PALYNOLOGY OF MIDDLE AND LATE TERTIARY SEDIMENTS FROM THE CENTRAL INTERIOR OF BRITISH COLUMBIA, CANADA

by

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ABSTRACT

Sediments of Mid - to Late Tertiary age from the Fraser River and its tributaries near Quesnel and Prince George in central British Columbia have been investigated for plant microfossils.

Three rock units have been studied. The Oligocene rock unit consists of interbedded clay, sand, gravel and lignite, and is exposed along the Fraser River at Alexandria Ferry and at the mouth of Narcosli Creek. This unit is dated by titanothere teeth.

The probable Miocene rock unit also consists of interbedded clay, silt, sand, gravel and lignite, and is exposed below Moose Heights, near Quesnel. This unit is dated on the basis of pollen and leaves.

The Mio-Pliocene rock unit is diatomite and diatomaceous clays, exposed at the Big Bend of the Fraser River, across from Moose Heights, and along the Nechako River. It appears to underlie radiometrically dated rocks.

Palynological studies have revealed a sub-tropical to warm temperate Oligocene flora which includes *Quercus*, *Alnus*, *Carya*, *Liquidambar*, *Ulmus*, *Juglans*, *Pterocarya*, *Taxodium*, *Glyptostrobus*, *Engelhardtia*, *Prosopis*, *Metasequoia*, *Osmunda*, *Psilotum*, *Ephedra* and *? Dorstenia*.

The probable Miocene assemblage contains *Juglans*, *Taxodium*, *Glyptostrobus*, *Metasequoia* and *Alnus*, with larger numbers of *Liquidambar*, *Pterocarya*, *Ulmus*, *Castanea*, *Carya* and *Quercus* than in the Oligocene flora.

The Mio-Pliocene paleoflora is distinguished by a predominance of cool temperate taxa, e.g. Pinus, Abies, Picea and Cedrus.

From pollen evidence a sub-tropical to warm temperate climate is suggested for the Early Oligocene, with the warm, humid climate probably due in large part to the influence of a warm polar sea.

The pollen and leaves from the probable Miocene sediments suggest a more temperate climate with less rainfall, due probably to the cooling during the Tertiary.

Pollen recovered from the Mio-Pliocene unit indicates a cool temperate climate and establishment of a predominantly coniferous forest.

This is the first Oligocene pollen assemblage studied in the Pacific Northwest and the probable Miocene, and Mio-Pliocene assemblages supplement those of other workers in the area. This thesis also provides information on past climatic history of British Columbia and the Pacific Northwest.

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INTRODUCTION

INITIATION AND PURPOSE OF THE INVESTIGATION

The study, of which this thesis is a part, was initiated in 1964 by the Groundwater Division, Water Investigations Branch, Department of Lands, Forests and Water Resources, of the Province of British Columbia for the location of groundwater resources in the Prince George area (McCallum, 1966).

Mr. Ed Livingston of that Department made a preliminary reconnaissance of Tertiary and Pleistocene sediments during 1964.

Mr. James McCallum spent the field seasons of 1965 and 1966 mapping surficial geology and carrying on reconnaissance stratigraphic studies. It was during the latter part of the 1965 field season that the Groundwater Service requested Dr. Glenn Rouse to supervise a graduate student in palynology, to assist in establishing stratigraphic control in the Prince George-Quesnel area. This stratigraphic control was deemed necessary to correlate sections in drilled water wells with known outcrop sequences.

In late August Dr. Rouse and myself, working closely with McCallum, spent ten days collecting samples in the Prince George-Quesnel area for palynological analysis. Sampling trips of shorter duration were taken in the summer of 1966 and early spring of 1967. In addition, samples were supplied by McCallum from outcrop sections studied by him, and from wells drilled by the Groundwater Division.

Still other samples were kindly supplied by Dr. J. E. Armstrong of the Geological Survey of Canada, Vancouver, from collections made by Mr. Stan Leaming and himself during the 1966 field season.

Palynological analyses of outcrop and selected well samples demonstrated that three Tertiary sedimentary units could be distinguished in outcrop sections. Subsequently, one or more of these units were found to occur in various water wells drilled in the area.

I. DESCRIPTION OF THE STUDY AREA

A. Location

The study area (see Text Figure 1, page 4) is roughly rectangular in outline, with its longest axis oriented north-south. It is roughly one hundred miles by twenty-eight miles, and is located in the central interior of British Columbia, Canada. The entire area studied is included easily between the boundaries formed by the lines of 52° and 54° North Latitude, and 122° and 124° West Longitude.

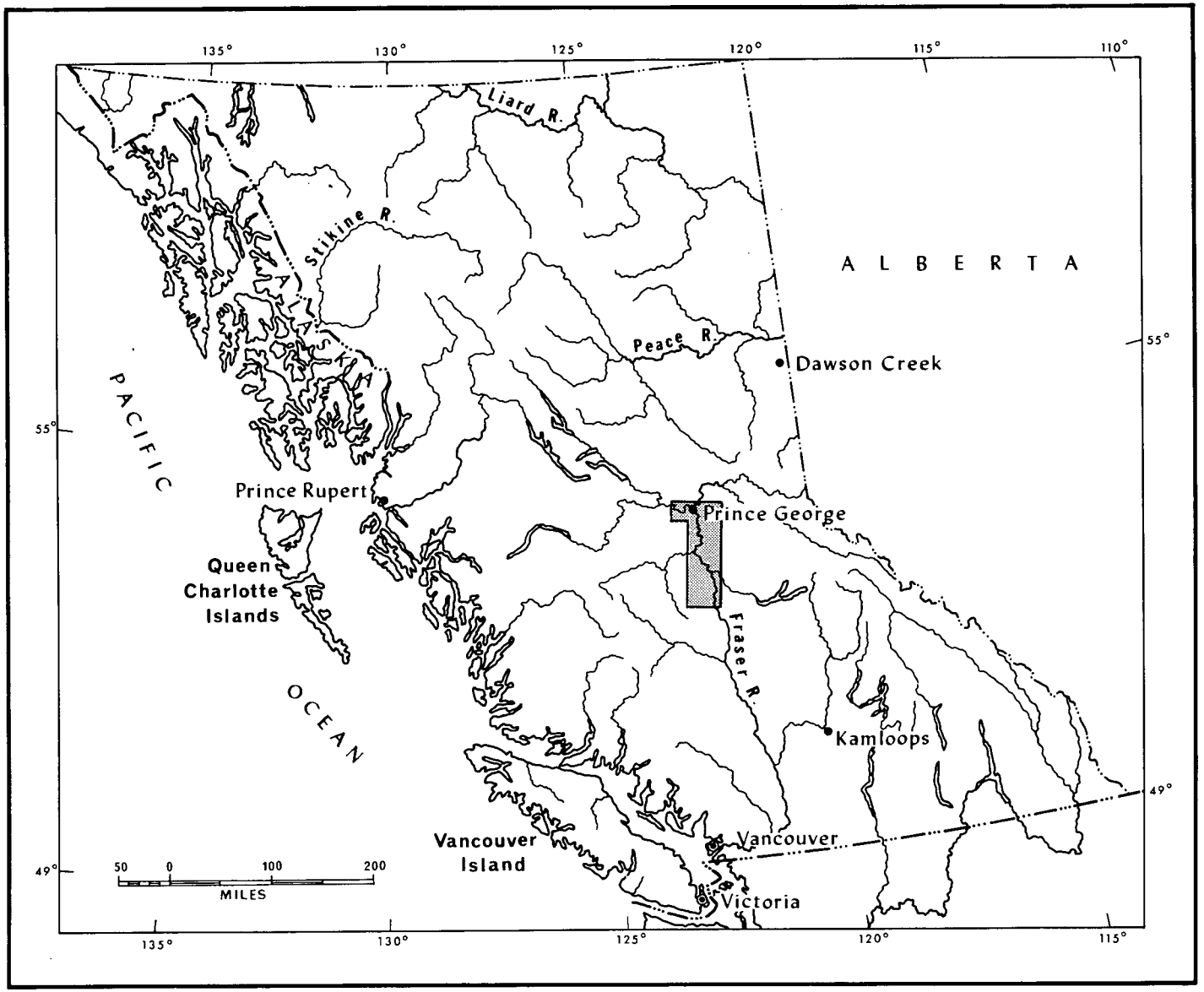
The study area includes the principal cities of Prince George and Quesnel, in addition to several smaller towns located mostly along the Fraser River.

The outcrops sampled for this thesis (see Text Figure 2, inside back cover) are confined to the channel of the Fraser River and the channels of its tributary creeks and rivers.

B. Topography

The elevation within the study area generally varies from slightly under 2000 feet to about 2500 feet. Some outcrops at or near Fraser River level may be as low as 1500 feet (Tipper, 1957, 1959-60). South of Prince George, relief increases rapidly toward the east, approaching the northwest-southeast trending Quesnel Highlands. To the west relief also increases toward the Telegraph Range, where the elevation is over 4500 feet.

South of Quesnel the dominant feature is the Interior Plateau, underlain to the west of the Fraser River by the Late Tertiary olivine



Text Fig.1 OUTLINE MAP OF BRITISH COLUMBIA SHOWING LOCATION OF THESIS AREA (STIPPLED).

basalts. To the east of the Fraser is an area of low foothills dominated by Granite Mountain (G.S.C. Map 932A, 2nd ed.), a number of small rivers, creeks and lakes, and an extensive marshy area. The creeks and rivers have incised channels, in some places cut quite deeply into Tertiary, Mesozoic and/or Paleozoic rocks (Lay, 1940). The area is largely covered by glacial deposits, mainly in the form of tills, outwash and recent alluvium, varying from five feet to twenty feet at Prince George to twenty-five to seven hundred feet in the Quesnel area (Tipper, 1957, 1959-60).

Drainage in the area is provided largely by the Fraser, Nechako, Chilako and Quesnel Rivers. Of these, the Fraser is by far the largest.

C. Vegetation

The vegetation in the study area can be classified into two biogeoclimatic zones (Krajina, 1965): the Cariboo Aspen-Lodgepole Pine-Douglas Fir Parkland and the Sub-Boreal Spruce Zones. The boundary between the two zones occurs approximately half-way between Prince George and Quesnel, with the Sub-Boreal Spruce Zone occurring more northerly. The nearby Cariboo Mountains are part of the Interior Subalpine Forest Zone, dominated by *Abies lasiocarpa* and *Picea engelmannii* which form the climatic climax forest.

The Cariboo Aspen-Lodgepole Pine-Douglas Fir Parkland is dominated by the three tree species contained in the name: *Populus tremuloides*, *Pinus contorta* and *Pseudotsuga menziesii* var. *glauca*. The forest is very limited and the land use is mainly agricultural (Krajina, 1965).

The Interior Subalpine Forest Zone contains, in addition to its climax forest of subalpine fir and Engelmann spruce, the dominants Tsuga mertensiana (mountain hemlock), Pinus albicaulis (white bark pine), Sorbus occidentalis (mountain ash), Empetrum nigrum (crowberry), several species of Vaccinium, Sambucus melanocarpa (black bead elder), Cornus canadensis (bunchberry), and the moss Rhytidiopsis robusta. The forest is good to very good for growth of Engelmann spruce (Krajina, 1965).

D. Climate

The Cariboo Aspen-Lodgepole Pine-Douglas Fir Parkland Zone has a microthermal continental subhumid to humid (Dfb) climate in Köppen's classification scheme (Krajina, 1959). The "D" type of climate is characterized by frozen ground and snow cover of several months' duration. The "f" and "b" refer, respectively, to having no distinct dry season, and cool summers with the average temperature of the warmest month less than 71.6° F. The average total precipitation is fourteen to twenty inches per year, including sixteen to seventy-five inches of snowfall. The mean annual temperature is 36-41° F., with a January mean of 10-16° F. and a July mean of 55-62° F. The number of frost-free days ranges (usually) from 50-150 (Krajina, 1965).

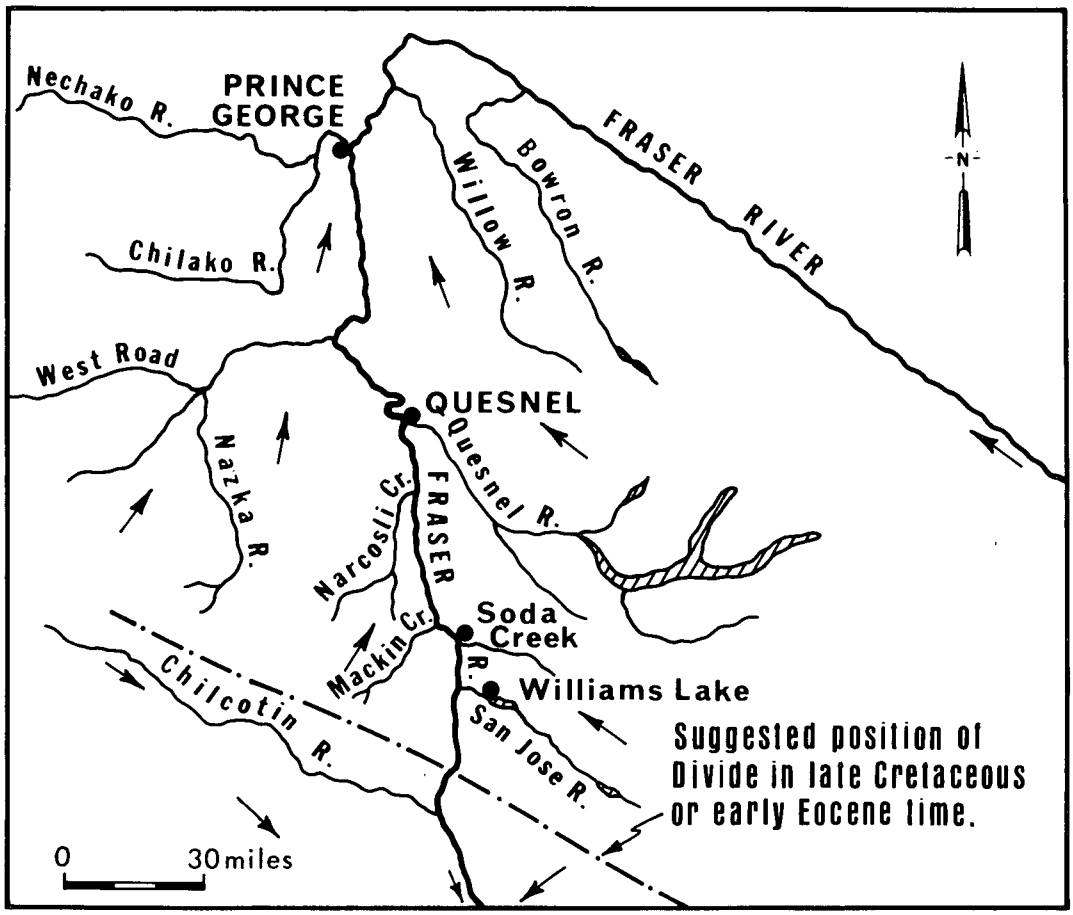
The Subalpine Fir Zone bears a Köppen classification of Dfc--microthermal, subalpine, cold humid. The "c" refers to a cool short summer, with less than four months in which the temperature exceeds 50° F. The annual total precipitation varies from 16-72 inches, and the yearly

snowfall ranges from 69-400 inches. The mean annual temperature is 33-39° F. The January mean is -1 to -20° F. and the July mean is 54-60° F. The number of frost-free days is from 50-100 (Krajina, 1959, 1965).

II. GEOLOGY OF THE AREA

A. Fraser River Drainage - History: British Columbia Department of Mines

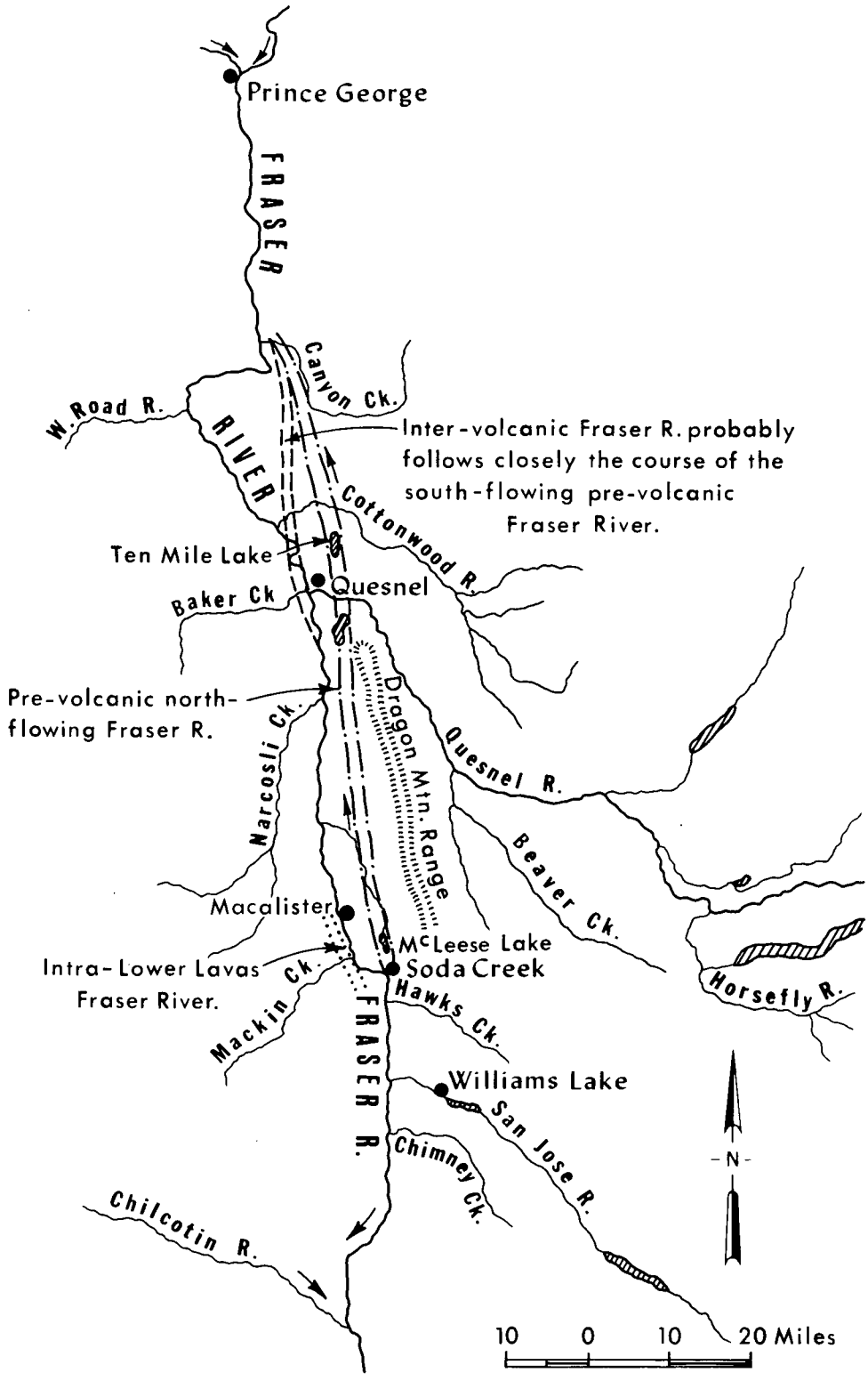
Lay (1940) made the first intensive efforts to study the Tertiary drainage-history of the Fraser River, and attempted to relate individual stratigraphic units to different periods of the drainage-history. He pointed out a number of topographic features supporting the idea that the Fraser flowed northward at one or more times since Late Cretaceous. These features were: (1) the sharp bend from northwest to south in the Fraser at its most northerly point (Text Figure 3, page 9), (2) the sharp contrast between the subdued relief of the Fraser River Valley north of Macalister and the gorge-like character south of Macalister (Text Figure 4, page 10), (3) the drainage pattern of the major tributaries (Text Figure 3), and (4) the presence of an immense bench between Ten Mile Lake and Soda Creek, sloping to the north and closely aligned with the northerly-trending valley of the lower part of Canyon Creek (Text Figure 4). Lay considered that the sharp bend executed by the Fraser and the contrasting segments of its valley, when combined with the drainage pattern of tributaries north of the mouth of the Chilcotin River, strongly suggested northward stream flow for the Fraser. He considered the extensive bench between Soda Creek and Ten Mile Lake to be an erosional remnant of a northward flowing Fraser River, noting its northward rather than southward slope. The elevation of the



UPPER PART OF FRASER RIVER SHOWING NORTHWARD FLOW OF ALL MAJOR TRIBUTARIES NORTH OF CHILCOTIN RIVER.

AFTER LAY, 1940

Text Figure 3



Text Fig. 4 SKETCH-MAP SHOWING FORMER CHANNELS OF FRASER RIVER.

After Lay, 1940

floor of the bench decreases, in a northward direction, from 3175 feet just north of Soda Creek to 2300 feet at Ten Mile Lake. The bench is terminated abruptly at Soda Creek where the Fraser River makes a sharp bend to the west.

The previously-mentioned features, along with the northerly-trending lower Canyon Creek Valley which is in line with the bench, strongly suggested stream piracy to Lay. He believed that in Late Cretaceous or Early Eocene times a divide had existed north of the mouth of the Chilcotin River, with northward drainage to the north, and southward drainage to the south of the divide. According to Lay (1940), the piracy was "accomplished by a tributary of the Chilcotin River which eroded northerly in much the same valley as that now occupied by the Fraser River in this region and, finally, accomplished a reversal of flow in the Fraser River Valley".

Because the Early Tertiary lavas, called the "Lower Lavas" by Lay, appeared to be of the valley-fill type deposited in deeply incised valleys, Lay postulated a "pre-Lower Lavas" age for the piracy. Subsequent to the piracy, and previous to the volcanic episode, diastrophic movement produced deeply incised, gorge-like valleys such as those now occupied by Narcosli and Baker Creeks (Lay, 1940). The ensuing Lower Lavas dammed the southerly-flowing Fraser, resulting in the deposition of the "Eocene or earlier Fraser River sediments (Intra-Lower Lavas Fraser River sediments of Lay, 1941). This sequence consists of interbedded "stratified breccias, tuffs and waterlaid sediments, varying from coarse conglomerates to silt intercalated with the Lower Lavas" (Lay, 1940).

The Fraser River Formation (the name given by Lay to the remaining later Tertiary sediments) consisted of three members as defined by him: (1) an Australian member, which included basal beds (the lignite coal measures) of the formation that are gently folded and dip up to 20-30° (Lay, 1940, p. 15), (2) Imbricated well-sorted gravels overlain by flat-lying "interstratified beds of fine gravel, sand, silt, clay, lignite, and occasional tuff beds", and (3) Diatomite deposits, "the uppermost members overlying (2)". Lay noted the distinct angular unconformity separating (1) and (2), and distinguished (2) and (3) on the basis of sedimentary differences. He reports imbricated gravels in (2) which "clearly express the restoration of a southerly flowing river" (his inter-volcanic Fraser River), "and its gradual reduction to lacustrine conditions". Lay states "It is clear that the diatomite deposits were laid down in river-made lakes, and not in basins due to lava damming, because the diatomite deposits in several exposures are overlain by Miocene (?) basalt, which is in turn capped with glacial deposits". Unfortunately, Lay located these exposures no closer than "the Big Bend of the Fraser River 10 miles north of Quesnel". To my knowledge no one else has seen them, including McCallum, Rouse and this writer, despite an intensive search by McCallum.

The latest Tertiary sequence discussed by Lay is his "Upper Volcanics". These "consist of fresh-looking, flay-lying or gently inclined olivine basalts, black in colour, usually vesicular, and frequently exhibiting columnar structure". At one exposure Lay observed

"8 feet of well-washed sand, silt and gravel" bedded between "40-45 feet of basalt" and "10 feet of pillow lavas". Imbrication in the gravel unit indicated to Lay the damming of a "southerly flowing stream by the Later Volcanics. This appears to contradict his earlier statement concerning the origin of the lakes in which the diatomite formed.

Further investigations by Lay (1941) produced evidence of sedimentation by a pre-volcanic Fraser River (sediments of which are not included in this study), a questionable date for the Intra-Lower Lavas Fraser River sediments, and additional exposures of his Intra-Upper Volcanics Fraser River sedimentary sequence. At one exposure near Macalister three volcanic episodes with interbedded sediments were measured. The date for the Intra-Lower Lavas Fraser River sediments was based on plant fragments taken from beds of tuffaceous grit exposed on Baker Creek (Lay, 1941, p. 42). The specimens were submitted to Dr. Walter A. Bell of the Paleontological Section, Geological Survey of Canada, Ottawa. His report is quoted by Lay as follows: "The leaves are too broken to be identifiable. Seemingly they represent a species of birch (Betula) like Betula macrophylla Heer. The age I think is probably Upper Eocene or Oligocene".

The features of Lay's tentative stratigraphic units and the comparison with McCallum's studies are shown in Table I, page 14.

B. Groundwater Survey: British Columbia Water Resources Service

McCallum (1969) re-defined Lay's Inter-Volcanics Fraser River Sediments (Fraser River Formation of Lay, 1940) as a Tertiary A-

LAY'S TENTATIVE STRATIGRAPHIC UNITS (After Lay, 1941)	AGE (Lay, 1941)	McCALLUM EQUIVALENTS (After McCallum, 1969)	AGE (Assigned here)	PIEL SAMPLING LOCALITIES (See Text Figure 2)
Tertiary Mine-Canyon Mine channel.	MIOCENE	Not Studied		
Lacustrine deposits in Fraser River Valley and tributary valleys.		Not Studied	?	Not Studied
Intra-Upper Volcanics Fraser River sediments.		Not Studied		
Upper Volcanics, chiefly basalt flows.		TERTIARY C - Volcanic and Sedimentary Unit	Miocene - Pliocene[2,3]	Volcanics Sampled only at Alexandria. Diatomite Sampled at Big Bend of Fraser River and on Nechako River.
Diatomite deposits (Members [c] of Fraser River formation).	OLIGOCENE			
Flat-Lying tuff beds of Horsefly area.		Not Studied	?	Not Studied
Inter-volcanic Fraser River sediments (Members (b) of Fraser River formation).		TERTIARY B - Sedimentary Unit	Probable Miocene	Big Slide Area - Moose Heights
Unconformity		Unconformity	Post-Early Oligocene	Unconformity
Australian members [a] of Fraser River formation (contain pebbles of Lower Lavas, but no intrusive igneous bodies).	EOCENE	TERTIARY A - Sedimentary Unit	Early Oligocene[4]	Alexandria Ferry and Narcosli Creek
Inclined tuff beds of Horsefly area with intercalated basalt flows of Lower Lavas.		Not Studied	?	Not Studied
Unconformity		Not Studied	?	Not Studied
Lower Lavas - dykes and sills.		1.	Eocene[1]	Narcosli Creek - Diamond Island
Intra-Lower Lavas Fraser River sediments.		Not Studied	Inferred Eocene[1]	Not Studied
Lower Lavas - andesite and basalt flows.		1.	Eocene	Narcosli Creek - Diamond Island
Unconformity		Not Studied	?	Not Studied
Pre-volcanic southerly-flowing Fraser River sediments.		Not Studied	?	Not Studied

Legend

1. Potassium-Argon dates: $42 \pm 3 \times 10^6$, $42 \pm 2 \times 10^6$, $43 \pm 3 \times 10^6$ years.
2. Potassium-Argon dates for associated ash beds: $10 \pm 2 \times 10^6$, $12 \pm 2 \times 10^6$ and $13 \pm 2 \times 10^6$ years (Mathews and Rouse, 1963).
3. Based on pollen and leaf information.
4. Based on titanothere teeth.

TABLE I Comparative Breakdown of Tertiary Rock Units: Lay (1941) and McCallum (1969).

Sedimentary Unit, a Tertiary B-Sedimentary Unit and a Tertiary C-Volcanics and Sedimentary Unit. For ages of these three units of McCallum, see Table I, page 14.

McCallum's Tertiary A-Sedimentary Unit consists of "interbedded sequences of clays, silts, sands, gravels and lignites". Based on dominant lithotypes McCallum recognized three facies. The Arkose Facies (type section located on lower Haggith Creek) consists mainly of "white and yellow arkosic sands and gravels, with thinner interbeds of green arkosic silts and clays". The arkosic sands and gravels are moderately well sorted. In some outcrops this facies contains brownish-black, compact lignites; in other outcrops lignite and heavily carbonized wood fragments are disseminated throughout the arkosic sediments, although lignite is generally associated with finer clastic fractions (McCallum, 1969).

The Gritty Clay Facies (type section on the west bank of the Fraser River approximately one-half mile south of Brodman Creek) consists "of grey green silty clays with a grit fraction (averaging roughly 10-15% of the rock type), of grains, granules, and small pebbles of clear (or white) subangular quartz and very dark grey subrounded argillite". Locally the clays are dark and carbonaceous, generally containing associated carbonized wood or lignite fragments. Included gravel interbeds are thin (average: 1-2 feet in thickness), lenticular, and "comprised of subangular to subrounded granules and small pebbles of very dark grey argillite with lesser clear (or white) quartz and minor

andesite or green schist". Dips of 15-55° to the southwest were recorded, the highest dips being located near the base of the section. At the mouth of Brodman Creek the gritty clays are in conformable contact with arkosic sands, gravels and clays. On the east bank of the Fraser River, at and below the mouth of Tabor Creek, McCallum noted "a progressive facies change from a dominant arkosic lithotype to a dominant gritty clay lithotype". Evidence from this section and a similar sequence approximately opposite the mouth of Haggith Creek led him to conclude a contemporaneous deposition for the Arkosic and Gritty Clay Facies.

The Gravel Facies (type section on the west bank of the Fraser River opposite the mouth of Cale Creek) consists of "dipping, poorly sorted gravels with a few gritty clay interbeds". According to McCallum (1969) the gravels vary in color from rusty yellow to grey brown, sorting is generally poor (fragments range from granules to boulders) and the predominant shape of the constituent particles is subangular. The green gritty clay beds associated with the gravels contain a few thin lignite seams. Dips in this section range from 25-35° to the southwest.

Structurally, McCallum found that the sediments of his Tertiary A-Sedimentary Unit had been subjected to mild diastrophism. He recorded dips ranging from horizontal to a maximum of 55° in the Prince George area, with an average dip of about 15°.

The Tertiary B-Sedimentary Unit does not outcrop in the South Prince George area, although it is present in water wells drilled

in the area. The type section of this unit is located at the "Big Slide" on the east bank of the Fraser River below Moose Heights, in the Quesnel area. Here, sediments "consist of flat-lying clays, silts, sands, gravels and lignites". McCallum believes these sediments were deposited by a northerly draining river system which then occupied the Fraser River Basin. While he did not cite evidence for this in his 1969 report, in personal conversation McCallum indicated a possible source area for the quartzite pebble gravels in the Cariboo Mountains. One of the main transport channels appeared to be along the Quesnel River, evidenced by outcrops of quartzite gravels along the Quesnel River.

The Tertiary B-Sedimentary Unit was divided by McCallum into "channel" and "off-channel" facies, on the basis of the dominant lithotypes of each. His 'channel facies' "consists of sands and gravels of fluvial origin that were probably deposited in the main channels of the Miocene river system. The 'off-channel' facies "consists of lacustrine and paludal clays, silts and lignites that were probably deposited in the lakes, swamps and floodplains that were part of this drainage system".

The Tertiary B sediments are found everywhere to be flat-lying, and resting with angular unconformity on top of gently folded Tertiary A sediments. The undeformed nature of the Tertiary B sediments led McCallum to conclude that no diastrophism had occurred in the Fraser Basin of central British Columbia since Oligocene or Miocene times.

The Tertiary C-Volcanics and Sedimentary Unit is best exposed along the banks of the Chilako and Nechako Rivers in the northwestern part of the thesis area, and at the Big Bend of the Fraser River opposite Moose Heights. That this unit records a Late Tertiary period of volcanism, with intermittent sedimentation, is demonstrated by exposures on the south bank of the Nechako River, roughly one mile east of the Canadian National Railway siding of Chilako. Here McCallum (1969) recorded "five feet of very dark, amygdaloidal and vesicular, olivine-rich basalt, exposed at Nechako River level, that contain fragments and bombs of dark, scoriaceous basalt". At another nearby exposure he reports "eighty feet of rusty pyroclastic-rich gravels and breccias containing blocks and bombs of dark amygdaloidal basalt". Another exposure in the vicinity shows clays interbedded with tuffaceous sands and pebble gravels. In the opinion of McCallum, the "period of contemporaneous sedimentation and volcanism came to a close with the emission of the flat-lying basalts that cap the valley rim".

It would appear then, based upon Lay's own evidence (Lay, 1941, p. 48), the data of McCallum (1969) and the radiometric evidence (see section III-D, E of this thesis) that the volcanic episode may have spanned considerable time and that the lakes in which the diatomite originated may indeed have been formed by lava dams.

