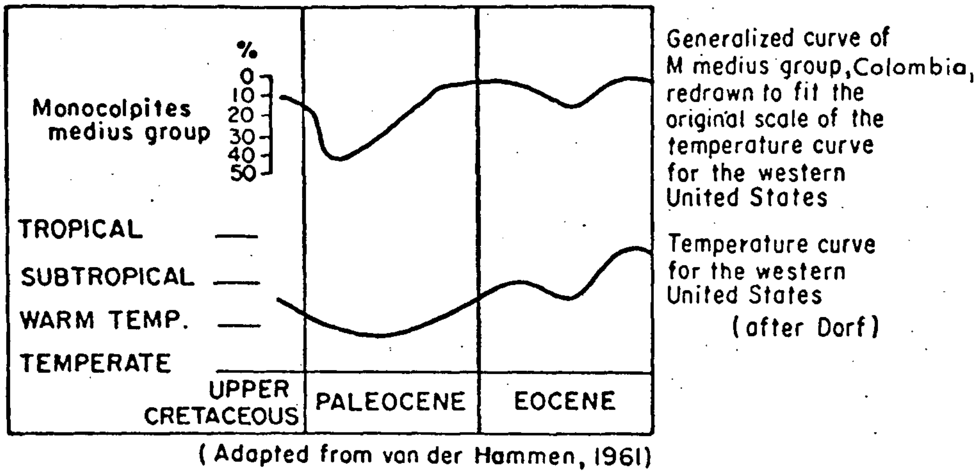
I. An Upper Cretaceous Normapollis group in Europe, whose western North American equivalent is the aquiloid and proteaceous element found in T.L.I & T.L.II. At that time Siberia and western North America formed one continental block separated from Europe and eastern North America by epicontinental seas.

II. An Arctotertiary group, present in the North (unspecified) already during Upper Cretaceous times, advancing during cold phases and retreating during warm phases (Krutzsch favors cyclical climatic variation rather than a uniformly slow warming up or cooling down). It is this group which constitutes the major angiosperm floral element of T.L.III i.e. the deciduous trees.

III. An Eocene-paleotropical group, which in Europe during the middle and upper Paleocene crowded out the Normapollis group completely. This group, characterized by tilioid and caryoid types, does not appear in either the Tate Lake or Bonnet Plume Formations. However, this group has been reported in western North America from Upper Paleocene and Eocene deposits.

Fig. 6. Schematic temperature curve of the early Tertiary for the western United States and Colombia, South America (after van der Hammen, 1961, and Dorf, 1969).

Fig. 7. Schematic diagram of climatic and floral changes in Central Europe (after Krutzsch, 1967).



(Adapted from van der Hammen, 1961)

Fig. 6.

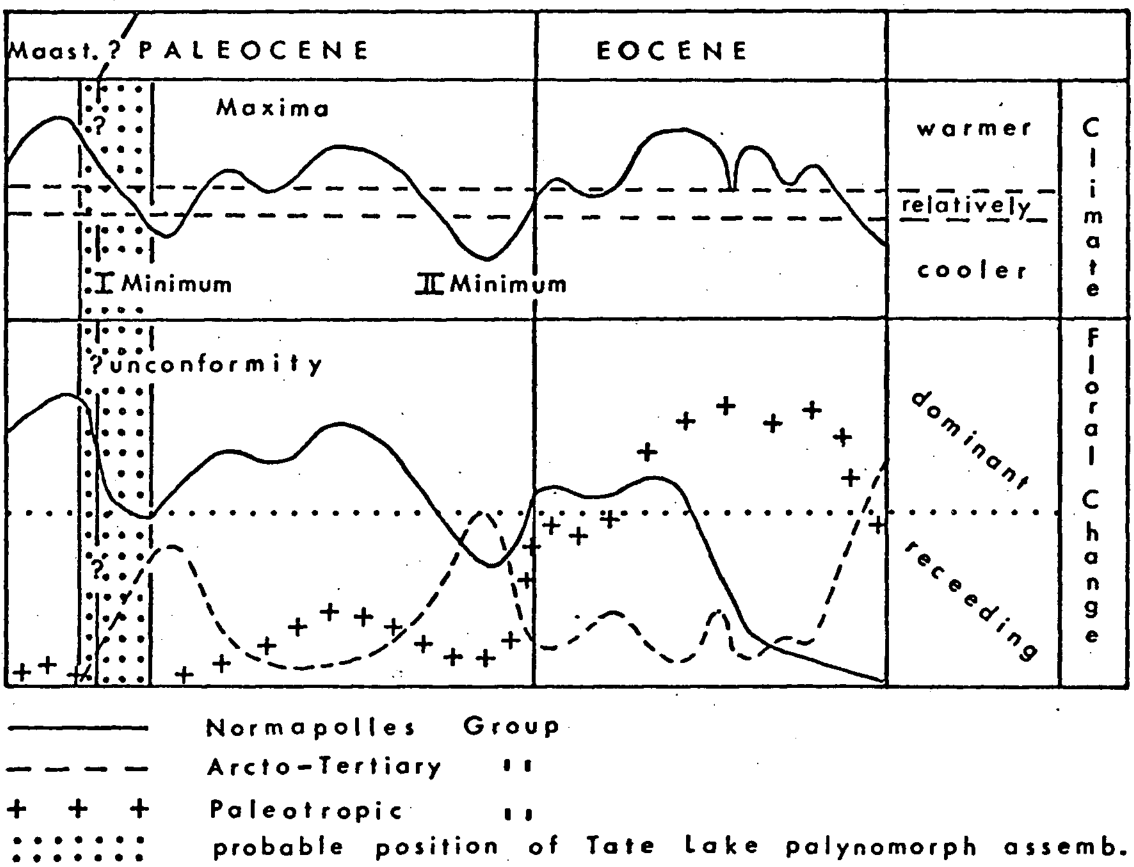


Fig. 7. Schematic diagram of climatic and floral changes in Central Europe after Krutzsch 1967.

According to Krutzsch all three groups formed a certain proportion of the total flora during each time interval, i.e. Arctotertiary elements were present but relatively rare during Maastrichtian times (cf. T.L.I), but increased rapidly near the Cretaceous-Tertiary boundary. This is in complete agreement with the findings in T.L.II and T.L.III and the results of all workers mentioned above. Comparable results were obtained by Axelrod (1966), Dorf (1969) and Lebedev (in Zaklinskaya 1967) working with leaf assemblages.(see Fig.6).

Krutzsch's first minimum flora (Fig.7) shows optimum conditions for Arctotertiary immigrants, in which alnoid, ulmoid, betuloid and bisaccate pollen were more abundant than either before or after. With the exception of the ulmoid types, this is the situation in zone 3 of the Bonnet Plume Formation (Rouse and Srivastava 1972), T.L.III at Tate Lake (this report), and the Spitzbergen palynoassemblages, reflecting a climatic depression that probably affected most of the Northern Hemisphere at that time. All of these minimum floras are intimately associated with coal seams.

Many hypotheses about coal formation have been proposed in the past, an excellent summary is given by Francis (1961) and Jansa (1972) discusses a model which may be applicable to the Tate Lake coals. According to Schwarz bach (1963) the greatest accumulation of organic material of continental origin today occurs in regions where the rate of plant growth exceeds the rate of decomposition of plant materials in soils and swamps (Fig.8)

Fig. 8. Relationship between plant growth, decomposition and rate of accumulation of plant debris.

A = rate of plant growth (maximum at temperature of about 25 C); B_1 = decomposition of plant material in soils; B_2, in swamps. The shaded area indicates where growth is faster than decomposition, i.e. where organic matter can accumulate (after Mohr, and van Baren, 1954).

