

PALYNOLOGIC ZONATION AND CORRELATION
OF THE PEACE RIVER COALFIELD,
NORTHEASTERN BRITISH COLUMBIA

By

JANE CATHERINE BROATCH

B.Sc., The University of British Columbia, 1981

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE

in

THE FACULTY OF GRADUATE STUDIES
Department of Geological Sciences

We accept this thesis as conforming
to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

October 1987

© Jane Catherine Broatch, 1987

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

Department of Geological Sciences

The University of British Columbia
1956 Main Mall
Vancouver, Canada
V6T 1Y3

Date October 14, 1987

ABSTRACT

The strata of the Peace River coalfield, in the Foothills of northeastern British Columbia, formed in a tectonically active region near the western margin of the craton. The complex pattern of intertonguing marine and non-marine strata which resulted was subsequently deformed by folding and thrusting, making interpretation and correlation extremely difficult.

The present palynologic study was undertaken in an attempt to resolve some of the stratigraphic problems, where sedimentological and geophysical methods have failed. The primary aim of the study is to generate a composite palynologic section that can be used to zone, correlate and date the coal-bearing strata in the southern half of the coalfield.

Eleven drill holes representing nearly 3000 meters of section from the Gething, Moosebar and Gates formations were sampled at 15 meter intervals. The 199 samples examined for palynomorphs yielded a total assemblage containing 232 pollen and spore species, 96 dinoflagellate and acritarch species and 22 algal cyst and fungal spore species. 256 of the 350 species are restricted in their occurrence within the section, and have been used to zone and correlate the strata.

Open marine, restricted marine and non-marine horizons are identified on the basis of type and relative abundance of palynomorphs. Contact relationships are examined and

clarified, the palynologic section is compared with lithologic information, and a geologic age is established for the rocks.

The Gething Formation consists of a thin basal marine unit, overlain by a thick non-marine succession characterized by poor preservation of palynomorphs, and two clearly defined marine tongues which occur in the northern and upper half of the formation. The marine unit at the base of the unit defines the Gething-Cadomin contact. The marine tongues near the top of the formation are palynologically distinct from the overlying marine strata of the Moosebar Formation, and represent a unique transgressive phase.

The lower half of the Moosebar Formation consists of marine shales, with an abundant and diverse assemblage of dinocysts and acritarchs, representing open marine conditions for most of this phase of deposition. The upper half of the formation consists of a palynologically barren, coarsening-upward sequence which is interpreted as a relatively high energy (non-marine) regressive phase.

The Gates Formation consists of a complex pattern of intertonguing marine and non-marine strata. The lower half of the Gates is open marine in the region of Bullmoose Mt., and intertonguing marine and non-marine in the region from Wolverine River to Monkman Pass. In the southeast, the terrestrial strata occurs between two restricted marine zones which are continuous with the open marine strata to

the northwest. The restricted marine unit which underlies the terrestrial strata, has been previously identified in whole or in part as the 'Torrens Member', and is considered here to be part of the Gates Formation on the basis of palynologic evidence. The basal marine/non-marine unit is overlain by a middle terrestrial and middle marine unit, and an upper terrestrial and upper marine unit.

The entire Gething through Gates section is middle Albian to early late Albian in age, based on the first appearance of early angiosperm monocolpate and tricolpate grains.

TABLE OF CONTENTS

TITLE PAGE.....	i
ABSTRACT.....	ii
TABLE OF CONTENTS.....	v
LIST OF FIGURES.....	vii
LIST OF PLATES.....	viii
ACKNOWLEDGEMENTS.....	ix
INTRODUCTION.....	1
PREVIOUS WORK.....	6
Stratigraphy.....	6
Paleontology.....	7
Palynology.....	7
PALEOGEOGRAPHY.....	8
STRATIGRAPHY.....	10
Cadomin Formation.....	12
Gething Formation.....	14
Moosebar Formation.....	16
Gates Formation.....	18
METHODS.....	20
Sampling.....	20
Processing.....	25
Identification of Species.....	27
Data Manipulation.....	28
Photography.....	29
RESULTS.....	30
Sample Content.....	30
Zonation & Correlation.....	32

Gething Formation.....	40
Moosebar Formation.....	43
Gates Formation.....	47
Age Determination.....	56
SUMMARY.....	57
CONCLUSIONS.....	62
REFERENCES.....	63
PLATES.....	68
APPENDIX I.....	86
APPENDIX II.....	93

LIST OF FIGURES

Figure 1: Map showing location of study area (shaded) in B.C. Foothills.....	2
Figure 2: Stratigraphic Nomenclature of the Peace River Coalfield.....	5
Figure 3: Lower Cretaceous Time Scale.....	9
Figure 4: Text-Figures 1 & 2 of Williams & Stelck (1975)	11
Figure 5: Detailed map of study area showing locations of drill hole and surface sections.....	21
Figure 6: NW-SE cross section showing drill hole distribution.....	23
Figure 7: NW-SE palynologic cross section containing drill hole data.....	<i>In Sp. Collection</i> in pocket
Figure 8: Generalized biostratigraphic zonation of the Peace River coalfield.....	33
Figure 9: NW-SE palynologic cross section.....	39
Figure 10: Lithologic correlation with palynologic cross section (modified after Carmichael, 1983)....	45
Figure 11: Data for DDH BPM-2.....	<i>In Sp. Collection</i> in pocket
Figure 12: Data for DDH BP-29.....	<i>In Sp. Collection</i> in pocket
Figure 13: Data for DDH QWD-7403 & QBD-7402.....	<i>In Sp. Collection</i> in pocket
Figure 14: Data for DDH MDD-7808, MDD-7804 & MDD-7821.....	<i>In Sp. Collection</i> in pocket
Figure 15: Data for DDH BWD-76-4 & BD-7802.....	<i>In Sp. Collection</i> in pocket
Figure 16: Data for DDH BXD-76-7 & BD-76-1.....	<i>In Sp. Collection</i> in pocket

LIST OF PLATES

Plate 1: GETHING FORMATION.....	69
Plate 2: MOOSEBAR FORMATION.....	71
Plate 3: MOOSEBAR & GATES FORMATIONS.....	73
Plate 4: GATES FORMATION - Basal Marine/Non-Marine Unit.	75
Plate 5: GATES FORMATION - Middle Terrestrial Unit.....	77
Plate 6: GATES FORMATION - Middle Marine Unit.....	79
Plate 7: GATES FORMATION - Upper Terrestrial Unit.....	81
Plate 8: GATES FORMATION - Upper Terrestrial & Upper Marine Units.....	83
Plate 9: GATES FORMATION - Upper Marine Unit.....	85

ACKNOWLEDGMENTS

I would like to express my appreciation to the British Columbia Ministry of Energy, Mines & Petroleum Resources for technical and financial assistance. I am particularly indebted to Dr. W.J. McMillan, without whose support this project would not have been possible.

I would especially like to thank Dr. Glenn Rouse, who provided his support and expertise, and who remained enthusiastic and patient beyond all reasonable expectations. I am also grateful to him for the opportunity to attend the Western Canada Coal Geoscience Forum in 1982 and 1986.

Additional thanks to M. Sullivan, who assisted with the drafting, F.C. MacKay, for her help in the darkroom, and E. Montgomery, who printed the final plates. Thanks are also due to J.E. deSequera for the use of his computer, and his patient assistance.

Finally, my love and thanks to my husband, David Gillis for his support and tolerance.

INTRODUCTION

British Columbia's Peace River coalfield lies in the Rocky Mountain Foothills midway between Dawson Creek and Prince George. It trends from Saxon Ridge, near the B.C. - Alberta border, northwest to Carbon Creek for a strike length of 250 km (Fig. 1).

The strata of the coalfield formed along the southwest margin of the Lower Cretaceous Clearwater Sea during a period of major tectonism centred just west of the craton. Successive transgressions from the north - northwest have resulted in a complex pattern of intertonguing marine, marginal marine and coal-bearing terrestrial rocks. The Laramide Orogeny, from Late Cretaceous to Oligocene time, compressed the strata in a series of northwest - southeast trending folds and thrusts. Subsequent erosion has exposed economic coal deposits in progressively younger rocks from north to south.

Coal was first reported in the Peace River area in the 1800's by early explorers. In the early 1900's geological investigations were initiated by the B.C. Ministry of Mines following reports of gold and petroleum, but extensive exploration for mineable coal did not begin until the late 1960's and early 1970's (Stott, 1968). Surface mapping and drill programs carried out by more than a dozen companies have established coking and thermal coal resources in excess of 8 billion tonnes (Carmichael, 1983) and reserves of several hundred million tonnes (Schiller et al, 1983).

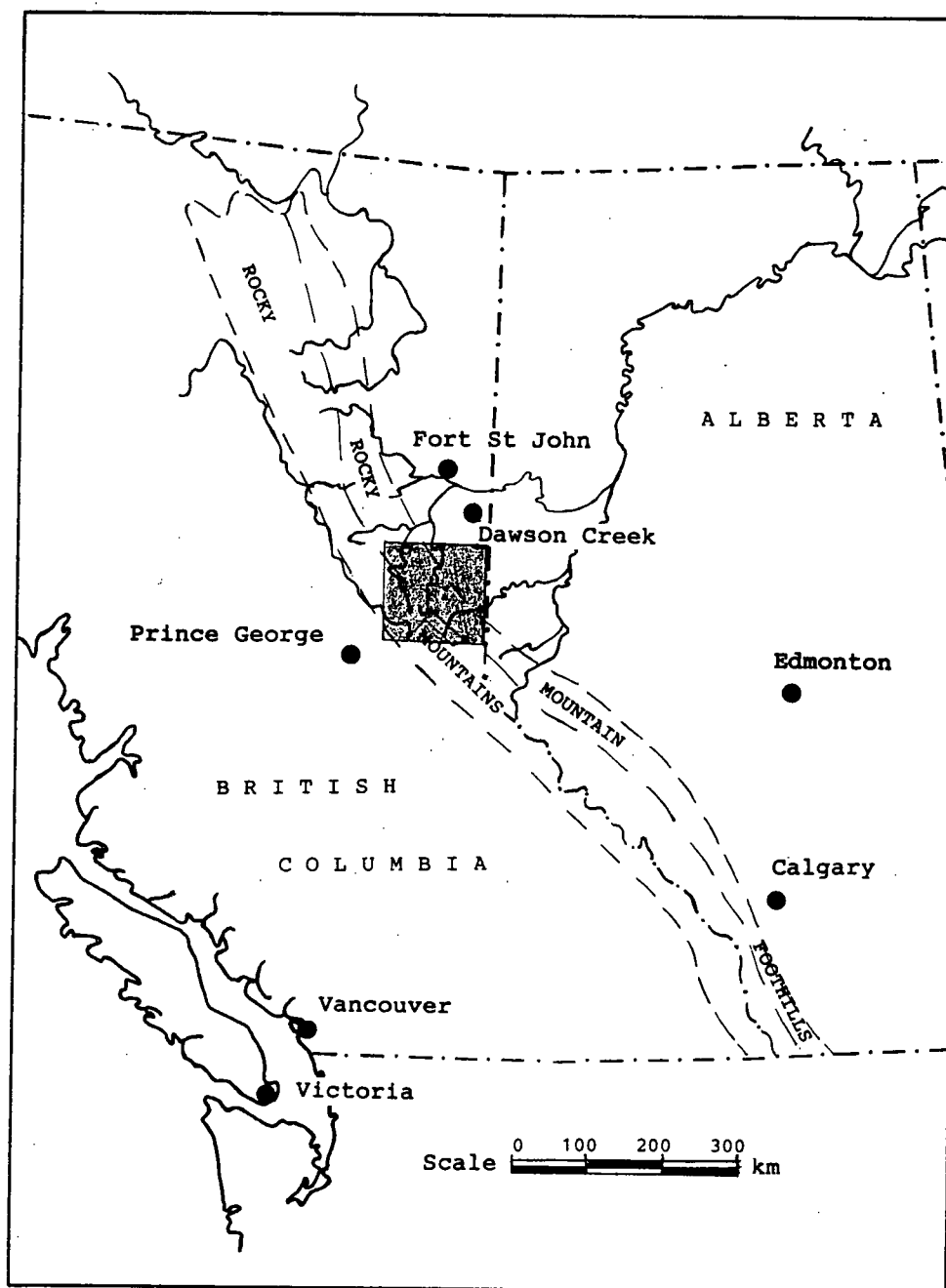


Figure 1 - Map showing location of study area (shaded) in B.C. Foothills.

Although much work has been done, and the general stratigraphy is fairly well understood, controversies still exist in interpretation and correlation of the strata. This is reflected in the two sets of nomenclature still in use within the coalfield (Fig. 2), and the recent surge of newly proposed divisions of the established units (Duff & Gilchrist, 1981; McLean, 1982; Carmichael, 1983).

The difficulties of interpretation and correlation are largely the result of two factors; the rapidly changing facies and a paucity of well preserved and/or stratigraphically useful fossils. Facies changes within the coalfield have resulted in gradational or intertonguing relationships at several contact boundaries causing inconsistent division of the strata from one region to another. Lithologically consistent and easily recognizable stratigraphic horizons are rare, thin and usually identifiable only on geophysical logs (eg. tonsteins, bentonite layers). To date fossil information has been of little value in assisting recognition and correlation of the strata. Within the coalfield paleontological studies have been limited in scope, and stratigraphically useful, well preserved fossils are rare. Information regarding the ranges of those that can be used is not yet complete enough to allow reliable dating and correlation of the rocks with outlying areas.

The present palynological study was undertaken in the summer of 1981 with the support of the B.C. Ministry of Energy, Mines and Petroleum Resources. The primary objec-

tive of this thesis is to establish a composite biostratigraphic section based on both the terrestrial pollen and spores, and the marine dinoflagellate cysts from the Lower Cretaceous coal-bearing strata in the southern half of the coalfield. The composite section is then used to determine whether biostratigraphic zonation is possible, and how it relates to known and proposed rock stratigraphic divisions. Individual sections used to establish the composite section are correlated across the study area, and marine and non-marine facies are identified within the formations.

The rocks of the Peace River coalfield are particularly suited to a study of this type for a number of reasons: the evolution of both land plants and dinoflagellates during Early Cretaceous time was rapid, with the appearance of flowering plants (angiosperms) occurring toward the end of this period (Singh, 1975; Hughes et al; 1979). This has resulted in a diversity of species with relatively short ranges. Furthermore, the presence of humic coals in the region has provided conditions suitable for the preservation of a rich pollen and spore assemblage. Palynomorphs are composed of organic material (sporopollenin) resistant to destruction or alteration except under conditions of severe (burial) temperature or abrasion. Pollen and spores are, in general, ubiquitous in many fine-grained terrestrial and nearshore rocks regardless of environment. In addition, marine and terrestrial palynomorphs are usually mixed in

nearshore facies, providing the potential for correlation between the two.

		HUGHES 1967	STOTT 1978	DUFF & GILCHRIST 1981		McLEAN & WALL 1981
				NW	SE	
LOWER CRETACEOUS	FORT ST JOHN GP	Hulcross Fm	Hulcross Fm	Hulcross Fm		BLAIRMORE GP
		Gates Fm	Gates Fm	Gates Fm	Upper Silty Mb Gates Marine Tongue Sandy Coal-bearing Mb	Mountain Park Fm
		Moosebar Fm	Moosebar Fm	Moosebar	Torrens Mb Spieker Mb Mudstone Mb Lower Silty Mb	Grande Cache Mb Torrens Mb Moosebar Mb
					Chamberlain Mb	
	CRASSIER GP	Gething Fm	Gething Fm	Gething Fm		Gladstone Fm
		Dresser Fm	Cadomin Fm	Cadomin Fm		Cadomin Fm
		Brenot Fm				
			Minnes Fm	Minnes Fm		Nikanassin Fm

Figure 2 - Stratigraphic Nomenclature of the Peace River Coalfield

PREVIOUS WORK

Stratigraphy - The first detailed studies of the stratigraphy in British Columbia's Peace River district were initiated by the Geological Survey of Canada in 1917 following reports by early explorers and fur traders of gold, petroleum, and coal in the area. Much of the work was carried out by F.H. McLearn (1921, 1923, 1940) who continued his investigation of the Lower Cretaceous strata into the 1950's. When the Alberta Study Group published descriptions of the subsurface geology (Alta. Study Group, 1954) the groundwork was laid for all subsequent stratigraphic investigations. In ongoing studies, D.F. Stott (1962, 1968, 1973, 1974, 1975 & 1981) has proposed and revised the nomenclature currently in use throughout most of the coalfield. Concurrent work by J.E. Hughes (1964, 1967) has also contributed to understanding the stratigraphy, and provides a workable local nomenclature for the Peace and Pine Valleys.

More recently Duff and Gilchrist (1981) have proposed a detailed division and correlation of the strata based on geophysical data from the numerous holes drilled during coal and gas exploration. Other studies have concentrated on specific formations and their geologic significance. McLean (1977) examined the stratigraphy, sedimentology and tectonic implications of the Cadomin Formation. Leckie (1981), Leckie and Walker (1982), and Carmichael (1983) have interpreted the depositional environments of the Moosebar and

Gates Formations based on detailed sedimentological studies. Taylor and Walker (1984) carried out a similar study of the depositional environments and paleogeography of the Moosebar Formation and equivalent strata.

Paleontology - Local paleontological studies aimed at dating and correlating the rocks with outlying areas have been carried out by a number of investigators. McLearn included faunal studies in much of his stratigraphic work and in separate works (McLearn; 1931, 1948) and prompted further investigation by Sternberg (1932) of the dinosaur tracks in Peace River Canyon. Bell (1956) did an extensive study of the megaf flora from these and other Lower Cretaceous rocks in western Canada. Chamney (reported in Stott, 1968) and Stelck, et al (1956) identified foraminifera from the marine Moosebar Formation, and Stelck identified marine macrofauna retrieved from core by Duff and Gilchrist (1981).

Palynology - The close association of the Early Cretaceous section in the northeast coalfield with similar aged rocks in the Arctic and western Interior of Canada and the United States has been well established (see Paleogeography). Palynological studies of the Plains region of Canada have been carried out by Pocock (1962, 1976), Singh (1964, 1971, 1975), Norris (1967, 1982), Steeves & Wilkins (1967), Brideaux (1971), Playford (1971), Norris, et al (1975), Norris, et al (1976) and Burden (1984). South of the Canadian border work has been done by Hedlund & Norris

(1968), and Paden-Phillips & Felix (1971). Contemporaneous rocks from Arctic Canada have been examined by Manum & Cookson (1964), McGregor (1965), Brideaux & McIntyre (1975), Brideaux & Fisher (1976), and Pocock (1976).

PALEOGEOGRAPHY

According to Williams and Stelck (1975) the deposits of the Peace River coalfield formed along the western margin of the Rocky Mountain Foreland Basin. The strata represent part of the Jurassic-Cretaceous clastic wedge shed eastward onto the craton during a major orogenic phase in the Cordilleran of terrain accretion and arc magmatism associated with subduction.

During Late Jurassic time the craton was emergent. With a rising Cordillera to the west, the interior remained connected to the Pacific Ocean through embayments which reached as far inland as the B.C. - Alberta border (Williams & Stelck, 1975). A large fluvial system draining much of the central and western United States flowed north and northwestward near the continental margin and drained into the Pacific, probably through the Peace River Embayment (Text-fig. 1 of Williams & Stelck, 1975: reproduced in Fig. 4). Upper Jurassic deposits of mixed marine and terrestrial origin are found in the Nikinassin and Minnes Formations of this region.

Uplift to the west may have caused temporary downwarping in the foreland basin during Neocomian (Lower

Cretaceous) time (Fig. 3) resulting in a gradient change in the fluvial system. Rapid erosion occurred and marine waters began to transgress into the lowlands. The connection to the Pacific remained open until late Neocomian time, and possibly as late as Early Aptian (Williams & Stelck, 1975) but was cut off when uplift caused rapid deposition of clastics eastward onto the craton, which may have choked the fluvial system and diverted it northward to drain into the Arctic region.

LOWER CRETACEOUS	NEOCOMIAN	ALBIAN	100 MY
		APTIAN	
		BARREMIAN	
		HAUTERIVIAN	118 MY
		VALANGINIAN	
		BERRIASIAN	141 MY

Figure 3 - Lower Cretaceous Time Scale

By Aptian time (Fig. 3) the Cordillera had become the main source of clastics which were being reworked by the rivers. Rocks of the Bullhead Group (Fig. 2) were likely laid down during this phase of aggradation. Eustatic changes in sea level resulted in flooding of the continental margins and the lowlands of the fluvial systems in the northern Arctic and along the Gulf of Mexico in the south.

In late Early Albian the transgression from the north had progressed into Alberta (Text fig. 2, Williams & Stelck, 1975; reproduced in Fig. 4) as far south as Calgary (McLean & Wall, 1981). A regressive phase followed in Middle Albian time depositing the rocks of the Lower Fort St. John Group (Fig. 2) in the Peace River area. By early Late Albian, the boreal sea had connected with the northward transgressing Tethyan Sea originating in the Gulf of Mexico, marking the end of a major depositional cycle (Kootenay-Blairmore). The continuous seaway through the interior of the craton became cut off by a regressive phase in late Late Albian time leaving a large landlocked inland sea (Mowry Sea) occupying much of the northern interior at the close of the Lower Cretaceous (Williams & Stelck, 1975).

STRATIGRAPHY

Although considerable work has been done toward understanding the stratigraphy and depositional history of the coalfield strata, a number of problems still exist. The sediments were laid down in a tectonically active region



a) Text-figure 1 (Williams & Stelck, 1975)
Map showing extent of the earliest Cretaceous Infravalanginian seas.



b) Text-figure 2 (Williams & Stelck, 1975)
Map showing extent of latest early Albian seas at the horizon of Subarchthoplites.

Figure 4

which resulted in fluctuating marine and non-marine conditions. Facies grade into one another both laterally and vertically, and several formations change character along the length of the coalfield. Correlating the strata, even over short distances, and establishing consistent criteria for identifying contact boundaries is often difficult. In addition, entire formations or parts of formations laid down under similar conditions are similar in character, making them difficult to identify in isolated outcrop occurrences, particularly in the absence of marker horizons and well preserved macrofossils.

Subsequent folding and thrusting has altered the already complex pattern of facies distribution and further obscured the lateral relationships.

The generalized stratigraphy of the coalfield is summarized in Figure 2. A brief description of the rock units is followed by a discussion intended to provide insight into the problems specific to the area and into the interpretation of the results.