From its present topographic position, the Big Bend diatomite (Text Figure 2, in pocket) appears to overlie the section of Tertiary B sediments on the east side of the river at Big Slide. According to Lay

(1940, p. 15) the diatomite is overlain by the flat-lying plateau basalts at several exposures; this relation of diatomite and basalt at the Big Bend could not be confirmed because no basalt was observed.

III. AGES AND DISTRIBUTION OF TERTIARY ROCKS

A. Early Tertiary Volcanic Rocks

Samples of the Early Tertiary Volcanic Rocks were taken from two outcrops along the west bank of the Fraser River: one from south of Diamond Island, and the second from an outcrop on Narcosli Creek (Text Figure 2, in pocket). Potassium-Argon analyses of whole rock samples yielded dates of 42 ± 3 and $42 \pm 2 \times 10^6$ years for the Narcosli Creek lavas, and $42 \pm 3 \times 10^6$ years for the Diamond Island sample. This places them in the Middle Eocene epoch according to Kulp (1961). The dates suggest a contemporaneous relationship with both the Kamloops volcanics from the southern interior (Rouse and Mathews, 1961), and the Endako Group to the west of Prince George (Mathews, 1964).

The basalts from both Diamond Island and Narcosli Creek are highly weathered and badly deformed. Their appearance is in rather sharp contrast to the later Tertiary Plateau Basalts in the area.

B. Alexandria-Narcosli Sediments (Tertiary A Unit of McCallum)

The place-names Alexandria and Narcosli are used to refer to the places where Tertiary A sediments outcrop most prominently. The Alexandria sediments are exposed on the east bank of the Fraser River approximately one-fourth mile downstream from the old Alexandria ferry landing (Text Figure 2, in pocket). The sequence consists of interbedded clays, lignites, gravels and sands, with clays and silts containing ironstone concretions occurring just above river level. The strata dip

gently to the south (estimated dip of 15°), are are overlain by glacial till and silts.

The Narcosli sediments are seen in outcrop just south of the mouth of Narcosli Creek, on the west bank of the Fraser River. Here also, clays and lignites are interbedded with scattered layers of pebbles. The only other outcrop of sediments of this age group (exposed only during periods of very low Fraser River level) occurs on the south side of the nose forming Moose Heights (Lay, 1940, p. 21). In addition, the sections described by McCallum (1966, 1969) at Brodman, Haggith, Cale and Tabor Creeks appear to be of approximately the same age on the basis of palynological determinations.

The age of the Alexandria-Narcosli sediments is Late Early Oligocene, based on titanothere teeth bedded with the lignites at the Narcosli Creek exposure. The teeth were transmitted to Dr. L. S. Russell, Chief Biologist for the Royal Ontario Museum, University of Toronto. Dr. Russell replied (in part):

> "In spite of their broken nature I can identify them with some confidence as representing the first and second molars and a premolar, probably the fourth, from the right lower dentition of a titanothere (= brontothere). The size is larger than most of the titanothere teeth that we get in the Cypress Hills formation, and compares more closely with that of examples from the Chadron formation of the White River group. I should therefore date the specimens with some confidence as from the later part of Early Oligocene time, somewhat younger than the titanotheres from Saskatchewan. The poorly developed external cingulum on the molars, according to Osborn's criteria, indicates a brontotherine genus, possibly Megacerops or Brontotherium".

3. Big Slide Sedimentary Rocks (Tertiary B Unit of McCallum)

Big Slide sediments derive their name from outcrops on the east bank of the Fraser River below Moose Heights, at the locality locally called the "Big Slide". The section consists of horizontally bedded clays, silts, sands, and lignites. This exposure appears to be the same as the "off-channel" facies described by McCallum (1969), and discussed earlier in this thesis.

The age of the Big Slide sediments is probably Miocene, based on palynomorphs and leaves. For a further discussion of age, see section V of this thesis. According to Lay (1940, pp. 15, 21) Big Slide sediments underlie the Late Tertiary Diatomite (Tertiary C-Volcanic and Sedimentary Unit of McCallum) with no obvious angular discordance. Inferences from this relationship also suggest that the age of the diatomite is close to that of the Big Slide sediments.

4. Late Tertiary Diatomite (Tertiary C Unit of McCallum)

Samples of this unit which were studied include the diatomaceous, low-bulk density sediments which outcrop along the Nechako River, and the diatomite exposed at Big Bend on the west bank of the Fraser River across from Moose Heights. The Nechako River diatomaceous sediments are underlain by olivine basalts that appear to be related to the plateau basalts of the Interior Plateau area. Ash beds in or near these plateau basalts have been dated at 10 ± 2, 12 ± 2 and $13 \pm 2 \times 10^6$ years (Mathews and Rouse, 1963; Mathews, 1964).

Mathews and Rouse (1963) describe leaves from diatomaceous sediments in several geologically related areas of British Columbia,

which indicate a close relationship to Late Miocene paleofloras of the Columbia Plateau (Chaney, 1959). Because of the uncertainty of the age relations of ashes, basalts and diatomaceous sediments, Mathews and Rouse (1963) assigned the diatomite and related sediments to the Late Miocene or Early Pliocene. An expanded discussion of the leaf and palynomorph assemblages is included in section V of this thesis.

5. Late Tertiary Plateau Basalts (Tertiary C Unit of McCallum)

Very little new information can be contributed, relative to the age of this unit. One new sample (whole rock analysis) from a flow of columnar-jointed, olivine basalt near Alexandria yielded two dates: 7 ± 2 and $10 \pm 2 \times 10^6$ years. This is three to six million years younger than the Chilcotin ash reported by Mathews (1964) as $13 \pm 2 \times 10^6$ years, possibly suggesting that the Alexandria flow occurred later than the basalt overlying the diatomite and associated sediments in other regions. However, with ages this young and standard deviations so large, no definite conclusions can be drawn here.

IV. PERTINENT PALYNOLOGICAL AND PALEOBOTANICAL LITERATURE

A number of important palynological studies have been conducted on sediments of similar age, particularly by Russian workers. Most significant are those edited by Pokrovskaya on the Miocene (1956a) and Oligocene (1956b) of various regions of the U.S.S.R. Also important is the three-volume series, entitled simply Paleopalynology (Ed. Pokrovskaya, 1966), which illustrates typical Russian palynomorph assemblages from Proterozoic to Quaternary. A most significant feature is the striking similarity of Eastern Russian and Western North American Oligocene and Miocene palynomorph assemblages, indicating the existence of a northern pan-Pacific paleoflora.

Also important are Zaklinskaya's (1963) work on Upper Cretaceous and Paleogene microfossils, and Dorofeev's (1963) investigation of fossil seed floras of Western Siberia.

Palynological and leaf studies on various Tertiary rocks have been performed in Japan. Sato (1963) studied Miocene sediments of Hokkaido. Takahashi investigated pollen and spores of the west Japanese older Tertiary and Miocene (1961); Tertiary coal fields of Northern Kyushu (1957), and the Hioki strata (Upper Oligocene) of Kyushu (1963). Tanai and Suzuki (1963), Huzioka (1963), and Matsuo (1963) studied Miocene leaf floras. Tanai and Suzuki (1965) also published studies on late Tertiary leaf floras from Northeastern Hokkaido, Japan.

In the European area, Macko investigated Miocene brown coals of Lower Silesia (1959) and the Lower Miocene pollen flora of Upper Silesia (1957). Manten (1958) has studied the Miocene brown coal deposits at Haanrade, Limburg, Netherlands, and Simpson (1961) published the Tertiary pollen flora of Mull and Ardnamurchan. Of taxonomic importance is the series by Krutzsch (1962) concerning the Middle and younger Tertiary dispersed spores and pollen.

Particularly significant in North America is the work by Traverse (1955) on the Oligocene Brandon lignite of Vermont. More specifically related to this thesis are Martin and Rouse (1966) on the Late Tertiary sediments of the Queen Charlotte Islands; Hopkins (1966, 1968) on the palynology of the Tertiary sediments of the Whatcom Basin of Northwest Washington.

Occurrence of specific palynomorphs and the conclusions drawn by the above workers are discussed in detail in the section dealing with palynological assemblages.

V. PALYNOLOGICAL ASSEMBLAGES AND PALEOECOLOGICAL CONSIDERATIONS

The sedimentary units studied are somewhat limited in both exposure and areal extent. Hence the microfossils recovered from all samples in each unit are treated as one assemblage. A range chart (Table V) of important palynomorphs is located in the pocket inside the back cover of this thesis.

A. Alexandria-Narcosli Assemblage (Early Oligocene)

Seven samples were analyzed from this unit, including three clay beds from the Alexandria Ferry locale, and one clay and three lignites from the Narcosli exposures. The lignites from Alexandria Ferry were generally lacking in pollen and spores, but were quite rich in fungal spores and hyphae.

A checklist of the palynomorphs from this sedimentary unit is given in Table II, page 27. The checklist contains a total of 97 described palynomorphs which appear to be important for characterizing the Alexandria-Narcosli assemblage. This includes 23 arboreal angiosperms; 26 gymnosperms; 25 probable or known non-arboreal angiosperms; 18 ferns and other lower plants; and 5 groups of uncertain taxonomic placement. Approximate percentages for the entire assemblage are: angiosperms - 37%; bladdered conifers - 8%; non-bladdered conifers - 19%; and ferns and lower plants - 36%. The rather high percentage for the ferns and *Lycopodium* can be attributed mainly to one sample in which they comprised 69% of the total number of microfossils counted. If this sample is not considered, the percentages for each group become: angiosperms - 44%; bladdered conifers - 11%; non-bladdered conifers - 22%;

TABLE II

Checklist for Alexandria - Narcosli Sediments

ARBOREAL ANGIOSPERMS		OTHER ANGIOSPERMS		GYMNOSPERMS		FERNS AND LOWER PLANTS	
Acer	(PG-94)	? Acanthaceae	(PG-103)	Abies		? Equisetum	(PG-6)
Acer	(PG-95)	? Acanthaceae	(PG-104)	Cedrus	(PG-29)	Laevigatosporites	(PG-15)
Alnus	(PG-76)	Boisduvalia	(PG-97)	Cedrus	(PG-30)	Laevigatosporites	(PG-16)
Alnus	(PG-77)		(PG-98)	Ephedra	(PG-52)	Laevigatosporites	(PG-17)
Betula	(PG-78	? Dorstenia	(PG-88)	Glyptostrobus	(PG-44)	Leiotriletes	(PG-21)
Carya	(PG-70)	Jussiaea	(PG-99)	Glyptostrobus	(PG-45)	Leiotriletes	(PG-22)
Carya	(PG-71)	Liliacidites	(PG-55)	Glyptostrobus	(PG-46)	Lycopodium	(PG-7)
Carya	(PG-72)	Diervilla	(PG-105)	Metasequoia	(PG-47)	Lycopodium	(PG-8)
Castanea	(PG-81)	Pachysandra or		Picea	(PG-31)	? Lycopodium	(PG-9)
Corylus	(PG-80)	Sarcococca	(PG-92)	Picea	(PG-32)	Osmunda	(PG-11)
Engelhardtia	(PG-73)	Potamogeton	(PG-53)	Picea	(PG-33)	Osmunda	(PG-12)
Fagus	(PG-82)	Psilastephanocolpites	(PG-62)	Pinus	(PG-34)	Osmunda	(PG-13)
Fagus	(PG-83)	? Symplocos	(PG-100)	Pinus	(PG-36)	Psilotum	(PG-10)
Fraxinus	(PG-101)		(PG-56)	Pinus	(PG-37)	Polypodiaceae	(PG-14)
Fraxinus	(PG-102)		(PG-57)	Podocarpus	(PG-24)	Stereisporites	(PG-18)
Juglans	(PG-74)		(PG-58)	Podocarpus	(PG-25)	Toroisporites	(PG-20)
Liquidambar	(PG-89)		(PG-59)	Podocarpus	(PG-26)	Triplanosporites	(PG-19)
Myrica	(PG-69)		(PG-60)	Pseudotsuga	(PG-38)		(PG-23)
Prosopis	(PG-91)		(PG-61)	Sciadopitys	(PG-48)		
Pterocarya	(PG-75)		(PG-64)	Taxodium	(PG-49)	INCERTAE SEDIS	
Quercus	(PG-84)		(PG-65)	Taxodium	(PG-50)		
Quercus	(PG-85)		(PG-66)	Taxodium	(PG-51)	Schizosporis	(PG-2)
Tilia	(PG-96)		(PG-67)	Tsuga	(PG-39)	Sigmopollis	(PG-3)
Ulmus	(PG-86)		(PG-68)	Tsuga	(PG-40)	Sigmopollis	(PG-4)
Ulmus	(PG-87)			Tsuga	(PG-41)		(PG-5)
				Tsuga	(PG-43)		
						DINOFLAGELLATES	
						Micrhystridium	(PG-1)

and ferns and lower plants - 23%. The latter figures appear to be more representative for the assemblage.

Immediately apparent is the predominance of angiosperms, non-bladdered conifers (largely Taxodium, Glyptostrobus and Metasequoia), and the ferns and lower plants (mostly ferns). The number of taxa is also large, these three categories accounting for 79 of the aforementioned 97 described palynomorphs.

Of the arboreal angiosperms, Alnus, Quercus, and Ulmus clearly occur most frequently. Carya, Fagus, Acer and Castanea each are moderately well-represented in one or more samples, but seldom, if ever, approach the percentages of Alnus, Quercus or Ulmus. The remainder of the arboreal angiosperms are either well-represented in only one sample, or are poorly represented in all samples.

Pinus, in the bladdered conifer group, clearly occurs with greatest frequency in five of the seven samples. In the remaining samples, Cedrus was the most abundant pollen of this group. Podocarpus was well-represented in only one sample. Tsuga occurs in the majority of samples, but is nowhere represented by a high percentage.

Of the non-bladdered conifers, Taxodium and the species of Glyptostrobus occur in far greater numbers than the other pollen of this group.

The most consistent representatives of non-arboreal angiosperm pollen are PG-53 (Potamogeton), PG-56, PG-57, PG-60 and PG-62. The occurrence of Potamogeton is not unexpected because the lithology of

the sediments suggests that deposition occurred mainly in marshes, ponds or lakes.

Spores of Laevigatosporites ovatus are the most prolific of the fern and lower plant group. The spores of the other two species of Laevigatosporites, along with Osmunda, occur consistently, but in much lower numbers than L. ovatus.

Finally, the microfossils Sigmopollis hispidus and PG-4 (Sigmopollis sp.) are common, although not in large numbers. Micrhystridium occurs consistently, but ? Equisetum spores occur to an appreciable extent in only one sample.

A comparison of the occurrence of palynomorphs in clays vs. lignites reveals surprisingly little difference between the two lithologies. Fagus and Laevigatosporites albertensis occur exclusively in the clays, and PG-51 (? Taxodium sp.) is also essentially restricted to clays. Sigmopollis sp. (PG-4) is restricted to lignite, and PG-62 was found almost exclusively in this lithotype. These differences cannot be regarded as highly significant however, since in no instance do these pollen types form a major component of the total microfossil content. Moreover, only seven samples have been analyzed. This is considered to be an inadequate number on which to establish an association between a pollen type, and a specific sediment and its environment of deposition. What does appear clear is that there is much more similarity than dissimilarity between assemblages in different lithologies.

The lithologies indicate deposition in adjacent marshes, small ponds and the river channel itself. Stream levels during periods of high rainfall would mix pollen produced in the ponds and marshes with that carried by the river. This appears to be one reasonable explanation for the similarity of pollen assemblages from the clays and lignites.

Another explanation could be somewhat similar edaphic conditions between the marshes and the adjacent stream bed. The lignites do contain quantities of clastic sediment, indicating periodic influx from the river itself. If clastic deposition in the marsh were rapid enough, edaphic conditions may not have been drastically different between marsh and stream bed.

Still another factor to be considered is the width of the river channel in Oligocene time. McCallum (1966) shows widths of eight miles and more for the Fraser channel in the Prince George area. If this were also true for the Alexandria-Narcosli area, the river discharge would spread over much of the wide channel and the natural levees would probably be quite low. In this case high river levels would probably cover both the marshes and small ponds in the river channel, thereby further minimizing any differences between the pollen rain deposited in the two areas.

The most striking features of the Alexandria-Narcosli assemblage are the paleoclimatological implications of some of its constituent palynomorphs. No less than eight pollen types from this

assemblage have modern counterparts with tropical or sub-tropical distribution. Included are Metasequoia, Glyptostrobus, Taxodium, Podocarpus, Ephedra, Engelhardtia, ?Dorstenia, and Psilotum. In addition, pollen type PG-62 appears to be identical to Psilastephanocolpites marginatus figured by Gonzalez Guzman (1967) from the Eocene of Colombia. The occurrence of Pachysandra, whose present day occurrence stretches from Florida to Louisiana, and Prosopis, presently occurring from the southwestern United States into Mexico, further indicate a very warm climate. Further confirmation is provided by the pollen of Diervilla (or Lonicera) and ? Symplocos; both have extant representatives in the sub-tropical area of Southestern China, in addition to their temperate occurrence. In fact, very few of the generically identifiable Oligocene taxa are without modern representatives in sub-tropical areas.

Specifically, the monotypic Metasequoia glyptostroboides occurs in Central China (Willis, 1966) in the provinces of Szechuan and Hupei (Hu and Cheng, in Chaney, 1950). The July surface temperature here exceeds 80°F., the January surface temperature ranges from 32° - 48° F., and the annual rainfall is 25 - 50 inches (University Atlas, 1964). Glyptostrobus pensilis, also monotypic, is presently distributed from the southeastern Chinese provinde of Kwangtung to the northeastern parts of the province of Kiangsi (Hu, 1962). In the southeastern province this species is a marsh dwelling tree or shrub, while in Kiangsi it is a tree up to 60 feet in height. The Kiangsi area has the

same temperature regime as previously mentioned for Metasequoia, but the rainfall is slightly higher at 40-60 inches per year. In Kwangtung the July surface temperature exceeds 80° F., whereas that of January ranges from 48° - 64° F. The rainfall in Kwangtung is from 70 - 90 inches per year (University Atlas, 1964).

The present distribution of Taxodium distichum (bald cypress) is concentrated in the Southeastern United States, with occurrences as far north as southern Delaware on the Atlantic Coast, and inland along river valleys to southeastern Oklahoma and southwestern Indiana (Collingwood and Brush, 1964). Taxodium mucronatum (montezuma bald cypress) occurs in Mexico, extending also into southern Texas (Preston, 1961). The distribution of Taxodium distichum corresponds very closely to the summer-wet, winter-dry areas of 35-50 inches annual rainfall. The July and January surface temperatures are, respectively, 64° - over 80° F. and 32° - 64° F. The maximum development of the species is in the areas where the summer and winter temperature are over 80° F. and 48° - 64° F., respectively (University Atlas, 1964).

Podocarpus (about 100 spp.) occurs in tropical to temperate climates in both northern and southern hemispheres. Polunin (1960) records its occurrence in the temperate rain forests of New Zealand, and I have personally observed a species of Podocarpus in the tropical rain forest of Veracruz, Mexico. In the Mexican area the annual rainfall is 80 - 120 inches and the July and January surface temperatures are over 80° F. and 64° - 80° F., respectively (University Atlas, 1964).

Ephedra (about 40 spp.) occurs in climates ranging from warm temperate to tropical (Willis, 1966; Lawrence, 1951). The genus is found only in arid areas, and in North America is restricted to California, Arizona, New Mexico, Texas and Mexico.

Engelhardtia occurs in Mexico and Central America as well as Southeastern Asia (Willis, 1966). Hu (1926) records Engelhardtia chrysolepis from the sub-tropical area of Southeastern China. Later, Hu (1929b) noted the occurrence of E. chrysolepis among the southern Chinese trees and shrubs, where it occurs with three species of Symplocos, another apparent element of the Alexandria-Narcosli assemblage. Stone (1968) commented on the occurrence of Engelhardtia mexicana and E. guatemalensis from the Volcan de San Martin area of Veracruz, Mexico, and Sharp (1966) has discussed the bicentric distribution of Engelhardtia in Southeastern Asia, Mexico and Central America. The climatic distribution of this genus thus appears to be tropical to sub-tropical.

? Dorstenia is a tropical, herbaceous member of the family Moraceae. The number of species in the genus varies from 125 (Lawrence, 1951) to 170 (Willis, 1966). Standley (1920) records the genus from Mexico and also from Costa Rica (1937).

Psilotum is represented by perhaps as many as three species, and occurs in tropical and sub-tropical areas, extending north (in hammocks) to Florida and the coast of South Carolina (Lawrence, 1951).

The occurrence of these eight genera, with their tropical to sub-tropical extant ranges, indicates a very warm temperate to sub-

tropical climate for the Early Oligocene period represented by the Alexandria-Narcosli pollen assemblage. In fact, of the arboreal angiospermous and gymnospermous genera shown in the checklist, only five (Abies, Cedrus, Picea, Taxodium and Sciadopitys) are not recorded by Hu (1926, 1929a, 1929b) from Southeastern China. In addition, the genera Symplocos, Lonicera and Diervilla are also mentioned as prominent members of this extant flora.

Taken in its entirety, the Alexandria-Narcosli assemblage suggests a prevailingly humid, sub-tropical to warm temperate climate, in which the winter temperature probably was seldom lower than 48° - 64° F. and the rainfall varied somewhere between 50 - 120 inches per year. I believe these ranges are appropriate in view of the presence of the several varieties of Taxodium and Glyptostrobus, and the occurrence of Engelhardtia and ?Dorstenia. The climate must have closely resembled that on the Gulf Coast of the United States, or that of the most southeastern area of coastal China between 20° and 23° North latitude. If the similarity between the extant flora of Southeastern China and the Alexandria-Narcosli paleoflora is a reliable indicator, the annual rainfall of 80 - 90 inches was largely concentrated in the months from May through September, and the winter temperature probably was seldom lower than 55° - 65° F. These figures are given for Hongkong (University Atlas, 1964), which is located approximately in the center of the aforementioned coastal area of Southeastern China. This same climate and rainfall regime is true for the area in Mexico and Costa Rica, where

the extant Dorstenia occurs. By inference, the climate of interior British Columbia in Early Oligocene time must have been a summer-wet, winter-dry type. The same summer-wet, winter-dry climate has been recorded by Chaney (1938, 1959), Axelrod (1956, 1964) and Smiley (1963) for other tertiary localities in the Pacific Northwest.

From a perusal of modern weather charts (University Atlas, 1964; Rumney, 1968) it is apparent that the rainfall pattern for the central interior regions of British Columbia has changed, both in amount and seasonality since Oligocene time. The annual rainfall for Kamloops, British Columbia, in the southern interior is approximately ten inches, distributed more or less evenly over the entire year. Mathews and Rouse (1963) report an annual precipitation of 16.74 inches for Quesnel in the central interior. These reduced amounts are attributable to the rain shadow created by the Coast Mountains located to the west. However, the rainfall is much heavier in the Pacific Costal areas and is concentrated in the winter rather than the summer. In Seattle only about 20% of the annual rainfall comes in the months from May through September, while in Vancouver the comparable value is 17%.

Mathews and Rouse (1963) have suggested that the Coast Range was much lower than its present altitude during much of Tertiary time. If this is true, the necessarily greater rainfall figures for the Early Oligocene would more easily be explainable. However, this would not explain the switch in the seasonal aspect of the rainfall which appears to have taken place since the Early Oligocene. It is possible that some change in the wind circulation could have occurred to account for the

apparently drastic change in seasonality of the rainfall since Oligocene time. This would, in turn, require substantial changes in the temperature regime for a large area of North America, including adjustments in amount of radiated heat. However, I believe that the rainfall changes can be explained without invoking changes in wind direction and heat budget. It is interesting to speculate on the factors which could have produced this change. Such conjecture is presented in the following paragraphs as a possible explanation for the apparent change in rainfall regime.

Mathews and Rouse (1963) have implied low Coast Mountains in the Late Tertiary to account for higher rainfall in the interior of British Columbia. Nevertheless, low elevations of the Coast Mountains cannot be assumed for the Early and Middle Tertiary. White (1959) shows strong orogenic pulses in the Coast Mountains in Upper Jurassic and Lower Cretaceous time, and believes these pulses "may have persisted in comparatively intense form into Upper Cretaceous time". He further shows the Coast Mountains area as "strongly positive" during Upper Cretaceous - Paleocene deposition.

Mathews' (1964) suggestion of about thirty million years for development of a late-mature erosion surface on resistant granite and metamorphic rocks suggests that the Coast Mountains could have been relatively high during Early Oligocene time.

If the Coast Mountains were not elevated to any appreciable extent during the Middle Tertiary, a partial explanation for the higher Oligocene rainfall may lie in the height of the Canadian Rockies. This

chain is commonly believed to have originated in Eocene - Oligocene time (Taylor, Mathews, and Kupsch, in McCrossan and Glaister, eds., 1964, p. 193; Haun and Kent, 1964; Eardley, 1961) with the Laramide Revolution. Cook (1960) states that many areas of the Rockies were further elevated by 5000 feet or more, by epirogenic uplift which began in the Oligocene and lasted until Late Pliocene. With this possibility of a rather high Rocky Mountain area, and if the Coast Mountains were of only moderate altitude, a quite moist province could have existed to the west of the Rockies. Although this could account, at least in part, for the increased rainfall, it still does not explain the seasonal reversal in precipitation.

It may be possible, however, to explain both the seasonal reversal and the increase in rainfall if the climatic implications of the Oligocene paleoflora are carried to their logical conclusion. The present cool temperate flora in the Alexandria-Narcosli region appears to be related to the Arctic ice cap, as well as to its isolation from oceanic influence by the Coast Mountains. Quesnel is within approximately 1500 miles of the edge of the minimum polar ice cap (Rumney, 1968). In this area winds sweep down from the polar area, bringing cold, dry air masses which materially contribute to the maintenance of the present vegetation. It follows then, that these same conditions would not have permitted the existence of sub-tropical vegetation, had they prevailed in Early Oligocene time. This would indicate the absence of a polar ice cap in Oligocene time; rather the

Arctic ocean must have been much warmer than at present, as suggested by Durham (1950). To provide the warm, moist conditions for the Quesnel area, the atmospheric circulation was likely much the same as today. The same winds which now bring cold, dry air from the polar area would have brought warm, moist air to the Quesnel region during the Oligocene. Westerly winds from the Pacific, even over a moderately elevated Coast Mountain Range would have driven the warm, moist polar air against the Rockies, thereby producing the warm, wet, humid regime indicated by the Oligocene paleoflora. This same condition, of warm, moist winds rising against a mountain range, is at least partially responsible for maintenance of the wet, humid conditions in sub-tropical and tropical areas of Mexico between the Sierra Madre Oriental and the Atlantic Ocean (a distance of some 50 - 100 miles). While largely conjectural, this explanation accommodates the climatic evidence derived from the Oligocene paleoflora, and the various possibilities based on evidence of mountain building.

The Alexandria-Narcosli flora must have existed on the aerial portions of the river bed, floodplains, and the low elevations near the river. The occurrence of Equisetum, Psilotum, Glyptostrobus and Taxodium suggest extensive moist, low-lying areas, and the presence of Potamogeton and Micrhystridium indicate the existence of open pools and streams. The small bladdered conifer element strongly suggests a distant source for conifers, such as the Rocky Mountains. A similar case of long-distance transport is recorded by Piel (1965) who found pollen of Picea in recent

cores from the delta of the Mississippi River. The nearest possible sources for Picea pollen is either the eastern Kentucky - Western North Carolina area, or the Rocky Mountains of Colorado (Preston, 1961).

B. Big Slide Assemblage (probable Miocene)

1. Pollen Assemblage

The age of this assemblage is more uncertain than the ages of the Alexandria-Narcosli or the diatomite assemblage (Unit C). Some of the pollen from the five clay and lignite samples compare favorably with examples shown by MacGinitie (1962) for the Late Miocene (Barstovian) Kilgore flora of Nebraska. MacGinitie's horizon was dated with mammalian faunas. On the basis of observed similarities between the two paleofloras, a tentative assignment of a Miocene age appears warranted for the Big Slide sediments.

With regard to recovered palynomorphs (see checklist, Table III, page 40) and leaves, the Big Slide sediments both resemble and differ from the Early Oligocene sediments. Of the 103 palynomorphs described in this thesis, 55 occur in the Big Slide sediments. The most conspicuous absentees from Big Slide are Engelhardtia, Ephedra, Pachysandra, Diervilla, Psilastephanocolpites marginatus, ? Symplocos, Sciadopitys, Sigmopollis hispidus, and one species of Glyptostrobus (PG-46). There are also lower numbers of both specimens and species of ferns and lower plants (with the exception of Laevigatosporites ovatus) in the Big Slide sediments.

One specimen of ? Dorstenia was observed in the Big Slide

TABLE III

Checklist for Big Slide Sediments

ARBOREAL ANGIOSPERMS

Alnus	(PG-76)
Alnus	(PG-77)
Carpinus	(PG-79)
Carya	(PG-70)
Carya	(PG-71)
Carya	(PG-72)
Castanea	(PG-81)
Corylus	(PG-80)
Fagus	(PG-82)
Fagus	(PG-83)
Fraxinus	(PG-102)
Juglans	(PG-74)
Liquidambar	(PG-89)
Liquidambar	(PG-90)
Myrica	(PG-69)
Pterocarya	(PG-75)
Quercus	(PG-84)
Quercus	(PG-85)
Tilia	(PG-96)
Ulmus	(PG-86)
Ulmus	(PG-87)

OTHER ANGIOSPERMS

? Acanthaceae	(PG-104)
? Dorstenia	(PG-88)
Jussiaea	(PG-99)
Potamogeton	(PG-53)
	(PG-57)
	(PG-60)
	(PG-63)
	(PG-66)
	(PG-68)

GYMNOSPERMS

Abies	(PG-27)
Cedrus	(PG-29)
Cedrus	(PG-30)
Glyptostrobus	(PG-44)
Glyptostrobus	(PG-45)
Metasequoia	(PG-47)
Picea	(PG-32)
Pinus	(PG-34)
Pinus	(PG-35)
Pseudotsuga	(PG-38)
Taxodium	(PG-49)
Taxodium	(PG-50)
Taxodium	(PG-51)
Tsuga	(PG-40)
Tsuga	(PG-43)

FERNS AND LOWER PLANTS

Laevigatosporites	(PG-15)
Laevigatosporites	(PG-16)
Lycopodium	(PG-7)
Osmunda	(PG-11)
Osmunda	(PG-13)
Stereisporites	(PG-18)

INCERTAE SEDIS

Schizosporis	(PG-2)
Sigmopollis	(PG-4)

sediments. The genera Liquidambar, Pterocarya, Ulmus, Castanea, Carya, and to a limited extent, Quercus, all occur in greater numbers in the Big Slide sediments than in the Early Oligocene sediments. The same holds for pollen of the family Acanthaceae. Alnus is well represented, as are the species of Laevigatosporites. The Liquidambar in Big Slide sediments appears to be a different species from that in the Oligocene unit. Also, Carpinus sp. (PG-79) occurs only in Big Slide sediments.

The pollen assemblage from the Big Slide unit bears considerable resemblance to assemblages shown by Sato (1963) and Takahashi (1961) from the Miocene of Japan. The latter author found the same increase in pollen of Castanea in the Miocene as I have found. He also shows Alnus and Carya to be reasonably well-represented in both Oligocene and Miocene.

Russian Miocene sediments also contain pollen assemblages which are similar to the Big Slide assemblage (see Pokrovskaya, ed., 1956a; 1966). Similarities at the generic level are so pronounced as to make over-emphasis of this point difficult.

Leaf and pollen assemblages from Alaska (Wolfe, 1966) also compare favorably with the Big Slide fossils. Wolfe noted Pterocarya leaves and pollen in the Homerian (upper half of the Miocene). Also present in the Homerian were Alnus, Betula-type, Ulmus-type, Corylus, Carya, taxodiaceous and pinaceous pollen.

Inasmuch as the ecologic setting, as evidenced by the alternating sequences of clay and lignite, seem to be the same for the

Big Slide and Alexandria-Narcosli units, there appears to have been some climatic change between the times of deposition of the two units. The heavy influx of Castanea and Pterocarya, together with the absence of Pachysandra, Ephedra, Psilastephanocolpites marginatus and the tropical Engelhardtia indicate a cooling of the climate by the time of Big Slide deposition. The presence of one specimen of ? Dorstenia is difficult to explain if extensive cooling occurred between Oligocene and Miocene time. Perhaps it survived in some type of protected habitat, or, this one specimen could be reworked.

The reduction in numbers of species present is probably another indication of cooler climate at the time of Big Slide deposition, or at least an intervening cool interval between Oligocene and Miocene. Comparisons between extant floras from sub-tropical or tropical areas and their temperate counterparts show this same reduction of species in the latter over the former.