Fig. 9. Present distribution of peat bogs (after Frueh and Schroeter, simplified from von Buelow's "Moorkunde", 1925, in Schwarzbach's "Climates of the Past", 1963).

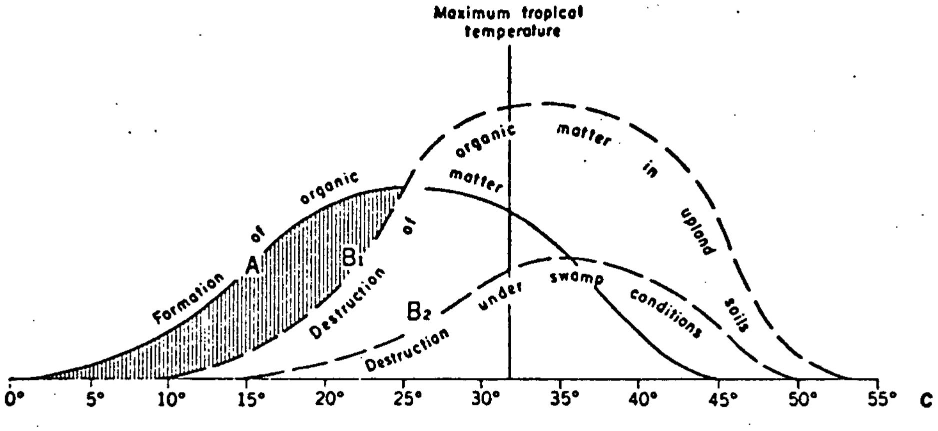

Maximum tropical temperature
organic matter in upland soils
Formation of organic
Destruction of organic matter
Destruction under swamp conditions
A
B1
B2
0°
5°
10°
15°
20°
25°
30°
35°
40°
45°
50°
55° C

Fig. 8

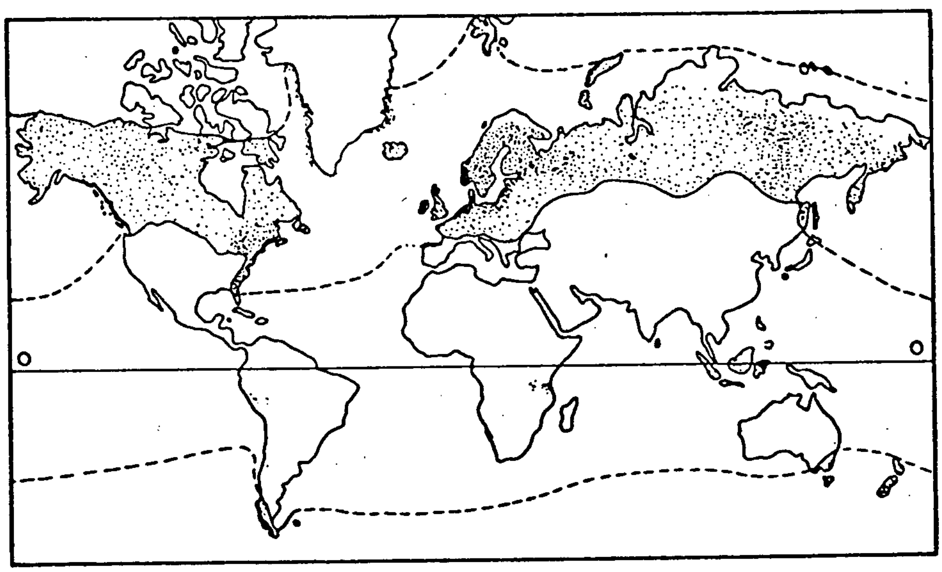

0
0

Fig. 9

i.e. most peat bogs at present are forming in temperate or cooler climates, or in high mountain ranges of the tropics e.g. the Ruwenzoris and Andes. Similarly black humic soils (chernozem) are not common to the tropics. Although Sphagnum-type spores occur throughout the Tate Lake strata they are not very abundant and do not support an interpretation that the lignites are derived mainly from peat bogs. The abundant taxodiaceaeous pollen and fern spores associated with the Tate Lake lignites seems to reflect present day conditions in e.g. Dismal Swamp, North Carolina, where Taxodium, Juniperus and allied species occupy the swamp, while Pinaceae are restricted to the higher areas (Moore 1950), which is indicated by the abundance of bisaccate grains in the shale stringers of the thick Tate Lake conglomerates.

The rate of plant decomposition can be further retarded by rapid burial in the form of intermittent but progressive subsidence of the substratum on which the coal swamp forest grew coupled with an increased rate of sedimentation. The subsiding sedimentary basins where these coal forests grew have been postulated by Mountjoy (1967) who holds that:

> "The Bonnet Plume Formation post dates most of the folding and faulting of the Richardson Mountains and are together with the Moose Channel Formation and Monster Formation products of this late Cretaceous (Laramide) orogeny . . .
> The Bonnet Plume, Monster and Moose Channel Formations were deposited at approximately the same time as the Edmonton and Paskapoo Formations of western and central Alberta."

Since the Upper East Fork Formation and the Tate Lake conglomerates correlate palynologically with the Bonnet Plume Formation it seems they were deposited in a subsiding basin similar to that of the Bonnet Plume, Monster and Moose Channel Formation at about the same geological time. The increase of lignites in the Paleocene recorded by many workers (Leffingwell 1966, Tschudy 1966, Norton & Hall 1969, Rouse & Srivastava 1972) can be explained by this coincidence of increase in plant productivity and preservation under optimum climatic conditions and increased subsidence of sedimentary basins. On the basis of a rich and varied coniferous record in association with betulaceous pollen and the apparent absence of Fagaceae, Juglandaceae and Tilia Manum (1962) concludes that the climate was temperate. His suggestion that:-

> " Alnus was relatively less important in the vegetation, in, and around, the former swamp than the representatives of Betulaceae and probably Myricaceae which contributed the triporate grains."

is supported by the Tate Lake data showing a definite increase of myricaceous pollen close to the coal seams and a decrease away from them. In general, thinner and less numerous lignite beds yield smaller numbers of myricaceaeous and taxodiaceaeous pollen and larger numbers of Alnipollenites sp., Tricolpites sp., and bisaccate grains. Myricipites dubius and Triporopollenites mullensis associated with the Tate Lake lignites were also reported from the Bonnet Plume Formation by Rouse & Srivastava.(1972). The coal seams exhibit a tendency to occur in close vertical proximity separated from another such series by thick conglomerates. Jansa (1972) attributes this "grouping" to the lateral shifting of sedimentary lobes in a fluviatile environment. Towards the top of the Tate Lake succession the number of coal seams decreases perhaps indicating that uplift and consequent sedimentary changes created unfavourable conditions for the formation of coal beds. Possibly alluvial fans of the rising Mackenzie Mountains prograded over the whole area and terminated coal formation. According to Moore (1950):

> "The coal-forming processes ended with the elevation of the Rocky Mountains as it did in the east with the rise of the Appalachians."

It is interesting to note that many of the above features are also associated with the Permian Karoo coals and the Glossopteris flora of Gondwanaland (Schwarzbach 1963). During fieldwork in Tanzania (East Africa) the writer observed many coarse immature clastic sequences between Karoo coal seams with shale stringers from which abundant Permian bisaccate grains were extracted (Hart 1963), probably indicating upland vegetation. The feldspars in these clastics were well preserved which is uncommon for sediments deposited under tropical conditions. Glacial till and striations associated with the Karoo both in South and East Africa, and often quoted as evidence of continental glaciation of the Southern Hemisphere, seem to support a temperate rather than tropical climate during the formation of the Karoo coal beds. A combination of worldwide cooling, at least in the Northern Hemisphere, and local mountain uplift may account for the Tate Lake minimum flora sensu Krutzsch and the associated lignite seams. Leopold and MacGinitie (1972) state that:

> "Some 5,000 feet of regional uplift, equivalent to an 18°C lowering of the average annual temperature using the average lapse rate probably alone could have caused regional cooling that shaped the trend toward a simplified Cordilleran flora."