Cadomin Formation - The Cadomin Formation of the Bullhead Group (Fig. 2) is a resistant conglomerate consisting of dominantly chert and quartzite pebble to cobble-size clasts in a clean sandy matrix. Locally it may vary to a pebbly sandstone or contain thin beds of mudstone, siltstone and coal, most commonly near its limits of deposition. It is generally thick-bedded to massive, and was deposited as a

wedge up to 200 meters thick along its western edge in the Rocky Mountain Foothills, tapering to a few meters less than 100 km to the east (McLean, 1977). It extends from the Pine River Valley in northeastern B.C. to southwestern Montana. The Cadomin lies unconformably on Late Jurassic to Early Cretaceous rocks within the coalfield, but overlaps progressively older rocks to the east and north. The angular relationship with the underlying rocks is not always apparent locally, but has been established on a regional scale (Stott, 1973).

The conglomerate is generally thought to have been laid down as a series of coalescing alluvial fans with an associated fluvial influence. The material was derived dominantly from the west during uplift in Late Jurassic time, with the northwest-southeast trending Fox Creek escarpment to the east acting as a minor secondary source, and marking the eastern limit of Cadomin deposition (McLean, 1977).

The thin coal stringers within the formation are of no economic importance, but oil and gas have been reported in the Cadomin southeast of the Peace River Coalfield in the Alberta Foothills.

Discussion - Although the angular relationship of the Cadomin conglomerate with the underlying rocks has been well established, the amount of time represented by the hiatus is still a matter of controversy. Stott (1968, 1973) considers the gap to encompass most of Neocomian time (Fig. 3) based on extensive mapping throughout the foothills, whereas

Hughes (1964, 1967) considers the unconformity to be of little significance in the Pine Valley region. In addition, the character of the Cadomin changes considerably from conglomerate in the south to pebbly sandstones interbedded with fine clastics and coal in the north. As a result, the unit has been mapped in part as the Dresser Formation of the Crassier Group (Hughes, 1964 & 1967), terminology which is currently used by the coal licence holders north of the Pine River.

Suitable material for a palynologic study of the Cadomin is scarce and consequently, few conclusions can be drawn about the age of the formation or its relationship to the overlying and underlying rocks. However, additional palynologic work on the Gething, Cadomin and Minnes formations to the north of the present study area is currently being done by the author and will likely resolve these problems.

Gething Formation - The Gething Formation of the Bullhead Group (Fig. 2) consists of a cyclical coal-bearing sequence of thin-bedded, fine-grained sandstones, siltstones, and mudstones. Thick to thin-bedded conglomerates and conglomeratic sandstones occur occasionally near the top of the formation, but more often near the base, particularly in more southern exposures. In the northern half of the study area, the coal-bearing sequence is divided into an upper and lower unit by a thick succession of fine-grained sandstone, which grades southward into interbedded marine

mudstones and siltstones. The marine interbeds have been traced as far south as Quintette Mountain (Duff & Gilchrist, 1981) where they appear to pinch out.

The Gething has been mapped by Stott (1973) from the Belcourt Mountain region northwest to Prophet River. Like the Cadomin conglomerate underlying it, it forms a wedge with its thickest sections toward the western edge of the foothills. It reaches a maximum thickness of 550 meters in the Pine Valley (Duff & Gilchrist, 1981) and thins eastward and northward.

Deposition of the formation likely occurred in a fluvial-deltaic setting. Clastics derived from alluvial fan deposition to the west were reworked along a north-flowing river system near the margin of a transgressing Arctic sea (Stott, 1973).

Coal occurs throughout the entire extent of the Gething Formation, but in most regions the seams are numerous, thin, and either discontinuous or difficult to correlate. At present, the three or four mineable seams occur in the upper part of the formation between Quintette Mountain and Sukunka River, just above the marine strata.

Discussion - Where thick conglomerates occur near the base of the Gething Formation, the contact with the underlying Cadomin conglomerate becomes largely arbitrary (Stott, 1973). Duff & Gilchrist (1981) note that the Cadomin conglomerate exhibits a clean matrix on geophysical logs, but within the coalfield the conglomerates are rarely

drilled or subjected to geophysical evaluation. As a consequence of the discontinuous nature of the Gething conglomerates, drill holes which terminate at the first thick conglomerate are often the subject of debate as to whether or not they have penetrated the Cadomin Formation (eg. BPM-2). The palynologic data from this study provide a reliable means of identifying the Cadomin - Gething contact.

Until work by Duff & Gilchrist (1981), no detailed studies had been done on the extent of the marine influence in the Gething Formation. Identification by them of a major marine tongue near the top of the formation, and the general absence in the coalfield of the Bluesky Formation, which marks the contact between the Gething and Moosebar Formations and their equivalents on the Plains, has raised new questions about the relationship of the contact between the two formations. The palynologic data clearly delineates the marine component of the Gething and resolves any questions about the nature of the Gething-Moosebar contact.

Moosebar Formation - The Moosebar Formation of the Fort St. John Group (Fig. 3) is a coarsening upward marine sequence consisting of fine, dark grey shales which grade to thin interbedded mudstones, siltstones and fine-grain sandstones, or at some locations, to a dominantly well sorted, fine-grain sandstone unit. At most locations its base is marked by a pebble layer and glauconitic mudstone bed, which thins noticeably to the west and is almost absent in the coalfield. In the past, field workers have mapped the Moosebar

Formation as basal marine shales and an overlying transition unit; recently formal member names (see Fig. 2) have been proposed for the lithologically distinct units (Duff & Gilchrist, 1981; McLean, 1982). The formation is relatively consistent lithologically throughout its distribution, from north of the Pine River, southeast into west-central Alberta. It is thickest in the northern foothills and thins to the northeast and southeast onto the Plains. McLean and Wall (1981) note a prominent thinning in the Mount Belcourt to Smokey River area, which they attribute to a topographic high resulting from unusually thick deposits of sediments during Cadomin and Gething time.

The Moosebar Formation represents the western and southwestern extent of the Clearwater Sea. The marine shales represent shallow shelf conditions following a major transgression from the north, with the coarser clastics marking the regressive phase (McLean & Wall, 1981). Although the formation is not of economic significance, stratigraphically equivalent rocks to the northeast (Wilrich Member of the Spirit River Formation) are a target for natural gas exploration.

Discussion - In the past the contact of the Moosebar Formation with the overlying Gates was defined as "the base of the first thick and relatively continuous succession of fine-grained sandstone" (Stott, 1968). This succession occurs at different horizons throughout the coalfield and "results in a highly irregular contact on Stott's regional

cross sections" (Leckie, 1981). More recently workers have recognized mappable divisions within the Moosebar Formation but have not successfully redefined the contact. Duff & Gilchrist (1981) have proposed an informal 'marine member' for the shale beds and formal Torrens and Spieker members for the 'transition' unit. McLean (1982) has also proposed a Torrens Member within stratigraphically equivalent rocks in the Alberta Foothills. He equates it to basal Gates on lithologic grounds, although it encompasses Duff & Gilchrists' Torrens Member and part of the Spieker Member of the Moosebar Formation in the coalfield. All of the newly proposed members lie below the previously defined Moosebar-Gates contact, and recognize the marine origin and resistant nature of the Torrens Member relative to the underlying and overlying units. The present study indicates that the Moosebar - Gates contact is palynologically distinct, and lies at the base of a resistant, lithologically persistent marine sandstone.

Gates Formation - The Gates Formation of the Fort St. John Group (Fig. 2) consists of interbedded sandstones, siltstones and mudstones. Minor conglomerates, and numerous coal seams ranging in thickness up to 10 meters are distributed throughout the formation. In more northern exposures there is a pronounced marine influence which, prior to this study, had been traced southward to the vicinity of Quintette Mountain (Duff & Gilchrist, 1981; Carmichael, 1983).

The Gates is recognized as a formation from just north of Peace River, where it occurs largely as erosional remnants, to the B.C. - Alberta border in the southeast. In the Alberta Foothills it is reduced to member status in the Malcolm Creek Formation (McLean, 1982). The strata were deposited in a floodplain environment that was occasionally inundated by marine transgressions from the north.

Several thick seams of mineable coal occur in the lower half of the unit from Sukunka River southeast along the regional strike into the Alberta Foothills. Numerous thin seams are distributed throughout the remainder of the formation but these are not economic to mine at present, except where thickened by local structure. Natural gas occurs in the stratigraphically equivalent Upper Wilrich and Fahler members of the Spirit River Formation immediately northeast of the coalfield.

Discussion - Although extensive and detailed work has been carried out on the Gates Formation, there has been considerable uncertainty regarding the extent of the marine influence. The number of transgressive deposits represented is of some importance, since it is known to influence the occurrence and distribution of coal, particularly in the region between Bullmoose and Quintette Mountains. Duff & Gilchrist (1981) have identified one major marine tongue, Carmichael (1983) recognizes two major and several minor transgressions, and Leckie & Walker (1982) suggest that at least four significant incursions have occurred at Mount

Spieker. The palynologic data indicate that the marine influence is more extensive than previously thought.

METHODS

In the late 1970's and early 1980's, renewed interest in coal led to the signing of a 15 year contract by two northeast license holders to sell thermal and coking coal to the Japanese. It also provided the opportunity for a number of stratigraphic studies (see Previous Work) which would improve interpretation and correlation of strata, and hence facilitate mine planning and reserve estimates.

As previously mentioned, the age and depositional setting of the rocks make the Peace River coalfield well suited to a palynological study. The economic importance of these and stratigraphically equivalent gas-bearing rocks to the northeast, and the availability of drill core material provide additional incentive for conducting a study in this area.

Sampling - 13 drill holes and 7 surface sections were selected for sampling (Figure 5). The drill hole sections are pieced together to get the best representative Lower Cretaceous section from 7 locations; Belcourt-Secus Mt., Triad Creek, Monkman Pass, Quintette Mt., Wolverine Rv., Bullmoose Mt., and Mt. Merrick-Sukunka North (Figure 6). Surface sections compliment, rather than complete, drill hole sections, since results from surface samples were

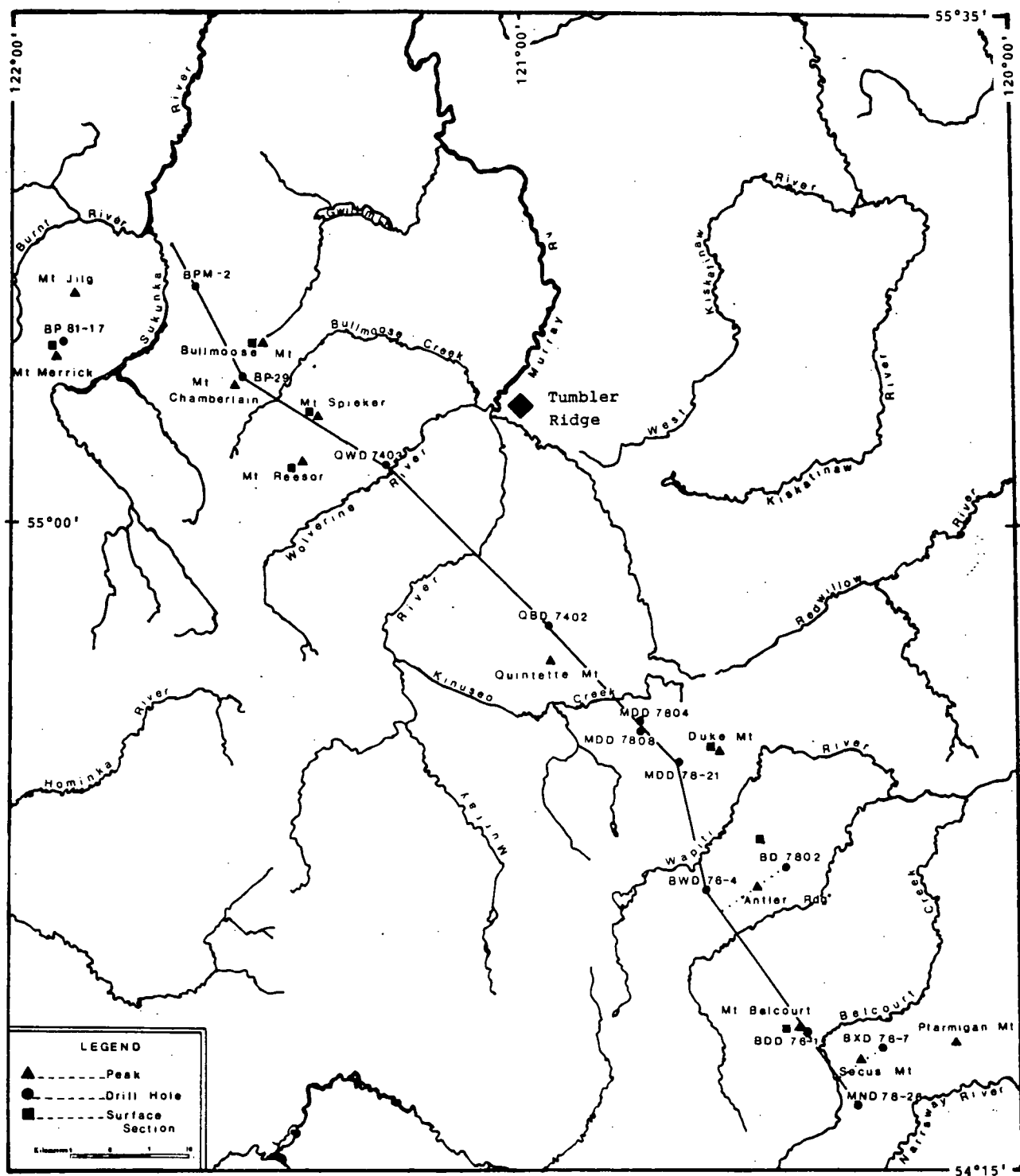


Figure 5 - Detailed map of study area showing locations of drill hole and surface sections

expected to be less reliable than core samples (see discussion of 'Surface Samples' in this section).

Initial selection of all sections was based primarily on 2 criteria: the upper and lower contacts of the formation(s) being sampled had to be intersected by the section; and the section had to be unfaulted. The first criterion ensures that the entire formation is sampled, with the upper and lower contacts providing stratigraphic control for correlation. In many cases sampling of the overlying and/or underlying formation was possible in order to determine the accuracy of the contact position and the nature of the contact relationship. The second criterion prevents repetitive sampling of a section, and hence confusion over exact position within a formation. Adhering to the criteria resulted in 'gaps' in sampling in some areas (see Fig. 6). In particular the Wolverine - Quintette region, although extensively drilled, failed to yield complete, unfaulted sections for most of the desired formations. Occasionally, inadequate information regarding location and/or content of a drill hole prevented sampling of what might otherwise have been a suitable section. Surface sections were selected after consultation with company geologists, since available maps were not detailed enough to indicate small local faults in a section.

Individual samples consisted of approximately 600-800 grams of the cleanest mudstone available at or near the desired sample interval. The most desirable sample is free

of 'contaminants' such as silt, pyrite, coal or other carbonaceous material. When these components cannot be avoided at the sampling stage, taking sufficient material allows them to be excluded from the sample prior to dissolution of the rock in acid.

Core Samples - 238 core samples were taken; 199 are used in this study, including 1 Cadomin sample, 70 Gething samples, 35 Moosebar samples (24 marine & 11 transition), 91 Gates samples and 1 Hulcross sample. The 39 unused samples are from the Minnes Formation and will be reported on in a separate study. The samples were taken at 15 meter intervals (on average) and represent approximately 2990 meters of section.

There are a number of advantages to the use of core samples over surface samples; core is easily accessible and provides continuous exposure of rock; contacts are more accurately pinpointed; sample intervals are consistent and depths are easily checked against core markers; and samples are unaltered by weathering. The only problems arising from core sampling, as previously mentioned, were difficulty obtaining complete unfaulted formations which contain both upper and lower contacts, and a lack of easily accessible information on drill hole location and content (a condition which has been subsequently remedied with the introduction of the B.C. Ministry of Mines' computerized Coal File).

Surface Samples - Of the 89 surface samples taken, 10 were selected for processing based on results from adjacent

core sections. Surface samples were taken primarily to determine the usefulness of surface material relative to 'fresh' or unweathered core material. Surface sections in this region are most often steeply dipping and deeply weathered. In addition, the mudstone is recessive and usually poorly exposed. As a result, surface samples were taken at 30 meter intervals and often required the use of an auger to obtain suitable material. Although it is easier to obtain a complete Cadomin through Gates section at one location if the selection criteria are met, access to sections is not always possible since many of these are best exposed on very steep slopes and cliff faces.

Processing - Samples were processed using standard palynological procedures (Kummel & Raup; 1965); the rock was crushed to pea-gravel size, placed in HCl for several hours to dissolve carbonate; then in HF acid overnight to dissolve silicates; clay was removed through settling and sieving. Any residual mineral matter (eg. CaF crystals, undissolved silica, glauconite, pyrite) was removed by heavy liquid separation in zinc bromide. Nitric acid and acetolysis solution were applied to samples containing excessive coaly or cellulosic material respectively; an oxidizing reagent (eg. Schultz's solution, household bleach) was used to lighten dark palynomorphs. Processed samples were stained with safranine dye, and 1 or 2 drops were dried onto a coverslip in Cellosize; the coverslip was inverted onto a

glass slide and secured with a mounting medium (eg. Gelva, Flo-texx).

During processing several problems were encountered which required modification of some procedures in order to enhance recovery of the palynomorphs. Since the smaller (12-20 μm) angiosperm pollen make their first appearance in late Lower Cretaceous rocks, particular care was taken not to lose these during removal of the clay. Settling of the sample after rinsing was allowed to continue a few minutes longer than usual resulting in a higher than normal clay content in the residue. This material was removed by drawing it through a 10-15 μm PVC mesh with the aid of a suction pump.

A number of samples were found to contain 'flakes' of ash. Larger fragments could be removed by trapping them in a 270 μm sieve but smaller fragments required treatment in heavy liquid. The ash had a specific gravity slightly greater than most organic matter, but less than mineral matter removed through settling in ZnBr_2 with a S.G. greater than 2.2. The ash fragments were found to settle out of the residue in ZnBr_2 with a S.G. between 1.7 and 1.9.

Another substance, occurring in approximately 1/3 of the samples, which failed to separate from the desired organic residue was a bituminous-looking substance identified only as 'wax'. It first appeared as a dark substance floating in the test tube after sieving. However, separation from the other organics was not complete, as

abundant discrete particles were found in the residue. Removal of the 'wax' was achieved by rinsing with full strength HCl (S.G. approximately 1.16) which allowed the remainder of the 'wax' to float.

For the first 60 samples processed the standard procedure of making 3 mounts (coarse, medium & fine fractions) was adhered to. When it became apparent that differences in colour (thermal alteration) between the dinoflagellate cysts and thin-walled spores, and the thick-walled spores was causing under-oxidation or over-oxidation of samples, and hence a loss of species, a change was made in the mounting procedure. Slides were made for each sample at various stages of bleaching, including a TAI mount prior to any lightening of the organics. Because of improved concentration and preservation of the palynomorphs after the modifications were made, the first 60 samples were reprocessed.

Identification of Species - Identification of the palynomorphs was carried out on a Leitz Orthoplan microscope with interference contrast. Slides were scanned in a systematic grid using 10X, 12X or 15X oculars and a 25 power lense. Identifications were carried out under oil immersion using a 100 power lense, giving a magnification of 1000-1500X.

Appendix II contains a complete list of references used to identify the Lower Cretaceous palynomorphs.

Data Manipulation - The number of samples taken and the unexpectedly large number of palynomorphs recovered make use of conventional ranking methods (Shaw, 1964; Hay, 1972) prohibitive. Instead, ranking of the species was achieved through a series of plots and diagrams. To facilitate this the species list was ordered alphabetically and a number assigned to each species (Appendix II).

From the original data the occurrence of each species in a formation was noted, thus identifying the ubiquitous palynomorphs, and forming a rough zonation based on the restricted ranges of the remaining species.

Ranking of the species list (ordering the species according to their earliest occurrence) was achieved by drawing a cross-sectional plot of the drill hole locations and sample depths (Fig. 7, in pocket). All non-ubiquitous species are plotted by sample, and the presence of ubiquitous dinocysts and acritarchs is noted. Correlation of the drill holes relies on type and abundance of palynomorphs (total assemblage), and the occurrence of individual species from one drill hole to the next. Finally, ranking of the species list was possible by noting the earliest or lowest occurrence of each species in the section.

The results of this ranking have been used to generate Figure 8, and to order the individual drill hole plots (Figs. 11-16, in pocket). The ranked list used in Figure 8 differs from that used in Figures 11-16, in that species that occur

as a single specimen have been omitted from the Generalized Zonation plot unless the species appears to be previously undescribed in the literature. These species are indicated on the list by single quotes (').

Relative abundance of each species is denoted on Figures 11-16 as follows; single occurrence - open circle (O), 2-5 specimens - half circle (◐), more than 5 specimens - full circle (●). The information is important in determining which species are reliable indicators for zonation and correlation. Figures 11-16 also include a plot of TAI values and the occurrence of ash and 'wax'.

Photography - Photographs for plates were taken with an Orthomat-W automatic microscope camera on Kodak PAN 2415 black and white film (ASA 50). Negatives and prints were developed using standard darkroom techniques.

Note: colour slides for presentation were taken on Fuji 50 colour slide film (ASA 50) using an 80A (blue) filter over the tungsten light source. The slide film was shot at ASA 12 to compensate for long exposure times. The slides were developed by a commercial lab.

RESULTS

The overall palynomorph assemblage obtained from the Gething through Gates succession is rich and varied. The abundance and diversity of species has allowed recognition of numerous, palynologically distinct zones within the section, most of which can be correlated throughout the length of the study area. The types of palynomorphs present, and the relative abundance of each provide insight into depositional environments and facies changes in each zone. The formation of coal appears to exhibit a degree of consistency with respect to the environments recognized. In addition, the palynomorphs provide a means of dating the formations.

Sample Content

Of the 197 core samples used for this study, 163 samples (83%) contain indigenous palynomorphs and 34 samples (17%) are barren or contain palynomorphs considered to be recycled. A total of 350 species has been identified, including 232 pollen and spore species, 96 dinoflagellate cyst and acritarch species, and 22 algal cyst and fungal spore species (Appendix II).