The aforementioned intervening cooler period is shown by Dorf (1955) and Brooks (in Dorf, 1959) in paleotemperature charts for the Tertiary of North America. Both charts show a decline in temperature from the Early Oligocene into the Early Miocene, with a warming in the Middle Miocene. This cooling interval could have resulted in the introduction of more temperate plants as postulated by Chaney (1947) and others. According to Dorf (1955) species involved in plant migration will: (1) adjust to the new climatic conditions rather than migrate; (2) be unable to either migrate or adjust and hence will be exterminated; (3) undergo changes during migration and end up as new species. It is

possible that the first two possibilities are evidenced in the Big Slide assemblage, for it has some taxa in common with the Oligocene assemblage and other Oligocene taxa are missing. Superimposed on this possibility is that of a return of some of the hardier Oligocene taxa due to the warming trend in the Middle Miocene.

The climatic change evidenced in the Big Slide assemblage was not, however, of the magnitude sufficient to establish the boreal vegetation typical of the modern flora in the area. The broadleaf element is still the predominant member of the Big Slide assemblage. While the exact climatic regime during Big Slide deposition is not completely clear, it well may have resembled that existing today in the upper Mississippi River Valley area of Illinois, Indiana and Kentucky. Another similar climatic setting could be the middle Atlantic coastal area of the United States. Both areas have a mean annual rainfall of 40 - 50 inches, a mean annual temperature of 47° - 59° F. and have only slightly more rainfall in the summer than in other months (University Atlas, 1964; Ward, Brooks and Connor, 1936). Most of the dominant members of the Big Slide assemblage occur in these areas today.

A reasonably exact age for the Big Slide sediments is more difficult to affix than is the climate. The change in the climate indicates an indefinable time break between depositional intervals, as does the unconformable structural relationship between the Big Slide and the underlying Alexandria-Narcosli unit. Any effort to state the exact period of elapsed time is highly speculative because of the number of variables, such as mountain building; rate of cooling of the warm Oligocene

polar sea; rate of floral migration; and rate of floral evolution.

Perhaps some evidence can be adduced by a comparison of the British Columbia unconformity with a similar feature in Montana. Such a Middle Tertiary feature in southwestern Montana is discussed by Kuenzi and Richard (1969). Several small basins in that area show this unconformity in drainage systems which, like the Fraser, were developed previous to Tertiary time. At various places erosional contacts and/or angular discordance were observed. The youngest strata below the unconformity are Middle to Lower Oligocene, and the oldest strata above the unconformity are Upper Miocene to Middle Pliocene. The extent of the unconformity led Kuenzi and Richard to suggest a regional rather than a local cause.

While the area studied by Kuenzi and Richard lies approximately 700 miles to the south-southeast of the Quesnel region, the ages of the unconformities in both areas and the proximity of both to the Rocky Mountain chain are strikingly similar. If the two unconformities are closely related in time of development, then the Big Slide sediments could very well be Miocene in age.

As is readily apparent from these discussions, any exact age assignment for the Big Slide unit is impossible because of the lack of detailed evidence. In view of this, no more precise assignment than probable Miocene has been attempted.

The ecologic setting appears similar to that of the Oligocene unit. The deciduous broadleaf vegetation covered the emergent portions

of the river bed and the adjacent floodplain and river valley. The absence of a large bladdered conifer element suggests that the source for this plant group was somewhat distant.

2. Leaf Assemblage

Fossil leaves were found at one site in the Big Slide unit. This exposure is located several feet above a terrace on a near-vertical river bank. The leaf assemblage includes the following taxa: *Zelkova* sp. cf. *Z. oregoniana* (Knowlton) Brown, *? Tilia* sp., *Salix* sp. cf. *S. wildcatensis* Axelrod, *? Sterculia* sp., *Dillenites* sp. cf. *D. ellipticus* Hollick, and *Platanus* sp.

Zelkova oregoniana was reported from the Late Miocene Trapper Creek flora of Southern Idaho by Axelrod (1964). He also summarized its occurrence in other earlier Tertiary to Pliocene floras. Axelrod believes the Trapper Creek paleoflora represents either an ecotone between a montane conifer forest and a montane conifer-deciduous forest, or the montane conifer forest itself.

Salix wildcatensis is also found in the Mio-Pliocene Middlegate flora of west-central Nevada (Axelrod, 1956). He indicates a Clarendonian age and a sub-humid character for the paleoflora.

The only reference to *Sterculia* is that by MacGinitie from the Florissant (Lower Oligocene) beds of Colorado (*Sterculia rigida*) and MacGinitie's reference to the related *Sterculia coloradensis* in the Green River (Eocene) beds. MacGinitie postulated a warm temperate (Koppen BShw - Cwa boundary) climate with summer-wet rainfall regime (total

annual rainfall less than 25 inches) for the Florissant paleoflora.

Dillenites ellipticus Hollick was described from the Alaskan Eocene (Hollick, 1936).

The Platanus leaf is too poorly preserved for further identification and the ? Tilia leaf is so incomplete as to render further identification hazardous.

If the identifications of Sterculia and Dillenites are correct, they conflict with the paleoclimatic evidence of Salix wildcatensis. Sterculia is today restricted to the tropics, and the Dilleniaceae are sub-tropical and tropical. They seem inconsistent with the Trapper Creek montane conifer forest and with the Clarendonian age for Salix wildcatensis.

The leaf evidence, in part, seems to suggest an older age for the Big Slide sediments than is suggested by the palynomorph assemblage. This is based mainly on the presence of Sterculia and Dillenites, which occur in the older Tertiary. Because the leaf collection is small and relatively poorly preserved, I prefer to place more confidence in the palynomorph assemblage and maintain the suggested Miocene age for the Big Slide sediments.

C. Late Tertiary Diatomite Assemblage (Mio-Pliocene)

In contrast to the two previously discussed paleofloras, the palynological assemblages from the diatomites indicate a rather cool climate, probably not too different from that of today.

The assemblage (see Table IV, page 47) is dominated by the

TABLE IV

Checklist for Late Tertiary Diatomites

ARBOREAL ANGIOSPERMS

Alnus	(PG-76)
Alnus	(PG-77)
Carya	(PG-71)
Castanea	(PG-81)
Fagus	(PG-83)
Juglans	(PG-74)
Liquidambar	(PG-89)
Myrica	(PG-69)
Pterocarya	(PG-75)
Quercus	(PG-84)
Ulmus	(PG-87)

OTHER ANGIOSPERMS

? Acanthaceae	(PG-104)
	(PG-66)

FERNS

Osmunda	(PG-11)

GYMNOSPERMS

Abies	(PG-27)
Abies	(PG-28)
Cedrus	(PG-29)
Cedrus	(PG-30)
Glyptostrobus	(PG-44)
Glyptostrobus	(PG-45)
Glyptostrobus	(PG-46)
Metasequoia	(PG-47)
Picea	(PG-31)
Picea	(PG-32)
Pinus	(PG-34)
Pinus	(PG-35)
Pinus	(PG-37)
Podocarpus	(PG-24)
Podocarpus	(PG-26)
Pseudotsuga	(PG-38)
Taxodium	(PG-49)
Taxodium	(PG-50)
Taxodium	(PG-51)
Tsuga	(PG-39)
Tsuga	(PG-40)
Tsuga	(PG-41)
Tsuga	(PG-43)

pollen of Pinus, Abies, Picea, Cedrus and the Taxodiaceae, almost to the exclusion of the broadleaf element. New bladdered conifer pollen appear which were not present in the previous two assemblages.

The near absence of the angiospermous element and the dominance of the conifers (both in quantity of pollen and number of taxa) must certainly indicate a radical cooling of the climate between Big Slide and diatomite times of deposition. The same genera of bladdered conifers which were minor constituents of the Alexandria-Narcosli and Big Slide paleofloras now represent nearly 60% of the total. If all gymnosperms are considered, they represent over 95% of the total. This latter figure is consistent with Mathews and Rouse's (1963) figures for four of the five sites sampled in the diatomite unit and equivalents.

If the rate of climatic change in the central interior of British Columbia were reasonably constant during the interval between Big Slide and diatomite deposition, it would seem that a long interval must have been involved. This would seem most logical if the climatic reconstruction for the Alexandria-Narcosli and Big Slide periods are true.

However, the geological evidence supplied by the flat-lying, apparently conformable nature of both the Big Slide and diatomite sediments mitigates against any long hiatus between the two periods of deposition. The most reasonable causes for a drastic change include: (1) a rapid cooling; and (2) edaphic and/or other environmental changes.

Such rapid cooling might be produced by mountain building superimposed on a progressively cooling climate. A pulse of mountain building in the Coast Mountains could have isolated the interior from

most or all of the warming influence of the Pacific Ocean. The gradual cooling of the polar sea during Tertiary time would have decreased the supply of warm, moist air to the interior, and by Mio-Pliocene time most of the warmer influence may have been coming from the Pacific Ocean. If this were the case, a sufficient uplift in the Coast Mountains would drastically alter the climate in the interior. This could, in turn, cause a rapid change from the broadleaf, deciduous angiosperm assemblage to the conifer assemblage.

An alternate explanation for the floral change could be dissimilar edaphic factors. The Oligocene and probable Miocene plant assemblages grew in stream bed and marshy environments, while the Mio-Pliocene plants existed adjacent to lacustrine environments. The change in pollen assemblages could then be a reflection of the change in edaphic conditions. If much of the low-lying marshy and stream bed environments were eliminated by the ponding of the Fraser River, the predominant plant association may have been that of the uplands. With climatic cooling during the Tertiary these uplands likely supported a largely coniferous flora by Mio-Pliocene time. This coniferous flora would then have supplied much of the pollen sedimented in the lakes.

VI. SUMMARY OF THE HISTORY OF THE AREA

A. Floral and Climatic History.

As stated earlier, the palynological assemblages of the Early Oligocene provide evidence of a sub-tropical to warm temperate climate. The most definitive evidence is the occurrence of fossil representatives of the extant genera ? Dorstenia, Engelhardtia, Psilotum, Ephedra, Glyptostrobus, Taxodium, Metasequoia and Podocarpus.

Psilastephanocolpites marginatus (PG-62), described from the Eocene of Colombia (Gonzalez-Guzman, 1967) provides further evidence of very warm conditions.

This is consistent with the summary presented by Dorf (1959), showing a sub-tropical climatic tongue extending into wewtern British Columbia. He further states that "numerous fossil remains of a forest transitional between subtropical and warm temperate are found in Late Eocene - Early Oligocene deposits of British Columbia. . . ." Brooks (in Dorf, 1959) shows a climatic warming trend in the Late Eocene and Early Oligocene, and Dorf (1959) shows a sub-tropical climate for Late Eocene time in the area. These conditions are supported by the work of Traverse (1955) who found pollen with sub-tropical affinities in the Brandon lignite (Oligocene) pollen assemblage.

The probably Miocene paleoflora, as represented in the Big Slide sediments, seems to indicate some cooling of the climate. The increase in Pterocarya, which presently occurs mostly in temperate regions of Asia (Traverse, 1955), may be especially important. Another indication

of cooling may be the increase in pollen of Castanea. The increase in Quercus pollen may indicate both a general cooling and drying. Such a trend is also supported by the absence of Engelhardtia, Pachysandra, Ephedra, and Psilastephanocolpites marginatus.

Paleobotanical literature is replete with descriptions of Tertiary floral migrations, ably summarized by Chaney (1947). The Early Tertiary Arcto-Tertiary flora migrated southward in response to a cooler and less humid climate which became established at the end of the Oligocene epoch. Four notable members of this group are Castanea, Quercus, Ulmus and Dillenia. Pollen of the first three and a leaf of the latter are present in the Big Slide sediments.

In its southward migration the Arcto-Tertiary flora replaced the Neotropical - Tertiary floras, of which the Raton and Denver floras (Knowlton, 1917; 1930), the Green River flora (Wodehouse, 1933; Brown, 1934), the Weaverville flora (MacGinitie, 1941), and the Goshen flora (Chaney and Sanborn, 1933) are examples. One of the tenets of plant migration is the necessary adjustment of some taxa to the new conditions imposed by the climatic changes in "preference" to migration (Dorf, 1955). This is illustrated (Dorf, 1955; Chaney, 1947) by relics of the Neotropical Tertiary floras occurring in the Miocene floras of Oregon. Possibly the same effect is being observed in the Big Slide sediments which show the retention of a number of the Oligocene types, together with taxa which probably entered the area in response to a cooler climate.

This type of mixing occurs also in the Miocene of China (Hu and Chaney, 1940), and in New Jersey and Maryland (Berry, 1916 in Chaney, 1947). According to Vakhrameyev (1966) an analagous situation occurs in the U. S. S. R. He states that "From the Oligocene onwards the climate gradually became cooler and there was a corresponding southward shift and extention of the temperate forest". Vakhrameyev continues "the climatic cooling, continuing in the Neogene, led to the emergence of a taiga zone . . . ." This same emergence is evident in the Late Tertiary diatomites studied in British Columbia. Pollen assemblages show the establishment of a cool temperate coniferous forest dominated by Pinus, Tsuga, Picea, Abies and other conifers. The few broad-leaved pollen types may indicate relics which survived in the more protected habitats of the area.

The continued cooling in the Late Tertiary and/or the onset of the Pleistocene apparently resulted in extinction of several genera (i.e. Cedrus, Taxodium, Glyptostrobus and Metasequoia). The relaxation of the more rigid extremes of the Pleistocene during interglacial and postglacial periods allowed the establishment of the modern boreal forest existing in the area today.

B. Geologic History

It is generally conceded that major uplift of the Rocky Mountains occurred during Eocene and Oligocene time, and succeeding intervals of uplift from Oligocene through Pliocene have been suggested by Cook (1960). If this resulted in high elevations for the Rockies in Oligocene time, the Rockies would have served as an excellent barrier to the eastward-

drifting winds from the Pacific. These eastward-drifting winds would have pushed the southward-drifting, warm, moist polar winds against the Rockies, stripping them of much of their moisture. This would, in large measure, account for the wet, humid climate in central British Columbia in the Early Oligocene. As previously mentioned, the humid, sub-tropical climate of southeastern Mexico is maintained in much the same manner.

The Coast Mountains have apparently had a much more complicated history. Owing to a lack of precise information on uplift during periods of the Tertiary, conclusions on their effects are highly speculative. While Mathews and Rouse (1963) have suggested a low elevation for the Coast Mountains in Late Tertiary time, this need not have been true in the earlier Tertiary. White (1959) has shown the Coast Mountains as "strongly positive" during Upper Cretaceous-Paleocene deposition. Depending on the level of that elevation and the rate of erosion, the Coast Mountains may still have been fairly well elevated during the Early Oligocene. If the Coast Mountains were elevated, the wet climate of the interior would owe its existence to another source--the hypothesis postulated here that warm, northerly winds came from a warm, ice-free polar sea.

During the ensuing Tertiary epochs the Coast Mountains were eroded and the Pacific Ocean may have supplied a fair amount of rainfall to the interior. Some compensating factor was almost certainly required, because the Tertiary cooling must also have cooled the polar sea, resulting in cooler and drier southward-moving winds.

White (1959) also shows less intense orogenies in the Miocene and Pliocene. One or more of these probably elevated the somewhat

eroded Coast Mountains to approximately their present height. These orogenic pulses could have cut off most of the remaining supply of moisture to the interior areas, resulting in the rainfall regime which exists today.

The interior area, in the meantime, appears to have been relatively stable geologically. The only evidence of tectonism is the tilting of the Oligocene sediments. In most cases the tilting amounts to only about 15°, possibly due to local folding.

An undetermined period of erosion took place after tilting of the Oligocene sediments, and a hiatus of unknown length followed before deposition of the probable Miocene sediments. The latter sediments, as well as those of the Mio-Pliocene diatomite unit, are presently flat-lying and appear to have undergone no deformation. Thus it appears that the interior of the province has been quite stable since some time in the Miocene or Oligocene.

C. Main Conclusions and Important Contributions

The main conclusions and important contributions of this thesis are as follows:

1. This thesis represents the first study of Oligocene palynological assemblages in the Pacific Northwest.
2. This study is the first Western Canadian investigation of the succession of Mid- to Late Tertiary pollen floras.
3. Three separate Tertiary pollen assemblages have been demonstrated in the Prince George-Quesnel area.

4. The pollen assemblages have provided evidence for climatic and physiographic reconstructions.
5. By comparison with already existing studies of materials from Oregon, Washington, Alaska and the U. S. S. R., the pollen and leaves studied in this thesis strengthen the existing evidence for a northern pan-Pacific paleoflora.

VII. SYSTEMATIC PALYNOLOGY

Microfossil types have been identified with the most finite taxonomic units possible. The pteridophytes are arranged according to the classification system of Engler and Diels, as shown in Lawrence (1951).

Unless otherwise noted, the size ranges are based on measurement of ten or more specimens. The first size given for each microfossil is that of the type specimen. Size measurements for morphological features are taken from the type specimen. The letters M.E.D. refer to maximum equatorial diameter.

The small letter "t" on a figured palynomorph indicates the type specimen when more than one specimen was figured. In the cases of PG-77, -79, and -87 the type specimen is not shown.

PG-numbers were assigned for easy and uniform reference to palynomorph types, and especially for the handling of those types of unknown taxonomic affinity.

Morphological descriptions follow the terminology of Erdtman (1952).

DIVISION: PYRROPHYTA

CLASS: Dinophyceae

Genus: Micrhystridium Deflandre

Micrhystridium sp. (PG-1)

Fig. 1, 2

SIZE: 23.2 microns. Range 19.2 - 25.8 microns.

EXINE: ± 0.5 microns.

SCULPTURE: Spines 2.4 - 3.6 microns long, frequently bifurcating, hollow, gradually tapering toward their tips.

SHAPE: Roughly spherical.

APERTURES: There appears to be an archeopyle which may be nearly as broad as the diameter of the specimen. In the type specimen the apparent archeopyle is 20.0 microns wide.

AGE: Oligocene.

DISCUSSION: This form genus is recorded in sediments ranging from Ordovician to Pleistocene in age. Hopkins (1966) found one specimen of this form in his Miocene section.

INCERTAE SEDIS

Genus: Schizosporis Cookson and Dettman

Schizosporis sp. (PG-2)

Fig. 3, 4

SIZE: 135.0 x 38.0 microns. Range: 58.0 - 135.0 microns x 25.0 - 52.0 microns.

EXINE: Uniformly ± 0.8 micron thick.

SCULPTURE: Densely and uniformly low, scabro-rugulate. The rugulae are sinuous and form short striae.

SHAPE: Ellipsoidal. The long axis in every specimen is two times or more greater than the short axis.

APERTURES: This microfossil possesses a furrow, 0.4 - 0.6 micron wide, which traverses the entire long axis of the specimen. In many

specimens the furrow can be observed traversing the long axis on both sides of the grain; in some cases this results in a splitting of the specimen into two "halves".

AGE: Oligocene and Miocene.

DISCUSSION: This microfossil type appears to be similar in its apertural configuration to specimens of Schizosporis illustrated by Cookson and Dettman (1959) from the Cretaceous of Australia. PG-2 will be described as a new species when this thesis is published.

INCERTAE SEDIS

Genus: Sigmopollis Hedlund

Sigmopollis hispidus Hedlund (PG-3)

Fig. 7

SIZE: 25.6 microns, M.E.D. Range: 22.0 - 25.6 microns, M.E.D.

EXINE: 0.5 micron thick, except 1.0 micron thick adjacent to the aperture.

SCULPTURE: Densely ornamented with delicate spines which are 1.0 - 2.0 microns long. Psilate between the spines.

SHAPE: Circular.

APERTURES: One, sigmoidal in shape.

AGE: Oligocene.

DISCUSSION: Spore type PG-3 is identical to Sigmopollis hispidus (Hedlund, 1965) from the Miocene of Elko County, Nevada.

Sigmopollis sp. (PG-4)

Fig. 8, 9

SIZE: 16.8 microns, M.E.D. Range: 16.0 - 20.5 microns, M.E.D.

EXINE: 1.2 microns thick.

SCULPTURE: Psilate.

SHAPE: Circular.

APERTURES: One, sigmoidal in shape.

AGE: Oligocene and Miocene.

DISCUSSION: This species has the same type of aperture as Sigmopollis hispidus, except it is psilate rather than spinose. This same type of pollen is figured by Macko (1957) from the Lower Miocene of Upper Silesia. His specimens are identical with those of PG-4 except that they are about one-half again as large. Macko made no taxonomic assignment.

PG-5

Fig. 5, 6

SIZE: 90.0 x 19.2 microns. Range: 70.0 - 108.0 microns x 13.0 - 37.0 microns.

EXINE: About 0.8 micron thick.

SCULPTURE: Psilate, with sub-parallel ridges 0.5 micron wide running the entire length of specimens and flanking the slit-like aperture which also traverses the entire length of the specimen.

SHAPE: Boat-shaped or fusiform.

APERTURES: One, ranging from 0.6 micron wide at either end of specimen to about 4.0 microns wide at the "equator" of the specimen. Some

have split into two halves along the aperture, the slit appearing to encompass both sides of the specimen, as in Schizosporis.

AGE: Oligocene.

DISCUSSION: I have not found this microfossil in any of the literature which I have examined. In view of its frequently exhibited tendency to split into two saucer-like halves, it may be a type of Schizosporis. Quite possibly it is not a spore at all, but some other type of organic-walled microfossil.

DIVISION: PTERIDOPHYTA

CLASS: Articulatae

Genus: ? Equisetum L.

? Equisetum sp. (PG-6)

Fig. 10

SIZE: 60.8 x 34.0 microns. Range: 42.0 - 86.0 microns x 16.0 - 40.0 microns.

EXINE: 0.8 micron thick.

SCULPTURE: Psilate.

SHAPE: Ellipsoidal.

APERTURES: Inaperturate, but frequently tearing. Often folded along the tear.

AGE: Oligocene.

DISCUSSION: Batten (1968) has recently reported the probably occurrence of spores of Equisetum from Cretaceous (Wealden) sediments of Britain, and has commented on the apparent absence of Equisetum

spores from the palynological record. This absence may be real, a result of no preservation, or only apparent, because of a lack of a distinctive morphology.

My specimens are slightly smaller than those of the extant E. ramosissimum in the Union Oil Company modern pollen collection.

CLASS: Lycopodiinae

Genus: Lycopodium L.

Lycopodium annotinioides Martin and Rouse (PG-7)

Fig. 11, 12

SIZE: 27.0 microns, M.E.D. Range: 27.0 - 38.0 microns, M.E.D.

EXINE: 4.0 microns thick, including 2.0 micron thick muri.

SCULPTURE: Heavily reticulate, muri sinuous, and lumina irregular in outline. Muri broader at base than at distal end.

SHAPE: Triangular in polar view, with the angles somewhat rounded. Sides only slightly convex.

APERTURES: Trilete. Laesurae 8.0 microns long, wavy. Margo 0.5 micron wide.

AGE: Oligocene and Miocene.

DISCUSSION: PG-7 slightly exceeds the size range given for L. annotinioides, but agrees well on the basis of muri and lumina measurements. Martin and Rouse noted that spores of L. annotinioides had characteristics which "agree exactly with those of the extant Lycopodium annotinum".

Lycopodium sp. (PG-8)

Fig. 13

SIZE: 30.0 microns, M.E.D. Only specimen encountered.

EXINE: 1.2 microns thick. Nexine 0.9 micron thick; sexine 0.3 micron thick.

SCULPTURE: Densely micro-scabrate to micro-echinate. Sculptural elements project less than 0.4 micron above the surface.

SHAPE: Triangular with rounded angles and concave sides as seen in polar view.

APERTURES: Trilete. Laesurae 12.0 microns long and 0.6 micron wide, tending to split open at their juncture. Margo 0.4 micron wide.

AGE: Oligocene.

DISCUSSION: PG-8 appears to resemble very closely Lycopodium miniatum pictured by Macko (1957, 1959) from the Miocene of Silesia. It is slightly smaller and its apices do not bulge outward as much as that shown for the modern form, also figured by Macko. While PG-8 resembles L. miniatum more than any other species I have seen, I must comment on Macko's use of the specific epithet. Since he cites no other occurrences of the spores of L. miniatum between the Miocene and the Recent, it would seem unwarranted to append the modern specific name to the fossil. In point of fact, Macko's fossil specimen differs from the modern specimen as does my own PG-8. It would seem better practice for Macko to have followed the procedure described by Rouse (1957) and others, and appended a suffix to the modern species name.

? Lycopodium sp. (PG-9)

Fig. 14-17

SIZE: 27.2 microns, M.E.D. Range: 27.2 - 37.0 microns, M.E.D.

EXINE: 1.0 micron thick.

SCULPTURE: Coarsely scabrate to small verrucate or verruco-rugulate with the verrucate elements joined to form low ridges.

SHAPE: Rounded triangular, the sides more or less straight.

APERTURES: Trilete, the commissures split open into a triangular outline.

AGE: Oligocene.

DISCUSSION: The taxonomic suggestion here is very weak. PG-9 may be a fern spore (i.e. Pteridium), or may be reworked from Mesozoic rocks. I have found no reference to spores resembling PG-9 in the Tertiary literature.

CLASS: Psilotinae

Genus: Psilotum Sw.

Psilotum sp. (PG-10)

Fig. 18, 19

SIZE: 34.4 x 24.0 microns. Only specimen encountered.

EXINE: 2.4 microns thick at thickest point.

SCULPTURE: Heavily rugulate. Ridges 1.6 - 2.8 microns wide, sometimes forming a closed loop to simulate the muri of a reticulum.

SHAPE: Ellipsoidal in polar view.

APERTURES: Monolete. Laesura about 24.0 microns long.

AGE: Oligocene.

DISCUSSION: To my knowledge, Psilotum has not been reported in

Tertiary microfloral assemblages. But the monolete nature and the sculptural similarity which it bears to Psilotum triquetrum (Union Oil Company modern pollen collection) strongly suggests that PG-10 belongs to the genus Psilotum. Spores of P. triquetrum are, however, considerably larger.

CLASS: Filicinae

Family: Osmundaceae R. Br.

Genus: Osmunda L.

Osmunda claytonites Graham (PG-11)

Fig. 20, 21

SIZE: 48.0 microns, M.E.D. Range: 48.0 - 68.0 microns x 38.0 - 62.0 microns.

EXINE: 0.8 - 1.2 microns thick, including projecting portion of bacula.

SCULPTURE: Rugulo-baculate, bacula arising from rugulae; bacula highly variable in size and shape.

SHAPE: Roughly circular, often splitting open.

APERTURES: Trilete; laesurae about 14.0 microns long; margo 0.8 - 1.2 microns wide.

AGE: Oligocene, Miocene and Mio-Pliocene.

DISCUSSION: This species was described by Graham (1965) on the basis of one specimen, and subsequently enlarged upon by Martin and Rouse (1966). PG-11 fits Martin and Rouse's expanded description very well.

Osmunda irregulites Martin and Rouse (PG-12)

Fig. 22-24

SIZE: 30.4 microns, M.E.D., excluding sculptural elements. Range: 26.0 - 39.0 microns, M.E.D. (Based on 8 specimens).

EXINE: 1.2 - 1.6 microns thick.

SCULPTURE: Baculate, bacula often slightly expanded at tip. Bacula 1.6 - 3.2 microns long and 0.8 - 2.4 microns in diameter, usually more or less circular in plan view, but sometimes oval, reniform or even rectangular.

SHAPE: Triangular. Sides convex and the angles prominently rounded.

APERTURES: Trilete. Laesurae 16.8 microns long and up to 0.5 micron wide. Margo 2.4 microns wide at pole, tapering to 0.8 micron at tips of laesurae.

AGE: Oligocene.

DISCUSSION: My specimens of PG-12 are somewhat smaller than the range given by Martin and Rouse (1966). However, in view of the variability observed among spores of Osmunda irregulites, PG-12 is included there instead of creating a new species.

Osmunda regalites Martin and Rouse (PG-13)

Fig. 25

SIZE: 52.8 microns, M.E.D. Range: 40.0 - 58.0 microns, M.E.D.

EXINE: 2.8 microns thick, including sculptural elements.

SCULPTURE: Heavily rugulate, rugulae of short length and mixed with some very stout bacula. Rugulae and bacula up to 2.0 microns broad and projecting up to 1.2 microns from the surface.

SHAPE: Nearly circular.

APERTURES: Trilete. Laesurae 18.0 microns long and about 0.5 micron wide. Margo about 0.5 micron wide.

AGE: Oligocene and Miocene.

DISCUSSION: Martin and Rouse gave no size range for Osmunda regalites, but it seems to be slightly over 50.0 microns in M.E.D. The sculptural features are quite similar for PG-13 and for Martin and Rouse's specimens.

CLASS: Polypodiaceae S.F. Gray

PG-14

Fig. 26-30

SIZE: 34.5 x 23.5 microns. Range: 30.0 - 43.2 microns x 21.6 - 27.0 microns. (4 specimens measured).

EXINE: 0.5 micron thick between the verrucae, to 2.0 microns thick measured through the large verrucae.

SCULPTURE: Verrucate. Verrucae range in size from 0.6 - 3.5 microns in maximum dimension and vary from near-isodiametric to elongated-undulating. The verrucae are usually densely packed, and decrease in size near the laesura.

SHAPE: Reniform.

APERTURES: Monolete, with laesura measuring about 18.0 microns in length.

AGE: Oligocene.

DISCUSSION: The treatment of this group is the same as that by Martin and Rouse (1966). Those authors present a discussion concerning

the similarity between spores from several genera in the Polypodiaceae, and so used form designations instead of generic and/or specific epithets. However, some of the spores assigned by me to PG-14 are not the same as those reported by Martin and Rouse.

Genus: Laevigatosporites (Ibrahim) Schopf, Wilson and Bentall

Laevigatosporites ovatus Wilson and Webster (PG-15)

Fig. 31-34

SIZE: 37.6 x 27.2 microns. Range: 29.0 - 63.0 microns x 19.0 - 45.0 microns.

EXINE: 0.5 - 1.2 microns thick.

SCULPTURE: Psilate.

SHAPE: Nearly circular to oval.

APERTURES: Monolete, sulcus about 20.0 microns long and about 0.5 micron wide.

AGE: Oligocene and Miocene.

DISCUSSION: My spores are identical with L. ovatus of Wilson and Webster (1946), except for the somewhat larger size range. Martin and Rouse (1966) encountered the same extended size range in specimens which they related to L. ovatus. Since the number of specimens falling in the upper and lower size ranges was small, they assumed that they were dealing with one population. The same assumption is made here. Rouse (1962) relates this taxon to Dryopteris or Asplenites, two genera of Polypodiaceous ferns recorded from the Burrard (Eocene) of southwest British Columbia.

Laevigatosporites albertensis Rouse (PG-16)

Fig. 35, 36

SIZE: 36.0 x 21.4 microns. Range: 35.0 - 50.0 microns x 21.4 - 30.0 microns.

EXINE: 0.8 micron thick.

SCULPTURE: Perforate. Perforations 0.8 - 1.0 micron in diameter near the sulcus, decreasing to about 0.4 micron in diameter near the equator and the distal pole.

SHAPE: Reniform with a concave area at sulcus.

APERTURES: Monolete. Sulcus about 27.0 microns long.

AGE: Oligocene and Miocene.

DISCUSSION: The size of PG-16 is in agreement with that given by Rouse (1957) in his description of L. albertensis. Rouse (1962) related this type also to Dryopteris and Asplenites from the Burrard (Eocene) of southwest British Columbia.

Laevigatosporites sp. (PG-17)

Fig. 37

SIZE: 34.0 x 24.0 microns. Range: 34.0 - 46.0 microns x 20.0 - 37.0 microns (9 specimens measured).

EXINE: 0.8 micron thick.

SCULPTURE: Psilate.

SHAPE: Oval.

APERTURES: Monolete. Commissure about 22.0 microns long, fusiform in shape, flaring portion about 12.0 microns long and 6.8 microns wide at widest point. Flaring portion has a 2.0 micron wide lip

on either side.

AGE: Oligocene.

DISCUSSION: Although the size of PG-17 falls within the size range of those specimens assigned to Laevigatosporites ovatus, I have not included it in that taxon for two reasons: 1) the unique nature of the commissure in PG-17 and, 2) the fact that PG-17 occurs only in the Oligocene, while L. ovatus occurs in both the Oligocene and Miocene.

Forms similar to PG-17, but 46.0 x 41.0 microns and 48.0 x 38.0 microns in size, are pictured by Macko (1959) from the Miocene Brown Coals of Lower Silesia. He related his specimens to spores of the extant Acrostichum axillarae, a tropical and subtropical epiphyte.

INCERTI ORDINIS

Genus: Stereisporites Thomson and Pflug

Stereisporites duplogranuloides Krutzsch (PG-18)

Fig. 38, 39

SIZE: 32.4 microns, M.E.D. Range: 26.5 - 36.0 microns, M.E.D.

EXINE: 1.0 - 1.6 microns thick, including verrucae.