The Tate Lake Formation in the study area at present occurs between 2000 and 3000 feet above sea level. The environment of deposition could have been higher during the Paleocene if subsidence continued after that time, but it seems unlikely that mountain uplift alone caused the cooling of climate which so drastically affected the contemporaneous flora.

In summary, the paleoecological conditions in the Tate Lake area during the Upper Maastrichtian were very similar to those described by Rouse & Srivastava (1972) for the Peel River area. The orogenic pulse which brought the Cretaceous to a close was just beginning, with the whole area relatively stable and of low relief judging from the fine grained sediments and abundant palynomorphs. The great species diversity in the Maastrichtian indicates warm temperate to subtropical conditions. When orogenic activity began or became more intense, as evidenced by many volcanic ash beds and an increase of coarse clastics, the climate deteriorated markedly in the Tate Lake area, accompanied by a temperate flora characterized by very low species diversity. It appears that *Metasequoia*, *Taxodium*, *Glyptostrobus* and locally *Tsuga* were associated in coal swamps with an abundant understorage of ferns, whereas *Pinus*, *Picea* and *Cedrus* dominated the surrounding uplands. Of the angiosperms present, the Myricaceae appear to be the only group that competed successfully with the conifers in the swamp environment. The vertical succession of lignites interbedded with clastic units suggests frequent burial of coal swamps in intermontane basins with continuous subsidence and sedimentation until uplift exceeded viable conditions for coal swamp vegetation and terminated coal formation in the area.

ABSOLUTE AGE CONSIDERATIONS

The significant floral changes between the Late Cretaceous and Early Tertiary noted by Axelrod (1966), Bell (1949), Dorf (1969), Leffingwell (1966), Norton & Hall (1969), Rouse & Srivastava (1972), Stanley (1965) and Tschudy (1966) were also observed in the Tate Lake succession and seem to reflect an essentially synchronous cooling of climate in the period around 60 ± 3 million years ago. Most workers agree that sedimentation was essentially continuous during that time and apparent unconformities are local in nature e.g. channeling and cross-bedding (Tschudy 1966). Major orogenic activity during this time is reported by many workers and reflected by the widespread occurence of volcanic ash horizons, many of which have been dated. K-Ar dates of 61.7 to 63.6 million years have been reported for the "Z" coal seam at the boundary of the Hell Creek and Tullock Formations, above which a major change in microflora takes place in Montana and Wyoming (Folinsbee et al in Norton & Hall 1969 and Folinsbee et al 1970). The Ardley seam above the Nevis coal from which Srivastava reports a change in microflora in Alberta is dated as 62.6 million years (Folinsbee et al 1970). A volcanic ash layer which occurs 225 meters above the coal seam at which the major change in microflora occurs at the Upper East Fork Formation-Tate Lake conglomerate boundary has been dated as 56 ± 1.7 million years (UBC # C-14). What is apparently the same volcanic ash horizon 2 kilometers east of the Tate Lake locality was sampled by Rouse and dated in two runs as 54 and 56 ± 3 million years (UBC # R-68-1). A minor ash layer about

34 meters higher up was dated by K-Ar as 51 ± 1.6 million years (Fig. 3). Not considering the possibility of Argon leakage, which would give a younger date for the ash horizons, I conclude that the lignite just above which the marked change in palynoassemblages takes place is somewhat older than 56 million years, based on the 225 meters of strata separating it vertically from the measured and dated ash horizon. Since the sedimentation rates in the Tate Lake conglomerates are not known at present no exact date can be given. However the evidence from palynostratigraphic studies of the Upper East Fork Formation and the Tate Lake conglomerates seems to suggest that these strata are part of the Hell Creek-Fort Union type formational sequences (Fig. 5) that have been studied along the eastern flank of the Rocky Mountains from Wyoming to the Peel River. In most of these formational sequences the Tertiary-Cretaceous boundary can be placed near the first major lignite series where a relatively sudden change from warm-temperate Maastrichtian to temperate Paleocene microflora and leaf flora takes place. The numerous coal seams in the Fort Union type strata to which the Tate Lake conglomerates belong seems to suggest that sedimentation was continuous. Since the Monster, Reindeer and Moose Channel Formations to the north and west of the Bonnet Plume area were laid down under similar environmental conditions at about the same geological time (Mountjoy 1967) correlative changes in palynoassemblages with the Bonnet Plume and Tate Lake strata could be expected.

SUMMARY AND CONCLUSIONS

Sedimentary strata near Tate Lake at the headwaters of the East Fork River, south of Norman Wells, N.W.T., contain two distinct lithological units. The lower one is characterized by soft brown and grey siltstones and shales and on the basis of palynological evidence referrable to the Upper Maastrichtian of the East Fork Formation. The upper unit, characterized by thick conglomerates and closely spaced lignites interbedded with siltstones, shales, many volcanic ash layers and minor sandstones, contains a Paleocene palynoassemblage and is informally described as the Tate Lake conglomerates.

Palynological data from the Upper East Fork Formation show that the Mancicorpus gibbus (T.L.I) and Wodehousea spinata (T.L.II) palynostratigraphic zones of Alberta are present at Tate Lake, N.W.T.. These two zones are also correlative with the palynoassemblages contained in the type Lancian (Hell Creek Formation) of Montana and Wyoming as well as part of the Bonnet Plume Formation (zone 2), N.W.T..

The palynoassemblage of the Paleocene Tate Lake conglomerates (T.L.III) is correlative with the microflora of the Upper Bonnet Plume Formation (zone 3), N.W.T., the post-Brazeau beds of the Alberta Foothills, and the Lower Fort Union Group of Montana and Wyoming. Reworking of a Mississippian-Albian microflora is very noticable in the Paleocene strata but very uncommon in the Upper East Fork examined. Its occurrence may be useful in helping to identify the Cretaceous-Tertiary boundary in subsurface oil exploration in the Mackenzie lowlands.

The East Fork-Tate Lake palynoassemblages are correlative with most Hell Creek-Fort Union type floral sequences ranging from Wyoming to the Peel River area. They reflect a major local and possibly worldwide climatic change at the Cretaceous-Tertiary boundary, associated with major mountain uplift towards the end of the Cretaceous which resulted in:

1/ the establishment of landbridges, with the development of a uniform flora over most of the Northern Hemisphere, and the extinction of endemic Maastrichtian floral elements;

2/ the formation of subsiding basins with optimum conditions for coal accumulation during Paleocene times.

The lignites of the Tate Lake conglomerates were formed under temperate climatic conditions probably in close proximity to the mountains during periods of volcanic activity. Sedimentation was continuous without major unconformities except local channelling and cross-bedding.

The palynostratigraphic data from the Upper East Fork Formation and the Tate Lake conglomerates suggests that they are time equivalent with the Hell Creek-Fort Union type formational sequences. K-Ar dates from the upper part of the Tate Lake conglomerates suggest a younger data but no conclusions can be reached until the critical horizons can be radiometrically dated.

REFERENCES

Axelrod, D.I. 1966. A method for determining the altitudes of Tertiary floras. Paleobotanist vol. 14, pp. 144-171.