Of the 89 surface samples collected, 10 were selected for processing based on their proximity to core samples known to have a rich palynomorph assemblage. Palynomorphs are present in all 10 samples, and abundant, relatively well preserved specimens occur in 7 of them. Although the assem-

blages do not exhibit the abundance and/or diversity of those found in corresponding core samples, they do indicate that surface samples can be of value when used in an area where the palynologic section is already established, or to supplement core results. Identifications were not done for surface samples since it was felt that the time invested would not result in a significant contribution to the data already obtained from core samples.

Recycled palynomorphs are present in varying amounts in a large number of samples and have been excluded from the results. Although often difficult to recognize, in this study recyclants have been identified as those specimens which exhibit a significantly higher TAI value, and/or greater corrosion (chemical degradation) or pitting (abrasion) of the wall relative to similar types of palynomorphs in the sample.

TAI values, determined for each sample based on cuticle colour, are plotted on Figures A-G. Although most values fall within the 2.25-2.50 range, several readings went as high as 3.0, and a few fell below 2.0. Most of the higher values occur in the Gething Formation but none of the anomalous readings shows any consistent association with other observable factors (eg. palynomorph type, proximity to facies boundaries or coal, mineralization, presence of ash or 'wax'). It is suspected that, particularly in the acidic environments where most peats form, TAI values are affected by conditions during deposition and early diagenesis ie.

that some alteration may take place due to chemical activity prior to thermal alteration associated with burial (see Manum et al, 1976).

The occurrence of volcanic ash in 19 of the core samples, and a waxy bituminous substance in 63 of the core samples is plotted also on Figures A-G. The volcanic ash produced an EDS profile similar to an andesite/basalt standard. The 'wax' occurs largely in zones interpreted as marine, and just over half of the notable occurrences of pyrite (8 of 13) are in conjunction with the 'wax'. However, it is not exclusive to marine units, nor does it exhibit any association with anomalously high (or low) occurrences of any particular palynomorph type (the reader is referred to an article by Adams & Bonnett (1969) on the Bute Inlet Wax). Although it is not within the scope of this study to determine the significance of these substances, the data are provided for others working in this area, or in similar depositional settings, who may find the information of value.

Zonation and Correlation

The edited data, when plotted on a cross section, reveal a pattern of frequent inundations from the north by a shallow sea over coastal lowlands to the south (Figs. 7 & 9). Six major and four minor transgressions are identified in the Gething through Gates section. All of the major transgressions, as well as the intervening non-marine

		GETHING FM	MOOSEBAR FM		GATES FM						
BIOSTRATIGRAPHIC ZONATION			Shale Mb	Transition Mb	Basal Marine/Non-marine	Terrestrial	Middle Marine	Middle Marine	Upper Terrestrial	Upper Marine	
SPORES & POLLEN											
15	Antulsporites distaverrucosus										15
21	Appendicisporites dentimarginatus 'var. A'										21
39	cf Auritulinasporites deltaformis										39
83	Cicatricosisporites cf tersus										83
165	Foraminisporis wonthaggiensis										165
199	Ischyosporites 'sp. A'										199
205	Laevigatosporites gracilis										205
213	Lycopodiacidites caperatus										213
221	Lycopodiumsporites eminulus										221
252	Ornamentifera baculata										252
351	Cooksonites 'sp. A'										351
230	Matonisporites cooksoni										230
323	Tigrisporites scurrandus										323
157	Distaltriangulisporites 'sp. B'										157
311	Sestrosporites irregularis										311
276	Podocarpidites ellipticus										276
227	Lycopodiumsporites sp. B										227
333	Trilobosporites trioreticulosus										333
3	Acanthotriletes levidensis										3
53	Callialasporites trilobatus										53
232	Matonisporites 'sp. A'										232
331	Trilobosporites purverulentus										331
166	Foveosporites canalis										166
87	Cingulatisporites distaverrucosus										87
104	Contignisporites cooksonii										104
106	Contignisporites multimuratus										106
280	Podocarpidites potomacensis										280
325	'Spore sp. A' (nov. gen.)										325
336	Undulatisporites pannuceus										336
18	Appendicisporites bilateralis										18
168	Foveotrilites subtriangularis										168
322	Tigrisporites reticulatus										322
329	Trilobosporites marylandensis										329
148	Dictyophyllidites equiexinosis										148
212	Lycopodiacidites canaliculatus										212
122	Cyathidites rafaeli										122
74	Cicatricosisporites exilioides										74
121	Cyathidites punctatus										121
160	Distaltriangulisporites 'sp. A'										160
29	Appendicisporites unicus										29
113	Costatoperforosporites foveolatus										113
260	Perinopollenites elatoides										260
350	Appendicisporites tricornitatus										350
114	Couperisporites complexus										114
152	Dictyotosporites speciosus										152
20	Appendicisporites dentimarginatus										20
151	Dictyotosporites complex										151
214	Lycopodiacidites cirniidites										214
52	Callialasporites segmentatus										52
65	Ceratosporites cf morrinicolus										65
85	Cibotiumspora juriensis										85
100	Concavissimisporites minor										100
109	Cooksonites variabilis										109
144	Densoisporites microrugulatus										144
200	Januasporites spiniferus										200
281	Psilatricolpites parvulus										281
284	Polycingulatisporites 'sp. A'										284
345	Vitreisporites pallidus										345
346	Klukisporites pseudoreticulatus										346
12	Alisporites similis										12
49	Biretisporites spectabilis										49
338	Undulatisporites undulapulus										338
223	Lycopodiumsporites marginatus										223
327	Trilobosporites apiverrucatus										327
77	Cicatricosisporites imbricatus										77
266	Phyllocladidites inchoatus										266
2	Abietineaepollenites sp.										2
161	Eucommiidites troedssonii										161
149	Dictyophyllidites pectinataeformis										149
163	Foraminisporis asymmetricus										163
204	Kuylisporites lunaris										204
211	Lycopodiacidites asperatus										211
25	Appendicisporites pschekhaensis										25
202	Klukisporites areolatus										202
274	Podocarpidites biformis										274
304	Schizosporis grandis										304
233	Matonisporites cf excavatus										233
269	Pinuspollenites										269
296	Reticulisporites elongatus										296
335	Undulatisporites fossulatus										335
339	Verrucosisporites asymmetricus										339
349	Piceapollenites										349
90	Classopollis chateauvovi										90
131	Cycadoides carpentieri										131
239	Podocarpidites ornatus										239
307	Schizosporis rugulatus										307
343	Vitreisporites cf craigii										343
347	Spheripollenites scabratus										347
70	Cicatricosisporites annulatus										70
93	Clavatipollenites couperii										93
95	Clavatipollenites minutus										95
108	Cooksonites reticulatus										108
112	Coptospora striata										112
174	Ginkgocycadophytus sp.										174
197	Inaperturopollenites dubius										197
234	Podocarpidites naumovai										234
243	Murospora truncata										243
302	Schizosporis sp.										302
344	Cicatricosisporites potomacensis										344
348	Reticulisporites semireticulatus										348
DINOFLAGELLATE CYSTS & ACRITARCHS											
156	Diplotesta anglica										156
235	Michrystidium stellatum										235
255	Palaeoperidinium cretaceum										255
290	Pterodinium sp. A										290
178	Gonyaulacysta archeopyle Type B										178
69	Chytroeisphaeridia cf pococki										69
31	Apteodinium grande										31
132	Cyclonephelium paucispinum										132
180	Gonyaulacysta cretacea										180
247	Oligosphaeridium anthophorum										247
248	Oligosphaeridium complex										248
310	Scriiodinium campanula										310
183	Gonyaulacysta orthoceras										183
38	Ascotomocystis maxima										38
54	Callaiosphaeridia cf reticulata										54
170	Fromea amphora										170
179	Gonyaulacysta cf cassidata										179
181	Gonyaulacysta cf episoma										181
186	Hystrichokolpoma 'sp. A'										186
201	cf Kalyptea monoceras										201
286	Prolixosphaeridium cf mixt										

Figure 8 - Generalized biostratigraphic zonation of the Peace River coalfield

deposits of the regressive phases, can be characterized by a unique palynomorph assemblage (Fig. 8).

Although a single non-ubiquitous species rarely occurs throughout a particular zone, each zone can still be recognized on the basis of palynomorph type, abundance and diversity. This allows all but a few palynologic zones to be correlated the entire length of the study area. The remaining zones can be traced to facies equivalents.

The zonation and correlation are illustrated in Figures 7 & 9, and Figure 8 summarizes the palynomorphs that characterize each zone. Of the 350 species identified in this study, 94 are ubiquitous (Appendix II). The remaining 256 species, made up of 150 pollen and spore species, 85 dinocyst and acritarch species and 21 algal cyst and fungal spore species, are restricted in occurrence.

Figure 7 shows the location of the drill holes used in this study, their relative position in the section and the position of the samples taken from each. The Gething-Moosebar lithologic contact, as determined by company geologists from core and geophysical logs, has been used as the datum since there is generally good agreement on its position. Lithologic contacts (solid lines) are placed according to company drill hole data or, where unavailable, by average thickness (dashed lines) based on measured sections and/or nearby drill hole information (Stott, 1968 & 1973; Duff & Gilchrist, 1981; Carmichael, 1983).

Sample numbers are plotted to the left of the drill holes and non-ubiquitous species are plotted on the right (Note: this is reversed where space between adjacent drill holes is limited). Type of palynomorph is distinguished by; an absence of parentheses for pollen and spores, square parentheses for dinocysts and acritarchs, and curved parentheses for algal cysts and fungal spores. The presence and relative abundance of ubiquitous dinocysts and acritarchs is also indicated to assist in the recognition and correlation of marine strata. The occurrence of coal, as single or multiple seams exceeding 0.5 meters in thickness, is plotted where geophysical or stratigraphic information is available.

The palynologic contacts (dotted lines) separate marine from non-marine strata based on the presence or absence of marine dinocyst and acritarch species. Although spores and pollen are not uncommon in marine strata, particularly restricted marine (or near shore) facies, dinocysts and acritarchs are absent from terrestrial strata with the exception of occasional flood or storm deposited specimens. In addition to recognizable marine and non-marine (terrestrial) palynologic zones, there are parts of the section in which the samples contain only rare ubiquitous species and abundant recyclants, or no palynomorphs whatsoever. The distribution of these 'barren' samples is consistent enough to allow them to be recognized as distinct palynologic units.

Two types of marine zones, open marine and restricted marine, are identified in this study based on the type(s) of palynomorph(s) present, and the relative abundance and diversity of each. Open marine strata are characterized by an abundant and diverse dinocyst/acritarch assemblage and an absence of pollen and spores, algal cysts and fungal spores. Restricted marine strata contain all types of palynomorphs in relative abundances that reflect proximity to open marine or terrestrial environments.

Terrestrial strata are characterized by an absence of dinocysts and acritarchs (except as qualified earlier), and the presence of variable quantities of pollen and spores, plus or minus algal and fungal debris. Barren zones, considered here to be predominantly non-marine, are characterized by an absence of diagnostic species and/or the presence of a large number of recycled specimens, or by a total absence of palynomorphs.

It should be emphasized here that the palynologic zones, as determined by the density of sampling used in this study, identify the prevailing depositional influence. Marine zones may contain non-marine strata and vice versa.

The marine/non-marine units have been determined solely on the basis of palynologic evidence. Placement of a palynologic boundary is somewhat arbitrary depending on the distance between samples in a vertical section. Occasionally, coal will persist along, or close to, palynologic horizons and a boundary will be placed to emphasize probable

concurrent episodes of coal development without compromising palynologic data.

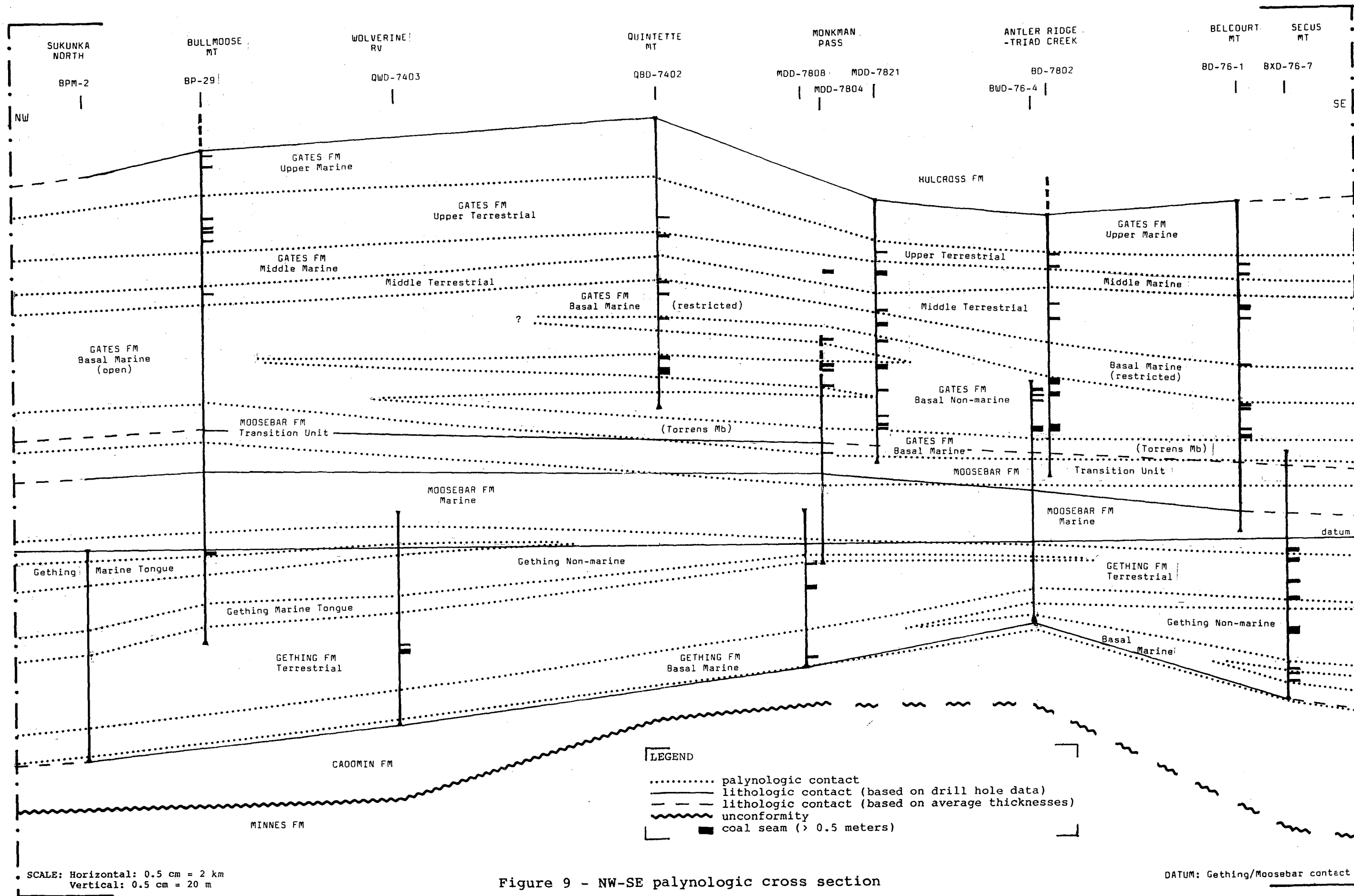
Comparison of the palynologic section with the lithologic section reveals a strong correlation between palynologic boundaries and lithologic breaks. Many of the lithologic units of Duff & Gilchrist (1981), determined largely on geophysical and paleontological evidence, are confirmed and refined by this study. A sedimentological study of the Moosebar-Gates section from Wolverine River to Secus Mt. by Carmichael (1983) resulted in detailed lithologs of a number of drill holes, including 3 sampled for this study. Comparison of several of these lithologs with the palynologic section (Fig. 10) reveals that palynologic boundaries frequently coincide with lithologic breaks. In many instances agreement between the two is maintained through facies changes where coarse and fine, or coal-bearing and non-coal-bearing relationships are stratigraphically reversed, making lithologic correlation extremely difficult. Carmichael's work has been relied on extensively to describe the lithologic changes, both vertical and lateral, that occur in the palynologic section in order to provide a familiar point of reference for others working in the area.

Figure 8 is a plot of species ranges based on the zonation established in Figure 7. The species list includes all non-ubiquitous species which occur more than once in a sample and/or in more than one sample. Single specimens

(listed in Appendix II) are omitted from Figure 8 since they are not considered reliable for zonation, although they are included on Figure 7. The exceptions to this are single specimens of any species not found in the literature and presumed to be new. Descriptions of new species are being prepared by the author for future publication.

The diagram shows the total species assemblage which characterizes each unit as well as the species unique to the zone. Solid lines indicate the presence of a species in a unit; dotted lines indicate the likely occurrence of a species in a zone based on the range established in this study. Dinocyst and acritarch species are not presumed to occur in non-marine units. Algal and fungal material, despite the restricted ranges shown, are not relied on heavily for zonation and interpretation for several reasons: initial identifications of palynomorphs, done on the Gething samples, concentrated on pollen, spores and dinocyst species and may have resulted in failure to recognize algal and fungal material; algal cysts and fungal spores commonly are not reported in the literature and; the geological significance (ie. range, depositional environment) of most species is not well documented. They are included in the zonation and illustrated in the plates in order to help rectify this omission.

The number of species, total and restricted, reported in the text for each zone is taken from Figure 8. As more palynologic work is done the zonation can be refined to



include some of the 50 pollen and spore species and 35 dinocyst/acritarch species which occur as single specimens, and whose ranges have not been determined.

Figure 9 summarizes the information on Figure 7. Six major marine transgressions, defined here as marine strata which can be correlated the entire length of the study area, and four minor marine incursions have been identified. Major transgressions occur at the base of the Gething Formation, in the lower half of the Moosebar Formation, at the base and the top of the basal Gates marine/non-marine unit, in the upper middle Gates, and at the top of the Gates Formation. Two marine tongues are identified in the upper half of the Gething, and another two occur in the basal Gates marine/non-marine unit, all in the northwest half of the study area.

The intervening non-marine strata, representing marine regressions, occur; in the Gething Formation above the basal marine unit and below the marine tongues; in the Basal Gates marine/non-marine unit in the southeast half of the study area. Two more are present in the upper half of the Gates Formation. Barren zones are identified above the marine tongues in the Gething, and in the upper half of the Moosebar Formation.

Gething Formation - The marine unit at the base of the Gething Formation is approximately 30 meters thick from Sukunka to Monkman Pass. Southeast of Monkman it splits into an upper and lower tongue. The upper tongue thins

rapidly and may be absent southeast of Secus Mt.. The lower tongue maintains a thickness of 20-30 meters, but evidence suggests that it splits again in the vicinity of Secus Mt., and that both tongues persist beyond the limits of the study area. The unit contains both marine and non-marine palynomorphs indicating a restricted marine environment, with the terrestrial influence notably stronger in the southeast (Fig. 7). There are four spore species (Clavatipollenites couperii, C. minutus, Cooksonites reticulatus, Podocarpidites naumovai) and one dinocyst species ('dino sp. A') exclusive to the Gething basal marine unit.

Although Dave Gibson (pers. comm.) found evidence of the marine influence at the bottom of QWD-7403, there appears to be no lithologic or geophysical means of consistently recognizing the basal marine unit other than its stratigraphic position immediately above the Cadomin Formation. Outside the study area, and in regions where the Cadomin/Gething contact is in doubt, paleontologic (particularly palynologic) work may provide the only evidence of its presence.

The Gething strata which lie between the basal marine unit and the lower marine tongue (fig. 9) are considered to be terrestrial, despite poor recovery of palynomorphs. Only a single spore species (Reticulisporites semireticulatus), of the 12 present in the Gething Formation (Fig.8), is confined to the non-marine zone. The unit contains numerous

ubiquitous species and recyclants, although many of the samples are barren. The poor preservation and pervasive recycling are consistent with the interpretation by Stott (1973) of deposition into the fluctuating, moderate to high energy conditions of an alluvial-deltaic environment.

The upper half of the Gething Formation north of Quintette contains two marine tongues. The lower tongue is approximately 30-35 meters thick between Sukunka North and Bullmoose Mt., and thins to less than 10 meters at Monkman Pass. Palynologic evidence suggests that it extends as far south as the Antler Ridge/Triad Creek region. The upper marine tongue is also approximately 35 meters thick at Sukunka North but thins rapidly and disappears just south of the Wolverine section. Of the 12 spore species and 4 dinocyst species found in the Gething, 2 spore (Coptospora striata, Cicatricosisporites potomacensis) and 2 dinocyst species (Apteodinium sp., Palaeoperidinium sp.) are restricted to these marine zones. No attempt was made to distinguish the upper and lower tongues palynologically, since there is insufficient data to do this reliably.

The marine influence in the upper half of the Gething Formation has been identified by Duff & Gilchrist (1981) using geophysical (and paleontological) evidence. Duff & Gilchrist describe their Gething Marine Tongue as "... several coarsening upward sequences that apparently represent a rapid transgressive cycle and a somewhat slower regressive cycle." (p. 12). "(It) may also extend up in the

section to include the next coarsening upward sequence." and "... would extend up to just below the Chamberlain seam...". The upper marine tongue identified in this study does indeed lie just below the Chamberlain seam, suggesting that the coarsening upward cycles which Duff & Gilchrist identify as probable marine transgressions are equivalent to the marine tongues identified palynologically. The intervening 'slower regressive cycle' is, palynologically, a barren zone except for a few ubiquitous spore species in the extreme northwest.

The strata which overlie the marine tongues are also barren of palynomorphs. This zone, referred to by Duff and Gilchrist as the Chamberlain Member, is an important coal-bearing unit of limited lateral extent. Approximately 25 meters thick at Bullmoose Mt., it thins rapidly to the southeast, disappearing between Wolverine River and Quintette Mt.. Duff and Gilchrist indicate that the coal zone also thins in a northwesterly direction, cut off by marine strata. At present no palynologic data are available for the region north of Bullmoose Mountain.

The barren strata in the upper part of the Gething Formation do not differ significantly from the underlying terrestrial strata and are presumed to have been deposited under similar conditions.

Moosebar Formation - The base of the Moosebar Formation is identified palynologically by the first major influx of marine species (Fig. 7). A lower marine zone containing 27 dinocyst and acritarch species and 30 spore species (Fig 8),

and an upper 'Transition Unit' completely barren of palynomorphs make up the Moosebar Formation.