SCULPTURE: Densely verrucate, verrucae 1.0 - 2.4 microns across, irregular in shape.

SHAPE: Triangular, sides convex, angles rounded.

APERTURES: Trilete, laesurae 12.8 microns long; margo 1.4 microns wide.

AGE: Oligocene and Miocene.

DISCUSSION: PG-18 resembles S. duplogranuloides very closely, except for being up to 6.0 microns larger than the upper size limits described by Krutzsch (1963) from the European Tertiary.

Genus: Triplanosporites Pflug

Triplanosporites microsinuosis Pflanzl (PG-19)

Fig. 40

SIZE: 30.0 x 27.2 microns. Range: 30.0 x 48.0 microns x 24.0 - 38.0 microns (9 specimens measured).

EXINE: 1.2 microns thick.

SCULPTURE: Psilate.

SHAPE: Triangular in polar view; sides intensely concave; angles sharply rounded.

APERTURES: Trilete; laesurae not distinct.

AGE: Oligocene.

DISCUSSION: Except for two larger-sized specimens, PG-19 fits very well the descriptions of T. microsinuosis as discussed by Martin and Rouse (1966). These authors relate its occurrence in German sediments from the Lower Oligocene to the Pliocene.

Genus: Toroisporis Krutzsch

Toroisporis lusaticus Krutzsch (PG-20)

Fig. 41

SIZE: 67.2 x 54.2 microns. Range: 48.0 - 68.0 microns x 36.0 - 54.2 microns.

EXINE: 0.8 micron thick.

SCULPTURE: Psilate on distal face; densely perforate on proximal face.

SHAPE: Circular to slightly oval, or slightly triangular with convex sides.

APERTURES: Trilete, laesurae 24.0 microns long; 0.5 micron wide. Margo about 1.5 microns wide.

AGE: Oligocene.

DISCUSSION: PG-20 is the same size and has the same "punctate" appearance, but both occupies and exceeds the upper size range given by Krutzsch (1963) from Lower (and Middle ?) Miocene specimens.

Genus: Leiotriletes (Naumova) R. Potonie and Kremp

Leiotriletes sp. cf. L. wolffi wolffi Krutzsch (PG-21)

Fig. 43

SIZE: 40.0 microns, M.E.D. Only specimen measured.

EXINE: 0.5 - 0.8 micron thick.

SCULPTURE: Psilate.

SHAPE: Triangular in polar view; sides nearly straight; angles rounded.

APERTURES: Trilete; laesurae about 0.4 micron wide and about 12.0 - 14.0 microns long; margo 1.2 - 1.6 microns wide.

AGE: Oligocene.

DISCUSSION: PG-21 resembles most closely L. wolffi wolffi Krutzsch (1962), however it is somewhat more sharply triangular in outline than that species. Krutzsch recorded his type from the Lower Miocene.

Leiotriletes apheles Krutzsch (PG-22)

Fig. 42

SIZE: 54.8 microns, M.E.D. Range: 52.0 - 60.0 microns, M.E.D. (7 specimens measured).

EXINE: 1.0 - 1.2 microns thick.

SCULPTURE: Psilate on distal face, weakly perforate or pitted on proximal face.

SHAPE: Nearly circular.

APERTURES: Trilete. Laesurae about 0.5 micron wide and about 22.0 microns long. Margo 1.6 - 2.0 microns wide.

AGE: Oligocene.

DISCUSSION: PG-22 is similar to L. apheles Krutzsch (1962) in having a weak trilete scar, in size, wall thickness and sculpture. Krutzsch's specimens were described from the Lower Miocene.

PG-23

Fig. 44

SIZE: 44.0 microns, M.E.D. Range: 34.0 - 44.0 microns, M.E.D. (3 specimens measured).

EXINE: 0.8 - 2.0 microns thick, including sculptural elements.

SCULPTURE: Densely verrucate. Verrucae 1.0 - 1.6 microns in width, with the distal face having smaller verrucae than the proximal face. Adjacent verrucae sometimes connected or fused to form a verruco-rugulate pattern. This feature is most prominent on the proximal face.

SHAPE: The shape is difficult to ascertain because of folding, although it appears to be somewhat triangular; with such broadly rounded angles and convex sides it is essentially circular in outline in polar view.

APERTURES: Trilete. Laesurae up to 0.5 micron wide and 16.0 microns long. Margo 0.8 micron wide.

AGE: Oligocene.

DISCUSSION: No closely similar forms have been encountered in the literature.

DIVISION: EMBRYOPHYTA SIPHONOGAMA (SPERMATOPHYTA)

SUBDIVISION: GYMNOSPERMAE

Family: Podocarpaceae Endl.

Genus: Podocarpus L'Herit. ex pers.

Podocarpus sp., cf. P. wallichianus Presl. (PG-24)

Fig. 45-47

SIZE: 99.2 microns long, overall. Body 53.6 x 44.0 microns. Bladders 48.0 x 56.0 microns and 50.4 x 57.6 microns. Range: Overall 97.0 - 117.6 microns; body 52.0 - 64.0 microns x 41.0 - 52.0 microns; bladders 46.0 - 56.0 microns x 50.0 - 70.4 microns (4 specimens measured).

EXINE: Body exine 4.0 - 5.2 microns thick in area of cap.

SCULPTURE: (A) Body: Prominently crenulate, the relief between the ridges and valleys seldom exceeding 1.2 microns. The ridges much wider than the valleys, and densely

reticulate. Lumina 0.4 micron - 0.8 micron in maximum dimension, with the muri nearly as wide as the lumina. Cap is tegillate.

(B) Bladders: Reticulate, the lumina about 1.6 - 3.2 microns in maximum dimension. Bladders tegillate, infrareticulate, the lumina as large as 7.2 microns in maximum dimension. Near the body the lumina are elongate rather than isodiametric, with their long axes at right angles to the body. This produces the rather typical "radiating pattern", characteristic of the bladders in this genus.

AGE: Oligocene and Mio-Pliocene.

DISCUSSION: Macko (1959) found pollen similar to PG-24 in the Miocene of Silesia. My specimens match and exceed the upper size ranges listed by Macko for the extant genus P. wallichianus.

Podocarpus sp., cf. P. nageia R. Browning (PG-25)

Fig. 50

SIZE: 73.6 x 64.8 microns, overall. Body 44.0 x 44.0 microns. Bladders 64.8 x 33.6 microns and 60.8 x 37.6 microns. Range: Overall 58.0 - 73.6 microns x 35.0 - 64.8 microns; body 21.0 - 44.0 microns x 24.0 - 44.0 microns; bladders 28.0 - 64.8 microns x 24.0 37.0 microns (8 specimens measured).

EXINE: 1.6 microns thick except in cap which is up to 6.4 microns thick, due to the pronounced, wavy crenulations.

SCULPTURE: (A) Body: Cap is small reticulate, lumina commonly 0.8 - 1.2 microns in maximum dimension. Muri are approximately ½ as wide as the diameter of the lumina.

(B) Bladders: Large reticulate, the lumina elongated radially from the body producing the radiating pattern.

AGE: Oligocene.

DISCUSSION: Macko (1959) reported pollen similar to PG-25 from the Miocene of Silesia. Rouse (1962) found one specimen of Podocarpus in the Burrard (Eocene) of British Columbia that also resembled P. nageia.

Podocarpus sp., cf. P. nubigenus Lindl. (PG-26)

Fig. 48, 49

SIZE: 40.8 x 35.2 microns, overall. Body 28.8 x 24.0 microns. Bladders 36.8 x 16.0 microns and 35.2 x 20.8 microns. Range: Overall 40.8 - 52.0 microns x 34.0 x 19.0 microns; body 26.0 - 28.8 microns x 24.0 - 29.0 microns; bladders 16.0 - 24.0 microns x 34.0 - 36.8 microns (3 specimens measured).

EXINE: 1.6 microns thick on body. Cap less pronounced than in the other two species in this thesis, and not deeply crenulate.

SCULPTURE: (A) Body: Cap is small, densely reticulate. Leptoma is psilate to irregularly flecked.

(B) Bladders: Openly reticulate, the lumina much larger relative to muri, than on the cap. Long axes of the lumina oriented radially from the body, although not as markedly as in P. nageia.

AGE: Oligocene and Mio-Pliocene.

DISCUSSION: PG-26 fits in the smaller size ranges of Podocarpus nubigenus Lindl. as shown by Macko (1959) from the Miocene of Silesia.

Family: Pinaceae Lindl.

Genus: Abies Mill.

Abies sp. (PG-27)

Fig. 51, 52

SIZE: Body 96.8 x 94.4 microns. Bladders 48.0 x 88.0 microns and 56.8 x 74.4 microns. Range: body 84.0 - 96.8 microns x 78.0 - 106.0 microns; bladders 46.0 - 60.0 microns x 70.0 - 96.0 microns (5 specimens measured).

EXINE: Body exine 1.6 microns thick, except 5.6 microns thick in the cap.

SCULPTURE: (A) Body: Reticulate, lumina commonly 1.6 - 2.8 microns in maximum dimension.

(B) Bladders: Coarsely and openly reticulate, lumina commonly 4.0 microns in maximum dimension. Infrareticulate, the lumina of the infrareticulum often twice the size of the sexinous lumina.

AGE: Miocene and Mio-Pliocene.

Abies sp. (PG-28)

Fig. 53, 54

SIZE: Body 86.4 x 44.8 microns. Bladders 40.8 x 50.4 microns and 36.0 x 50.4 microns. Range: body 86.4 - 114.0 microns x 44.8 - 70.0 microns; bladders 36.0 - 62.0 microns x 50.4 - 72.0 microns (5 specimens measured).

EXINE: 4.0 microns thick in cap.

SCULPTURE: (A) Body: Baculate to rugulo-reticulate. The bacula of the mesexine are frequently free from any attachment with their neighbors and in other areas the reticulum is incompletely formed, giving rise to the rugulo-reticulate pattern. The cap is formed into an only slightly wavy crest at the junction of the bladders.

(B) Bladders: Reticulate, the lumina commonly 1.0 - 3.2 microns in maximum dimension. Muri about 0.6 micron wide. Infrareticulate, lumina of infrareticulum commonly as large as 3.2 - 7.2 microns.

AGE: Mio-Pliocene.

Genus: Cedrus Link.

Cedrus perialata Martin and Rouse (PG-29)

Fig. 55

SIZE: Overall 80.0 x 62.4 microns. Range: 78.0 - 100.0 microns x 60.0 - 80.0 microns.

EXINE: Cap is 4.8 microns thick near proximal pole and is continuous over the bladders, terminating at the point of attachment of the bladders to the body.

SCULPTURE: Cap is rugulo-reticulate, the muri 0.8 - 1.0 micron wide, the lumina (when present) commonly 0.4 - 0.8 micron in maximum dimension. The size of the muri in comparison to the size of the lumina gives the sculpture a heavy, closed appearance. The cap

is gently undulating along almost its entire length. The leptoma area is coarsely, but irregularly, flecked.

AGE: Oligocene, Miocene and Mio-Pliocene.

DISCUSSION: Despite its slightly larger size range, PG-29 appears to be identical with Cedrus perialata described by Martin and Rouse from the Mio-Pliocene sediments of the Queen Charlotte Islands.

Cedrus sp. (PG-30)

Fig. 56

SIZE: 92.0 x 78.8 microns, overall. Range: 92.0 - 116.0 microns x 75.0 - 102.0 microns (4 specimens measured).

EXINE: Cap is 5.6 - 7.2 microns thick near the proximal pole, enveloping the bladders, terminating near the point of attachment of the bladders to the body and sometimes becoming quite wavy in optical cross-section.

SCULPTURE: Reticulate, lumina commonly 1.0 - 2.4 microns in maximum dimension. Muri about 0.8 - 1.0 micron thick.

STRUCTURE: Infrareticulate, the lumina of the infrareticulum commonly 2.8 - 6.4 microns in maximum dimension.

AGE: Oligocene, Miocene and Mio-Pliocene.

DISCUSSION: While bearing some resemblance to Cedrus perialata, PG-30 has been maintained separately because of its larger size and frequently very wavy cap outline.

Genus: Picea A. Dietr.

Picea sp. (PG-31)

Fig. 57-59

SIZE: Overall, 89.6 x 77.6 microns. Range: 89.6 - 138.0 microns x 97.6 - 94.0 microns.

EXINE: Body exine about 4.8 microns thick in area of cap.

SCULPTURE: (A) Body: Finely reticulate, diameter of lumina 0.6 - 0.8 micron.

(B) Bladders: Finely to coarsely reticulate, diameter of lumina 0.6 - 4.0 microns. Warts 0.6 - 0.8 micron in diameter are present distally in the leptoma area.

AGE: Oligocene and Mio-Pliocene.

DISCUSSION: I have seen no described fossil species with the prominent warty leptoma; however, the modern Picea abies has such a feature (Praglowski, 1962).

Picea sp. (PG-32)

Fig. 60

SIZE: 111.2 x 88.2 microns, overall. Range: 105.0 - 130.0 microns x 88.2 - 90.0 microns (6 specimens measured).

EXINE: Up to 4.0 microns thick in the cap.

SCULPTURE: (A) Body: Finely reticulate. Lumina not exceeding 1.2 - 1.6 microns in maximum dimension and often tending to be more elliptical than isodiametric in outline, suggestive of a rugulo-reticulate pattern.

(B) Bladders: Coarsely reticulate, lumina as large as 5.2 microns in maximum dimension.

AGE: Oligocene, Miocene and Mio-Pliocene.

Picea sp. (PG-33)

Fig. 61

SIZE: Overall length 64.8 microns. Body 52.5 x 55.0 microns. Bladders 35.0 x 50.0 microns. Another specimen measured 65.0 x 49.0 microns overall; body 40.0 x 40.0 microns; bladders 30.0 x 40.0 microns and 28.0 x 40.0 microns. Only two specimens noted.

EXINE: Body exine 2.5 microns thick in area of cap.

SCULPTURE: (A) Body: Finely reticulate, diameter of lumina about 0.6 - 0.8 micron.

(B) Bladders: Reticulate, lumina as large as 2.5 microns in diameter.

AGE: Oligocene.

Genus: *Pinus* L.

Pinus sp., cf. *P. peuce* Griesb. (PG-34)

Fig. 62

SIZE: 72.8 x 49.6 microns, overall. Bladders 30.4 x 49.6 microns. Body 40.0 x 48.0 microns. Range: 56.0 - 80.0 microns x 46.0 - 60.0 microns, overall; body 30.0 - 44.0 microns x 43.0 - 60.0 microns; bladders 23.0 - 37.0 microns x 43.0 - 60.0 microns.

EXINE: 0.5 micron thick, except cap which is up to 3.2 microns thick.

SCULPTURE: (A) Body: Finely reticulate, latimurate, homobrochate. Diameter of lumina about 0.4 micron.

(B) Bladders: Coarsely reticulate, angustimurate, more or less homobrochate, lumina from 0.8 micron in diameter at roots of bladders to 4.0 microns in diameter away from the roots. Muri about 0.4 micron thick.

AGE: Oligocene, Miocene and Mio-Pliocene.

DISCUSSION: Pollen similar or identical to PG-34 are rather common in Early and Middle Tertiary sediments of Europe, Russia and North America. Macko (1957, 1959) found them in the Miocene sediments of Silesia. He related them to the pollen of the modern Pinus peuce Griesb. His description of the fossil material fits very well the description of PG-34, including the size range, the outline and the size of the lumina in the reticulum of the bladder. Pokrovskaya (1956a, b) has shown similar pollen from various regions of the U. S. S. R., referring to it as Pinus (subgenus Haploxylon).

Pinus sp. (PG-35)

Fig. 63

SIZE: 48.8 microns long, overall. Body 32.0 x 24.0 microns. Bladders 30.4 x 20.0 microns. Range: 48.8 - 60.0 microns long, overall; body 32.0 - 44.0 microns x 24.0 - 34.0 microns; bladders 30.0 - 46.0 microns x 18.0 - 26.0 microns.

EXINE: 1.6 microns thick at cap, decreasing to 0.8 micron away from the cap.

SCULPTURE: (A) Body: Finely reticulate, more or less homobrochate, lumina 0.8 micron in diameter, muri 0.4 micron in diameter. Strong leptoma area on distal side.

(B) Bladders: Coarsely reticulate, lumina up to 2.4 microns in diameter, muri about 0.6 micron in diameter.

Pinus sp. (PG-37)

Fig. 64, 65

SIZE: 84.0 microns long, overall. Body 49.2 x 46.4 microns. Bladders 31.8 x 46.4 microns and 34.4 x 51.2 microns. Range: 64.0 - 84.0 microns long, overall; body 40.0 - 50.0 microns x 34.0 - 48.0 microns; bladders 30.0 - 34.4 microns x 32.0 - 52.0 microns (5 specimens measured).

EXINE: 4.8 - 7.2 microns thick in the cap, decreasing to 0.6 micron on the distal surface.

SCULPTURE: (A) Body: Finely reticulate, diameter of lumina 0.6 micron, width of muri ½ the diameter of the lumina or greater. Outline of cap is extremely wavy as seen in cross-section. Warts about 1.6 microns in diameter appear in the area of attachment of bladders to the body.

(B) Bladders: Coarsely reticulate, lumina from 1.6 microns to about 4.0 microns in diameter, muri 0.6 - 0.8 micron wide. Area of attachment of bladders is small.

AGE: Oligocene and Mio-Pliocene.

Genus: Pseudotsuga Carr.

Pseudotsuga sp. (PG-38)

Fig. 66

SIZE: 75.2 x 64.0 microns. Range: 75.2 - 104.0 microns, M.E.D.

EXINE: 1.5 - 2.0 microns thick.

SCULPTURE: Psilate.

SHAPE: Spheroidal to slightly ellipsoidal.

APERTURES: None.

AGE: Oligocene, Miocene and Mio-Pliocene.

DISCUSSION: This type is classed as Pseudotsuga rather than Larix since its size is slightly above that usually reached by Larix (60.0 - 70.0 microns). Pollen of the two genera is largely indistinguishable except for the size ranges which overlap slightly.

Genus: Tsuga Carr.

Tsuga sp. (PG-39)

Fig. 67

SIZE: 60.8 x 56.0 microns. Range: 60.0 - 82.0 microns x 40.0 - 74.0 microns.

SCULPTURE: Body has what appear at low magnifications to be verrucae--upon examination at higher magnifications these prove to be very tightly closed loops, similar to those of the velum. Velum is 7.2 - 12.0 microns wide and adorned with the characteristic looped sculpture present in this genus.

AGE: Oligocene and Mio-Pliocene.

DISCUSSION: While PG-39 is within the size range of T. heterophyllites Martin and Rouse (1966) it does not possess the spinae on top of the loops of the velum. While it is possible that this is a preservational phenomenon, I have chosen to leave PG-39 separate from T. heterophyllites for the present.

Tsuga heterophyllites Martin and Rouse (PG-40)

Fig. 68-71

SIZE: 84.0 x 64.0 microns. Range: 60.0 - 89.6 microns x 40.0 - 68.0 microns.

SCULPTURE: Exine tegillate. Bacula and spines occur on the uneven surface of the tegillum. Processes 0.8 - 1.8 microns long, varying from stout triangular spines to bacula about 0.5 micron wide. Exine covered by velum, loops of which also possess 0.4 - 0.8 micron long processes in the form of blunt, stout spinose elements.

STRUCTURE: Intrabaculate, bacula sometimes fused to give an intrarugulate appearance.SHAPE: Ellipsoidal.

AGE: Oligocene, Miocene and Mio-Pliocene.

DISCUSSION: PG-40 matches very well the description given by Martin and Rouse (1966), except for the slightly larger size range for PG-40.

Tsuga minisacca Martin and Rouse (PG-41)

Fig. 72

SIZE: 50.4 microns, M.E.D. (only specimen measured).

SCULPTURE: Body appears to be rugulate. Velum is convoluted, with the loops much smaller than in T. heterophyllites. Some loops have bacula about 1.2 microns long, or spines projecting outward.

SHAPE: More or less circular.

AGE: Oligocene and Mio-Pliocene.

DISCUSSION: PG-41 has nearly the same size and has very nearly the same morphological characteristics as T. minisacca, as described by Martin and Rouse (1966). Those authors allied this fossil type to the modern Tsuga sieboldii, a native of Japan.

Tsuga sp. (PG-43)

Fig. 73

SIZE: 42.4 microns, M.E.D. Range: 42.0 - 52.0 microns (4 specimens measured).

SCULPTURE: Body is coarsely verrucate. Verrucae commonly 1.0 - 1.6 microns in diameter, and often fused to form rugulae. Velum about 6.5 microns wide with very large "heterophyllites-type" convolutions. When observed in plan view, loops appear as vermiculae which can be traced over longer distances than those of T. heterophylla. Convolutions commonly extend about 4.5 - 5.0 microns beyond solid part of velum.

SHAPE: Circular.

AGE: Oligocene, Miocene and Mio-Pliocene.

DISCUSSION: While PG-43 may be a small example of T. heterophyllites,

I have chosen to maintain it outside that taxon because of its small size, the greater area over which vermiculae can be traced, and the somewhat larger velum.

Family: Taxodiaceae Neger.

Genus: Glyptostrobus Endl.

Glyptostrobus vacuipites Wodehouse (PG-44)

Fig. 74

SIZE: 27.2 x 15.0 microns. Range: 27.2 - 40.0 microns x 14.0 - 26.0 microns.

EXINE: 0.6 micron thick with 2.4 - 3.2 micron wide thickenings adjacent to the split in the exine.

SCILPTURE: Scabrate.

SHAPE: Ellipsoidal.

APERTURES: None.

AGE: Oligocene, Miocene and Mio-Pliocene.

DISCUSSION: The grains assigned to PG-44 are similar to G. vacuipites described by Wodehouse (1933) from the Green River (Eocene) shales.

? Glyptostrobus sp. (PG-45)

Fig. 75, 76

SIZE: 60.0 x 20.0 microns. Range: 32.0 - 60.0 microns x 10.0 - 28.0 microns.

EXINE: 0.5 micron thick.

SCULPTURE: Irregularly punctate by means of 0.3 - 0.5 micron wide, more or less isodiametric positive elements.

SHAPE: Fusiform.

APERTURES: Apparently there are no true apertures. However, the exine tends to split much in the manner of the Taxodiaceae.

AGE: Oligocene, Miocene and Mio-Pliocene.

DISCUSSION: Pokrovskaya has shown forms similar to PG-45 from the Miocene of the Baltic and from the Oligocene of the Kazakhstan area of the U. S. S. R., and has referred them to Glyptostrobus sp. However, the sculptural elements of PG-45 and of Pokrovskaya's specimens do not resemble the scabrate sculpture of the specimens of Glyptostrobus described by Wodehouse (1933) from the Green River (Eocene) shales or by Martin and Rouse (1966) from the Mio-Pliocene of the Queen Charlotte Islands.

Glyptostrobus sp. (PG-46)

Fig. 77-79

SIZE: 28.8 x 23.2 microns. Range: 26.0 - 33.0 microns x 20.5 - 28.0 microns (9 specimens measured).

EXINE: 0.6 micron thick. Sexine and nexine of essentially equal thickness.

SCULPTURE: Irregularly and moderately densely scabrate. Scabrae are more or less isodiametric and in optical cross-section appear as very small bacula.

SHAPE: Ellipsoidal.

APERTURES: This microfossil splits open in the same manner as Taxodium, Glyptostrobus, etc. Longitudinal folds 2.0 microns wide occur along the split, which traverses essentially the entire length of

the grain. The split seldom, if ever widens to the extent commonly exhibited by Taxodium. This pollen type is further characterized by possession of a furrow, furrow-like aperture or tear which parallels the small dimension of the grain. The temptation is strong to refer to this feature as a colpus because of its constant expression and the lack of real evidence that it is a tear. With its 0.8 micron wide thickenings on either side, this furrow-like feature indeed seems to be genetic. The furrow is about 18.4 microns long.

AGE: Oligocene and Mio-Pliocene.

DISCUSSION: Except for the furrow and slightly smaller size, PG-46 matches the description given by Wodehouse (1933) for Glyptostrobus vacuipites. I have, however, for the reasons set forth under the discussion on apertures, decided to maintain it as a separate entity. It is my belief that it represents a new species of Glyptostrobus.

Genus: Metasequoia Miki ex Hu and Cheng.

Metasequoia papillapollenites Rouse (PG-47)

Fig. 80-82

SIZE: 26.0 x 21.6 microns. Range: 20.0 - 29.0 microns x 18.0 - 26.0 microns.

EXINE: 0.6 micron thick in psilate area to 1.2 microns thick in scabrate area.

SCULPTURE: Densely and regularly scabrate, except for the area subtending the papillum.

SHAPE: Ellipsoidal.

APERTURES: Papillum present, 2.0 microns long and 2.0 microns in diameter.

AGE: Oligocene, Miocene and Mio-Pliocene.

DISCUSSION: PG-47 is nearly identical to M. papillapollenites as described by Rouse (1962) from the Burrard (Eocene) of British Columbia. The papillum of PG-47 is slightly shorter, but the size and ornamentation are the same.

Genus: Sciadopitys Sieb. and Zucc.

Sciadopitys serratus (R. Potonie and Venite) Martin and Rouse (PG-48)

Fig. 83

SIZE: 45.6 x 28.0 microns. Range: 32.0 - 46.0 microns x 23.0 - 34.0 microns.

EXINE: 2.4 microns thick, including verrucae.

SCULPTURE: Densely verrucate, verrucae 1.6 microns high, and up to 3.2 microns in diameter.

STRUCTURE: Tegillate. Intrabaculate, the 0.4 micron wide capita of the bacula fused to form the tegillum from which the verrucae arise.

SHAPE: Ellipsoidal to rounded rectangular.

APERTURES: Leptoma infrequently visible.

AGE: Oligocene.

DISCUSSION: Except for being up to 5.0 microns larger, PG-48 resembles very closely S. serratus as described by Martin and Rouse from the Mio-Pliocene of the Queen Charlotte Islands.

Genus: Taxodium Rich.

Taxodium hiatipites Wodehouse (PG-49)

Fig. 84, 85

SIZE: 28.0 x 21.2 microns. Range: 22.0 - 28.0 microns x 20.0 - 24.0 microns.

EXINE: 0.5 micron thick.

SCULPTURE: Scabrate.

SHAPE: Oval to circular, splitting open.

APERTURES: None.

AGE: Oligocene, Miocene and Mio-Pliocene.

DISCUSSION: The size, sculpture and tearing of the grains of PG-49 matches very well the descriptions of T. hiatipites as described by Wodehouse from the Green River (Eocene) shales. He related T. hiatipites to the extant Taxodium distichum.

Taxodium sp. (PG-50)

Fig. 86

SIZE: 22.8 microns, M.E.D. Range: 22.0 - 24.8 microns.

EXINE: 0.8 micron thick except for 2.0 micron thick areas adjacent to each side of the tear.

SCULPTURE: Irregularly and rather sparsely flecked.

SHAPE: Ellipsoidal, splitting open into a "V-shaped" figure.

APERTURES: None.

AGE: Oligocene, Miocene and Mio-Pliocene.

DISCUSSION: While tentatively assigned to Taxodium, the grains

classified as PG-50 may well represent another genus of bladder-less conifers. Assignment of fossil pollen within the bladder-less conifers is often difficult at best due to the lack of morphologic diversity within the group. The specimens were almost always on or very near 22.0 microns in longest dimension.

? Taxodiaceae

(PG-51)

Fig. 87

SIZE: 25.6 x 21.6 microns. Range: 24.0 - 30.0 microns x 18.0 - 22.0 microns.

EXINE: 0.8 micron thick. No thickenings adjacent to split in exine.

SCULPTURE: Strio-rugulate by means of 0.4 micron wide sinuate ridges which are usually lying parallel to each other, instead of intersecting.

SHAPE: Ellipsoidal.

APERTURES: Sometimes a papillum (about 4.0 microns long and 3.2 microns in diameter) is found, while the specimens always have been found with the split in the exine. The split appears, in some cases to occur along the leptoma.

AGE: Oligocene, Miocene and Mio-Pliocene.

DISCUSSION: A pollen grain which appears to be identical to my PG-51 was described by Manum (1962) from the Late Paleocene of Spitzbergen. Manum's type, which he referred to as <u>Inaperturopollenites</u> sp. (Type B), "has a rugate sculpturing consisting of short delicate ridges that in surface view are very

faintly spotted indicating a granular composition . . . . . Exine appears granular in profile; thickness slightly greater than 0.5 micron". I believe this pollen type represents an extinct species or genus in the Taxodiaceae.

Genus: Ephedra L.

Ephedra sp. (PG-52)

Fig. 88, 89

SIZE: 54.5 x 13.0 microns. Only specimen encountered.

EXINE: 0.8 micron thick.

SCULPTURE: Longitudinal ridges, separated by V-shaped valleys, both with psilate surfaces. The ridges are few in number (probably 5 - 7); the valleys are slightly sinuous with short (3.5 micron long), wavy branches leading away from them.

SHAPE: "Cigar-shaped".

AGE: Oligocene.

DISCUSSION: This is the first recorded occurrence of Ephedra in British Columbia. It has been reported from the Miocene and Oligocene in various regions of the U. S. S. R. by Pokrovskaya (1956a, b).

DIVISION: EMBRYOPHYTA SIPHONOGAMA (SPERMATOPHYTA)

SUBDIVISION: ANGIOSPERMAE

CLASS: Monocotyledoneae

Family: Potamogetonaceae Dum.

Genus: Potamogeton L.

Potamogeton sp. (PG-53)

Fig. 90

SIZE: 25.6 x 18.4 microns. Range: 20.0 - 26.0 microns x 15.0 - 24.0 microns.

EXINE: About 1.0 micron thick, except about 0.4 micron thick at the poles, where the sexine is missing.

SCULPTURE: Reticulate, the lumina about 0.4 - 1.0 micron in maximum dimension, the width of the muri mostly one-half or less than the maximum dimension of the lumina. Reticulum missing at the poles and for a distance of about 2.8 microns on either side of the poles.

STRUCTURE: Tegillate, infrabaculate, the capita of the bacula fused to form a simplibaculate, tegillate reticulum.

APERTURES: Monocolpate, the colpus narrow and reaching to at least within 1.0 micron of the poles.

AGE: Oligocene and Miocene.

DISCUSSION: PG-53 compares favorably with modern pollen of Potamogeton which I have examined.

Family: Graminae

(PG-54)

Fig. 91-93

SIZE: 27.6 x 20.0 microns. Only specimen encountered.

EXINE: 0.6 - 0.8 micron thick.

SCULPTURE: Very distinctly flecked. These flecks appear to be perforate elements, but, owing to the problem of resolution, could be small granules.

SHAPE: Slightly ellipsoidal, probably mostly due to folding.

APERTURES: Monoporate. The pore is 2.5 microns in diameter and is surrounded by a 2.5 micron wide annulus.

AGE: Mio-Pliocene.

DISCUSSION: The pollen of the Graminae are essentially inseparable, even at the generic level, because of the uniform morphology of all members of the family. The family is poorly represented in British Columbia pollen records, being recorded previously only by Martin and Rouse (1966) from the Miocene or Early Pliocene Skonun Formation of the Queen Charlotte Islands.

Family: Liliacae Dum.

Genus: Liliacidites Couper

Liliacidites sp. (PG-55)

Fig. 94, 95

SIZE: 35.2 x 16.0 microns. Range: 28.0 - 36.0 microns x 16.0 - 24.0 microns (7 specimens measured).

EXINE: 1.0 micron thick.

SCULPTURE: Reticulate, lumina not exceeding 1.0 micron in diameter and about the same size and shape over the entire surface.

STRUCTURE: Tegillate, simplibaculate, intrabaculate or small intraclavate, the capita forming the tegillum.

SHAPE: Prolate to perprolate.

APERTURES: Monocolpate. The colpus extending almost the entire length of the grain.

AGE: Oligocene.

DISCUSSION: I have referred PG-55 to the genus Liliacidites because of its resemblance to members of that taxon, as described by Couper (1953) from Upper Cretaceous and Tertiary sediments of New Zealand. PG-55 resembles Couper's Liliacidites variegatus, except for having smaller lumina.

CLASS: Dicotyledoneae

Incerti Ordinis

(PG-56)

Fig. 96

SIZE: 22.0 x 19.2 microns. Range: 22.0 - 30.0 microns x 19.2 - 29.0 microns.

EXINE: 1.2 microns thick.

SCULPTURE: Reticulate. Heterobrochate, essentially latimurate, lumina 0.4 - 1.6 microns in diameter.

STRUCTURE: Tegillate, intrabaculate. Muri supported by single rows of 0.8 microns long bacula (simplibaculate).

SHAPE: Ellipsoidal.

APERTURES: Tricolpate. Colpi 0.6 micron wide and 11.2 microns long with an 0.6 - 0.8 micron wide thickening on either side of each colpus.

AGE: Oligocene.