Bell, W.A. 1949. Uppermost Cretaceous and Paleocene floras of western Alberta. Geol.Surv.Can.Bull. 13, pp.21-28

Dawson, J.W. 1889, On fossil plants collected by Mr. R.A. McConnel, on Mackenzie River, and by Mr. T.C.Weston, on Bow River. Roy.Soc.Can.Trans. vol 7, sec.4, pp. 69-74.

Dorf, E. 1969. Paleobotanical evidence of Mesozoic and Cenozoic climatic changes. Proc.N.Am. Paleont. Convention: 323-346.

Eliuk, L.S. 1969. Correlation of the Entrance conglomerate, Alberta by palynology. M.Sc. thesis, Univ. of Alberta, 143 pages, unpubl.

Francis, W. 1961. Coal, its formation and composition. Edward Arnold Publ. Ltd. London, Ch. 1.

Hart, G.F. 1963. Microflora from the Ketewaka-Mchuchuma coalfield, Tanganyika(Tanzania). Geol.Surv.Tanz.Bull. 36, 27 pages.

Hart, R.M. 1944. Final geological report on Gravel River and East Fork of Little Bear River, Kay Mountains and Summit Anticline. Canol # 10 Report, unpublished.

Hume, G.S. 1954. The Lower Mackenzie River area, N.W.T. and Yukon. Geol.Surv.Can.Mem. 173, pp. 3-5, 45-55.

Jansa, L. 1972. Depositional history of the coal-bearing Upper-Jurassic-Lower Cretaceous Kootenay Formation, southern Rocky Mountains, Canada. Geol.Soc.Am.Bul. vol. 83. pp. 3199-3222.

Koch, B.E. 1963. Fossil plants from the Lower Paleocene, Northwest Greenland. Meddelelser om Groenland, Bd. 172, Nr. 5.

Krutzsch, W. 1959. Mikropalaeontologische Untersuchungen in der Braunkohle des Geiseltales. Geol.Beih. 21,22, pp. 138-143.

----- 1967. Der Florenwechsel im Alttertiaer Mitteleuropas auf Grund von sporenpalaeontologischen Untersuchungen. Abh.zentr.geol.Inst., H. 10, pp. 17-37.

Leffingwell, H.A. 1966. Palynology of the Lance (Late Cretaceous) and Fort Union (Paleocene) Formations of the type Lance area, Wyoming. Geol.Soc.Am.Spec.Paper 127, pp. 1-64.

Leopold, E.B. & MacGinitie, H.D., 1972. Development & Affinities of Tertiary Floras in the Rocky Mountains. Ch. 12, pp. 164, in "Floristics & Paleofloristics of Asia & Eastern North America", A. Graham, Elsevier Publ. Co., Amsterdam.

Manum, S. 1962. Studies in the Tertiary flora of Spitzbergen, with notes on the Tertiary flora of Ellesmere Island, Greenland and Iceland. Norsk Polarinst. Skrifter 125, 127 pages.

Moore, E.S. 1950. Coal. Wiley & Sons Publ., New York. pp. 152.

Mountjoy, E.W. 1967. Upper Cretaceous and Tertiary stratigraphy, northern Yukon Territory and northwestern district of Mackenzie. Geol.Surv.Can.Pap. 66-16, 69 pages.

Norton, N.J. & Hall, J.W. 1969. Palynology of the Upper Cretaceous and Lower Tertiary in the type locality of the Hell Creek Formation, Montana, U.S.A., Palaeontographica 125, Abt. B, 64 pages.

Potonie, R. 1956. Synopsis der Gattungen der Sporae dispersae. Beih.Geol. Jb.,H. 23, pp. 33,34.

Robinson, P. 1972. Geological Atlas of the Rocky Mountain Region, U.S.A.. Rocky Mnt. Assoc.Geol.Hirschfeld Press, Denver,Colo..

Rouse, G.E. & Srivastava, S.K. 1970. Systematic revision of Aquilapollenites Rouse. Can.Jour.Bot. 48, no. 9, pp. 1591-1601.

----- 1972. Palynological zonation of Cretaceous and Early Tertiary rocks of the Bonnet Plume Formation, Northeastern Yukon, Canada. Can. Journ.Ear.Sci. 9, no. 9, pp. 1163-1179.

Samoilovich, S.R. & Mtchedlishvili, N.D. 1961. (Pollen and spores of western Siberia, Jurassic to Paleocene). Trudy Vses.Neft.Nauk.-Issled Geol.-Razv.Inst., Leningrad 177, 657 pages.

Samoilovich, S.R. 1967. Tentative botanico-geographical subdivision of northern Asia in Late Cretaceous time. Rev. Palaeobot.Palynol. 2, pp. 127-139.

Schwarzbach, M. 1963. Climates of the Past. pp.60-61. Transl. by Muir, R.O., D. Van Nostrand Co., London.

Shafiqullah, M. 1963. Geochronology of the Cretaceous-Tertiary boundary, Alberta, Canada. M.Sc. thesis, Univ. of Alberta, 65 pages, unpublished.

Singh, C. 1963. Palynology of the Mannville Group (Lower Cretaceous), central Alberta. PhD. thesis, Univ. of Alberta, 414 pages, unpublished.

Smith, A.G. 1971. Continental Drift. in "Understanding the Earth", Ch. 15, pp. 213-232, M.I.T. Press.

Snead, R.G. 1969. Microfloral diagnosis of the Cretaceous-Tertiary boundary, central Alberta. Research Council of Alberta Bull. 25, 147 pages.

Srivastava, S.K. 1968. Angiosperm microflora of the Edmonton Formation, Alberta, Canada. Ph.D. thesis, Univ. of Alberta, 343 pages unpublished.

----- 1970. Pollen biostratigraphy and paleoecology of the Edmonton Formation (Maastrichtian), Alberta, Canada. Palaeogeogr. Palaeoclimatol. and Palaeocol. 7, pp. 221-276.

----- 1972. Systematic description of some spores from the Edmonton Formation (Maastrichtian), Alberta, Canada. Palaeontographica 139B, pp. 1-46.

Stanley, E.A. 1965. Upper Cretaceous and Paleocene plant microfossils and Paleocene dinoflagellates and hystrichosphaerids from northwestern South Dakota. BULL.AM.Paleont. 49, no.222, pp. 1- 378.

----- 1969. The occurrence and distribution of pollen and spores in marine sediments. Proc.First Inter.Conf. on planktonic microfossils, vol. II, pp. 641-643.

----- 1970. The stratigraphical, biogeographical, paleoautecological & evolutionary significance of the fossil group Triprojectates. Bull.Georgia, Acad.Sci. 28, pp. 1-44.

Staplin, F.L. 1960. Upper Mississippian plant spores from the Golata Formation, Alberta, Canada. Palaeontographica 107B, 40 pages.

Tassonyi, E.J. 1969. Subsurface geology, Lower Mackenzie River and Anderson River area, district of Mackenzie. Geol.Surv. Can.Pap. 68-25.

Tschudy, R.H. 1966. Palynology of the Cretaceous-Tertiary boundary in the Northern Rocky Mountains and Mississippi embayment regions. Geol.Soc.Am.Pap. 127, pp. 64-89.

Williams, M.Y. 1922. Reconaissance across northeastern British Columbia and the geology of the northern extention of the Franklin Mountains., N.W.T. Geol.Surv.Can.Sum.Rept. 1922B, pp. 65-87.

Zaklinskaja, E.D. 1967. The early-Paleocene flora of the Northern Hemisphere and palaeofloristic provinces of this age. Abh.zent.geol.Inst. 10, pp. 183-187.