The marine unit varies in thickness from 100 meters in the northwest to 70 meters in the southeast and is characterized palynologically by 9 dinocyst/acritarch species and 5 spore species (Fig. 8). Although it is dominated by marine species throughout most of the study area, indicating open marine conditions, there is an increase in terrestrial palynomorphs in the Mt. Belcourt - Secus Mt. region, suggesting proximity to a terrestrial source. In addition, three of the drill holes contain a single barren sample in the middle of the marine sequence, and a fourth hole contains a sample with only a few spores, indicating a regressive or emergent phase at this level (Fig. 7).

Lithologically, the Moosebar marine unit consists of 2 or 3 coarsening-upward cycles of fine to silty black shales (Leckie, 1981; Carmichael, 1983). At most locations the top of the second coarsening-upward cycle corresponds to the regression identified palynologically (Fig. 10).

Although the palynologic boundary between the Moosebar and Gething formations is fairly consistent with the lithologic contact in the southern half of the study area, it lies above the Gething/Moosebar contact in the northern half. This may be due in part to the presence of marine strata so close to the top of the Gething, and to the discontinuous nature of the 'Chamberlain Member' and the coal within it, making the lithologic contact somewhat

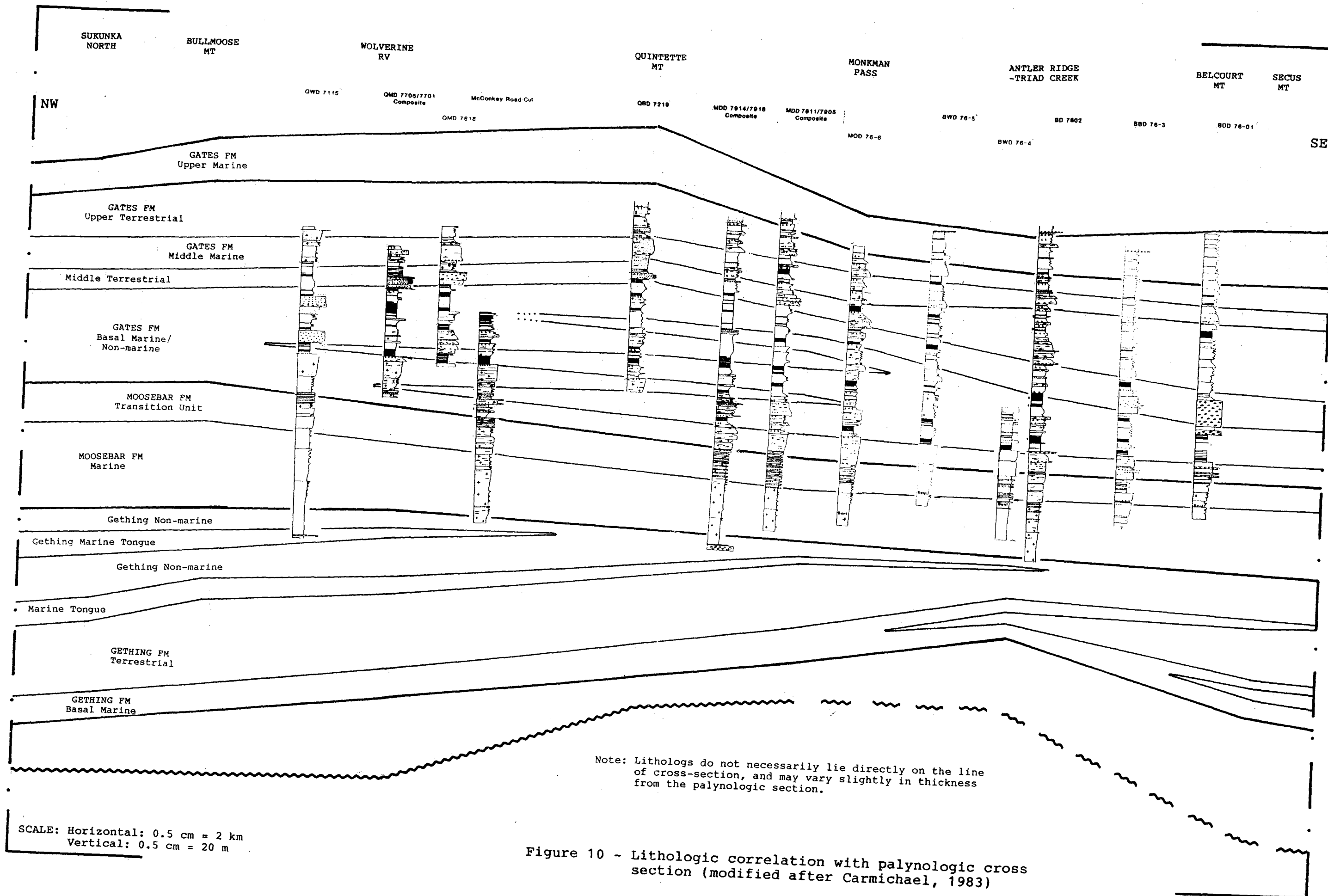


Figure 10 - Lithologic correlation with palynologic cross section (modified after Carmichael, 1983)

difficult to locate accurately. Speculation by Duff and Gilchrist (1981) that their Gething Marine Tongue correlates to the Moosebar marine north of Bullmoose Mt. is not supported by palynologic evidence. Of the 32 zoneable marine species in the two formations, only a single dinocyst species was found to be common to both (Fig. 8).

The 'Transition Unit' lying above the marine shales is distinguished by a total absence of palynomorphs. The unit thins from 40 meters in the northwest to 30 meters in the southeast. Lithologically it is recognized by the introduction of bedded siltstones and sandstones into the dark shales, but the amount of coarse material is highly variable across the section. A comparison of the palynologic section with lithologs (Fig. 10) described by Carmichael (1983), indicates that between Wolverine Rv. and Quintette Mt. in the northwest, and south of the Antler Ridge/Triad Crk. section, the Transition Unit consists of thick-bedded siltstones and sandstones overlain by thin interbeds of sandstone, siltstone and shale. In the intervening region the unit consists only of thin-bedded sandstone, siltstone and shale. Thin coals are occasionally present near the top. At Mt. Spieker in the northwest, Leckie (1981) describes a section similar to the Wolverine/Quintette section, which he divides lithologically between the thick-bedded coarse material and the overlying finer sediments, placing the former at the top of one coarsening-upward cycle and the latter at the base of a second cycle. Outside of

his study area this division into coarsening upward cycles is not always apparent, and would likely result in the correlation of different stratigraphic horizons. The 'Spieker Member' of Duff & Gilchrist (1981) "includes all strata between the mudstone member and the clean well-sorted sandstone of the upper Torrens member." and is equivalent to the Transition Unit with the exception of the top few meters, considered here to be palynologically part of the overlying unit (Torrens Mb). This is explained more fully in the following section.

Gates Formation - The base of the Gates Formation, as interpreted in this study, occurs as an influx of marine palynomorphs above the barren 'Transition Unit'. The Gates contains 3 major, palynologically distinct marine units: a basal marine unit which is divided into an upper and lower zone by a non-marine wedge, a middle marine unit, and an upper marine unit which marks the top of the formation. Non-marine strata are present in the basal Gates unit, immediately above the basal marine/non-marine unit and between the middle and upper marine units (Fig. 9).

The basal Gates unit is predominantly open marine in the northwest, rapidly giving way to a complex pattern of intertonguing marine and non-marine strata and, further southeast, to upper and lower restricted marine tongues, separated by 60 meters (on average) of non-marine strata. The zone is characterized by 29 dinocyst and acritarch

species, 7 of which are restricted to this unit, and 41 spore species, 9 of which are restricted (Fig. 8).

At Bullmoose Mt. in the northwest, open marine conditions are indicated by a 100 meter thick succession containing an abundant and diverse dinocyst/acritarch assemblage. A few non-marine species near the middle and top of the succession (Fig. 7) indicate occasional regression. Four of the lower Gates 7 dinocyst species (54,179,181,286) appear to be exclusively open marine.

Between Bullmoose and Quintette Mts. palynologic data are lacking. A somewhat simplified interpretation of the intertonguing of marine and non-marine strata (Fig. 7) is based on a northward projection of the information from Quintette Mt. and Monkman Pass, and on comparison with lithologs from Carmichael's study (Fig. 10). The data indicate that restricted marine conditions persist throughout the study area at the base and top of the Gates basal marine/non-marine unit, and that at least 2 minor marine transgressions penetrate as far south as Monkman Pass. South of Monkman Pass a thick succession of non-marine strata lies between the upper and lower restricted marine zones.

The lower restricted marine zone is characterized palynologically by an assemblage of dinocysts, spores, algal cysts and fungal material. Of the 7 dinocysts restricted to the Gates marine/non-marine unit, 2 (Fromea amphora,

Hystrochokolpoma 'sp. A') are found exclusively in this lower marine zone.

Carmichael's drill hole lithologs indicate that this zone consists primarily of resistant, thick-bedded sandstone, containing thin interbeds of conglomerate in the southeast, becoming finer in the northwest (Fig. 10). Lithologic and palynologic data show that the zone varies only slightly in thickness from 25 to 30 meters across most of the section, possibly reaching a minimum thickness of 20 meters in the northwest part of the study area.

This lower marine zone has been mapped in whole or in part as the Torrens Member by a number of other workers. Carmichael (1983) accurately identifies the sandstone in most of his drill holes, but occasionally correlates it with thick non-marine sandstones of the underlying 'Transition Unit'. The "clean, well-sorted sands" mapped by Duff & Gilchrist (1981), using geophysical logs, are highly variable in thickness (from 5 to 20 meters), and correspond to the top of the marine sandstones identified palynologically. A closer look at the geophysical logs indicates a slight coarsening-upward cycle just below these 'clean sands'. At most locations the combined thickness of the coarsening upward cycle and the clean sands that overlies it ranges from 25 to 30 meters. Leckie (1981) identifies this sandstone unit at Mt. Spieker at the top of his 'Torrens/Sukunka Member'. He describes an "amalgamated sandstone" which is "20 to 30 m thick and occurs as a

continuous body, with occasional thick conglomeratic lenses, across the whole of the study area. Conglomerate lenses excluded, there is an overall upward increase in grain size from very fine, or fine grained to medium grained sandstone." (p. 22).

Recognition of the Torrens Member in the field has resulted in much confusion and likely will continue to do so. As Carmichael points out "Coal companies working in the Foothills of northeastern British Columbia generally refer to the first thick sandstone interval beneath the lowermost economic coal seam as the Torrens Member." (p. 14). Coal is present immediately above the Torrens Member only in the region south of Quintette, where the sandstone is overlain by thick non-marine deposits. North of Quintette Mt. the coal occurs above a stratigraphically higher marine sandstone, which marks the first minor transgression into the Monkman area (Fig. 10).

The marine sandstones of the Torrens Member are considered by some workers to mark the top of the Moosebar Formation (Duff & Gilchrist, 1981; Leckie, 1981), while others consider it to be equivalent to the basal Gates Formation (McLean, 1982; Carmichael, 1983). Palynologic evidence strongly supports the interpretation of the Torrens Member as basal Gates. Although a distinct, restricted marine unit in the southeast, it is palynologically inseparable from the open marine strata of the basal Gates in the northwest. In addition, none of the 8 marine species

found in the Torrens Member (Fig. 7) are restricted exclusively to the Torrens Member and Moosebar marine shales. The two units, in fact, are separated by the palynologically barren 'Transition Unit' (Fig. 8).

Above the Torrens Member in the northwest half of the study area is a thickened succession of intertonguing marine and non-marine strata. Although palynologic data are lacking between Bullmoose and Quintette Mts., the consistency of the data at Quintette and Monkman Pass allows reasonable extrapolation into this region (Fig. 7). A marine regression lying immediately above the Torrens Member over much of the study area stopped short of Bullmoose Mt., and was followed by a minor transgression into the Monkman Pass region. Carmichael (1983) is able to identify this transgression in part, as the 'Sheriff Member' but none of the drill holes used in his study penetrate deep enough to allow him to accurately identify the base of the transgression, and facies changes prevent him from tracing it south of Quintette Mt. A second regression probably reached Bullmoose Mt. in the northwest, as evidenced by the presence of several non-marine species in the middle of the open marine sequence. The transgression overlying this can also be traced southward to Monkman Pass. A third regression shown just north of Quintette Mt. is located primarily on the basis of abundant spores, relative to dinocysts, and a persistent coal horizon (Fig. 10) at this position in the section.

Detailed sedimentologic work by Carmichael (1981) in the region from Secus Mt. to Wolverine River, and by Leckie (1981) between Wolverine River and Bullmoose Mt., provide excellent lithologic evidence for accurately locating the transgressions and regressions north of Quintette Mt. Coal horizons in particular (Fig. 10) are strongly developed at the base and/or top of non-marine strata where the transition with marine strata occurs, and can be used to trace the transgressions and regressions identified palynologically. Although Leckie recognizes a regressive phase immediately overlying his 'Torrens/Sukunka Member' at Mt. Spieker, and two more transgressive/regressive cycles in the overlying basal Gates (his Cycle 3), it would be unwise to equate these regressions to the three found in this study. The large number of coal horizons in the basal Gates Formation between Wolverine River and Quintette Mt (Fig. 10) suggests that the intertonguing of marine and non-marine strata is more complex than can reasonably be extrapolated from present palynologic and lithologic information.

The top of the basal Gates unit is marked by a second major transgression (the upper restricted marine zone on Fig. 9). A 40 meter thick sequence of restricted marine strata, characterized by near equal numbers of marine and non-marine species, can be traced southward to Secus Mt. and beyond the study area. Two of the 7 basal Gates dinocyst species (Ascotomocystis maxima, cf Kalyptea monoceras), and 8 of the 9 spore species (Callialasporites segmentatus,

Cerratosporites cf morrinicolus, Cibotiumspora juriensis, Concavissimisporites minor, Cooksonites variabilis, Densoisporites microrugulatus, Januasporites spiniferus, Polycingulatisporites 'sp. A') are restricted to the upper marine unit.

The upper restricted marine unit and the open marine strata to the northwest correspond to the Gates Marine Tongue of Duff & Gilchrist (1981).

The non-marine component of the basal Gates marine/non-marine unit lies immediately above the Torrens Member. It is 30 meters thick in the southeast, increasing to 90 meters at Monkman Pass where it first begins to interfinger with marine strata. The unit contains only 1 characteristic spore species (Psilatricolpites parvulus) and is a major coal-bearing succession. It corresponds approximately to the Sandy Coal-bearing Unit of Duff & Gilchrist (1981), which they trace as far northwest as Sukunka River using geophysical logs. Palynological evidence indicates that all strata in the lower Gates from Bullmoose Mt. northwest are predominantly marine.

The Gates middle terrestrial unit lies above the basal marine/non-marine unit and contains 17 spore species, 4 of which are exclusive to this zone (Fig. 8). It consists of 80 meters of strata at Belcourt Mt. in the southeast, but thins rapidly to 20 meters at Monkman Pass. It appears to maintain this thickness to the northwest limit of the study

area, although it may pinch out or interfinger with marine strata in the vicinity of Bullmoose Mt..

Lithologically the unit may be recognized at most locations by an influx of coarse material (Fig. 10) above the finer, coal-bearing sediments of the restricted marine zone at the top of the underlying basal Gates unit. However, south of the Antler Ridge/Triad Creek section this relationship appears to be reversed; the underlying restricted marine tongue is coarser and contains thick conglomerates, whereas the thickened terrestrial strata become finer-grained and coal-bearing (Fig. 10).

A thin, restricted marine unit overlies the middle non-marine unit. It is identified palynologically by the presence of a few zoneable, and numerous ubiquitous marine species, in a thin zone between two distinctly non-marine zones. Of the 25 non-marine and 4 marine species present, only 3 spores and a single dinocyst species are exclusive to this unit (Fig. 8). It thins from 30 meters in the northwest to 10 meters in the southeast.

The middle marine unit is dominated by sandstone, but becomes coal-bearing in the Monkman Pass region. Carmichael (1983) identifies this, and the coarse non-marine strata of the underlying middle terrestrial unit, as the marine 'Babcock Member'. He traces it with confidence from Wolverine River southward to the region north of Monkman Pass, and then with some uncertainty to just south of Monkman where the coal is present. The facies changes which

occur in this region make the unit virtually impossible to trace lithologically south of Monkman.

The Gates upper terrestrial zone is only weakly defined, both palynologically and lithologically. Palynologically, it is recognized as a thin zone lacking marine species between two marine units. It contains a total of 19 spore species, 2 of which are unique to the zone (Fig. 8). The unit is thickest in the northwest (50-60 meters) and thins to 25-30 meters between Monkman Pass and Belcourt Mt.. Although this is a reversal of the normal trend, gaps in sampling of the upper Gates at Bullmoose and Quintette Mts., and the distance between the two sections, may obscure a more complex relationship between marine and non-marine strata in this region.

Lithologically, the upper terrestrial unit is quite variable, making it difficult to distinguish from the underlying and overlying marine units. However, two or three thin coal horizons persist throughout.

The top of the Gates Formation is restricted marine, and contains a rich assemblage of 24 marine and 44 non-marine species, including 4 species of dinocysts and 11 species of spores that are unique to this zone (Fig. 8). The Gates upper marine unit consists of 40-60 meters of predominantly thick-bedded sandstone, with minor siltstones, shales and thin coals.

Age Determination

According to Singh (1975) the appearance of early angiosperm pollen in North America follows a consistent pattern with respect to time, and allows fairly accurate dating of mid-Cretaceous rocks. Monosulcate (reticulate) grains first appear in sediments in the Eastern United States in Barremian-Aptian time, but in Western Canada and United States they have not been recorded in strata older than Middle Albian. Tricolpate (reticulate) grains make their appearance in Middle Albian rocks throughout North America, and tricolporate (smooth, triangular) grains mark the Albian-Cenomanian boundary.

In the present study several monosulcate pollen species (Clavatipollenites hughesii, C. couperii, C. minutus) have been found throughout the Gething Formation and a single tricolpate grain (Tricolpites crassimuras) is present near the top of the Gething terrestrial unit. Another tricolpate grain (Psilatricolpites parvulus) was found in the non-marine horizon of the basal Gates unit. Tricolpites crassimuras was recorded by Singh (1971) from late Middle Albian to early Late Albian rocks in northwestern and central Alberta, but he notes an Albian age for the species. Psilatricolpites parvulus was recorded in early Late Albian rocks by Singh (1971) and given a Late Albian to Cenomanian age in North America.

In addition a number of the non-ubiquitous species present in the coalfield strata are restricted in range to the Middle Albian in North America including:

Antulsporites distaverrucosus
Baltisphaeridium sp. A
Foveosporites canalis
Januasporites spinulosus
Klukisporites areolatus
Piceapollenites sp.

Several others range from the Late Albian upward including:

Lycopodiacidites caperatus
Murospora truncata
Oligosphaeridium anthophorum
Ascotomocystis maxima
Hystrichosphaeridium cooksoni

The palynological evidence indicates that the entire Gething through Gates section in the Peace River coalfield is of Middle Albian to early Late Albian age.

SUMMARY

With renewed interest in coal, a number of studies have been undertaken in the Peace River Coalfield in the past 10 years, with the express purpose of recognizing and correlating the complexly interfingered marine and non-marine strata. Although considerable progress has been made, rapid facies changes and the structurally disturbed nature of the strata, along with the absence of stratigraphically useful macrofossils make this task extremely difficult over distances greater than a few tens of kilometers.

The present palynologic study takes advantage of the economic development, and near ideal conditions of depositional setting and geologic age in order to resolve a number of problems of facies distribution, contact relationships, and nomenclature. Extensive drilling of the coalfield strata provides abundant, easily obtainable material for study. The coal-bearing strata, laid down in a marginal marine setting, is rich in both marine and non-marine palynomorphs which exhibit overlap in near shore environments and provide a means of correlating strata where sedimentologic methods fail. The Lower Cretaceous age of the rocks ensures an abundant and diverse assemblage which enhances correlation of the strata within the coalfield and with outlying areas, and provides a reliable means of dating the rocks.

One hundred and ninety nine core samples, representing almost 3000 meters of section from the Gething, Moosebar and Gates formations in the southern half of the coalfield, have been examined for palynomorphs. Of the 350 species of pollen, spores, dinoflagellate cysts, acritarchs, algal cysts and fungal spores identified 94 are ubiquitous and the remaining 256 are restricted in their occurrence to specific formations or zones within a formation.

The type and relative abundance of palynomorph indicate the general depositional setting, and allow identification of open marine, restricted marine, and non-marine environments. Palynologically barren zones also represent

distinct environmental conditions. Both ubiquitous and restricted species are used to identify the marine and non-marine zones, and to correlate these zones throughout the coalfield, or with facies equivalent strata.

The Gething Formation consists of a thin restricted marine deposit which marks the base of the formation in the study area; a thick non-marine succession characterized palynologically by a few zoneable and ubiquitous species and numerous recyclants; and two marine tongues which occur in the northern and upper half of the formation. The first of these transgressions penetrated as far south as the Antler Ridge/ Triad Creek region; the second went no further than the Quintette Mt. region and is overlain by a thin, discontinuous, non-marine wedge containing economic coal.

The Moosebar Formation is a thick succession of marine shales rich in palynomorphs, overlain by a thick, palynologically barren non-marine succession.

The Gates Formation consists of a complex pattern of alternating and interfingering marine and non-marine strata. At the base of the formation is a thick succession of open marine strata in the northwest, which rapidly gives way to restricted marine strata intertonguing with non-marine coal-bearing strata in the central part of the study area. To the southeast, the restricted marine conditions persist above and below a single non-marine zone. The thin marine zone underlying the terrestrial wedge is the marine sandstone of the 'Torrens Member'. The upper half of the

Gates Formation is made up of thin, alternating marine and non-marine units which appear to be continuous throughout the length of the study area. The basal marine/non-marine unit is overlain by a middle terrestrial unit which thickens in a southeasterly direction, and a thin middle marine unit. Above this lie an upper terrestrial unit, which appears to thicken in a northwesterly direction, but which may interfinger with marine strata near the northern limits of the study area, and a thick, restricted marine unit which marks the top of the Gates Formation.

The palynologic zones exhibit a strong correlation with lithologic horizons. Coal in particular is consistent in its occurrence along the transition zones between restricted marine and non-marine strata, and in terrestrial strata in close proximity to marine influence. In addition, several units which have been identified, in whole or in part, by other workers using sedimentological or geophysical means, including the Gething marine tongue, the Speiker and Torrens members and the Sandy coal-bearing member of Duff & Gilchrist (1981), the Sheriff and Babcock members of Carmichael (1983) and the Sukunka/Torrens member of Leckie (1981), are correlative with palynologic zones. For each of these examples the palynologic data more accurately define the upper, lower and lateral limits of the horizon, and trace it through lithologic (ie facies) changes.