(PG-57)

Fig. 97, 98

SIZE: 25.2 x 17.6 microns. Range: 22.0 - 28.0 microns x 15.0 - 20.0 microns (8 specimens measured).

EXINE: 1.2 microns thick overall. Nexine 0.8 micron thick; sexine 0.4 micron thick.

SCULPTURE: Psilate.

SHAPE: Ellipsoidal.

APERTURES: Tricolpate. Colpi 0.6 micron wide and 20.0 microns long. Grain has a tendency to fold along the colpi. Folds commonly 4.8 microns wide at equator, tapering gradually toward the poles.

AGE: Oligocene and Miocene.

(PG-58)

Fig. 99

SIZE: 25.5 x 19.0 microns. Range: 24.0 - 32.0 x 17.0 - 22.0 microns (5 specimens measured).

EXINE: 1.0 micron thick, overall.

SCULPTURE: Reticulate, homobrochate. Lumina about 1.2 microns in diameter, reticulum latimurate.

STRUCTURE: Tegillate, intrabaculate. Muri are supported by a single row of bacula (simplibaculate). Bacula 0.2 - 0.6 micron in diameter.

SHAPE: Ellipsoidal.

APERTURES: Tricolpate. Colpi 22.4 microns long and 0.6 micron wide, flanked on either side by 1.6 micron wide thickenings. This grain may in fact be tricolporate, but its thickness and orientation prevent confirmation of pores. A slight bulging and somewhat thin areas at the equator suggest the possibility of pores.

AGE: Oligocene.

(PG-59)

Fig. 100

SIZE: 25.5 microns, M.E.D. Range: 20.0 - 28.0 microns, M.E.D.

EXINE: 1.5 microns thick, overall. Nexine and sexine of equal thickness.

SCULPTURE: Psilate.

SHAPE: Circular, but folded in the specimen in figure 100.

APERTURES: Tricolpate. Colpi ragged along their edges, 2.8 microns wide.

AGE: Oligocene.

(PG-60)

Fig. 101, 102

SIZE: 22.4 microns microns, M.E.D. Range: 18.0 - 22.4 microns, M.E.D.

EXINE: 0.6 micron thick.

SCULPTURE: Reticulate, heterobrochate, simplibaculate, the width of the muri about ½ the width of the lumina.

SHAPE: Oblate spheroidal to peroblate.

APERTURES: Tricolpate, colpi about 11.2 microns long; colpi 0.8 micron wide at the equator.

AGE: Oligocene and Miocene.

(PG-61)

Fig. 103-106

SIZE: 31.2 microns, M.E.D. Range: 25.0 - 32.0 microns, M.E.D. (5 specimens). Two other specimens, seen in equatorial view, measured 26.0 x 28.0 microns and 28.0 x 34.5 microns (Polar x Equatorial).

EXINE: Maximum thickness about 2.8 microns at equator, midway between the colpi. Exine thinner toward colpi.

SCULPTURE: Reticulate, simplibaculate, more or less homobrochate and essentially latimurate. Lumina typically elongated and 0.8 - 1.2 microns in maximum dimension.

STRUCTURE: Intrabaculate, with the bacula having only a slight suggestion,

if any, of thickening near the distal end. Fusion of the tips of the bacula form the tegillum.

SHAPE: Tricolpate forms essentially circular in polar view; tetracolpate forms ellipsoidal in polar view.

APERTURES: Tricolpate or tetracolpate, colpi extending 8.0 - 12.0 microns on either side of the equator, and about 1.2 microns wide at the equator.

AGE: Oligocene.

Psilastephanocolpites marginatus Gonzalez Guzman (PG-62)

Fig. 107, 108

SIZE: 21.6 x 13.6 microns. Range: 18.0 - 24.0 microns x 13.6 - 17.0 microns.

EXINE: 1.2 microns thick, overall.

SCULPTURE: Psilate to very minutely granular under 1250X phase contrast.

SHAPE: Prolate.

APERTURES: Tetracolpate. Colpi 16.0 microns long and 0.4 micron wide. A thickening, 0.2 - 0.3 micron wide at the distal ends and 1.0 micron wide at the equator, flanks the colpi on either side. Thickenings are capped with scabrae or small bacula, with concentrations of the sculptural elements greatest near the equator and decreasing toward the poles.

AGE: Oligocene.

DISCUSSION: Gonzalez Guzman (1967) described P. marginatus from the Eocene of Columbia. No other record of this distinctive pollen is known to me, and the botanical affiliation is completely unknown.

(PG-63)

Fig. 109

SIZE: 16.4 microns, M.E.D. Range: 14.0 - 26.4 microns, M.E.D.

EXINE: 0.6 micron thick at a point midway between the pores, thickening to 1.6 microns at the pores.

SCULPTURE: Psilate to small scabrate, the scabrae barely discernible in optical cross-section.

SHAPE: Roughly circular, but with the areas between the pores being convex and the pores themselves slightly protruding.

APERTURES: Tricolporate. The colpi extend to a point of about 6.5 microns above the equator and measure 0.4 - 0.6 micron in width. Sometimes they are quite inconspicuous. Pores are ragged in appearance, from 2.4 - 3.2 microns wide, and possess a thickened "pad" surrounding them, much on the order of the pollen of Tilia. In addition, there is a trilete tetrad scar at one or both poles.

AGE: Miocene.

DISCUSSION: Microfossils similar to PG-63, and assigned to Triporoletes singularis, were reported by Samoilovitch and Mtchedlishvili (1961) from the Albian - Cenomanian interval in the Western Siberian lowlands. They suggested a possible affinity to Quisqualis indica in the Combretaceae. If PG-63 is really synonymous with T. singularis, it may represent reworking of Cretaceous palynomorphs into the Miocene sediments.

(PG-64)

Fig. 110, 111

SIZE: 24.4 x 20.4 microns. Range: 22.5 - 30.0 microns x 17.0 - 26.0 microns (8 specimens measured).

EXINE: About 1.5 microns thick.

SCULPTURE: Psilate.

SHAPE: Subprolate.

APERTURES: Tetracolporate. Colpi about 13.5 microns long and about 0.6 micron wide. Each colpus has a margo which varies in thickness from 1.2 microns at the extremities of the colpus to 2.4 microns at the equator, where it forms the thickening adjacent to the pores. Pores lalongate, 0.8 - 1.2 microns x 4.0 microns.

AGE: Oligocene.

(PG-65)

Fig. 112, 113

SIZE: 23.6 x 20.8 microns. Range: 20.0 - 25.0 microns x 14.5 - 22.5 microns.

EXINE: 1.0 - 1.6 microns thick.

SCULPTURE: Psilate.

SHAPE: Spheroidal to subprolate.

APERTURES: Tetracolporate. The colpi about 14.8 microns long and 0.5 micron wide. Each has a margo which reaches a maximum thickness of 2.4 microns in the knob-like areas which form the annulus of the pore. Pores circular, 3.2 microns in diameter, to slightly

elongated along their polar axis. The pore membranes are prominently flecked.

AGE: Oligocene.

(PG-66)

Fig. 114, 115

SIZE: 20.8 microns, M.E.D. Range: 22.0 - 26.5 microns, M.E.D.

EXINE: 0.8 micron thick, increasing to 1.2 microns at the pores.

SCULPTURE: Densely, irregularly and finely scabrate. Scabrae not isodiametric, or if isodiametric, then fused with one or more adjacent scabrae.

SHAPE: Rounded triangular.

APERTURES: Triporate, pores slightly protruding. A roughened, tarsus-like pattern is developed on the nexine of the pores. In polar view the pores are 2.4 microns wide x 1.0 micron "deep".

AGE: Oligocene, Miocene and Mio-Pliocene.

DISCUSSION: Macko (1959, Pl. 20, Fig. 1) figures a pollen grain which somewhat resembles PG-66, and refers it to Carpinus. However, the pores in Macko's specimen protrude more than those of PG-66, so I have not referred my type to Carpinus.

(PG-67)

Fig. 116, 117

SIZE: 92.0 x 67.2 microns. Only specimen seen.

EXINE: 0.8 micron thick.

SCULPTURE: Baculate, the bacula arising from the tegillum, about 4.8 microns long, constricted at a point slightly above their point

of origin, and again near the tip, the latter constriction forming a spiny-looking tip to the baculum. Between the bacula, the exine is finely reticulate, with lumina about 0.4 - 0.6 micron in maximum dimension.

STRUCTURE: Tegillate, intrabaculate.

SHAPE: Ellipsoidal.

APERTURES: Tricolporate, the inconspicuous colpi narrow, about 1.6 microns wide, and extending a maximum of only about 2.5 microns on either side of the annulus of the pore. Pores ellipsoidal, about 10.8 x 4.8 microns, with a 2.4 - 3.2 micron wide annulus.

AGE: Oligocene.

DISCUSSION: Pollen similar to PG-67 is found in the Caprifoliaceae, particularly the genera Lonicera and Diervilla. Hence, PG-67 may be related to PG-105 of this thesis.

(PG-68)

Fig. 118-120

SIZE: 24.8 x 15.2 microns. Range: 16.0 - 28.0 microns x 10.0 - 17.0 microns (9 specimens measured).

EXINE: 1.0 micron thick at the equator; nexine 0.4 micron thick; sexine 0.6 micron thick. At the poles the exine is 1.4 microns thick, with the nexine 0.4 micron thick and the sexine 1.0 micron thick.

SCULPTURE: Very finely granular under 1250X phase contrast; appears psilate to faintly roughened under 400X.

STRUCTURE: Tegillate. Supporting bacula are closely spaced and have their distal ends fused to form a 0.4 micron thick tegillum.

SHAPE: Prolate.

APERTURES: Tricolporate. Colpi 20.8 microns long and 0.6 micron wide with adjacent flap-like thickenings, 2.4 microns wide at the equator and thinning gradually until extinction near the ends of the colpi. Pores circular, 2.4 microns in diameter, with a 0.4 micron wide annulus. A "plug" 0.8 micron in diameter occupies the center of the pores.

AGE: Oligocene and Miocene.

Family: Myricaceae S. F. Gray

Genus: Myrica L.

Myrica annulites Martin and Rouse (PG-69)

SIZE: 26.4 microns, M.E.D. Range: 26.4 - 32.5 microns, M.E.D.

EXINE: 0.8 micron thick in mesoporia, becoming 2.0 microns thick at the pores.

SCULPTURE: Finely, uniformly and very densely scabrate.

SHAPE: Circular.

APERTURES: Triporate, pores about 2.0 microns in diameter, slightly aspidate. Exine of aspides dissected to form "tarsus" pattern on the inside layer.

AGE: Oligocene, Miocene and Mio-Pliocene.

DISCUSSION: PG-69 matches exactly the description given by Martin and Rouse (1966) for M. annulites, especially in its size range and the granular texture of the annulus.

Family: Juglandaceae A. Rich. ex Kunth.

Genus: Carya Nutt.

Carya juxtaporipites (Wodehouse) Rouse (PG-70)

Fig. 123-125

SIZE: 31.2 microns, M.E.D. Range: 21.0 - 32.0 microns, M.E.D.

EXINE: 0.8 micron thick in mesoporia to 1.6 microns thick in areas adjacent to pores.

SCULPTURE: Minutely, uniformly and densely granular.

SHAPE: Circular to sub-triangular.

APERTURES: Triporate. Pores 3.2 microns in diameter to 3.6 x 2.0 microns, with the long axis parallel to the plane of the equator. Pores all in one hemisphere.

AGE: Oligocene and Miocene.

DISCUSSION: PG-70 resembles very closely C. juxtaporipites as described by Rouse (1962) and Hicoria juxtaporipites described by Wodehouse (1933), except for the thickening of the exine near the area of the pores. This feature is not described by either author. The latter species was emended by Rouse (1962).

Genus: Caryapollenites R. Potonie

Caryapollenites simplex R. Potonie (PG-71)

Fig. 126

SIZE: 33.2 microns, M.E.D. Range: 33.2 - 38.0 microns, M.E.D.

EXINE: 1.2 microns thick, except 2.4 microns near the pores.

SCULPTURE: Very finely and regularly scabrate. Scabrae about 0.2 micron wide and more or less isodiametric.

SHAPE: Circular.

APERTURES: Triporate. Pores oval, 2.4 x 1.6 microns.

AGE: Oligocene, Miocene and Mio-Pliocene.

DISCUSSION: The size range is larger than that given for Carya juxtaporipites (Wodehouse) Rouse (1962). Hopkins (1966) included this size range in C. juxtaporipites. My type is too small for Carya viridifluminipites and the pores are too small. The size range of PG-71 does, however, conform to the upper half of the size range given by Potonie (1960) for Caryapollenites simplex.

Genus: Carya Nutt.

Carya viridifluminipites Wodehouse (PG-72)

Fig. 127-129

SIZE: 42.4 microns, M.E.D. Range: 40.0 - 47.0 microns x 29.0 - 42.0 microns.

EXINE: 0.8 micron between pores, thickening to 2.4 microns at the pores.

SCULPTURE: Densely, uniformly and very finely scabrate under phase contrast illumination. Scabrae about 0.5 micron in diameter and more or less isodiametric.

SHAPE: Rounded triangular.

APERTURES: Triporate. Pores circular to slightly elliptical, 4.0 x 3.2 microns.

AGE: Oligocene and Miocene.

DISCUSSION: The size range of PG-72 is in the upper limits of, and slightly exceeds the size range of the specimens of C.

viridifluminipites described by Wodehouse (1933) from the Green River shales (Eocene). Martin and Rouse (1966) places grains with a size range of 35.0 - 45.0 microns in this species.

Genus: Engelhardtia Leschen. ex B. Carr. Bl.

Engelhardtia sp., cf. E. chrysolepis (PG-73)

Fig. 130, 131

SIZE: 15.6 microns, M.E.D. Range: 14.0 - 18.0 microns, M.E.D. (7 specimens measured).

EXINE: 1.4 microns thick between the pores, often thinning at pole and thinning to 0.8 - 1.0 micron at the pores.

SCULPTURE: Psilate, except for flecking on polar thinning which is prominent under 1250X phase contrast.

SHAPE: Rounded Triangular.

APERTURES: Triporate. Pores are notch-like or half-moon shaped. They are 1.6 microns "deep" and 1.2 microns wide when seen in polar view. Each pore is subtended by a pronounced "vault-like" area (under 1250X phase contrast) produced by the thinning of the exine.

AGE: Oligocene.

DISCUSSION: Pollen grains resembling PG-73 are often referred to the genus Momipites (Hopkins, 1966; Anderson, 1960; and others). However, PG-73 bears strong resemblance to specimens of Engelhardtia chrysolepis in the Union Oil Company modern pollen collection.

Genus: Juglans L.

Juglans horniana Traverse (PG-74)

Fig. 132, 133

SIZE: 37.6 microns, M.E.D. Range: 30.5 - 38.0 microns x 26.0 - 34.0 microns.

EXINE: 0.6 - 0.8 micron thick, except 1.2 microns thick at the pores.

SCULPTURE: Very finely perfero-reticulate under 1250X interference contrast illumination. Perforations or lumina about 0.4 micron in diameter, circular in outline.

SHAPE: Roughly circular.

APERTURES: Polyporate, heteropolar, pores about 12 - 15 in number, circular to slightly oval in outline, and 1.6 - 1.8 microns in maximum dimension.

AGE: Oligocene, Miocene and Mio-Pliocene.

DISCUSSION: PG-74 is nearly the same in size and wall thickness as J. horniana, as described by Traverse (1955). Traverse describes the sculpture as psilate-scabrate, but the fine perfero-reticulum shows up only under 1250X phase contrast illumination.

Genus: Pterocarya Kunth.

Pterocarya stellatus (R. Potonie) Martin and Rouse (PG-75)

Fig. 134, 135

SIZE: 28.8 microns, M.E.D. Range: 26.0 - 35.0 microns x 20.0 - 28.0 microns.

EXINE: 0.8 micron thick in mesoporia, thickening slightly to 1.2 microns at the pores.

SCULPTURE: Psilate under bright field illumination, very finely scabrate under 1250X phase contrast.

SHAPE: Pentagonal to oval-octagonal.

APERTURES: Penta- to octaporate, most often hexaporate. Pores 3.2 microns x 2.0 microns, with their long axes perpendicular, or nearly so, to the equator.

AGE: Oligocene, Miocene and Mio-Pliocene.

DISCUSSION: The size range of PG-75 falls into the lower end of the size range listed for specimens of Pterocarya stellatus by Martin and Rouse (1966) from the Late Miocene - Early Pliocene of the Queen Charlotte Islands. PG-75 may, in fact, encompass two species since some specimens have noticeably smaller pores; however, all have been maintained as one pollen type for the present. Pterocarya is common in the Miocene and Oligocene assemblages of the U. S. S. R. (Pokrovskaya, 1956a; 1956b; 1966). Wolfe (1966) reports the leaves and pollen from the Alaskan Tertiary, and Traverse (1955) reports the pollen from the Brandon lignite (Oligocene).

Family: Betulaceae S. F. Gray

Genus: Alnus Mill.

Alnus sp. (PG-76)

Fig. 137

SIZE: 24.0 x 24.0 microns. Range: 20.0 - 26.0 microns x 18.0 - 25.0 microns.

EXINE: 0.8 micron thick between the pores, reaching 2.0 microns at the pores. The sexine is 1.2 microns thick and the nexine is 0.8 micron thick at the pores.

SCULPTURE: Very finely, densely and uniformly scabrate.

SHAPE: Square.

APERTURES: Tetraporate, the pores more or less circular, about 1.6 microns in diameter. The pores are slightly protruding, extending about 1.2 - 1.6 microns above the amb of the grain.

AGE: Oligocene and Mio-Pliocene.

Alnus verus (R. Potonie) Martin and Rouse (PG-77)

Fig. 136, 138, 139

SIZE: 25.6 microns, M.E.D. Range: 23.0 - 34.0 microns x 20.0 - 31.0 microns.

EXINE: 0.8 micron thick midway between the pores, thickening to 2.8 microns at the pores. Arci reach a maximum thickness of 3.2 microns.

SCULPTURE: Psilate.

SHAPE: Pentagonal to square.

APERTURES: Pentaporate or tetraporate, with occasional hexaporate specimens. Pores ellipsoidal, about 2.8 x 4.8 microns, elongated in the plane of the polar axis. Pores protrude about 2.8 microns above the amb of the grain.

AGE: Oligocene, Miocene and Mio-Pliocene.

DISCUSSION: The specimens of PG-77 match rather well the descriptions

of A. verus as described by Martin and Rouse (1966) from the Queen Charlotte Islands. My specimens seem to exceed the upper size range of the specific description by the above authors.

Genus: Betula L.

Betula claripites Wodehouse (PG-78)

Fig. 140, 141

SIZE: 17.6 microns, M.E.D. Range: 17.6 - 23.0 microns, M.E.D.

EXINE: 1.2 microns thick.

SCULPTURE: Psilate to micro-perforate or micro-scabrate.

SHAPE: Triangular, bulging in the mesoporial areas.

APERTURES: Triporate, pores aspidate, protruding about 1.5 - 2.0 microns above the normal amb. Diameter of aspides 6.0 microns. Endosexine dissected below the aspides to form bacula which support the aspides.

AGE: Oligocene.

DISCUSSION: PG-78 appears to be identical with B. claripites described by Wodehouse (1933) and enlarged upon by Martin and Rouse (1966). The latter authors cite its identity in all respects to the modern pollen of Betula papyrifera.

Genus: Carpinus L.

Carpinus sp. (PG-79)

Fig. 142, 143

SIZE: 51.2 microns, M.E.D. Range: 44.0 - 54.0 microns, M.E.D

EXINE: 1.6 - 2.4 microns thick.

SCULPTURE: Irregularly, densely and very finely scabrate under phase contrast illumination. Scabrae irregularly shaped.

SHAPE: Circular.

APERTURES: Triporate or tetra- to octaporate. Most forms are triporate or tetraporate. Pores 3.6 x 1.6 microns, with a 4.4 micron wide annulus. Pores with a well defined tarsus-like pattern similar to that occurring the the genus Myrica. Pores equatorial or nearly so.

AGE: Miocene.

DISCUSSION: The pollen most resembling PG-79 is that which I collected from the specimen of Carpinus betulus in the University of British Columbia arboretum. This taxon is rather variable between three and four pores per pollen grain and approaches the size of PG-79. Pokrovskaya (1966) assigned pollen of this type to Carpinus sp., from Lower and Middle Oligocene sediments of the U. S. S. R.

Genus: Corylus L.

Corylus sp. (PG-80)

Fig. 144

SIZE: 24.8 microns, M.E.D. Range: 20.5 - 26.0 microns, M.E.D.

EXINE: 1.6 microns thick except at the pores, where it is 3.2 microns thick. Arci-like thickenings connect the pores.

SCULPTURE: Psilate.

SHAPE: Triangular, with convex sides.

APERTURES: Triporate, the pores typically betuloid in nature with aspides and atria. The band-like nexinous thickenings compose most of the thickness of the exine at the pores.

AGE: Oligocene and Miocene.

DISCUSSION: Pokrovskaya shows pollen from the Russian Lower and Middle Oligocene which appears to be identical to PG-80, and which she refers to Corylus sp.

Family: Fagaceae Dum.

Genus: Castanea Mill.

Castanea sp. (PG-81)

Fig. 145

SIZE: 16.0 x 14.4 microns. Range: 15.0 - 20.0 microns x 12.0 - 16.0 microns.

EXINE: 1.0 - 1.6 microns thick, the maximum thickness occurring at the poles and at the equator. Nexine 0.8 micron thick at the poles, sometimes thinning to 0.4 micron on either side of the pole.

SCULPTURE: Psilate.

STRUCTURE: This type appears to be tegillate, although this is difficult to ascertain because of the small size.

SHAPE: Prolate - spheroidal.

APERTURES: Tricolporate, colpi about 0.4 - 0.6 micron wide and about 11.0 microns long. The pores lalongate, 0.4 - 0.6 micron x 2.4 microns. A 0.8 - 1.6 micron wide margo adjoins the colpi.

AGE: Oligocene, Miocene and Mio-Pliocene.

DISCUSSION: The pollen of the two genera Castanea and Castanopsis are virtually indistinguishable. It may be that PG-81 contains representatives of both groups.

Genus: Fagus L.

Fagus sp. (PG-82)

Fig. 146, 147

SIZE: 34.4 microns, M.E.D. Range: 32.0 - 38.0 microns, M.E.D.

EXINE: 1.0 micron thick, except at pores, where it is up to 2.0 microns thick. Nexine about 0.2 micron thick.

SCULPTURE: Very finely reticulate, the lumina 0.4 micron or less in maximum dimension.

STRUCTURE: Tegillate, intrabaculate, the bacula about 0.6 micron long, with their 0.4 micron wide capita fused to form the tegillum.

SHAPE: Circular.

APERTURES: Tricolporate, the colpi about 1.0 micron wide and about 14.4 microns long. The pores appear to be lolongate, oval, and about 3.2 - 2.0 microns. Each pore has an annulus up to 3.2 microns wide and the colpi have 1.0 micron wide costae colpi.

AGE: Oligocene and Miocene.

Fagus granulata Martin and Rouse (PG-83)

Fig. 148

SIZE: 30.4 microns, M.E.D. Range: 28.0 - 38.0 microns, M.E.D

EXINE: 0.8 micron thick.

SCULPTURE: Finely, densely and uniformly scabrate.

STRUCTURE: Tegillate, intrabaculate, capita fused to form tegillum.

SHAPE: Circular to ellipsoidal.

APERTURES: Tricolporate, colpi 0.8 micron wide and of difficult to determine length. Pores 8.0 x 5.6 microns, with a 0.6 - 0.8 micron wide annulus.

AGE: Oligocene, Miocene and Mio-Pliocene.

DISCUSSION: PG-83 compares most favorably with F. granulata as described by Martin and Rouse (1966). The overall size of the grains and the size of the pores are especially close.

Genus: Quercus L.

Quercus shiabensis Simpson (PG-84)

Fig. 149, 150

SIZE: 24.8 x 18.4 microns. Range: 24.0 - 28.0 microns x 13.0 - 18.5 microns.

EXINE: 1.2 microns thick.

SCULPTURE: Finely, densely and uniformly scabrate.

STRUCTURE: Tegillate, appears to be finely intrabaculate, with capita of bacula fused to form the tegillum.

SHAPE: Subprolate to prolate.

APERTURES: Tricolpate. Colpi about 19.0 microns long, and with a maximum width of 1.5 microns at the equator. Margo adjoining colpi varies in width from 1.6 microns near the poles to 2.4 microns at the equator. There may be a slight tendency toward a colporate habit, as evidenced by the jagged break in each

margo at the equator.

AGE: Oligocene, Miocene and Mio-Pliocene.

DISCUSSION: Pollen which appears to be identical with my PG-84 is described as Quercus shiabensis by Simpson (1961), from the Lower Tertiary of Britain. He compared it with the pollen of the extant Quercus lanata.

Quercus sp. (PG-85)

Fig. 151

SIZE: 30.0 x 17.0 microns. Range: 27.0 - 30.5 microns x 12.0 - 20.0 microns.

EXINE: Overall thickness 1.0 micron at the equator and 1.6 microns at the poles; nexine 0.2 micron thick at the equator and 0.4 micron thick at the poles.

SCULPTURE: Finely and uniformly scabrate under phase contrast. Individual scabrae project about 0.2 - 0.4 micron above the surface of the tegillum.

STRUCTURE: Tegillate, intrabaculate.

SHAPE: Mostly prolate.

APERTURES: Tricolpate. Colpi 1.0 micron wide and 24.0 microns long. Thickenings 0.4 micron wide near the poles and 1.2 microns wide at the equator flank the colpi on either side.

AGE: Oligocene and Miocene.

Family: Ulmaceae Mirb.

Genus: Ulmus L.

Ulmus sp. (PG-86)

Fig. 152, 153

SIZE: 28.8 microns, M.E.D. Range: 22.0 - 32.0 microns x 22.0 - 28.0 microns.

EXINE: 0.8 micron thick, except 1.6 microns thick at the poles.

SCULPTURE: Rugulate, the 0.4 - 0.6 micron high rugulae curved, but continuous over a distance of up to 8.0 microns.

SHAPE: Roughly circular to somewhat pentagonal.

APERTURES: Tetraporate to pentaporate, the pores ellipsoidal, 1.0 x 2.8 microns, elongated in the plane of the polar axis.

AGE: Oligocene and Miocene.

Ulmus sp. (PG-87)

Fig. 154, 155

SIZE: 30.4 x 22.4 microns. Range: 24.0 - 36.0 microns x 19.5 - 31.0 microns.

EXINE: 1.2 - 1.6 microns thick, tending to be thickest at the pores.

SCULPTURE: Reticulate, the low, broad ridges of the muri forming lumina of varying size and shape. Muri as much as 2.0 microns wide, with lumina generlly less than 1.6 microns in maximum dimension. Relief between top of muri and bottom of lumina 0.4 - 0.8 micron.

SHAPE: More or less ellipsoidal in equatorial view; rounded quadrangular in polar view.

APERTURES: Predominantly tetraporate, with three- and five-pored specimens noted. Pores 1.6 microns wide and more or less circular in outline.

AGE: Oligocene, Miocene and Mio-Pliocene.

DISCUSSION: PG-87 most closely resembles the modern pollen of Ulmus fulva. Traverse (1955) erected Ulmus inaequaliarcuata for

reticulate specimens from the Brandon (Oligocene) lignite, which he also related to Ulmus fulva. However, Traverse's new type was irregularly arcuate, which I have not noted in PG-87 or in the specimens of Ulmus fulva in the Union Oil modern pollen collection.

? Family: Moraceae Link.

Genus: ? Dorstenia sp.

? Dorstenia sp. (PG-88)

Fig. 156-159

SIZE: 28.0 microns, M.E.D. The only other specimen noted was 32.0 x 25.0 microns.

EXINE: 0.8 - 1.2 microns thick.

SCULPTURE: Psilate.

SHAPE: Spheroidal.

APERTURES: Polyporate. Pores about 75 in number. Pores annulate, annulus 0.8 - 1.2 microns thick, and projecting about 1.6 microns above the surface of the grain. Overall diameter of pores, including annulus, about 3.2 microns. Annulus is tegillate, by means of simple bacula. Structured part of annulus is the same thickness as adjoining exine. Endexine of pores appears to be weakly punctate.

AGE: Oligocene and Miocene.

DISCUSSION: To my knowledge, this is the first time that pollen resembling Dorstenia has been reported from the fossil record. Its 125 species (Lawrence, 1951) are pantropical in distribution,

with representatives in Mexico today. PG-88 bears some resemblance to the pollen of D. contrajerva and D. eccentrica which I have examined from the Union Oil modern pollen collection.

Family: Hamamelidaceae R. Br.

Genus: Liquidambar L.

Liquidambar sp. (PG-89)

Fig. 160, 161

SIZE: 29.2 microns, M.E.D. Range: 22.5 - 35.0 microns x 22.0 - 35.0 microns.

EXINE: 1.6 microns thick.

SCULPTURE: Perforate, perforations uniformly about 0.4 micron in diameter.

STRUCTURE: Tegillate, intrabaculate, capita of bacula fused to form tegillum. Sexine thicker than nexine, endosexine and ectosexine of equal thickness.

SHAPE: Circular to ellipsoidal.

APERTURES: Polyporate, pores oval in shape, 5.6 x 2.4 microns.

AGE: Oligocene, Miocene and Mio-Pliocene.

DISCUSSION: PG-89 has been maintained separately from PG-90 on the basis of its smaller size and slightly different sculpture. However, as Traverse (1955) has commented, the pollen of the extant Liquidambar styraciflua is quite variable, so that PG-89 and PG-90 may represent variant pollen of a single species of Liquidambar.

Liquidambar brandonensis Traverse (PG-90)

Fig. 162, 163

SIZE: 34.4 microns, M.E.D. Range: 34.0 - 40.0 microns x 23.0 - 37.0 microns.

EXINE: 1.8 microns thick overall, nexine 0.8 micron thick and sexine 1.0 micron thick.

SCULPTURE: Reticulate, homobrochate, lumina 0.5 micron across, latimurate.

STRUCTURE: Tegillate by means of clavate elements whose capita are fused to form a tegillum. Endosexine and ektosexine are of essentially equal thickness.

SHAPE: Ellipsoidal.

APERTURES: About 10 - 15, each pore approximately 7.6 x 4.8 microns, with a 0.4 micron wide annulus.

AGE: Miocene.

DISCUSSION: PG-90 is separated from PG-89 on the basis of size ranges, sculptural features and the apparent restriction of PG-90 to the Miocene sediments. PG-90 is very similar to Liquidambar brandonensis (Traverse, 1955), except for its slightly thinner exine. Traverse also made no reference to the tegillum.

Family: Leguminosae Juss.

Genus: Prosopis L.

Prosopis sp. (PG-91)

Fig. 164-166

SIZE: 24.0 microns, M.E.D. Range: 17.5 - 24.5 microns.

EXINE: 1.2 microns thick. Sexine 0.8 micron thick; nexine 0.4 micron thick.

SCULPTURE: Reticulate, latimurate, simplibaculate, the lumina not exceeding 1.0 micron in maximum dimension, and appearing to be only about ½ the size at the pole as near the equator.

STRUCTURE: Tegillate, intrabaculate to intraclavate, the capita united to form the tegillum. The sexine is not present near the pores.

SHAPE: Circular in polar view.

APERTURES: Tricolporate. The colpi are rather indistinct, but reach to within 4.0 - 5.0 microns of the poles. There is no nexinous thickening along the edge of the colpi, while the nexine thickens to a maximum of 1.6 microns to form an annulus about each pore. Width of pores about 2.4 microns.

AGE: Oligocene.

DISCUSSION: PG-91 very closely resembles Prosopis juliflora, which I have examined, except that PG-91 is about 6.0 microns larger and has a somewhat bolder reticulum. The pores and colpi are identical. PG-91 is different from P. glandulosa, as described by Vishnu-Mittre and Sharma (1962). Jain and Nanda (1966) figure the pollen of the modern P. spicigera, which resembles PG-91 very closely.

Family: Buxaceae Loisel

Genus: Pachysandra Michx. or Sarcococca Lindl.

Pachysandra sp. or Sarcococca sp. (PG-92)

Fig. 169

SIZE: 42.4 microns, M.E.D. Range: 32.8 - 45.0 microns x 28.8 - 34.0 microns (only 3 specimens noted).

EXINE: 3.2 microns thick overall. Sexine is 2.4 microns thick; nexine 0.8 micron thick.

SCULPTURE: Reticulate in plan view, by means of fusiform, trapezoidal, needle-like, or triangular, wedge-shaped thickenings of the sexinous layer. The elements which appear triangular in plan view are located only at the junction of intersecting muri and are seen as bacula or clavae in optical cross-section. These elements are 2.4 microns long and 1.0 micron wide, whereas the other three types of elements are commonly 1.4 microns long and 0.5 micron wide. The lumina vary in size from a diameter of 2.4 microns, to ellipsoidal with axes 5.6 x 3.5 microns.