APPENDICES

AND

PHOTOMICROGRAPH

PLATES

APPENDIX I

TAXONOMIC PALYNOLOGY

Most palynomorphs recovered from the three assemblage zones of the East Fork and Tate Lake Formations are well known from previous studies, and generally long ranging. However several new species have been discovered which are potentially important as index palynomorphs; these are described formally here.

1/ Scollardia normanensis n.sp.

Form Genus Scollardia Srivastava 1966 emend. 1968 emend.

1966 Scollardia Srivastava; Pollen et Spores, vol.8,no.3, p. 544.

1968 Scollardia Srivastava; Ph.D. thesis, p. 161

Form Genotype: Scollardia trapaformis Srivastava 1966

Emended diagnosis: Heteropolar grains with three well developed equatorial projections showing sexinal outgrowth on both the margins of the colpi and having a convex triangular contour are herewith included in the form genus Scollardia sensu Srivastava.

Scollardia normanensis n.sp.

Plate II, Fig. 19-21,23

Holotype dimensions: Equatorial diameter 58 microns, polar axis 65 microns

Holotype preparation: E1(30); 100.5/46; Pl.II Fig. 19

Locality: Zone T.L.I & II, sections E & E2, near headwaters of the East Fork of the Little Bear River.

Description(based on 30 specimens): Heteropolar; tricolpate, short colpi meridional across apices of equatorial projections; sexine along the margins of colpi ending in a thin membranous' frill; equatorial contour triangular, sides slightly convex;

equatorial projections well developed and pointed at the tips (tips are broken off in many specimens); sexine tectate,baculate; ornamentation striate, striations discontinuous, often teardrop shaped more or less parallel to each other and arranged perpendicular to the margins of the equatorial projections.

Size range: Equatorial diameter 58 to 76 microns; polar axis 45 to 60 microns.

Remarks: Scollardia normanensis seems to fill stratigraphically and paleoecologically the niche of Scollardia trapaformis from which it differs in size and the development of polar projections. Although Scollardia normanensis is locally more abundant in the W. spinata zone (T.L.II) it is also a common component of the M. gibbus zone (T.L.I).

Specific epithet: normanensis refers to the Fort Norman area.

2/ Baculatisporites ilexiformis n. sp.

Form Genus Baculatisporites Thomson & Pflug 1953

1953 Baculatisporites Thomson & Pflug; Paleontographica, vol. 94

Form Genotype: Baculatisporites (as Sporites) primarius (Wolff) Thomson & Pflug 1953

Baculatisporites ilexiformis n.sp.

Plate IV, Fig. 45,46

Holotype dimensions: Equatorial diameter 45 microns

Holotype preparation: D25(30): 117.8/50.2; Plate IV, Fig.45,

Locality: Zone T.L.III, section D.

Description: Equatorial outline subcircular; diameter 35 to 50 microns; exine 0.8 to 1.0 microns; sculptured with clavae and bacula spaced at intervals approximately equal to their diameter as seen from surface view; clavae 2.5 microns high, 0.8 microns in diameter at the top end which is usually flattened squarely, base of clavae somewhat constricted; bacula towards the proximal surface become smaller in size and tend to fuse with each other at the bottom; trilete scar covers nearly the full radius of the spore and is elevated as a small ridge on the proximal surface; area around the trilete scar is psilate without ornamentation. Grains are usually folded; in expanded grains the distal surface hemispherical, and the proximal surface plane to slightly concave with the trilete scar extending as a ridge to the equatorial rim.

Remarks: Both Potonie (1956) and Krutzsch (1959) note that smaller echinate and baculate osmundaceaeous spores are common in the upper Neogene, whereas larger spores with verrucate, gemmate to clavate ornamentation have only been observed in the lowest Tertieary. The occurrence in the Tate Lake Formation of _Baculatisporites ilexiformis_ together with both _Baculatisporites comauensis_ (Cookson) Potonie, and _B. gemmatus_ Krutzsch, described from the Paleocene of the USSR (Zaklinskaja 1953) and the lower Tertiary of Spitzbergen (Manum 1954), appears to conform with this observation, and hence supports a Paleocene age. _B. ilexiformis_ ranges down into the Upper Maastrichtian as does _B. comauensis_. _B. ilexiformis_ is very distinct from other species of this genus in having clavae very similar to those of _Ilex_.

Specific epithet: ilexiformis refers to the ornamentation of _Ilex_.

3/ <u>Aquilapollenites</u> <u>adamas</u> n.sp.

Form Genus <u>Aquilapollenites</u> Rouse emend.
Rouse & Srivastava 1970

Form Genotype <u>Aquilapollenites</u> <u>quadrilobus</u> 1957

Remarks: The taxonomy of this stratigraphically important group of index fossils is in a state of flux. The magnitude of the problems can be ascertained by reference to Rouse & Srivastava (1970), Tschudy & Leopold (1971) and Stanley (1972). The writer follows the system proposed by Rouse & Srivastava.

<u>Aquilapollenites</u> <u>adamas</u> n.sp.

Plate III, Fig. 37, 43

Holotype dimensions: Polar axis 27 microns; equatorial axis 12 microns; distance from centre of polar axis to the tips of equatorial projections 15 microns; maximum breadth of equatorial projections 4 microns.

Holotype preparation: A8(20-0-X): 100/41.9; Plate III, Fig.43

Locality: Zone T.L.III, section A, type section of the Tate Lake Formation.

Description(based on 7 specimens): Pollengrains with three equatorially situated projections; isopolar with well developed polar extensions; poles conical unles folded or flattened by preservation; equatorial projections moderately long; tricolpate, colpi meridional across equatorial projections, long, almost reaching polar regions; sexine bastionate;ornamentation microreticulate, mesh size variable, larger on the body and smaller on poles and equatorial projections.

Size range: Polar axis 27 to 28 microns.

Specific epthet: adamas refers to the diamond-shaped outline.

4/ General remarks about size variation in Aquilapollenites dispositus Mtchedlishvili: The writer counted in excess of 30 specimens and noted a bimodal size distribution with relatively sharp peaks around 65 and 90 microns. The larger forms have never been recorded before, and may well belong to a different species. Electronmicroscopy may establish morphological differences not observable under the light-microscope. Size differenc alone does not seem to be a valid criteria for species differentiation.

APPENDIX II

1/ List of species restricted to the T.L.I zone of the East Fork Formation:

Liburnisporites adnacus Srivastava

Styx minor Norton

Aquilapollenites cf. A. amicus Srivastava

A. argutus Srivastava

A. cf. A. paplionis Srivastava

A. polaris Funkhouser

A. reductus Norton

A. reticulatus Stanley

Callistopollenites tumidiporus Srivastava

Extratriporopollenites sp.

Mancicorpus gibbus Srivastava

M. rostratus Srivastava

Proteacidites angulatus Samoilovich

P. thalmannii Anderson

2/ List of species of T.L.I. and T.L.II zones:

Ceratosporites masculus Norris

Hamulatisporites hamulatis Krutzsch

Retitrilàtes austroclavatides (Cookson) Krutzsch

Schizosporis complexus Stanley

Zlivisporites sp.

Aquilapollenites conatus Norton , restricted to T.L.II

A. dispositus Mtchedlishvili

Callistopollenites radiostriatus Mtchedlishvili

Cranwellia cf. *C. rumseyensis* Srivastava

Liliacidites mirus Srivastava

Loranthacites pilatus Mtchedlishvili

Mancicorpus pulcher (Funkhouser) Srivastava

M. senonicum Mtchedlishvili

Prodeacidites asper Samoilovich

P. crispus Samoilovich

P. occallatus Samoilovich

Pulcheripollenites krempii Srivastava

Retitricolpites foveoloides Pierce

Santalumidites sp.