The palynologic data, in addition to identifying and correlating the marine and non-marine strata, have resolved

the longstanding controversy surrounding the contact between the Moosebar and Gates formations, placing it below the clean, marine sandstone of the 'Torrens Member', and above the palynologically barren 'Transition Unit'. The data also provide answers to the more recent questions regarding the relationship of the Gething Formation to the underlying and overlying formations. The marine horizon at the base of the Gething Formation provides a means of accurately locating the contact between the Gething and Cadomin formations, particularly in the presence of thick conglomerates near the base of the overlying unit. The marine tongues at the top of the Gething are palynologically distinct from the overlying marine strata of the Moosebar Formation, and likely remain so, even to the northwest where the intervening coal-bearing terrestrial strata may be absent.

Based on the first appearance of a few monocolpate and tricolpate angiosperm species the coalfield strata can be assigned a Middle to Late Albian age. The Gething Formation at the base of the section is likely early to middle Middle Albian and the top of the section is no younger than late Middle Albian to early Late Albian. This age indicates that, at least within the southern half of the coalfield, a considerable amount of Lower Cretaceous strata is absent above the Jurassic-Cretaceous Minnes Formation.

CONCLUSIONS

A composite palynologic section has been established for the Lower Cretaceous rocks of the Peace River coalfield. The data have provided a wealth of information, which is used to zone, correlate and date the strata, as well as resolve a number of stratigraphic problems. With the groundwork laid, additional palynologic studies may be undertaken within the coalfield on a more detailed scale in order to accurately define and correlate the coal-bearing strata, or in outlying areas, in order to expand on the present knowledge.

For those working within the coalfield the palynologic cross-section provides a reference for comparison of lithologic information similar to the method used in this study, as well as a reliable fossil zonation for accurately identifying stratigraphic position in the section. For the latter, well chosen surface samples can be of as much value as drill core samples.

In other areas a palynologic study, although time consuming on a large scale, can be an extremely useful tool for resolving stratigraphic problems, particularly in regions where facies changes and structural deformation become major obstacles to the more conventional sedimentological methods of interpretation and correlation.

REFERENCES

- Adams, K.R. & Bonnett, R. (1969): Bute Inlet wax, Nature, Vol. 223, No. 5209, pp. 943-944.
- Alberta Study Group (1954): Lower Cretaceous of the Peace River Region, Western Canada Sedimentary Basin, Rutherford Memorial Vol., Amer. Assoc. Petro. Geol., Tulsa, Oklahoma, pp. 268-278.
- Bell, W.A. (1956): Lower Cretaceous floras of Western Canada, Geol. Surv. Canada, Memoir 285, 153 pp.,
- Brideaux, W.W. (1971): Palynology of the Lower Colorado Group, Central Alberta, Canada, Palaeontographica, Band 135, Abt. B, pp. 53-114,
- & Fisher, M.J. (1976): Upper Jurassic-Lower Cretaceous dinoflagellate assemblages from Arctic Canada, Geol. Surv. Canada, Bull. 259, 53 pp., 7 plates.
- & McIntyre, D.J. (1975): Miospores and Microplankton from Aptian-Albian rocks along Horton River, District of MacKenzie, Geol. Surv. Canada, Bull. 252, 85 pp., 14 plates.
- , McIntyre, D.J. & Young, F.G. (1977): Discussion of Pocock's dinoflagellate zonation of Upper Jurassic-Lower Cretaceous Canadian Arctic, Bull. Can. Pet. Geol., Vol. 25, pp. 1264.
- Burden, E.T. (1984): Terrestrial palynomorph biostratigraphy of the lower part of the Mannville Group (Lower Cretaceous), Alberta and Montana, in: The Mesozoic of Middle North America, Stott & Glass (eds.), Can. Soc. Petrol. Geol., Memoir 9, pp. 249-269, 4 plates.
- Carmichael, S.M. (1983): Sedimentology of the Lower Cretaceous Gates and Moosebar Formations, Northeast Coalfields, British Columbia, unpublished Ph.D. Thesis, University of British Columbia, 285 pp.
- Duff, P.McL.D. & Gilchrist, R.D. (1981): Correlation of Lower Cretaceous coal measures, Peace River Coalfield, B.C., B.C. Ministry of Energy, Mines and Petrol. Res., Paper 1981-3, 31 pp.
- Hay, W.W. (1972): Probabilistic stratigraphy, Ecologiae geol. Helvet., Vol. 65, pp. 255-266.
- Hedlund, R.W. & Norris, G. (1968): Spores and pollen grains from Fredricksburgian (Albian) strata, Marshall County, Oklahoma, Pollen et Spores, Mus. Nat. D'Hist. Naturelle, Vol.X, No. 1, pp. 129-159, 9 plates.

- Hughes, J.E. (1964): Jurassic and Cretaceous strata of the Bullhead succession in the Peace and Pine River Foothills, British Columbia Dept. Mines, Bull. 51, 73 pp.
- (1967): Geology of the Pine Valley, British Columbia Dept. Mines, Bull. 52, 137 pp.
- Hughes, N.F., Drewry, G.E. & Laing, J.F. (1979): Barremian earliest angiosperm pollen, Palaeontology, Vol.22, Pt.3, pp. 513-535, 8 plates.
- Kummel, B. & Raup, D. (1965): Handbook of Paleontological Techniques, W.H. Freeman & Co., San Francisco, London, 852 pp.
- Leckie, D.A. (1981): Shallow-marine transitional to non-marine sedimentation in the Upper Moosebar - Lower Gates Member, Fort St. John Group, N.E. British Columbia: storm and tidally influenced shorelines, Tech-Memo 81-1, McMaster University, Hamilton, 64 pp.
- & Walker, R.G. (1982): Storm- and tide-dominated shorelines in Cretaceous Moosebar - Lower Gates interval - outcrop equivalents of Deep Basin gas traps in Western Canada, Amer. Assoc. Petro. Geol. Bull., Vol. 66, pp. 138-157.
- Manum, S.B., Bjaerke, T., Throndsen, T. & Eien, M. (1976): Preservation and abundance of palynomorphs, and observations on thermal alteration in Svalbard, Norsk Polarinstitutt Arbok, Oslo, 1977, pp. 121-130.
- & Cookson, I.C. (1964): Cretaceous microplankton in a sample from Graham Island, Arctic Canada, collected during the second "Fram"-Expedition (1898-1902) - with notes on microplankton from the Hassel Formation, Ellef Ringnes Island, Skrifter Utgitt av Det Norske Videnskaps-Akademi i Oslo, I. Mat-Naturv. Klasse. Ny Serie. No. 17, 36 pp., 7 plates.
- McGregor, D.C. (1965): Triassic, Jurassic and Lower Cretaceous spores and pollen of Arctic Canada, Geol. Surv. Canada, Paper 64-55, 32 pp.
- McLean, J.R. (1977): The Cadomin Formation: stratigraphy, sedimentology, and tectonic implications, Bull. Can. Petrol. Geol., Vol. 25, pp. 92-827.
- (1982): Lithostratigraphy of the Lower Cretaceous coal-bearing sequence, Foothills of Alberta, Geol. Surv. Canada, Paper 80-29, 31 pp.

- & Wall, J.H. (1981): The Early Cretaceous Moosebar Sea in Alberta, Bull. Can. Petrol. Geol., Vol. 29, pp. 334-377.
- McLearn, F.H. (1921): Mesozoic of Upper Peace River, British Columbia, Geol. Surv. Canada, Summ. Rept. 1920, Pt. B, pp. 1-6.
- , (1923): Peace River Canyon Coal Area, British Columbia, Geol. Surv. Canada, Summ. Rept. 1922, Pt. B, pp. 1-46.
- , (1931): The Gastroplites and other Lower Cretaceous faunas of the Northern Great Plains, Trans. Roy. Soc., Canada, 3rd Ser., Vol. XXV, Sec. IV, pp. 1-8.
- , (1940): Notes on the geography and geology of the Peace River Foothills, Trans. Roy. Soc., Canada, 3rd Ser., Vol. XXXIV, Sec. IV, pp. 63-74.
- , (1948): New Lower Cretaceous species, Appendix, Geol. Surv. Canada, Paper 44-17, 2nd Ed.
- Norris, G. (1967): Spores and pollen from the Lower Colorado Group (Alb.? - Cenom.) of Central Alberta, Palaeontographica, Series B, Vol. 120, pp. 71-115, 18 plates.
- , (1982): Mesozoic palynology of the Moose River Basin, in Mesozoic Geology and Mineral Potential of the Moose River Basin, Telford & Verma (eds.), Ontario Geological Survey, Study 21, pp.93-133, 12 plates.
- , Jarzen, D.M. & Awai-Thorne, B.V. (1975): Evolution of the Cretaceous terrestrial palynoflora in Western Canada, in: The Cretaceous System in the Western Interior of North America, W.G.E. Caldwell (ed.), Geol. Assoc. Canada, Spec. Paper No. 13, pp. 333-364, 3 plates.
- , Telford, P.G. & Vos, M.A. (1976): An Albian microflora from the Mattagami Formation, James Bay Lowlands, Ontario, Can. Jour. Earth Sc., Vol. 13, No. 2, pp. 400-403.
- Paden-Phillips, P. & Felix, C.J. (1971): A study of Lower and Middle Cretaceous spores and pollen from the southeastern United States; I- Spores, in Pollen et Spores, Mus. Nat. D'Hist. Naturelle; Publ. trimestrielle, Vol. XIII, No. 2, (Aug. 1971), pp. 279-348, 12 plates.
- Playford, G. (1971): Palynology of basal Cretaceous (Swan River) strata of Saskatchewan and Manitoba, Palaeontology, Vol. 14, Pt. 4, pp. 533-565, 5 plates.

- Pocock, S.A.J. (1962): Microflora analysis and age determination of strata at the Jurassic-Cretaceous boundary in the Western Canada Plains, Palaeontographica, Ser. B, Vol. 111, 95 pp., 15 plates.
- (1976): A preliminary dinoflagellate zonation of the uppermost Jurassic and lower part of the Cretaceous in the Canadian Arctic and possible correlation southward into the Western Canada Basin, Geoscience & Man, Vol. 15, pp. 104-114, 2 plates.
- Schiller, E.A., Santiago, S.P. & Plachner, W.A. (1983): Monkman coal property, British Columbia, Can. Inst. Mining Bull., Vol. 76, No.850 (Feb. '83), pp. 65-71.
- Schultheis, N.H. & Mountjoy, E.W. (1978): Cadomin conglomerate of western Alberta - a result of Early Cretaceous uplift of the Main Ranges, Bull. Can. Pet. Geol., Vol. 26, pp. 297-342.
- Shaw, A.B. (1964): Time in Stratigraphy, McGraw-Hill, New York, 365 pp.
- Singh, C. (1964): Microflora of the Lower Cretaceous Mannville Group, East-central Alberta, Res. Council. Alta., Bull. 15, 238 pp., 29 plates.
- (1971): Lower Cretaceous microfloras of the Peace River area, N.W. Alberta, Res. Council. Alta., Bull. 28, Vol. 1, pp. 1-299, 38 plates, & Vol. 2, pp. 300-542, 41 plates.
- (1975): Stratigraphic significance of early angiosperm pollen in the mid-Cretaceous strata of Alberta, in: The Cretaceous System in the Western Interior of North America, W.G.E. Caldwell (ed.), Geol. Assoc. Canada, Spec. Paper No. 13, pp. 365-389.
- Staplin, F.L. (1982): Determination of thermal alteration index from colour of exinite (pollen, spores), in: How to Assess Maturation and Paleotemperatures, Soc. Econ. Paleont. & Mineral., Short Course No. 7, pp. 7-11.
- Steeves, M.W. & Wilkins, L.K. (1967): Spores and pollen from the Lower Cretaceous of Saskatchewan, Canada. Part 1. Sporites, Can. Jour. Botany, Vol. 45, pp. 2329-2365, 8 plates.
- Stelck, C.R., Wall, J.H., Bahan, W.W. & Martin, L.J. (1956): Middle Albian foraminifera from Athabasca and Peace River drainage areas of Western Canada, Res. Council. Alta., Rep. No. 75, 60 pp.

- Sternberg, C.M. (1932): Dinosaur tracks from Peace River, British Columbia, Annual Report, 1930, National Museum of Canada, pp. 59-85, 5 plates.
- Stott, D.F. (1962): Cretaceous rocks of Peace River Foothills, Geol. Surv. Canada Reprint from Edmonton Geol. Soc. Guide Book 1962, pp. 22-45.
- (1968): Lower Cretaceous Bullhead and Fort St. John Groups, between Smokey and Peace Rivers, Rocky Mountain Foothills, Alberta and British Columbia, Geol. Surv. Canada, Bull. 152, 279 pp.
- (1973): Lower Cretaceous Bullhead Group between Bullmoose Mt. and Tetsa River, Rocky Mountain Foothills, northeastern British Columbia, Geol. Surv. Canada, Bull. 219, 228 pp.
- (1974): Lower Cretaceous coal measures of the Foothills of west-central Alberta and northeastern British Columbia, Can. Mining & Metal. Bull., Vol. 67, pp. 87-101.
- (1975): The Cretaceous system in northeastern British Columbia, in: The Cretaceous System in the Western Interior of North America, W.G.E. Caldwell (ed.), Geol. Assoc. Canada, Spec. Paper No.13, pp. 441-467.
- (1981): Bickford and Gorman Creek, two new formations of the Jurassic-Cretaceous Minnes Group, Alberta and British Columbia, Scientific and Technical Reports, Geol. Surv. Canada, Paper 81-1B, pp. 1-9.
- & Gibson, D.W. (1980): Minnes coal, northeastern British Columbia, Current Research, Part C, Geol. Surv. Canada, Paper 80-1C, pp. 135-137.
- Taylor, D.R. & Walker, R.G. (1984): Environments and paleogeography in the Albian Moosebar Formation and adjacent fluvial Gladstone and Beaver Mines Formations, Alberta, Can. Jour. Earth Sc., Vol. 21, pp. 698-714.
- Williams, G.L. & Stelck, C.R. (1975): Speculations on the Cretaceous paleogeography of North America, in The Cretaceous System in the Western Interior of North America, Caldwell (ed.), Geol. Assoc. Canada, Spec. Paper No. 13, pp. 1-20.

PLATE 1 - GETHING FORMATION

All specimens are shown at X1000 magnification
unless otherwise stated

- Figure 1: Murospora truncata Singh
- Figure 2: Cicatricosisporites potomacensis Brenner
- Figure 3: Reticulisporites semireticulatus (Burger) Norris
- Figure 4: Cyclonephelium distinctum var. brevispinatum
(Millioud) Lentin & Williams
- Figure 5: Cooksonites reticulatus Pocock
- Figure 6: Classopollis chateauvovi Reyre
- Figure 7: dino sp. A (nov. sp.)
- Figure 8: Palaeoperidinium sp. A Bujak & Williams

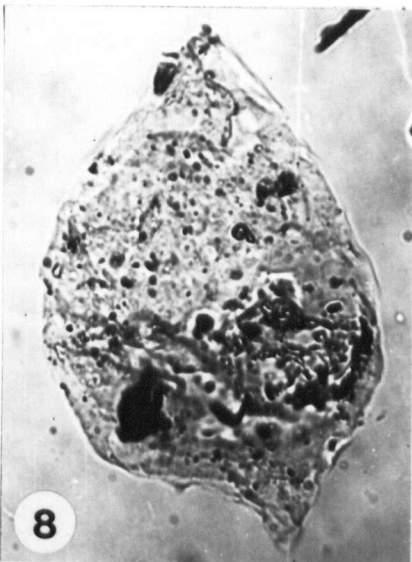
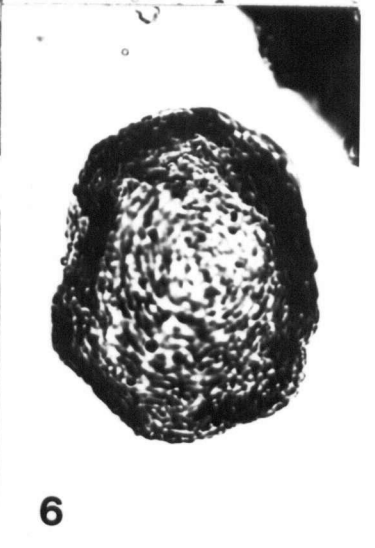
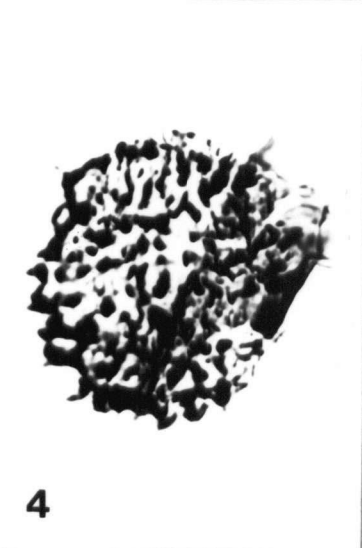


PLATE 2 - MOOSEBAR FORMATION

All specimens are shown at X1000 magnification
unless otherwise stated

- Figure 1: Undulatisporites fossulatus Singh, distal focus
2: same specimen; proximal focus
- Figure 3: Reticulisporites elongatus Singh
- Figure 4: Eucommiidites troedsonii (Erdtman) Hughes
- Figure 5: Piceapollenites sp. (cf Singh)
- Figure 6: Pinuspollenites sp. (X500)
- Figure 7: Cymatiosphaera pachythea Eisenack
- Figure 8: Hystrichokolpoma ferox (Deflandre) Davey
- Figure 9: Gardodinium eisenacki Alberti
- Figure 10: Cleistosphaeridium diversispinosum Davey et al
- Figure 11: Pareodinia cf aphelia Cookson & Eisenack (X500)
- Figure 12: Subtilisphaera perlucida (Alberti) Jain &
Millepied

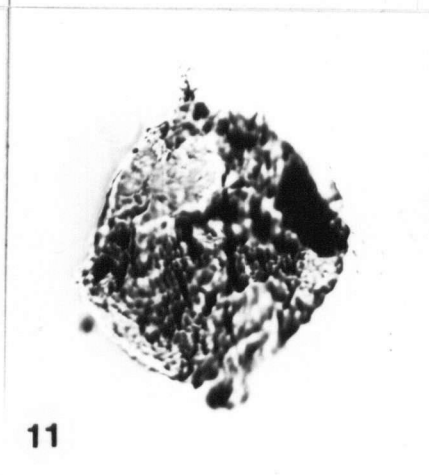
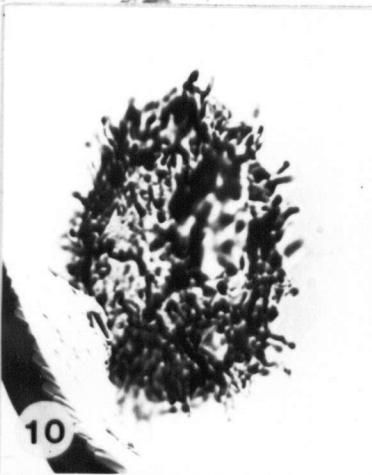
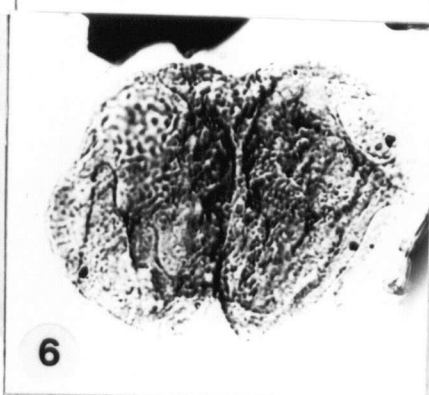
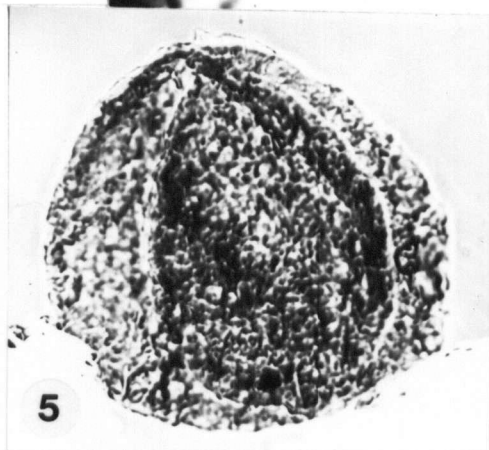
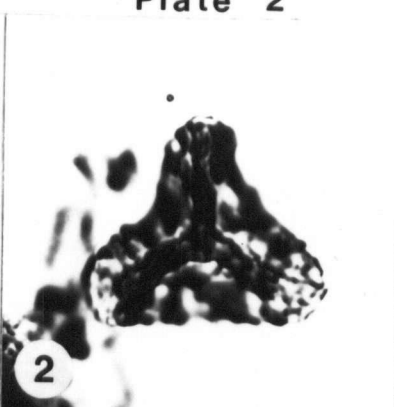


PLATE 3 - MOOSEBAR & GATES FORMATIONS

All specimens are shown at X1000 magnification
unless otherwise stated

- Figure 1: Trilobosporites apiverrucatus Couper
- Figure 2: Klukisporites aureolatus Singh
- Figure 3: Tanyosphaeridium sp. B (cf Brideaux)
- Figure 4: Cyclonephelium distinctum Deflandre & Cookson
- Figure 5: Cyclonephelium distinctum Deflandre & Cookson
- Figure 6: Baltisphaeridium sp. A Singh (X500)
- Figure 7: Spiniferites cingulatus (O. Wetzel) Davey &
Williams
- Figure 8: Odontochitina operculata (O. Wetzel) Deflandre
& Cookson (X500)
- Figure 9: Apteodinium maculatum Eisenack & Cookson (X500)
- Figure 10: Hystriospheridium stellatum Maier (X500)