SHAPE: Circular.

APERTURES: Polyporate. The exact number of pores is uncertain, but probably ranges from 25 - 35. Approximately 13 were counted on one hemisphere. The pores are irregularly spaced, often located beneath lumina of the reticulum. The pores are elliptical, 3.6 x 2.4 microns.

AGE: Oligocene.

DISCUSSION: Gray and Sohma (1964) have studied the modern species of Pachysandra and Sarcococca, and have plotted the fossil occurrences of Pachysandra in North America. It was their conclusion that pore number was the single most diagnostic character, and was useful in conjunction with size for distinguishing modern species of the two genera.

The size and pore numbers of my type do not allow a definite

generic assignment. Gray and Sohma's group of taxa with the pore numbers of 30 - 39 includes species of both Pachysandra and Sarcococca. Their size group which measured less than 42.0 microns contained one species of Pachysandra and all of the species (10) of Sarcococca.

Family: Aquifoliaceae Bartl.

Genus: Ilex (Tourn.) L.

Ilex longipolliniata Traverse (PG-93)

Fig. 170, 171

SIZE: 28.8 microns, M.E.D. (Only specimen noted).

EXINE: Overall, 1.8 microns thick at colpi and 2.4 microns thick in mesocolpial areas. Nexine 1.6 microns thick at the colpi and 0.8 micron thick in mesocolpial areas.

SCULPTURE: Clavate. Pila 0.8 micron long and 0.6 micron in diameter; capita 0.8 micron high and 1.2 microns in diameter in the mesocolpial areas. Clavae decrease sharply in height and diameter approaching the colpi, so that a scabrate sculpture is present at the colpi.

SHAPE: Circular to ellipsoidal.

APERTURES: Tricolpate. Colpi 3.2 microns wide at the equator.

AGE: Mio-Pliocene.

DISCUSSION: The single specimen of PG-93 seems to resemble very closely the description given by Traverse (1955) for Ilex longipolliniata. It appears to possess the nexinous thickenings (costae) at the

colpi as described by Traverse. PG-93 is not prolate in shape, as were Traverse's specimens, but Martin and Rouse (1966) figured specimens of Ilex longipolliniata which are shaped like PG-93.

Family: Aceraceae Juss.

Genus: Acer L.

Acer sp. (PG-94)

Fig. 167, 168

SIZE: 33.6 x 21.6 microns. Range: 25.0 - 33.6 microns x 14.5 - 21.6 microns (5 specimens measured).

EXINE: 1.5 microns thick, overall. Nexine 0.5 micron thick.

SCULPTURE: Striate by means of rows of small closely spaced granules which are interconnected to form the striae. The striae are about 0.2 micron wide, with a 0.3 micron wide distance between. The granules of adjacent rows often appear to touch, thereby creating an almost scalariform appearance.

STRUCTURE: Tegillate, intrabaculate, bacula about 0.6 micron long, with their distal ends fused to form a 0.4 micron thick tegillum.

SHAPE: Prolate.

APERTURES: Tricolpate, colpi about 0.5 micron wide, with no discernible adjacent thickenings, and reaching nearly to the poles.

AGE: Oligocene.

DISCUSSION: Pollen of Acer was not reported by Traverse (1955) or by Martin and Rouse (1966); Hopkins (1966) reports it as "rare, but omnipresent in all Whatcom basin rocks" of southwestern British Columbia and adjacent Washington. It is also a constituent of the Miocene and Oligocene assemblages of the U. S. S. R.

(Pokrovskaya, 1956a, b).

Acer sp. (PG-95)

Fig. 172-174

SIZE: 30.5 microns, M.E.D. Range: 27.2 - 30.5 microns, M.E.D. (4 specimens measured).

EXINE: 1.2 microns thick.

SCULPTURE: Densely striate.

STRUCTURE: Tegillate, intrabaculate, capita of bacula fused to form the striate exine pattern.

SHAPE: Circular.

APERTURES: Tricolpate, colpi about 16.0 microns long; and 5.6 microns wide at the equator.

AGE: Oligocene.

DISCUSSION: See under PG-94.

Family: Tiliaceae Juss.

Genus: Tilia L.

Tilia crassipites Wodehouse (PG-96)

Fig. 175

SIZE: 34.4 microns, M.E.D. Range: 27.2 - 40.0 microns, M.E.D

EXINE: 1.6 microns thick. Nexine about 0.6 micron thick, except at pores; sexine about 1.0 micron thick.

SCULPTURE: Reticulate.

STRUCTURE: Tegillate. Tegillum formed by fused capita of bacula. Simplibaculate.

SHAPE: Circular.

APERTURES: Tricolporate. Colpi short, narrow and obscured by the pad-like thickening of the nexine about the pores. Pads are about 3.2 microns thick. Pores have a maximum diameter of 4.0 microns.

AGE: Oligocene and Miocene.

DISCUSSION: PG-96 resembles closely the brief description given by Wodehouse (1933) for his type from the Eocene Green River shales. Takahashi (1963) has included pollen similar to PG-96 under his Tiliaepollenites tiliaceous. The same author (1961) figures pollen similar to PG-96 as Intratriporopollenites tiliaceous.

Family: Onagraceae Juss.

Genus: Boisduvalia Spach.

Boisduvalia sp. (PG-97)

Fig. 176-178

SIZE: 46.4 microns, M.E.D. Range: 46.0 - 58.0 microns, M.E.D.

EXINE: 1.6 microns thick, except at pores where the total thickness is about 3.2 microns.

SCULPTURE: Sparsely to rather densely clavate, the pila inconspicuous, and the somewhat irregularly shaped capita about 4.0 microns high and as much as 3.2 microns across. Areas between the clavae irregularly scabrate.

SHAPE: Roughly circular to slightly triangular in polar view.

APERTURES: Triporate, the pores protruding about 3.2 microns above

the amb of the grain. Sexine ridged and dissected in the pores, giving a "splotched" appearance to the pores. The sexine also appears to be divided into two layers within the pore.

AGE: Oligocene.

DISCUSSION: No specimens similar to this have been described in fossil form, to my knowledge. My specimens are certainly in the family Onagraceae, and almost certainly belong in the genus Boisduvalia. Pollen of this genus tends to remain in tetrads, a trait which is quite restricted in occurrence. The extant B. densiflora and B. cleistogama are examples of species with unseparated tetrads. This and other characters of Boisduvalia are discussed by Ting (1966).

(PG-98)

Fig. 179, 180

SIZE: 54.4 microns, M.E.D. Only two specimens noted; both were the same size.

EXINE: 2.0 microns thick, excluding clavae.

SCULPTURE: Predominantly large clavate, the capita attached to very short, slender bacula. Capita range from 2.4 - 4.4 microns in diameter. Clavae clustered and unevenly distributed.

SHAPE: Essentially triangular, with sharply protruding pores.

APERTURES: Triporate, the pores 18.4 microns wide at the base and protruding 9.6 microns above their junction with the triangular outline of the grain. Exine dissected in the pores to form punctate and striate patterns.

AGE: Oligocene.

DISCUSSION: Although in all probability a member of the Onagraceae, the different pore structure of PG-98 indicates it is likely affiliated with another genus of the Onagraceae.

Genus: Jussiaea L.

Jussiaea sp. (PG-99)

Fig. 181, 182

SIZE: 34.4 x 43.2 microns. Range: 40.0 - 58.0 microns x 40.0 - 48.0 microns.

EXINE: 1.6 microns thick, except at pores. Exine often torn, and folded back into a propeller-shaped area on the proximal surface, thereby giving the grain a certain resemblance to a spore with a tetrad scar.

SCULPTURE: Psilate.

SHAPE: Triangular, bulging in the poral and mesoporial areas; sometimes appearing nearly hexagonal due to the bulging.

APERTURES: Triporate (sometimes appearing weakly tricolporate). Pores with 3.2 micron wide annulus formed by a thickening (costae) of the nexine. Pore and annulus together are 12.8 x 11.2 microns, with the long axis perpendicular to the plane of the equator.

AGE: Oligocene and Miocene.

DISCUSSION: Grains with pores similar to PG-97 are shown by Pokrovskaya (1956a, b) from the Miocene and Oligocene of various parts of the U. S. S. R. Traverse's (1955) Jussiaea champlainensis is similar, but around 70.0 microns in size.

? Family: Symplocaceae Desf.

Genus: ? Symplocos Jacq.

? Symplocos sp. (PG-100)

Fig. 183, 184

SIZE: 36.0 microns, M.E.D. Range: 26.0 - 38.5 microns, M.E.D. (9 specimens measured).

EXINE: 2.0 microns thick, overall. Nexine 0.8 micron thick; sexine 1.2 microns thick.

SCULPTURE: Baculo-verrucate. Elements range in diameter from 0.4 micron to 1.6 microns.

STRUCTURE: Tegillate. Tegillum formed from fusion of the part of the capita nearest the supporting bacula, but with the outer portion of the capita left free to give the verrucate appearance.

SHAPE: Triangular.

APERTURES: Tricolporate. Colpi about 19.2 microns long. In addition to the colpi, this type has a propeller-shaped scar at one pole. The scar has a 2.0 micron wide thickening around it. Pores 4.8 - 5.6 microns in diameter.

AGE: Oligocene.

DISCUSSION: The taxonomic assignment of PG-100 is not at all certain. The colpi are longer than species of Symplocos I have examined. (S. chiriquensis, S. laeviramulosa, S. paniculata, S. prionophylla, and S. tinctoria). Of these, S. paniculata is most like PG-100 in size, pore structure and in having a propeller-shaped, smooth

area at the pole. In S. paniculata the propeller-shaped area appears to represent an area free of sculptural elements rather than a tetrad scar.

Family: Oleaceae Hoffmgg. and Link.

Genus: Fraxinus L.

Fraxinus sp. (PG-101)

Fig. 185, 186

SIZE: 25.6 microns, M.E.D. Range: 24.0 - 28.0 microns, M.E.D.

EXINE: 1.2 microns thick, overall. Nexine 0.4 micron thick; sexine 0.8 micron thick.

SCULPTURE: Weakly perfero-reticulate, lumina more or less uniformly 0.4 micron in diameter. Sculpture extends to the margins of the colpi.

STRUCTURE: Tegillate. Supporting bacula 0.4 micron long and tegillum an additional 0.4 micron thick. Bacula very closely spaced.

SHAPE: Circular, with the colpi giving the appearance of a maltese cross.

APERTURES: Tetracolpate. Colpi up to 1.6 microns wide, except when tearing near the equator due to compression. Ends of the colpi are about 3.2 microns from the poles.

AGE: Oligocene.

DISCUSSION: While PG-101 has the typically unthickened colpal margins of extant pollen of Fraxinus, the perforate sculpture is finer than in any modern species I have examined.

Fraxinus sp. (PG-102)

Fig. 187

SIZE: 32.8 microns, M.E.D. Range: 25.0 - 35.0 microns, M.E.D.

EXINE: 1.2 microns thick, overall. Nexine 0.4 micron thick; sexine 0.8 micron thick.

SCULPTURE: Reticulate, latimurate except at the margins of the colpi. Lumina commonly 1.0 - 1.2 microns in diameter, but with occasional small lumina interspersed with the larger ones, decreasing to about 0.4 micron in diameter at the margins of the colpi.

STRUCTURE: Tegillate, with the supporting bacula widely spaced and having their distal ends connected to form a simplibaculate reticulum. Diameter of individual bacula 0.2 - 0.3 micron.

SHAPE: Circular, with the colpi giving the appearance of a maltese cross.

APERTURES: Tetracolpate, colpi ragged and tearing at the equator resulting from compression.

AGE: Oligocene and Miocene.

DISCUSSION: PG-102 has the unthickened colpal margins and reticulate sculpture typical of such modern species as Fraxinus americana, F. anomala, F. caroliniana, and F. tomentosa.

? Family: Acanthaceae Juss.

(PG-103)

Fig. 188-190

SIZE: 19.2 x 14.0 microns. Range: 16.0 - 23.0 microns x 12.0 - 18.0 microns.

EXINE: 1.4 microns thick, overall.

SCULPTURE: Very finely, densely and more or less uniformly granular. Granules 0.2 - 0.4 micron in diameter and isodiametric.

STRUCTURE: Tegillate, intrabaculate. Bacula crowded so closely together as to render measurement of their diameter impossible.

SHAPE: Ellipsoidal.

APERTURES: Tricolpate. Colpi 14.4 microns long and 1.0 micron wide, with a 0.4 micron thickening on either side of each colpus. Colpal areas each contain a single row of baculate or clavate elements, 0.6 - 0.8 micron in diameter. Approximately 8 such elements occur in each colpus.

AGE: Oligocene.

DISCUSSION: The possession of sculptural elements in the colpi is a characteristic of some extant genera of the Acanthaceae (i.e. Beloperone, Acanthus), and of the Bixaceae (Bixa). I have not noted similar fossil material in any literature I have studied.

(PG-104)

Fig. 191-193

SIZE: 21.3 x 14.3 microns. Range: 19.0 - 29.6 microns x 10.0 - 14.3 microns (7 specimens measured).

EXINE: 0.6 micron thick.

SCULPTURE: Psilate.

SHAPE: Prolate.

APERTURES: Tricolporate. Colpi extend to poles and reach a maximum width of about 5.0 microns on either side of the equator, where each is 3.7 microns wide. Margo adjacent to colpus varies in

width from 0.5 micron at its polar extremities to 3.7 microns at the pores. Pores elliptical, long axis in plane of equator, 3.8 x 1.9 microns. Colpi each with 5 rows of small, round verrucae, about 0.5 micron in diameter.

AGE: Oligocene, Miocene and Mio-Pliocene.

DISCUSSION: Martin and Rouse (1966) show a similar specimen from the Tertiary sediments of the Queen Charlotte Islands, and refer it to Castanea or Castanopsis. I believe that this pollen type is more closely related to the family Acanthaceae. Also see discussion under PG-103.

Family: Caprifoliaceae Juss.

Genus: Diervilla Mill.

Diervilla sp. (PG-105)

Fig. 194-196

SIZE: 53.6 microns, M.E.D. Range: 50.0 - 74.0 microns x 44.0 - 64.0 microns.

EXINE: 2.4 microns thick, except at pores where it is 4.0 microns thick.

SCULPTURE: Echinate. Spines are 3.2 - 4.4 microns long, somewhat flask-like, with a rather bulbous base which tapers to a more or less blunt tip. The area between the spines is densely populated with more or less uniformly spaced granules.

SHAPE: Nearly circular to slightly rounded-triangular.

APERTURES: Tricolporate. The pores have a 2.8 - 3.2 micron wide annulus in plan view. Colpi are 1.6 microns wide, with a 0.6 micron wide lip, and are short, extending only slightly, if at all, past

the edge of the annulus.

AGE: Oligocene.

DISCUSSION: Pollen very similar to PG-105 occurs in the modern *Diervilla japonica*; less similar modern pollen are *D. lonicera*, *Lonicera flava* and *Lonicera sempervirens*. Sato (1963) refers pollen similar to PG-105 to *Lonicera*.

All Figures X1000 magnifications unless otherwise stated.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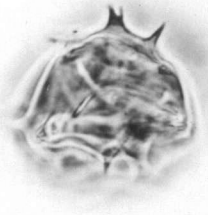
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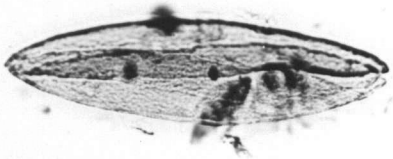
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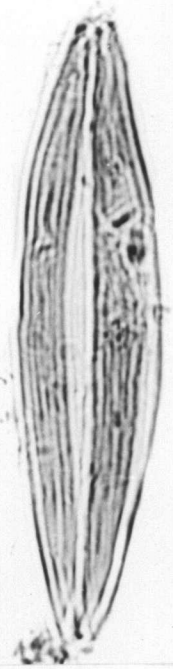
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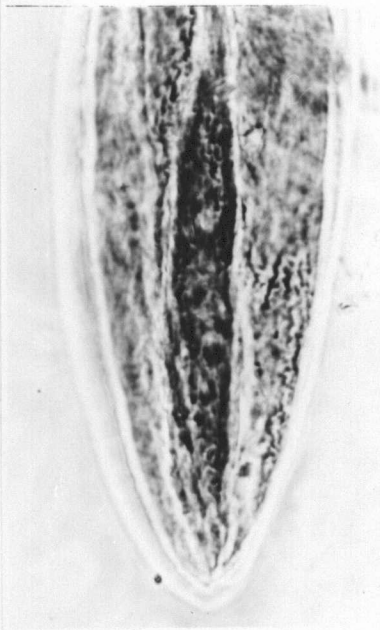
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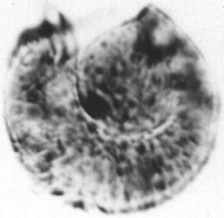
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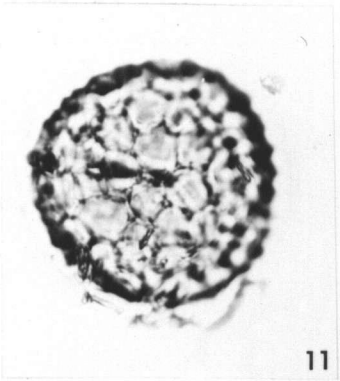
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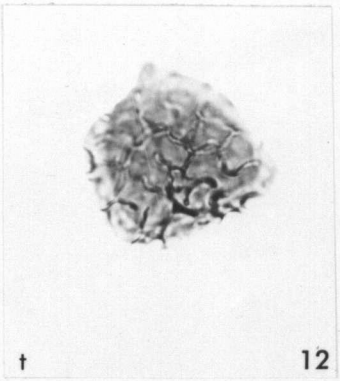
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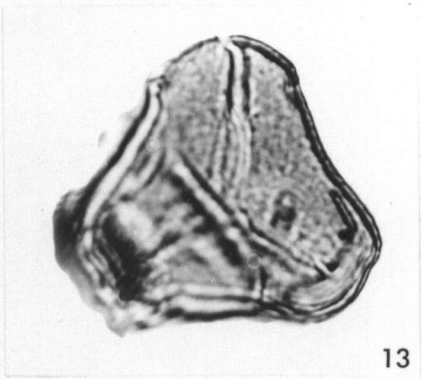
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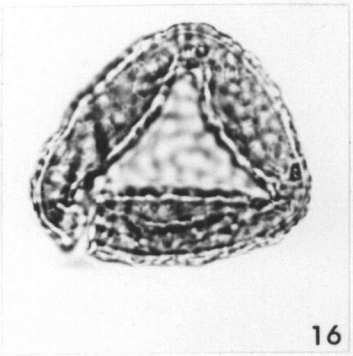
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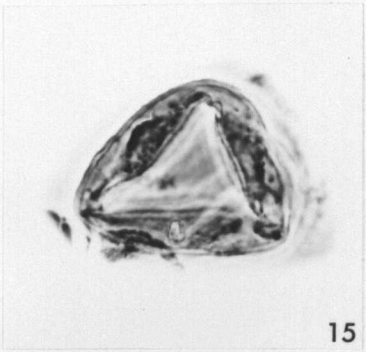
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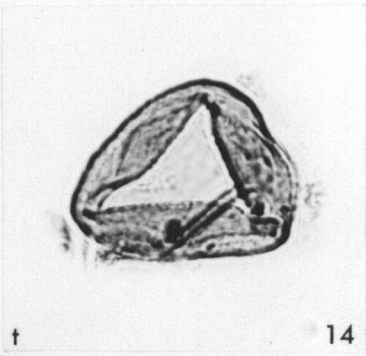
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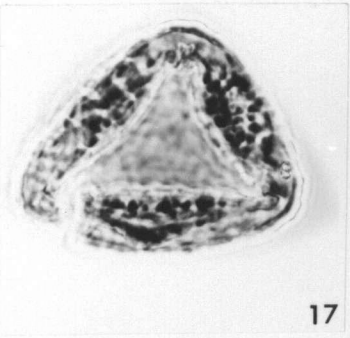
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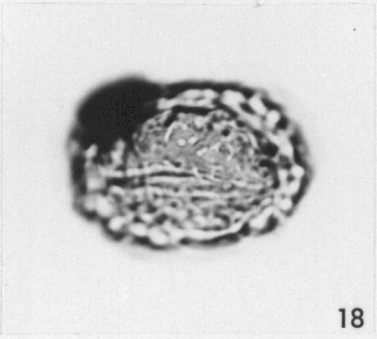
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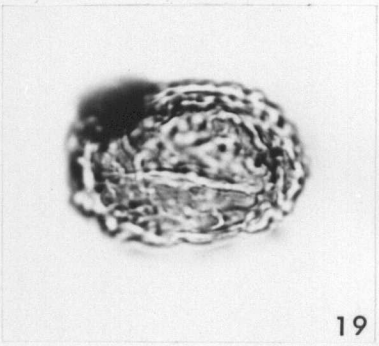
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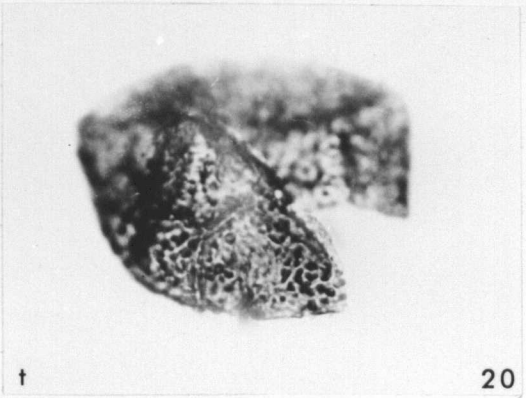
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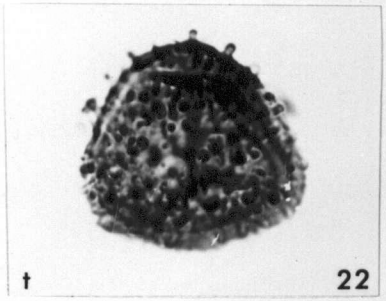
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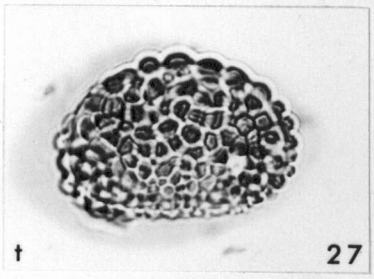
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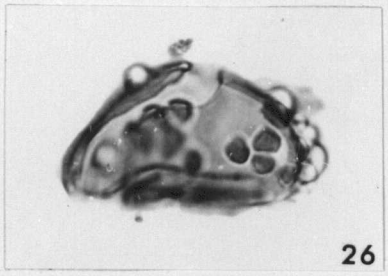
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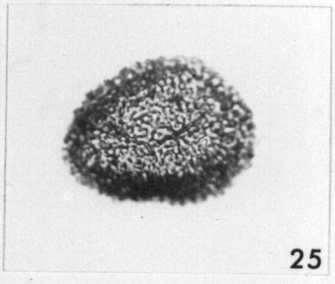
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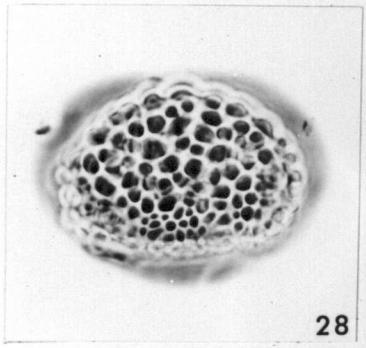
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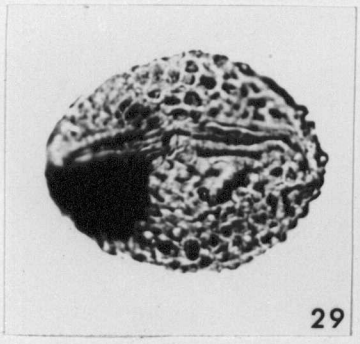
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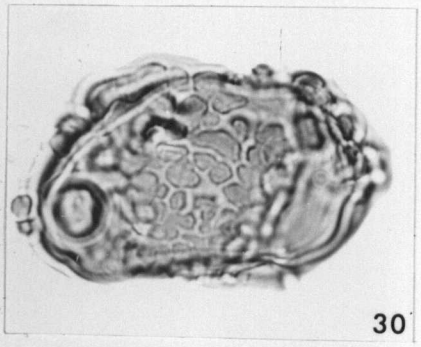
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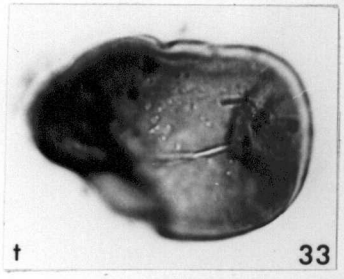
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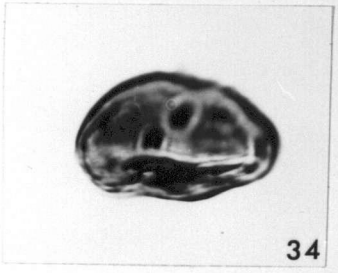
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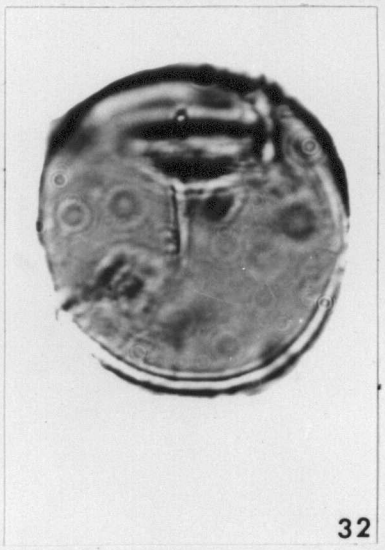
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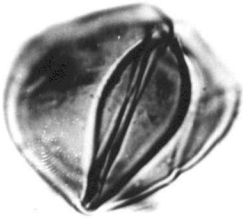

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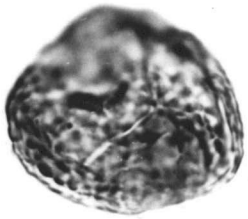

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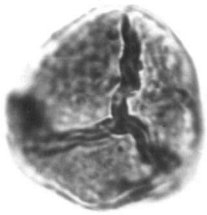

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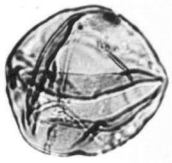

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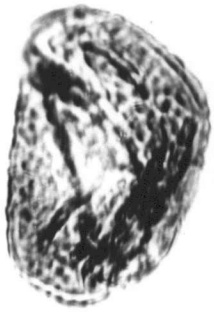

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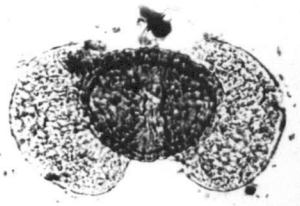

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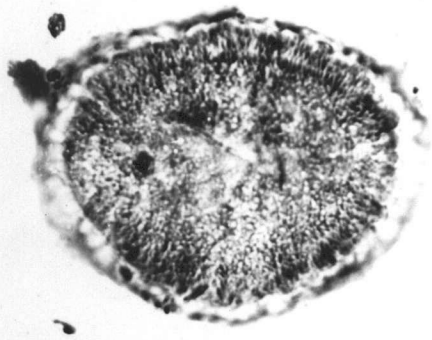

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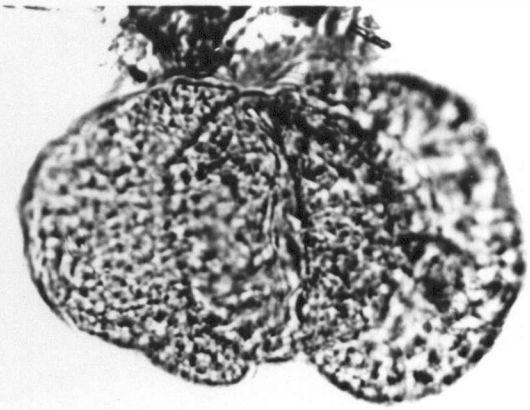

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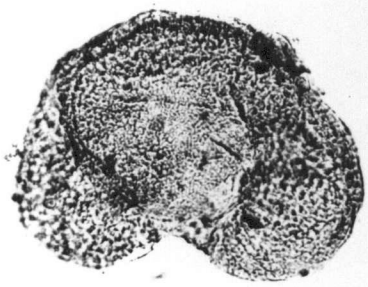

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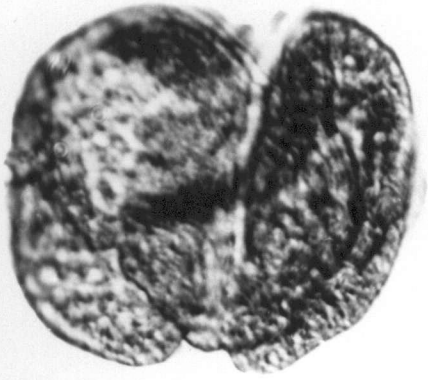

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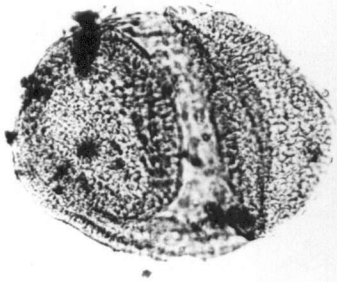

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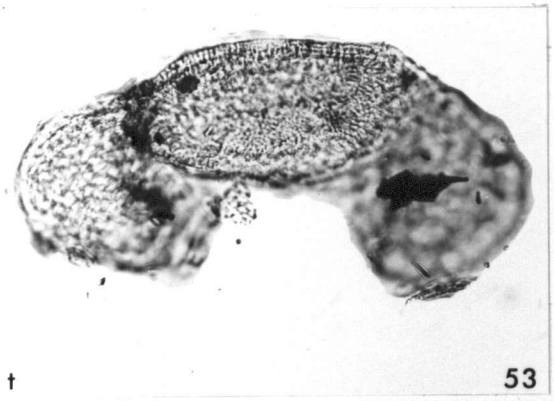
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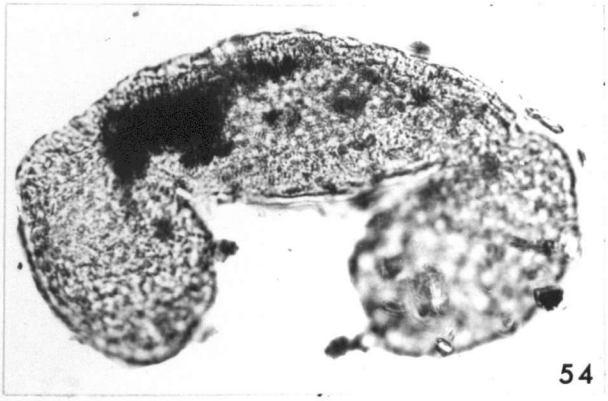
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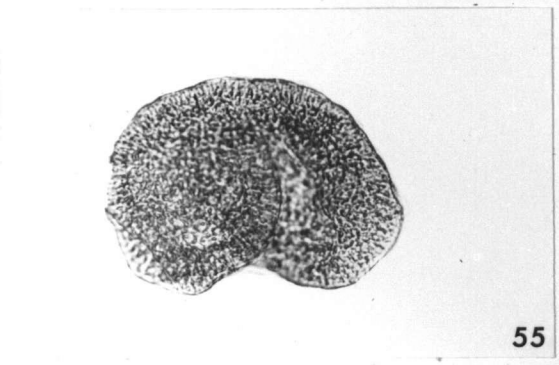
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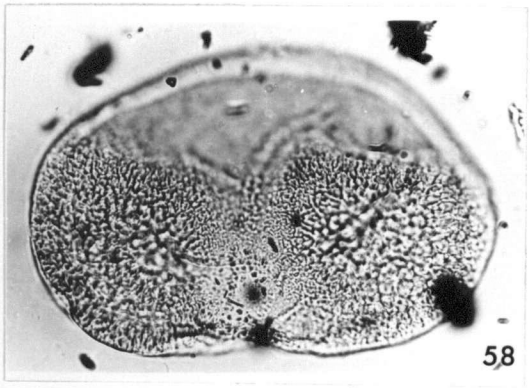
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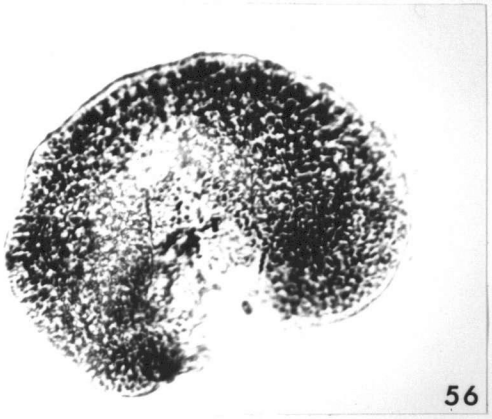
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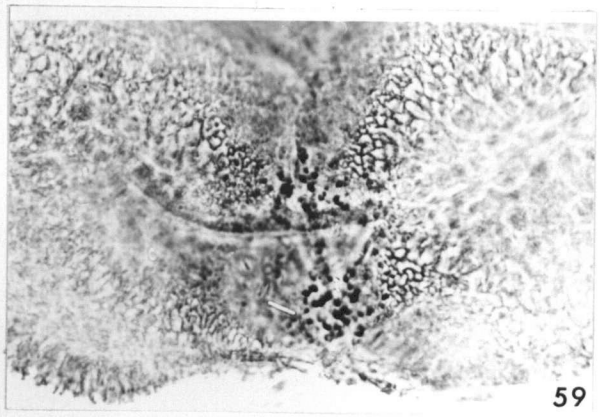
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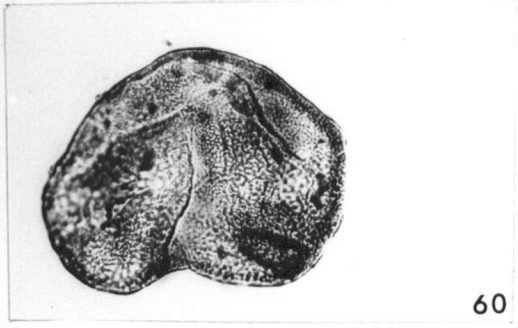
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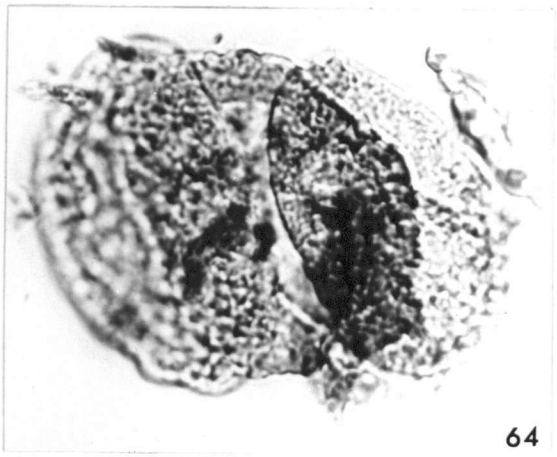