Scollardia normanensis n.sp.

Tricolpites matauraensis Couper

Wodehousea cf. *W. gracile* Samoilovich

W. spinata Stanley

3/ List of longranging species occurring in all zones of the Tate Lake composite section:

Acanthtriletes sp.

Baculatisporites comauensis (Cookson) Potonie

B. gemmatus Krutzsch

B. ilexiformis n. sp.

Concavisporites sp.

Deltoidospora sp.

Foveotriletes sp.

Gleicheniidites senonicus Rouse

Hazaria sheopiarii Srivastava

Laevigatosporites adiscordatus Krutzsch

L. ovatus Wilson & Webster

Leiotriletes sp.

Leptolepidites bullatus van Hoeken-Klinkenberg

L. tenuis Stanley

Lycopodiumsporites sp.

Osmundacidites wellmannii Couper

Stereisporites antiquasporites (Wilson & Webster) Dettman

Taurocusporites segmentatus Stover

Varirugosisporites cf. V. tolmanensis Srivastava

gymnospermous pollen undifferentiated, including Podocarpites, Abietineaepollenites and Taxodiaceaepollenites spp..

Aquilapollenites dolium Samoilovich

Erdtmanipollis pachysandroides Krutzsch

E. procumbentiformis (Samoilovich) Krutzsch

4/ List of species restricted to the T.L.III zone of the Tate Lake Formation:

Phragmothyrites eocaenicus Edwards

Cicatricosisporites dorogensis Potonie & Gelletich

Cedripites cf. C. parvus Norton

Piceapollenites grandivescipites Wodehouse

Podocarpites marwickii Couper

P. maximus (Stanley) Norton

Sequoiapollenites palaeocenicus Stanley

S. polyformus Stanley

S. sp.

Taxodiaceaepollenites hiatus

Tsugaepollenites sp.

Interaperturopollenites cf. *I. magnus* (Potonie) Thomson & Pflug

Alnipollenites sp.

Aquilapollenites adamas n. sp.

Betulaceoipollenites infrequens (Stanley) Rouse & Srivastava

Carpinites cf. *C. ancipites* Wodehouse

Fraxinoipollenites variabilis Stanley

Liquidambar sp.

Myricipites dubius Wodehouse

Paraalnipollenites confusus (Zaklinskaja) Hills & Wallace

Tricolpites anguloluminosus Anderson

T. lillei Couper

T. hians Stanley

Tricolpopollenites cf. *T. sinosus* Norton

Triporopollenites mullensis (Simpson) Rouse & Srivastava

PHOTOMICROGRAPHY

Note: all figures magnified X 1000 unless otherwise mentioned.

Plate I :

Fig. 1. Mancicorpus rostratus Srivastava

Fig. 2,3. Mancicorpus gibbus Srivastava

Fig. 4. Aquilapollenites reductus Norton

Fig. 5. Aquilapollenites reticulatus Stanley

Fig. 6. Aquilapollenites polaris Funkhouser

Fig. 7. Aquilapollenites dolium Samoilovitch

Fig. 8. Aquilapollenites cf A. paplionis Srivastava

Fig. 9. Aquilapollenites argutus Srivastava

Fig.10. Liburnisporites adnacus Srivastava

Fig.11. Rousea subtilis Srivastava

Fig.12. Proteacidites angulatus Samoilovitch

PLATE I.

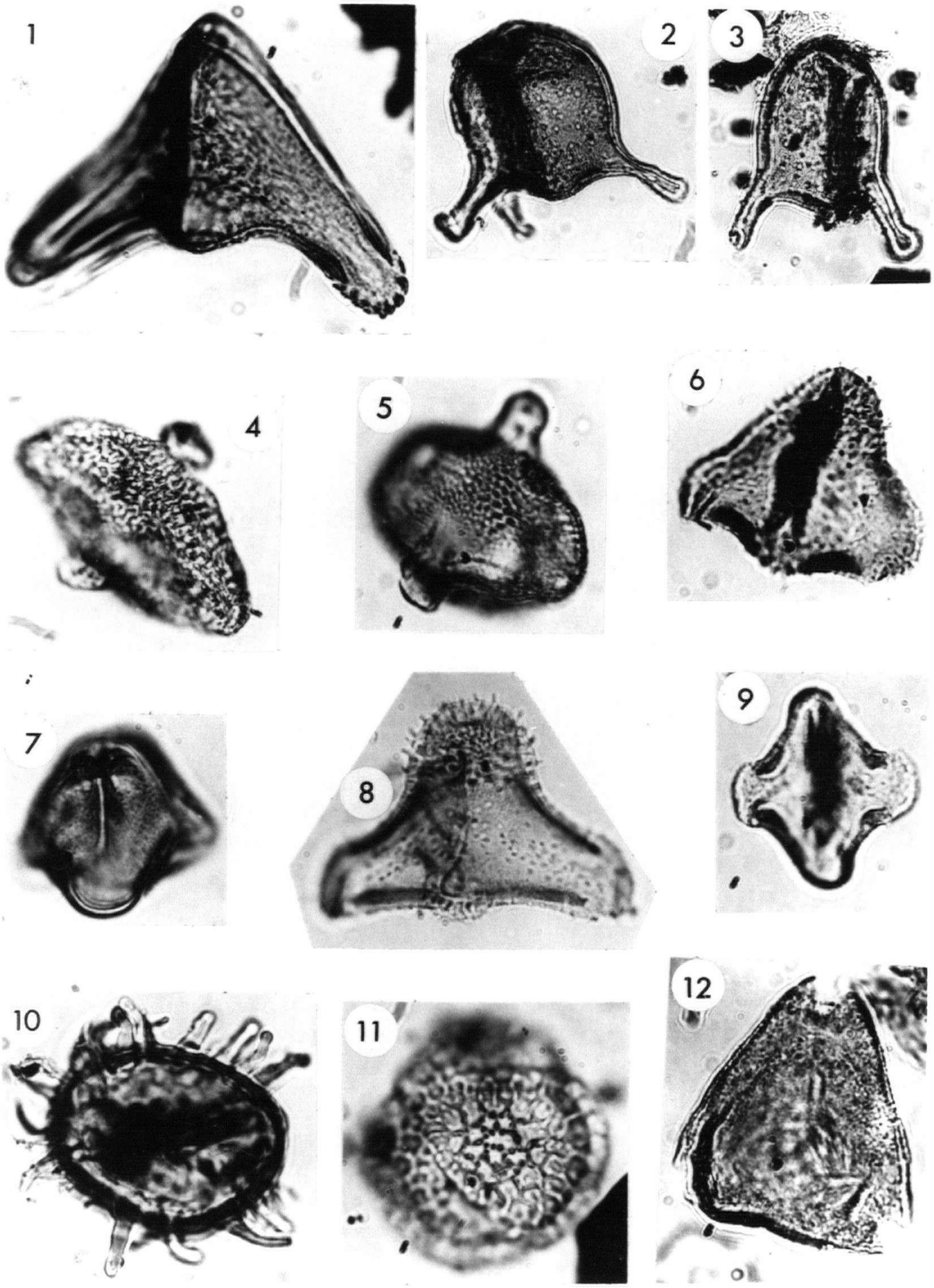


Plate II :

Fig.13. Wodehousea spinata Stanley

Fig.14. Aquilapollenites dispositus Mtchedlishvili , showing the larger variety. (X 440)

Fig.15,18. Aquilapollenites dispositus Mtchedlishvili , showing the smaller variety. (X 440)

Fig.16. Santalumidites sp.