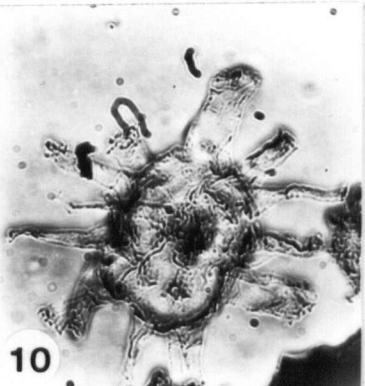
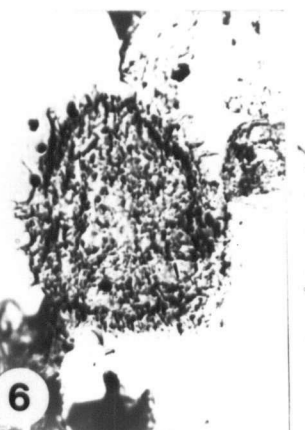
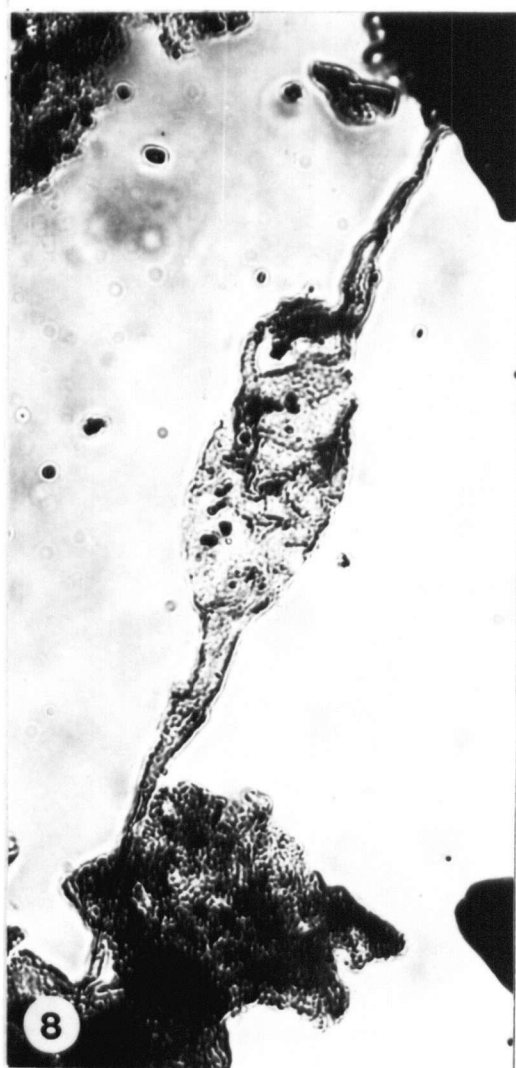
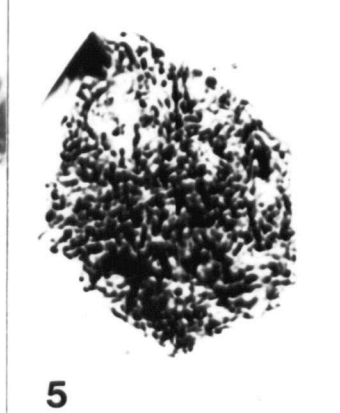
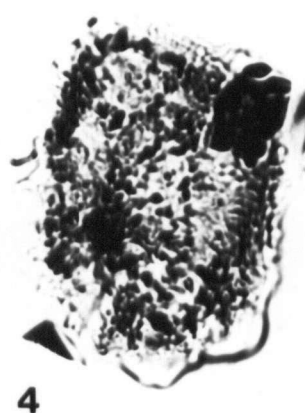
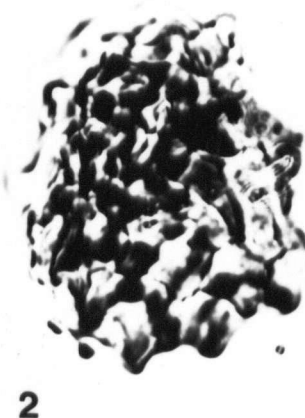
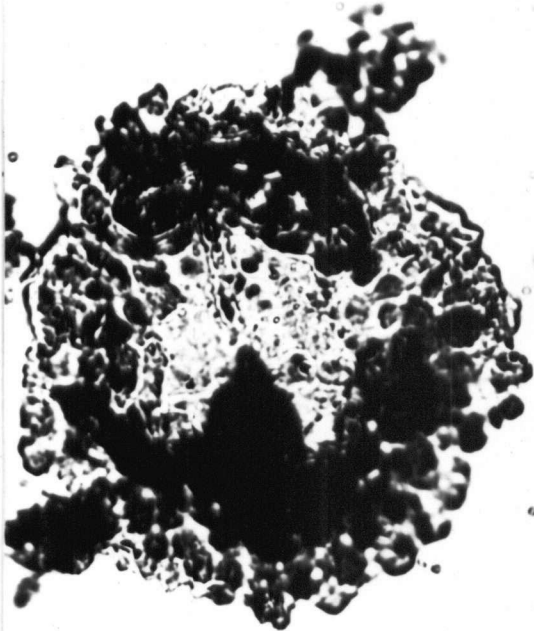


PLATE 4 - GATES FORMATION Basal Marine/Non-Marine Unit

All specimens are shown at X1000 magnification
unless otherwise stated

- Figure 1: Cooksonites variabilis Pocock
- Figure 2: Cibotiumspora juriensis (Balme) Filatoff
- Figure 3: Ceratosporites cf morrinicolus Srivastava
- Figure 4: Polysingulatisporites 'sp. A' (nov. sp.)
- Figure 5: Cleistosphaeridium multispinosum (Singh)
Brideaux (X500)
- Figure 6: Fromea amphora Cookson & Eisenack
- Figure 7: Spiniferites cingulatus (O. Wetzel) Davey &
Williams (X500)
- Figure 8: Callialasporites segmentatus (Balme) Sukh Dev
- Figure 9: Hystriochokolpoma 'sp. A' (nov. sp.)
- Figure 10: Ascotomocystis maxima Singh (X500)
- Figure 11: Gonyaulacysta cf episoma Sarjeant (X500)



1



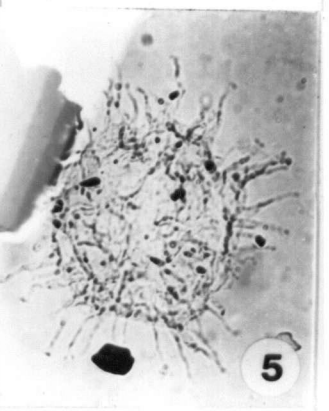
2



3



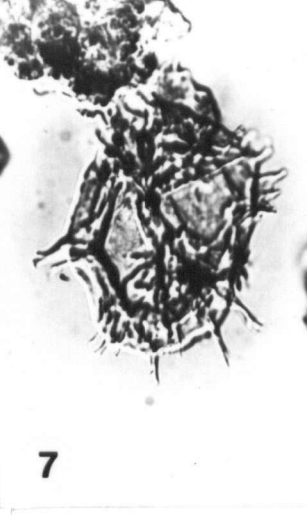
4



5



6



7



8



9



10



11

PLATE 5 - GATES FORMATION Middle Terrestrial Unit

All specimens are shown at X1000 magnification
unless otherwise stated

- Figure 1: Dictyotosporites complex Cookson & Dettmann
- Figure 2: Klukisporites pseudoreticulatus Couper
- Figure 3: 'spore sp. A' (nov. gen.)
- Figure 4: Dictyophyllidites equiexinuous (Couper) Dettmann
- Figure 5: Appendicisporites tricornitatus Weyland &
Greifeld; distal focus
- Figure 6: same specimen; proximal focus
- Figure 7: Lycopodiacidites cirniidites (Ross) Brenner
- Figure 8: Cingulatisporites distaverrucosus Brenner;
distal focus
- Figure 9: same specimen; proximal focus
- Figure 10: Contignisporites multimuratus Dettmann

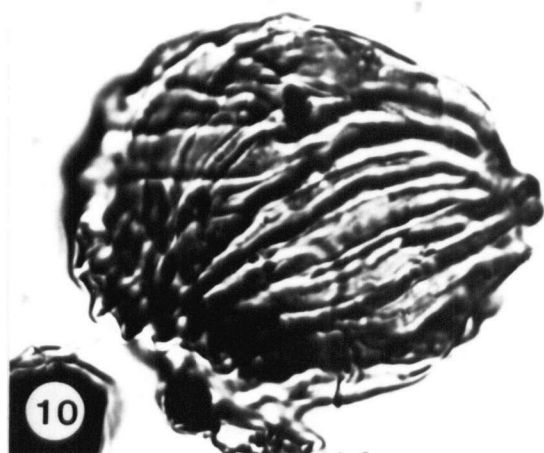
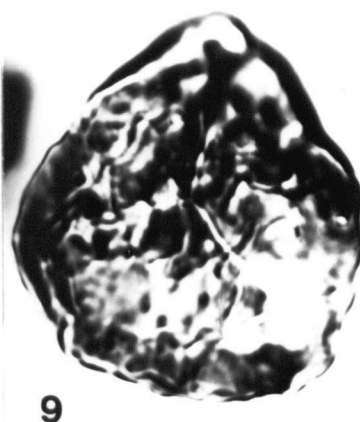
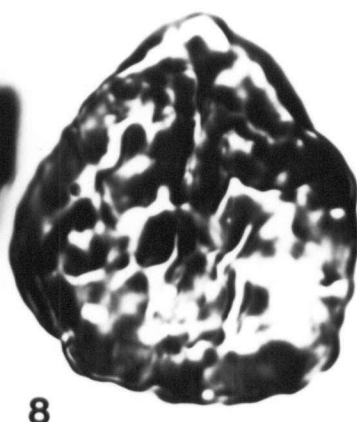
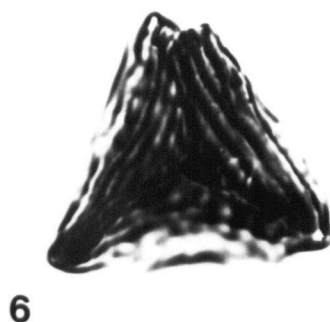
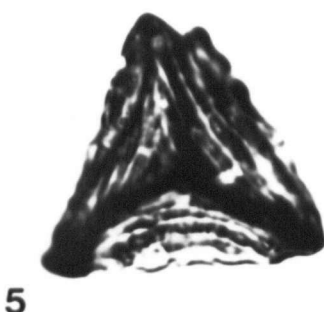
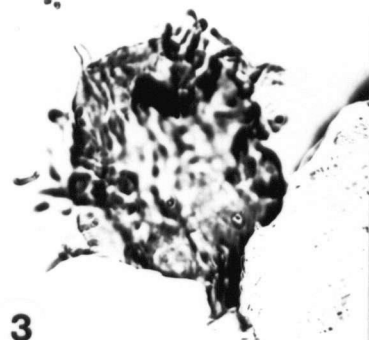
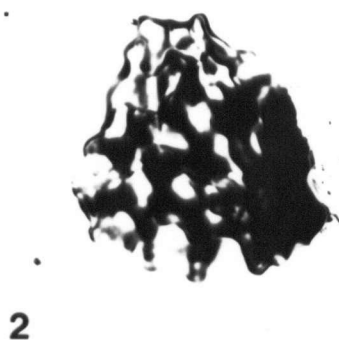
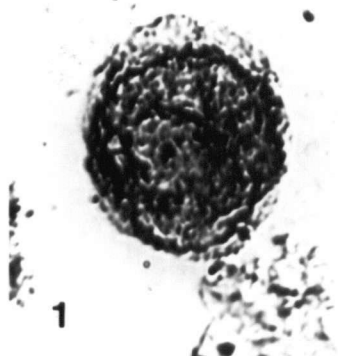


PLATE 6 - GATES FORMATION Middle Marine Unit

All specimens are shown at X1000 magnification
unless otherwise stated

- Figure 1: Lycopodiacidites asperatus Dettmann
- Figure 2: Matonisorites 'sp. A' (nov. sp.)
- Figure 3: Dictyotosporites speciosus Cookson & Dettmann
- Figure 4: Kuylsporites lunaris Cookson & Dettmann
- Figure 5: Acanthotriletes levidensis Balme
- Figure 6: Cyathidites raphael (Burger) Burger
- Figure 7: Undulatisporites undulapolus Brenner
- Figure 8: Gonyaulacysta archeopyle operculum Type B
(cf Singh, 1971)
- Figure 9: Tasmanites tardus Eisenack
- Figure 10: Gonyaulacysta orthoceras (Eisenack) Sarjeant
(X500)
- Figure 11: Chytroisphaeridia cf pococki Sarjeant; near
focus
- Figure 12: same specimen; mid focus

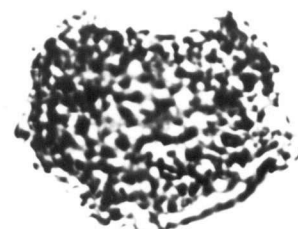
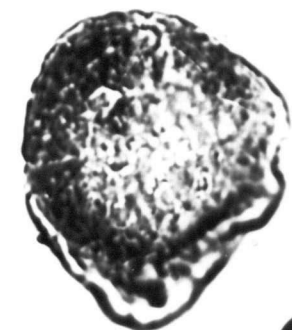
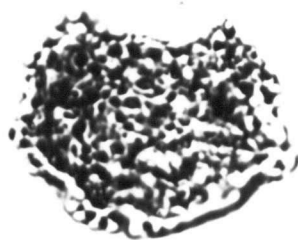
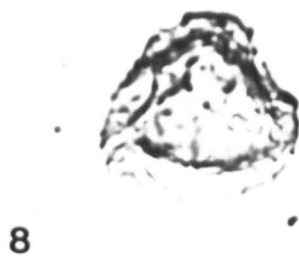
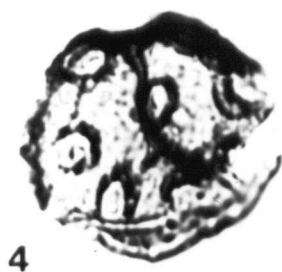
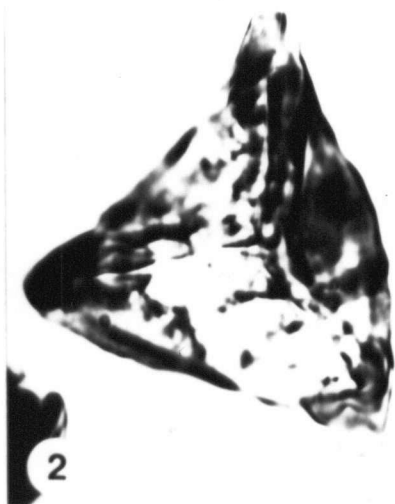
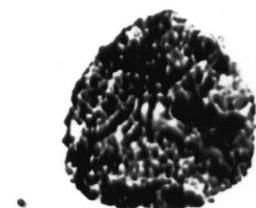


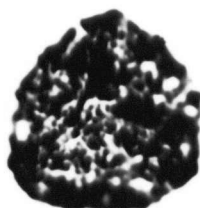
PLATE 7 - GATES FORMATION Upper Terrestrial Unit

All specimens are shown at X1000 magnification
unless otherwise stated

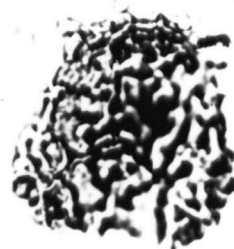
- Figure 1: Sestrosporites irregularus (Couper) Dettmann;
distal focus
- Figure 2: same specimen; proximal focus
- Figure 3: Tigrisporites reticulatus Singh
- Figure 4: Distaltriangulisporites 'sp. B' (nov. sp.);
distal focus
- Figure 5: same specimen; equatorial focus
- Figure 6: Foraminisporis asymmetricus (Cookson & Dettmann)
Dettmann
- Figure 7: Appendicisporites bilateralis Singh
- Figure 8: Distaltriangulisporites 'sp. B' (nov. sp.);
proximal focus
- Figure 9: Matonisporites cooksonii Dettmann
- Figure 10: Tasmanites newtoni Wall
- Figure 11: Palambages Form A Manum & Cookson; near focus
- Figure 12: same specimen; mid focus



1



2



3



4



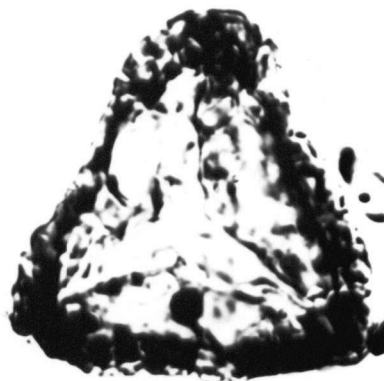
6



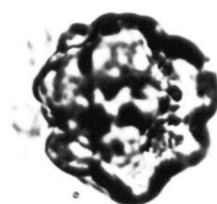
7



5



8



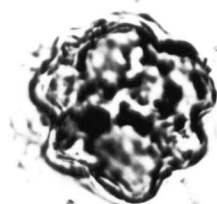
11



9



10



12

PLATE 8 - GATES FORMATION Upper Terrestrial
& Upper Marine Units

All specimens are shown at X1000 magnification
unless otherwise stated

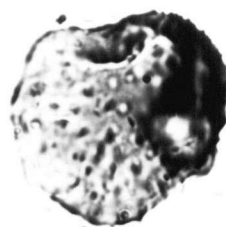
- Figure 1: Distaltriangulisporites 'sp. A' (nov. sp.)
- Figure 2: Cyathidites punctatus (Delcourt & Sprumont)
Delcourt, Dettmann & Hughes
- Figure 3: Foraminisporis wonthaggiensis (Cookson &
Dettmann) Dettmann
- Figure 4: Appendicisporites unicus (Markova) Singh
- Figure 5: Phragmothyrites 'Form B'
- Figure 6: Baltisphaeridium sp. B Singh
- Figure 7: Cyclonephelium paucispinum Davey (X500)
- Figure 8: Palaeoperidinium cretaceum Pocock (X500)
- Figure 9: Apteodinium maculatum Eisenack & Cookson (X500)
- Figure 10: Crassosphaera sp. A (cf Backhouse); near focus
- Figure 11: same specimen; mid focus
- Figure 12: Pterospermella australiensis (Deflandre & Cook-
son) Eisenack & Cramer



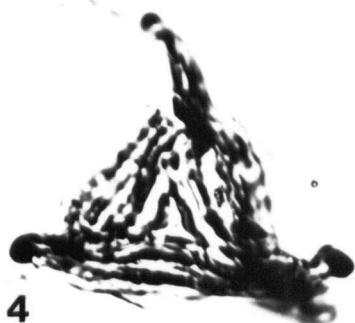
1



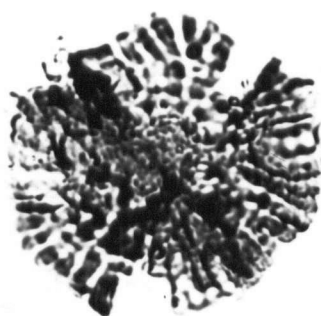
2



3



4



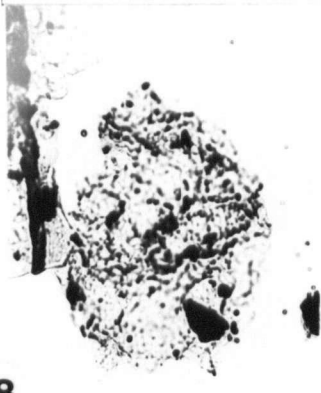
5



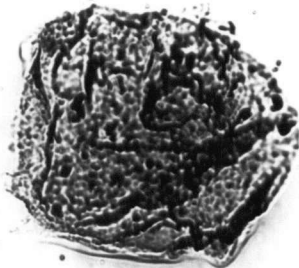
6



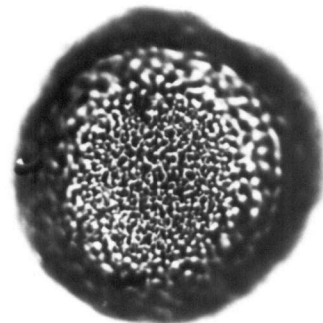
7



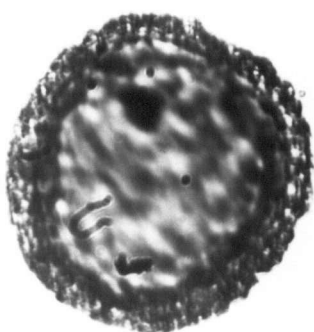
8



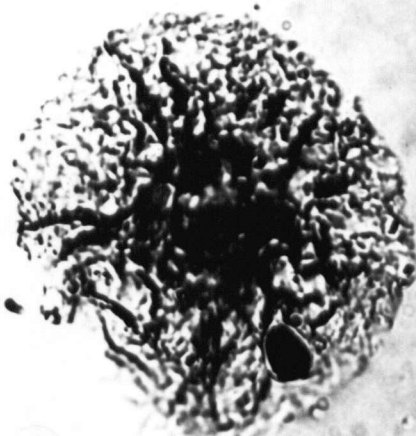
9



10



11

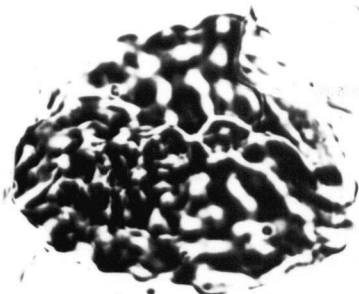


12

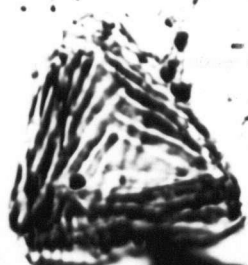
PLATE 9 - GATES FORMATION Upper Marine Unit
All specimens are shown at X1000 magnification
unless otherwise stated

- Figure 1: Ischyosporites 'sp. A' (nov. sp.); proximal focus
- Figure 2: same specimen; distal focus
- Figure 3: Cicatricosisporites cf tersus (Kara Mursa) Pocock; proximal focus
- Figure 4: same specimen; distal focus
- Figure 5: Foveotriletes subtriangularus Brenner; proximal focus
- Figure 6: same specimen; distal focus
- Figure 7: Appendicisporites dentimarginatus 'var. A' (nov. comb.)
- Figure 8: Phragmothyrites 'Form A'
- Figure 9: Pterodinium sp. A (cf Brideaux & McIntyre) (X500)
- Figure 10: Oligosphaeridium complex (White) Davey & Williams (X500)
- Figure 11: Gonyaulacysta cretacea Neale & Sarjeant (X500)
- Figure 12: Oligosphaeridium diastema Singh (X500)