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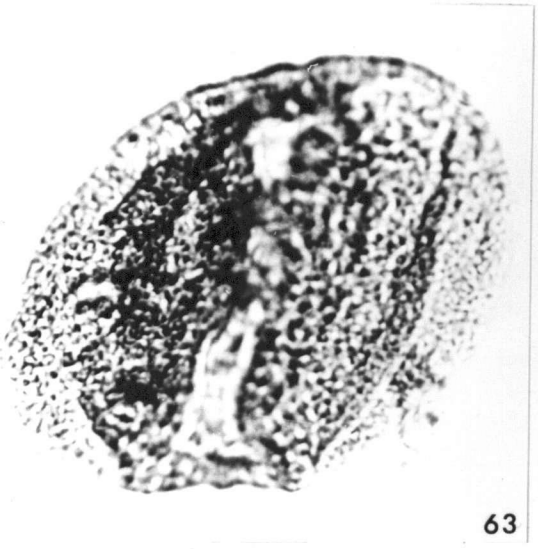

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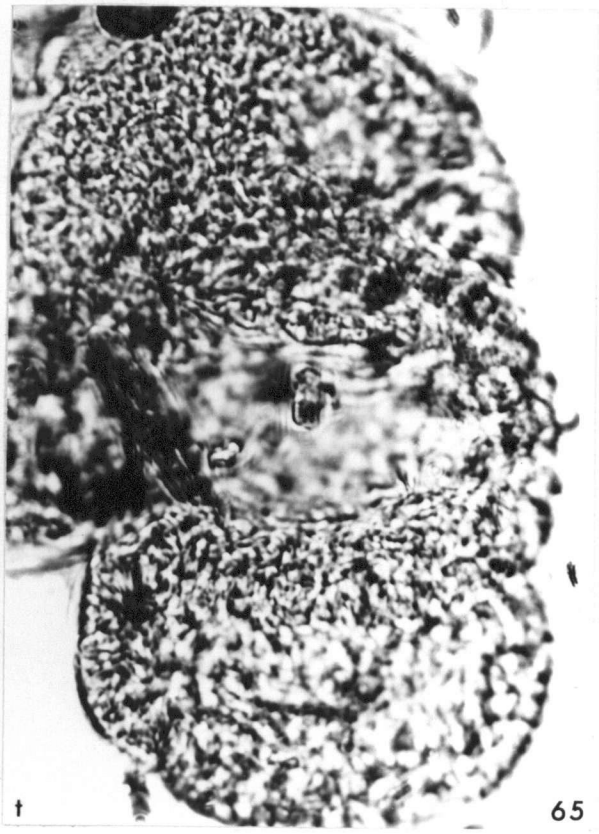

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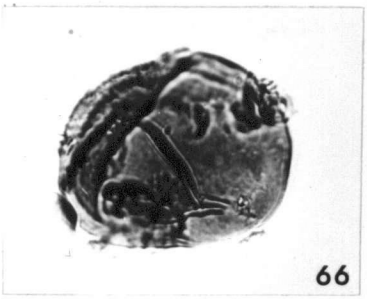
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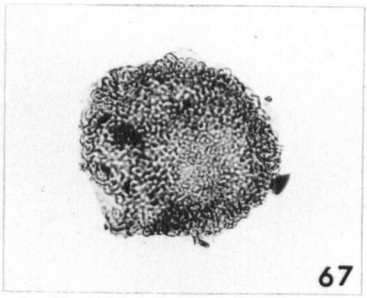
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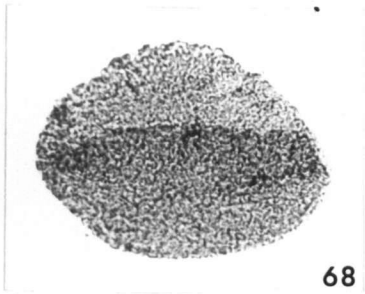
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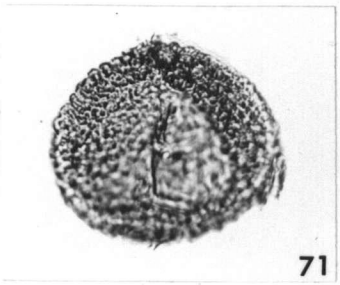
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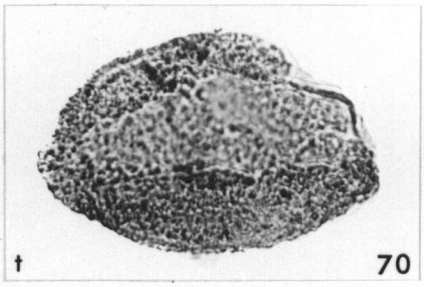
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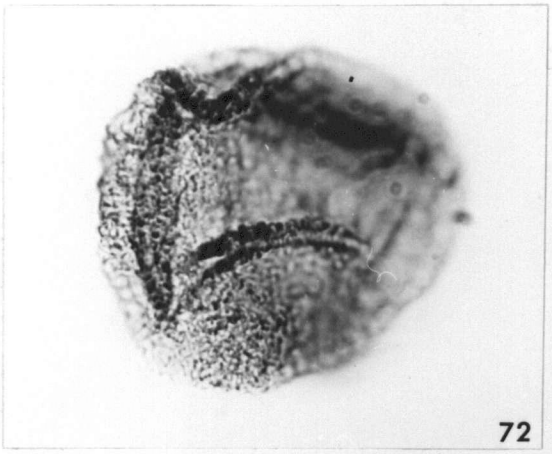
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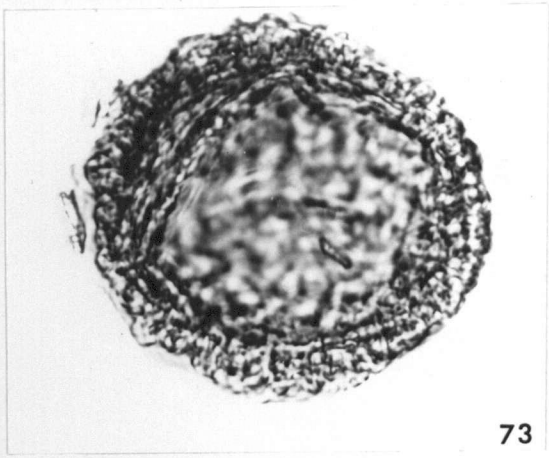
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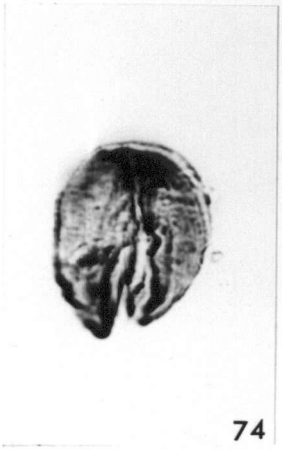
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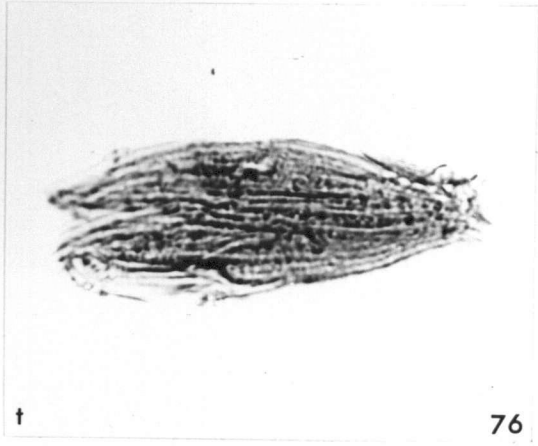
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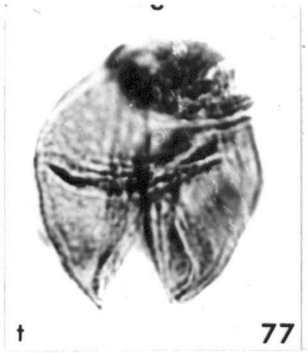
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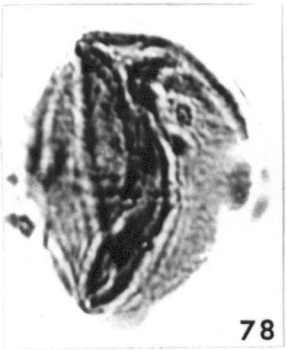
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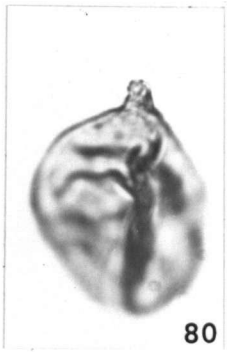
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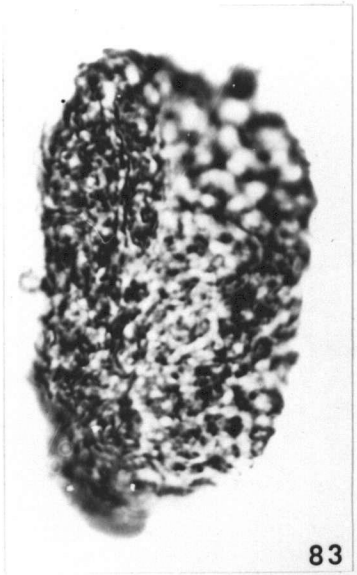
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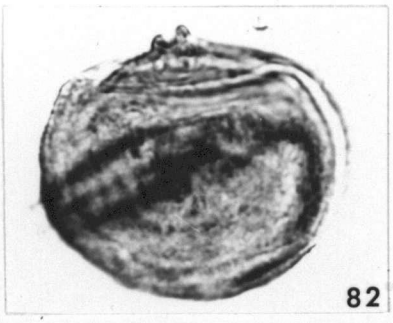
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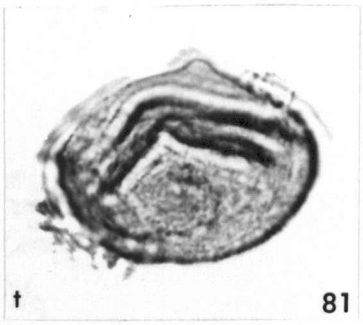
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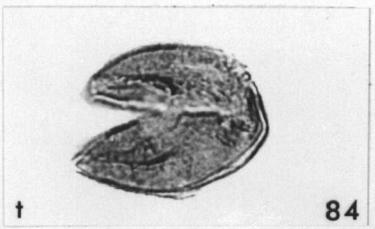
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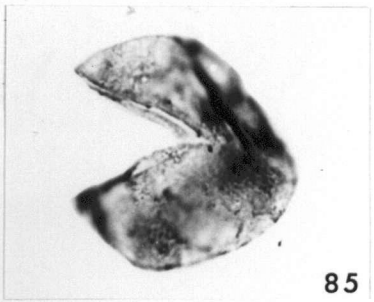
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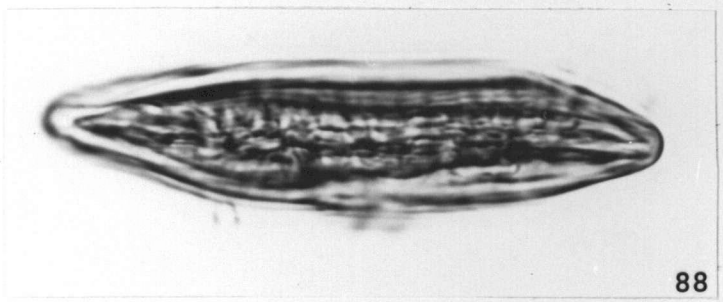
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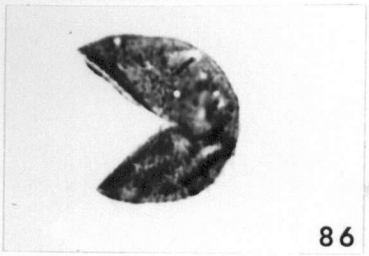
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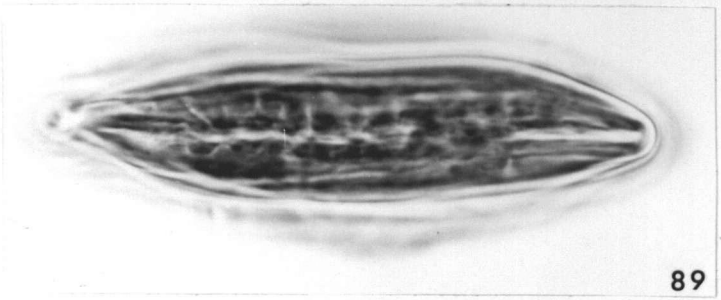
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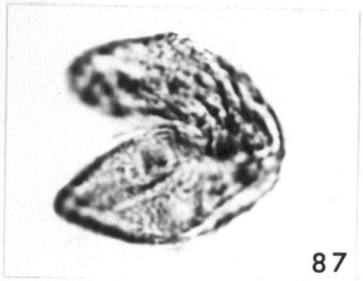
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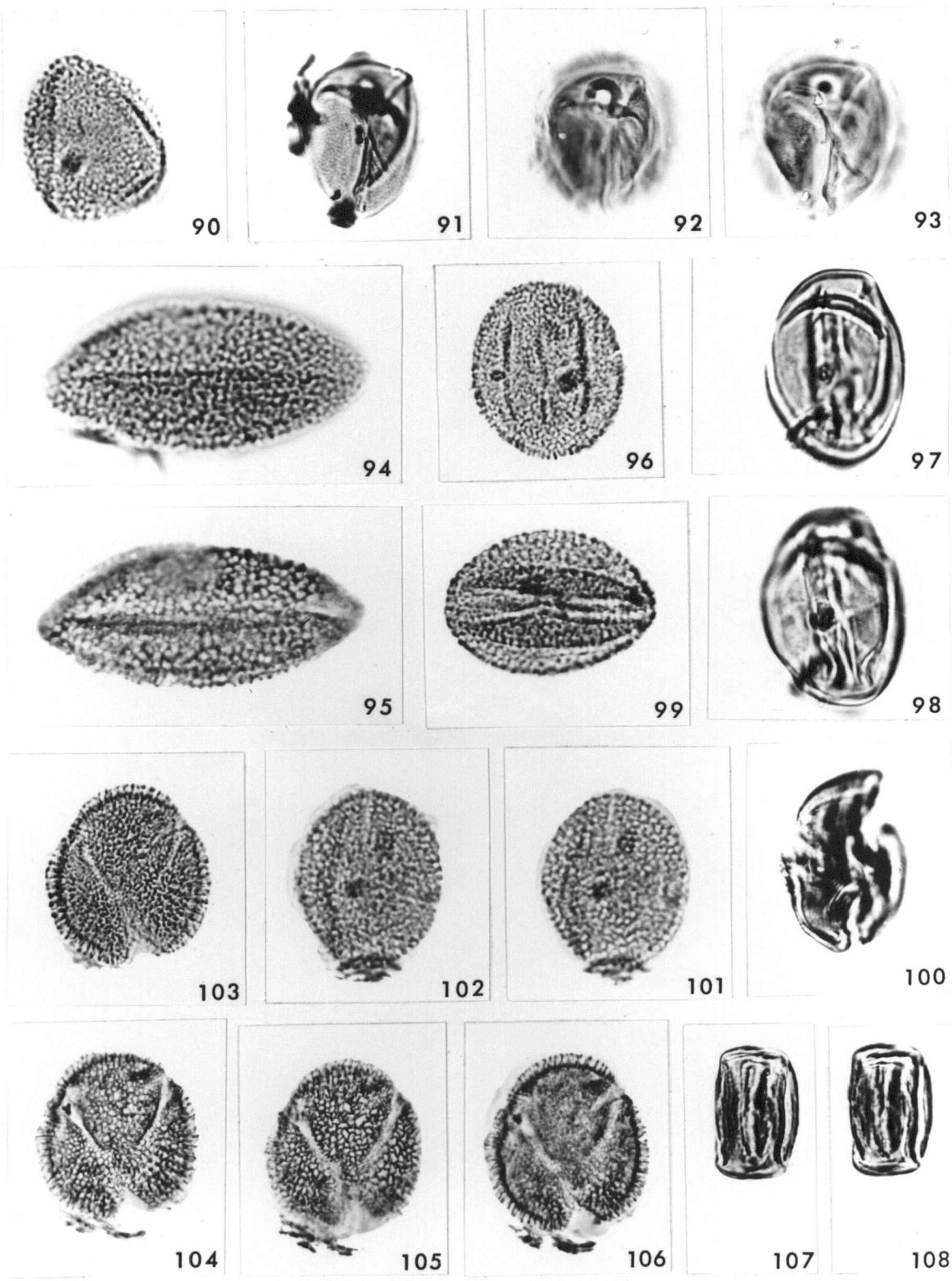
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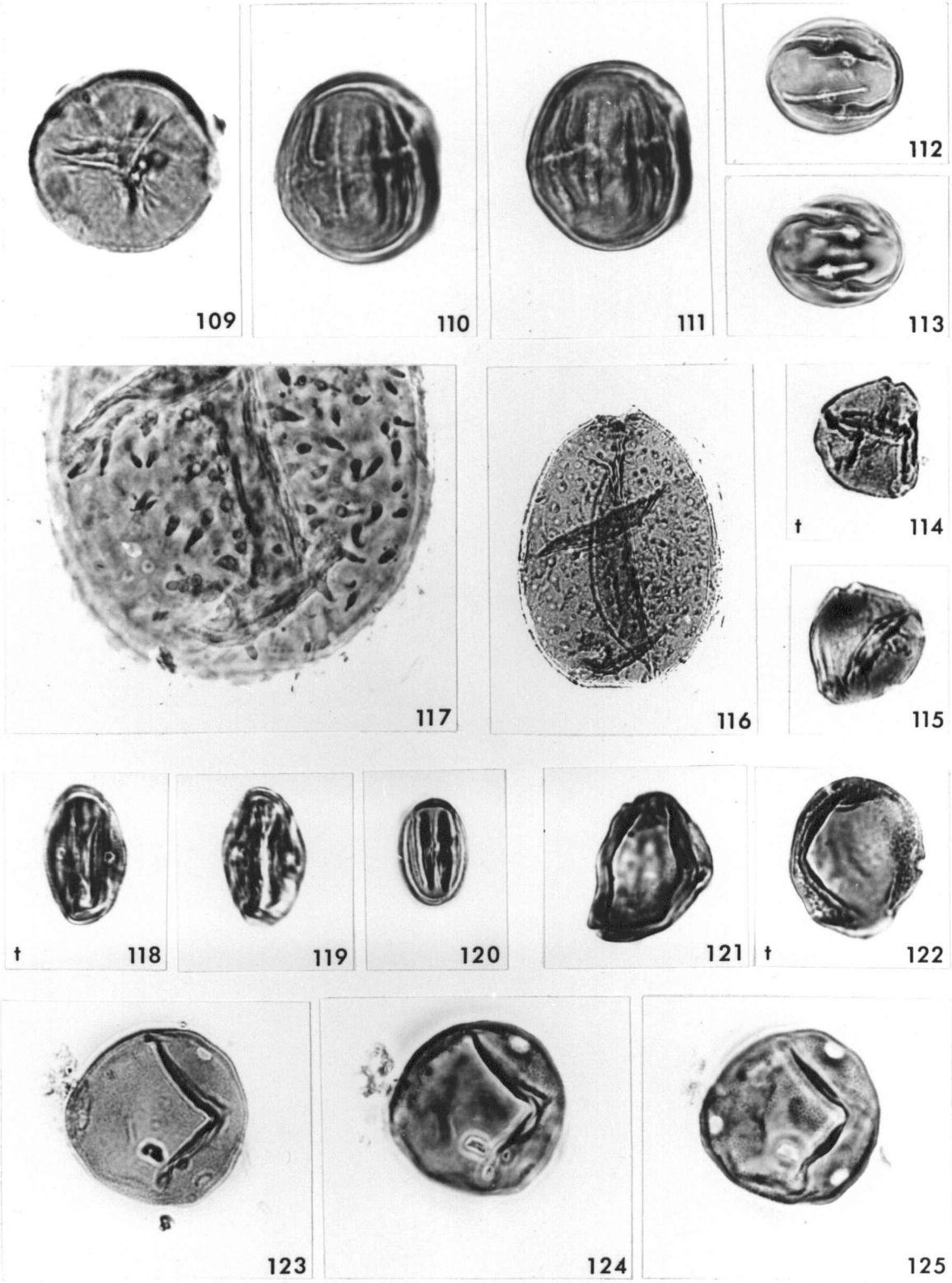
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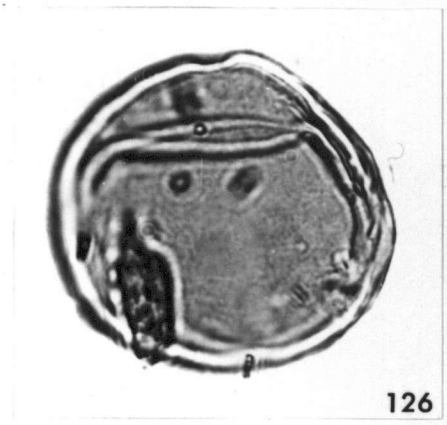
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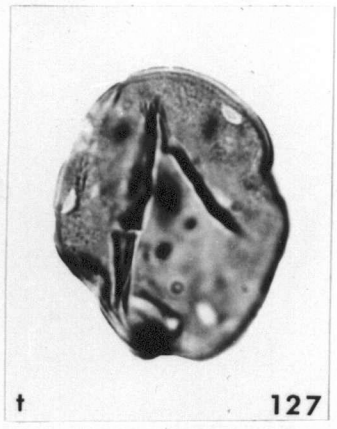
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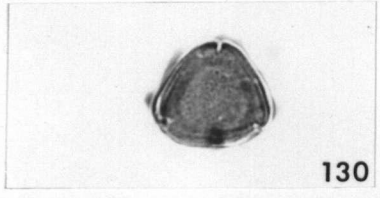
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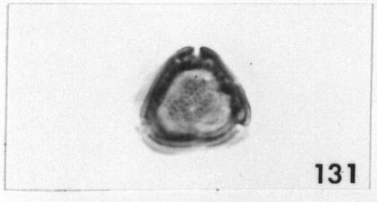
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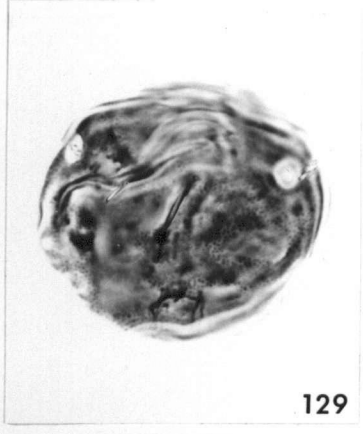
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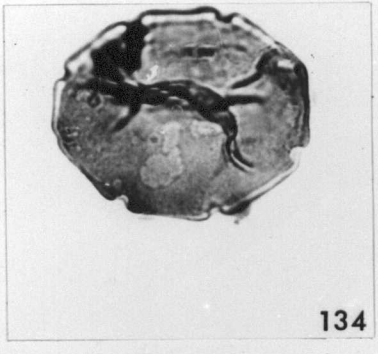
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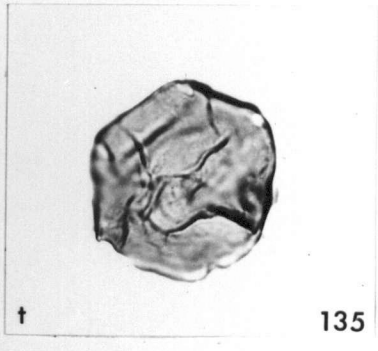
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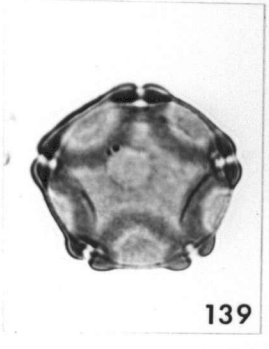
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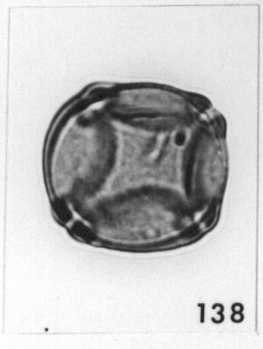
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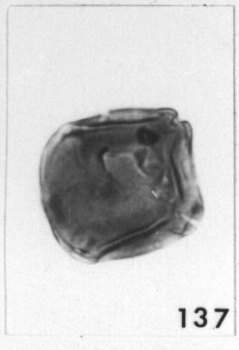
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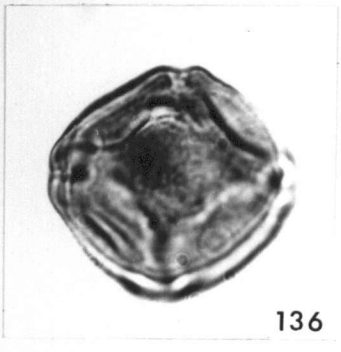
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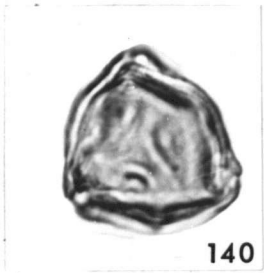
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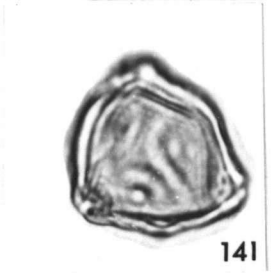
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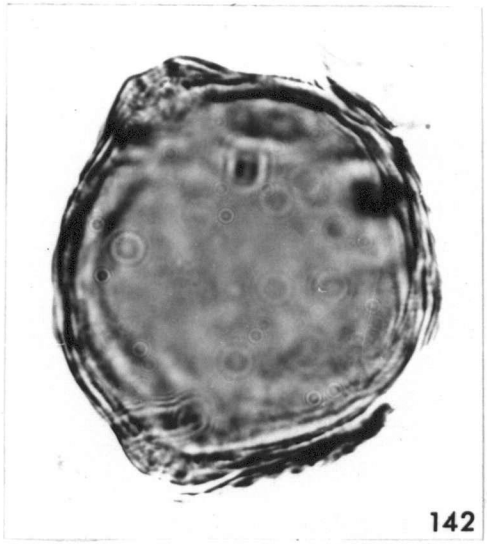
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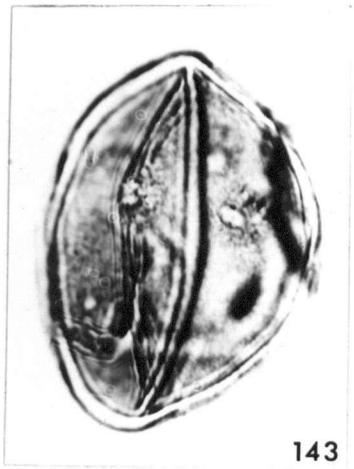
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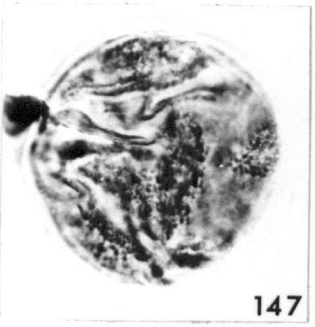
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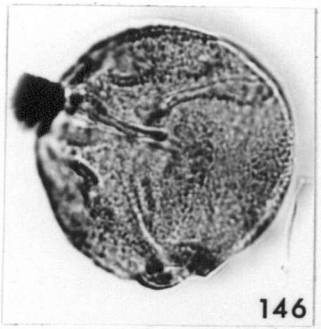
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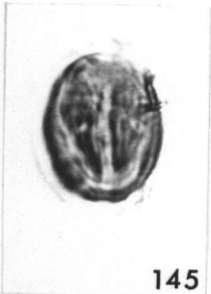
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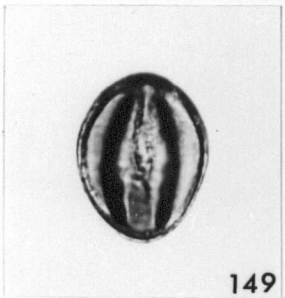
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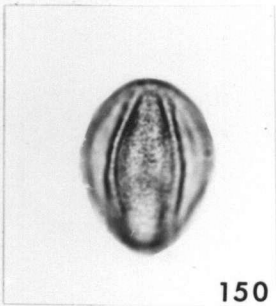
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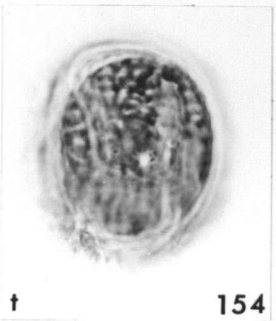
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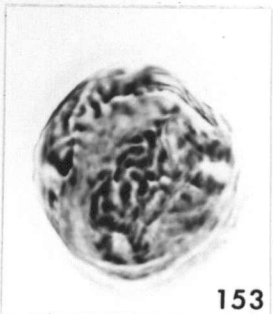
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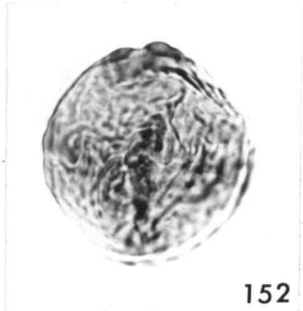
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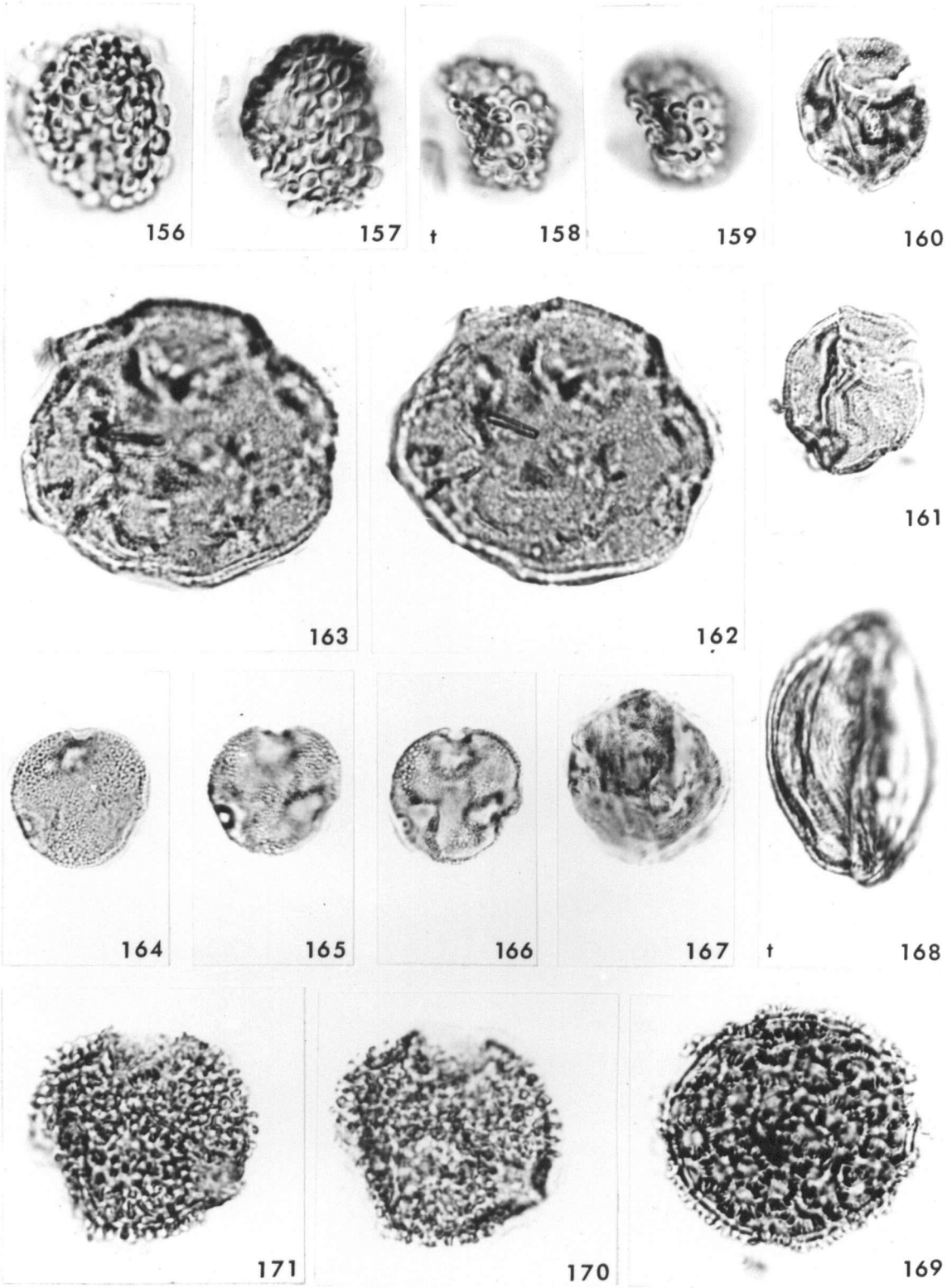
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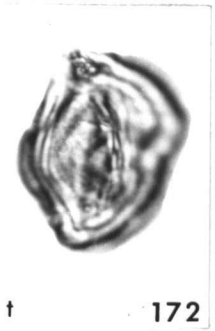
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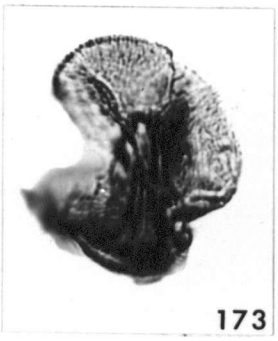
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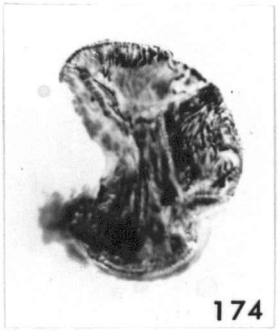
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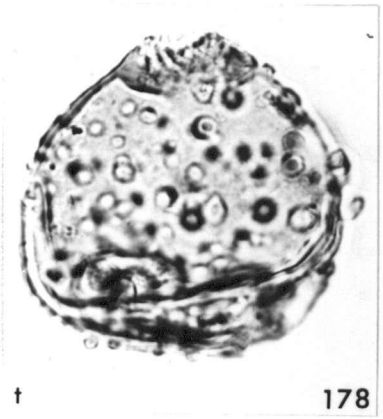
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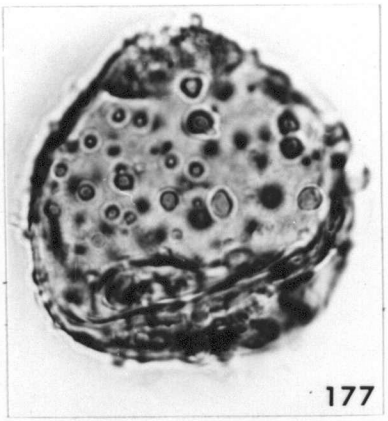
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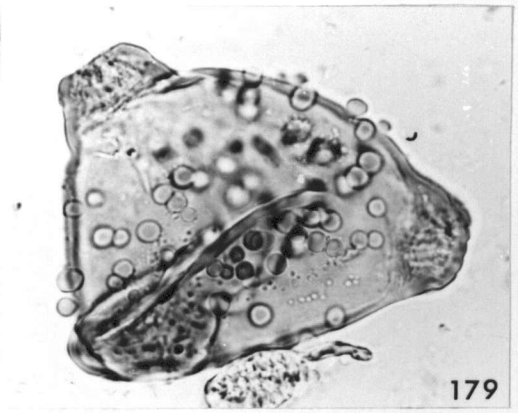
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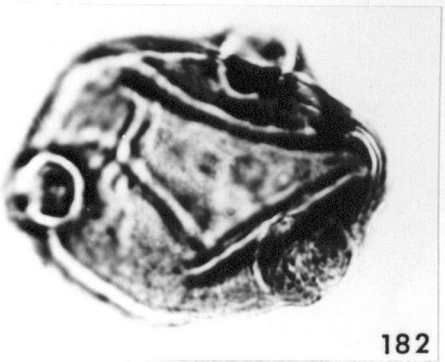
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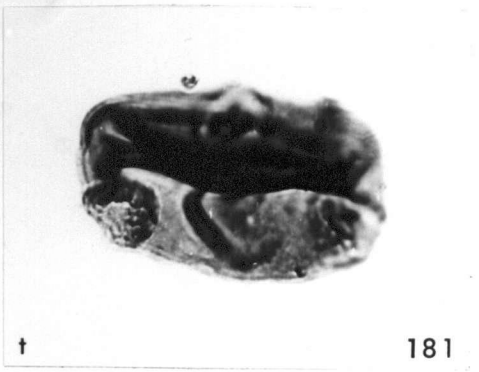
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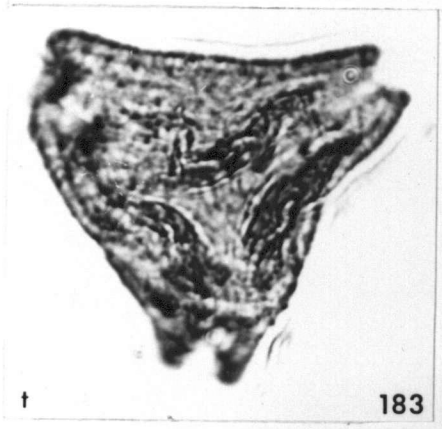
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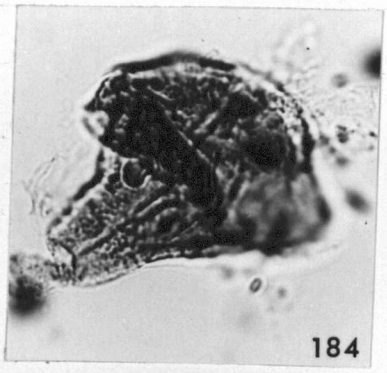
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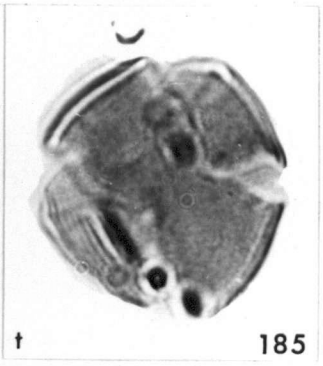
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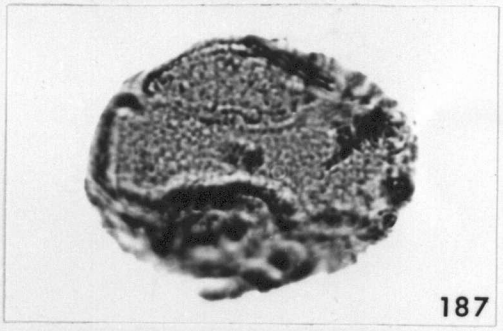
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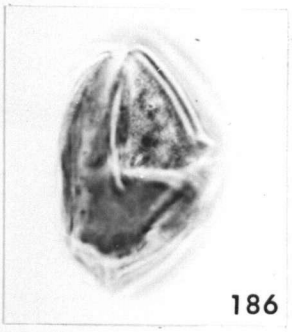
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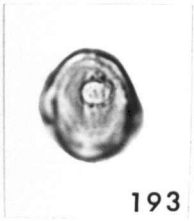
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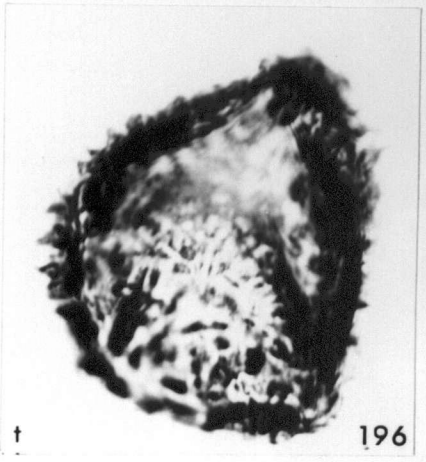
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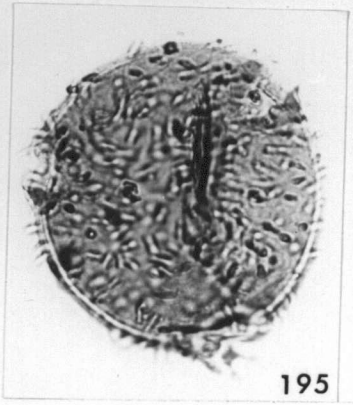
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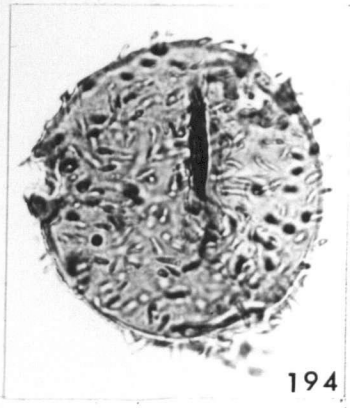
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LITERATURE CITED