Fig.19-21. Scollardia normanensis n. sp. (X 440) ,
19. polar view,
20. equatorial view,
21. grain with tips of equatorial projections removed, common occurrence.

Fig.22. Aquilapollenites conatus Norton

Fig.23. Scollardia normanensis n. sp. , showing tear drop ornamentation.

Fig.24. Proteacidites occallatus Samoilovich

PLATE II

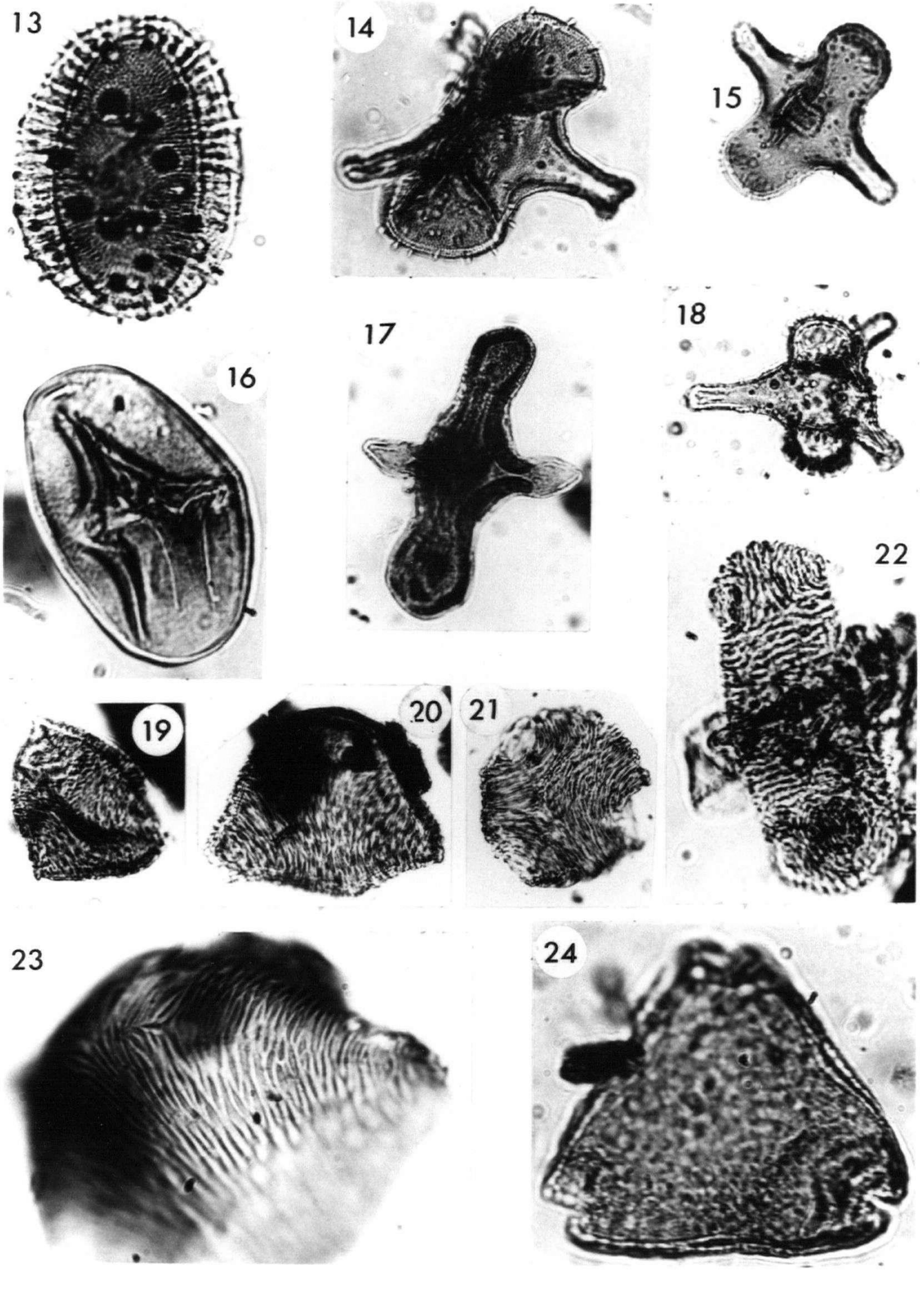


Plate III :

Fig.26. Pulcheripollenites krempii Srivastava

Fig.27. Policolpites pocockii Srivastava

Fig.28. Tetracolpites reticulatus Srivastava

Fig.29. Tricolpites matauraensis Couper

Fig.30. Proteacidites crispus Samoilovich

Fig.31. Proteacidites sp.

Fig.32. Extratriporopollenites sp.

Fig.33. Wodehousea cf W. gracile Samoilovich

Fig.34. Erdtmanipollis procumbentiformis (Samoilovich) Krutzsch , common appearance.

Fig.35. cf Gothanipollis

Fig.36. Cranwellia cf C. rumseyensis Srivastava

Fig.37. Aquilapollenites adamas n.sp.

Fig.38. Loranthacites pilatus Mtchedlishvili

Fig.38,40. Callistopollenites radiostriatus Mtchedlishvili , showing different foci.

Fig.41. Aquilapollenites catenireticulatus Srivastava

Fig.42. Liliacidites mirus Srivastava

Fig.43. Aquilapollenites adamas n. sp. (X 2000)