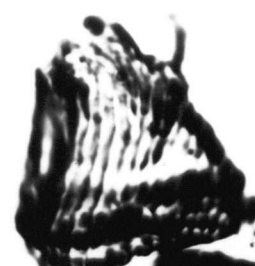
1



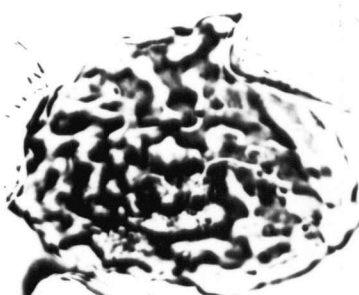
3



4



2



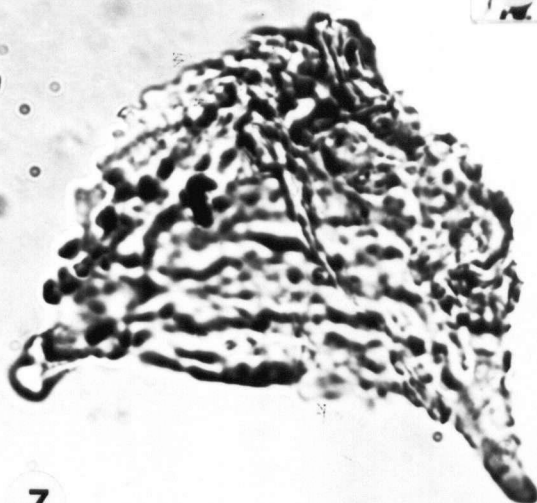
5



6



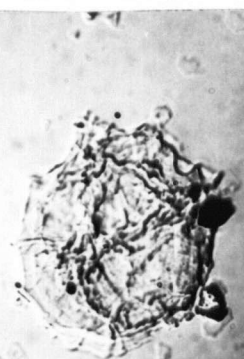
7



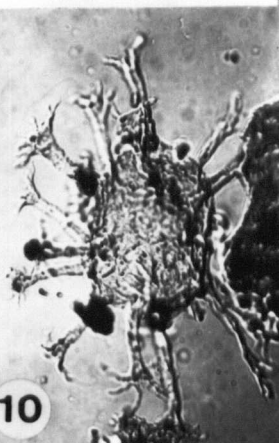
8



9



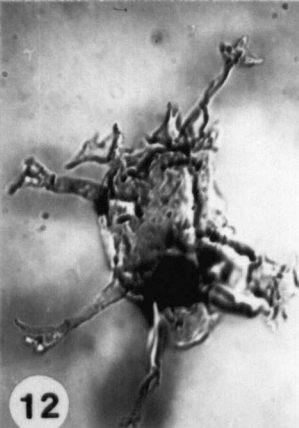
10



11



12



APPENDIX I

Lower Cretaceous Palynomorph References

- Anan-York, R. & Stelck, C.R. (1978): Microfloras from Upper Albian Neogastrolites Zone, Sikanni Chief River, northeast British Columbia, in: Western and Arctic Canada Biostratigraphy, Stelck & Chatterton (eds.), Geol. Assoc. Canada, Spec. Paper #18, pp. 473-493.
- Batten, D.J. (1973): Palynology of Early Cretaceous soil beds and associated strata, Palaeontology, Vol. 16, Pt. 2, pp. 399-424, 7 plates.
- Brenner, G.J. (1963): The spores and pollen of the Potomac Group of Maryland, Dept. of Geol., Mines and Water Res., State of Maryland, Bull. 27, 215 pp., 43 plates.
- , (1974): Palynostratigraphy of the Lower Cretaceous Gevar'am and Talme Yafe Formations of the Gevar'am 2 well (South Coastal Plain, Israel), Geological Survey of Israel, Bull. #59, pp. 1-27, 10 plates.
- Brideaux, W.W. (1971): Palynology of the Lower Colorado Group, Central Alberta, Canada, Palaeontographica, Band 135, Abt. B, pp. 53-114.
- & Fisher, M.J. (1976): Upper Jurassic-Lower Cretaceous dinoflagellate assemblages from Arctic Canada, Geol. Surv. Canada, Bull. 259, 53 pp., 7 plates.
- & McIntyre, D.J. (1975): Miospores and microplankton from Aptian-Albian rocks along Horton River, District of MacKenzie, Geol. Surv. Canada, Bull. 252, 85 pp., 14 plates.
- , McIntyre, D.J. & Young, F.G. (1977): Discussion of Pocock's dinoflagellate zonation of Upper Jurassic-Lower Cretaceous Canadian Arctic, Bull. Can. Pet. Geol., Vol. 25, pp. 1264.
- Bujak, J.P. & Williams, G.L. (1978): Cretaceous palynostratigraphy of offshore south-eastern Canada, Geol. Surv. Canada, Bull. 297, 19 pp., 3 plates.
- Burden, E.T. (1984): Terrestrial palynomorph biostratigraphy of the lower part of the Mannville Group (Lower Cretaceous), Alberta and Montana, in: The Mesozoic of Middle North America, Stott & Glass (eds.), Can. Soc. Petrol. Geol., Memoir 9, pp. 249-269, 4 plates.

- Burger, D. (1966): Palynology of uppermost Jurassic and lowermost Cretaceous strata in the Eastern Netherlands, Overdruk Uit, Leidse Geologische Mededelingen, Deel 35, pp. 209-276, 39 plates.
- (1973): Spore zonation and sedimentary history of the Neocomian, Great Artesian Basin, Queensland, Spec. Publs. Geol. Soc. Australia, No. 4, pp. 87-118, 2 plates.
- (1974): Palynology of subsurface Lower Cretaceous strata in the Surat Basin, Queensland, Bureau of Mineral Resources, Australia, Bull. 150, 16 pp., 3 plates.
- (1980): Palynological studies in the Lower Cretaceous of the Surat Basin, Australia, Bureau of Mineral Res., Geol. & Geophys., Bull. 189, 106 pp., 48 plates.
- Clarke, R.F.A. & Verdier, J.P. (1967): An investigation of microplankton assemblages from the Chalk of the Isle of Wight, England, Verhandelingen der Koninklijke Nederlandse Akademie van Wetenschappen, Afd. Natuurkunde, Eerste Reeks - Deel XXIV - No. 3, 96 pp., 17 plates.
- Cookson, I.C. & Dettmann, M.E. (1958): Some trilete spores from Upper Mesozoic deposits in the eastern Australian region, Proc. Roy. Soc. Victoria, Vol. 70, Pt. 2, pp. 95-128, 6 plates.
- Cookson, I.C. & Eisenack, A. (1958): Microplankton from Australian and New Guinea Upper Mesozoic sediments, Proc. Roy. Soc. Victoria, Vol. 70, Pt. 1, pp. 19-79, 12 plates.
- & Eisenack, A. (1960): Upper Mesozoic microplankton from Australia and New Guinea, Palaeontology, Vol. 2, Pt. 2, pp. 243-261, 3 plates.
- & Eisenack, A. (1960): Microplankton from Australian Cretaceous sediments, Micropaleontology, Vol. 6, No. 1, pp. 1-18, 3 plates.
- & Eisenack, A. (1961): Upper Cretaceous microplankton from the Belfast No. 4 Bore, south-western Victoria, Proc. Roy. Soc. Victoria, Vol. 74, Pt 1, pp. 69-76, 2 plates.
- & Eisenack, A (1965): Microplankton from the Datrmoor Formation, S.W. Victoria, Proc. Roy. Soc. Victoria, Vol. 79, Pt. 1, pp. 133-137, 2 plates.

- & Eisenack, A. (1965): Microplankton from the Browns Creek Clays, S.W. Victoria, Proc. Roy. Soc. Victoria, Vol. 79, Pt. 1, pp. 119-131, 5 plates.
- Cookson, I.C. & Hughes, N.F. (1964): Microplankton from the Cambridge Greensand (mid-Cretaceous), Palaeontology, Vol. 7, Pt. 1, pp. 37-59, 7 plates.
- Couper, R.A. (1964): Spore - pollen correlation of the Cretaceous rocks of the Northern and Southern Hemispheres, in: Palynology in Oil Exploration; A Symposium, A.T. Cross (ed.), Soc. Econ. Paleont. & Mineralog., Spec. Publ. No. 11, Tulsa, Okla.
- Davey, R.J. (1969): Non-calcareous microplankton from the Cenomanian of England, Northern France and North America, Part I, Bull. Brit. Mus. (Nat. Hist.), Geol., Vol. 17, No. 3, pp. 103-180, 11 plates.
- , Downey, C., Sarjeant, W.A.S. & Williams, G.L. (1966): Studies on Mesozoic and Cainozoic dinoflagellate cysts, Bull. Brit. Mus. (Nat. Hist.), Geol., Supp. 3, 248 pp., 26 plates.
- Delcourt, A.F., Dettmann, M.E. & Hughes, N.F. (1963): Revision of some Lower Cretaceous microspores from Belgium, Palaeontology, Vol. 6, Pt. 2, pp. 282-292, 4 plates.
- Dettmann, M.E. (1963): Upper Mesozoic microfloras from south-eastern Australia, Proc. Roy. Soc. Victoria, Vol. 77, Pt. 1, pp. 1-148, 27 plates.
- & Playford, G. (1968): Taxonomy of some Cretaceous spores and pollen grains from Eastern Australia, Proc. Roy. Soc. Victoria, Vol. 8, Pt. 2, pp. 69-94, 3 plates.
- Dorhofer, G. (1977): Palynologie und stratigraphie der Buckeberg-Formation (Berriasian-Valanginian) in der Hilsmulde (N.W.-Deutschland), Geologisches Jahrbuch, Reihe A, Heft 42, 122 pp., 15 plates.
- Doyle, J.A. (1977): Spores and pollen: the Potomac Group (Cretaceous) angiosperm sequence, in: Concepts and Methods of Biostratigraphy, Kauffman & Hazel (eds.), Dowden, Hutchinson & Ross, Inc., Stroudsburg, Pennsylvania, pp. 339-363.
- Elsik, W.C. & Jansonius, J. (1974): New genera of Paleogene fungal spores, Can. Jour. Bot., Vol. 52, pp. 953-958, 1 plate.

- Evitt, R.W. (ed.) (1975): Proceedings of a Forum on Dinoflagellates held at Anaheim, California, October 16, 1973 as part of the Sixth Annual Meeting, Amer. Assoc. Stratig. Palynologists, Contrib. Series, No. 4, 71 pp., 7 plates.
- Hedlund, R.W. & Norris, G. (1968): Spores and pollen grains from Fredricksburgian (Albian) strata, Marshall County, Oklahoma, Pollen et Spores, Mus. Nat. D'Hist. Naturelle, Vol.X, No. 1, pp. 129-159, 9 plates.
- Hughes, N.F. (1969): Jurassic and Early Cretaceous pollen and spores, in: Aspects of Palynology, Tschudy & Scott (eds.), Wiley-Interscience, John Wiley & Sons, New York, Toronto, pp. 311-329, 4 plates.
- , Drewry, G.E. & Laing, J.F. (1979): Barremian earliest angiosperm pollen, Palaeontology, Vol.22, Pt.3, pp. 513-535, 8 plates.
- & Moody-Stuart, J.C. (1969): A method of stratigraphic correlation using Early Cretaceous spores, Palaeontology, Vol. 12, Pt. 1, pp. 84-111.
- Jain, K.P. (1975): Additional dinoflagellates and acritarchs from Grey Shale Member of Dalmiapuram Formation, South India, The Palaeobotanist, Vol. 24, No. 3, pp. 170-194, 6 plates.
- Kotova, I.Z. (1978): Spores and pollen from Cretaceous deposits of the eastern North Atlantic Ocean, Deep Sea Drilling Project, Leg 41, Sites 367 & 370, Initial Reports of the Deep Sea Drilling Project, Vol. XLI, pp. 841-881, 14 plates.
- & Cookson, I.C. (1964): Cretaceous microplankton in a sample from Graham Island, Arctic Canada, collected during the second "Fram"-Expedition (1898-1902) - with notes on microplankton from the Hassel Formation, Ellef Ringnes Island, Skrifter Utgitt av Det Norske Videnskaps-Akademi i Oslo, I. Mat-Naturv. Klasse. Ny Serie. No. 17, 36 pp., 7 plates.
- McGregor, D.C. (1965): Triassic, Jurassic and Lower Cretaceous spores and pollen of Arctic Canada, Geol. Surv. Canada, Paper 64-55, 32 pp., 10 plates.
- Millioud, M.E. (1969): Dinoflagellates and acritarchs from some Western European Lower Cretaceous type localities, Proceedings of the First International Conference on Planktonic Microfossils, Geneva, Vol. 2, pp. 420-434.

- Norris, G. (1967): Spores and pollen from the Lower Colorado Group (Alb.? - Cenom.) of Central Alberta, Palaeontographica, Series B, Vol. 120, pp. 71-115, 18 plates.
- (1969): Miospores from the Purbeck Beds and marine Upper Jurassic of southern England, Palaeontology, Vol. 12, Pt. 4, pp. 574-620, 12 plates.
- (1982): Mesozoic palynology of the Moose River Basin, in Mesozoic Geology and Mineral Potential of the Moose River Basin, Telford & Verma (eds.), Ontario Geological Survey, Study 21, pp.93-133, 12 plates.
- , Jarzen, D.M. & Awai-Thorne, B.V. (1975): Evolution of the Cretaceous terrestrial palynoflora in Western Canada, in: The Cretaceous System in the Western Interior of North America, W.G.E. Caldwell (ed.), Geol. Assoc. Canada, Spec. Paper No. 13, pp. 333-364, 3 plates.
- , Telford, P.G. & Vos, M.A. (1976): An Albian microflora from the Mattagami Formation, James Bay Lowlands, Ontario, Can. Jour. Earth Sc., Vol. 13, No. 2, pp. 400-403.
- Paden-Phillips, P. & Felix, C.J. (1971): A study of Lower and Middle Cretaceous spores and pollen from the southeastern United States; I- Spores, in Pollen et Spores, Vol. 13, No. 2, pp. 279-348, 12 plates.
- Playford, G. (1971): Palynology of basal Cretaceous (Swan River) strata of Saskatchewan and Manitoba, Palaeontology, Vol. 14, Pt. 4, pp. 533-565, 5 plates.
- , Haig, D.W. & Dettmann, M.E. (1975): A mid-Cretaceous microfossil assemblage from the Great Artesian Basin, northwestern Queensland, N. Jb. Geol. Palaont. Abh. (Stuttgart), 149, pp. 333-362, 6 plates.
- Pocock, S.A.J. (1962): Microfloral analysis and age determination of strata at the Jurassic-Cretaceous boundary in the Western Canada Plains, Palaeontographica, Ser. B, Vol. 111, 95 pp., 15 plates.
- (1967): The Jurassic-Cretaceous boundary in northern Canada, Review of Palaeobotany and Palynology, Vol. 5, pp. 129-136.
- (1976): A preliminary dinoflagellate zonation of the uppermost Jurassic and lower part of the Cretaceous in the Canadian Arctic and possible correlation southward into the Western Canada Basin, Geoscience & Man, Vol. 15, pp. 104-114, 2 plates.

- (1980): The Aptian-Albian boundary in Canada, IV International Palynol. Conf., Lucknow (1976-77) 2, pp. 419-424.
- Rouse, G.E. (1959): Plant microfossils from Kootenay coal-measures strata of British Columbia, Micropaleontology, Vol. 5, No. 3, pp. 303-324, 2 plates.
- & Srivastava, S.K. (1972): Palynological zonation of Cretaceous and Early Tertiary rocks of the Bonnet Plume Formation, northeastern Yukon, Canada, Can. Jour. Earth Sc., Vol. 9, No. 9, pp. 1163-1179, 6 plates.
- Sepulveda, E.G. & Norris, G. (1982): A comparison of some Paleogene fungal palynomorphs from Arctic Canada and from Patagonia, South Argentina, Revista de la Asociacion Paleontologica Argentina, Tomo XIX, No. 3-4, pp. 319-334, 4 plates.
- Singh, C. (1964): Microflora of the Lower Cretaceous Mannville Group, East-central Alberta, Res. Counc. Alta., Bull. 15, 238 pp., 29 plates.
- (1971): Lower Cretaceous microfloras of the Peace River area, N.W. Alberta, Res. Counc. Alta., Bull. 28, Vol. 1, pp. 1-299, 38 plates, & Vol. 2, pp. 300-542, 41 plates.
- (1975): Stratigraphic significance of early angiosperm pollen in the mid-Cretaceous strata of Alberta, in: The Cretaceous System in the Western Interior of North America, W.G.E. Caldwell (ed.), Geol. Assoc. Canada, Spec. Paper No. 13, pp. 365-389.
- Srivastava, S.K. (1968): Fungal elements from the Edmonton Formation (Maestrichtian), Alberta, Canada, Can. Jour. Bot., Vol. 46, pp. 1115-1118, 1 plate.
- (1972): Systematic description of some spores from the Edmonton Formation (Maestrichtian), Alberta, Canada, Palaeontographica, Band 139, Abt. B, 46 pp., 35 plates.
- (1984): Barremian dinoflagellate cysts from southeastern France, Cahiers de Micropaleontologie, Centre National de la Recherche Scientifique, Anatole, France, 90 pp., 39 plates.
- Steeves, M.W. & Wilkins, L.K. (1967): Spores and pollen from the Lower Cretaceous of Saskatchewan, Canada. Part 1. Sporites, Can. Jour. Botany, Vol. 45, pp. 2329-2365, 8 plates.

- Stover, L.E. & Evitt, W.R. (1978): Analysis of pre-Pleistocene organic-walled dinoflagellates, Stanford University Publ., Geological Sciences, Vol. XV, Stanford, California, 300 pp.
- Williams, G.L. & Brideaux, W.W. (1975): Palynological analysis of Upper Mesozoic and Cenozoic rocks of the Grand Banks, Atlantic Continental Margin, Geol. Surv. Canada, Bull. 236, 162 pp., 47 plates.
- Wilson, G.J. (1984): New Zealand Late Jurassic to Eocene dinoflagellate biostratigraphy - A summary, Newsl. Stratig., Vol 13, No. 2, Berlin, Stuttgart, pp. 104-117.
- Wiseman, J.F. & Williams, A.J. (1974): Palynological investigations of samples from Sites 259, 261 & 263, Leg 27, Deep Sea Drilling Project, Initial Reports of the Deep Sea Drilling Project, Vol. XXVII, Washington, (U.S. Gov't Printing Office), pp. 915-924.

APPENDIX II - Species List

Note: Although the species list is ordered alpha-numerically several species are not in the correct order alphabetically due to deletions, additions and corrections after coding.

-(*) indicates ubiquitous species

-(+) indicates single specimens

- 1 **Abiespollenites* sp. (cf Singh, 1971)
- 2 *Abietineaepollenites* sp. (cf Brenner, 1963)
- 3 *Acanthotriletes levidensis* Balme, 1957
- 4 **Acanthotriletes varispinosus* Pocock, 1962
- 5 **Aequitriradites spinulosus* (Cookson & Dettmann) Cookson & Dettmann, 1961
- 6 +*Aequitriradites verrucosus* (Cookson & Dettmann) Cookson & Dettmann, 1961
- 7 **Alisporites bilateralis* Rouse, 1959
- 8 **Alisporites grandis* (Cookson) Dettmann, 1963
- 9 **Alisporites microsaccus* (Couper) Pocock, 1962
- 10 **Alisporites* cf *minutus* Rouse, 1959
- 11 **Alisporites* sp.
- 12 *Alisporites similis* (Balme) Dettmann, 1963
- 13 algal colony (cf 172 - fungal colony Burden, 1984)
- 14 +*Antulsporites baculatus* (Archangel'sky & Gamero) Archangel'sky & Gamero, 1966
- 15 *Antulsporites distaverrucosus* (Brenner) Archangel'sky & Gamero, 1966
- 16 **Apiculatisporis asymmetricus* Cookson & Dettmann, 1958
- 17 +*Apiculatisporis babsae* Brenner, 1963
- 18 *Appendicisporites bilateralis* Singh, 1971
- 19 **Appendicisporites crimensis* (Bolkhovitina) Pocock, 1964
- 20 *Appendicisporites dentimarginatus* Brenner, 1963
- 21 +*Appendicisporites dentimarginatus* 'var. A' (nov. comb.)
- 22 **Appendicisporites erdtmanii* Pocock, 1964
- 23 **Appendicisporites potomacensis* Brenner, 1963
- 24 **Appendicisporites problematicus* (Burger) Singh, 1971
- 25 *Appendicisporites pschekhaensis* (Bolkhovitina) Pocock, 1964
- 26 *Appendicisporites* (cf *Plicatella*) *pseudomacrorhyza* (cf Dörrhöfer, 1977)
- 27 +*Appendicisporites spinosus* Pocock, 1964
- 28 +*Appendicisporites cooksonii* (Balme) Pocock, 1964
- 29 *Appendicisporites unicus* (Markova) Singh, 1964
- 30 **Aptea polymorpha* Eisenack, 1958
- 31 *Apteodinium grande* Cookson & Hughes, 1964
- 32 +*Apteodinium granulatum* Eisenack, 1958
- 33 +*Appendicisporites segmentus* Brenner, 1963
- 34 *Apteodinium maculatum* Eisenack & Cookson, 1960
- 35 **Apteodinium reticulatum* Singh, 1971
- 36 *Apteodinium* sp. Gocht, 1969
- 37 **Araucariacites australis* Cookson, 1947
- 38 *Ascotomocystis maxima* Singh, 1971
- 39 cf *Auritulinasporites deltaformis* Burger, 1966
- 40 **Baculatisporites comaumensis* (Cookson) Potonié, 1956