Anderson, R.Y., 1960. Cretaceous-Tertiary Palynology, Eastern Side of the San Juan Basin, New Mexico. New Mexico Bureau of Mines and Mineral Resources, Memoir 6, 59 pp.

Axelrod, D. I., 1956. Mio-Pliocene Floras from West-Central Nevada. The Middlegate Flora. University of California Publications in Geological Sciences, Vol. 33, pp. 177-229.

_____, 1964. The Miocene Trapper Creek Flora of Southern Idaho. University of California Publications in Geological Sciences, Vol. 51, 181 pp.

Batten, D. J., 1968. Probable dispersed spores of Cretaceous Equisetites. Paleonotology, Vol. 11, Part 4, pp. 633-642.

Brown, R. W., 1934. Recognizable Species of the Green River Formation. United States Geological Survey Professional Paper No. 185.

Chaney, R. W., 1938. Ancient Forests of Oregon. Carnegie Institution of Washington, Publication 501, pp. 631-648.

_____1947. Tertiary Centers and Migration Routes. Ecological Monographs, Vol. 17, No. 2, pp. 140-148.

_____1959. Miocene Floras of the Columbia Plateau. Part I: Composition and Interpretation. Carnegie Institution of Washington, Publication 617, pp. 1-134.

_____and E. I. Sanborn, 1933. Goshen Flora of West Central Oregon. Carnegie Institution of Washington, Publication 439, pp. 1-103.

Collingwood, G. H. and W. D. Brush, 1964. Knowing Your Trees. American Forestry Association, Washington, D. C. 349 pp.

Cook, H. J., 1960. New Concepts of Late Tertiary Major Crustal Deformations in the Rocky Mountain Region of North America. Proceedings, XXI International Geological Congress, Part 12, pp. 198-212.

Cookson, I. C. and M. E. Dettman, 1959. On Schizosporis, a new form genus from Australian Cretaceous deposits. Micropaleontology, Vol. 5, No. 2, pp. 213-216.

Couper, R. A., 1953. Upper Mesozoic and Cenozoic Spores and Pollen Grains from New Zealand. New Zealand Geological Survey, Paleontological Bulletin 22, 77 pp.

Dorf, E., 1955. Plants and the Geologic Time Scale. Geological Society of America, Special Paper 62, pp. 575-592.

_____1959. Climatic Changes of the Past and Present. Contributions from the Museum of Paleontology, University of Michigan, Vol. 13, No. 8, pp. 181-210.

Dorofeev, P. I., 1963. Tertiary Floras of Western Siberia. Academy of Science of the U. S. S. R., Moscow and Leningrad, pp. 1-65 and 344-345.

Durham, J. W., 1950. Cenozoic Marine Climates of the Pacific Coast. Geological Society of America Bulletin No. 61, pp. 1243-1264.

Eardley, A. J., 1961. Relation of Uplifts to thrusts in Rocky Mountains. (Abstract), American Association of Petroleum Geologists Bulletin, Vol. 45, No. 3, pp. 415-416.

Erdtman, G., 1952. Pollen Morphology and Plant Taxonomy--Angiosperms. Almqvist and Wiksell, Stockholm. 539 pp.

Geological Survey of Canada, 1932. Geological Map of British Columbia, Map 932-A (Second Edition), Ottawa.

Gonzalez Guzman, A. E., 1967. A Palynological Study on the Upper Los Cuervos and Mirador Formations (Lower and Middle Eocene; Tibu Area, Colombia). E. J. Brill, Leiden, Netherlands. 68 pp.

Graham, A., 1965. The Sucker Creek and Trout Creek Miocene Floras of Southeastern Oregon. Kent State University Bulletin, Research Series IX, Vol. 53, No. 12, 147 pp.

Gray, J. and K. Sohma, 1964. Fossil Pachysandra from Western North America with a Comparative Study of Pollen in Pachysandra and Sarcococca. American Journal of Science, Vol. 262, pp. 1159-1197.

Haun, J. D. and H. C. Kent, 1964. Geologic History of Rocky Mountain Region. (Abstract), American Association of Petroleum Geologists Bulletin, Vol. 48, No. 11, p. 1873.

Hedlund, R. W., 1965. Sigmopollis hispidus Gen. et Sp. Nov. from Miocene Sediments, Elko County, Nevada. Pollen et Spores, Vol. 7, No. 1, pp. 89-92.

Hollick, A., 1936. The Tertiary Floras of Alaska. United States Geological Survey Professional Paper No. 182.

Hopkins, W. S., Jr., 1966. Palynology of Tertiary Rocks of the Whatcom Basin, Southwestern British Columbia and Northwestern Washington. Unpublished Ph.D. Thesis, University of British Columbia, Vancouver. 184 pp.

_____1968. Subsurface Miocene Rocks, British Columbia--Washington, A Palynological Investigation. Geological Society of America Bulletin, Vol. 79, No. 6, pp. 763-767.

Hu, H. H., 1926. A Preliminary Survey of the Forest Flora of Southeastern China. Contributions from the Biological Laboratory of the Science Society of China, Vol., 2, No. 5, 20 pp.

_____1929a. Further Observations on the Forest Flora of Southeastern China. Bulletin of the Fan Memorial Institute of Biology, Vol. 1, pp. 51-62.

_____1929b. The Nature of the Forest Flora of Southeastern China. Peking Society of Natural History Bulletin, Vol. 4, Part 1, pp. 47-56.

_____and R. W. Chaney, 1940. A Miocene Flora from Shantung Province, China. Carnegie Institution of Washington, Publication 507, 147 pp.

_____and W. C. Cheng. In: Chaney, R. W., 1950., A Revision of Fossil Sequoia and Taxodium in Western North America based on the recent discovery of Metasequoia. American Philosophical Society Transactions, Vol. 40, Part 3, pp. 171-263.

Huzioka, K., 1963. The Utto Flora of Northern Honshu. In: Tertiary Floras of Japan--Miocene Floras. Collaborating Association to commemorate the 80th Anniversary of the Geological Survey of Japan, Tokyo, pp. 153-216.

Jain, R. K. and S. Nanda, 1966. Pollen Morphology of some Desert Plants of Pilani, Rajasthan. Palynological Bulletin, Vol. 2-3, pp. 56-69.

Knowlton, F. H., 1917. Fossil Floras of the Vermejo and Raton Formations of Colorado and New Mexico. United States Geological Survey Professional Paper No. 101, pp. 233-349.

_____1930. Flora of the Denver and Associated Formations of Colorado. United States Geological Survey Professional Paper No. 155, pp. 1-142.

Krajina, V. J., 1959. Bioclimatic Zones in British Columbia. University of British Columbia Botanical Series No. 1, Vancouver. 47 pp.

_____1965. Biogeoclimatic Zones and Classification of British Columbia. In: Ecology of Western North America, Vol. 1, Vancouver. pp. 1-17.

Krutzsch, W., 1962. Atlas der mittel- und jungtertiaren dispersen Sporen- und Pollen- sowie der Mikroplanktonformen des nordlichen Mitteleuropas. Lieferung I. VEB Deutscher Verlag Der Wissenschaften, Berlin. 108 pp.

_____1963. Atlas der mittel- und jungtertiaren dispersen Sporen- und Pollen- sowie der Mikroplanktonformen des nordlichen Mitteleuropas. Lieferung III. VEB Deutscher Verlag Der Wissenschaften, Berlin. 128 pp.

Kuenzi, W. D. and B. H. Richard, 1969. Middle Tertiary Unconformity, North Boulder and Jefferson Basins, Southwestern Montana. Geological Society of America Bulletin, V. 80, pp. 315-320.

Kulp, J. L., 1961. Geologic Time Scale. Science, Vol. 133, pp. 1105-1114.

Lay, D., 1940. Fraser River Tertiary Drainage-History in relation to Placer-Gold Deposits. British Columbia Department of Mines, Bulletin No. 3, Victoria. 30 pp.

_____1941. Fraser River Tertiary Drainage-History in relation to Placer-Gold Deposits (Part II). British Columbia Department of Mines, Bulletin No. 11, Victoria. 75 pp.

Lawrence, G. H. M., 1951. Taxonomy of Vascular Plants. The Macmillan Company, New York. 823 pp.

MacGinitie, H. D., 1941. Flora of Weaverville Beds of Trinity County, California. Carnegie Institution of Washington, Publication 465, Part 3, pp. 83-151.

_____1953. Fossil Plants of the Florissant Beds, Colorado. Carnegie Institution of Washington, Publication 599. 198 pp.

_____1962. The Kilgore Flora--A Late Miocene Flora from Northern Nebraska. University of California Publications in Geological Sciences, Vol. 35, No. 2, pp. 67-158.

Macko, S., 1957. Lower Miocene Pollen Flora from the Valley of Klodnica near Gliwice (Upper Silesia). Society of Science and Letters of Wroclaw, Series B, No. 88, 314 pp.

_____1959. Pollen Grains and Spores from Miocene Brown Coals in Lower Silesia I. Society of Science and Letters of Wroclaw, Series B, No. 96, 178 pp.

Manten, A. A., 1958. Palynology of the Miocene Browncoal mined at Haanrade (Limburg, Netherlands). Acta Botanica Neerlandica, Vol. 7, pp. 445-488.

Martin, H. A. and G. E. Rouse, 1966. Palynology of Late Tertiary Sediments from Queen Charlotte Islands, British Columbia. Canadian Journal of Botany, Vol. 44, pp. 171-208.

Mathews, W. H., 1964. Potassium-Argon Age Determinations of Cenozoic Volcanic Rocks from British Columbia. Geological Society of America Bulletin, Vol. 75, pp. 465-468.

_____and G. E. Rouse, 1963. Late Tertiary Volcanic Rocks and Plant-Bearing Deposits in British Columbia. Geological Society of America Bulletin, Vol. 74, pp. 55-60.

Matsuo, H., 1963. The Notonakajima Flora of Noto Peninsula. In: Tertiary Floras of Japan--Miocene Floras. Collaborating Association to commemorate the 80th Anniversary of the Geological Survey of Japan, Tokyo, pp. 219-259.

McCallum, J A., 1966. An Interim Report on ARDA Project No. 10014--Prince George Area Ground Water Appraisal. Water Investigations Branch, Department of Lands, Forests and Water Resources, Victoria, British Columbia, pp. 1-19.

_____1969. Groundwater Geology of the South Prince George Area, Central British Columbia. Water Investigations Branch, Department of Lands, Forests and Water Resources, Victoria, British Columbia, pp. 1-67.

Piel, K. M. 1965. Palynology of Some Recent Sediments from the Mississippi River Delta. Unpublished Masters Thesis, Tulane University, New Orleans, 74 pp.

Pokrovskaya, I. M. (Editor), 1956a. Atlas of Miocene Spore and Pollen Complexes from various regions of the U. S. S. R. (In Russian), Materialy Vses. Nauchn.-Issled. Geol. Inst. (VSEGEI), N. S. No. 13, pp. 1-461.

_____1956b. Atlas of Oligocene Spore and Pollen Complexes from various regions of the U. S. S. R. (In Russian), Materialy Vses. Nauchn.-Issled. Geol. Inst. (VSEGEI), N. S. No. 13, pp. 1-312.

_____1966. Paleopalynology. (In Russian), Materialy Vses. Nauchn.-Issled. Geol. Inst. (VSEGEI), N. S. No. 141, 3 Vols.

Polunin, N., 1960. Introduction to Plant Geography. McGraw-Hill, New York. 640 pp.

Potonie, R., 1960. Synopsis der Gattungen der Sporae Dispersae. Geol. Jahrb. Beih., Vol. 39, pp. 1-189.

Praglowski, J. R., 1962. Notes on the Pollen Morphology of Swedish Trees and Shrubs. Grana Palynologica, Vol. 3, No. 2, pp. 45-65.

Preston, R. J., 1961. North American Trees (Second Edition). The Iowa State University Press, Ames. 395 pp.

Rouse, G. E., 1957. The Application of a new Nomenclatural Approach to Upper Cretaceous Plant Microfossils from Western Canada. Canadian Journal of Botany, Vol. 35, pp. 349-375.

_____1962. Plant Microfossils from the Burrard Formation of Western British Columbia. Micropaleontology, Vol. 8, pp. 187-218.

_____and W. H. Mathews, 1961. Radioactive dating of Tertiary Plant-Bearing Deposits. Science, Vol. 133, pp. 1079-1080.

Rumney, G. R., 1968. Climatology and the World's Climates. The Macmillan Company, New York. 656 pp.

Samoilovitch, S. R. and N. D. Mchedlishvili, 1961. Pollen and Spores of Western Siberia, Jurassic to Paleocene. Tr. Vses. Neft. Nauchn.-Issled. Geologorazved. Inst. (In Russian), Vypusk 177, pp. 1-658.

Sato, S., 1963. Palynological Study on Miocene Sediments of Hokkaido, Japan, Journal of the Faculty of Science, Hokkaido University, Series IV, Vol. 12, No. 1, pp. 1-110.

Sharp, A. J., 1966. Some Aspects of Mexican Phytogeography. Ciencia, Mexico, Vol. 24, No. 5-6, pp. 229-232.

Simpson, J. B., 1961. Tertiary Pollen-Flora of Mull and Ardnamurchan. Transactions of the Royal Society of Edinburgh, Vol. 64, No. 16, pp. 421-468.

Smiley, C. J., 1963. The Ellensburg Flora of Washington. University of California Publications in Geological Sciences, Vol. 35, No. 3, pp. 159-276.

Standley, P. C., 1920. Trees and Shrubs of Mexico. Contributions from the United States National Herbarium, Vol. 23. Smithsonian Press, Washington, D. C. 848 pp.

_____1937. Flora of Costa Rica. Field Museum of Natural History, Botanical Series, Vol. 18, Publication 391. 1571 pp.

Stone, D. E., 1968. New World Juglandaceae: A New Species of Alfaroa from Mexico. American Journal of Botany, Vol. 55, No. 4, pp. 477-484.

Takahashi, K., 1957. Palynologisch-stratigraphische Untersuchung der tertiaren Schichten im Kasuya und Fukuoka Kohlenfeld von Nordkyushu, Japan. Memoirs of the Faculty of Science, Kyushu University, Series D, Vol. 5, No. 4, pp. 199-221.

_____1961. Pollen und Sporen des Westjapanischen Alttertiars und Miozans. Teil I, II. Memoirs of the Faculty of Science, Kyushu University, Series D, Vol. 11, No. 2, pp. 151-345.

_____1963. Sporenpalaontologische Untersuchungen der Hioki-Schichtengruppe von Waku and Kiwado. Memoirs of the Faculty of Science, Kyushu University, Series D, Vol. 14, No. 2, pp. 143-157.

Tanai, T. and N. Suzuki, 1963. Miocene Floras of Southwestern Hokkaido, Japan. In: Tertiary Floras of Japan--Miocene Floras. Collaborating Association to commemorate the 80th Anniversary of the Geological Survey of Japan, Tokyo, pp. 9-149.

_____1965. Late Tertiary Floras from Northeastern Hokkaido, Japan. Paleontological Society of Japan, Special Paper No. 10. 117 pp.

Taylor, R. S., W. H. Mathews and W. O. Kupsch, 1964. In: Geological History of Western Canada (Tertiary), McCrossan, R. G. and Glaister, Eds., p. 232.

Ting, W. S., 1966. Pollen Morphology of Onagraceae. Pollen et Spores, Vol. 8, No. 1, pp. 9-36.

Tipper, H. W., 1959. Geology of Quesnel Area, Cariboo District, British Columbia. Map 12-1959, Geological Survey of Canada, Ottawa.

_____1959-60. Geology of Prince George Area, Cariboo District, British Columbia. Map 49-1960, Geological Survey of Canada, Ottawa.

Traverse, A., 1955. Pollen Analysis of the Brandon Lignite of Vermont. United States Department of the Interior, Bureau of Mines, Report of Investigations 5151. 107 pp.

University Atlas (Fullard, H. and H. C. Darby, eds.), 1964. George Philip and Son Ltd., London. 176 pp.

Vakhrameyev, V. A., 1966. Botanic-Geographic Zonality in the Geologic Past and the Evolution of the Plant Kingdom. Paleontological Zhurnal, Vol. 1, pp. 6-18.

Vishnu-Mittre and B. D. Sharma, 1962. Studies of Indian pollen grains. I. Leguminosae. Pollen et Spores, Vol. 4, No. 1, pp. 5-45.

Ward, R. D., C. F. Brooks and A. J. Connor, 1936. The Climates of North America. In: Handbuch der Klimatologie (Koppen, W. and R. Geiger, eds.), Band II, Teil J. Gebruder Borntraeger, Berlin. 325 pp.

White, W. H., 1959. Cordilleran Tectonics in British Columbia. American Association of Petroleum Geologists Bulletin, Vol. 43, No. 1, pp. 60-100.

Willis, J. C., 1966. A Dictionary of the Flowering Plants and Ferns. Cambridge University Press. 1214 pp.

Wilson, L. R. and R. M. Webster, 1946. Plant Microfossils from a Fort Union Coal of Montana. American Journal of Botany, Vol. 33, pp. 271-278.

Wodehouse, R. P., 1933. Tertiary Pollen II. The Oil Shales of the Green River Formation. Bulletin of the Torrey Botanical Club, Vol. 60, pp. 497-524.

Wolfe, J. A., 1966. Tertiary Plants from the Cook Inlet Region, Alaska. United States Geological Survey Professional Paper No. 398-A, -B.

Zaklinskaya, E. D., 1963. Angiosperm Pollen and its Significance for the Stratigraphy of the Upper Cretaceous and Paleogene. (In Russian), Academy of Science of the U. S. S. R., Moscow, Vypusk 74, 256 pp.

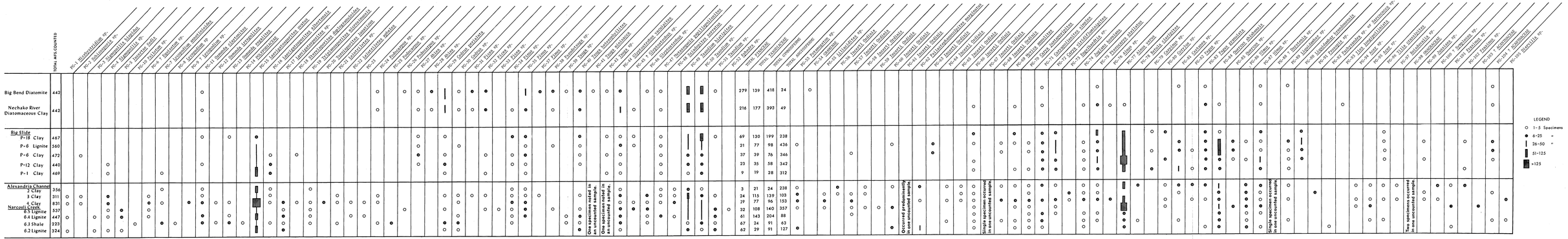
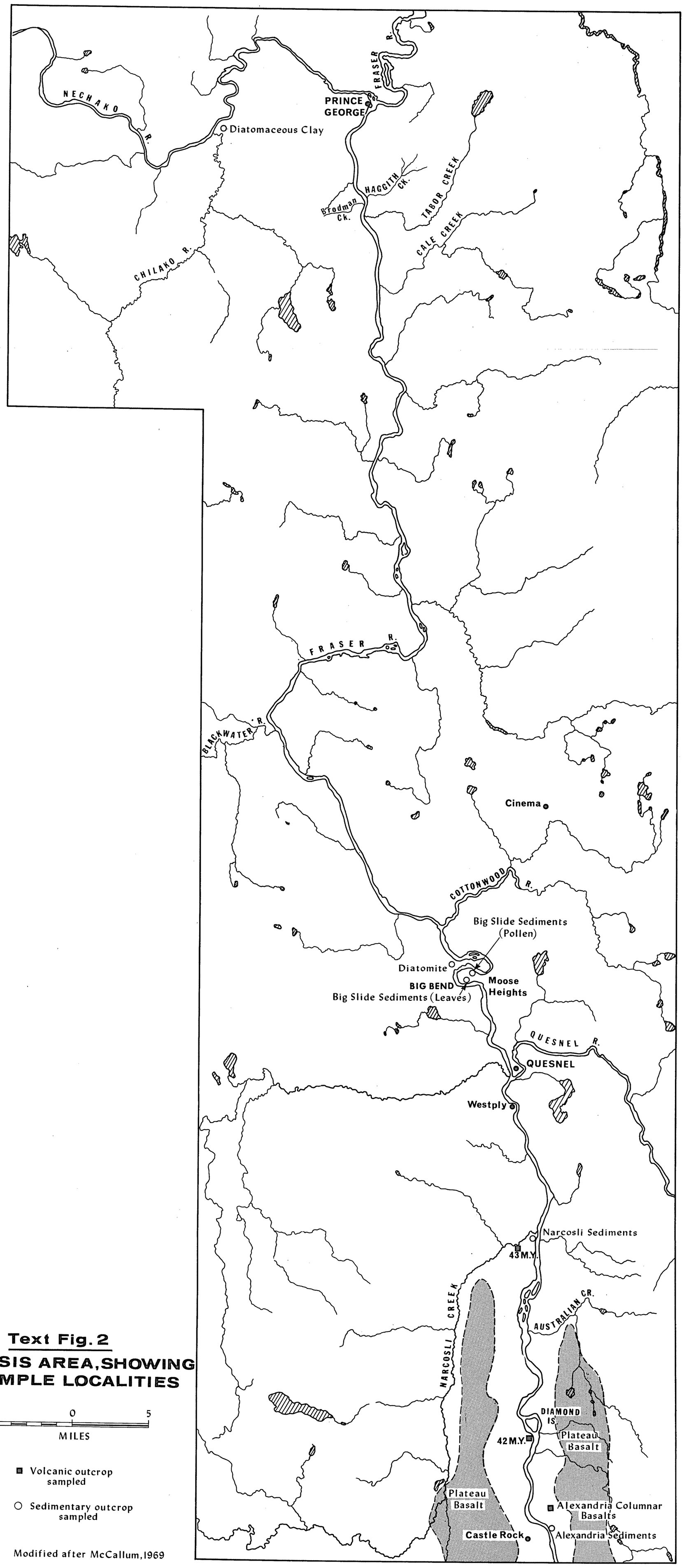


TABLE V. RANGE CHART FOR MID-TO LATE TERTIARY PALYNOMORPHS, CENTRAL BRITISH COLUMBIA



Text Fig. 2

THESIS AREA, SHOWING SAMPLE LOCALITIES

Modified after McCallum, 1969