PLATE III

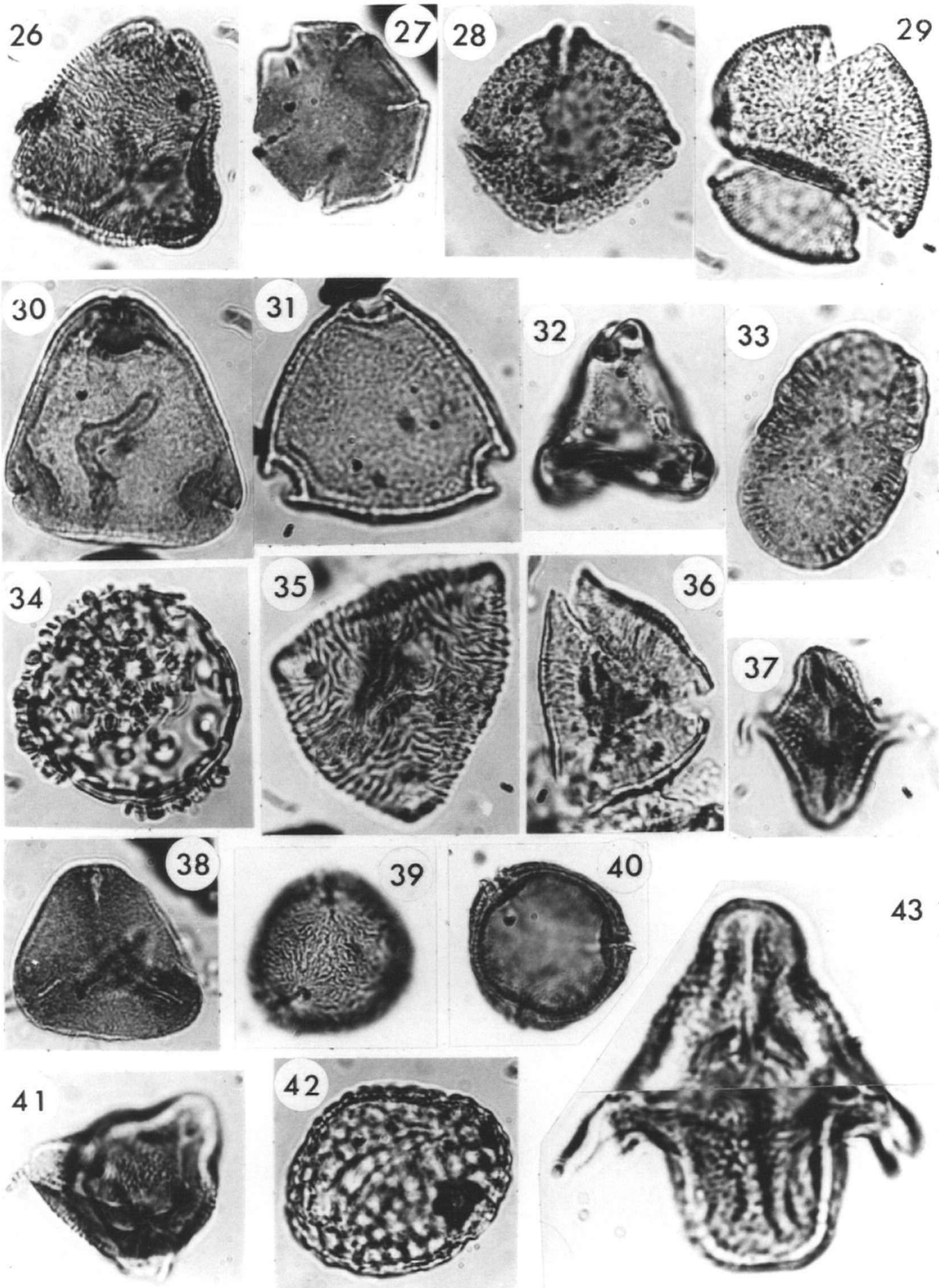


Plate IV :

Fig.44. Taurocusporites segmentatus Stover

Fig.45,46. Baculatisporites ilexiformis n.sp.

Fig.47. Sequoiapollenites sp.

Fig.48. Sequoiapollenites paleocenicus Stanley cf Metasequoia.

Fig.49,50. Varirugosisporites cf V. tolmanensis Srivastava

Fig.51. Taxodiaceaepollenites hiatus cf Glyptostrobus

Fig.52,53. Tsugaepollenites sp.

Fig.54. Cedripites sp.

Fig.55. cf typhaceaeous pollen tetrads

Fig.56. Tricolpites anguloluminosus Anderson

Fig.57. Tricolpites lillei Couper

Fig.58. Myricipites dubius Wodehouse

Fig.59. Triporopollenites mullensis (Simpson) Rouse & Srivastava

Fig.60. Paraalnipollenites confusus (Zaklinskaja) Hills & Wallace

Fig.61. Tricolpites hians Stanley

Fig.62. Fraxinoipollenites variabilis Stanley

PLATE IV

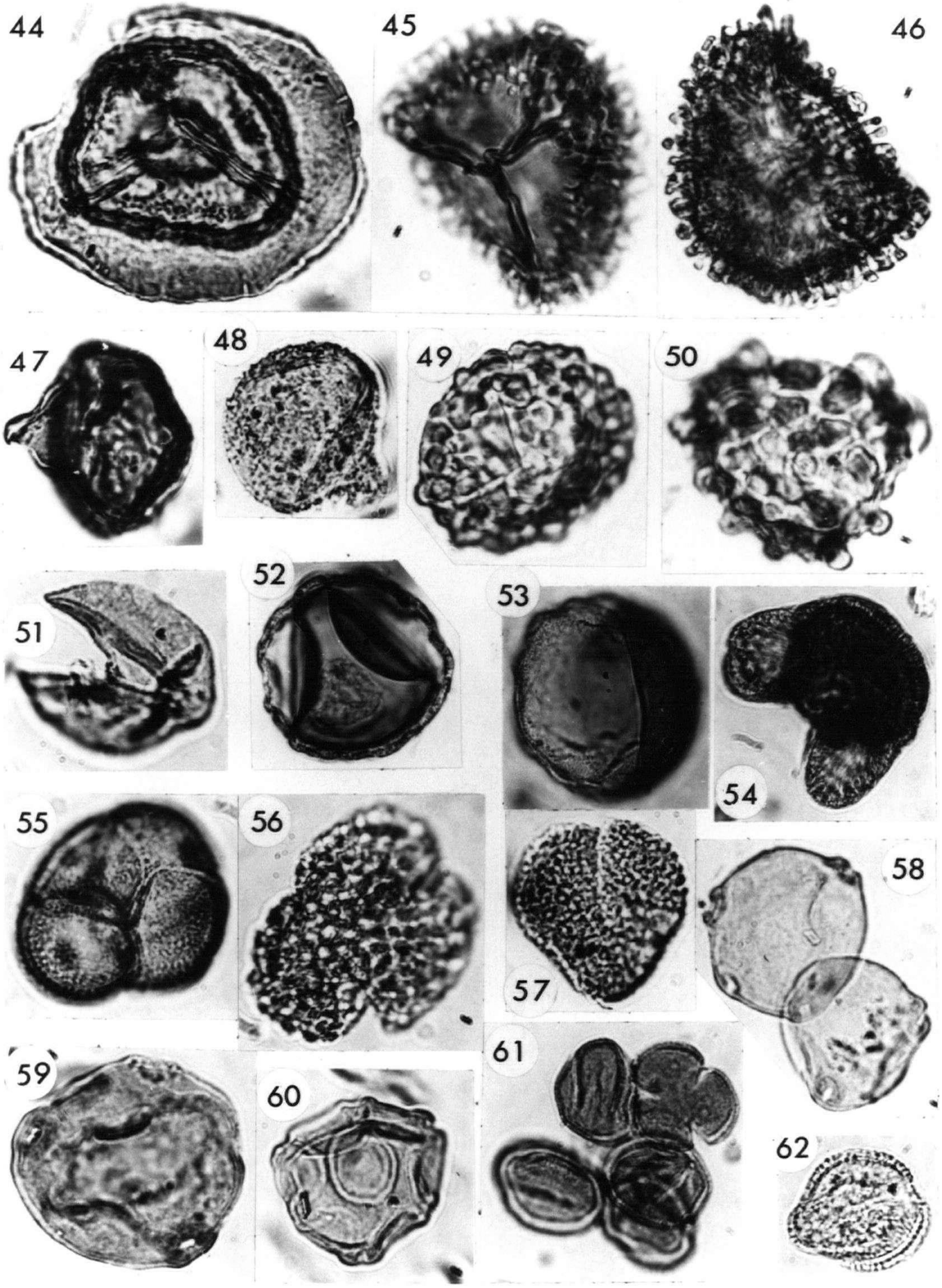


Plate V :

Note: all figures magnified X 440 unless otherwise stated.

Fig.63. Appendicisporites perplexus Singh, X 1000

Fig.64. A. cf. A. trichacanthus , Fig.64 and 65 X 1000

Fig.65. Cicatricosisporites dorsostriatus (Bolkhovitina) Singh

Fig.66. Hystrichosphaeridium irregulare Pocock

Fig.67. Cyclonephelium cf. C. distinctum

Fig.68. Palaeoperidinium cretaceum Pocock

Fig.69. Odontochitina sp.

Fig.70. Spiridinium sp.

Fig.71. Deflandrea sp.

Fig.72. Baltisphaeridium neptuni Eisenack

Fig.73. Ascodinium sp.

Fig.74. Baltisphaeridium multispinosum Singh

Fig.75. Vittatina sp.

Fig.76. Tripartites golatensis Staplin

Fig.77. Tripartites inciso-trilobus Waltz

Fig.78. Hymenozonotriletes cf. H. lepidophytes

N.B. Microfossils from Fig. 63 to 74 are of Albian, Fig. 75 of Permian, and Fig. 76 to 78 of Mississippian age.

PLATE V