- 41 **Baculatisporites* 'sp B' (nov. sp.)
- 42 +*Baltisphaeridium crameri* Singh, 1971
- 43 *Baltisphaeridium fimbriatum* (White) Sarjeant, 1959
- 44 *Baltisphaeridium* sp. A (cf Singh, 1971)
- 45 *Baltisphaeridium* sp. B (cf Singh, 1971)
- 46 +*Baltisphaeridium* cf *stimuliferum* (Deflandre) Sarjeant, 1960
- 47 **Baltisphaeridium whitei* (Deflandrea & Courteville) Sarjeant, 1959
- 48 **Biretisporites potoniaei* Delcourt & Sprumont, 1955
- 49 *Biretisporites spectabilis* Dettmann, 1963
- 50 +*Bullasporis* cf *aequitorialis* Krutzsch, 1959
- 51 **Callialasporites dampieri* (Balme) Sukh Dev, 1961
- 52 *Callialasporites segmentatus* (Balme) Sukh Dev, 1961
- 53 *Callialasporites trilobatus* (Balme) Sukh Dev, 1961
- 54 *Callaiosphaeridium asymmetricum* (Deflandre & Courteville) Davey & Williams, 1966
- 55 +cf *Camarozonosporites ohaiensis* (Couper) Dettmann & Playford, 1968
- 56 +*Cassiculosphaeridia* cf *reticulata* Davey, 1969
- 57 **Canningia aspera* Singh, 1971
- 58 **Canningia colliveri* Cookson & Eisenack, 1960
- 59 **Canningia minor* Cookson & Hughes, 1964
- 60 *Canningia reticulata* Cookson & Eisenack, 1960
- 61 +cf *Cannosphaeropsis filamentosis* Cookson & Eisenack, 1958
- 62 +*Cannosphaeropsis* cf *peridictya* Eisenack & Cookson, 1960
- 63 **Cedripites canadensis* Pocock, 1962
- 64 **Cedripites cretaceus* Pocock, 1962
- 65 *Ceratosporites* cf *morrinicolus* Srivastava, 1972
- 66 **Cerebropollenites mesozoicus* (Couper) Nilsson, 1958
- 67 *Chlamydophorella nyei* Cookson & Eisenack, 1958
- 68 **Chytroeisphaeridia* cf *chytroeides* Sarjeant, 1962
- 69 +*Chytroeisphaeridia* cf *pococki* Sarjeant, 1968
- 70 **Cicatricosisporites annulatus* Archangelsky & Gamberro, 1966
- 71 **Cicatricosisporites augustus* Singh, 1971
- 72 **Cicatricosisporites australiensis* (Cookson) Potonié, 1956
- 73 **Cicatricosisporites dorogensis* Potonié & Gelletich, 1933
- 74 *Cicatricosisporites exilioides* (Maljavkina) Bolkhovitina, 1953
- 75 **Cicatricosisporites hallei* Delcourt & Sprumont, 1955
- 76 **Cicatricosisporites hughesi* Dettmann, 1963
- 77 *Cicatricosisporites imbricatus* (Markova) Singh, 1971
- 78 **Cicatricosisporites minor* (Bolkhovitina) Pocock, 1964
- 79 *Cicatricosisporites mohrioides* Delcourt & Sprumont, 1955
- 80 **Cicatricosisporites pseudotripatitus* (Bolkhovitina) Dettmann, 1963
- 81 +*Cicatricosisporites* cf *sewardi* Delcourt & Sprumont, 1955

- 82 +*Cicatricosisporites* cf *sternum* van Ameron, 1965
- 83 *Cicatricosisporites* cf *tersus* (Kara-Mursa) Pocock, 1964
- 84 **Cicatricosisporites auritus* Singh, 1971
- 85 *Cibotiumspora juriensis* (Balme) Filatoff, 1974
- 86 **Cingulatisporites caminus* Balme, 1957
- 87 *Cingulatisporites distaverrucosus* Brenner, 1963
- 88 **Cingutritetes clavus* (Balme) Dettmann, 1963
- 89 **Cirratriradites teter* Norris, 1967
- 90 *Classopollis chateaunovi* Reyre, 1970
- 91 **Classopollis classoides* (Pflug) Pocock & Jansonius, 1961
- 92 +*Classopollis* cf *hammenii* Burger, 1965
- 93 +*Clavatipollenites couperii* Pocock, 1962
- 94 **Clavatipollenites hughesii* Couper, 1958
- 95 +*Clavatipollenites minutus* Brenner, 1963
- 96 *Cleistosphaeridium diversispinosum* Davey, Downie, Sarjeant, & Williams, 1966
- 97 *Cleistosphaeridium granulatum* Burger, 1980
- 98 *Cleistosphaeridium multispinosum* (Singh) Brideaux, 1971
- 99 +cf *Comasphaeridium* sp. A (cf Pocock, 1964)
- 100 *Concavissimisporites minor* (Pocock) Delcourt, Dettmann Hughes, 1963
- 101 **Concavissimisporites punctatus* (Delcourt & Sprumont) Brenner, 1963
- 102 **Concavissimisporites variverrucatus* (Couper) Brenner, 1963
- 103 +*Concavissimisporites verrucosus* (Delcourt & Sprumont) Delcourt, Dettmann & Hughes, 1963
- 104 *Contignisporites cooksonii* (Balme) Dettmann, 1963
- 105 +*Contignisporites* cf *glebulentus* Dettmann, 1963
- 106 *Contignisporites multimuratus* Dettmann, 1963
- 107 +*Converrucosisporites exquisitus* Singh, 1971
- 108 *Cooksonites reticulatus* Pocock, 1962
- 109 *Cooksonites variabilis* Pocock, 1962
- 110 **Coptospora* cf *paradoxa* (Cookson & Dettmann) Dettmann, 1963
- 111 **Coptospora* sp. A (cf Dettmann, 1963)
- 112 *Coptospora striata* Dettmann, 1963
- 113 *Costatoperforosporites foveolatus* Deak, 1962
- 114 *Couperisporites complexus* (Couper) Pocock, 1962
- 115 *Crassosphaera bella* Singh, 1971
- 116 *Crassosphaera* sp. A (cf Backhouse, 1984)
- 117 +*Cribroperidinium* cf *intricatum* Davey, 1969
- 118 **Cyathidites asper* (Bolkhovitina) Dettmann, 1963
- 119 **Cyathidites australis* Couper, 1953
- 120 **Cyathidites minor* Couper, 1953
- 121 *Cyathidites punctatus* (Delcourt & Sprumont) Delcourt, Dettmann & Hughes, 1963
- 122 *Cyathidites rafaelli* (Burger) Burger, 1980
- 123 **Cycadopides formosus* Singh, 1964
- 124 **Cycadopides fragilis* Singh, 1964
- 125 +*Cycadopides ovatus* Rouse, 1959
- 126 **Cycadopides* sp. (cf Singh, 1964)
- 127 +*Cyclonephelium compactum* Deflandre & Cookson, 1955

- 128 *Cyclonephelium distinctum* Deflandre & Cookson, 1955
- 129 *Cyclonephelium distinctum* var. *brevispinatum* (Millioud) Lentin & Williams, 1973
- 130 **Cyclonephelium membraniphorum* Cookson & Eisenack, 1962
- 131 *Cycadopites carpentieri* (Delcourt & Sprumont) Singh, 1964
- 132 *Cyclonephelium paucispinum* Davey, 1969
- 133 +*Cyclopsiella ornamenta* Jain, 1977
- 134 *Cymatiosphaera pachythea* Eisenack, 1957
- 135 *Isabelidinium* cf *acuminata* (Cookson & Eisenack) Lentin & Williams, 1975
- 136 +*Alterbia asymmetrica* (Davey & Verdier) Lentin & Williams, 1975
- 137 *Subtilisphaera perlucida* (Alberti) Jain & Millepied, 1973
- 138 +cf *Isabelidinium thomasi* (Cookson & Eisenack) Lentin & Williams, 1977
- 139 *Chatangiella* cf *victoriensis* (Cookson & Manum) Lentin & Williams, 1976
- 140 **Deltoidospora diaphana* Wilson & Webster, 1946
- 141 **Deltoidospora hallii* Miner, 1935
- 142 **Deltoidospora psilostoma* Rouse, 1959
- 143 +*Densoisporites circumundulatus* (Brenner) Playford, 1971
- 144 *Densoisporites microrugulatus* Brenner, 1963
- 145 *Diconodinium* cf *arcticum* Manum & Cookson, 1964
- 146 +*Diconodinium* cf *glabrum* Eisenack & Cookson, 1960
- 147 fungal body 'Type W'
- 148 *Dictyophyllidites equiexinous* (Couper) Dettmann, 1963
- 149 *Dictyophyllidites pectinataeformis* (Bolkhovitina) Dettmann, 1963
- 150 +*Dictyophyllidites* sp. (cf Singh, 1971)
- 151 *Dictyotosporites complex* Cookson & Dettmann, 1958
- 152 *Dictyotosporites speciosus* Cookson & Dettmann, 1958
- 153 +*Dingodinium cerviculum* Cookson & Eisenack, 1958
- 154 dino sp A (nov sp)
- 155 *Dinopterygium cladoides* Deflandre, 1935
- 156 *Diplotesta anglica* Cookson & Hughes, 1964
- 157 *Distaltriangulisporites* 'sp. B' (nov.sp.)
- 158 *Distaltriangulisporites irregularis* Singh, 1971
- 159 **Distaltriangulisporites perplexus* (Singh) Singh, 1971
- 160 *Distaltriangulatisporites* 'sp. A' (nov. sp.)
- 161 *Eucommiidites troedssonii* (Erdtman) Hughes, 1961
- 162 +*Exochosphaeridium* cf *phragmites* Davey, Downie, Sarjeant & Williams, 1966
- 163 *Foraminisporis asymmetricus* (Cookson & Dettmann) Dettmann, 1963
- 164 +*Foraminisporis bifurcatus* (Couper) ?
- 165 *Foraminisporis wonthaggiensis* (Cookson & Dettmann) Dettmann, 1963
- 166 **Foveosporites canalis* Balme, 1957
- 167 +*Foveosporites labiosus* Singh, 1971
- 168 *Foveotriteles subtriangularis* Brenner, 1963
- 169 *Fractisporonites* sp. Clarke, 1965
- 170 *Fromea amphora* Cookson & Eisenack, 1958

- 171 fungal body 'Type M'
- 172 fungal colony (cf Burden, 1984)
- 173 *Gardodinium eisenacki* Alberti, 1961
- 174 *Ginkgocycadophytus* sp.
- 175 **Ginkgocycadophytus nitidus* (Balme) de Jersey, 1962
- 176 **Gleicheniidites circinidites* (Cookson) Dettmann, 1963
- 177 **Gleicheniidites senonicus* Ross, 1949
- 178 *Gonyaulacysta archeopyle operculum* Type B (cf Singh, 1971)
- 179 *Gonyaulacysta* cf *cassidata* (Eisenack & Cookson) Sarjeant, 1966
- 180 *Gonyaulacysta cretacea* Neale & Sarjeant, 1960
- 181 *Gonyaulacysta* cf *episoma* Sarjeant, 1966
- 182 +*Gonyaulacysta helicoidea* (Eisenack & Cookson) Sarjeant, 1966
- 183 *Gonyaulacysta* cf *orthoceras* (Eisenack) Sarjeant, 1966
- 184 fungal body 'Type B'
- 185 +cf *Hexasphaera asymmetrica* (Deflandre & Courteville) Clarke & Verdier, 1967
- 186 +*Hystrichokolpoma* 'sp. A' (nov. sp.)
- 187 *Hystrochokolpoma ferox* (Deflandre) Davey, 1969
- 188 *Spiniferites cingulatus* (O. Wetzel) Davey & Williams, 1966
- 189 +fungal body 'Type O'
- 190 +*Spiniferites cornutus* var. *laevimura* Davey & Williams, 1966
- 191 +*Spiniferites ramosa* var. *brevispinosum* ?
- 192 *Spiniferites ramosa* var. *multibrevis* Davey & Williams, 1966
- 193 **Spiniferites ramosa* var. *ramosa* Davey & Williams, 1966
- 194 +cf *Spiniferites wetzelii* (Deflandre) Sarjeant, 1970
- 195 *Hystrichosphaeridium cooksoni* Singh, 1971
- 196 *Hystrichosphaeridium stellatum* Maier, 1959
- 197 *Inaperturopollenites dubius* (Potonie & Venitz) Thomson & Pflug, 1953
- 198 +*Ischyosporites disjunctus* Singh, 1971
- 199 +*Ischyosporites* 'sp. A' (nov. sp.)
- 200 *Januasporites spiniferus* Singh, 1964
- 201 cf *Kalyptea monoceras* Cookson & Eisenack, 1960
- 202 *Klukisporites areolatus* Singh, 1971
- 203 **Klukisporites foveolatus* Pocock, 1964
- 204 *Kuylisporites lunaris* Cookson & Dettmann, 1958
- 205 *Laevigatosporites gracilis* Wilson & Webster, 1946
- 206 **Laevigatosporites ovatus* Wilson & Webster, 1946
- 207 **Laricoidites magnus* (Potonie) Potonie, Thomson & Thiergart, 1950
- 208 *Lecaniella foveata* Singh, 1971
- 209 +*Gleicheniidites* 'sp.' ? (nov. sp.)
- 210 +*Lycopodiacidites ambifoveolatus* Brenner, 1963
- 211 *Lycopodiacidites asperatus* Dettmann, 1963
- 212 *Lycopodiacidites canaliculatus* Singh, 1971
- 213 *Lycopodiacidites caperatus* Singh, 1971
- 214 *Lycopodiacidites cirniidites* (Ross) Brenner, 1963

- 215 **Lycopodiacidites dettmannae* Burger, 1980
- 216 +*Lycopodiacidites irregularis* Brenner, 1963
- 217 **Lycopodiumsporites austroclavatidites* (Cookson)
Potonié, 1956
- 218 +*Lycopodiumsporites circolumenus* Cookson & Dettmann,
1958
- 219 **Lycopodiumsporites crassatus* Singh, 1971
- 220 **Lycopodiumsporites crassimacerius* Hedlund, 1966
- 221 *Lycopodiumsporites eminulus* Dettmann, 1963
- 222 +*Lycopodiumsporites expansus* Singh, 1971
- 223 *Lycopodiumsporites marginatus* Singh, 1964
- 224 +*Lycopodiumsporites nodosus* Dettmann, 1963
- 225 **Lycopodiumsporites reticulumsporites* (Rouse) Dettmann,
1963
- 226 +*Lycopodiumsporites* cf *semireticulatus* Burger, 1966
- 227 *Lycopodiumsporites* sp.
- 228 +*Leptodinium alectrolophum* Davey, Downie, Sarjeant, &
Williams, 1966
- 229 **Lygodioisporites* sp. B (cf Singh, 1964)
- 230 *Matonisorites cooksoni* Dettmann, 1963
- 231 +*Matonisorites crassiangulatus* (Balme) Dettmann, 1963
- 232 +*Matonisorites* 'sp. A' (nov.sp.)
- 233 *Matonisorites* cf *excavatus* Brenner, 1963
- 234 *Podocarpidites naumovi* (Naumova) Singh, 1964
- 235 *Michrystroidium stellatum* Deflandre, 1945
- 236 +*Michrystroidium* cf *sydus* Valensi, 1953
- 237 **Microreticulatisporites uniformis* Singh, 1964
- 238 +*Monosulcites scabrus* Brenner, 1963
- 239 *Podocarpidites ornatus* Pocock, 1962
- 240 +*Muderongia* sp. A (cf Brideaux & McIntyre, 1975)
- 241 *Muderongia tetracantha* (Gocht) Alberti, 1961
- 242 +*Murospora florida* Balme, 1957
- 243 *Murospora truncata* Singh, 1971
- 244 **Neoraistrickia truncata* (Cookson) Potonié, 1956
- 245 *Odontochitina operculata* (O. Wetzell) Deflandre, 1946
- 246 +*Odontochitina* cf *striatoperforata* Cookson & Eisenack,
1962
- 247 *Oligosphaeridium anthophorum* (Cookson & Eisenack)
Eisenack & Kjellstrom, 1971
- 248 *Oligosphaeridium complex* (White) Davey & Williams, 1966
- 249 *Oligosphaeridium diastema* Singh, 1971
- 250 +*Oligosphaeridium* cf *prolixispinosum* Davey & Williams,
1966
- 251 *Oligosphaeridium pulcherrimum* (Deflandre & Cookson)
Davey & Williams, 1966
- 252 +*Ornamentifera baculata* Singh, 1971
- 253 **Osmundacidites wellmanii* Couper, 1953
- 254 *Palambages* Form A Manum & Cookson, 1964
- 255 *Palaeoperidinium cretaceum* Pocock, 1962
- 256 *Palaeoperidinium* sp. A Bujak & Williams, 1978
- 257 *Pareodinia* cf *aphelia* Cookson & Eisenack, 1958
- 258 **Pareodinia ceratophora* Deflandre, 1947
- 259 **Parvisaccites radiatus* Couper, 1958
- 260 *Perinopollenites elatoides* Couper, 1958

- 261 +*Perotriletes pannuceus* Brenner, 1963
- 262 +*Pflugipollenites trilobatus* (Balme) Pocock, 1962
- 263 *Phragmothyrites* 'Form A'
- 264 *Phragmothyrites* 'Form B'
- 265 +*Phragmothyrites* 'Form C'
- 266 *Phyllocladidites inchoatus* (Pierce) Norris, 1967
- 267 **Phyllocladidites mawsonii* Cookson, 1947
- 268 *Phragmothyrites* 'Form D'
- 269 *Pinuspollenites* sp.
- 270 **Pityosporites alatipollenites* (Rouse) Singh, 1964
- 271 **Pityosporites constrictus* Singh, 1964
- 272 *Pluricellaesporites psilatus* Clarke, 1965
- 273 +*Polysphaeridium subtile* Davey, Downie, Sarjeant & Williams, 1966
- 274 *Podocarpidites biformis* Rouse, 1957
- 275 **Podocarpidites canadensis* Pocock, 1962
- 276 *Podocarpidites ellipticus* Cookson, 1947
- 277 **Podocarpidites herbstii* Burger, 1966
- 278 **Podocarpidites minisulcus* Singh, 1964
- 279 **Podocarpidites multesimus* (Bolkhovitina) Pocock, 1962
- 280 *Podocarpidites potomacensis* Brenner, 1963
- 281 +*Psilatricolpites parvulus* (Groot & Penny) Norris, 1967
- 282 **Polycingulatisporites reduncus* (Bolkhovitina) Playford & Dettmann, 1965
- 283 +*Polycingulatisporites* cf *triangularus* (Bolkhovitina) Playford & Dettmann, 1965
- 284 +*Polycingulatisporites* 'sp. A' (nov.sp.)
- 285 +cf *Polypodiisporites* (cf Dörhöfer, 1977)
- 286 *Prolixosphaeridium* cf *mixtispinosum* Klement, 1960
- 287 +*Prolixosphaeridium* sp. (cf Singh, 1971)
- 288 +*Pseudoceratium dettmannae* Cookson & Hughes, 1964
- 289 +*Pterodinium aliferum* Eisenack, 1958
- 290 *Pterodinium* sp. A (cf Brideaux & McIntyre, 1975)
- 291 **Pterospermella* cf *aureolata* Cookson & Eisenack, (1962)?
- 292 *Pterospermella australiensis* (Deflandre & Cookson) Eisenack & Cramer, 1973
- 293 *Pterospermella hartii* (Sarjeant) Srivastava, 1984
- 294 *Pterospermella* sp. B Singh, 1971
- 295 +*Reticulatasporites* (cf Norris, 1982)
- 296 *Reticulisporites elongatus* Singh, 1971
- 297 +*Rouseisporites radiatus* Dettmann, 1963
- 298 **Rouseisporites reticulatus* Pocock, 1962
- 299 +*Occisucysta* sp. A (cf Bujak & Williams, 1978)
- 300 +*Scriniodinium* sp. (cf Sarjeant, 1972)
- 301 **Rugubivesiculites rugosus* Pierce, 1961
- 302 *Schizosporis* sp.
- 303 **Schizosporis cooksonii* Pocock, 1962
- 304 *Schizosporis grandis* Pocock, 1962
- 305 **Schizosporis parvus* Cookson & Dettmann, 1959
- 306 +*Schizosporis reticulatus* Cookson & Dettmann, 1959
- 307 *Schizosporis rugulatus* Cookson & Dettmann, 1959
- 308 **Schizosporis spriggii* Cookson & Dettman, 1959
- 309 *Scolecospores* Lange & Smith, 1971
- 310 *Scriniodinium campanula* Gocht, 1959

- 311 *Sestrosporites irregularus* (Couper) Dettmann, 1963
- 312 **Spheripollenites psilatus* Couper, 1958
- 313 +*Staplinisporites caminus* (Balme) Pocock, 1962
- 314 **Stereisporites antiquasporites* (Wilson & Webster) Dettmann, 1963
- 315 **Stereisporites psilatus* (Ross) Manum, 1962
- 316 *Tanyosphaeridium* sp. B (cf Brideaux, 1971)
- 317 *Tasmanites newtoni* Wall, 1965
- 318 *Tasmanites suevicus* (Eisenack) Wall, 1965
- 319 *Tasmanites tardus* Eisenack, 1957
- 320 +*Tauroculusporites reduncus* (Bolkhovitina) Stover, 1962
- 321 **Taxodiaceapollenites hiatus* (Potonié) Kremp, 1949
- 322 *Tigrisporites reticulatus* Singh, 1971
- 323 *Tigrisporites scurrandus* Norris, 1967
- 324 **Todisporites minor* Couper, 1958
- 325 + 'spore sp. A' (nov. gen.)
- 326 +*Trilites tuberculiformis* Cookson, 1947
- 327 **Trilobosporites apiverrucatus* Couper, 1958
- 328 **Trilobosporites crassus* Brenner, 1963
- 329 *Trilobosporites marylandensis* Brenner, 1963
- 330 +*Stellatopollis* sp. (cf Burden, 1984)
- 331 *Trilobosporites purverulentus* (Verbitskaya) Dettmann, 1963
- 332 +*Trilobosporites tribotrys* Dettmann, 1963
- 333 *Trilobosporites trioreticulosus* Cookson & Dettmann, 1958
- 334 +*Tripartina variabilis* Maljavkina, 1949
- 335 *Undulatisporites fossulatus* Singh, 1971
- 336 *Undulatisporites pannuceus* (Brenner) Singh, 1971
- 337 +*Undulatisporites* sp. (cf Singh, 1971)
- 338 **Undulatisporites undulapolus* Brenner, 1963
- 339 *Verrucosisporites asymmetricus* (Cookson & Dettmann) Pocock, 1962
- 340 **Verrucosisporites rotundus* Singh, 1962
- 341 +*Tricolpites crassimurus* (Groot & Penny) Singh, 1971
- 342 +*Veryhachium rhomboidium* Downie, 1959
- 343 *Vitreisporites* cf *craigii* Pocock, 1964
- 344 *Cicatricosisporites potomacensis* Brenner, 1963
- 345 *Vitreisporites pallidus* (Reissinger) Nilsson, 1958
- 346 *Klukisporites pseudoreticulatus* Couper, 1958
- 347 *Spheripollenites scabratus* Couper, 1958
- 348 *Reticulisporites semireticulatus* (Burger) Norris, 1969
- 349 *Piceapollenites* sp. (cf Singh, 1964)
- 350 *Appendicisporites tricornitatus* Weyland & Greifeld, 1953
- 351 +*Cooksonites* 'sp. A' (nov. sp.)